DOCKET	
09-AFC-9	
DATE	JUN 08 2010
RECD.	JUN 08 2010

June 8, 2010

Eric Solorio
Project Manager
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

RE: Ridgecrest Solar Power Project (RSPP), Docket No. 09-AFC-9, Bridging Document Submitted to the Lahontan Regional Water Quality Control Board (RWQCB)

Dear Mr. Solorio:

Please find the three documents provided to the Lahontan RWQCB that will serve as the "bridging document" for the Report Of Waste Discharge (ROWD) being prepared for the evaporation ponds at the RSPP site. The three documents will provide the design basis, the Design, Operation, and Maintenance plan, and the Detection Monitoring Plan for the ponds in advance of the complete ROWD. A complete ROWD will be provided to the RWQCB by mid-June

This has been docketed in accordance with CEC requirements.

If you have any questions, please feel free to contact me at 510-809-4662 (office) or 949-433-4049 (cell).

Sincerely,

Billy Owens
Director, Project Development

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APPLICATION FOR CERTIFICATION For the *RIDGECREST SOLAR POWER PROJECT*

Docket No. 09-AFC-9

PROOF OF SERVICE (Revised 5/12/2010)

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DECLARATION OF SERVICE

I, Elizabeth Copley, declare that on June 8, 2010, I served and filed copies of the attached Ridgecrest Solar Power Project (Docket No. 09-AFC-9) Bridging Document. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at:

[http://www.energy.ca.gov/sitingcases/solar_millennium_ridgecrest].

The documents have been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(C*heck all that Apply*)

For service to all other parties:

_ sent electronically to all email addresses on the Proof of Service list;

_ by personal delivery;

X by delivering on this date, for mailing with the United States Postal Service with first-class postage thereon fully prepaid, to the name and address of the person served, for mailing that same day in the ordinary course of business; that the envelope was sealed and placed for collection and mailing on that date to those addresses **NOT** marked "email preferred."

AND

For filing with the Energy Commission:

X sending an original paper copy and one electronic copy, mailed and emailed Respectively, to the address below (preferred method);

OR

__ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
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1516 Ninth Street, MS-4
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I declare under penalty of perjury that the foregoing is true and correct.

Prepared for:
Ridgecrest Solar I, LLC

Design Basis Memorandum
Ridgecrest Solar Power Project
Kern County, California
Appendix B of the
Application/Report of Waste Discharge

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1.0 Summary

Ridgecrest Solar Power Project consists of one power block requiring ponds to receive process wastewater from the plant and dispose of the water by evaporation. This document provides design information used in sizing these evaporation ponds.

The pond area and depth were established to receive the process wastewater and direct precipitation and evaporate them to dryness over the course of a year. The power block area will include two ponds. During normal operation both ponds will receive process wastewater. However, during periods when one pond is being dried to allow maintenance or removal of accumulated sediments, the other pond will be capable of receiving all of the process wastewater and storing / evaporating it until the other pond is brought back online.

The power block will require a total of eight acres (348,480 square feet) of evaporation pond area, split into two four acre ponds. Average pond depth will be 7 feet: two feet for sludge accumulation, two feet of freeboard, and three feet of active storage area.

2.0 Purpose and Objective

A total of two (2) evaporation ponds will be used at the Ridgecrest Solar Power Plant located in located in the high northern Mojave Desert in northeastern Kern County, California, about five miles southwest of the City of Ridgecrest, California. Process wastewater from the plant's operation will be discharged to these ponds and will be stored and allowed to evaporate. Monthly average discharge from the plant to the pond was determined through water balance of the plant processes. The ponds are required to hold any precipitation directly falling on the pond along with process water discharge from the plant. Runoff from the surrounding area will be diverted away from the pond.

Average values of precipitation and evaporation were used to determine the pond size. The pond bottom area was selected to allow all water entering the ponds to evaporate every year. Pond depth was selected to allow storage of plant discharge and rainfall through low-evaporation months, including sludge accumulation from salts in the process water and wind-blown silt as well as required freeboard.

3.0 Design Criteria

3.1 Process Water Discharge

Process water discharge was determined through the development of a water balance based on the process flow diagram provided by the water treatment vendor. The water balance provided the discharge flows for each of the heat balance cases. A conservative load profile for each month was then developed using a day and night heat balance case. This approach provided a plant discharge in terms of a monthly rate. See Section 4.

3.2 Precipitation

Precipitation data was obtained from the Western Regional Climate Center. The average monthly total precipitation data for the years 1931 through 2005 was obtained from the WRCC website http://www.wrcc.dri.edu. The average yearly total precipitation was 4.54 inches.

3.3 Evaporation

Mojave is the closest weather station to the project site that records evaporation data. Monthly average pan evaporation data recorded at this station for a period of 1948 to 2005 was obtained from the website http://www.wrcc.dri.edu/htmfiles/westevap.final. The total of recorded monthly average pan evaporation for the months from January through December is 111.59 inches. Factors were applied for conversion of pan evaporation to pond evaporation and correction for salinity, and the resulting equation takes this form:

Pond evaporation = k1*K2*(Pan Evaporation)

K1 is a pan coefficient, necessary for converting pan data to pond evaporation estimates. A value of 0.75 was used.

K2 is the salinity correction coefficient. A practical maximum concentration for mixed salt salinity suggested by the literature is around 17%, which would lower the vapor pressure of water by about 10% (CRC Handbook 1995), corresponding to a 10% decline in the rate of evaporation. However, due to the high concentration of TDs of the water entering the pond, a factor of 0.7 was used which is an industry standard for salinity. It was assumed that the plant discharge will not contain constituents such as scum or oil that could further reduce evaporation rates.

This procedure resulted in average monthly pond evaporation values totaling 58 inches per year.

3.4 Freeboard

Additional height of embankment was added to the maximum depth of storage as freeboard. A minimum of 2 feet is required, and this value is used.

Evaporation Pond Design Summary

Pond bottom area (per pond)	149,310 SF	3.43 Ac
Pond top area (per pond)	171,738 SF	3.94 Ac
Required maximum storage volume per pond	481,400 CF	11.1 AF
Sludge storage depth	24 In	
Active storage depth	36 In	
Freeboard	24 In	
Total required depth	84 In	

Pond top dimensions:

North pond 800 x 218 ft

South pond 465 x 375 ft

4.0 Process Water Quality

Figure B-1 presents a schematic representation of process water treatment and flows. Table B-1 presents anticipated process water flows corresponding to the flow streams labeled in Figure B-1. Table B-2 presents anticipated quality of the various process streams.

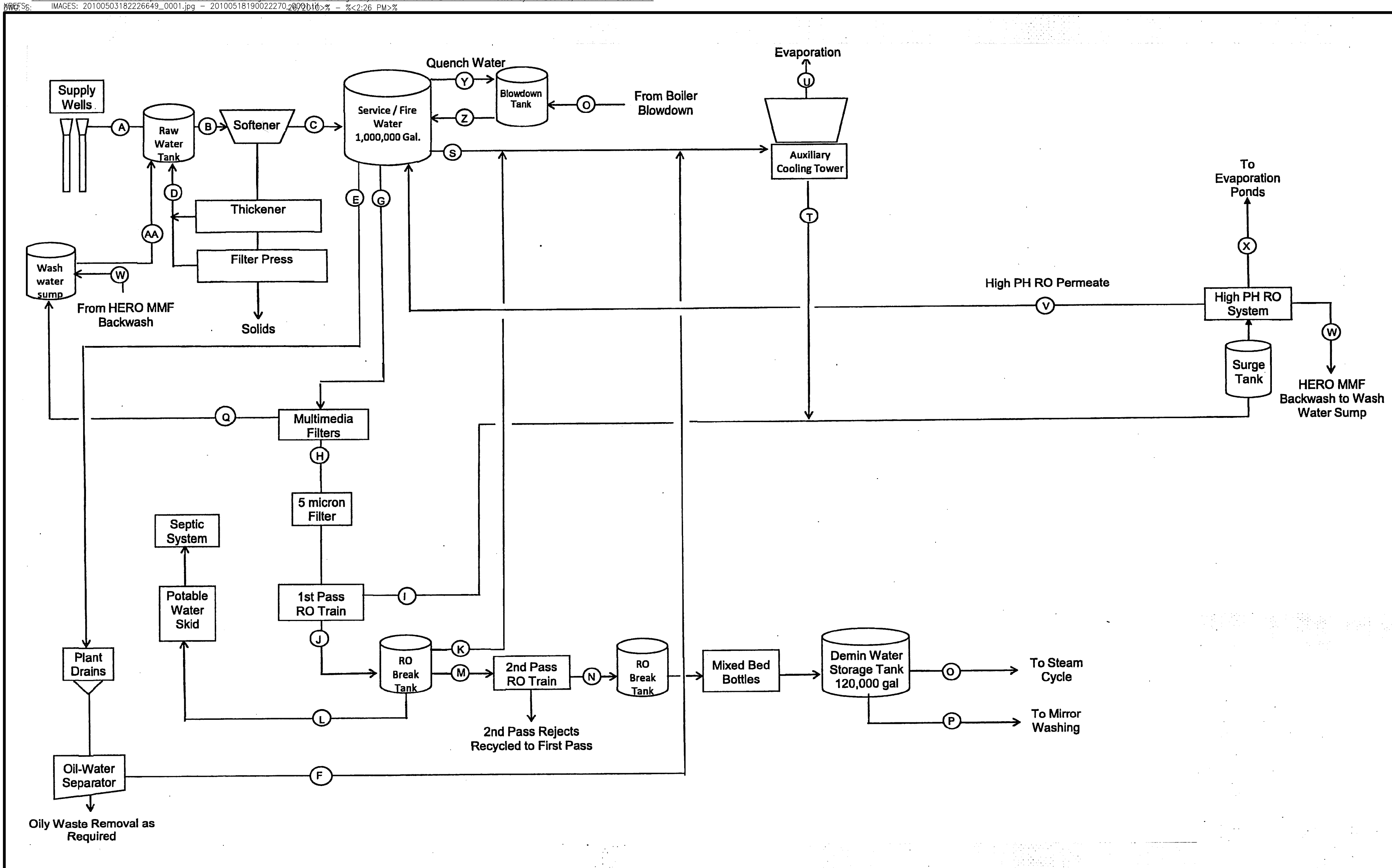

FIGURE B1	SOLAR MILLENNIUM	AECOM PROJECT NO.	AECOM
	RIDGECREST EVAPORATION PONDS FIGURE B-1	60092528.0010	AECOM USA, Inc. 5001 E. Commercenter Dr. Suite 100 Bakersfield, California 93309 T 661.325.7253 F 661.395.0359 www.aecom.com

Table B-1
Process Water Flows

		24 Hr Average	24 Hr Total	Peak Operation
	Ambient Conditions	96.7F/66.5F_WB	96.7F/66.5F_WB	96.7F/66.5F_WB
	Boiler Duty	100%	100%	100%
Stream ID	**Description**	**GPM**	**GPD**	**GPM**
A	Flow from supply wells	63	90,917	97
B	Softener Makeup	99.46	143,225	153.52
C	Softener Effluent	98.47	141,793	151.98
D	Recovered dewatering water	0.4	573	0.61
	Water in dewatered sludge	0.6	859	0.92
E	Service water to plant users	4	5,760	4
F	OWS effluent	4	5,760	4
G	Multimedia filter makeup	133.4	192,121	197.1
H	First pass RO makeup	120	172,909	177
I	First pass RO reject	48	69,164	71
J	First pass RO permeate	72	103,746	106
K	RO permeate to cooling tower	0	-	0
L	RO permeate to potable water	2	2,880	2
M	Second pass RO makeup	70	100,866	104
N	Second pass RO permeate	53	75,649	78
O	Steam cycle makeup / blowdown	16	23,398	42
P	Demin water to mirror washing	36	52,251	36
Q	Multimedia filter backwash	13	19,212	20
	Service water to cooling tower	27	38,694	76
S	Total cooling tower makeup	31	44,454	80
T	Cooling tower evaporation	21	29,636	53
U	Cooling tower blowdown	10	14,818	27
V	High pH RO permeate	50	71,384	83
W	High pH filter backwash	5.832	8,398	9.758
X	High pH RO reject of Evap Pond	8.748	12,597	14.636
Y	Quench Water	65	93,732	130
Z	Quenched Boiler Blowdown	81	117,130	172
AA	Multimedia filter backwash	36	51,735	56

Design Basis:

1. Steam cycle makeup and cooling tower evaporation from Kiewit.
2. Recovery rates depend upon influent water chemistry.
3. Based on water analysis April 2008 from Indian Wells Valley Water District Wells 18, 33, and 34.

Table B-2
Anticipated Water Quality

Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporation Pond
		A, B	C, D	E,G,H,S,Y	J,L,K,M	J	O,P	P	Z	F+K+S		V	
Cations													
Calcium	mg/L	37	16	11	5	40	0	1	9	11	32	0	39
Magnesium	mg/L	5.4	5	3	1	12.5	0	1	3	3	10	0	12
Sodium	mg/L	44	44	36	10	110	0	77	44	36	108	20	767
Potassium	mg/L	4	4	4	0	10	0		3	4	12	4	10
Ammonia	mg/L	ND	0.1	0	0	0.25	0		0	0	0	0	0
Anions													
Chloride	mg/L	86	86	60	10	215	0	1	48	60	180	9	1045
Sulfate	mg/L	44	44	38	5	110	0	4	32	38	115	27	111
Alkalinity	mg/L	117	32	21	1	80	0		17	21	64	0	77
Bicarbonate	mg/L	143	39	26	1	97.5	0		21	26	78	0	94
Carbonate	mg/L	ND	0	0	0	0	0		0	0	1	1	0
Cyanide	µg/L	ND		0	0	0	0		0	0	0	0	0
Silica	mg/L	42	10	7	0	25	0	2	6	7	21	1	24
Phosphate	mg/L	ND	0	0	0	0	0		0	0	0	0	0
Polyphosphate	mg/L	ND	0	0	0	0	0	0.5	0	0	0	0	0
Fluoride	mg/L	0.8	0.8	1	2	2	0		0	1	2	0	2
Nitrate	mg/L	8	8	5	0	20	0		4	5	16	0	19
General													
Suspended Solids	mg/L	0	5	3	0	12.5	0		3	3	10	0	12
Total Dissolved Solids	mg/L	287	280	209	36	700	0	85	184	209	626	68	2124
Hardness	mg/L	115	50	34	28	125	0		27	34	102	2	121
Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporation Pond
Trace Metals													
Aluminium	µg/L	ND	ND	0	0	0	0		ND	0	0		0
Antimony	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
		4	4	3	0	10	0		2	3	8	0	10
Arsenic	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Barium	µg/L	0.28	0.28	0.19	1	0.7	0	28	6	0	1	0	1

Table B-2
Anticipated Water Quality

Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporation Pond
Boron	mg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Cadmium	µg/L	ND	ND	0	0	0	0	10	2	0	0	0	0
Chromium	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Cobalt	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Copper	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Hexavalent Chromium	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Iron	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Lead	µg/L	0.7	0	0	0	0	0		0	0	0	0	0
Manganese	µg/L	ND	ND	0	0	0	0	1	0	0	0	0	0
Molybdenum	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Nickel	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Selenium	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Strontium	µg/L	ND	ND	0	0	0	0		ND	0	0	0	0
Thallium	µg/L	14	14	9	0	0	0		7	9	28	0	5
Vanadium	µg/L	0.022	0.07	0.05	0	0.175	0	0.005	0.04	0.05	0.14		0.17
Zinc	mg/L	ND	ND	0	0	0	0		ND	0	0		0

Table B-3
Evaporation Pond Sludge Quality

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg
Cations					
Calcium	mg/L	4	1,479	18,066	1626
Magnesium	mg/L	1	462	5,646	508
Sodium	mg/L	81	29,407	359,182	32326
Potassium	mg/L	1	396	4,843	436
Ammonia	mg/L	0	9	113	10
Anions					
Chloride	mg/L	110	40,050	489,190	44027
Sulfate	mg/L	12	4,248	51,882	4669
Alkalinity	mg/L	8	2,958		0
Bicarbonate	mg/L	10	3,605	44,036	3963
Carbonate	mg/L	0	7	82	7
Cyanide	µg/L	-	-	-	0
Silica	mg/L	3	931	11,373	1024
Phosphate	mg/L	-	-	-	0
Polyphosphate	mg/L	-	-	-	0
Fluoride	mg/L	0	74	903	81
Nitrate	mg/L	2	740	9,033	813
General					
Suspended Solids	mg/L	1	462	5,646	465000
Total Dissolved Solids	mg/L	223	N/A		0
Hardness	mg/L	13	N/A		0
Trace Metals		-			
Aluminium	µg/L	-	-	-	0
Antimony	µg/L	-	-	-	0
Arsenic	µg/L	0.001	0.37	5	0
Barium	µg/L	-	0.00	-	0
Boron	mg/L	0.000	0	0	0
Cadmium	µg/L	-	-	-	0
Chromium	µg/L	-	-	-	0
Cobalt	µg/L	-	-	-	0

Table B-3
Evaporation Pond Sludge Quality

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg
Copper	µg/L	-	-	-	0
Hexavalent Chromium	µg/L	-	0.00	-	0
Iron	µg/L	-	0.00	-	0
Lead	µg/L	-	-	-	0
Manganese	µg/L	-	0.00	-	0
Molybdenum	µg/L	-	0.00	-	0
Nickel	µg/L	-	0.00	-	0
Selenium	µg/L	-	-	-	0
Strontium	µg/L	-	0.00	-	0
Thallium	µg/L	-	-	-	0
Vanadium	µg/L	0.001	0	2	0
Zinc	mg/L	0.000	0.0	0	0

5.0 Annual Precipitation Data

Pond top surface area = 176400 SF

= 4.04 Ac

Monthly Average Rainfall		
	Depth (In)	**Volume (CF)**
January	0.95	14,665
February	0.87	12,790
March	0.82	12,050
April	0.13	1,911
May	0.13	1,911
June	0.02	294
July	0.10	2,790
August	0.32	4,704
September	0.25	3,675
October	0.19	2,793
November	0.27	3,970
December	0.49	7,200
Total	4.54	68,753

Data source: http://www.wrcc.dri.edu

6.0 Evaporation Data

Required pond area = 152,100 SF

= 3.49 Ac

Correction factor, pan to pond = 0.75 (Assumed)

Correction factor, salinity = 0.70 (Assumed)

	Pan Evaporation (inches)	**Corrected Evaporation (inches)**	**Evaporation Volume (CF)**
January	0	0.00	0
February	4.65	2.44	35,886
March	6.45	3.39	49,778
April	9.97	5.23	76,943
May	13.59	7.13	104,881
June	15.33	8.05	118,309
July	17.21	9.04	132,818
August	16	8.40	123,480
September	11.83	6.21	91,298
October	8.28	4.35	63,901
November	4.76	2.50	36,735
December	3.52	1.85	27,166
Total	111.59	58.58	861,196

Data Source: http://www.wrcc.dri.edu/htmfiles/westevap.final.html

Pond top dimensions:

North pond 406 ft x 423 ft

South pond 290 ft x 605.5 ft

Attachment A
Action Leakage Rate Calculation

Action Leakage Rate Calculation for Palen Solar Power Plant

OBJECTIVE:

Determine the Action Leakage Rate (ALR) for Palen Solar Power Plant evaporation ponds. The ALR is defined as "the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot" (U.S. EPA 1992; United States Government Printing Office 2002).

GIVEN:

- Leak collection and recovery system (LCRS) configuration.
- Evaporation pond configuration (Figures B-1 through B-9).
- Drainage Material Properties (Attachment 1).

GEOMETRY:

- The evaporation pond configuration and liner system details are given in Figures 1 through 9 of Attachment A.
- Sump lengths are:
  - North pond: 350 feet
  - South pond: 534 feet

The sumps are placed at the toe of the side slope at the bottom edge of the ponds and extend essentially the entire width of the pond bottoms. Therefore the sumps can receive inflow from both the pond bottom and the side slope.

MATERIAL PROPERTIES:

The drainage geonet considered in this analysis is the Hypernet manufactured by GSE. Hypernet has a thickness of 200 mil and transmissivity of 9.66 gallons/minute/foot.

METHOD:

The ALR calculation is based on the U.S. EPA Guidelines published by U.S. EPA (1992).

ASSUMPTIONS:

- Darcy's law is valid
- The gradient of the floor of the evaporation ponds is a minimum of 1 percent. The gradient of the side slopes for the cells is approximately 33 percent
- One foot of water head is developed on the bottom liner.

CALCULATIONS:

The maximum flow rate within the LCRS geonet is calculated using Darcy's equation:

$$Q = KiA$$

Where:

Q = flow through unit width of the LCRS drainage layer (ft^3/sec);
K = hydraulic conductivity of the LCRS drainage later (ft/sec);
i = hydraulic gradient; and
A = area of the flow per unity width (ft^2/ft).

For a geonet the flow through the layer is calculated by using the following equation:

$$q_{ult} = i \; □ \; W$$

where:

q_{ult} = flow through the geosynthetic layer (ft^3/sec/ft)
I = hydraulic gradient
□ = transmissivity (ft/sec); and
W = width of the drain (ft).

A factor of safety should be applied to consider the reduction in flow capacity of the geonet due to deformations, intrusions, clogging, or precipitation of chemicals (Koerner, 2005):

$$q_{allow} = q_{ult} /(RFin * RFcr * RFcc * FRbc)$$

where:

q_{allow} = flow through the geosynthetic layer
q_{ult} = allowable flow rate
RF_{in} = reduction factor for elastic deformation or intrusion
RF_{cr} = reduction factor for creep deformation
RF_{cc} = reduction factor for chemical clogging, and
RF_{bc} = reduction factor for biological clogging.

Table 1 shows the adopted reduction factors for a secondary leachate collection system according to Table 3 in Koerner (2005).

Table 1 **Reduction Factors for Determining Allowable Flow Rate of Geonets**		
Factor	Recommended Value Range	Use for Geonet
RF_{in}	1.5-2.0	1.5
RF_{cr}	1.4-2.0	1.4
RF_{cc}	1.5-2.0	2.0
RF_{bc}	1.5-2.0	2.0

Water head equal to 1 foot is assumed to be acting over the bottom liner so the hydraulic gradient can be assumed to be equal to the slope of the geonet. For the bottom of the evaporation pond:

$$i = 1\%$$

For the side slope of the evaporation pond (3H:1V):

$$i = 33\%$$

The flow in the geonet per unit width for the bottom of the evaporation pond is:

$$q_{ult} = 0.01 * 9.66 \text{ gal/min/ft} = 0.097 \text{ gal/min/ft}$$

The flow in the geonet per unity width for the side slopes is

$$q_{ult} = 0.33 * 9.66 \text{ gal/min/ft} = 3.19 \text{ gal/min/ft}$$

The allowable flow rate per unit width for the bottom of the evaporation pond is

$$q_{allowb} = 0.097/(1.5*1.4*2.0*2.0) = 0.012 \text{ gal/min/ft}$$

The allowable flow rate per unit width for the side slopes of the evaporation pond is

$$q_{allowss} = 3.19/(1.5*1.4*2.0*2.0) = 0.38 \text{ gal/min/ft}$$

The total allowable flow rate per unit width of the sump is

$$q_{allow} = q_{allowb} + q_{allowss} = 0.012 + 0.38 = 0.392 \text{ gal/min/ft}$$

Because the sump is much longer than it is wide, it is assumed that the flow contribution from the ends is negligible.

The ALR expressed in gallons per acre per day (gpad) for the north and south ponds is summarized in Table 2:

Table 2: Action Leakage Rates		
	North Ponds	South Ponds
Sump length, feet	350	534
q_{allow}, gal/min/ft	0.392	0.382
ALR, gpm	137	209
ALR, gal/day	197,000	301,000
Pond area, acres	4	4
ALR, gpad	**49,320**	**75,360**

References:

U.S. Environmental Protection Agency (U.S. EPA). 1992. “Action leakage rates for detection systems (supplemental background document for the final double liners and leak detection systems rule for hazardous waste landfills, waste piles, and surface impoundments).”

Koerner, Robert M. and Koerner, George R., “GSI White Paper #4 Reduction Factors (RFs) Used in Geosynthetic Design”, Geosynthetic Institute, 2005, rev. 2007.

Attachment 1

GSE

GSE STANDARD PRODUCTS

Product Data Sheet

GSE HyperNet Geonets

GSE HyperNet geonets are synthetic drainage materials manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. HDPE resins are inert to chemicals encountered in most of the civil and environmental applications where these materials are used. GSE geonets are formulated to be resistant to ultraviolet light for time periods necessary to complete installation. GSE HyperNet geonets are available in standard, HF, HS, and UF varieties.

The table below provides index physical, mechanical and hydraulic characteristics of GSE geonets. Contact GSE for information regarding performance of these products under site-specific load, gradient, and boundary conditions.

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE[c]			
			HyperNet	HyperNet HF	HyperNet HS	HyperNet UF
Product Code			XL4000N004	XL5000N004	XL7000N004	XL8000N004
Transmissivity[a], gal/min/ft (m^2/sec)	ASTM D 4716-00	1/540,000 ft^2	9.66 (2×10^{-3})	14.49 (3×10^{-3})	28.98 (6×10^{-3})	38.64 (8×10^{-3})
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft^2	200 (5)	250 (6.3)	275 (7)	300 (7.6)
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft^2	45 (7.9)	55 (9.6)	65 (11.5)	75 (13.3)
Carbon Black Content, %	ASTM D 1603, modified	1/50,000 ft^2	2.0	2.0	2.0	2.0
Roll Width, ft (m)			15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)
Roll Length, ft (m)[b]			300 (91)	250 (76)	220 (67)	200 (60)
Roll Area, ft^2 (m^2)			4,500 (418)	3,750 (348)	3,300 (305)	3,000 (278)

NOTES:

- [a]Gradient of 0.1, normal load of 10,000 psf, water at 70° F (20° C), between steel plates for 15 minutes.
- [b]Please check with GSE for other available roll lengths.
- [c]These are MARV values that are based on the cumulative results of specimens tested by GSE.

DS017 R07/07/03

Americas	GSE Lining Technology, Inc.	Houston, Texas	800-435-2008	281-443-8564	Fax: 281-230-8650
Europe/Middle East/Africa	GSE Lining Technology GmbH	Hamburg, Germany		49-40-767420	Fax: 49-40-7674233
Asia/Pacific	GSE Lining Technology Company Ltd.	Bangkok, Thailand		66-2-937-0091	Fax: 66-2-937-0097

This product data sheet is also available on our website at:

www.gseworld.com

AECOM

Prepared for:
Ridgecrest Solar I, LLC

Evaporation Pond Preliminary Design, Operations, and Maintenance Plan Ridgecrest Solar Power Project Kern County, California

Appendix C of the Application/Report of Waste Discharge

Prepared for:
Ridgecrest Solar I, LLC

Evaporation Pond Preliminary Design, Operation and Maintenance Plan Ridgecrest Solar Power Project

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1.0 Introduction

Ridgecrest Solar I LLC (RSI) proposes to construct the Ridgecrest Solar Power Project (RSPP) on 3,995 acres. The Project site is located southwest of U.S. Highway 395 and approximately five miles southwest of the City of Ridgecrest, California in northeastern Kern County. The location of the Facility and its existing physiographic and topographic setting are shown on Figure 1. The Facility will consist of a nominal 250 megawatt (MW) concentrating solar power (CSP) plant that will use parabolic trough solar thermal technology to produce electrical power with a steam turbine generator (STG) fed from a solar steam generator (SSG). The Facility will include one power block Unit, solar arrays, administration buildings, evaporation ponds, bioremediation areas and land farming. An Application for Certification (AFC) for the project was submitted to the California Energy Commission (CEC) in September 2009 and contains a detailed description of the project and related impacts, requirements and mitigation measures.

The Facility will generate wastewater from cooling tower blowdown and plant water treatment activities and requires a Waste Discharge Requirements (WDR) Permit from the California Regional Water Quality Control Board (RWQCB), Lahontan Basin Region to discharge this wastewater into a total of two evaporation ponds. The evaporation ponds are regulated under Title 27 of the California Code of Regulations (CCR) and the California Water Code for waste management and are classified as Class II surface impoundments. The wastewater and accumulated sludge from evaporation in the evaporation ponds is classified as a designated waste. A designated waste is defined as a non-hazardous waste that consists of pollutants which, under ambient environmental conditions at the waste management unit, could be released at concentrations in excess of applicable water quality objectives, or which could cause degradation of waters of the state.

This Evaporation Pond Preliminary Design, Operations and Maintenance Plan (the Plan) addresses certain requirements of Title 27 CCR and a Report of Waste Discharge (ROWD) under Section 13260 of the California Water Code. Specifically, the following requirements are addressed in this Plan:

- Waste Characterization;
- Design and Construction Standards;
- Operating Criteria;
- Environmental Controls; and
- Pond Inspection, Monitoring and Maintenance Activities.

Additional requirements of Title 27 CCR and Section 13260 of the California Water Code are being addressed under separate cover by AECOM Environment. These requirements include the following:

- Description of Project Setting, Hydrology and Hydrogeology;
- Detection Monitoring and Reporting Program;
- Contingency Plan, including response actions and design criteria for addressing releases;
- Description of all BMPs;

- Closure Plan; and
- Post Closure Maintenance Plan.

In addition to the above, various plan documents pertinent to addressing and implementing operating requirements for the proposed evaporation ponds will be prepared as specified in the AFC for the project, including the following:

- Emergency Action Plan
- Personal Protective Equipment Program
- Injury and Illness Prevention Plan
- Fire Protection and Prevention Plan
- Operations Safety Training Program
- Operations Dust Control Plan; and
- Drainage, Erosion and Sediment Control Plan.

2.0 WASTE CHARACTERIZATION

Wastewater from within the Facility will be piped to two 4.0-acre evaporation ponds (total combined area of 8 acres) for disposal. Details regarding the pond design are presented in Section 3.1. The pond area provides sufficient evaporative capacity to dispose of the anticipated wastewater stream, and allows for one pond to be taken out of service for up to approximately one year for cleaning, potential future maintenance, and repair without impacting the operation of the plant. The sources, and processes generating the wastewater stream disposed in the ponds and their relative contributions are shown on Figure B-1 (Attachment B). Raw water for the Facility is supplied from the Indian Wells Valley Water District (IWVWD). Discharge into the evaporation ponds is from one source:

1. High pH RO (Reverse Osmosis Concentrate

2.1 Groundwater Water Supply

The Project will be dry cooled. The Project's various water uses include water for solar collector mirror washing, makeup for the SSG feed water, dust control, water for cooling plant auxiliary equipment, potable water and fire protection. Water needs for the Project will be met by the IWVWD. The estimated water supply need for the Project is 150 af per year. To characterize raw water quality, data provided by the IWVWD for Wells 18, 33, and 34 was used for key chemistry parameters (refer to Table B-1, Attachment B).

The groundwater will be pretreated using a softener, with a focus on reducing the silica content as silica forms highly-insulating and difficult-to-remove deposits in cooling systems, boilers and turbines. The treated water from the softener is stored in a 1,500,000 gallon treated water storage tank for use in the cooling tower process as discussed in Section 2.2.1. Raw water and pre-treated water are used to supply various plant needs, including cooling tower circulating water, solar steam generator makeup water (after further treatment by demineralization), and various plant service, sanitary and potable water needs. All these water streams eventually discharge into the high pH reverse osmosis system and then to the evaporation ponds as is explained further in the following sections. A list of chemical components added in trace/small amounts during the treatment process and that are not expected to survive or to affect the final wastewater chemistry is presented in Table B-2 (Attachment B).

2.2 Waste Water Discharge

The chemical components in the different waste water streams and final expected concentrations in the evaporation pond are shown in Table B-2 (Attachment B).

2.2.1 Wastewater Treatment System

Wastewater is generated by auxiliary cooing tower blowdown, RO concentrate, and plant chemical drain collection. Each of these sources is collected and treated by the plant's wastewater treatment system which consists of a high pH reverse osmosis process.

Wastewater is stored in a 120,000 gallon storage tank upstream of the wastewater treatment system. While shown as a single box on the flow diagram (Attachment B), the wastewater treatment system is a very complex system that allows for the concentration of a water source containing high dissolved solids. The wastewater treatment system utilizes filtration, softening, pH adjustment, and reverse osmosis to accomplish the concentration of dissolved solids.

Wastewater is pumped from the storage tank by wastewater transfer pumps. Wastewater is treated with coagulant and pumped to multimedia filters and then further filtered by ultrafiltration units. Filtered wastewater is stored in an ultrafilter product tank. Water will be pumped from the ultra filter product tank to backflush both the ultra filter and the multimedia filter. Caustic, acid, and sodium hypochlorite will all be dosed to the ultra filter during the cleaning cycle.

Product water from the ultra filter product storage tank will be pumped to softeners to remove water hardness from the wastewater system. A brine regeneration system is provided to restore the softening capability of the resin. Softened wastewater is treated with acid to lower the pH of the wastewater stream upstream of a decarbonator. The decarbonator removes carbon dioxide from the wastewater stream, which in turn lowers the alkalinity of the water. Wastewater from the decarbonator is then treated with caustic to raise the pH of the water stream.

High pH water is treated downstream of the decarbonator transfer pumps with antiscalant and fed to the high pH RO units. Permeate generated by the RO is returned to the service water tank Concentrate is pumped to the chemical sump and eventually the evaporation pond.

Plant drains will contain water from component wash down and cleaning, potential miscellaneous leaks and draining of plant equipment, condensation from plant equipment and other sources. Water from these areas will be collected in a system of floor drains, sumps, and pipes and routed to the wastewater collection system. This water will be routed through an Oil-Water Separator to capture the oil and prevent it from reaching the environment.

The anticipated flow rates of the water treatment system are shown on Figure B-1 and the predicted chemical composition of evaporation pond makeup is summarized in Table B-3 (Attachment B).

2.3 Evaporation Residue

We estimate that during the 30-year operating life of the Facility, about 6,400 tons of evaporites will accumulate in the ponds. However, because it is anticipated that wind-blown silt will accumulate in the ponds at a rate of perhaps six inches per year, it will be necessary to clean out the ponds on approximately 4 year intervals. Assuming two feet of silt accumulation, the sludge removed from the ponds will be approximately 9 percent evaporate and 91 percent silt. The predicted chemical makeup of the evaporite, based on information about the raw water chemistry and knowledge of the water use and treatment processes at the Facility, is summarized in Table B-3 (Attachment B).

3.0 DESIGN AND CONSTRUCTION STANDARDS

The containment strategy for the evaporation ponds is summarized as follows:

- Meet or exceed regulatory requirements for containment of waste fluids;
- Select materials that are compatible with the physical, chemical and thermal characteristics of the water and contaminated soils being contained;
- Protect against physical damage to the containment layers by including protective layers into the designs of each containment facility;
- Allow for occasional removal of contained media without otherwise damaging the integrity of the containment systems; and
- Include the ability to monitor the integrity of the containment system, to transfer fluids out of permeable layers on a continuous basis, and to transfer fluids from one evaporation pond to another.

The proposed design for the evaporation ponds has been selected to optimize performance based on these operating criteria. Figures 1 through 9 (Attachment A) illustrate the proposed design for evaporation ponds

3.1 General Design Description

3.1.1 Overview

Each 4.0 acre evaporation pond has a proposed design depth of seven feet which incorporates:

- Drying each pond at alternating four year intervals;
- 3 feet of operational depth;
- 2 foot of sludge build up over 4 years; and
- 2 feet of freeboard.

The containment design for the evaporation ponds, from the surface of the evaporation ponds downwards, consists of the following:

- A hard surface / protective layer;
- A primary 60 mil high density polyethylene (HDPE) liner;
- An interstitial leak detection system (LDS) comprising a drainage layer and piping;
- A secondary 40 mil HDPE liner; and
- A 2 foot thick compacted silty-sand base;
- A moisture detection system.

3.1.2 Hard Surface / Protective Layer

The hard surface / protective layer provides protection against accidental damage to the HDPE liners which could be caused by burrowing animals, falling objects, varying climatic conditions and worker activities. Second, the hard surface / protective layer will allow for occasional removal of the precipitated solids within the evaporation ponds. Various hard surface media such as reinforced concrete, roller compacted concrete, revetments, or combinations of these media will be assessed prior to the selection of the preferred option.

3.1.3 Primary Liner, Secondary Liner and Basal Layer

High density polyethylene (HDPE) was selected as the preferred fabric for the primary and secondary liners for the following reasons:

- It is chemically resistant to potentially high concentrations of dissolved salts;
- It is very durable during installation;
- It is strong and possesses desirable stress-strain characteristics; and
- It is the most common synthetic liner material and as such there is a broad base of practical experience associated with the installation of HDPE amongst construction contractors.

A 60 mil upper liner was selected to provide appropriate balance between strength and ductility characteristics, which is very important during liner installation. A non-woven geotextile will be installed on top of the 60 mil liner to act primarily as a protective layer. A 40 mil lower liner was selected for the lower and secondary liner to provide slightly better ductility and handling characteristics during installation, as strength is of lesser importance for the secondary liner. HDPE possesses large thermal expansion and contraction characteristics, and exhibits stress when liner temperature exceeds 122 ^oF. The temperature of the blowdown water is not expected to exceed 122 ^oF.

A 2 foot thick basal layer of compacted silty sand is included in the design profile to protect the underlying groundwater in the unlikely event that both synthetic liner materials are punctured during construction or operation of the evaporation ponds. This base layer also serves to provide a smooth, competent surface to support the overlying synthetic liners and leak detection system layers.

3.1.4 Leak Detection System

A drainage layer is included in the design profile for the evaporation ponds which consists of a granular drainage layer with perforated piping to collect and convey fluids to an extraction riser in a leak detection sump (LDS). Geocomposite drainage materials, consisting of HDPE geonet and non-woven geotextiles heat bonded to one or both sides, may be used in conjunction with or as a substitute for the granular drainage layer on slopes.

The water collected in the LDS will drain by gravity to a unique monitoring well that is constructed for each of the leak collection layer. Automated pneumatic, solar-powered pumping systems are included in the design of each of these monitoring wells to automatically return water to that pond, which in turn minimizes the hydraulic pressures across the secondary liners and therefore the risk of impact to groundwater quality.

The base of the evaporation pond leak detection and collection layer will slope at a minimum inclination of 1 percent to a leak collection trench. The trench will contain screened sand (with no fines) and a perforated pipe that will slope at a minimum inclination of ¾ percent towards a leak detection and collection sump, located at the lowest point in the pond. The water in the collection sump will drain by gravity to a monitoring well that is constructed for each evaporation pond (one well per pond). Automated pneumatic pumping systems in the monitoring wells will automatically return water collected in the sump to that evaporation pond, which in turn minimizes the hydraulic pressures across the secondary liners and, therefore, minimizes the risk of leakage through the secondary liner. Leakage rates will be measured using a flow totalizer.

The collection sump, pipe, and monitoring well, will include prefabricated and field-fabricated HDPE components with water tight, extrusion welded and wedge-welded seams and penetrations. The liner system will be installed in accordance with current practices. Destructive and non-destructive testing procedures will be used to verify sump and penetration tightness and continuity.

This design is consistent with CCR Title 27, Section 20340, which requires an LDRS between the liners for the evaporation ponds.

3.1.5 Berms and Side Slopes

The side slopes around the evaporation ponds will contain the same liner system as the base of the ponds, except that leak collection pipes will not be located on the pond side slopes.

The berms shall be covered with a minimum 6-inch thick road base or approved equivalent. The top of the berms will be a minimum of 2 feet above the surrounding grade to prevent potential inflow of stormwater.

3.1.6 Material Compatibility

The wastewater will come into contact with the hard surface/protective layer. As outlined in Section 7.1.1.2, the media for this layer will either be roller-compacted concrete or an approved equivalent alternate. All final media selection will be compatible with the wastewater by using quality concrete with maximum chemical resistance (specifications will be provided to the concrete manufacturer to ensure proper mix selection).

If there is leakage in the evaporation pond, the wastewater will come into contact with the primary/secondary liner. HDPE is chemically resistant to saline solutions and long-term contact between the wastewater in the evaporation ponds and the HDPE liner system will not compromise liner integrity. Further explanation for HPDE selection is provided in Section 7.1.1.3.

The hard surface/protective layers, liner system, and base layer will have the ability to withstand the dissolved solids content of the water without degradation. These systems will not fail due to pressure gradients from physical contact with the wastewater and residue or undergo chemical reactions or degradation.

3.2 Construction Methods and Sequence

3.2.1 General

The containment construction process will follow these general steps:

a. Prior to construction, the topsoil and subsoil covering the area will be stripped and stockpiled.

b. Placement and compaction of the silty sand base material;

c. Installation of the carrier pipe for the moisture detection (neutron probe) system beneath the base of the ponds;

d. Construction of finish grading to sub grade, as needed, and excavation of the leak collection trench and detection/collection sumps.

e. Scarification, moisture conditioning, compaction, proof rolling and testing of subgrade materials;

f. Installation of secondary HDPE liner;

g. Installation of leak detection layer, sump, and leak extraction risers;

h. Installation of primary HDPE liner;

i. Installation of the non-woven geomembrane liner;

j. Installation of granular fill;

k. Installation of liner protection layers; and

l. Hard surface placement.

3.2.2 Site Preparation, Excavation and Compaction

The excavation and berm construction will use standard cut and fill techniques. The silty sand material on site will be used for general earthworks construction and to construct the compacted base or subgrade. The silty sand material will be compacted to a minimum of 95% of the maximum dry density as determined by ASTM D1557. The soil will be spread with a dozer and compacted in lifts using a sheeps foot roller or other suitable compaction equipment. Field testing of the density of the soil will be performed at regular intervals. Compaction results will be recorded.

3.2.3 Liner System Installation

3.2.3.1 Secondary Liner

The secondary liner or lower liner will consist of a 40 mil thick HDPE geomembrane liner. This liner will be installed in accordance with current practices and will employ the use of wedge welding and extrusion welding procedures. In addition destructive and non-destructive testing procedures will be used to ensure liner quality and continuity.

3.2.3.2 Leak Detection System

The leak detection system between the upper and lower liners consists of a 1 foot thick granular drainage layer. Piping will be used to convey collected fluids to a leak detection system extraction riser. The granular drainage layer, including the perforated piping system will have to be carefully placed on top of the underlying 40 mil HDPE liner. The construction sequence will have to be developed with the emphasis of material placement, spreading, and consolidation techniques that will ensure that damage to the liner does not occur. Geocomposite or geonet drainage media may be used in lieu of or in conjunction with the granular drainage layer in light of the requirement to prevent damage to the geomembrane liner.

3.2.3.3 Primary Liner

The upper or primary liner will consist of a 60 mil thick HDPE geomembrane liner. As is the case for the secondary 40 mil HDPE liner, current installation, quality control monitoring, testing, and quality assurance measures and techniques will be employed to ensure liner quality and continuity. The primary liner will be protected by a non-woven geotextile that will be installed directly on top of the liner.

3.2.4 Hard Surface / Protective Layer

A hard surface / protective layer will be constructed on the granular fill and non-woven geotextile that covers the primary liner. The hard surface will allow for vehicular traffic during cleanout. Hard surface types to be considered and assessed include:

- Reinforced concrete;
- Roller compacted concrete;
- Revetment systems; or
- A combination of these.

Prior to the placement of the hard surfacing, a 1 foot thick granular fill layer will be placed, spread and consolidated over the non-woven geotextile that serves to protect the underlying primary geomembrane liner. This granular fill layer is intended to serve two purposes:

- As the supporting base for the hard surfacing; and
- As a drainage layer between the hard surfacing and underlying primary liner.

Roller-compacted concrete can be transported in dump trucks and can be spread with a dozer or motor grader and compacted with a vibratory roller. Additionally, the roller-compacted concrete can be placed without joints, forms, or reinforcing steel, and is not required to be finished. This will make the application of the hard surface/protective layer relatively economical.

An aggregate road base material will be placed along the top of each berm to provide an all weather access location for maintenance vehicles. The material will conform to the Department of Transportation Specifications for Class II Aggregate Base. This will be installed to a minimum thickness of 6 inches and will be placed and compacted in accordance with the Department of Transportation requirements.

3.3 Construction Quality Assurance

3.3.1 Introduction

The quality assurance program is based on the State Water Resources Control Board- Construction Quality Assurance (CQA) Requirements under Title 27 of the California Code of Regulations. The requirements themselves will be highlighted and an explanation of how the requirements will be met will follow immediately afterwards.

The evaporation ponds will be constructed as per the construction specifications that will be developed in accordance with the CQA plan provided herein. The CQA program will be implemented to ensure that construction is completed in accordance with design specifications.

CQA testing will be performed on the sub-grade, compacted silty sand base, HDPE liners, granular, and hard surface materials.

Construction inspection requirements will include approving of each layer to ensure that there are no deficiencies in that layer prior to placement of the next material. This will also include review of other CQA results to ensure that they are within the project's specifications.

Change authorization will flow through the on-site construction manager and will ensure that the required personnel have input in the decision. Daily reports will be kept to ensure that activities are documented and personnel involved in the project are updated daily.

3.3.2 Performance Standard

Quoting from the State Water Resources Control Board CQA requirements section (a):

The construction quality assurance (CQA) program, including all relevant aspects of construction quality control (CQC), shall provide evidence that materials and procedures utilized in the placement of the any containment feature at a waste management unit (Unit) will be tested and monitored to assure the structure is constructed in accordance with the design specifications approved by the RWQCB.

The project will implement quality control procedures that incorporate inspection and test procedures to make sure that the containment facilities are constructed properly and that they are monitored appropriately throughout the life of the project. These tests and procedures will be documented in detail throughout the project.

3.3.3 Professional Qualifications

Quoting from the State Water Resources Control Board CQA requirements section (b):

1. The design professional who prepares the CQA plan shall be a registered civil engineer or certified engineering geologist; and

2. The construction quality assurance program shall be supervised by a registered civil engineer or certified engineering geologist who shall be designated the CQA officer.

The Project will ensure that a design professional will prepare the CQA plan and will provide a design professional that will act as a CQA officer whose responsibility is to supervise the CQA program. Construction activities and operations will be directed and supervised by qualified individuals and the design will be conceived and presented in accordance with recognized civil, mechanical and electrical engineering procedures and practices.

3.3.4 Reports

Quoting from the State Water Resources Control Board CQA requirements section (c):

1. The project's CQA report shall address the construction requirements, including any vegetation procedures, set forth in the design plan for the containment system. For each specified phase of construction, this report shall include, but not be limited to:

    a. a delineation of the CQA management organization, including the chain of command of the CQA inspectors and contractors;

    b. a detailed description of the level of experience and training for the contractor, the work crew, and CQA inspectors for every major phase of construction in order to ensure that the installation methods and procedures required in the containment system design will be properly implemented.

    c. a description of the CQA testing protocols for preconstruction, construction, and postconstruction which shall include at a minimum:

        i. the frequency of inspections by the operator,

        ii. the sampling and field testing procedures and equipment to be utilized, and the calibration of field testing equipment,

        iii. the frequency of performance audits determined by the design professional and examined by the CQA officer,

        iv. the size, method, location and frequency of sampling, sampling procedures for laboratory testing, the soils or geotechnical laboratory to be used, the laboratory procedures to be utilized, the calibration of laboratory equipment and quality assurance and quality control of laboratory procedures,

        v. the pass/fail criteria for sampling and testing methods used to achieve containment system design, and

        vi. a description of the corrective procedures in the event of test failure.

The Project will provide the following:

- An outline of the chain of command of the CQA inspectors and contractors in the CQA management organization.
- A description of the CQA testing procedures for the preconstruction, construction, and post construction phases of the project.
- A CQA report that includes construction quality control requirements included in the design plan for each specified phase of construction outlined in Section 5- Construction.

3.3.5 Documentation

Quoting from the State Water Resources Control Board CQA requirements section (d):

> *Construction quality assurance documentation requirements shall include, at the minimum: reports bearing unique identifying sheet numbers for cross referencing and document control, the date, project name, location, descriptive remarks, the data*

sheets, inspection activities, and signature of the designated authorities with concurrence of the CQA officer.

1. *The documentation shall include:*

    a. *Daily Summary Reports — daily record keeping, which shall include preparation of a summary report with supporting inspection data sheets, problem identification and corrective measures reports. Daily summary reports shall provide a chronological framework for identifying and recording all other reports. Inspection data sheets shall contain all observations (i.e., notes, charts, sketches, or photographs), and a record of field and/or laboratory tests. Problem identification and corrective measures reports shall include detailed descriptions of materials and/or workmanship that do not meet a specified design and shall be cross-referenced to specific inspection data sheets where the problem was identified and corrected;*

    b. *Acceptance Reports — all reports shall be assembled and summarized into Acceptance Reports in order to verify that the materials and construction processes comply with the specified design. This report shall include, at a minimum, inspection summary reports, inspection data sheets, problem identification and corrective measures reports;*

    c. *Final Documentation — at the completion of the project, the operator shall prepare a Final Documentation which contains all reports submitted concerning the placement of the containment system. This document shall provide evidence that the CQA plan was implemented as proposed and that the construction proceeded in accordance with design criteria, plans, and specifications. The discharger shall submit copies of the Final Documentation report to the RWQCB as prepared by the CQA officer.*

2. *Once construction is complete, the document originals shall be stored by the discharger in a manner that will allow for easy access while still protecting them from any damage. All documentation shall be maintained throughout the postclosure maintenance period.*

These documents will include daily summary reports with supporting inspection data sheets that contain all observations. A record of field and laboratory tests will also be kept. Acceptance reports will be documents to ensure construction and materials comply with the original design and specifications. At the completion of the project, project closure documentation will be submitted to provide evidence that the CQA plan was implemented as proposed and that construction met design criteria, plans and specifications.

3.3.6 Laboratory Testing Requirements

Quoting from the State Water Resources Control Board CQA requirements section (e):

1. *Analysis of earthen materials shall be performed prior to their incorporation into any containment system component. Representative samples for each layer within the containment system shall be evaluated. The following minimum laboratory testing procedures shall be performed:*

a. *ASTM Designation: D 1557 91 [1/91], "Laboratory Compaction Characteristics of Soil Using Modified Effort (2,700 kN-m/m3)" which is incorporated by reference;*

b. *ASTM Designation: D 422 63 (Reapproved) [9/90], "Standard Method for Particle Size Analysis of Soils," which is incorporated by reference; and*

c. *ASTM Designation: D 2487 93 [11/93], "Standard Classification of Soils for Engineering Purposes," which is incorporated by reference.*

2. *In addition to the tests listed in (e and f), the following minimum laboratory tests shall be performed on low-hydraulic-conductivity layer components constructed from soil:*

a. *ASTM Designation: D 4318 93 [11/93], "Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils," which is incorporated by reference; and*

b. *United States Environmental Protection Agency (USEPA) Test Method 9100 [Approved 9¬86], "Triaxial-Cell Method with Back Pressure," which is incorporated by reference.*

The Project will send materials proposed for construction to the lab to an accredited laboratory so that the quality and characteristics can be confirmed and compared to project specifications.

The tests will include the following as per section (e) of the State Water Resources Control Board CQA requirements above:

- ASTM Designation: D 1557 91 [1/91], "Laboratory Compaction Characteristics of Soil Using Modified Effort (2,700 kN-m/m3)"
- ASTM Designation: D 422 63 (Reapproved) [9/90], "Standard Method for Particle Size Analysis of Soils,"
- ASTM Designation: D 2487 93 [11/93], "Standard Classification of Soils for Engineering Purposes,"
- And for permeability (hydraulic conductivity) layers the following tests will be taken at a minimum:
- ASTM Designation: D 4318 93 [11/93], "Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils,"
- United States Environmental Protection Agency (USEPA) Test Method 9100 [Approved 9-86], "Triaxial-Cell Method with Back Pressure,"

3.3.7 Field Testing Requirements

Quoting from the State Water Resources Control Board CQA requirements section (f):

The following minimum field test procedure shall be performed for each layer in the containment system: ASTM Designation: D 2488 93 [9/93], Standard Practice for Description and Identification of Soils (Visual Manual Procedure), which is incorporated by reference.

The Project will use the following test on each layer in the containment systems associated with the evaporation ponds and bioremediation pad:

- ASTM Designation: D 2488 93 [9/93], Standard Practice for Description and Identification of Soils (Visual Manual Procedure)

In addition, in place nuclear densiometer testing ASTM D2922 will be performed paired with maximum density and optimum moisture content test, ASTM D 698.

3.3.8 Test Fill Pad Requirements

Quoting from the State Water Resources Control Board CQA requirements section (g):

Before installing the compacted soil barrier layer component of a final cover system, or the compacted soil component of a liner system, the operator shall accurately establish the correlation between the design hydraulic conductivity and the density at which that conductivity is achieved. To accomplish this the operator shall:

1. *Provide a representative area for a test on any compacted foundation and low-hydraulic-conductivity layers. The following minimum testing procedures shall be performed:*

   a. *the test pad foundation and, for final covers, the barrier layers shall be compacted with the designated equipment to determine if the specified density/moisture-content/ hydraulic-conductivity relationships determined in the laboratory can be achieved in the field with the compaction equipment to be used and at the specified lift thickness;*

2. *perform laboratory tests as specified in State Water Resources Control Board CQA requirements subsection (e); and*

3. *perform field tests as specified in State Water Resources Control Board CQA requirements subsection (f). The discharger shall perform hydraulic conductivity tests in the test area under saturated conditions by using the standard test method ASTM Designation: D 3385 94 [9/94], "Standard Test Method for Infiltration Rate of Soils in Field Using Double Ring Infiltrometer," which is incorporated by reference, for vertical hydraulic conductivity measurements. A sufficient number of tests shall be run to verify the results. Other methods that provide an accurate and precise method of measuring field hydraulic conductivity may be utilized as approved by the RWQCB.*

4. *Correlations between laboratory tests and test pad results shall be established for each of the various types of fill materials and blends to be used in construction of the actual cover.*

When constructing compacted soil barrier layers, or a compacted soil component of a liner system, The Project will provide a representative area for a test. The soil layers will be compacted with equipment that can achieve density, moisture content, and hydraulic-conductivities, where applicable at specified lift thicknesses. The laboratory tests mentioned in State Water Resources Control Board CQA requirements section (e) will all be performed.

Results from lab tests and field tests will be compared to ensure that the specified requirements can be met and that the methods and procedures selected and used achieve the required construction quality standard.

3.3.9 Earthen Material Requirements

Quoting from the State Water Resources Control Board CQA requirements section (h):

1. *The following minimum tests shall include, but not be limited to:*

    a. *Laboratory tests as specified in State Water Resources Control Board CQA requirements subsection (e); and*

    b. *Field tests as specified in State Water Resources Control Board CQA requirements subsections (f and g).*

2. *The following minimum testing frequencies shall be performed:*

    c. *Four (4) field density tests shall be performed for each 1,000 cubic yards of material placed, or at a minimum of four (4) tests per day;*

    d. *Compaction curve data (ASTM Designation: D 1557 91) graphically represented, and Atterberg limits (ASTM Designation: D 4318 93) shall be performed on the barrier layer material once a week and/or every 5,000 cubic yards of material placed;*

    e. *For field hydraulic conductivity tests, representative samples shall be performed on barrier layer material;*

        i. *The frequency of testing may be increased or decreased, based on the pass/failure status of previous tests, as approved by the RWQCB.*

        ii. *Field infiltration tests shall be performed for the duration necessary to achieve steady conditions for the design hydraulic conductivity.*

        iii. *The following interpretive equation shall be used to determine the design hydraulic conductivity:*

        The infiltration rate (I) is defined as: $I = Q/(tA)$

        where: Q *= volume of flow;* t *= interval of time corresponding to flow Q; and*
        A *= area of the ring;*

        then the hydraulic conductivity (k) can be calculated from Darcy's law as follows:

        $k = I/i$

        where:
        I *= infiltration rate; and*
        i *= hydraulic gradient.*

When testing soils used for construction, the tests mentioned in State Water Resources Control Board CQA requirements section e) above, will be performed as a minimum. There will be four field density tests performed per 1000 cubic yards of material placed or at least four tests per day. Compaction curve data including Atterberg Limits, will be performed at least once per week or every 5000 cubic yards of material placed. For field hydraulic conductivity tests, the frequency of testing will be based on the pass/failure status of previous tests. They will be performed for the amount of time necessary to make sure steady conditions for the design hydraulic conductivity are met. The above equation I = Q / (tA) will be used to determine design hydraulic conductivity.

During construction, all compacted soils and granular material will be tested using a nuclear density / moisture gauge (densiometer) (ASTM D2922 and D3017) to determine compaction percentage and moisture content. Nuclear densiometer testing will be performed to ensure compaction and moisture condition requirements as outlined in the project specifications are being achieved. Each material will be tested following compaction in multiple locations to ensure compliance to projects specifications prior to proceeding with placement of the next material.

3.3.10 Geosynthetic Membrane Requirements

Quoting from the State Water Resources Control Board CQA requirements section (i):

1. *Performance requirements for the geosynthetic membrane include, but are not limited to, the following:*

   a. *a need to limit infiltration of water, to the greatest extent possible;*

   b. *a need to control landfill gas emissions;*

   c. *for final covers, mechanical compatibility with stresses caused by equipment traffic, and the result of differential settlement of the waste over time; and*

   d. *for final covers, durability throughout the postclosure maintenance period.*

2. *Minimum Criteria — The minimum construction quality assurance criteria to ensure thatgeosynthetic membranes will meet or exceed all design specifications shall include, but not be limited to:*

   a. *Preconstruction quality control program:*

      i. *inspection of the raw materials (e.g., density, melt flow index, percent carbon Black);*

      ii. *manufacturing operations and finished product specifications (e.g., thickness, puncture resistance, multi axial stress/strain tests),*

      iii. *fabrication operations (e.g., factory seaming);*

      iv. *observations related to transportation, handling, and storage of the geosynthetic membrane; and*

      v. *inspection of foundation preparation;*

   b. *Construction activities:*

i. *the geosynthetic membrane shall have thickness strength sufficient to withstand the stresses to which it shall be subjected, including shear forces, puncture from rocks or, for final covers, penetration from roots.*

ii. *inspection of geosynthetic membrane placement (e.g., trench corners, monitoring systems).*

iii. *seaming of the material; and*

iv. *installation of anchors and seals;*

c. *Postconstruction Activity — postconstruction activity includes checking for material and placement imperfections in the installed geosynthetic membrane. Imperfections that jeopardize the integrity of the membrane's function as an impermeable barrier (i.e., pin holes, rips, creases created during placement) shall be repaired to the original manufacturer's specifications and reinspected by the CQA officer; and*

d. *Evaluation — evaluation of the personnel and equipment to be used to install and inspect the geosynthetic membrane, and pass/fail criteria and corrective procedures for material and installation procedures shall be specified as required in State Water Resources Control Board CQA requirements subsection (c).*

The Project will make sure that the geosynthetic membrane (geomembrane) used for containment will limit the infiltration of water to the greatest extent possible and be designed to maintain durability throughout the life of the project. The Project will ensure that a preconstruction quality control program is in place to ensure that manufactured geomembrane products conform to the project specifications. Once construction activities begin, The Project will make sure that the proper material is used and supervise and inspect the placement of the geomembrane and the seaming of the material. After construction, The Project will check for imperfections in the installed geomembrane and ensure that repairs are completed in accordance with project specifications. The HDPE liner will be manufactured and installed according to industry standards and test procedures and the installer's CQA methods and procedures. Typical quality assurance methodologies include the review and inspection of the following:

- Copy of the mill certificates;
- Coupons from every seam;
- Perform air pressure tests;
- Inspections to ensure the absence of tears, punctures, and blisters;
- Liner production tests, thickness, dimensions, visual inspection;
- Product testing, tensile properties, tear resistance, etc;
- Sub-grade preparation sign-off; and
- Wedge welding and extrusion welding seam logs and weld tests.

3.3.11 Relevant Specifications

The following specifications from the Construction Specification Institute will be developed, as a minimum:

- 31 14 13 Soil Stripping and Stockpiling
- 31 14 11 Earthwork and Related Work
- 31 23 10 Excavating, Trenching and Backfilling
- 32 11 23 Aggregate Base Courses
- 31 32 21 Geotextiles
- 31 32 22 Geomembranes
- 32 12 16 Asphalt Paving (If applicable)
- 32 13 23 Roller Compacted Concrete Paving (If applicable)
- 32 21 13 or 32 31 25 Fencing

4.0 OPERATING CRITERIA

4.1 Site Records

In accordance with Title 27 CCR 20510, key site records will be kept in the office at the RSI Facility.

Records will be available for inspection by authorized representatives of the LEA and RWQCB during the facilities regular working hours. Alternatively, an inspection can be arranged by notifying the Facility manager. All required records will be properly completed, filed for retention and maintained throughout the operating life of the evaporation ponds.

4.1.1 Operating Record

The operating record maintained at the RSI Facility will include the following information.

- Discharge Volumes - Date and Volume of discharges into each evaporation pond
- Monitoring Results - Results of monitoring, analyses, and testing required by permit or regulatory requirement:
- Inspection Forms - Inspection results that include a description of any required maintenance or remedial action and the date of implementation.
- Contingency Implementation - Written reports prepared in response to any incident requiring implementation of the Contingency Plan.
- Correspondence with Local Agencies - Correspondence associated with emergency arrangements agreed to or refused by local authorities.
- Training Records - Records documenting employee information such as job title for each position, job description, names of employees in each job, and introductory and continuing training received.
- Notifications of Violations - Notices of deficiency, abatement orders or any other notification of violation by any regulatory agency.
- Complaints – The Facility manager will record public complaints received regarding operation of the ponds, including:
  - the nature of the complaint,
  - the date the complaint was received,
  - if available, the name, address, and telephone number of the person or persons making the complaint, and
  - actions taken to respond to the complaint.

4.1.2 Discharge Volumes

In accordance with Title 27 CCR 21720(f), all discharges into the evaporation ponds will be recorded in the Operating Record. The following items will be recorded include:

- Volume in million gallons per day (mgd)
- Cumulative total of wastewater flow, in million gallons, per month
- The maximum daily flow rate, in mgd, each month

4.1.3 Monitoring Results

Monitoring Plan results will be retained at the Facility as part of the Operating Record.

4.1.4 Inspection and Operations Records

Site personnel will complete the inspection logs and other required operation documentation and the facility management will review the applicable documents for completeness and accuracy. Completed inspection logs and notations of needed repairs will be maintained for a minimum of three years.

Further information regarding Inspection and Maintenance requirements are outlined in Section 6

4.1.5 Record of Contingency Plan Implementation

Following any incident which requires implementation of the Facility's Contingency Plan, a report will be prepared containing the information described in Title 27 CCR Section 21760(b)(2). As a minimum, the report will be submitted to the LEA and the RWQCB. In addition, a copy will be retained on filed at the Facility as part of the Operating Record.

Further information regarding the Contingency Plan requirements is outlined in Section 7.

4.1.6 Correspondence Regarding Arrangements with Local Authorities

Copies of all correspondence with local authorities regarding emergency response arrangements and revisions of the Contingency Plan will be maintained at the Facility.

4.1.7 Training Records

In accordance with Title 27 CCR Section 20610, the following records will be retained for each position related to waste management as part of the Operating Record:

- A job title and written job description including assigned duties and required qualifications;
- Name of the employee filling each job;
- Description of initial and continuing training; and
- Documentation of initial and continuing training received.

Whenever a training course is conducted, the records for each employee who completed the course will be updated. When a new employee is hired, a training record file will be initiated for the new employee. Personnel training records on current employees are retained until final closure of the Facility. Records on former employees are retained for three years after the employees' leave date.

4.1.8 Design Documents

In accordance with the requirements of Title 27 CCR Section 21760, all design, as-built, and operating documentation related to the evaporation pond system will be retained at the Facility as part of the Operating Record.

4.1.9 Other Required Technical Records

In accordance with Title 27 CCR Section 20510 and 20517, all other technical records associated with evaporation ponds will be retained at the Facility as part of the Operating Record.

4.1.10 Excavations Records

In accordance with Title 27 CCR Section 20510 (b), records of excavations which may affect the safe and proper operation of the ponds or cause damage to adjoining properties, are kept in the Operating Record.

4.1.11 Operator / Responsible Party Records

In accordance with Title 27 CCR Section 20510 (e), records of written notification to the LEA, local health agency, and fire authority of names, addresses and telephone number of the operator or responsible party of the site, are kept in the Operating Record.

4.2 Reporting Requirements

This section describes key reporting requirements to be met by the RSI Facility for the evaporation ponds.

4.2.1 Implementation of the Contingency Plan

Incidents that result in implementation of the Facility Contingency Plan will be reported to the appropriate agencies. Where such incidents threaten to result in an off-site discharge or may present a potential threat to human health or the environment, immediate verbal notification shall be made as specified in the Contingency Plan. A record of such verbal communications will be maintained in the operating record. As specified by state and Federal regulations, a written report describing the incident and the implementation of the Contingency Plan will be prepared and submitted to LEA and RWQCB within 15 days. Additional reporting may be required under the Waste Discharge Requirements and Monitoring and Reporting Program established by the RWQCB.

4.2.2 Environmental Monitoring Reports

There are several environmental monitoring reports required as part of the Monitoring and Reporting Plan (MRP). Copies of these reports will be kept at the Facility and may include:

- Groundwater Monitoring Reports
- Drainage Reports
- Annual Report

4.3 Security

In accordance with Title 27 CCR Section 21600(b)(5)(B), security measures will be provided to ensure the safest environment for employee working at the Facility. Security measures include barriers and warning signs.

4.3.1 Barriers

The Project solar fields and support facilities' perimeter will be secured with a combination of chain link and wind fencing. Chain link metal fabric security fencing consists of eight-foot tall fencing with one-foot barbed wire or razor wire on top along the north and south sides of the facilities. Thirty-foot tall wind fencing, comprised of A-frames and wire mesh, will be installed along the east and west sides of each solar field.

Controlled access gates will be located at the site entrance. Access through the main gate will require an electronic swipe card, preventing unaccompanied visitors from accessing the Project. All Project personnel, contractors, and visitors will be logged in and out of the Project at the main office during normal business hours. Visitors will be allowed entry only with approval from a staff member at the Project. Visitors will be issued visitor passes that are worn during their visit and returned at the main office when leaving.

4.3.2 Operational Hours

Personnel will staff the Facility 24 hours per day/seven days per week. Even when the solar power plant is not operating, personnel will be present as necessary for maintenance, to prepare the plant for startup, and/or for site security.

4.3.3 Warning Signs

Each point of access from a public road shall be posted with an easily visible sign indicating the facility name, and other pertinent information as required by the WDR.

4.4 Sanitary Facilities

In accordance with Title 27 CCR Section 21600(b)(5)(C), sanitary facilities will be provided at the site for facility employees in the office. The Facility will maintain all sanitary and hand-washing facilities which may be required, by applicable state or local requirements, in a reasonably clean and adequately supplied condition.

4.5 Communication Systems

Communication facilities will be provided at the site for facility employees that meet the requirements of Title 27 CCR Section 21600(b)(5)(D).

4.5.1 Internal Communication

The internal communication system for the Facility will include the following devices:

- Alarm system;
- Two-way radios;
- Telephones; and
- Intercoms.

Each Facility building will also be equipped with telephones. Operations supervisors and other key personnel may carry hand-held two-way radios that can be used to contact the Facility office or other site personnel in an emergency.

4.5.2 External Communications

Twenty-four hour access to outside emergency services, including police and fire departments and emergency response teams, is available through the commercial telephone system at the Facility

4.6 Lighting

Lighting will be provided at the Facility to ensure safety of employees during night time activities, and will meet the requirements of Title 27 CCR Section 21600(b)(5)(E). The Facilities lighting system will provide operations and maintenance personnel with illumination in both normal and emergency conditions. The system will consist primarily of AC lighting, but will include DC lighting for activities or emergency egress required during an outage of the facilities' AC electrical system. The lighting system will also provide AC convenience outlets for portable lamps and tools. Permanent lighting will be provided primarily along the paved access road to the Facility and in the power block area. Lighting in the bioremediation and land farm unit areas will be provided when needed using portable light stands.

4.7 Safety Equipment

In accordance with 27 CCR Section 21600(b)(5)(F), safety equipment will be provided for the health and safety of employees at the Facility.

As specified in the AFC, a Personnel Protective Equipment (PPE) Program will be developed for the facility, which will apply to all contractor and subcontractor employees, as well as direct RSI employees during operation. Specific requirements of the PPE Program include:

- Determine and provide personal protective devices for specific jobs.
- Provide proper head protection requirements.
- Establish eye and face protection requirements.
- Identify body protection equipment requirements.
- Implement hand protection requirements.
- Define proper foot protection.
- Provide proper sanitation facilities.
- Determine safety belts and life lines job requirements.
- Establish procedures to prevent and protect personnel from electric shock.
- Identify onsite and offsite medical services and first aid requirements.
- Specify respiratory protection requirements for jobs.

Required PPE will be approved for use and distinctly marked to facilitate identification. The type of PPE required to operate, maintain and monitor the evaporation ponds will be described in the job safety analysis undertaken prior to the commencement of operations.

4.7.1 Required Equipment

The following equipment shall be available at the Facility to minimize hazards associated with Facility operations:

- Alarm systems and internal communications;
- Radio and telephone systems;
- Emergency equipment for fires and spills; and
- Water supplies for fire fighting.

4.7.2 Emergency Equipment

In accordance with the Emergency Action Plan as specified in the AFC, the Facility will include obtaining emergency response equipment. This equipment will be strategically located throughout the facility in order to respond to emergencies in a timely fashion. Further information on the Emergency Action Plan is provided in Section 7.2.

4.7.3 Water Supplies for Fire Fighting

In accordance with the Fire Protection and Prevention Plan as specified in the AFC, the Facility will be equipped with water at adequate volume and pressure to supply water hose streams. The primary source of water for firefighting is a 1,500,000-gallon raw water storage tank. Only a portion of that tank (360,000 gallons) is dedicated to the plant's fire protection water system.

Further information on the Fire Protection and Prevention Plan at the Facility is provided in Section 5.2.

4.7.4 Equipment Testing and Maintenance

In accordance with the Emergency Action Plan as specified in the AFC, all emergency equipment at the Facility, including communications and alarm systems and fire and spill prevention equipment, will be tested and maintained.

4.8 Personnel Requirements

In accordance with Title 27 CCR Section 21600(b)(5)(G), written job descriptions will be maintained for each position at the facility related to management of waste in the permitted surface impoundments at the Facility, including the evaporation ponds. These descriptions will be updated periodically by facility managers and supervisors to reflect the changing needs of the facility. Job descriptions will be kept on file at the facility and include the following information:

- Job title/position;
- Duties/responsibilities; and
- Job prerequisites and qualifications.

All Facility employees will receive training in general Facility procedures and operations and emergency response procedures. Personnel receive job-specific training during on-the-job training as required. This training ensures that personnel are sufficiently proficient in the particular skills required to perform their assigned duties and that they are aware of the inherent hazards. The management, planning, and operations personnel will have varying backgrounds with respect to the management and operation of the evaporation ponds at the Facility. Technical staff will gain experience with these systems mainly through on-the-job training. A record of training and experience of each employee will be maintained at the Facility office.

4.9 Personnel Training

An Operations Safety Training Program for employees and contractors will be developed for the Facility as specified in the AFC that will meet the requirements of Title 27 CCR Section 21600(b)(5)(H). The Operations Safety Training Program will be revised as required to include any additional training necessary as Facility equipment or operations change. Additional job-specific training may be completed by Facility personnel as needed.

The staff person overseeing the portion of the training program pertinent to the bioremediation and land farm units will be experienced in the operation of such units, waste management procedures and applicable regulations, emergency response and contingency plan implementation.

All Facility employees will be required to receive training in the following areas:

- Injury and Illness Prevention;
- Emergency Action Plan;
- Personal Protective Equipment (PPE);
- Fall Protection;
- Fire Protection and Prevention;
- Confined Space Entry Program;
- Hazard Communication;
- Hand and portable power tool safety;
- Heat Stress and Cold Stress Safety;
- Hearing Conservation; and
- Back Injury Prevention.

Additional training will be required for specific tasks. The topics applicable to operation of the evaporation ponds may include:

- Evaporation Pond Operation;
- Forklift Operation;
- Front-End Loader Operation;
- Mobile Equipment Safety;
- Inspection and Monitoring Program;
- Sludge and Water Sampling;
- Equipment Inspections;
- Employee Exposure Monitoring Program; and
- Housekeeping and Material Handling.

4.10 Supervisory Structure

In accordance with 27 CCR Section 21600(b)(5)(I), the Facility Supervisor will be experienced in solar facilities operations and maintenance to ensure that the facility is properly operated in accordance with all applicable laws, regulations, permit conditions and other requirements. All shift managers and equipment operators will report to the Facility Supervisor.

5.0 ENVIRONMENTAL CONTROLS

5.1 Nuisance Control

As defined by Rule 402 of the Mojave Desert Air Quality Management District, the definition of a nuisance is:

"A person shall not discharge from any source whatsoever such quantities of air contaminants or other material which cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public or which endanger the comfort, repose, health or safety of any such persons or the public or which cause or have a natural tendency to cause injury or damage to business or property."

In accordance with Title 27 CCR Section 21600(b)(8)(A), the evaporation ponds will be operated in compliance with all applicable permits and regulatory conditions to prevent creating environmental hazards and public nuisance. Given compliance with permits and conditions and the nature of the evaporation ponds, nuisance conditions are unlikely to arise. In addition, the land treatment units are located in a relatively isolated area away from potential receptors, so the public is unlikely to be impacted by these operations. If complaints are generated, they will be reported to the LEA within 24 hours.

5.2 Fire Control

A Fire Protection and Prevention Program will be prepared for the Facility as specified in the AFC and will meet the requirements of Title 27 CCR Section 21600(b)(8)(B). The plan will include measures relating to safeguarding human life, preventing personnel injury, preservation of property and minimizing downtime due to fire or explosion. Fire protection measures will include fire prevention methods to prevent the inception of fires. Of concern are adequate exits, fire-safe construction, reduction of ignition sources, control of fuel sources, and proper maintenance of fire water supply and sprinkler systems.

The Fire Protection and Prevention Plan for the Facility will include the following sections:

- Scope, purpose, and applicability
- Potential fire hazards
- Proper handling and storage of potential fire hazards
- Potential ignition sources
- Control of potential ignition sources
- Persons responsible for equipment and systems maintenance
- Portable fire extinguishers
- Automatic sprinkler fire suppression system
- Water-spray fire system

- Local fire department
- Training
- Housekeeping procedures
- Record keeping requirements

The Facilities fire protection water system will be supplied from a dedicated 360,000-gallon portion of the 1,500,000-gallon raw water storage tank located on each power block. One electric and one diesel-fueled backup firewater pump per Unit, each with a capacity of 3,000 gallons per minute, will deliver water to the fire protection water-piping network. A smaller electric motor-driven pump jockey pump will maintain pressure in the piping network. If the jockey pump is unable to maintain a set operating pressure in the piping network, the diesel fire pump starts automatically.

A piping network will be configured in a loop so that a piping failure can be isolated with shutoff valves without interrupting the supply of water to a majority of the loop. The piping network will supply fire hydrants located at intervals throughout each power block area, a sprinkler deluge system at each unit transformer, HTF expansion tank and circulating pump area and sprinkler systems at the STG and in the operations and administration buildings. Portable fire extinguishers of appropriate sizes and types will be located throughout each power block.

5.3 Leak Detection and Removal System

In accordance with Title 27 CCR Section 21600(b)(8)(C), there is a leak detection system (LDS) located beneath the primary liner in the evaporation pond. Due to the nature of an evaporation pond, there is no leachate detection and collection system (LDCS) required above the primary liner.

In accordance with Title 27 CCR Section 21600(b)(8)(C), a leak detection and removal system (LDS) will be located beneath the primary and secondary liners underlying the each evaporation pond. As discussed in Section 3.1, the LDS will comprise of a layer of granular material (sand / gravel) and a perforated collection piping system (refer to Attachment A). In addition, a drainage Geocomposite may be utilized. The LDS will be sloped to drain leakage to a separate leak detection sump for each pond to detect and capture fluids leaking through the primary liners. The leak detection sump will include a 16-inch diameter leak detection and removal well fitted an electronic leak sensor and a submersible pump to allow removal of leakage. The pump will discharge back into the evaporation pond. The discharge pipe may be equipped with a recording flow totalizer to allow monitoring of the amount of fluid removed over time and calculation of leakage rates.

The inspection and maintenance requirements for the LDS are outlined in Section 6.

5.3.1 Action Leakage Rate

The action leakage rate (ALR) is the allowable leakage from the primary liner system. According to Title 40, Section 264.222 of the Code of Federal Regulations, the ALR is defined as the maximum design flow rate that the leak detection system can remove without the fluid head on the bottom liner exceeding 1 foot. The ALR must also include an adequate safety margin to allow for variability in the containment system design (e.g. liner and collection pipe slope, interstitial fill hydraulic conductivity, thickness of drainage material). Based on the available information, an ALR of 24,800 gallons/acre/day for the north ponds and 46,800 gallons/acre/day for the south ponds is proposed for management of the facility.

The recording flow totalizer at each sump will be monitored at least weekly to determine the leakage rate through the primary liner. If the leakage rate exceeds the ALR, then the appropriate actions in the Contingency Plan will be implemented.

5.4 Dust Control

An Operations Dust Control Plan will be prepared for the Facility as specified in the AFC to manage fugitive dust emissions and comply with the requirements of Title 27 CCR Section 21600(b)(8)(D). Best Management Practices for dust control from the evaporation ponds will be implemented as necessary and will include the following:

- Maintaining at least 2 feet of freeboard during operation of the ponds to reduce potential for dust entrainment;
- Use of moisture conditioning during removal and loading of accumulated sludge;
- Adherence to speed limits during travel on dirt roads for monitoring and maintenance of the ponds; and
- Tarping of any truck loads of sludge removed from the Facility for off-site disposal.

5.5 Vector Control

In accordance with Title 27 CCR Section 21600(b)(8)(E), a vector control program will be implemented at the Facility as needed. In the event that there is a vector problem such as flies or rodents, the Facility will take the adequate steps to control the problem, which may include trapping, acoustic controls, poison, spraying or engaging a licensed pest control service. Integrated pest control practices will be utilized when practical. Brush will be cleared for a distance of at least 30 feet from the ponds, to reduce habitat for rodents and hiding places for predators that could prey on birds attracted to the ponds.

Water fowl and other birds may be attracted to the evaporation ponds. The primary constituent of concern to bird life in the wastewater at the Facility is selenium; however, as shown in Table B-1 (Attachment B), selenium was not detected in the well water. Nevertheless, mitigation measures will need to be implemented to deter birds. Bird exclusion nets or screens over the entire evaporation pond areas will be utilized. Alternative measures that may be implemented, if needed, include the following:

- Hazing using propane cannons, injured bird calls or other methods;
- Installation of a grid system of nylon monofilament line strung between fasteners on the sides and ends of the evaporation ponds;
- Installation of streamers on lengths of nylon monofilament line strung across the ponds; and/or
- Clearing of brush for a distance of at least 30 feet from the ponds to remove potential hiding places for predators that could prey on the birds.

5.6 Drainage and Erosion Control

A Drainage, Erosion and Sediment Control Plan will be prepared for the Facility as specified in the AFC and will address the requirements of Title 27 CCR Section 21600(b)(8)(F). The plan will outline describe the management and control of storm water runoff at the site and will specify site-specific

Best Management Practices for erosion and sediment control that will include side slope protection of the berms surrounding the evaporation ponds. These berms will control and prevent potential inflow (run-on) of surface storm water into the ponds. Precipitation that falls on the ponds will be contained in the ponds and evaporated. Storm water run-off that falls outside the ponds will be controlled and routed as shown in Attachment A.

5.7 Noise Control

Noise control requirements for the Facility have been investigated in the AFC and will comply with the requirements of Title 27 CCR Section 21600(b)(8)(H). Due to the remoteness of the site and operating procedures of the treatment units, noise is not anticipated to be a problem. Offsite noise levels for the operation of the entire Facility diminish to the point of being indistinguishable from ambient levels before reaching the offsite noise sensitive or residential receptors. The Facility operator will comply with Local, State, and Federal requirements and regulations regarding noise control.

On-site mobile equipment used for pond maintenance will be equipped with approved mufflers and will conform to applicable OSHA and CAL OSHA noise requirements. In addition, hearing protection will be available to facility personnel.

5.8 Traffic Control

Traffic control requirements for the Facility have been investigated in the AFC and will meet the requirements of Title 27 CCR Section 21600(b)(8)(I) for the evaporation ponds. The proposed access to the evaporation pond areas will be off the main paved entrance roadway for the Facility. Traffic is expected to be limited to trucks and mobile equipment used in occasional inspection and maintenance activities. Control measures to mitigate on-site safety hazards and interference with site operations will include signs, paint markings, mirrors and imposition of speed limits as needed.

The Project site is located southwest of U.S. Highway 395 on the north and south sides of Brown Road, approximately five miles southwest of Ridgecrest, California. Regional access is provided to the Project site and the surrounding Ridgecrest area by U.S. Highway 395. U.S. Highway 395 is a primary north/south regional arterial that extends northerly along the eastern side of the Sierra Nevada Mountain Range to Bishop. It extends southerly to I-15 approximately 10 miles south of Victorville. In the Project vicinity, U.S. Highway 395 is a two-lane facility with two, 12-foot travel lanes with approximately 6-foot paved shoulders and 6- to 8-foot graded shoulders on each side. The site is linked to U.S. Highway 395 via Brown Road, an existing two-lane paved road, approximately 24-feet wide, with variable graded shoulders from 4 to 10 feet on each side.

Additionally, the Project can be accessed from West Inyokern Road (SR-178), which extends westerly from the City of Ridgecrest as a four lane road to Inyokern and crosses Brown Road approximately nine miles north of the Project site. Between Ridgecrest and Brown Road, SR-178 is about 72 feet wide, including an approximately 24-foot wide unpaved median strip. It typically includes 4-foot paved shoulders with an additional 4-foot graded shoulder on each side. SR-178 is the northern-most boundary of the city of Ridgecrest.

Proposed traffic mitigation for the Project include the development and implementation of a construction phase Traffic Management Plan (TMP) in consultation with Caltrans and Kern County for the roadway network potentially affected by construction activities at the plant site and offsite linear facilities. In addition, RSI may split the arrival of the workforce in the morning into two parts arriving one hour or more apart when the total number of workers onsite will exceed 300.

6.0 INSPECTION, SAMPLING AND MAINTENANCE PROGRAMS

The following section outlines the inspection and maintenance requirements for the evaporation pond system.

The ALR will be field tested at the commencement of the evaporation pond operation. On the first day of operation, the pump, piping and control switches will be checked to ensure they are in proper working condition per the manufacturer's specifications.

6.1 Inspection Program

6.1.1 Evaporation Pond Liner and Dike Areas

The liner at the perimeter of the pond and perimeter dikes should be visually inspected on a monthly basis for rips and tears, evidence of animal intrusion, weed growth (through the liner or around the perimeter), environmental degradation, and failure of the liner anchoring system (i.e., the liner pulling away from the pond edges). The perimeter fence and the pond inlet (when visible) and outlets should also be inspected monthly to ensure they are in good repair and that these areas are free of debris.

6.1.2 Evaporation Pond Leak Detection System

Monitoring of leaked water is achieved through the addition of vertical monitoring wells that are hydraulically isolated with the leak detection layer. The flow totalizes, which quantify flow and the potential leakage that may occur between containment layers in the monitoring wells, should be monitored weekly for flow and monthly (quarterly after the first six months) to check for built up of material or degradation of the system.

6.1.3 Moisture Detection Monitoring

Moisture detection monitoring will be undertaken semi-annually using a neutron probe. This sampling method must be undertaken by a trained, certified, and licensed technician as the neutron probe uses radioactive material.

Moisture in the soil is detected by the speed that the neutrons move and scatter when emitted. The soil causes neutrons to slow however if the soil is dry, the cloud of neutrons will be less dense and extend further from the probe and if the soil is wet, the neutron cloud will be more dense and extend a shorter distance (Texas AM 2009). The density of the cloud is measured by a detector and results are displayed electronically on the front panel. The measurement is the total water content in the soil, therefore the background levels of water moisture in the soil must be removed to assess if any additional moisture has been released from the evaporation pond liner system.

6.1.4 Sludge Inspections and Removal

Monthly inspections of the pond inlet, outlet, and all associated drainage ditches/pipes/culverts will be conducted for sludge including sediment and debris accumulation. If sludge appears to be impeding flow into the pond or potential flow from the pond, maintenance actions will be scheduled for cleaning these areas as soon as possible. Sludge removal activities will be conducted on an as-needed basis depending upon the inspections and the process is outlined in Section 6.3.2.

6.2 Sampling Program

Samples are to be properly documented and a written record of the chain-of-custody recorded. The chain-of-custody record will track the samples from the field to the laboratory. The form documents the time, date, location, person collecting the sample, and names and signatures of all persons handling the samples from the field to the laboratory.

6.2.1 Evaporation Pond - Wastewater

The evaporation ponds should be sampled at the commencement of operation, semi-annually thereafter to document constituent concentrations.

Grab samples of wastewater collected at the start of operation and annually from each pond shall be analyzed by a state certified laboratory to determine the concentration of the parameters listed in Table 1. The annual samples are to be collected in the last quarter of each year.

Table 1: Evaporation Pond Wastewater Start Up and Annual Sampling Parameters

	Unit
Ammonia	As N
Aluminum	mg/l
Arsenic	mg/l
Boron	mg/l
Calcium	mg/l
Chloride	mg/l
Cyanide	mg/l
Fluoride	mg/l
Iron	mg/l
Magnesium	mg/l
Molybdenum	mg/l
Nitrate as nitrogen	mg/l
Nitrite as nitrogen	mg/l
Phosphate	mg/l
Potassium	mg/l
Selenium	mg/l

Wastewater samples from each pond shall also be collected semi annually and composited into one same by the state certified laboratory and analyzed to determine the quantification of the parameters list in Table 2.

Table 2: Evaporation Pond Wastewater Semi-Annual Sampling Parameters

	Unit
Silica	mg/l
Silicon	mg/l
Sodium	mg/l

Table 2: Evaporation Pond Wastewater Semi-Annual Sampling Parameters

	Unit
Strontium	mg/l
Sulfate	mg/l
Total dissolved solids	mg/l
Total alkalinity	mg/l as $CaCO_3$
Zinc	mg/l
Biphenyl	mg/l
Diphenyl	mg/l
pH	pH
Chloride	mg/l
Chlorine	mg/l
Selenium	mg/l
Sulfate	mg/l
Total dissolved solids	mg/l
Temperature	Fahrenheit or
	Celsius
pH	pH

6.2.2 Evaporation Pond - Sludge

Annually, in the last quarter to each year, two representative grab samples of the bottom sludge in each pond if present, shall be collected, composited and analyzed for the parameters show in Table 3.

Table 3: Evaporation Pond Sludge Sampling Parameters

	Unit
Title 22 metals (total)	mg/kg
Biphenyl, diphenyl oxide	mg/kg

6.3 Maintenance Program

6.3.1 Clean Out

The general requirements for undertaking clean out works for evaporation ponds are outlined below.

Before water can be pumped out of the pond for maintenance, the capacity of the other evaporation ponds must be assessed to verify that sufficient capacity exists to contain wastewater from continued operation for a sufficient amount of time to allow planned maintenance activities. Preliminary design estimates indicate that if one pond is undergoing clean out activities, the additional pond can operate effectively for up to one year.

The appropriate time of year and ideal weather conditions to undertake the clean out activities should be investigated. Dust generated during the activities will need to be controlled in accordance with the Facilities Operations Dust Control Plan. Health and safety issues for the clean out activity include potentially slipping or falling into the pond. As part of the Facilities Operations Safety Training Program and PPE Plan, employees will be trained on how to undertake the clean out activities in a safe manner, which may include having ropes and ladders accessible at the evaporation ponds.

6.3.2 Sludge Removal

If the pond is being drained for liner maintenance or excessive storm water volumes, the sediment and sludge in the pond will be evaluated and removed if necessary as preventative maintenance. The general requirements for undertaking sludge and sediment removal for evaporation ponds is outlined below

The removal activities should only be conducted on an as-needed basis depending upon the inspection of the system. The inspections should include estimating the volume of sludge, assessing if the sludge or sediment is impeding flows into the pond and impacting on the evaporation rate or capacity of the system. The evaporation ponds are design to hold two feet of sludge.

Each pond will be in use for about 3.5 years, after which time the pond will be removed from service and the sludge allowed to dry for a period of 6-7 months. All waste flows will be discharged to the other pond during this period. Sludge removal will commence when the sludge reaches 50 to 80 percent water content as required by the receiving facility. Initial pond cleaning will occur after 2 years of facility operation, and thereafter one pond will be cleaned every two years. If wind-blown silt accumulation varies from 6 inches per year the cleaning interval will be adjusted accordingly so that removal will occur when about 2 feet of sludge accumulates in the pond.

The sludge shall be removed by a pumping or vacuum system if fluid, or should be dried and removed using conventional excavation and loading equipment light enough to reduce the potential for damage to the liner system. If necessary, the sludge should be sampled and analyzed to meet the characterization requirements of the receiving disposal facility. The characteristics of the sludge will determine the transportation and disposal methodology.

7.0 CONTINGENCY & EMERGENCY PLANS

7.1 Contingency Plan

A Contingency Plan compliant with the requirements of Title 27 CCR Section 21760(b)(2) has been prepared for the evaporation pond and presented under separate cover. The Contingency Plan outlines procedures to be followed in the following events:

- Detected primary liner leakage exceeding the ALR;
- Physical or statistically-significant evidence of a release from the impoundments, as identified during implementation of the Monitoring Program;
- Damage to the impoundment berm or liner systems, as observed during inspections;
- Insufficient pond freeboard;
- Overflow of the pond system; or
- Excessive HTF in the pond residue or sheen on the water.

7.2 Emergency Action Plan

An Emergency Action Plan will be prepared for the Facility that will meet the requirements of Title 8 CCR § 3220. This plan will address a variety of potential emergencies across the entire Facility, including chemical releases, fires, bomb threats, pressure vessel ruptures, aqueous ammonia releases and other potential catastrophic events. The plan will describe evacuation routes, alarm systems, points of contact, assembly areas, responsibilities, and other actions to be taken in the event of an emergency. The plan will include a layout map, equipment list, and describe arrangements with local emergency response agencies for responding to emergencies. The Emergency Action Plan will be used in conjunction with the facility Injury and Illness Prevention Plan to identify and administrate site safety procedures. The written Emergency Action Plan will be comprised of the following components:

- Scope, purpose, and applicability,
- Roles and responsibilities,
- Emergency incident response training,
- Emergency response protocol,
- Evacuation protocol,
- Post emergency response protocol, and
- Notification and incident reporting.

Attachment A

Design Details

DWG: S:\Solar Millennium LLC\60093833\Evaporation Ponds\CAD\RIDGECREST\EVAP PONDS FIG 1.dwg Layout Name: FIG 01 – Plotted by: Bedford, Kevin Date: 5/28/2010 – 11:06 AM
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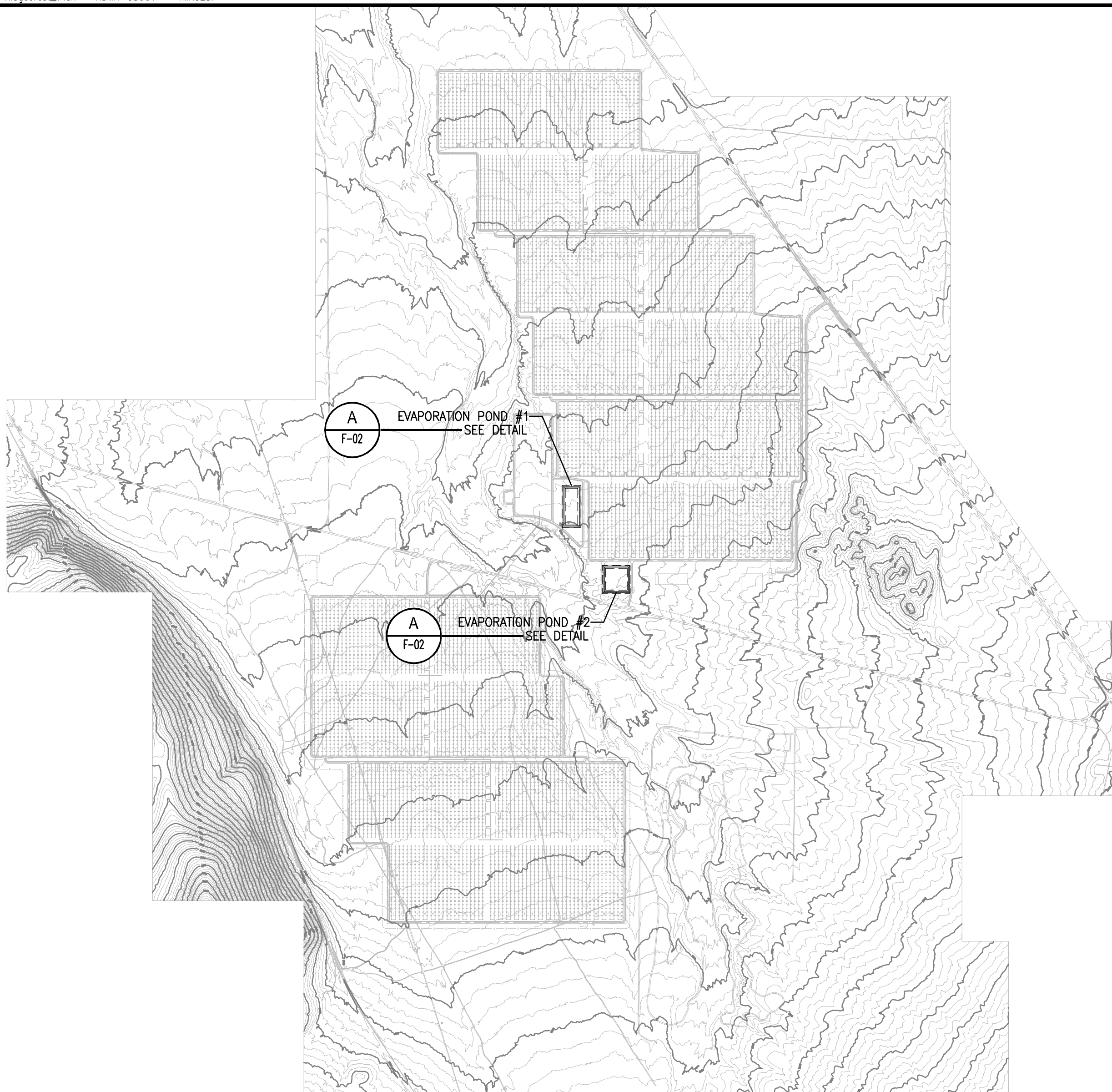

FIGURE 01	SOLAR MILLENNIUM RIDGEGECREST EVAPORATION PONDS SITE PLAN	AECOM PROJECT NO. 60092528.0010	AECOM AECOM USA, Inc. 5001 E. Commercenter Dr. Suite 100 Bakersfield, California 93309 T 661.325.7253 F 661.395.0359 www.aecom.com

DWG: S:\Solar Millennium LLC\60093833\Evaporation Ponds\CAD\RIDGECREST\EVAP PONDS.dwg Layout Name: FIG 02 - Plotted by: Bedford, Kevin Date: 5/28/2010 - 11:20 AM
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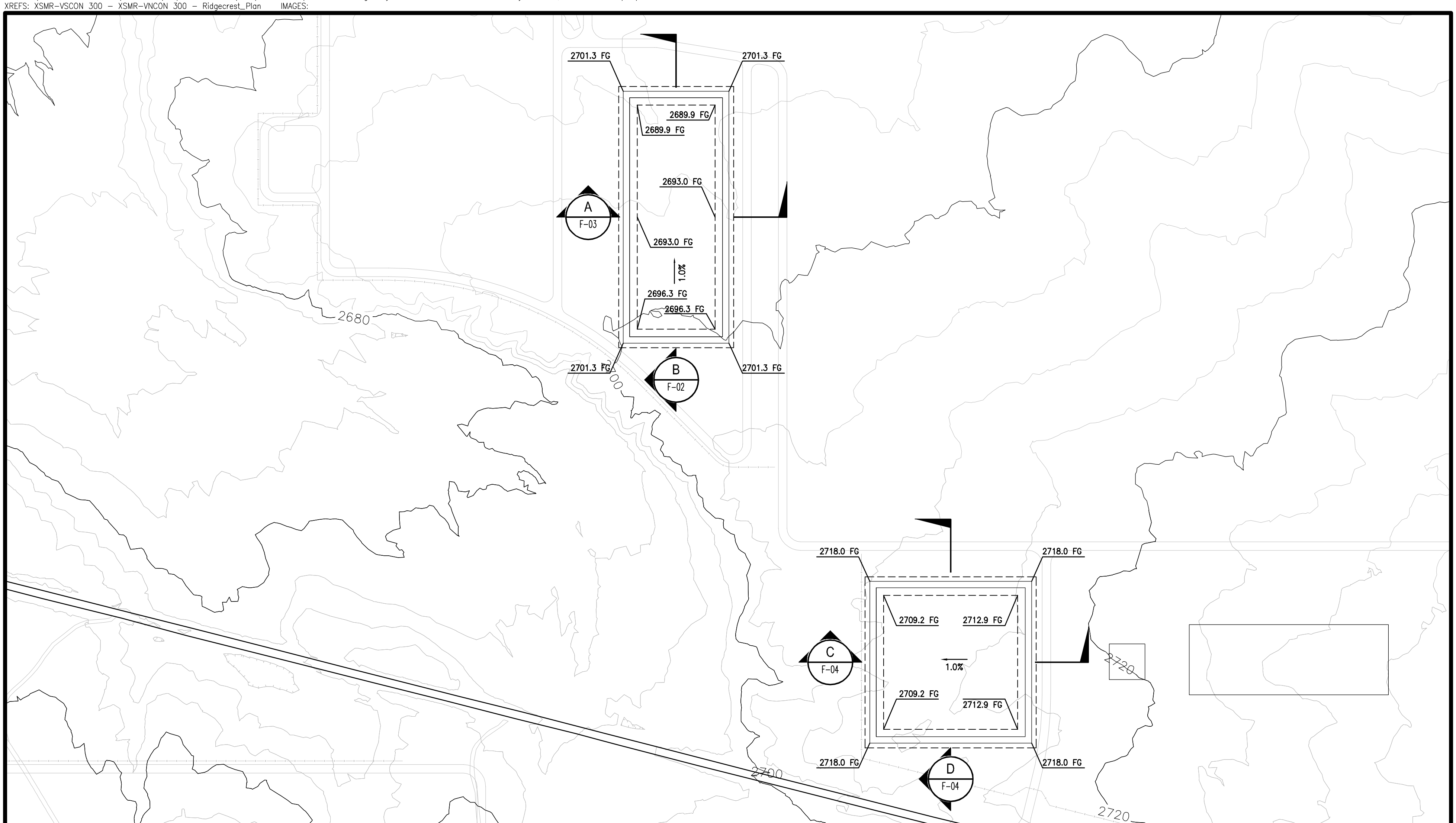

EVAPORATION PONDS (A / –)

SCALE: NONE

FIGURE 02

SOLAR MILLENNIUM

RIDGEGECREST EVAPORATION PONDS
GRADING PLAN

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DWG: S:\Solar Millennium LLC\60093833\Evaporation Ponds\CAD\RIDGECREST\EVAP PONDS.dwg Layout Name: FIG 03 — Plotted by: Bedford, Kevin Date: 5/28/2010 - 1:36 PM
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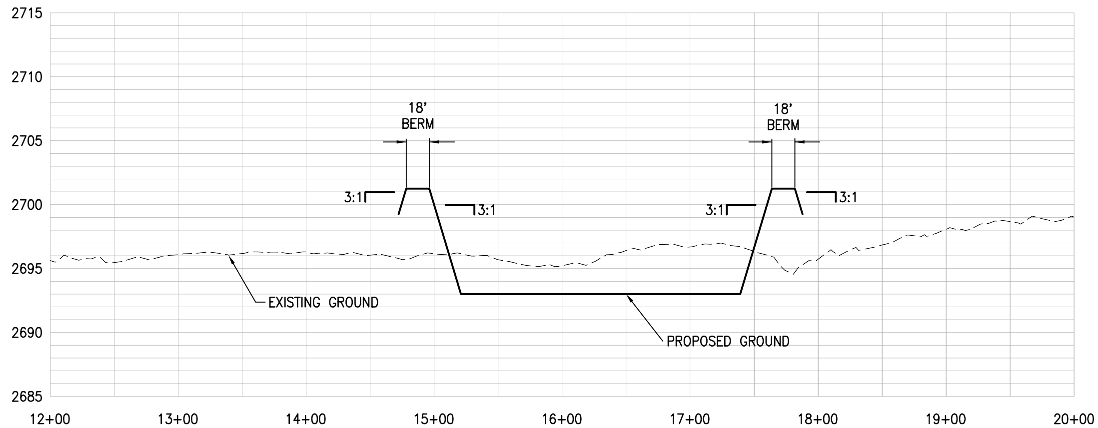

CROSS SECTION A
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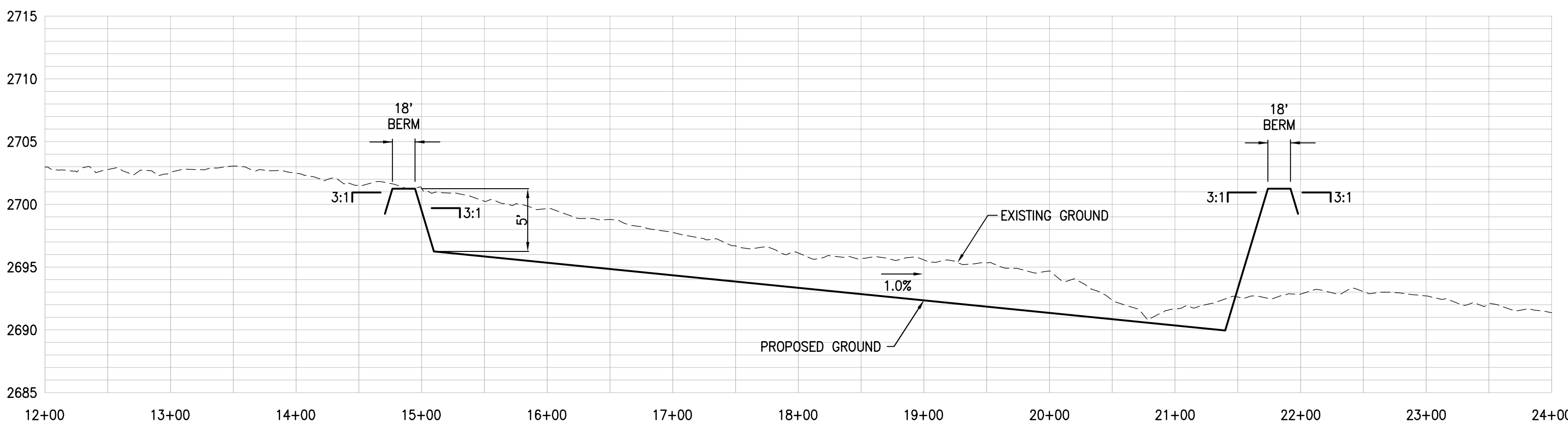
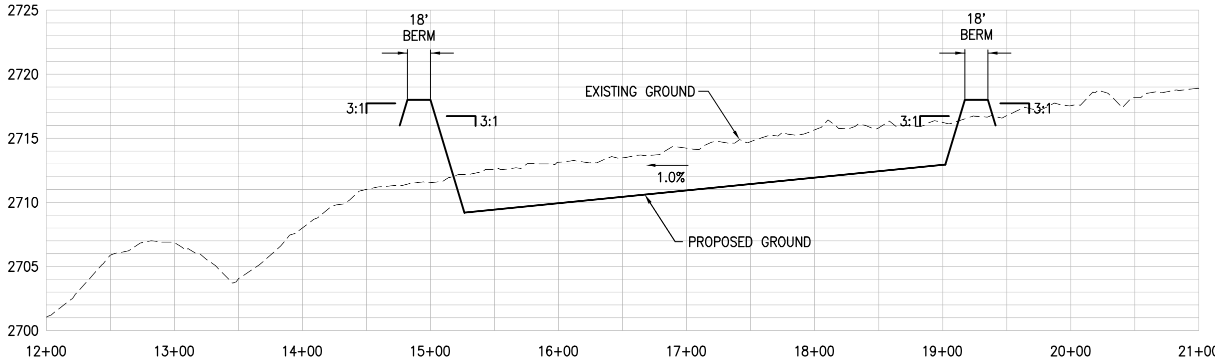


CROSS SECTION B
SCALE: NONE

FIGURE 03	SOLAR MILLENNIUM RIDGEGECREST EVAPORATION PONDS CROSS SECTIONS	AECOM PROJECT NO. 60092528.0010	AECOM AECOM USA, Inc. 5001 E. Commercenter Dr. Suite 100 Bakersfield, California 93309 T 661.325.7253 F 661.395.0359 www.aecom.com



CROSS SECTION C –

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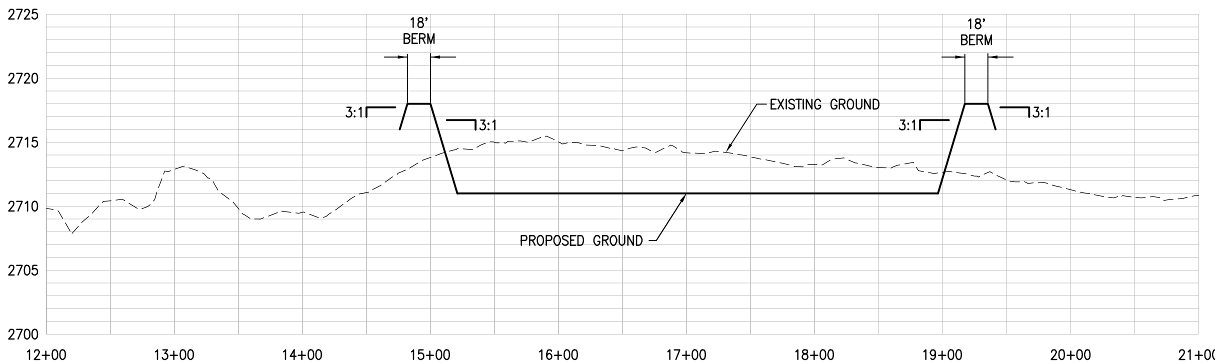

CROSS SECTION D –

SCALE: NONE

FIGURE 04

SOLAR MILLENNIUM

RIDGEGECREST EVAPORATION PONDS
CROSS SECTIONS

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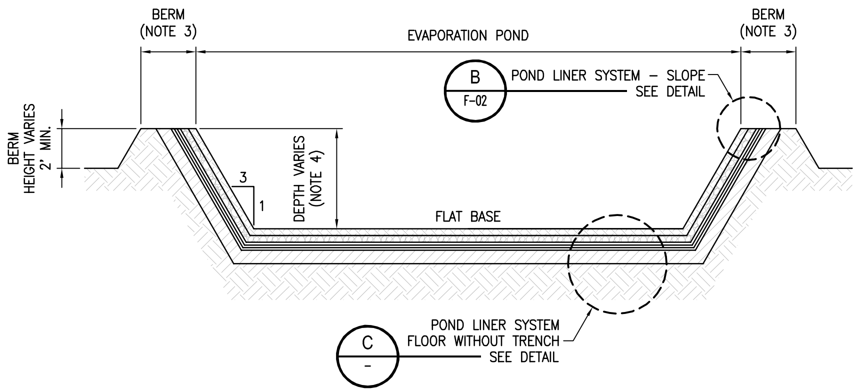

POND - UPSTREAM CROSS SECTION (A –)

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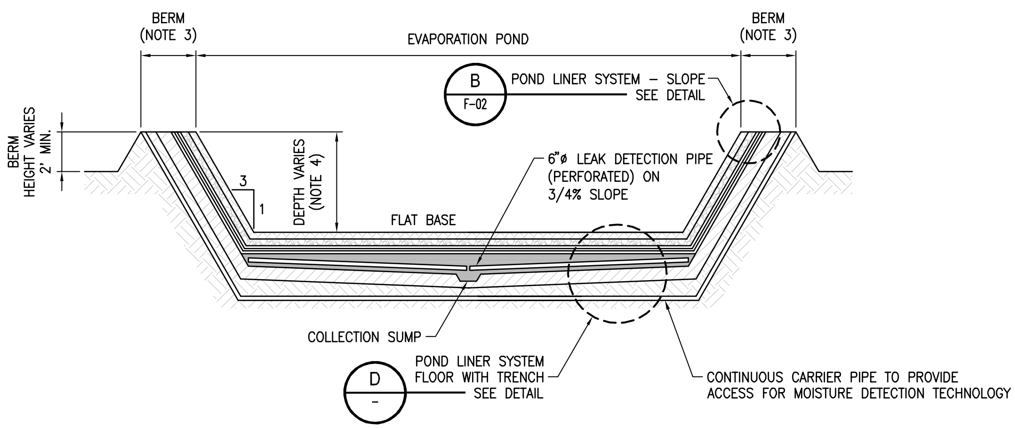

POND - DOWNSTREAM CROSS SECTION (B –)

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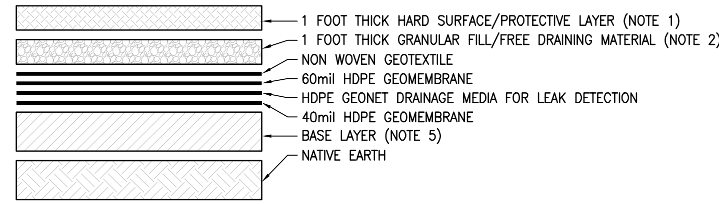

POND LINER SYSTEM DETAIL FLOOR TRENCH (C –)

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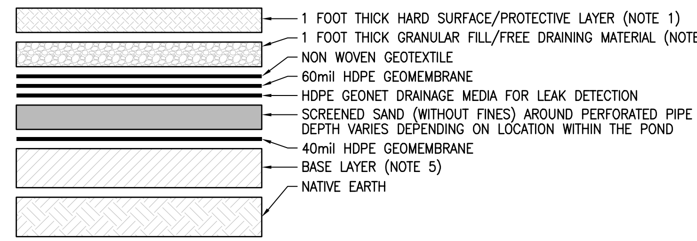

POND LINER SYSTEM DETAIL FLOOR WITHOUT TRENCH (D –)

SCALE: N.T.S.

NOTE:

1. HARD SURFACE/PROTECTION LAYER TO BE 1 FOOT OF ROLLER COMPACTED CONCRETE OR APPROVED EQUIVALENT.
2. GRANULAR FILL/FREE DRAINING SUB BASE MUST HAVE MAXIMUM PARTICLE SIZE OF 1/2 INCH.
3. BERM IS A MINIMUM OF 12 FEET WIDE AND MAXIMUM OF 18 FEET WIDE. BERM IS COVERED BY A MINIMUM OF 6 INCHES OF ROADBASE MATERIAL.
4. AVERAGE POND DEPTH OF 7 FEET ALLOWS FOR 2 FEET OF FREEBOARD, 3 FEET OF OPERATIONAL DEPTH AND 2 FEET OF SLUDGE ACCUMULATION. MINIMUM 1% SLOPE ACROSS POND BASE, THEREFORE UPSTREAM END OF POND WILL HAVE A DEPTH OD LESS THAN 7 FEET AND DOWNSTREAM END OF POND WILL HAVE A DEPTH OF MORE THAN 7 FEET.
5. BASE LAYER: PREFERRED MATERIAL IS 2 FOOT OF AN SITE MATERIAL WITH HYDRAULIC CONDUCTIVITY OF LESS THAN 1 X 10–6 CM/S, OF WHICH AT LEAST 30% OF THE MATERIAL SHALL PASS THROUGH A NO. 200 U.S. STANDARD SIEVE. IF THIS MATERIAL IS NOT AVAILABLE, THE ALTERNATIVE DESIGN IS A GEOSYTHENTIC CLAY LINER (GCL).
6. SEE TEXT FOR FURTHER DETAILS.

FIGURE 05

SOLAR MILLENNIUM

RIDGECREST EVAPORATION PONDS
SECTION AND DETAILS

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DWG: S:\Solar Millennium LLC\60093833\Evaporation Ponds\CAD\RIDGECREST\EVAP POND DETAILS.dwg Layout Name: FIG 06 – Plotted by: Bedford, Kevin Date: 5/28/2010 – 1:41 PM
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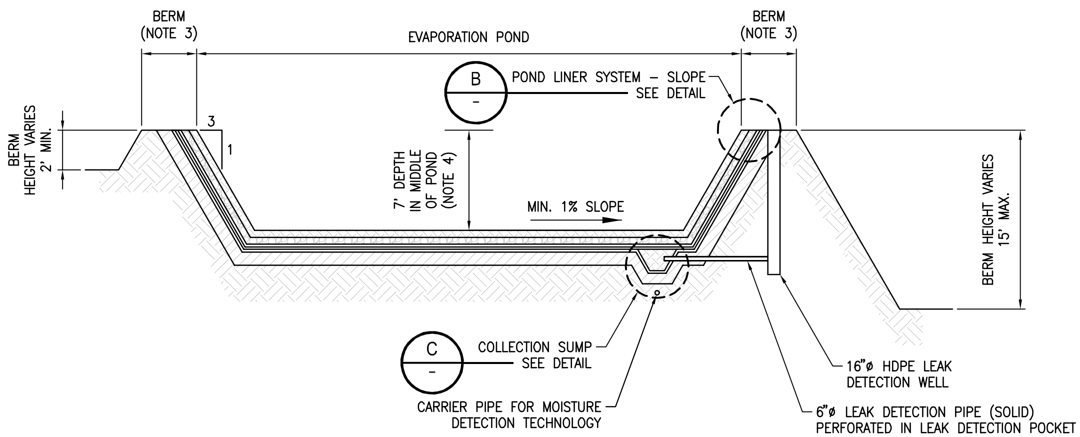

CROSS SECTION THROUGH THE MIDDLE OF THE PONDS (A –)

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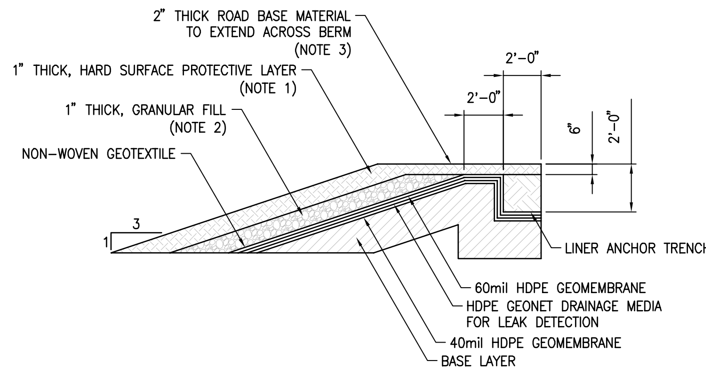

POND LINER SYSYTEM - SLOPES (B –)

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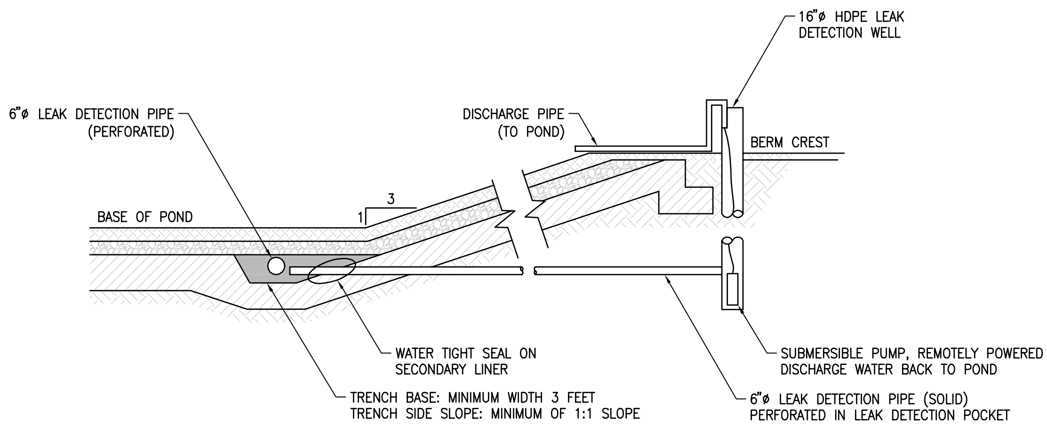

COLLECTION SUMP DETAIL (C –)

SCALE: N.T.S.

NOTE:

1. HARD SURFACE/PROTECTION LAYER TO BE 1 FOOT OF ROLLER COMPACTED CONCRETE OR APPROVED EQUIVALENT.
2. GRANULAR FILL/FREE DRAINING SUB BASE MUST HAVE MAXIMUM PARTICLE SIZE OF 1/2 INCH.
3. BERM IS A MINIMUM OF 12 FEET WIDE AND MAXIMUM OF 18 FEET WIDE. BERM IS COVERED BY A MINIMUM OF 6 INCHES OF ROADBASE MATERIAL.
4. AVERAGE POND DEPTH OF 7 FEET ALLOWS FOR 2 FEET OF FREEBOARD, 3 FEET OF OPERATIONAL DEPTH AND 2 FEET OF SLUDGE ACCUMULATION. MINIMUM 1% SLOPE ACROSS POND BASE, THEREFORE UPSTREAM END OF POND WILL HAVE A DEPTH OD LESS THAN 7 FEET AND DOWNSTREAM END OF POND WILL HAVE A DEPTH OF MORE THAN 7 FEET.
5. BASE LAYER: PREFERRED MATERIAL IS 2 FOOT OF AN SITE MATERIAL WITH HYDRAULIC CONDUCTIVITY OF LESS THAN 1 X 10–6 CM/S, OF WHICH AT LEAST 30% OF THE MATERIAL SHALL PASS THROUGH A NO. 200 U.S. STANDARD SIEVE. IF THIS MATERIAL IS NOT AVAILABLE, THE ALTERNATIVE DESIGN IS A GEOSYTHENTIC CLAY LINER (GCL).
6. SEE TEXT FOR FURTHER DETAILS.

FIGURE 06

SOLAR MILLENNIUM

RIDGECREST EVAPORATION PONDS
SECTION AND DETAILS

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Attachment B

Water Cycle

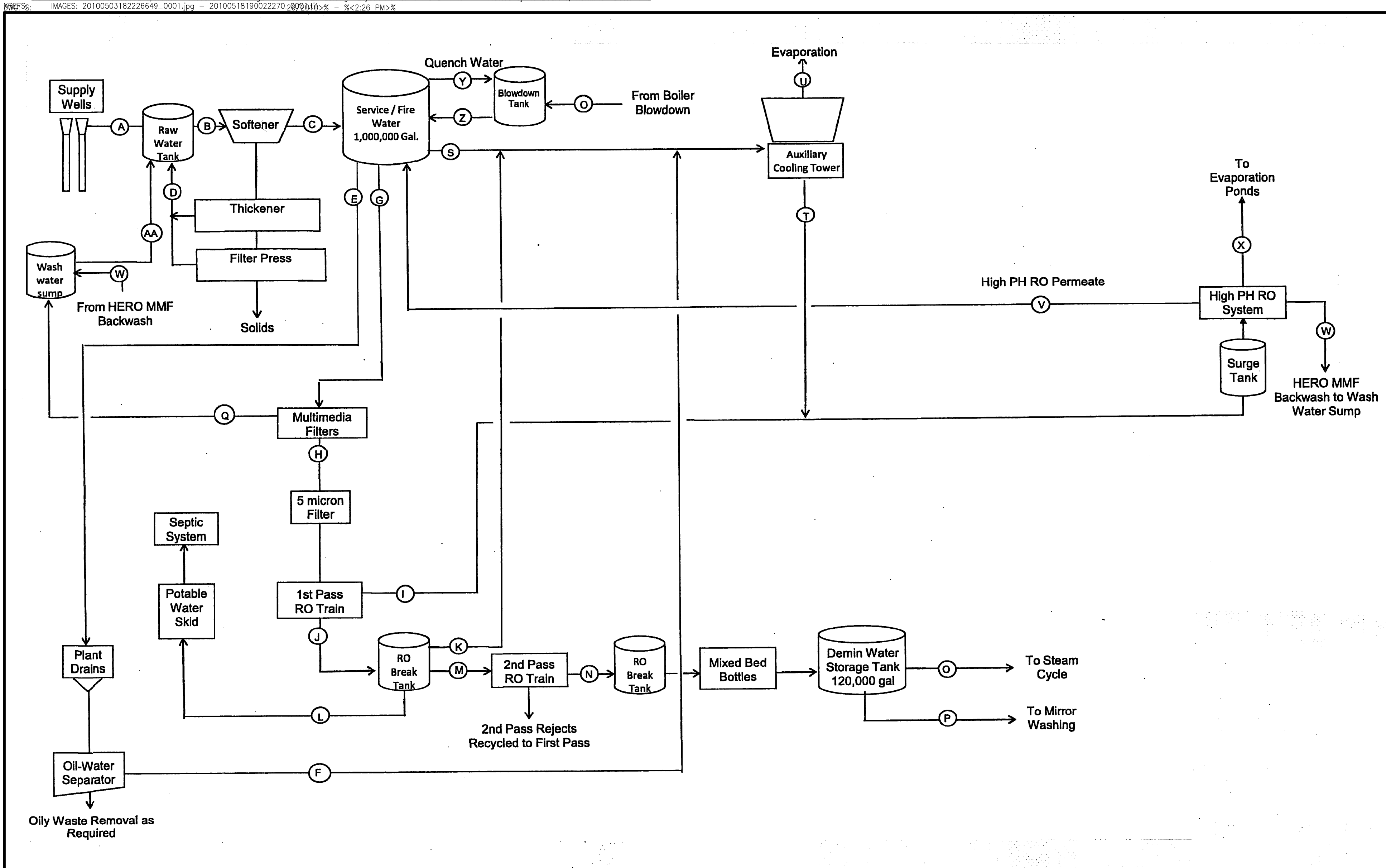

FIGURE B1	SOLAR MILLENNIUM	AECOM PROJECT NO.	AECOM
	RIDGECREST EVAPORATION PONDS FIGURE B-1	60092528.0010	AECOM USA, Inc. 5001 E. Commercenter Dr. Suite 100 Bakersfield, California 93309 T 661.325.7253 F 661.395.0359 www.aecom.com

Table B-1
Process Water Flows

		24 Hour Average	24 Hour Total	Peak Operation
	Ambient Conditions	96.7F/66.5F_WB	96.7F/66.5F_WB	96.7F/66.5F_WB
	Boiler Duty	100%	100%	100%
Stream ID	Description	GPM	GPD	GPM
A	Flow from IWVWD	63	90,917	97
B	Softener Makeup	99.46	143,225	153.52
C	Softener Effluent	98.47	141,793	151.98
D	Recovered dewatering water	0.4	573	0.61
	Water in dewatered sludge	0.6	859	0.92
E	Service water to plant users	4	5,760	4
F	OWS effluent	4	5,760	4
G	Multimedia filter makeup	133.4	192,121	197.1
H	First pass RO makeup	120	172,909	177
I	First pass RO reject	48	69,164	71
J	First pass RO permeate	72	103,746	106
K	RO permeate to cooling tower	0	-	0
L	RO permeate to potable water	2	2,880	2
M	Second pass RO makeup	70	100,866	104
N	Second pass RO permeate	53	75,649	78
O	Steam cycle makeup / blowdown	16	23,398	42
P	Demin water to mirror washing	36	52,251	36
Q	Multimedia filter backwash	13	19,212	20
	Service water to cooling tower	27	38,694	76
S	Total cooling tower makeup	31	44,454	80
T	Cooling tower evaporation	21	29,636	53
U	Cooling tower blowdown	10	14,818	27
V	High pH RO permeate	50	71,384	83
W	High pH filter backwash	5.832	8,398	9.758
X	High pH RO reject of Evap Pond	8.748	12,597	14.636
Y	Quench Water	65	93,732	130
Z	Quenched Boiler Blowdown	81	117,130	172
AA	Multimedia filter backwash	36	51,735	56

Design Basis:
1. Steam cycle makeup and cooling tower evaporation from Kiewit.
2. Recovery rates depend upon influent water chemistry.
3. Based on water analysis April 2008 from Wells18, 33, and 3. Information provided by IWVWD.

Table B-2
Anticipated Water Quality

Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporati on Pond
		A, B	C, D	E,G,H,S, Y	J,L,K,M	J	O,P	P	Z	F+K+S		V	
Cations													
Calcium	mg/L	31	20	13	5	50	0	1	11	13	40	0	48
Magnesium	mg/L	4.7	5	3	1	12.5	0	1	3	3	10	0	12
Sodium	mg/L	352	352	240	10	880	0	77	208	240	721	20	5968
Potassium	mg/L	4	4	4	0	10	0		3	4	12	4	10
Ammonia	mg/L	<0.1	0.1	0	0	0.25	0		0	0	0	0	0
Anions													
Chloride	mg/L	200	280	189	10	700	0	1	152	189	566	9	3385
Sulfate	mg/L	380	271	189	5	677.5	0	4	152	189	567	27	658
Alkalinity	mg/L	122	170	113	1	425	0		90	113	338	0	410
Bicarbonate	mg/L	149	207	137	1	517.5	0		110	137	412	0	499
Carbonate	mg/L	ND	50	34	0	125	0		27	34	101	1	121
Cyanide	µg/L	<.05		0	0	0	0		0	0	0	0	0
Silica	mg/L	15	7	5	0	17.5	0	2	4	5	15	1	17
Phosphate	mg/L	<.31	0	0	0	0	0		0	0	0	0	0
Polyphosphate	mg/L	0	0	0	0	0	0	0.5	0	0	0	0	0
Fluoride	mg/L	6.1	1.8	1	2	4.5	0		1	1	4	0	4
Nitrate	mg/L	0.7	0.7	0	0	1.75	0		0	0	1	0	2
General													
Suspended Solids	mg/L	1960	5	3	0	12.5	0		3	3	10	0	12
Total Dissolved Solids	mg/L	1010	952	654	36	2380	0	85	542	654	1963	68	10725
Hardness	mg/L	830	71	48	28	177.5	0		38	48	143	2	172

Table B-2
Anticipated Water Quality

Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporati on Pond
Constituent	Units	Well Water	Softened Water	Service Water	RO First Pass Permeate	1st pass RO Reject	Mixed Bed Effluent	Boiler Blow down	Quenched Blowdown	Cooling Tower Makeup	Cooling Tower Blow down	High pH RO Permeate	High pH Reject to Evaporati on Pond
Trace Metals													
Aluminum	µg/L	0	50	33	0	125	0		27	33	99		121
Antimony	µg/L	<15	<15	0	0	0	0		0	0	0	0	0
		A, B	C, D	E,G,H,S, Y	J,L,K,M	J	O,P	P	Z	F+K+S		V	
Arsenic	µg/L	16	16	11	0	40	0		9	11	32	0	39
Barium	µg/L	31	0	0	0	0	0		0	0	0	0	0
Boron	mg/L	1.8	1.8	1	1	4.5	0	28	6	1	4	0	4
Cadmium	µg/L	<5	<5	0	0	0	0		0	0	0	0	0
Chromium	µg/L	<5	<5	0	0	0	0	10	2	0	0	0	0
Cobalt	µg/L	<5	<5	0	0	0	0		0	0	0	0	0
Copper	µg/L	<5	<5	0	0	0	0		0	0	0	0	0
Hexavalent Chromium	µg/L	0.37	0.37	0	0	0.925	0		0	0	1	0	1
Iron	µg/L	<100	0.05	0	0	0.125	0		0	0	0	0	0
Lead	µg/L	<10	<10	0	0	0	0		0	0	0	0	0
Manganese	µg/L	13	0	0	0	0	0		0	0	0	0	0
Molybdenum	µg/L	73	73	48	0	182.5	0	1	39	48	145	0	176
Nickel	µg/L	<5	<5	0	0	0	0		0	0	0	0	0
Selenium	µg/L	<15	<15	0	0	0	0		0	0	0	0	0
Strontium	µg/L	0	0	0	0	0	0		0	0	0	0	0
Thallium	µg/L	<15	<15	0	0	0	0		0	0	0	0	0
Vanadium	µg/L	<5	<5	0	0	0	0		0	0	0	0	0
Zinc	mg/L	0.022	0.07	0.05	0	0.175	0	0.005	0.04	0.05	0.14		0.17

Table B-3
Evaporation Pond Sludge Quality

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg
Cations					
Calcium	mg/L	4	1,479	18,066	1626
Magnesium	mg/L	1	462	5,646	508
Sodium	mg/L	81	29,407	359,182	32326
Potassium	mg/L	1	396	4,843	436
Ammonia	mg/L	0	9	113	10
Anions					
Chloride	mg/L	110	40,050	489,190	44027
Sulfate	mg/L	12	4,248	51,882	4669
Alkalinity	mg/L	8	2,958		0
Bicarbonate	mg/L	10	3,605	44,036	3963
Carbonate	mg/L	0	7	82	7
Cyanide	µg/L	-	-	-	0
Silica	mg/L	3	931	11,373	1024
Phosphate	mg/L	-	-	-	0
Polyphosphate	mg/L	-	-	-	0
Fluoride	mg/L	0	74	903	81
Nitrate	mg/L	2	740	9,033	813
General					
Suspended Solids	mg/L	1	462	5,646	465000
Total Dissolved Solids	mg/L	223	N/A		0
Hardness	mg/L	13	N/A		0
Trace Metals		-			
Aluminium	µg/L	-	-	-	0
Antimony	µg/L	-	-	-	0
Arsenic	µg/L	0.001	0.37	5	0
Barium	µg/L	-	0.00	-	0
Boron	mg/L	0.000	0	0	0
Cadmium	µg/L	-	-	-	0
Chromium	µg/L	-	-	-	0

Table B-3
Evaporation Pond Sludge Quality

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg
Cobalt	μg/L	-	-	-	0
Copper	μg/L	-	-	-	0
Hexavalent Chromium	μg/L	-	0.00	-	0
Iron	μg/L	-	0.00	-	0
Lead	μg/L	-	-	-	0
Manganese	μg/L	-	0.00	-	0
Molybdenum	μg/L	-	0.00	-	0
Nickel	μg/L	-	0.00	-	0
Selenium	μg/L	-	-	-	0
Strontium	μg/L	-	0.00	-	0
Thallium	μg/L	-	-	-	0
Vanadium	μg/L	0.001	0	2	0
Zinc	mg/L	0.000	0.0	0	0

AECOM
Environment

Prepared for:
Ridgecrest Solar I, LLC

Detection Monitoring Program Ridgecrest Solar Power Project Kern County, California
Appendix E of the Application/Report of Waste Discharge

June 2010

60139696-5450-DMP

AECOM
Environment

Prepared for:
Ridgecrest Solar I, LLC

Detection Monitoring Program Ridgecrest Solar Power Project Kern County, California

Appendix E of the Application/Report of Waste Discharge

Prepared By: Carmen Caceres-Schnell, PG

Reviewed By Bob Wilson

June 2010

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List of Acronyms

°F	degrees Fahrenheit
AF	acre-feet
AFC	Application for Certification
bgs	below ground surface
CAP	Corrective Action Plan
CCR	California Code of Regulations
DMP	Detection Monitoring Plan
DTSC	Department of Toxic Substances
DWR	Department of Water Resources
EPA	U.S. Environmental Protection Agency
ft^2/d	square feet per day
gpd/ft	gallons per day per foot
gpm/ft	gallons per minute per foot
HTF	Heat transfer fluid
LTU	land treatment unit
mg/kg	milligrams per kilogram
MW	megawatts
PQL	practical quantitation limits
RSI	Ridgecrest Solar I, LLC
RSPP	Ridgecrest Solar Power Project
ROWD	Report of Waste Discharge
RWQCB	Regional Water Quality Control Board
SEGS	Solar Electric Generating System
SPCC	Spill Prevention, Control and Countermeasure
SSG	solar steam generator
TDS	total dissolved solids
TSDF	Treatment Storage and/or Disposal Facility
USGS	U.S. Geological Survey

1.0 Introduction

Ridgecrest Solar I, LLC (RSI), a wholly owned subsidiary of Solar Millennium, LLC, is proposing to construct, own and operate the Ridgecrest Solar Power Project (herein or "Project"). The Project is a concentrating solar electric generating facility proposed on an approximately 3,995-acre site located in the high northern Mojave Desert in northeastern Kern County, California, about five miles southwest of the City of Ridgecrest, California. RSI proposes to use evaporation ponds as part of the Project. The evaporation ponds will be used to store waste water from various plant processes.

This Detection Monitoring Program (DMP) was developed as part of the Report of Waste Discharge (ROWD) application for the proposed Project. The ROWD will be submitted to the Regional Water Quality Control Board –Lahontan Region (RWQCB).

The monitoring requirements for the Project's waste facilities are specified under California Code of Regulations (CCR) Title 27 Chapter 3, Subchapter 3, Article 1, Sections 20380 through 20435 (CCR 27 20380 through 20435). Article 1 includes provisions for a Detection Monitoring Program (CCR 27 20385). The objective of the DMP is to determine if a release has occurred from the evaporation ponds, and if groundwater quality is being degraded.

This document describes the elements of the DMP and is considered to be a stand-alone document that supplements other elements of the ROWD application including the Evaporation Pond Construction Engineering Design Package, the Construction Quality Assurance Plan, and the Closure- and Post-Closure Maintenance and Corrective Action Plans.

1.1 Site Background

The Project is a concentrated solar thermal electric generating facility located in the high northern Mojave Desert in northeastern Kern County, California, about five miles southwest of the City of Ridgecrest, California (**Figure 1-1**). The Project will use well-established parabolic trough solar thermal technology to produce electrical power using a steam turbine generator (STG) fed from a solar steam generator (SSG). The SSG receives heated heat transfer fluid (HTF) from solar thermal equipment comprised of arrays of parabolic mirrors that collect energy from the sun.

The Project proposes to use a dry cooling condenser for power plant cooling. Water for the cooling tower makeup, process water makeup, and other industrial uses such as mirror washing will be supplied by the local municipal water district via a new pipeline. This source will also be used to supply water for employee use (e.g., drinking, showers, sinks, and toilets). Water received from the Indian Wells Valley Water District (IWVWD) will meet the requirements of the California Department of Health Services for potable water supplies and will not require further treatment for this purpose. Power cycle makeup, mirror washing water, and cooling of ancillary equipment will require onsite treatment for reduction of dissolved solids, and this treatment varies according to the quality required for each of these uses. A sanitary septic system and onsite leach field will be used to dispose of sanitary wastewater.

The Project will have a nominal electrical output of 250 megawatts (MW), consisting of one independent Unit, Unit #1. **Figure 1-2** shows the general arrangement of the site. Commercial operation of Unit #1 is expected to commence by the third quarter of 2013, subject to timing of regulatory approvals and Applicant achievement of project equipment procurement and construction milestones. The solar thermal technology will provide 100 percent of the power generated by the Project; no supplementary energy source (e.g., natural gas to generate electricity at night) is proposed to be used for electric energy production. The Project will utilize an auxiliary boiler fueled by propane gas to reduce startup time and for HTF freeze protection. The Project will also have one electric and one backup diesel-fueled fire water pump for fire protection.

The Project wastewater will be piped to lined, on-site evaporation ponds. Discharge into the evaporation ponds is derived from one primary source: High pH RO (Reverse Osmosis Concentrate). Unit#1 will consist of two evaporation ponds. Each pond area provides sufficient evaporative capacity to dispose of the anticipated wastewater stream, and allows for one pond to be taken out of service for cleaning, potential future maintenance, and repair for up to one year without impacting the operation of the plant. The ponds will be designed in accordance with Lahontan River Basin Regional Water Quality Control Board (RWQCB) requirements. If required for maintenance, dewatered residues from the ponds will be excavated, characterized and sent to an appropriately permitted off-site landfill (most likely as non-hazardous waste).

The estimated project life is 30 years. Personnel will staff the Project 24 hours per day/seven days per week. Even when the solar power plant is not operating, personnel will be present as necessary for maintenance, to prepare the Project for startup, and/or for site security.

1.2 Geologic and Hydrologic Setting

The Project is located in the alluvial-filled basin of the Indian Wells Valley (IWV) in the southern end of the Basin and Range province. A topography map is provided in **Figure 1-3** and the regional geology is depicted in **Figures 1-4A and 1-4B**. Regionally, The Valley is characterized by a broad alluvial basin of Cenozoic-age sedimentary and volcanic material overlying older plutonic and metamorphic rocks. Quaternary lacustrine deposits are also found in the region as a result of playas in the northeastern portion of the valley. Indian Wells Valley is underlain with alluvial deposits up to 2,000 feet thick. The majority of the Project site is underlain by Quaternary alluvium and alluvial fan deposits of Holocene age. These deposits consist of unconsolidated moderately to well-sorted gravel, sand silt, and clay. These deposits are derived as alluvial fans from the surrounding mountainous regions and may include fluvial deposits.

There are no perennial surface water bodies in Indian Wells Valley. During wet years, some surface flow enters the Valley through the Little Lake Gap. The water budget inflows for the Valley consist of mountain front recharge, subflow from the Rose Valley Basin and Coso Valley Basin, and infiltration of surface flows through Little Lake Gap. The only outflows are through groundwater pumping and evapotranspiration from the playa areas. Generally, groundwater flow directions throughout Indian Wells Valley are directed towards the playa just north of Ridgecrest. Groundwater flow direction on the Project site trends northeast towards the playa. In the region, groundwater elevations range from approximately 2,150 feet above msl to 2,350 feet above msl. Beneath the Project plant site groundwater flows to the northeast towards Ridgecrest and ranges from approximately 2,250 feet above msl and 2,350 feet above msl.

1.2.1 Hydrostratigraphy

Previous investigations have divided the unconsolidated Quaternary deposits into two main aquifers: the shallow aquifer and the deep aquifer. However, a recent study by Brown and Caldwell identified four hydrostratigraphic features in the IWV Groundwater Basin. The features are: 1) Fine-Grained Sediment Plug, 2) Gravel Zone, 3) High Gradient, and 4) Playa. **Figure 1-5** shows the location of these features.

- The Fine-Grained Sediment Plug located approximately three to four miles east of the Sierra Nevada mountain front and trends north-south. The upper contact of this feature begins at depth of approximately 340 feet bgs and sediments may be as much as 1,340 feet thick. The areal extent of this deposit is not well defined due to limited borehole data.
- The Gravel Zone is a west-east trending area of coarse-grained high permeability sediments. This area is located from the mouth of Indian Wells Canyon to approximately the northwest portion of Ridgecrest, extends approximately two miles north-south, and fines to the east. This region is referred to the Inyokern and Intermediate Areas and contains high volume production wells. Wells within the Ridgecrest city limits are believed to be associated with this Gravel Zone; however, wells in this area have a higher percentage of fines and, therefore, their groundwater production is lower than the wells to the west.

- The High Gradient area extends from the El Paso sub-Basin into the main IWV Groundwater Basin near the southwestern portion of the valley. Groundwater gradients in this area have been measured at approximately 100 feet per mile. Brown and Caldwell propose that the high gradient may be caused by a combination of a narrowing of the area available for flow and the influx of recharge from Freeman Canyon. In addition, the high hydraulic gradient could be related to the contrast in aquifer transmissivity from the narrows to the high permeability zone to the north.

The Playa feature identified by Brown and Caldwell is located in the area of China Lake. The thickness of these sediments is not known, but are likely several tens of feet thick. Deposits are highly micaceous, silt sandy silt, and fine sand with occasional plastic clays. Shallow water beneath China Lake is highly saline and unfit for most uses.

1.2.2 Aquifer Characteristics

Figure 1-6 shows the water level contours for the Indian Wells Valley from water level data for 2006. In the development of a groundwater flow model and hydorgeologic study for the IWV Groundwater Basin, Brown and Caldwell used hydraulic conductivity values ranging from 0.1 ft/d to 100 ft/d. These values were based on geologic logs, pre-existing groundwater modeling studies, and interpretations based on local geology, depositional environments, and groundwater flow regime. The model showed that the areas with the highest hydraulic conductivities are generally located immediately east of the Sierra Nevada. Areas of the IWV Groundwater Basin with lower hydraulic conductivities are localized and distributed throughout the Basin.

Published aquifer testing data reports transmissivity values from less than 1,400 ft^2/d to 36,800 and 44,000 ft^2/d to 155,000 ft^2/d. Both sets of values were based on aquifer testing and geologic data. The Brown and Caldwell (2009) model used specific yield ranges of 0.05 to 0.15. Reported well yields in the lower aquifer are more than 1,000 gpm and some wells consistently yield more than 2,000 gpm. The IWV Groundwater Basin has an estimated storage capacity of about 2,200,000 acre-feet (af) and 5,120,000 af. The calculated storage of 2,200,000 af is based on 1921 water levels as a steady state limit and 200 feet below this level as the economically feasible limit to extract groundwater.

1.3 Waste Handling Facilities – Evaporation Ponds

The configuration of the planned evaporation ponds and adjacent areas are shown in the aforementioned **Figure 1-2**. Topography of the RSPP and surrounding areas are shown on **Figure 1-3**.

The two, 4.0-acre evaporation ponds (total combined pond top area of 8 acres) have an average proposed design depth of seven feet, which incorporates the following:

- Drying each pond at alternating four year intervals;
- 3 feet of operational depth;
- 2 feet of residue build up over 4 years; and
- 2 feet of freeboard.

The containment design for the evaporation ponds, from the surface of the evaporation ponds downwards, consists of the following:

- A hard surface / protective layer with granular fill/free draining sub-base over geotextile;
- A primary 60 mil high density polyethylene (HDPE) liner;
- An interstitial leak detection system (LDS) comprising a drainage layer and piping;

- A secondary 40 mil HDPE geomembrane liner;
- A two foot thick compacted silty-sand base; and
- A moisture detection system.

The design details of the evaporation ponds are shown on **Figure 1-7a** and **1-7b.** The cross sections of the evaporation ponds are provided in **Figure 1-8a** and **1-8b**.

2.0 Detection Monitoring Program Standards

The monitoring requirements for the Project's waste facilities are specified under CCR Title 27 Chapter 3, Subchapter 3, Article 1, Sections 20380 through 20435 (CCR 27 20380 through 20435). These standards include provisions that include requirements to: establish background values for monitoring parameters, conduct sampling and analyses for monitoring parameters, set forth monitoring schedules (both quarterly and annual basis), and perform statistical analysis of data to determine if evidence of a significant release has occurred. If evidence of a release has occurred, these standards specify notification requirements to the RWQCB as well as specify sampling and analytical protocols to further evaluate releases from the waste storage unit including reporting schedules and deadlines.

Standards for a DMP are specified in CCR 27, Chapter 3, Subchapter 3: Water Monitoring. Under Subchapter 3, Article 1, the general applicability for water quality monitoring and response programs for solid waste management units are addressed in Section 20380 (CCR 27, 20380). Required monitoring programs such as a DMP, Evaluation Monitoring, and Corrective Action programs are defined in CCR 27, 20385.

Establishment of Water Quality Protection Standard (Water Standard) for each waste unit are required under CCR 27 20390. CCR 27 2395 addresses Constituents of Concern (COC) to which the Water Standard applies. The COC list includes all waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste contained in the evaporation ponds.

CCR 27 20400 requires the establishment of concentration limits for each COC including the determination of background values. Monitoring Points and Point of Compliance (CCR 27, 20405) specifies the downgradient (horizontal) extent to which groundwater will be monitored. The compliance period is defined in CCR 27 20410, which is typically the number of years equal to the active life of the waste unit plus the closure period. The compliance period is the minimum time period during which RSPP will conduct a groundwater quality monitoring program subsequent to a release from a waste unit.

General Water Quality Monitoring and System Requirements at addressed in CCR 27 20415 which define the elements of a groundwater monitoring system for a DMP, Evaluation Program, or a corrective action plan, provisions for monitoring well standards, surface water monitoring systems, and unsaturated zone monitoring systems as well as descriptions of statistical data analysis methods are addressed in CCR 27 20415.

Requirements in a DMP are specifically addressed in CCR 27 20420. This includes requirements to establish the following: background values, monitoring parameters, routine monitoring, monitoring schedules, data recording format, and data analysis. This standard also provides provisions in the event that a release is indicated.

If evidence of a significant release from evaporation ponds is determined, then an Evaluation Monitoring Program pursuant to CCR 27 20425 will be implemented to assess if groundwater has been impacted. If groundwater has been impacted above the RWQCB thresholds, then the measures described in the Corrective Action Plan (CAP) pursuant to CCR 27 20430 will be implemented.

3.0 Waste Unit Inspection, Sampling, and Maintenance Programs

The DMP encompasses inspection of the evaporation ponds as well as periodic sampling of waste unit contents and a maintenance program to ensure that the waste units operate as designed. The following section outlines the inspection and maintenance requirements for the evaporation ponds.

The Action Leak Rate (ALR) monitoring system will be field tested at the commencement of the evaporation pond operation. On the first day of operation, the pump, piping and control switches will be checked to ensure they are in proper working condition per the manufacturers' specifications.

3.1 Waste Unit Inspection Program

3.1.1 Evaporation Pond Liner and Dike Areas

The exposed area of the evaporation ponds shall be inspected on a monthly basis. As the liner system will not be exposed, this will include observations for displaced or degradation of the hard/protective layer, and observations for eroded areas within the berm systems. The perimeter fence and the pond inlet (when visible) and outlets should also be inspected monthly to ensure they are in good repair and that these areas are free of debris.

3.1.2 Evaporation Pond Leak Detection System

Monitoring of leaked water is achieved through the addition of vertical monitoring wells that are hydraulically isolated with the leak detection layer. The flow totalizers, which quantify flow and the potential leakage that may occur between containment layers in the monitoring wells, will be monitored weekly for flow and monthly (quarterly after the first six months) to check for built up of material or degradation of the system.

3.1.3 Residue Inspections and Removal

Monthly inspections of the pond inlet and all associated drainage ditches/pipes/culverts will be conducted for residue including sediment and debris accumulation. If residue appears to be impeding flow into the pond or potential flow from the pond, maintenance actions will be scheduled for cleaning these areas as soon as possible. Residue removal activities will be conducted on an as-needed basis depending upon the inspection results.

Each pond will be in use for 3.5 years, after which time waste water will be discharged to the second pond. Preliminary design indicates that the water in the now unused pond should be fully evaporated after 7 months, at which time liner maintenance and residue removal activities should commence.

The residue shall be removed by a pumping or vacuum system if fluid, or should be dried and removed using conventional excavation and loading equipment light enough to reduce the potential for damage to the liner system. The residue should be sampled and analyzed to meet the characterization requirements of the receiving disposal facility. The characteristics of the residue will determine the transportation and disposal methodology.

3.2 Waste Unit Sampling Program

Samples of wastewater and residue will be collected periodically over the operational life of each evaporation pond. This section describes the sampling program. Samples will be properly documented and a written record of the chain-of-custody recorded. The chain-of-custody record will track the samples from the field to the laboratory. This form documents the time, date, sample location, person collecting the sample, and names and signatures of all persons who are maintaining custody of the samples from the time the samples are collected in the field to their arrival at the laboratory.

3.2.1 Evaporation Pond - Wastewater

Discharge into the evaporation ponds will come from one source: 1) High pH RO system. Each Unit will consist of two evaporation ponds, for a total of two ponds for the project. **Table 3-1** lists the estimated chemistry of the wastewater stream.

The evaporation ponds will be sampled at the commencement of operation, and then on a semi-annually basis thereafter to document constituent concentrations. Grab samples of wastewater collected at the start of operation and annually from each pond will be analyzed by a state-certified laboratory for the parameters listed in **Table 3-2**. The annual samples will be collected in the last quarter of each year.

Wastewater samples from each pond will also be collected semi-annually and composited into one sample by the state-certified laboratory and analyzed for the parameters list in **Table 3-3.**

In addition, quarterly water quality testing of selenium concentrations and TDS will be undertaken in conjunction with qualitative behavioral and avian health monitoring. Individual water samples will be taken from each pond. Should bird mortality occur, an additional water grab sample will be collected from the ponds for analysis at the time of discovery. Because water quality is difficult to tie directly to ecological risk by implementation of numeric standards, selenium and TDS concentrations will not trigger remedial action; however, the data will be collected to assess potential long-term correlations between water quality, as well as the pond water level, pond salinity, and temperature data, and bird behaviors and mortality, if any.

3.2.2 Evaporation Pond – Residue

Table 3-4 lists the predicted chemistry of evaporation pond residue. Annually, in the last quarter to each year, two representative grab samples of the bottom residue in each pond, if present, will be collected, composited and analyzed for the parameters shown in **Table 3-5**.

3.3 Maintenance Program

3.3.1 Evaporation Pond Cleanout

The ponds are designed to hold up to two feet of accumulated residue/precipitated solids before clean out is required. Before water can be pumped out of the pond for maintenance, the capacity of the other evaporation ponds must be assessed to verify that sufficient capacity exists to contain wastewater from continued operation for a sufficient amount of time to allow planned maintenance activities. Preliminary design estimates indicate that if one pond is undergoing clean out activities, the additional pond can operate effectively for up to one year.

Should a pond need emergency repairs, a manually placed pumping system will be used to transfer the water into an adjacent evaporation pond. As the ponds are covered with a hard protective layer, it will be possible to place and activate these pumping systems without otherwise damaging the pond liners or transfer piping. During pond drainage, the flow rates from the pumps will be monitored to ensure that the outflow is not negatively impacting on the receiving evaporation pond. Details of this pumping system will be provided by the manufacturer.

The appropriate time of year and ideal weather conditions to undertake the clean out activities should be investigated. Dust generated during the activities will need to be controlled in accordance with the Facilities Operations Dust Control Plan. Health and safety issues for the clean out activity include potentially slipping or falling into the pond. As part of the Facilities Operations Safety Training Program and PPE Plan, employees will be trained on how to undertake the clean out activities in a safe manner, which may include having ropes and ladders accessible at the evaporation ponds.

3.3.2 Evaporation Pond Residue Removal

If the pond is being drained for liner maintenance or excessive storm water volumes, the sediment and residue in the pond will be evaluated and removed if necessary as preventative maintenance. The general requirements for undertaking residue and sediment removal for evaporation ponds is outlined below.

The removal activities should only be conducted on an as-needed basis depending upon the inspection of the system. The inspections should include estimating the volume of residue, assessing if the residue or sediment is impeding flows into the pond and impacting on the evaporation rate or capacity of the system. The evaporation ponds are design to hold two feet of residue.

Each pond will be in use for about 3.5 years, after which time the pond will be removed from service and the residue allowed to dry for a period of 6-7 months. All waste flows will be discharged to the other pond during this period. Residue removal will commence when the residue reaches 50 to 80 percent water content as required by the receiving facility. Initial pond cleaning will occur after 2 years of facility operation, and thereafter one pond will be cleaned every two years. If wind-blown silt accumulation varies from 6 inches per year the cleaning interval will be adjusted accordingly so that removal will occur when about 2 feet of residue accumulates in the pond.

The residue shall be removed by a pumping or vacuum system if fluid, or should it be dried removal will be by conventional excavation and loading equipment light enough to reduce the potential for damage to the liner system. If necessary, the residue should be sampled and analyzed to meet the characterization requirements of the receiving disposal facility. The characteristics of the residue will determine the transportation and disposal methodology.

3.3.3 Unsaturated Zone Moisture Detection Monitoring

To monitor for water between the two geomembranes, an interstitial leak detection system (LDS) consisting of a granular drainage layer with perforated piping to collect and convey fluids to an extraction riser in a leak detection sump will be installed. The water collected in the LDS will drain by gravity to a unique monitoring well that is constructed for each of the leak collection layers. The volume of the water accumulating in each sump will be monitored to ensure it does not exceed the action leakage rate (ALR) for each pond. Monitoring of the interstitial LDS will be in accordance with the schedule presented in Section 3.1.2.

Moisture in the soil is detected by the speed that the neutrons move and scatter when emitted. The soil causes neutrons to slow however if the soil is dry, the cloud of neutrons will be less dense and extend further from the probe and if the soil is wet, the neutron cloud will be more dense and extend a shorter distance (http://sanangelo.tamu.edu/agronomy/sorghum/neutron.htm). The density of the cloud is measured by a detector and results are displayed electronically on the front panel.

Prior to the discharge of any waste water into the ponds, soil moisture measurements will be taken to establish background soil moisture levels. Neutron probe measurements will be taken beneath each pond at least four times in order to determine a value that is statistically representative of background moisture conditions.

Once the evaporation ponds become operational and wastewater is discharged to the ponds, moisture detection monitoring will be performed on a semi-annual basis. For each monitoring event neutron probe measurements will be performed beneath each pond. A statistical analysis will be performed comparing the results to the background soil moisture level using the statistical methods described in **Section 4.7.2**. If the moisture content is statistically significantly higher than the background value, then field verification testing will be performed and the RWQCB will be notified with a report of physical evidence of a release. Field verification testing may consist of a combination of the following measures: additional neutron analysis, laboratory analysis of liquids drawn from the neutron probe casing, and visual observation to verify existence of a release.

3.3.4 Avian Monitoring

Avian monitoring at the evaporation ponds will be conducted by the RSPP Designated Biologist twice monthly for the first two years of project operation. The RSPP Environmental Compliance Manager will continue monitoring after the first two years, under the direction of the RSPP Designated Biologist, at least twice a month for the life of the project. The monitor (biologist or ECM) would identify bird species and/or functional groups (e.g., waterfowl, waders, shorebirds, upland shorebirds) utilizing the ponds, record the behavior of the birds (e.g., feeding, swimming, wading, nesting), and note any mortalities or physical infirmities (e.g., birth defects or reduced growth) associated with any bird observed on or adjacent to the evaporation ponds. Any dead bird that can be safely retrieved from the evaporation ponds would be collected by the biologist or ECM and sent to a qualified laboratory to determine if the mortality was directly related to selenium poisoning or salt toxicosis or encrustation. Documented mortality resulting from selenium poisoning or salt toxicosis or encrustation would result in corrective measures implemented in coordination with the agencies.

4.0 Groundwater Monitoring Network

In accordance with CCR Title 27, Chapter 3, Subchapter 3, Article 1, Section 20380, a groundwater monitoring network (GMN) will be established at the RSPP to monitor groundwater for impacts from potential releases from the two proposed evaporation ponds. The proposed GMN will consist of four (4) new proposed onsite monitoring wells (MW-1 through MW-4).

The depth to groundwater below the southern portion of the site, measured in 1959 from the one onsite well, is estimated to be approximately 230 feet bgs. That same year groundwater was measured at 451 feet bgs in a well approximately one mile west of the northern portion of the Project. The difference in the depth to groundwater in these two wells is approximately 220 feet. One possible explanation for the difference in groundwater elevations is that there is a groundwater barrier across the Project site, more specifically, a fault.

Current depth to groundwater west of the western Project boundary and north of Brown Road (based on 2006 data) is estimated at 480 feet below the ground surface. The contours show that groundwater flows in a radial pattern toward China Lake and toward the cone of depression beneath the City of Ridgecrest. Based on regional groundwater trends and topography, groundwater flow beneath the plant site is expected to flow to the north-northeast towards the cone of depression. The groundwater gradient beneath the site is not currently known due to the lack of groundwater data in the area. .Therefore, based on topography and the groundwater gradient, the depth to groundwater beneath the evaporation ponds would be expected to be approximately 450 feet bgs.

The proposed GMN is designed to monitor upgradient and downgradient groundwater quality near the ponds and at the project boundaries.

To provide construction and operational water to the proposed facility, RSPP proposes to use groundwater supplied by the IWVWD. Water from the wells will be piped to an existing tank and transmitted via pipeline that will be built by the RSPP to the Project site.

A list of chemical additives that are anticipated to be added to process water on a regular basis is presented in **Appendix A**.

4.1 Groundwater Monitoring Network Layout for Regional Groundwater

The proposed GMN layout includes three categories of monitoring wells: 1) background wells which are located upgradient of the evaporation ponds; 2) detection wells, which are located adjacent to the evaporation ponds; and 3) compliance wells, which are located near the property boundaries, downgradient of the evaporation ponds. The background well (MW-1) will be located upgradient of the evaporation ponds along the southwestern Site boundary; the two proposed detection wells (MW-2 and MW-3) will be located immediately adjacent to the downgradient corner of each evaporation pond; and the proposed compliance well (MW-4) will be located downgradient of the evaporation ponds, along the northeastern Site boundary (**Figure 4-1**).

There will be no onsite pumping of groundwater for project use; therefore, based on regional groundwater gradients, groundwater beneath the Site is expected to flow to the northeast (**Figure 1-6**).

4.2 Groundwater Monitoring Network Layout for Shallow (Perched) Groundwater

Shallow (perched) groundwater is not expected beneath the Site. If perched groundwater is encountered during the installation of the proposed monitoring wells, then additional wells may be installed to evaluate the perched groundwater. The criteria for adding wells will include the areal and vertical extent of the perched groundwater and the temporal nature of the perched groundwater. The decision to install the shallow wells would be made after the proposed wells have been completed and well logs as well as geophysical logs can be reviewed.

4.3 GMN Well Installation Activities

The GMN is based on four (4) new monitoring wells at the approximate locations shown on **Figure 4-1**. The steps associated with well installation activities are described below.

Field activities including drilling, well installation, well development, groundwater sampling, field analytical procedures, and record keeping will be performed using the standard operating procedures provided in **Appendix B**. Field activities will be performed under the oversight of a California-registered Professional Geologist.

<u>New Monitoring Well Installation</u>

1. Well installation permits will be obtained from Kern County Department of Environmental Health;

2. Well locations will be cleared for utilities/unexploded ordinance (UXO), by notifying Underground Service Alert and having a third party underground utility locator/UXO specialist firm perform a utility/UXO clearance geophysical survey;

3. Wells will be installed using air/mud rotary drilling methods in accordance with all local and state regulations and requirements. The pilot boring will be advanced to a minimum of 50 feet bgs and a maximum of 100 feet bgs using the air rotary drilling method. During advancement of the borehole using air rotary methods, the on-site geologist will be looking for evidence of perched water zones in the cuttings. If a potential perched zone is identified, drilling will be suspended and the following activities performed: a) the borehole will be cleaned of cuttings; b) the drill rod will be removed from the borehole; c) the borehole will be allowed to sit for between 30 (gravel sand lithology) and 60 (silt to clay lithology) minutes to allow free water to enter the borehole, if present; and d) a water level sounder will be lowered into the borehole to check for free water. Air rotary drilling methods may be halted if large volumes of water are required to aid in cleaning the borehole;

4. After air rotary drilling is halted, mud rotary drilling methods will be utilized to complete the advancement of the pilot boring to depths of approximately 75 feet below the top of the regional water table, which will be confirmed during drilling activities;

5. After borehole completion, the following suite of downhole geophysical logs (e-logs) will be run: 16- and 64-inch resistivity logs, a spontaneous potential log, a borehole caliper log, a natural gamma log and a sonic log. The sonic log will be especially important in identifying the top of the regional water table and any perched units that may have been encountered in the vadose zone during mud rotary drilling;

6. The monitoring wells will be constructed with 4-inch Schedule 80 PVC or low carbon steel well casing. The screen interval for each monitoring well will be sufficient to allow for monitoring of the regional groundwater under both static and dynamic (pumping) conditions. The screen opening (slot size) will be based on the screen interval lithology. The monitoring well will be centered in the borehole using centralizers placed every 40 feet along the well casing and screen interval;

7. Filter pack material will be placed in the annular space between the well screen and borehole using a tremie pipe. As with the screen opening, the filter pack material will be dependent on the lithology and the chosen screen opening. The filter pack will extend a minimum of 5 feet above the screen interval;

8. An annular seal, consisting of a ten sack sand/cement grout, will be placed between the well casing and the borehole to within 20 feet of the surface (Kern County requirements for wells completed in desert environments) using a tremie pipe;

9. The monitoring well surface completion will consist of a traffic-rated, flush-mount or stove-pipe well box set into a concrete skit that extends to the top of the grout seal; and,

10. Following the surface completion, the monitoring well will be developed to remove drilling mud from the borehole, filter pack and surrounding formation, remove fines from the filter pack, and to ensure proper groundwater connection to the surrounding formation.

After the monitoring well has been developed, additional sampling events will be conducted using a dedicated or portable pump. Regardless of the type of pump used, the pump intake will always be set so it is between 5 and 6 feet below the top of the water table. **Appendix B** contains SOPs for drilling, borehole logging, well design, etc. that will be followed by the field personnel.

4.4 Monitoring Well Sampling

Groundwater samples will be analyzed to establish background water quality concentrations. Following this, groundwater samples will be analyzed on a quarterly basis. All monitoring wells will be sampled using dedicated or portable pumps and low-flow sampling techniques. The procedures for monitoring well sampling are presented in the SOP for water sampling in **Appendix B**.

4.5 Background Groundwater Monitoring

Initial background sampling will be performed that will consist of four quarters of groundwater sampling and analysis. All four quarters' data will be collected prior to the discharge of wastes into the evaporation ponds. This data will represent existing or static (non-pumping) hydrogeologic conditions. When the facility becomes operational and groundwater is pumped to provide process water, the hydrogeologic conditions beneath the Site will become dynamic and the condition will remain dynamic for the life of the facility. For this reason, groundwater samples from the first quarterly sampling under the pumping conditions will be evaluated and with prior RWQCB concurrence, may also be considered background. Groundwater samples will be analyzed for the parameters listed on **Table 3-2, Evaporation Pond Wastewater Startup and Annual Sampling Parameters**. Background groundwater data will be evaluated statistically using the methods described in Section 4.7.2.

During project site construction activities, groundwater will be used for dust suppression and other construction uses. When this water use occurs, additional groundwater monitoring and sampling will be performed. Depending on the projected time-frame for construction water use, it is anticipated that up to three additional rounds of groundwater sampling will be performed. The first construction sampling would occur approximately one week after groundwater pumping commenced, the second round of sampling would be near the middle of the groundwater pumping and the final sampling event would occur approximately two days prior to pumping ceasing.

4.6 Routine Groundwater Monitoring

Groundwater will be sampled and analyzed from each monitoring well on a quarterly basis. After water levels are measured in each well, each well will be purged and sampled using low-flow groundwater sampling techniques (see **Appendix B**). Groundwater samples from the first, second and third quarterly events will be analyzed for the parameters listed on **Table 4-1**. The fourth quarter monitoring event is also referred to as the "Annual" monitoring event and groundwater from this event will be analyzed for the parameters listed on the aforementioned **Table 4-2**.

4.7 Data Evaluation

Using approved statistical or non-statistical data analysis methods approved in Board Order No. 6-98-74, the Project will, for each monitoring event, compare the concentration of each monitoring parameter with its respective concentration limit to determine if there has been a release from the evaporation ponds. Monitoring will be completed as follows:

- Consistent with the CCR Title 22, 66264.97(e), the groundwater monitoring report will include a graphical and statistical trend analysis of the groundwater monitoring data.

4.7.1 Graphical Analysis

Time series graphs of groundwater chemical data will be presented. Graphs will be at a scale appropriate to show trends or variations in water quality. Wells that have been primarily below detection limits for a given constituent will not be graphed.

Maps illustrating the groundwater flow direction and chemical data (e.g., chloride, nitrate as nitrogen, phosphate, sulfate, total dissolved solids (TDS), biphenyl oxide, and diphenyl oxide will be presented.

4.7.2 Statistical Trend Analysis

A trend is defined as the general increase or decrease in observed values of some variable over time. Trend analysis can be used to determine the significance of an apparent trend and to estimate the magnitude of that trend. The Mann Kendall trend test and the Sen's slope estimator were chosen to statistically analyze the data because they are the accepted non parametric trend analysis methods for data that are not normally distributed.

<u>Mann Kendall Trend Test</u>. The test was conducted on the wells to evaluate the existence of significant trends. The Mann Kendall formula is as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k)$$

The resulting statistic is the number of positive differences minus the number of negative differences. The statistics can be used to test the null hypothesis for the absence of a trend or the presence of a trend.

<u>Sen's Slope Estimator</u>. This simple procedure developed by Sen is used to estimate the slope or rate of change of the parameters in question. The advantage of this method over simple linear regression is that it is not greatly affected by gross data errors or outliers, and can even be computed when data are missing.

The N' individual slope estimates, Q, are computed for each time period:

$$Q = \frac{Xi'-Xi}{i'\ i}$$

where

Xi' and Xi are data values at time i' and i, respectively

N' is the number of data pairs for which i'>i

The median of these N' values of Q is Sen's estimator of slope.

N' is determined as follows:

$$N' = \frac{n(n-1)}{2}$$

If only one datum per time period exists, n is the number of time periods.

A value of one half of the detection limit will be substituted for Xi values below the detection limit.

The median of the N' slope estimates is obtained by ranking the values of Q from smallest to largest and computing as follows:

Sen's estimator = median slope

$Q_{(N'+1)/2}$ if N' is even

$1/2 \{Q_{(N'/2)} + Q_{[(N'+2)/2]}\}$ if N' is odd

5.0 Reporting

The "General Provisions for Monitoring and Reporting," dated September 1, 1994, will be followed for all submittals to the RWQCB.

5.1 Record Keeping and Reporting Requirements

5.1.1 Scheduled Reports Filed with the RWQCB

A detection monitoring report will be submitted on a quarterly basis to the RWQCB with reports submitted on April 30th, July 30th, October 31st and January 31st of each year. Each report will include the following information:

- Results of sampling analysis, including statistical limits for each monitoring point;
- A description and graphical presentation of the velocity and direction of groundwater flow under/around the Unit, based upon water level elevations taken during the collection of the water quality data submitted in the report;
- A map or aerial photograph showing the locations of observation stations, monitoring points, and background monitoring points;
- An evaluation of the effectiveness of the leakage monitoring and control facilities, and of the runoff/run-on control facilities; and
- A letter transmitting the essential points in each report, including a discussion of any permit excursions found since the last report was submitted and actions taken or planned for correcting those excursions. If a detailed time schedule for correcting permit excursions has been previously submitted, a reference to the correspondence transmitting this schedule will be satisfactory. If no excursions have occurred since the last submittal, this will be stated in the letter of transmittal.

5.1.2 Unscheduled Reports Filed with the Regional Board

Incidents that result in implementation of the Contingency Plan will be reported to the appropriate agencies. If such incidents threaten to result in an off-site discharge or may present a potential threat to human health or the environment, immediate verbal notification shall be made as specified in the Contingency Plan. A record of such verbal communications will be maintained in the operating record. As specified by State and Federal regulations, a written report describing the incident and the implementation of the Contingency Plan will be prepared and submitted to LEA and RWQCB within 15 days. Additional reporting may be required under the Waste Discharge Requirements and Monitoring and Reporting Program established by the RWQCB. Further discharge situations are outlined in the following sections.

5.1.2.1 Physical or Statistically Significant Evidence of a Release from the Impoundment

The Facility Manager shall immediately notify the RWQCB verbally whenever a determination is made that there is a physical or statistically significant evidence of a release from the evaporation ponds. A written notification, via certified mail, shall be undertaken within seven days of such determination. The notification shall include the following information:

- Evaporation pond that may have released/be releasing;
- General information including the date, time, location and cause of the release;
- An estimate of the flow rate and volume of the waste involved;
- A procedure for collecting samples and description of laboratory tests to be conducted;
- Identification of any water bearing media affected or threatened; and
- A summary of proposed corrective actions.

In addition, for a statistically significant evidence of a release, monitoring parameters and/or constituents of concern that have indicated statistically significant evidence of a release from the evaporation pond must be outlined. For physical evidence of a release, physical factors that indicate physical evidence of a release must be described.

Upon notification, the RSPP may initiate verification procedures or demonstrate that a source other than the evaporation ponds, caused the evidence of a release. Written notification to the RWQCB will be undertaken with seven days of the initial notification. A supporting technical report must be provided to the RWQCB within 90 days demonstrating the different source of the discharge.

5.1.2.2 Exceeding the Action Leakage Rate

Exceeding the ALR contained in Section II.C.1. (Board Order No. 6-98-74) is an Adverse Condition. The ALR is the allowable leakage from the primary liner system. According to Title 40, Section 264.222 of the Code of Federal Regulations, the ALR is defined as the maximum design flow rate that the leak detection system can remove without the fluid head on the bottom liner exceeding one foot. The ALR must also include an adequate safety margin to allow for variability in the containment system design (e.g. liner and collection pipe slope, interstitial fill hydraulic conductivity, thickness of drainage material). Based on the available information, an ALR of 24,800 gallons/acre/day for the north pond and 46,800 gallons/acre/day for the south pond is proposed for management of the facility.

If the ALR is exceeded, the RWQCB will be notified within 24 hours whenever of the determination. The verbal notification shall be followed by a written notification via certified mail, within seven days of such determination. This written notification shall be followed by a technical report via certified mail within thirty days of such determination. The technical report shall describe the actions taken to address the adverse condition, and shall describe any proposed future actions to abate the adverse condition.

<u>Evaluation Monitoring</u>

Within 90 days of determining a release, an amended Report of Waste Discharge proposing an evaluation monitoring program will be submitted to the RWQCB.

<u>Preliminary Engineering Feasibility Study Report</u>

Within 180 days of discovering the release, a Preliminary Engineering Feasibility Study for corrective action will be submitted to the RWQCB.

5.2 Submittal Periods

<u>Quarterly Monitoring Report</u>

A quarterly monitoring report including the previously described information will be submitted to the RWQCB. Subsequent quarterly monitoring reports will be submitted to the RWQCB by April 30th, July 30th, October 31st and January 31st of each year.

<u>Annual Report</u>

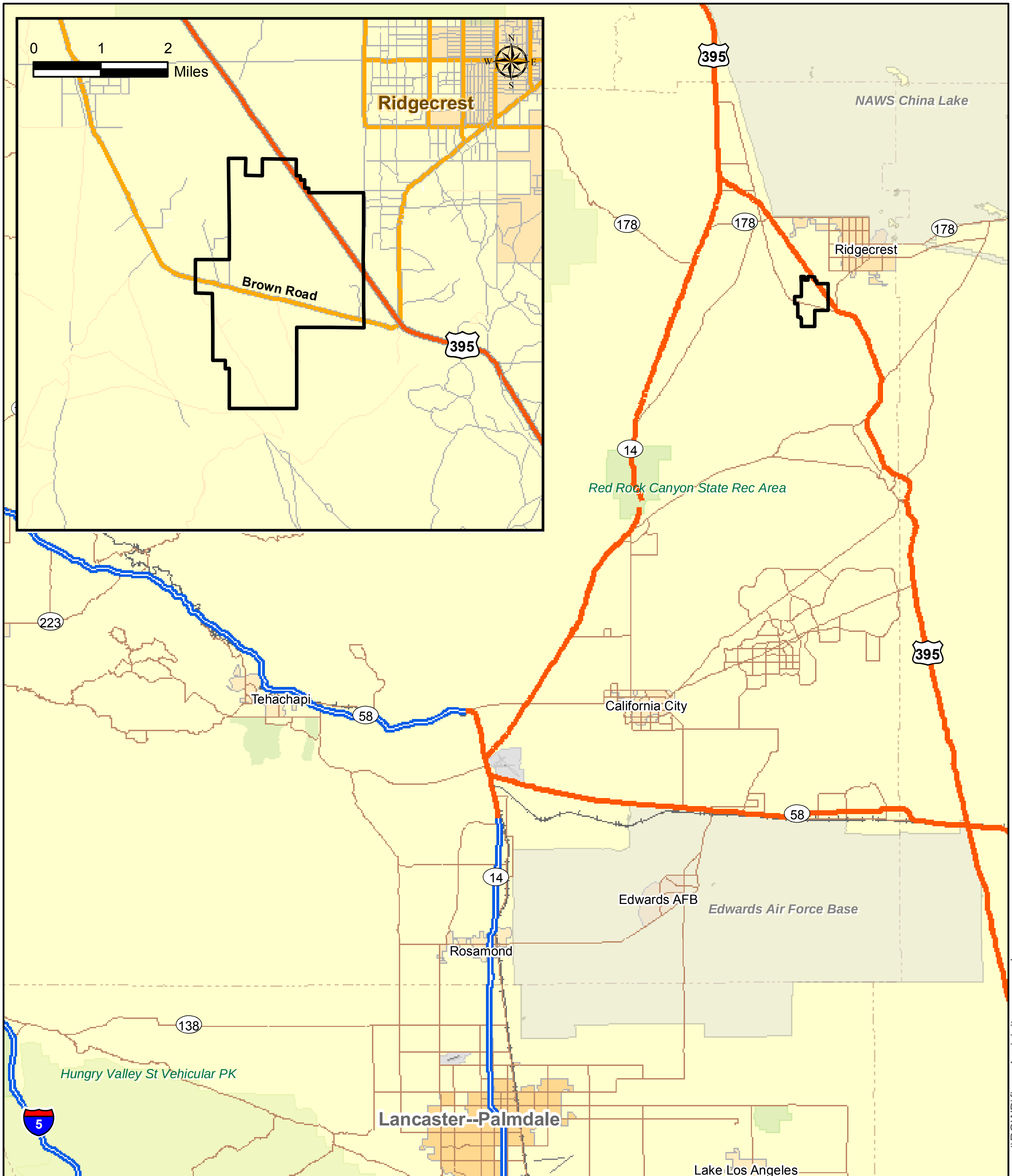
By January 31st of each year, an Annual Report to the RWQCB will be submitted and will include tables of the historic data as well as describing the specific monitoring activities conducted between January and December of the previous year. The annual report will be signed by a California registered geologist or professional civil engineer. The signature page will contain his or her license number.

The groundwater monitoring report will include a graphical and statistical trend analysis of the groundwater monitoring data.

6.0 References

AECOM, 2009, Ridgecrest Solar Power Project Hydrogeologic Report, December.

Figures



Map Location

Ridgecrest Solar Power Plant

Figure 1-1
Regional Location and Vicinity Map

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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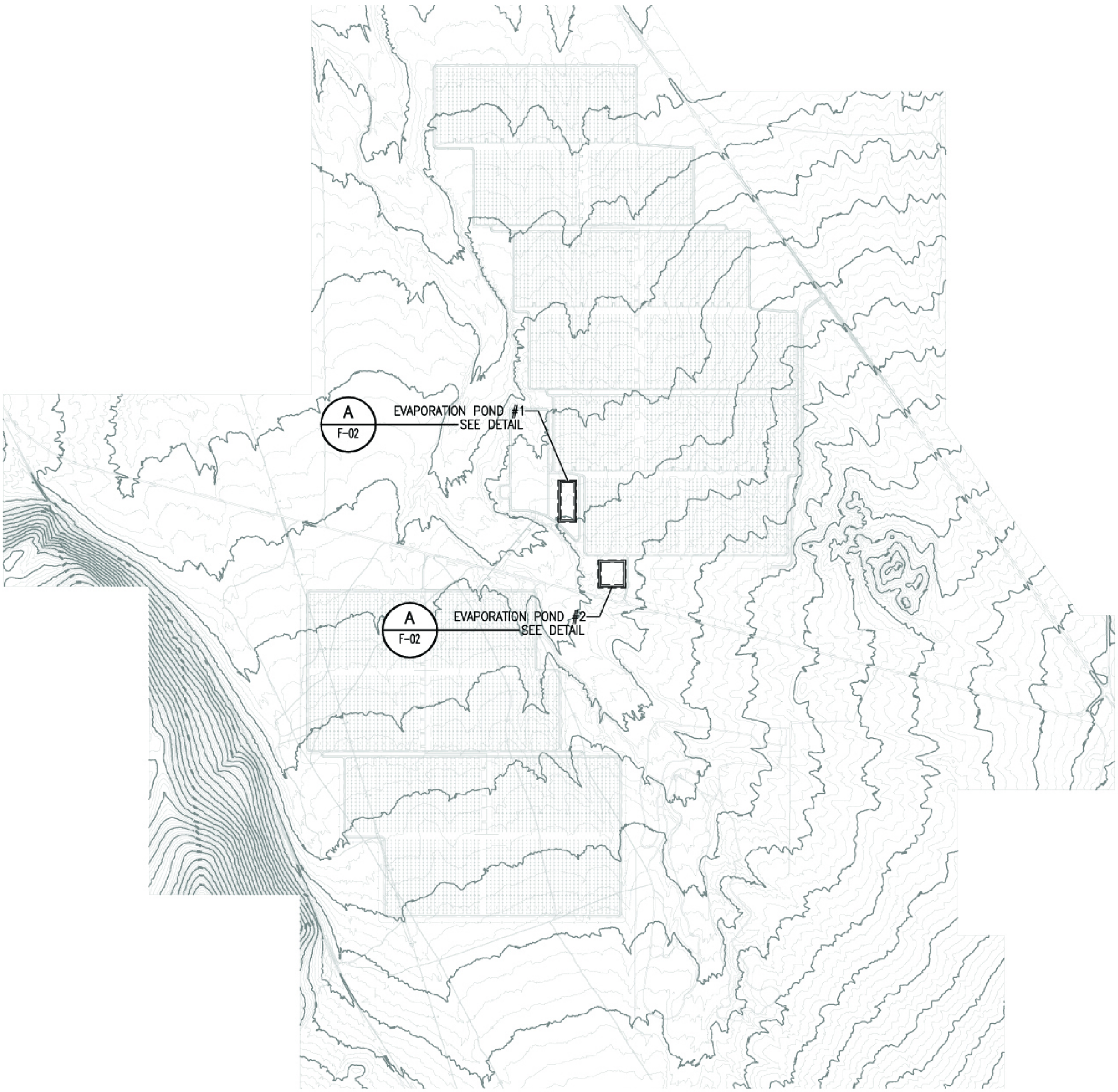

Map Location

Ridgecrest Solar Power Project

Figure 1-2
General Arrangement Site Plan

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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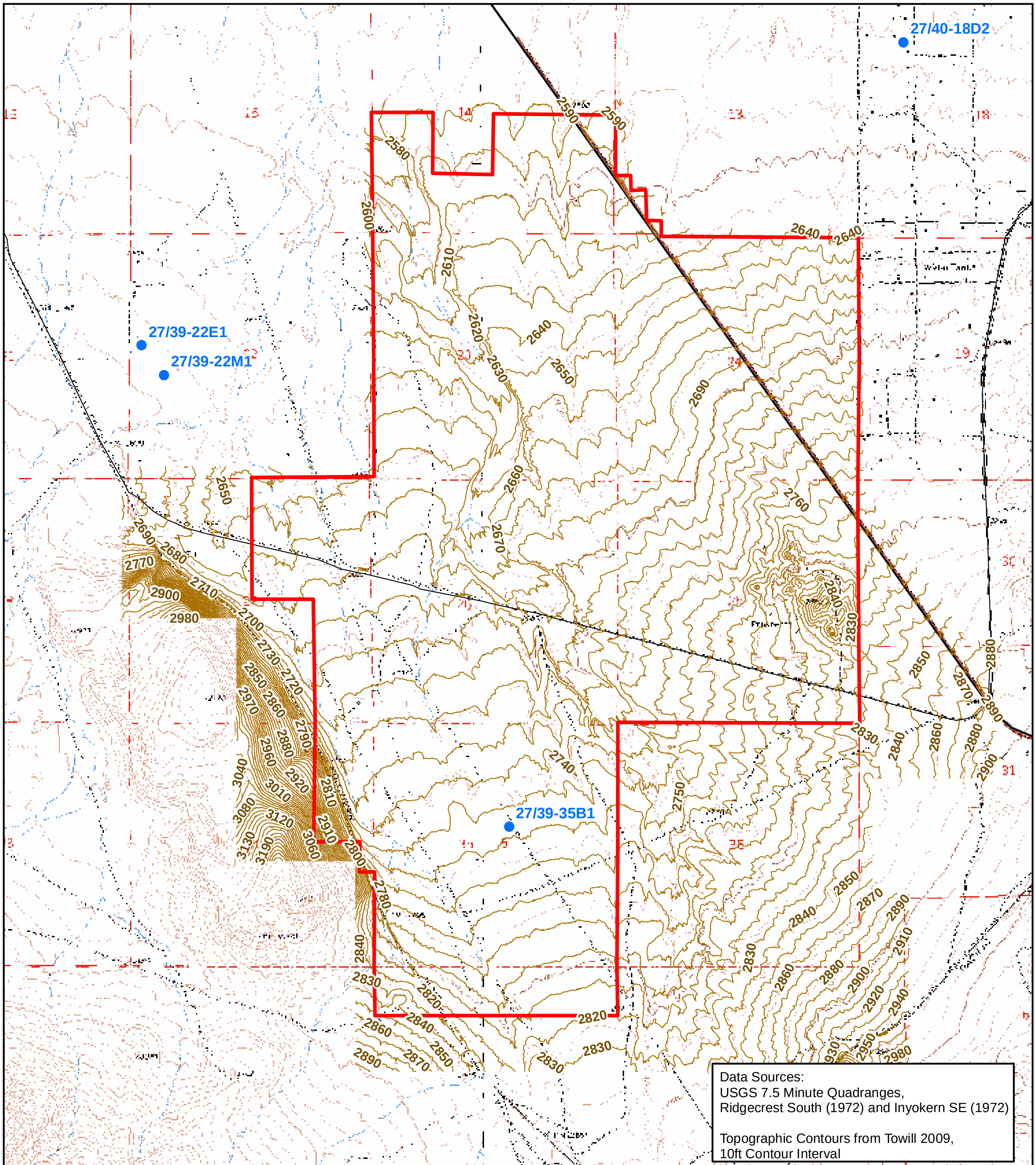


Data Sources:
USGS 7.5 Minute Quadranges,
Ridgecrest South (1972) and Inyokern SE (1972)

Topographic Contours from Towill 2009,
10ft Contour Interval

Map Location

Legend

Project Right-of-Way

Groundwater Well Location based on Latitude and Longitude in USGS Database

0 3,000 6,000 Feet

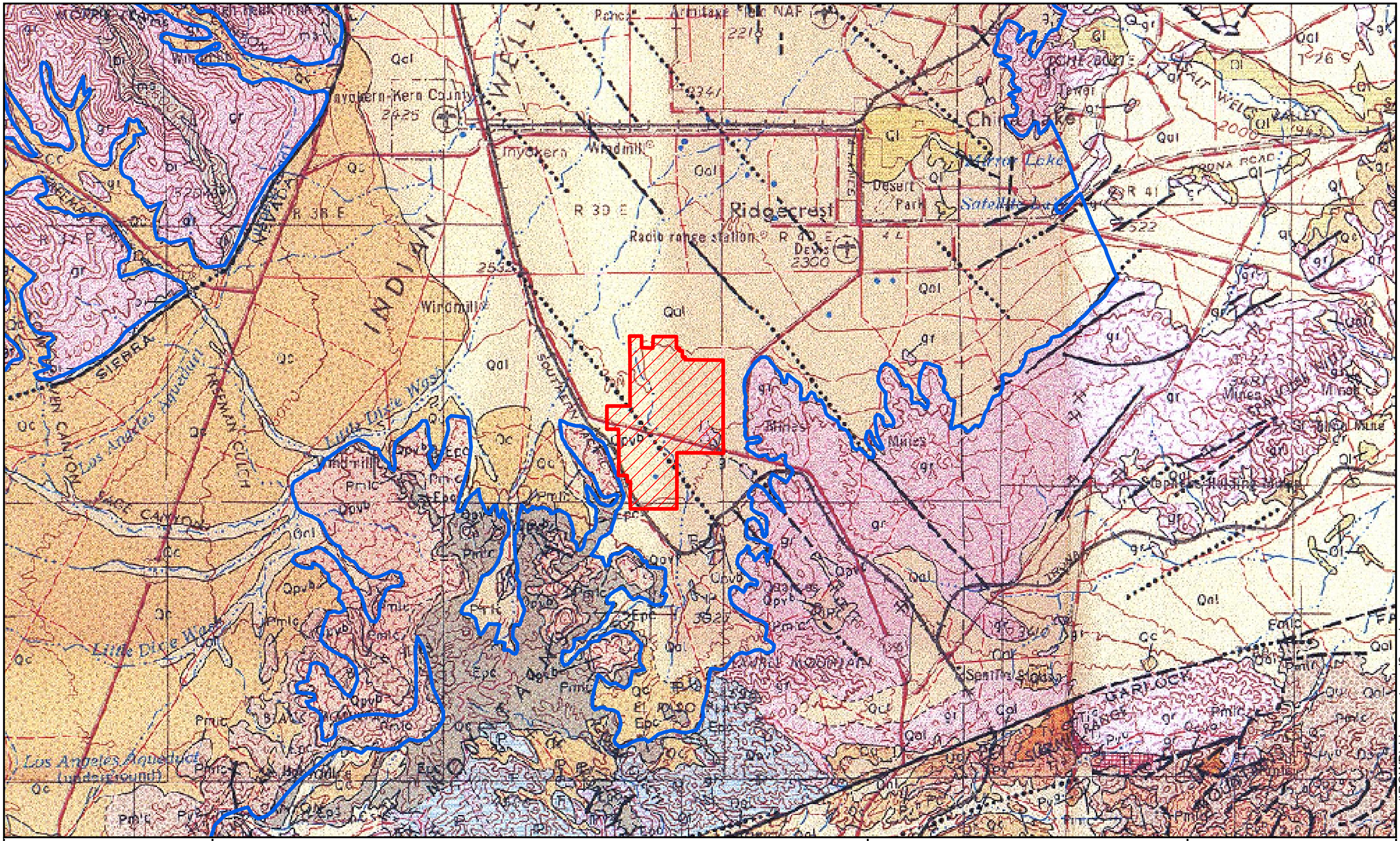
Ridgecrest Solar Power Plant

Figure 1-3
Site Topographic Map

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010



Map Location

Legend

Project Right-of-Way

Indian Wells Valley Groundwater Basin

See Figure 1-4b for Geologic Legend

Sources:
Division of Mines and Geology, Geologic Map of California, Trona Sheet, Scale 1:250,000, 1963

1 in = 3 miles

0 3 6 Miles

N E S W

Ridgecrest Solar Power Plant

Figure 1-4a
Regional Geologic Map

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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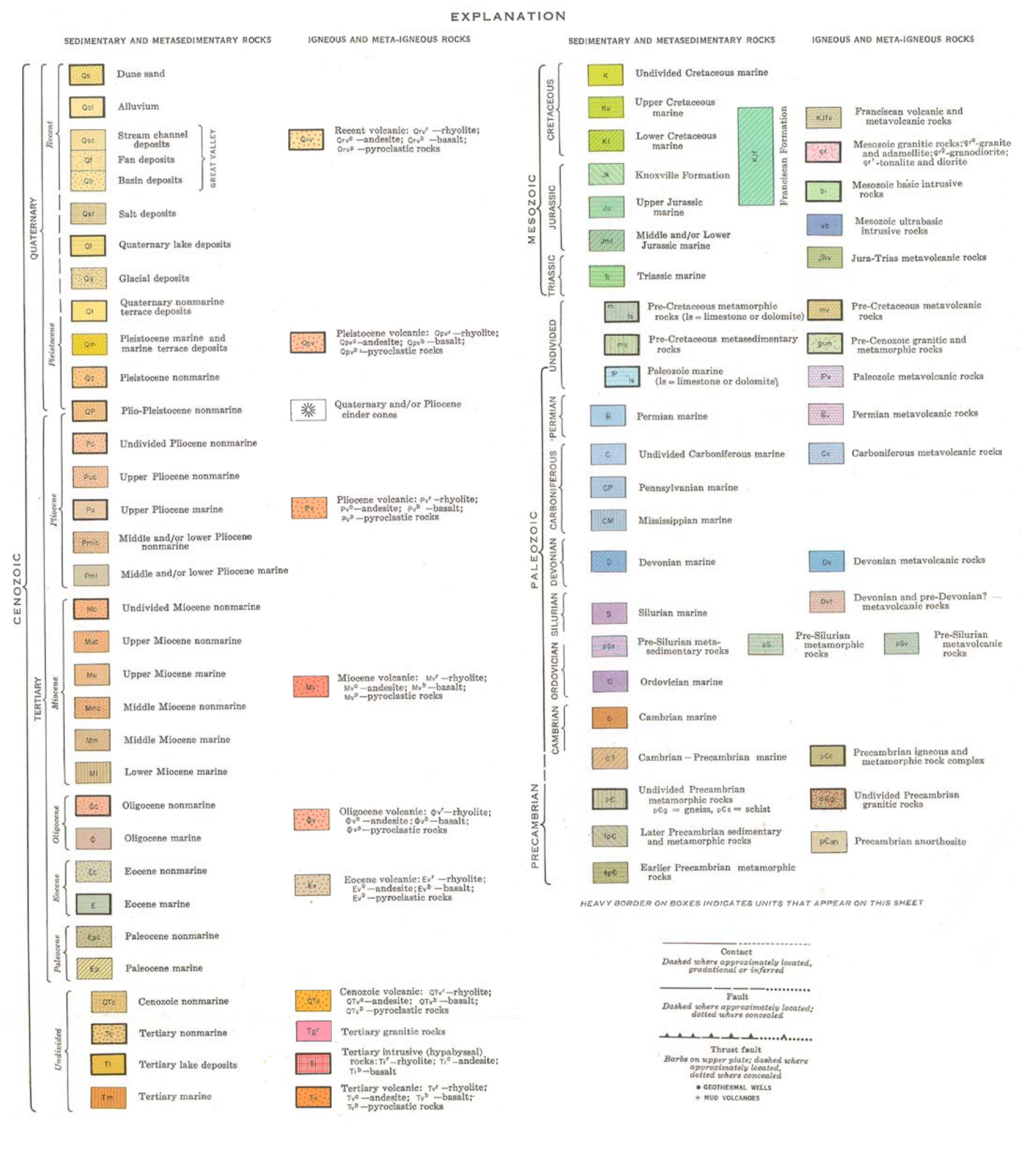

Map Location

Legend

Sources:
Division of Mines and Geology, Geologic Map of California, Trona, Scale 1:250,000, 1963

Ridgecrest Solar Power Project

Figure 1-4b
Regional Geologic Map Legend

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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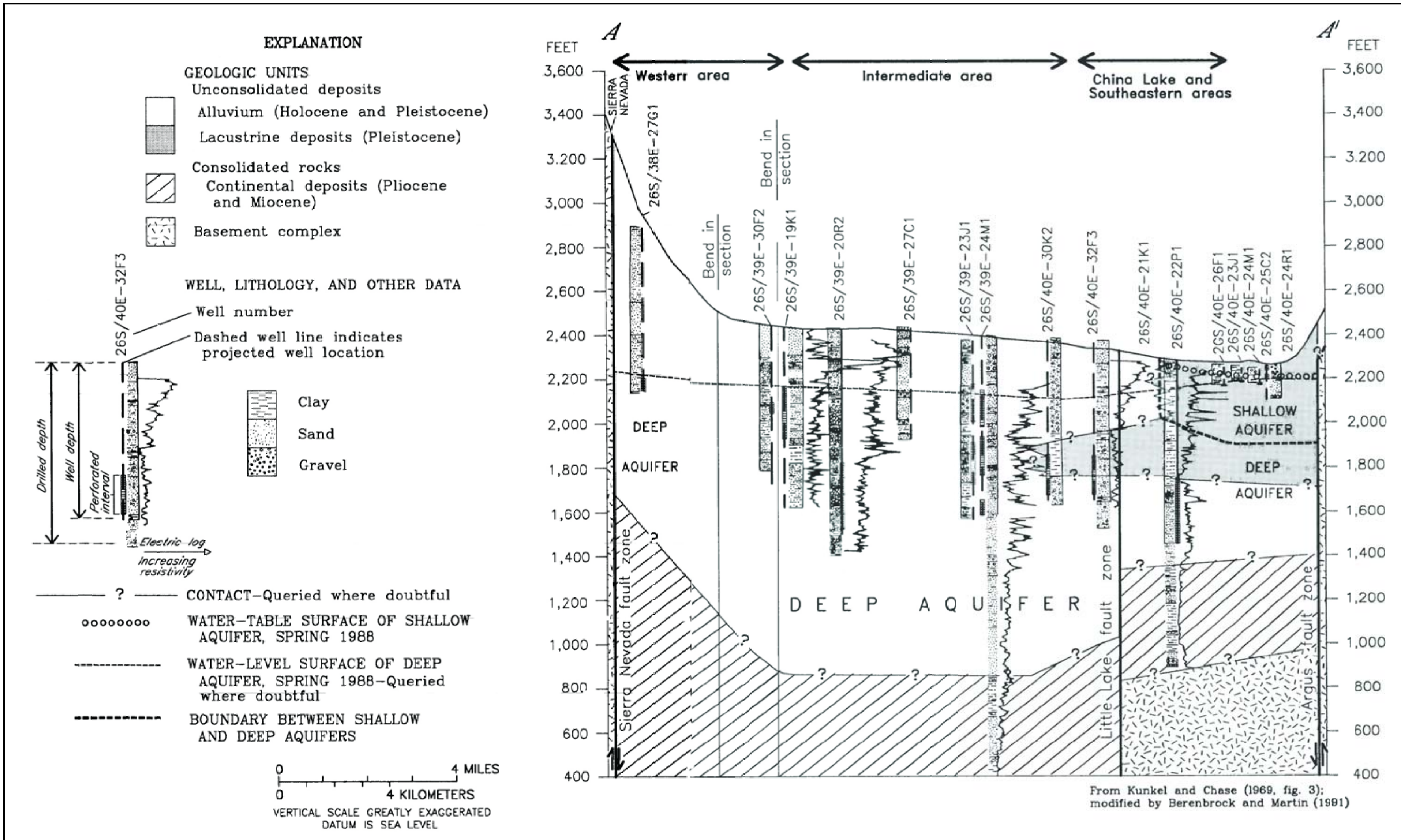

Map Location

Note:
Cross-Section line shown on Figure 5.17-3a Regional Geologic Map.

Source:
Berenbrock, Charles and Schroeder. 1994, Groundwater Flow and Quality, and Geochemical Processes, in Indian Wells Valley, Kern, Inyo, and San Bernardino Counties, CA 1987-88

Ridgecrest Solar Power Plant

Figure 1-4c
Cross Section A-A'

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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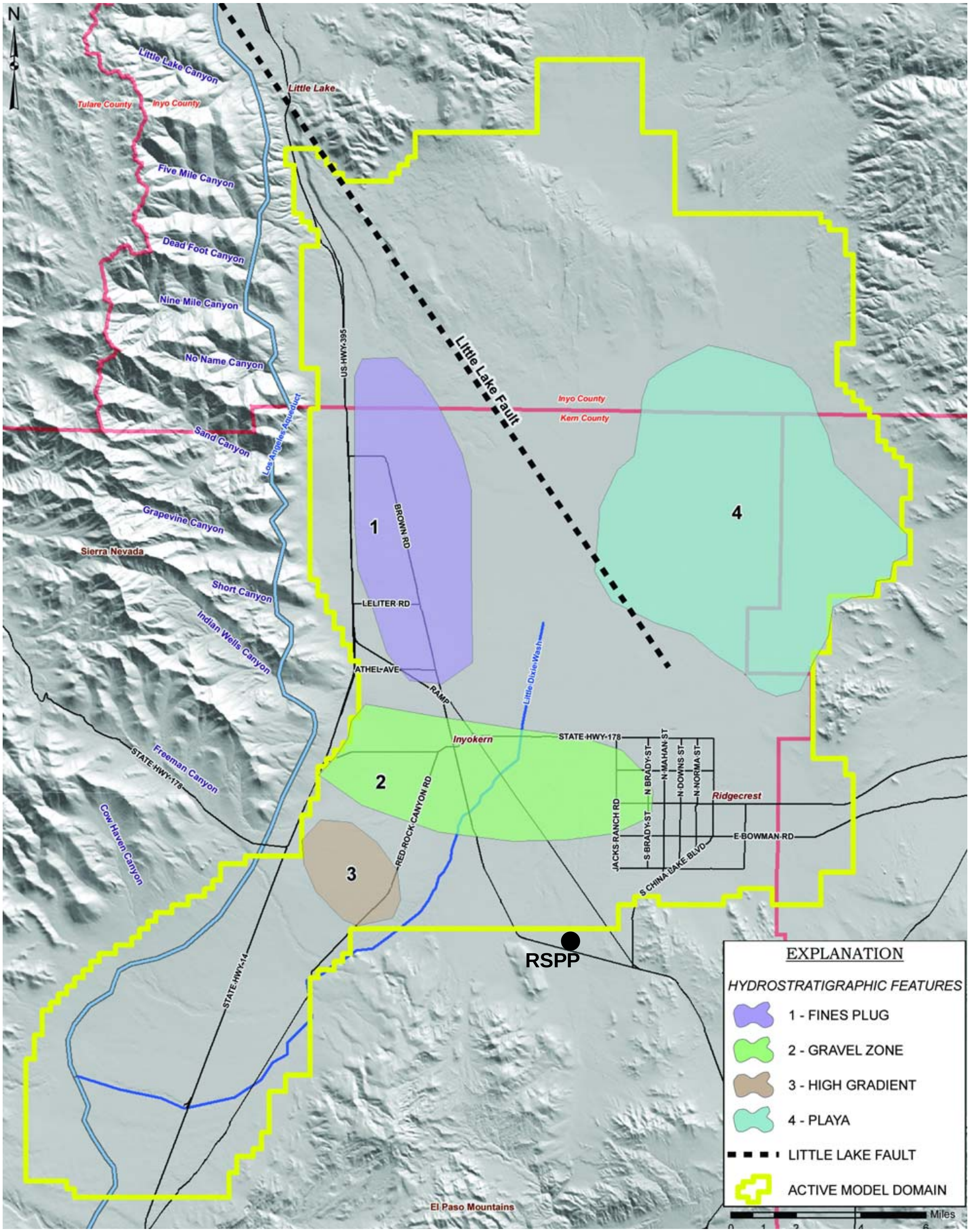

Map Location

Sources:
Modified from Brown and Caldwell
Indian Wells Valley Basin Groundwater
Flow Model and Hydrogeologic Study,
March 27, 2009

Ridgecrest Solar Power Project

Figure 1-5
Hydrostratigraphic Features in the Indian Wells Valley Groundwater Basin

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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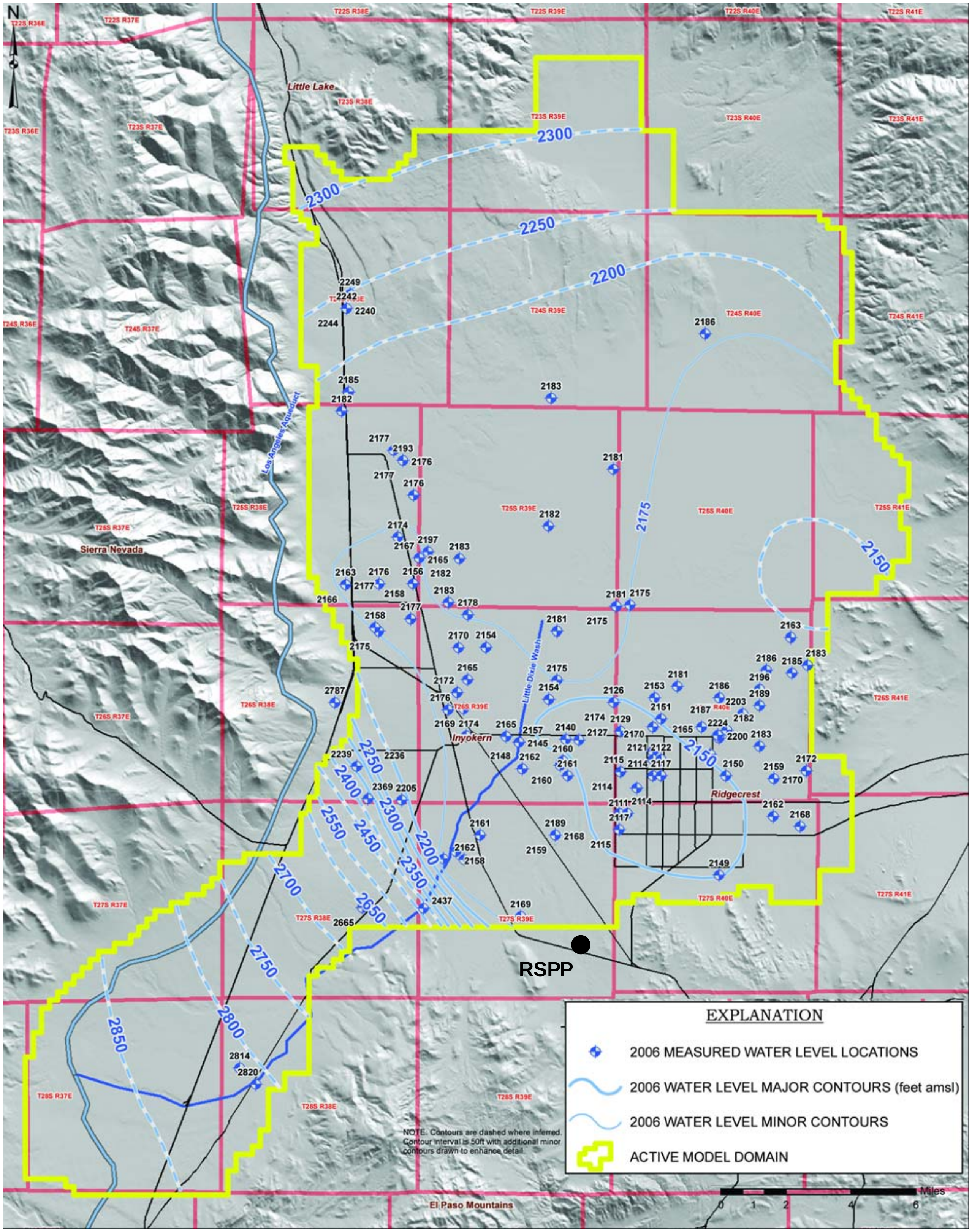

Map Location

Sources:
Modified from Brown and Caldwell
Indian Wells Valley Basin Groundwater
Flow Model and Hydrogeologic Study,
March 27, 2009

Ridgecrest Solar Power Project

Figure 1-6
Groundwater Level Map - 2006

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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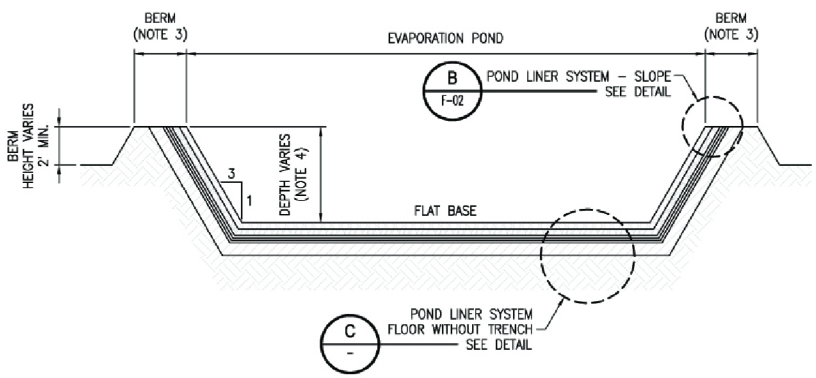
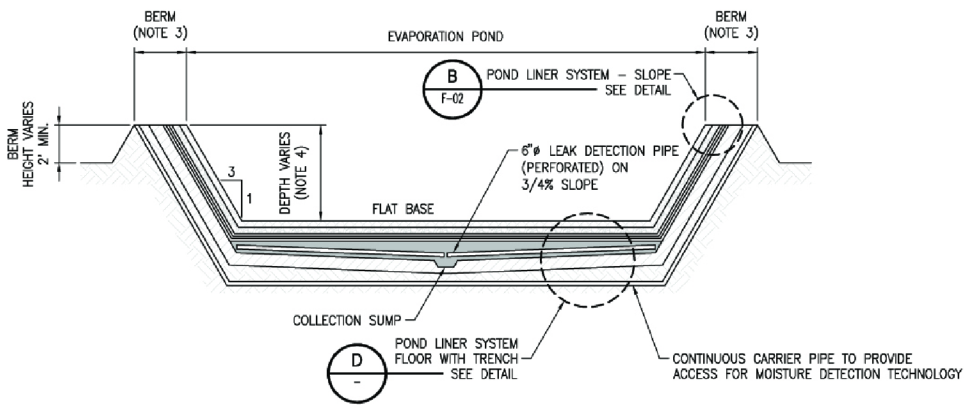


POND - UPSTREAM CROSS SECTION (A –)

SCALE: N.T.S.



POND - DOWNSTREAM CROSS SECTION (B –)

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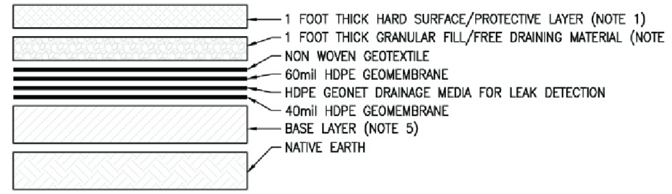
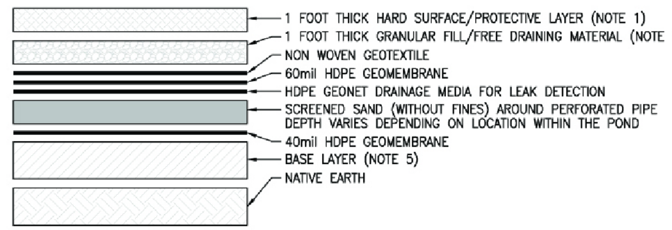


POND LINER SYSTEM DETAIL
FLOOR TRENCH (C –)

SCALE: N.T.S.



POND LINER SYSTEM DETAIL
FLOOR WITHOUT TRENCH (D –)

SCALE: N.T.S.

NOTE:

1. HARD SURFACE/PROTECTION LAYER TO BE 1 FOOT OF ROLLER COMPACTED CONCRETE OR APPROVED EQUIVALENT.
2. GRANULAR FILL/FREE DRAINING SUB BASE MUST HAVE MAXIMUM PARTICLE SIZE OF 1/2 INCH.
3. BERM IS A MINIMUM OF 12 FEET WIDE AND MAXIMUM OF 18 FEET WIDE. BERM IS COVERED BY A MINIMUM OF 6 INCHES OF ROADBASE MATERIAL.
4. AVERAGE POND DEPTH OF 7 FEET ALLOWS FOR 2 FEET OF FREEBOARD, 3 FEET OF OPERATIONAL DEPTH AND 2 FEET OF SLUDGE ACCUMULATION. MINIMUM 1% SLOPE ACROSS POND BASE, THEREFORE UPSTREAM END OF POND WILL HAVE A DEPTH OD LESS THAN 7 FEET AND DOWNSTREAM END OF POND WILL HAVE A DEPTH OF MORE THAN 7 FEET.
5. BASE LAYER: PREFERRED MATERIAL IS 2 FOOT OF AN SITE MATERIAL WITH HYDRAULIC CONDUCTIVITY OF LESS THAN 1 X 10-6 CM/S, OF WHICH AT LEAST 30% OF THE MATERIAL SHALL PASS THROUGH A NO. 200 U.S. STANDARD SIEVE. IF THIS MATERIAL IS NOT AVAILABLE, THE ALTERNATIVE DESIGN IS A GEOSYTHENTIC CLAY LINER (GCL).
6. SEE TEXT FOR FURTHER DETAILS.

Map Location

Ridgecrest Solar Power Plant

Figure 1-7a
Evaporation Pond Section and Details

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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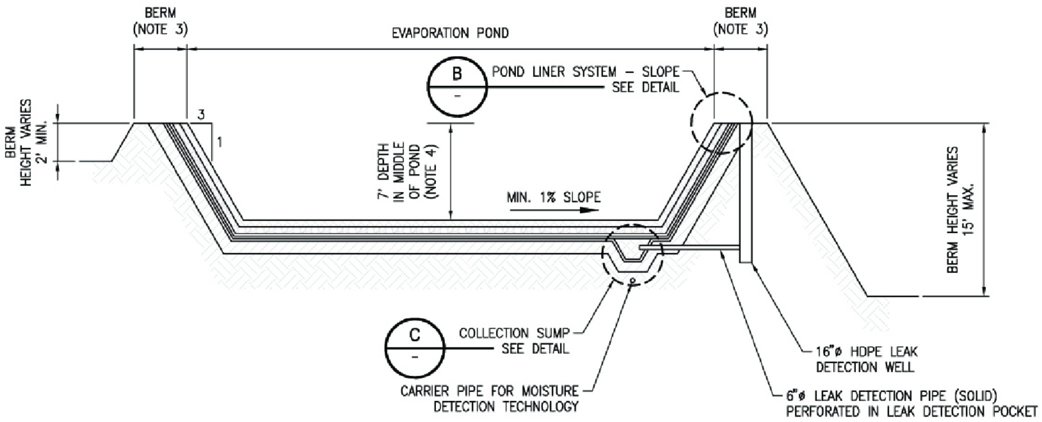
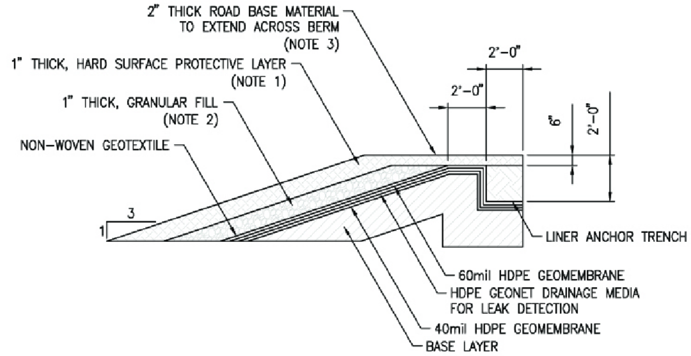


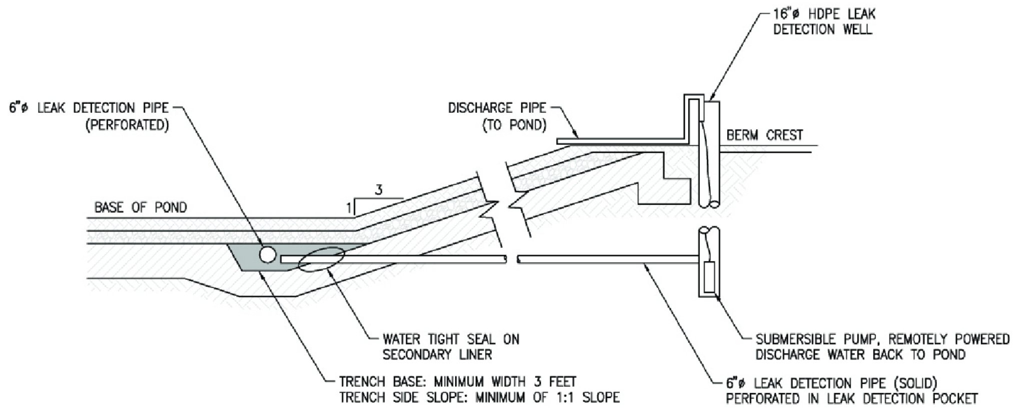
CROSS SECTION THROUGH THE MIDDLE OF THE PONDS (A)

SCALE: N.T.S.



POND LINER SYSYTEM - SLOPES (B)

SCALE: N.T.S.



COLLECTION SUMP DETAIL (C)

SCALE: N.T.S.

NOTE:

1. HARD SURFACE/PROTECTION LAYER TO BE 1 FOOT OF ROLLER COMPACTED CONCRETE OR APPROVED EQUIVALENT.
2. GRANULAR FILL/FREE DRAINING SUB BASE MUST HAVE MAXIMUM PARTICLE SIZE OF 1/2 INCH.
3. BERM IS A MINIMUM OF 12 FEET WIDE AND MAXIMUM OF 18 FEET WIDE. BERM IS COVERED BY A MINIMUM OF 6 INCHES OF ROADBASE MATERIAL.
4. AVERAGE POND DEPTH OF 7 FEET ALLOWS FOR 2 FEET OF FREEBOARD, 3 FEET OF OPERATIONAL DEPTH AND 2 FEET OF SLUDGE ACCUMULATION. MINIMUM 1% SLOPE ACROSS POND BASE, THEREFORE UPSTREAM END OF POND WILL HAVE A DEPTH OD LESS THAN 7 FEET AND DOWNSTREAM END OF POND WILL HAVE A DEPTH OF MORE THAN 7 FEET.
5. BASE LAYER: PREFERRED MATERIAL IS 2 FOOT OF AN SITE MATERIAL WITH HYDRAULIC CONDUCTIVITY OF LESS THAN 1 X 10–6 CM/S, OF WHICH AT LEAST 30% OF THE MATERIAL SHALL PASS THROUGH A NO. 200 U.S. STANDARD SIEVE. IF THIS MATERIAL IS NOT AVAILABLE, THE ALTERNATIVE DESIGN IS A GEOSYTHENTIC CLAY LINER (GCL).
6. SEE TEXT FOR FURTHER DETAILS.

Map Location

Ridgecrest Solar Power Plant

Figure 1-7b
Evaporation Pond Section and Details

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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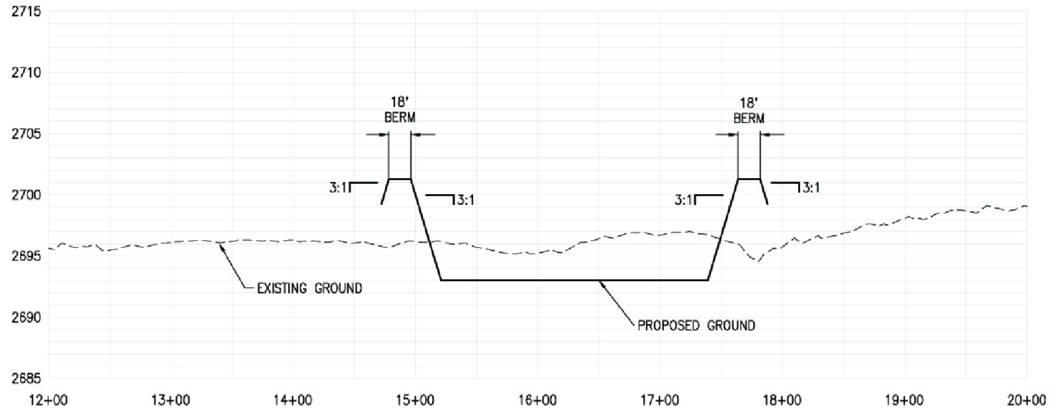
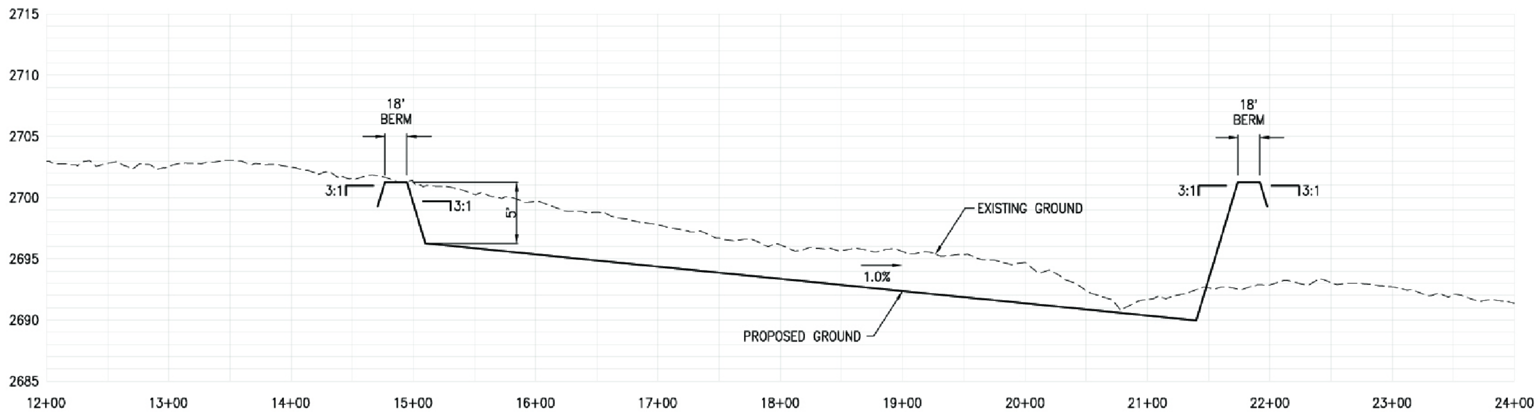


CROSS SECTION A
SCALE: NONE



CROSS SECTION B
SCALE: NONE

Map Location

Ridgecrest Solar Power Plant

Figure 1-8a Evaporation Pond Cross Section

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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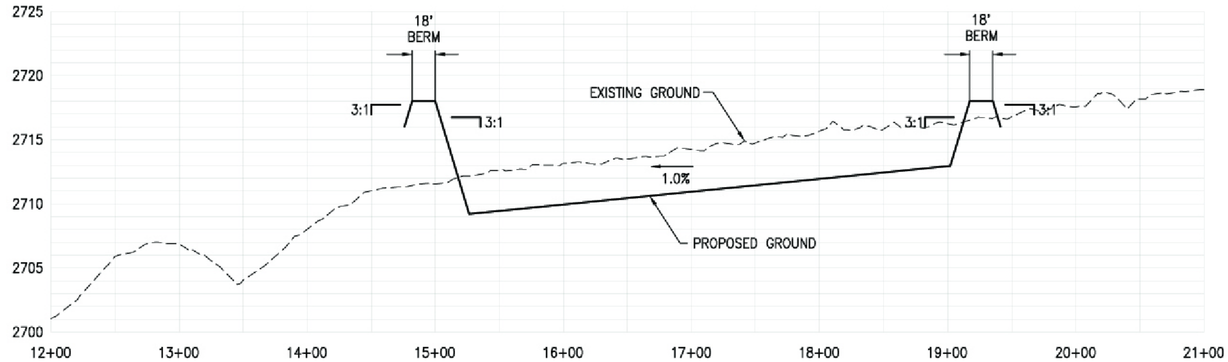
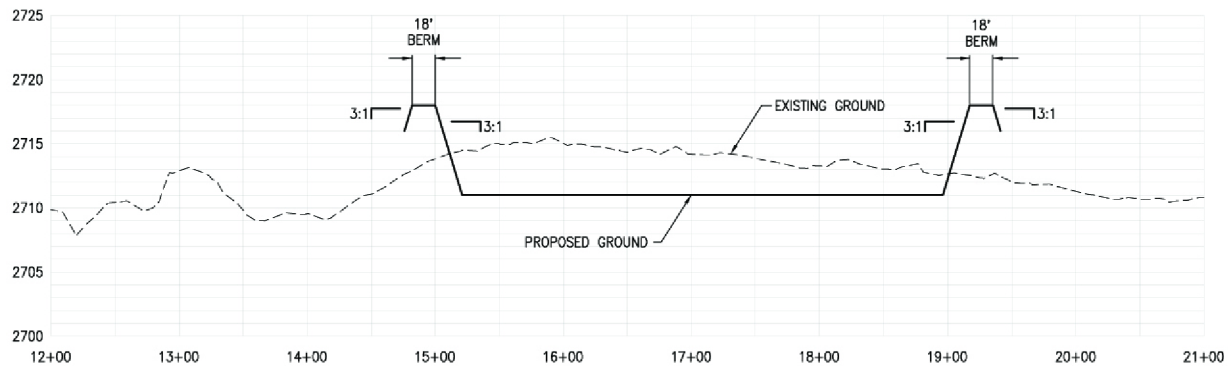


CROSS SECTION C

SCALE: NONE



CROSS SECTION D

SCALE: NONE

Map Location

Ridgecrest Solar Power Plant

Figure 1-8b
Evaporation Pond Cross Section

Ridgecrest Solar I, LLC

AECOM

Project: 60139696
Date: June 2010

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Tables

Table 3-1 Raw Water Quality and Estimated Chemistry of Wastewater Streams

	Supply Water[1]	Wastewater to Evaporation Pond[2]	STCL[3]	TCLP[4]
24-Average Flow Rate (GPM)	63	8.748	---	---
Peak Operation Flow Rate (GPM)	97	14.636	---	---
Constituent	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Cations				
Calcium	37	39	---	---
Magnesium	5.4	12	---	---
Sodium	44	767	---	---
Potassium	4	10	---	---
Ammonia	<ND	0		
Anions				
Alkinity	117	77	---	---
Sulfate	44	111	---	---
Chloride	86	1,045	---	---
Nitrate	8	19	---	---
Cyanide	ND	0		
Silica	42	24	---	---
General Water Quality				
Bicarbonate	143	94	---	---
Carbonate	ND	0	---	---
TDS	287	2,124	---	---
Total Hardness ($CaC0_3$)	115	121		
Phosphate	ND	0	---	---
Fluoride	0.8	19	180	---
Barium	0.00028	1	100	---
Iron	ND	0	---	---
Total Suspended Solids	0	12	---	---
Biological Oxygen Demand			---	---
Trace Metals				
Boron	ND	0	--	--
Cadmium	ND	0	1.0	
Copper	ND	0	25	--
Lead	0.0007	0	5.0	
Molybdenum	ND	0	350	--

Table 3-1 Raw Water Quality and Estimated Chemistry of Wastewater Streams

	Supply Water[1]	Wastewater to Evaporation Pond[2]	STCL[3]	TCLP[4]
Selenium	ND	0	1.0	
Thallium	0.014		7.0	
Vanadium	0.000022	0.17	24	--
Zinc	ND	0	250	--

1 - Water quality data from AFC Table Water 4, AECOM, 2009
2 - Water Quality data from AECOM Evaporation Pond Preliminary Design, Operations and Maintenance Plan, April 2010
3 - STLC = Soluble Threshold Limit Concentration, Regulated by CCR Title 22, Division 4.5, Article 3, Section 66261.24
4 - TCLP = Toxicity Characteristics Leaching Procedure; Regulate under 40 CFR Section 261.24

Table 3-2 Evaporation Pond Wastewater Startup and Annual Sampling Parameters

Parameter	U.S. EPA or Standard Method	RL Goal	Units
Ammonia (as N)	350.1	100	µg/L
Aluminum	200.7	20	µg/L
Arsenic	6020	2.0	µg/L
Boron	200.7	140	µg/L
Calcium	200.7	40,000	µg/L
Chloride	300.0	14,000	µg/L
Cyanide (total)	SM 4500	10	µg/L
Fluoride	300.0	500	µg/L
Iron	200.7	20	µg/L
Magnesium	200.7	10,000	µg/L
Manganese	200.7	15	µg/L
Molybdenum	6020	10.00	µg/L
Nitrate as Nitrogen	300.0	1,000	µg/L
Nitrite as Nitrogen	SM 4500	4	µg/L
Potassium	200.7	3,000	µg/L
Phosphate (total)	365.3	100	µg/L
Selenium	6020	0.5	µg/L
Silica (as SiO2)	200.7	1,000	µg/L
Silicon (as Si)	200.7	1,000	µg/L
Sodium	200.7	10,000	µg/L
Strontium	200.7	500	µg/L
Sulfate	300.0	100,000	µg/L
TDS	SM 2540C	10,000	µg/L
Total Alkalinity (as $CaCO_3$)	SM 2320B	100,000	µg/L
Zinc	6020	10	µg/L
Biphenyl Oxide	8015M	500	µg/L
Diphenyl Oxide	8015M	500	µg/L
Cyclohexamine (20-40%)	8015M	500	µg/L
Morpholine (1-10%)	8015M	500	µg/L
pH reading	Field	+/- 0.1	pH units
Temperature	Field	+/- 0.1	°F or °C
Nalco 3D Trasar 177	Hand-Held Fluorometer	na	na
Nalco 3D Trasar 190	Hand-Held Fluorometer	na	na

Key:
$CaCO_3$ - calcium carbonate
µg/L – micrograms per liter
RL – reporting limit
SM – Standard Method
na – not applicable

Table 3-3 Evaporation Pond Wastewater Semi-Annual Sampling Parameters

Parameter	**Unit**
Chloride	mg/l
Chlorine	mg/l
Selenium	mg/l
Sulfate	mg/l
Total dissolved solids	mg/l
Temperature	Fahrenheit or Celsius
pH	pH

Table 3-4 Predicted Chemistry of Evaporation Residue

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg	STLC mg/L	TTLC mg/kg	TCLP mg/L
Cations								
Calcium	mg/L	4	1,479	18,066	1626			
Magnesium	mg/L	1	462	5,646	508			
Sodium	mg/L	81	29,407	359,182	32326			
Potassium	mg/L	1	396	4,843	436			
Ammonia	mg/L	0	9	113	10			
Anions								
Chloride	mg/L	110	40,050	489,190	44027			
Sulfate	mg/L	12	4,248	51,882	4669			
Alkalinity	mg/L	8	2,958		0			
Bicarbonate	mg/L	10	3,605	44,036	3963			
Carbonate	mg/L	0	7	82	7			
Cyanide	µg/L	-	-	-	0			
Silica	mg/L	3	931	11,373	1024			
Phosphate	mg/L	-	-	-	0			
Polyphosphate	mg/L	-	-	-	0			
Fluoride	mg/L	0	74	903	81	180	18,000	
Nitrate	mg/L	2	740	9,033	813			
General								
Suspended Solids	mg/L	1	462	5,646	465000			
Total Dissolved Solids	mg/L	223	N/A		0			
Hardness	mg/L	13	N/A		0			
Trace Metals		-						
Aluminium	µg/L	-	-	-	0			
Antimony	µg/L	-	-	-	0			
Arsenic	µg/L	0.001	0.37	5	0	5.0	500	5.0
Barium	µg/L	-	0.00	-	0			
Boron	mg/L	0.000	0	0	0			

Constituent	Units	Lb/day	Lb/Year	Concentration in dry solids, mg/Kg	Concentration with Silt, mg/kg	STLC mg/L	TTLC mg/kg	TCLP mg/L
Cadmium	µg/L	-	-	-	0			
Chromium	µg/L	-	-	-	0			
Cobalt	µg/L	-	-	-	0			
Copper	µg/L	-	-	-	0			
Hexavalent Chromium	µg/L	-	0.00	-	0			
Iron	µg/L	-	0.00	-	0			
Lead	µg/L	-	-	-	0			
Manganese	µg/L	-	0.00	-	0			
Molybdenum	µg/L	-	0.00	-	0			
Nickel	µg/L	-	0.00	-	0			
Selenium	µg/L	-	-	-	0	1.0	100	1.0
Strontium	µg/L	-	0.00	-	0			
Thallium	µg/L	-	-	-	0			
Vanadium	µg/L	0.001	0	2	0			
Zinc	mg/L	0.000	0.0	0	0	250	5,000	

Table 3-5 Evaporation Pond Residue Sampling Parameters

Parameter	U.S. EPA or Standard Method	RL Goal	Units
Biphenyl Oxide	8015M	1.0	mg/kg
Diphenyl Oxide	8015M	1.0	mg/kg

Key:

mg/kg – milligrams per kilogram
RL – reporting limit

Table 4-1 Groundwater Sample Analytical Parameters – Quarterly Monitoring

Parameter	U.S. EPA or Standard Method	RL Goal	Units
Chloride	300.0	14,000	µg/L
Nitrate as Nitrogen	300.0	1,000	µg/L
Phosphate (total)	365.3	100	µg/L
Sulfate	300.0	100,000	µg/L
TDS	SM 2450C	10,000	µg/L
Biphenyl Oxide	8015M	1,000	µg/L
Diphenyl Oxide	8015M	1,000	µg/L
Static Water Depth	Field	+/- 0.1	feet bgs
pH reading	Field	+/- 0.1	pH units
Temperature	Field	+/- 0.1	°F or °C

Key:

µg/L – micrograms per liter
RL – reporting limit
SM – Standard Method

Note: If turbidity exceeds 10 NTU, groundwater samples will be field filtered and both the unfiltered and filtered groundwater samples will be submitted to the laboratory for metals and TDS analysis.

Table 4-2 Groundwater Sample Analytical Parameters – Annual Monitoring

Parameter	U.S. EPA or Standard Method	RL Goal	Units
Ammonia (as N)	350.1	100	µg/L
Aluminum	200.7	20	µg/L
Arsenic	6020	2.0	µg/L
Boron	200.7	140	µg/L
Calcium	200.7	40,000	µg/L
Chloride	300.0	14,000	µg/L
Cyanide (total)	SM 4500	10	µg/L
Fluoride	300.0	500	µg/L
Iron	200.7	20	µg/L
Magnesium	200.7	10,000	µg/L
Manganese	200.7	15	µg/L
Molybdenum	6020	10.00	µg/L
Nitrate as Nitrogen	300.0	1,000	µg/L
Nitrite as Nitrogen	SM 4500	4	µg/L
Potassium	200.7	3,000	µg/L
Phosphate (total)	365.3	100	µg/L
Selenium	6020	0.5	µg/L
Silica (as SiO2)	200.7	1,000	µg/L
Silicon (as Si)	200.7	1,000	µg/L
Sodium	200.7	10,000	µg/L
Strontium	200.7	500	µg/L
Sulfate	300.0	100,000	µg/L
TDS	SM 2540C	10,000	µg/L
Total Alkalinity (as $CaCO_3$)	SM 2320B	100,000	µg/L
Zinc	6020	10	µg/L
Biphenyl Oxide	8015M	500	µg/L
Diphenyl Oxide	8015M	500	µg/L
Cyclohexamine (20-40%)	8015M	500	µg/L
Morpholine (1-10%)	8015M	500	µg/L
pH reading	Field	+/- 0.1	pH units
Temperature	Field	+/- 0.1	°F or °C
Nalco 3D Trasar 177	Hand-Held Fluorometer	na	na
Nalco 3D Trasar 190	Hand-Held Fluorometer	na	na

Key:
$CaCO_3$ - calcium carbonate
µg/L – micrograms per liter
RL – reporting limit
SM – Standard Method
na – not applicable

Note: If turbidity exceeds 10 NTU, groundwater samples will be field filtered and both the unfiltered and filtered groundwater samples will be submitted to the laboratory for metals and TDS analysis.

Appendix A

Chemical Additives Used in Plant Process Water

Chemical Additives

The chemicals listed below will be used in boiler treatment or general plant operations. Storage volumes are estimated based upon previous projects.

Table A-1 Chemical Additives Used in Boiler Treatment or General Plant Operations

Chemical	Service	Volume Stored	Estimated Storage Method
Amine (Morpholine)	Boiler water treatment, corrosion inhibitor	300 gal	Tote
Ferric sulfate, 35%	Boiler water treatment, coagulant aid	10,000 gal	Tank
Carbohydrazide	Boiler water treatment, oxygen scavenger	600 gal	Tote
Phosphate	Boiler water treatment, anti-scalant	1,500 gal	Tote
Sodium hydroxide, 50%	Boiler water treatment, pH adjustment	10,000 gal	Tank
Ultra low sulfur diesel fuel	Emergency UPS generator & emergency fire pump fuel	1150 gal	150 gallons – UPS generator fuel tank. 1000 gal estimated for fire pump fuel tank.
Hydrogen gas	Generator cooling medium	1000 lb	350 lb. in the generator and associated piping. 650 lb. in storage trailer.
Insulating oil	Electrical transformer cooling medium	36,000 gal	16,000 gal in the GSU. 10,000 gal in each of 2 UATs.
Lubricating oil	Lubrication of rotating equipment	Up to 4000 gal.	In equipment and drums.
Sulfur Hexafuoride	Gaseous dielectric	640 lb.	In electrical equipment
Therminol VP-1 or similar	Solar heat transfer fluid	2,114,000 gallons	In piping, tanks, and equipment.
Carbon dioxide	STG generator hydrogen system purge for maintenance	4,000 lb	Carbon steel tank.

The chemicals listed below will be used in water treatment or cooling tower operations. Storage volumes are estimated based on previous projects.

Table A-2 Chemical Additives Used in Water Treatment or Cooling Tower Operations

Chemical	Service	Volume Stored	Estimated Storage Method
Polymer	Agglomeration of suspended solids in clarifier, thickening of solids in filter press	500 gallons	Tote
Coagulant	Agglomeration of suspended solids in clarifier.	500 gallons	Tote
Lime	Hardness reduction	10 tons	Silo
Soda ash	Hardness reduction	10 tons	Silo
Magnesium chloride	Silica reduction	500 gallons	Tote
Sodium metabisulfite	RO feed dechlorination	500 gallons	Tote
Antiscalant	RO scale control	500 gallons	Tote
Sodium hydroxide	RO CO2 rejection, pH adjustment, filter chemically enhanced backwash	400 gallons	Tote
Sodium hypochlorite (13%)	Microbiological control in raw water tank, multimedia filters, cooling tower, and potable water	1000 gallons	Tank
Sulfuric acid, 93-98%	Cooling tower alkalinity and pH control, filter chemically enhanced backwash	1000 gallons	Tank
Mineral dispersant	Cooling tower scale control	1000 gallons	Tank
Corrosion inhibitor	Cooling tower corrosion control	1000 gallons	Tank
Non-oxidizing biocide	Cooling tower microbiological shock	100 gallons	Drum
Coagulant	Filter aid in multimedia filters	500 gallons	Tote
Brine solution (20-26%)	Sodium zeolite softener regeneration	1500 gallons	tank

Appendix B

Standard Operating Procedures for Field Work

STANDARD OPERATING PROCEDURES

SOP-01

DRILLING METHODS

STANDARD OPERATING PROCEDURES

SOP-1
DRILLING METHODS

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

Drilling is a common activity associated with many phases of environmental investigations. A variety of drilling methods can be used to collect site data during investigations and studies, and to install vapor extraction or water wells associated with remedial actions, treatability studies, or pilot studies.

Field investigations usually require invasive activities to gather information for site evaluation. The investigation may require a borehole to facilitate the collection and subsequent analysis of soil and/or groundwater samples. The borehole is often converted into a well for evaluating vapor or groundwater conditions over a longer period of time. In addition to the collection of samples for analyses, other data, such as sediment or rock classification; the presence of contamination; geophysical, geotechnical, or physical parameters of the sediment or rock; and the occurrence of groundwater, can be obtained from boreholes.

To determine the most appropriate drilling method for investigations or studies, primary consideration must be given to obtaining samples that are representative of existing conditions and are valid for chemical analysis. The samples must not be contaminated or adversely affected by the drilling method.

Drilling associated with remedial actions, pilot studies, or treatability studies may include the installation of vapor or water extraction and/or injection wells. In selecting the most appropriate drilling method for these projects, primary consideration must be given to completion of a well that will perform as designed.

This Standard Operating Procedure (SOP) describes the principles of operation and the applicability and implementability of standard drilling methods used during field investigations. The purpose of this document is to aid in the selection of appropriate drilling methods for site-specific conditions. This SOP is intended to be used by the Project Manager (PM), Project Engineer (PE), Field Team Leader (FTL), and site hydrogeologist or geologist (of which a minimum of one must be a qualified Nevada Certified Environmental Manager [C.E.M.]) to develop an understanding of each drilling method sufficient to plan, schedule, and perform the activities associated with drilling.

This SOP focuses on methods and equipment that are readily available and typically applied. It is not intended to provide a comprehensive discussion of drilling methods. Two general drilling methods are discussed: (1) methods that do not use circulating fluids; and (2) methods requiring the circulation of drilling fluids to transport cuttings to the surface. More specific drilling methods or techniques can be researched, as necessary, by contacting a drilling subcontractor and learning about the specific methodology that may be most beneficial to implement.

2.0 DEFINITIONS

Bailer	A cylindrical tool designed to remove material, both solid and liquid, from a well or borehole. A valve, which can be a ball or flap, at the bottom of the bailer retains the material in the bailer. There are four types of bailers: ball-valve, flat-valve, dart-valve, and the sand pump with rod plunger.
Cone Penetrometer	An instrument used to determine and evaluate subsurface conditions by measuring the ratio of cone tip resistance to sleeve friction, and then comparing that ratio to a standardized set of ratios. The cone penetrometer can be fitted with other instruments that are able to determine pore pressure (the presence of groundwater), to detect contamination and identify the contaminant, and to determine other physical parameters of the sediment. The cone penetrometer consists of a conical point attached to a drive rod of smaller diameter. Penetration of the cone into the formation forces the soil aside, creating a complex shear failure. The cone penetrometer is very sensitive to small differences in soil consistency.
Cuttings	As a borehole is drilled, the subsurface material displaced by drilling and brought to the surface.
Drilling Fluids or Muds	A water-based or air-based fluid used in the well drilling operation to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill string and the sides of the borehole, to stabilize borehole walls, and to seal the borehole.
Dual-Purpose Well	A well that can be used as both a monitoring and extraction or injection well.
Flight	An individual auger section, usually 5 feet in length.
Heaving Formation	Unconsolidated, saturated substrate encountered during drilling where the hydrostatic pressure of the formation is greater than the borehole pressure causing the sands to move up into the borehole, and frequently causing drilling or well installation complications. Clean water or drilling muds may need to be introduced into the borehole to minimize or eliminate the potential for heaving.
Kelly Bar	A hollow steel bar or pipe that is the main section of drill string to which the power is directly transmitted from the rotary table to rotate the drill pipe and bit. The cross section of the kelly is either square, hexagonal, or grooved. The kelly works up and down through drive bushings in the rotary table.
Pitch	The distance along the axis of an auger flight that it takes for the helix to make one complete 360-degree turn.
Rotary Table	A mechanical or hydraulic assembly that transmits rotational torque to the kelly, which is connected to the drill pipe and the bit. The rotary table has a hole in the center through which the kelly passes.
Split-Spoon Sampler	A thick-walled, typically 18-inch long steel tube split lengthwise and used to collect soil samples. The sampler is commonly lined with brass or

	stainless steel sample sleeves and is driven or pushed downhole by the drill rig to collect samples.
Thin-Walled Sampler	A sampling devise used to obtain undisturbed soil samples made from thin-wall tubing. The sampler is also known as a Shelby tube. The thin-wall sampler minimizes the most serious sources of disturbance: displacement and friction.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** will select site-specific drilling methods, with input from the FTL and Site Hydrogeologist or Geologist, and will maintain close supervision of the activities and progress.

The **Site Hydrogeologist** (a California licensed Professional Geologist (P.G)) selects site-specific drilling options and assists in the preparation of technical provisions of drilling procedures and details.

The **Field Team Leader** implements the selected drilling program and assists in the selection of drilling methods.

4.0 DRILLING METHODS

Drilling methods can be separated into two general types: techniques that use circulating fluids and techniques that do not use circulating fluids. The following section discusses the drilling methods that fall into these two general categories.

4.1 Methods Without Circulating Fluids

There are two drilling methods that do not require circulating fluids: augering and percussion drilling. SOPs for each of these methods are described below.

4.1.1 Augering

Auger drilling is accomplished by rotating a pipe or rod that has a cutting bit. The common auger drilling methods discussed in this section are hand, continuous-flight, hollow-stem, and bucket.

4.1.1.1 Hand Auger

A hand auger typically cuts a hole 2 to 9 inches in diameter and, depending on the geologic materials, may be advanced to about 15 or 20 feet. Generally, the borehole cannot be advanced below the water table because the hole collapses. Soil samples for chemical or geotechnical analyses should not be collected directly from a hand auger because the samples are disturbed and cross contamination may occur. Samples for chemical or geotechnical analyses should be taken with a sampling tool such as a drive sampler driven at the desired depth. Samples for lithologic logging purposes may be taken directly from the auger.

Applications

- Shallow soil investigations
- Requires minimal access
- Soil sample collection
- Water-bearing zone identification

Limitations

- Limited to shallow depths
- Unable to penetrate dense or rocky soil
- Borehole stability difficult to maintain
- Labor intensive

4.1.1.2 Continuous-Flight Auger

Continuous-flight augers consist of a plugged, tubular steel center shaft around which a continuous steel strip, in the form of a helix, is welded. An individual auger is known as a "flight" and is generally 5 feet long. Auger drill heads are generally designed to cut a hole 10 percent greater in diameter than the actual diameter of the auger they serve. In addition to diameter, augers are specified by the pitch of the auger and the shape and dimension of the connections.

Applications

- Shallow soils investigations
- Soil sample collection
- Vadose zone monitoring wells
- Groundwater monitoring wells in saturated, stable soils
- Identification of depth to bedrock
- Fast and mobile

Limitations

- Soil sampling difficult and limited to areas of stable soils
- Difficult to build monitoring wells in unstable soils
- Depth capability decreases as diameter of auger increases
- Monitoring well diameter limited by auger diameter

4.1.1.3 Hollow-Stem Auger

Hollow-stem augers are commonly used in unconsolidated materials to depths of approximately 150 feet. An advantage of this drilling method is that undisturbed soil samples can be collected and the augers act as a temporary outer casing when installing a monitoring well.

Hollow-stem augers are generally made of two pieces: an annular outer head attached to the bottom of the lead auger and an inner pilot or center bit mounted in a plug that is removable from the center of the auger to the surface. The removable inner plug is the primary advantage of this drilling method. Withdrawing the plug while leaving the auger in place provides an open, cased hole into which samplers, down-hole drive hammers, instruments, casing, wire, pipe, or numerous other items can be inserted. Replacing the center bit and plug allows for continuation of the borehole.

Hollow-stem augers are specified by the inside diameter of the hollow stem, not by the hole size it drills. Hollow-stem augers are available with inside diameters of 2.5, 3.25, 3.375, 4.0, 4.25, 6.25, 6.625, 8.25, and 10.25 inches. The larger diameter augers, 8.25 and 10.25 inches, are not generally used for monitoring well installation, although they have been used for the installation of dual-purpose wells.

The rotation of the augers causes the cuttings to move upward and “smear” along the borehole walls. This smearing may effectively seal off the upper zones, thereby reducing the possibility of cross contamination of the upper zones to the deeper zones, but increases the possibility of deep to shallow contamination. However, this is not a method that is used for the purpose of sealing a borehole.

Drilling speed with hollow-stem augers is dependent upon the types of materials encountered. Heavy formations such as “fat” clays should be drilled at 30 to 50 revolutions per minute (rpm). Good clean sand that will stand open can be successfully augered at 75 rpm.

Applications

- Most frequently used method
- Most types of soil investigations
- Permits good soil sampling with split-spoon or thin-wall samplers
- Monitoring well installation in unconsolidated formations
- Can serve as temporary casing
- Can be used in stable formations to set surface casing

Limitations

- Difficulty in preserving sample integrity in heaving formations
- Formation invasion by water or drilling mud if used to control heaving
- Possible cross contamination of aquifers where annular space not positively controlled by water or drilling mud or surface casing
- Limited diameter of augers limits casing size
- Smearing of clays may seal off aquifer to be monitored

4.1.1.4 Bucket Auger

Bucket augers have a depth capacity of 30 to 75 feet and are used for large diameter holes (16 to 48 inches). Most bucket augers are “gravity fed” and are used for vertical holes. They are not normally used to drill monitoring wells or for soil sampling but may be used to drill production and recovery wells. Bucket augers may also be used to set conductor or surface casings for production wells.

Generally, the auger bucket advances into the formation by combination of dead weight and the tooth cutting angle. The auger cuts into the formation approximately 1 to 2 feet at a time, filling the auger bucket. The bucket is attached to the lower end of a kelly bar that passes through and is rotated by a large ring gear that serves as a rotary table. The kelly is square in cross section and consists of two or more lengths of square tubing, one length telescoped inside the other. When the bucket is withdrawn from the hole by means of a wire-line hoist cable, it is swung to the side of the hole and the spoil is dumped out through the bottom by means of a hinge and latch device on the bucket bottom.

Applications

- Drilling of large diameter boreholes to a maximum depth of 75 feet
- Drilling in unconsolidated formations

Limitations

- Difficult to advance the borehole below the water table
- Consolidated formations and cobbles are difficult to drill
- Loose sand formations may slough during drilling
- Undisturbed soil sampling difficult to achieve

4.1.2 Percussion Drilling

The basic method of advance in percussion drilling is hammering, striking, or beating on the sediments or formation. Common percussion methods that do not use circulating fluids are cable-tool, driven boreholes, and sonic drilling.

4.1.2.1 Cable-Tool Drilling

Cable-tool operates by alternately raising and dropping a bit, hammer, or other heavy tool. In consolidated formations, the drill bit breaks or crushes the formation. In unconsolidated formations, the drill bit primarily loosens the formation when drilling. In both instances, the reciprocating action of the tools mixes the crushed or loosened particles with water to form a slurry or sludge at the bottom of the borehole. If little or no water exists in the penetrated formation, water is added to form the slurry. Slurry accumulation increases as drilling proceeds and eventually it reduces the impact of the tools. When the drop of the string of tools is hindered by the thickened slurry, the slurry is removed by a bailer. Water is then added, if needed, and drilling resumes.

Most boreholes drilled in unconsolidated formations are drilled “open hole;” that is, no casing is used during part or all of the drilling operation. Drilling in unconsolidated formations differs from hard-rock drilling as pipe or well casing must follow the drill bit closely as the well is deepened to prevent caving and to keep the borehole open.

Using the cable-tool drilling technique in monitoring work is limited because the method is slow. Drilling rates of 20 to 100 feet per day are typical with the average being approximately 50 feet per day. Holes much smaller than 6 inches are impractical because of the need for a relatively large, heavy bit. The method does not use drilling muds but does allow sampling of groundwater with a drive and bail technique as the hole is advanced in high-yielding formations.

Applications

- Drilling in most types of geologic formations
- Almost any depth and diameter range
- Ease of monitoring well installation
- Ease and practicality of well development
- Excellent samples of geologic materials

Limitations

- Drilling relatively slow
- Heaving of unconsolidated materials must be controlled
- Equipment availability more common in central, north central and northeast sections of the United States

4.1.2.2 Driving

A borehole can be constructed by driving a solid probe or plugged pipe into the ground. The information obtained by this technique can be either minimal or extensive.

Driven wells, commonly referred to as wellpoints, are driven into the ground by hand or with heavy drive heads mounted on a tripod, drill rig derrick, or similar hoisting device. Wellpoints consist of a wellpoint (screen) that is attached to the bottom of a casing. Wellpoint and casing diameters generally range from 1.25 to 2 inches. Depths of 30 feet can be achieved by hand in sands or sands and gravels with thin clay seams. Depths of 50 feet or more can be achieved in loose soils with hammers weighing up to 1,000 pounds.

Driving through dense silts and clays and/or bouldery silts and clays is often extremely difficult or impossible. The well point may not be structurally strong enough and may be damaged or destroyed by driving through dense soils. Additionally, the screen may become plugged when driving through silts and clays and may be very difficult to reopen during development. Soil samples cannot be collected during this process; however, crude stratigraphic information may be obtained by recording the number of blows per foot of penetration. Driven wells or well points are usually installed for the collection of groundwater samples and the determination of static water levels to establish the regional groundwater gradient.

A large track-mounted backhoe (CAT 245) has been used to install extraction wells in a landfill to the 30-foot depth. The bucket of the backhoe is used to push a 6-inch diameter drive pipe with a plugged bottom. When the drive pipe reaches the final depth for the well, the plug at the bottom of the drive pipe is removed and the well screen and casing materials are placed inside the drive pipe. A large 50-ton crane then pulls the drive pipe, leaving the well materials in the borehole. This technique is highly dependent upon the geologic formation and required depth. The drive pipe pushes the formation aside. This can cause a compaction of the formation, which could impact the performance of the well.

Considerably more information can be obtained by driving a penetrometer or a Dutch Cone. Penetration of the soil with a cone forces the soil aside, creating a complex shear failure. The degree of resistance yields the geologic logs of the borehole. Penetrometers can also obtain groundwater samples and possibly soil samples. The borehole that the penetrometer makes is usually abandoned; however, occasionally a small-diameter piezometer can be constructed within the borehole. For more information on cone penetrometer testing, see the SOP on Cone Penetrometer Testing (SOP-11).

Applications

- Drilling of a borehole when soil samples are not needed
- Installation of a shallow well point when there are site access and work place limitations

Limitations

- Geologic formations must be conducive for driven wells
- Driven wells should be limited to shallow wells
- Formation compaction usually occurs that can affect well production

4.1.2.3 Sonic Drilling

Sonic drilling, also known as resonance drilling, is a percussion drilling technique that uses a high-frequency drive hammer. The drilling rig uses a combination of mechanically generated vibrations and limited rotary power to penetrate the soil. The drill head, which is attached to the drill pipe, consists of two counter rotating, out-of-balance rollers that cause the drill pipe to vibrate. Resonance occurs when the frequency of the vibrations equals to the natural frequency of the drill pipe. The resonance and weight of the drill pipe along with the downward thrust of the drill head permit easier penetration of the formation, without adding drilling muds or lubricating fluids. The drive pipe is either closed bottom or fitted with a soil sampling tube. If the bottom of the drive pipe is closed, the borehole is made without the removal of any formation. Instead, the formation is literally pushed to the side and out of the way of the drive pipe, which acts as well casing as the boring proceeds.

A soil sampling device, such as a split-spoon sampler or a core barrel, can be placed inside the drive pipe in lieu of the end plug. The sampler is removed at 5- or 10-foot intervals and replaced with an empty sampler. This procedure yields a continuous soil sample and produces minimal waste as only the formation within the sampler is brought to the surface. A monitoring well can be installed in the borehole by removing the sampler and setting the well screen and casing inside the drive pipe. The drive pipe is then withdrawn. This drilling technique again pushes the formation aside to create the borehole. Certain formation compaction can occur which could impact the performance of a well. Sonic drilling can produce considerable heat at the bit on the drive pipe and within the sampler. The heat in the sampler may have a detrimental effect on soil samples such for chemical analysis that are impacted by heat, such as volatile organic compounds.

Applications

- Rapid drilling technique especially in difficult drilling formations
- Use when drilling in contaminated areas and disposal costs for wastes are high
- Can obtain continuous core

Limitations

- Very limited equipment availability
- Heat generated with drive pipe can compromise soil samples
- Formation compaction usually occurs that can affect well production

4.2 Methods With Circulating Fluids

Many drilling techniques use a circulating fluid, such as water or drilling mud, gas such as air, or a combination of air, water, and a surfactant to create foam. Circulation fluids flow from the surface either through the drill pipe, out through the bit, and up the annulus between the borehole wall and the drill pipe (direct rotary) or down the borehole annulus, into the bit, and up the drill pipe (reverse rotary). Generally the up-hole velocity needed to transport cuttings to the surface is between 100 to 150 feet per minute for plain water with no additives, 80 to 120 feet per minute for high-grade bentonite drill muds, 50 to 1,000 feet per minute for foam drilling, and up to 3,000 feet per minute for air with no additives. Additives decrease the required minimum velocity. Excessive velocities can cause erosion of the borehole wall.

The use of circulating fluids may involve the addition of chemicals to the borehole. Drilling mud utilizes bentonite clay and possibly polymers. Additives to air drilling may include surfactants (detergents) and water mist to generate foam. Compressed air may also contain various amounts of hydrocarbon lubricants. Therefore, attention should be given to the circulating fluids and any possible additives that are used when using drilling methods utilizing circulation fluids.

4.2.1 Rotary Drilling Methods

Rotary drilling methods require the rotation of the drill pipe and the drill bit to advance the borehole. The common drilling methods that use circulating fluids to remove the drill cuttings from the borehole are presented in the following sections.

4.2.1.1 Conventional Mud Rotary Drilling

In conventional mud rotary drilling, the circulating fluid is pumped from the surface through the rotating drill pipe and bit to flush cuttings to the surface. At the surface the fluid is directed into a circulation pit or tank where the cuttings settle out. The circulating fluid is then picked up with the mud pump and again directed downhole. Bentonite is usually added to water to make the drilling mud or fluid. The functions of the drilling fluid are to:

- Lift the cuttings from the bottom of the borehole and carry them to a settling pit
- Support and stabilize the borehole wall to prevent caving
- Seal the borehole wall to reduce fluid loss
- Cool and clean the drill bit
- Allow the cuttings to drop out in the settling pit
- Lubricate the bit, cone bearings, mud pump, and drill pipe

For effective rotary drilling, the down force on the bit should be great enough to cause continuous penetration of the boring. The pounds per inch of bit weight depends upon the configuration of the bit and the formation being penetrated. Rotary speeds are generally in the range of 60 to 200 rpm.

Applications

- Rapid drilling of clay, silt, and reasonably compacted sand
- Allows split-spoon and thin-walled samples in unconsolidated materials
- Allows core sampling in consolidated rock
- Drilling rigs widely available
- Abundant and flexible range of tool sizes and depth capabilities
- Very sophisticated drilling and mud programs available
- Geophysical borehole logs

Limitations

- Difficult to remove drilling mud and wall cake from borehole wall during development
- Bentonite and other drilling additives may influence quality of groundwater samples
- Circulated samples poor for monitoring well screen selection
- Split-spoon and thin-wall samplers are expensive and of questionable cost-effectiveness at depths greater than 150 feet
- Wireline coring techniques for sampling both unconsolidated and consolidated formations often not available locally
- Difficult to identify aquifers
- Drilling fluid invasion of permeable zones may compromise validity of subsequent monitoring well samples

4.2.1.2 Air Rotary Drilling

In air rotary drilling, the circulation fluid is compressed air or a mixture of compressed air, a surfactant, and water mist, which creates a foam. As in conventional mud rotary, the drilling fluid is forced through the rotating drill pipe and bit to flush cuttings to the surface. At the surface the fluid is directed into a pit or storage container. The up-hole velocity of the air and cuttings should be approximately 3,000 feet per minute. Air rotary drilling method is primarily used in consolidated formations due to the fact that the rapidly rising cuttings would cause considerable erosion of the borehole wall in unconsolidated formations. With the air rotary drilling method, the circulating fluid is not reused again. The following are functions of the drilling fluid:

- Lifting the cuttings from the bottom of the borehole and carrying them to the surface
- Cooling and cleaning the drill bit
- Lubricating the bit, cone bearings, mud pump, and drill pipe

Rotary speeds are generally in the range of 75 to 200 rpm. If the hardness of the formation increases to the point that roller-cone rock bits cannot successfully penetrate the formation, then a down-hole air hammer is used to penetrate the formation. The rotating speed using the down-hole air hammer is in the range of 15 to 30 rpm.

Applications

- Rapid drilling of semi-consolidated and consolidated rock
- Good quality/reliable formation samples
- Equipment generally available
- Allows easy and quick identification of lithologic changes
- Allows identification of most water bearing zones
- Allows estimation of yields in strong water-producing zones with short “down time”

Limitations

- Surface casing frequently required to protect top of hole
- Drilling restricted to semi-consolidated and consolidated formations
- Samples reliable but occur as small particles that are difficult to interpret
- Drying effect of air may mask lower yield water producing zones
- Air stream requires contaminant filtration
- Air may modify chemical or biological conditions. Recovery time uncertain

4.2.1.3 Air Rotary Casing Hammer (Drill and Drive)

Air rotary casing hammer method combines percussion and air rotary drilling methods to drill in unconsolidated formations. The borehole is drilled with the air rotary drilling method. Casing or drive pipe follows closely behind the rotary bit to prevent the erosion of the borehole wall. The casing is driven similar to a pile driver except for a hole through its axis through which a drill pipe is inserted and rotated. The drill bit is usually extended approximately 1-foot below the bottom of the drive pipe that acts as temporary casing.

Applications

- Rapid drilling of unconsolidated sands, silts, and clays
- Drilling in alluvial materials (including boulder formations)
- Casing supports borehole thereby maintaining borehole integrity and minimizing inter-aquifer cross contamination
- Eliminates circulation problems common with direct mud rotary method
- Good formation samples
- Minimal formation damage as casing pulled back

Limitations

- Thin, low pressure water bearing zones easily overlooked if drilling not stopped at appropriate places to observe whether or not water levels are recovering
- Samples pulverized as in rotary drilling
- Air may modify chemical or biological conditions
- Difficult to obtain soil samples for chemical analysis

4.2.1.4 Center Stem Recovery Rotary Drilling (Reverse Circulation)

In reverse circulation drilling, the circulating fluid (water) flows from the surface down the borehole annulus outside the drill pipe, into the drill bit, and up the inside of the drill pipe to ground surface. The fluid carries the cuttings to the surface and discharges them into a settling pit or tank. Reverse circulation is especially advantageous in very large boreholes and also in those cases where the erosive velocity of conventional rotary circulation would be detrimental to the borehole wall. Drilling is accomplished typically with water without additives. A large and dependable water supply is required to keep the borehole full of drilling fluid to maintain sufficient hydrostatic head on the borehole walls to prevent sloughing. Reverse circulation has few applications in monitoring work except when nested wells are desired. Production wells with 18- to 24-inch-diameter casing are typically drilled by the reverse circulation drilling method. Typical borehole diameters range from 15 to 36 inches; however, 60-inch-diameter boreholes are not uncommon.

Applications

- Large capacity production wells
- Nested wells
- Normally does not use drilling muds (little if any mud cake is formed on the wall of the borehole)
- Drills best in unconsolidated sands, silts, and clays

Limitations

- Requires large and dependable source of water during drilling and well installation
- Cobbles and bedrock are difficult to drill

4.2.1.5 Dual-Tube Rotary

Dual-tube rotary is an exploratory drilling technique utilizing two concentric drill pipes. Both drill pipes are rotated during drilling. The outside of the outer drill pipe is typically 4.5 inches in diameter. The diameter of the borehole is approximately 5 inches. Compressed air is forced between the two drill pipes and is directed to the center pipe at the bit. The cuttings are carried to the surface by the returning air at a velocity of approximately 3,000 feet per minute. This is an excellent drilling method to identify lithology and the locations of aquifers in deep boreholes. It is very difficult to obtain undisturbed soil samples for chemical or geotechnical analyses; however, groundwater samples can be obtained as aquifers are encountered. Geophysical logs can be obtained if the borehole is filled with drilling mud as the drill pipe is removed. Monitoring wells are typically not installed in dual-tube rotary boreholes unless the borehole is reamed out by the mud rotary method. Depths of 1,000 feet are not uncommon for this drilling method and typically, the more consolidated the formation, the better the drilling, as unconsolidated formations cause more drag or friction on the outside of the rotating drill pipe.

Applications

- Used mostly for exploratory boreholes
- Rapid extraction of drill cuttings from the borehole
- Drill cuttings are representative of formation
- Very rapid penetration rate in most formations
- Can collect groundwater samples as aquifers are encountered

Limitations

- Equipment availability
- Cannot obtain undisturbed soil samples for chemical analysis
- Borehole size is limited (5 inches)

4.2.2 Dual-Tube Percussion Drilling

Dual-tube percussion drilling is very similar to dual-tube rotary drilling with the exception that the two drive pipes do not rotate during drilling. Two concentric drive pipes are driven into the ground with a hammer. The hammer is similar to units on pile drivers. The typical outside diameter of the outer drive pipe is 9 to 12 inches. The typical inside diameter of the inner pipe, where well materials would be inserted, is 6 to 8 inches. This drilling system is also a center stem recovery system. This drilling technique has been developed and is used primarily in hazardous waste investigations. This method is rapid and effective to depths of about 250 feet.

The outer pipe effectively seals off the formation while drilling, reducing the chance of cross contamination. Air is pumped between the annulus of the two pipes to the bit where it is deflected upward into the center pipe. Cuttings are transported to the surface through the center pipe.

In general, three systems are available: 7-inch outside diameter (OD)/4.25-inch inside diameter (ID), 9-inch OD/6-inch ID, and 12-inch OD/8-inch ID. A 2-inch-diameter monitoring well can be constructed in the 7-inch system, a 4-inch-diameter monitoring well can be constructed in the 9-inch system, and a 5- or 6-inch-diameter monitoring well can be constructed in the 12-inch system.

Applications

Limitations

- Very rapid drilling through both unconsolidated and consolidated formations
- Allows continuous sampling for lithologic logging in most types of formations
- Very good representative samples can be obtained with minimal risk of contamination of sample and/or water bearing zone
- In stable formations, wells with diameters as large as 6 inches can be installed in open hole completions
- Soil samples can be easily obtained for chemical analysis

- Limited borehole size that limits diameter of monitoring wells
- In unstable formations wells are limited to approximately 4 inches
- Equipment availability more common in the southwest
- Air may modify chemical or biological conditions; recovery time is uncertain

4.2.3 Suction Drilling

Suction drilling has been used to drill into consolidated formations that yield little if any groundwater. This is an experimental drilling method that has been used by the U.S. Geological Survey (USGS) to drill in basalts in Idaho. The drilling technique is very similar to the reverse circulation drilling technique discussed in Section 4.2.1.4 with the exception that air is circulating, not water. To drill the borehole, a drill rig rotates a modified air rotary bit at the end of the drill pipe. The cuttings are removed by the suction from a high-pressure, high-volume air and steam ejector/eductor siphon system. The suction is directed to the interior of the drill pipe. The formation cuttings, including formation fluids, are brought to the surface via the interior of the drill pipe.

To drill a 10-inch-diameter borehole, two 600 cubic feet per minute (cfm)/250 pounds per square inch (psi) air compressors are connected parallel to the ejector/eductor siphon device. Suction from the siphon device is directed to the 2-3/8-inch-diameter drill pipe. A 1.5-horsepower blower fan is used to direct air down the borehole.

Applications

- Allows continuous sampling for lithologic logging
- Very good representative samples can be obtained
- Drilling is not impeded in fractured formations that typically cause lost circulation problems

Limitations

- Formations must be very consolidated to prevent the borehole wall from sloughing during drilling
- Cuttings are very abrasive to the drill pipe and discharge lines
- Difficult to maintain an adequate vacuum as air leaks form easily at threaded joints of the drill pipe
- Groundwater could prevent the advancement of the borehole

Drilling contractors have had numerous mechanical problems advancing boreholes beyond the 150-foot depth. Vacuum leaks have caused a loss in suction and the plugging of the drill pipe. The drill pipes have twisted off and the abrasive cuttings have worn holes in hoses and pipes. This drilling method has some unique advantages; however, until the mechanical problems are solved, this technique will not be available for use.

5.0 CONSIDERATIONS FOR SELECTION OF DRILLING METHODS

Each project or drilling site has its own considerations for the selection of a particular drilling method. Prior to selecting a drilling method, several factors must be considered. The major factors that this section will address include the objective of the drilling program, site conditions, wastes generated, and Tronox preferences. Other factors include drilling costs, availability of trained crews and appropriate equipment, and project schedule requirements. Recognize that it may be very difficult to fulfill all of the sampling/drilling objectives with a single drilling method. The drilling method selected may compromise some of the objectives of the drilling program.

5.1 Drilling Objectives

The primary consideration in selecting any drilling method is to ensure the selected method is capable of meeting the objective(s) of the drilling/sampling program. It is common to have more than one objective for the drilling/sampling program and it may be difficult to satisfy all of the program objectives.

For example, if sample collection (soil or groundwater) is the objective, the selected method must be capable of collecting, in an appropriate and approved manner, the necessary samples. Additionally, the contaminants of concern may influence the drilling and sampling method.

Alternatively, if the objective of the drilling program is to install vapor or groundwater extraction wells, the selected method must be suitable for the installation of the designed well. It is important to not only consider the physical limitations of a particular drilling technique (i.e., depth and diameter), but examine the consequences of the drilling method with the drilling objective (i.e., smearing of the borehole walls rendering wells ineffective or inefficient).

5.2 Site Conditions

Site conditions can limit the drilling methods available for a particular program. Site conditions to be considered include both subsurface and surface conditions.

5.2.1 Subsurface Conditions

The subsurface stratigraphy of a site is a fundamental consideration when selecting a particular drilling method. The drilling equipment selected must be capable of effectively and economically penetrating the strata at the site to meet the project objectives. Particular stratigraphy that may pose problems for certain drilling methods include tight clayey soils, swelling clays, flowing sands, caliche, gravels, cobbles, lost circulation zones, and bedrock.

In addition to stratigraphy, the site hydrology must also be considered. If multiple water-bearing zones are expected, a conductor casing may be needed to seal off shallow water-bearing zones and prevent potential cross contamination. The need for conductor casings can affect the selection of a particular drilling method. Wells that deeply penetrate aquifers can also affect the selection of a particular drilling method.

5.2.2 Surface Conditions

Surface conditions can affect access to the site and the amount of available work space (both horizontal and vertical or overhead space). These in turn can affect the selection of a particular method or type of drill rig. Limited access and work space may require smaller or remotely powered drill rigs. The site terrain is a very important factor in choosing the drilling method as it is very expensive and difficult to mobilize large and/or heavy equipment over rugged terrain. For sites such as these, drill rigs (typically hollow-stem auger) are mounted on all-terrain equipment.

In addition to access and work space, the work environment must also be considered. This includes both weather and other site activities. Extremely hot or cold climates may require use of special drilling equipment or methods. Sites such as refineries where explosive atmospheres could exist may also require very special equipment.

5.3 Waste Generation

Drilling operations typically generate significant volumes of waste that must be handled, stored, and eventually disposed. This is of particular concern when drilling into contaminated or hazardous materials. The type and volume of wastes generated during drilling differs for different drilling methods. The different handling and disposal requirements of drilling wastes can greatly affect project costs. The different drilling methods can also require vastly different volumes of groundwater be removed to fully develop the well.

STANDARD OPERATING PROCEDURES

SOP-02

GROUNDWATER MONITORING WELL DESIGN AND INSTALLATION

STANDARD OPERATING PROCEDURES

SOP-02
GROUNDWATER MONITORING WELL DESIGN AND INSTALLATION

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) is applicable to the design and installation of permanent groundwater monitoring wells at BSEP. Each monitoring well must be designed to suit the hydrogeologic setting, the type of contaminants to be monitored, overall purpose of the monitoring program, and other site-specific variables. As such, site-specific objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Additionally, within a monitoring system, different monitoring wells may serve different purposes and thus require different types of construction. Therefore, during all phases of well design, BSEP contractors must clearly document the basis for design decisions, the details of well construction, and the materials to be used.

2.0 DEFINITIONS

Absorption	The penetration or apparent disappearance of molecules or ions of one or more substances into the interior of a solid or liquid.
Adsorption	The process by which atoms, ions, or molecules are assimilated to the surface of a material. Ion-exchange processes involve adsorption.
Annular Sealant	Material used to provide a positive seal between the borehole and the casing of the well. Annular sealants should be impermeable and resistant to chemical or physical deterioration.
Annular Space	The space between the borehole wall and the well casing, or the space between a casing pipe and a liner pipe.
Aquifer	A geologic formation, group of formations, or part of a formation that can yield water to a well or a spring.
Backwashing	A method of filter pack emplacement whereby the filter pack material is allowed to fall freely through the annulus while clean fresh water is simultaneously pumped down the casing.
Bentonite	Hydrous sodium montmorillinite mineral available in powder, granular, or pellet form. It is used to provide a tight seal between the well casing and the borehole.
Bridging	The development of gaps or obstructions in either grout or filter pack materials during emplacement.
Continuous Slot Wire-Wound Well Screen	A well intake that is made by winding and welding triangular-shaped, cold-rolled wire around a cylindrical array of rods. The spacing of each successive turn of wire determines the slot size of the intake.
Corrosion	The adverse chemical alteration that reverts elemental metals back to more stable mineral compounds and that affects the physical and chemical properties of the metal.

Filter Pack	Sand, gravel, or glass beads that are uniform, clean, and well-rounded that are placed in the annulus of the well between the borehole wall and the well intake to prevent formation material from entering through the well intake and to stabilize the adjacent formation.
Grout	A fluid mixture of neat cement and water with various additives or bentonite of a consistency that can be forced through a pipe and placed in the annular space between the borehole and the casing to form an impermeable seal.
Monitoring Well	A well that is capable of providing a groundwater level and sample representative of the zone being monitored.
Naturally Developed Well	A well construction technique whereby the natural formation materials are allowed to collapse around the well intake and fine formation materials are removed using standard development techniques.
Neat Cement	A mixture of Portland cement and water in the proportion of five to six gallons of clean water per bag (94 pounds) of cement.
Piezometers	A small-diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface.
Sieve Analysis	Determination of the particle-size distribution of soil, sediment, or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.
Slurry	A thin mixture of liquid, especially water, and any of several finely divided substances such as cement or clay particles.
Tremie Pipe	A device, usually a small-diameter pipe that carries grouting materials to the bottom of the borehole and that allows pressure grouting from the bottom up without introduction of appreciable air pockets.
Well Cluster	Two or more wells completed (screened) to different depths in a single borehole or in a series of boreholes in close proximity to each other. From these wells, water samples that are representative of different horizons within one or more aquifers can be collected.
Well Point	A sturdy, reinforced well screen or intake that can be installed by being driven into the ground.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** will select the site-specific monitoring well design and installation methods, with input from the site geologist or hydrogeologist and field team leader, and will maintain close supervision of the activities and progress.

The **Site Hydrogeologist** selects site-specific drilling/sampling options and helps prepare technical provisions of drilling methods.

The **Field Project Leader/Geologist** implements the selected drilling program.

The **Drilling Rig Geologist** supervises and/or performs actual monitoring well installation.

4.0 WELL DESIGN

Consideration should be given to the following site-specific information before a groundwater monitoring system is designed:

- Purpose of the groundwater monitoring program (water quality, water levels, remediation, flow direction, and velocities)
- Surficial conditions, including topography, climate, drainage, site access
- Known or anticipated hydrogeologic setting including geology (consolidated/ unconsolidated), physical characteristics of the aquifer (porosity/permeability), type of aquifer (confined/unconfined), recharge/discharge conditions, aquifer thickness, and groundwater/surface water interrelationships
- Borehole geophysical logs, if any
- Known or anticipated contaminant chemical characteristics (chemistry, density, viscosity, reactivity, and concentration)
- Anticipated seasonal fluctuations in groundwater levels
- Anthropogenic or tidal influences
- Regulatory requirements

Common mistakes in groundwater monitoring system design include the following:

- Use of well casing or well screen materials that are incompatible with the hydrogeologic environment, and/or the anticipated contaminants, resulting in chemical alteration of the samples or failure of the well
- Use of nonstandard well screen (field slotted or perforated) or incorrect slot size, resulting in well sedimentation and turbid groundwater samples
- Improper length or placement of the well screen so that acquisition of accurate water level or water quality data from discrete zones is impossible
- Improper selection and placement of filter pack materials resulting in well sedimentation, well screen plugging, or chemical alteration of the groundwater
- Improper selection and placement of annular seal materials resulting in alteration of groundwater chemistry, plugging of the filter pack and/or well screen, or cross-contamination from geologic units that have been sealed off improperly
- Inadequate surface protection resulting in surface water entering the well

Siting of monitoring wells should be performed after a preliminary estimation of the hydraulic gradients and groundwater flow direction. In most cases this may be done through review of background data and site terrain. Additionally, production wells in the area may be used to assess the local groundwater flow direction. If the groundwater flow direction cannot be determined by any of these methods, it may be practical to install piezometers in a preliminary phase to determine flow direction.

4.1 Casing Diameter and Screen Length

Monitoring well casing diameter is dependent on the purpose of the well and the amount and size of downhole equipment that must be accommodated. Additional criteria for selecting casing diameters include: drilling or well installation method used, anticipated depth of the well and associated strength requirements, ease of well development, volume of water required to be purged prior to sampling, rate of recovery of the well after purging, and cost.

Monitoring well casing diameters are generally two or four inches. Pumping tests or some types of borehole geophysical equipment may require wells six inches or larger in diameter. Four-inch-diameter wells are usually preferred due to their versatility. In smaller diameter wells, the volume of stagnant water to be purged prior to sampling is minimized, the cost of well construction is reduced, and the well stabilizes relatively quickly. The quantities of potentially contaminated drill cuttings and development and purge water are also reduced.

The borehole diameter should be a minimum of four to six inches larger than the well casing and screen to allow for proper placement of annular materials.

In situations where vertical groundwater gradients are minimal, screen lengths are typically 10 to 20 feet, with stratified formations possibly requiring shorter screen lengths. If non-aqueous phase liquids (NAPLs) that are lighter than water are anticipated, the well screen should extend above the water table so these liquids can be sampled. Consideration should be given to seasonal fluctuations in water levels when locating the well screen above the top of the water table. If dense NAPLs are anticipated, the screen interval should extend to the base of the aquifer. Well clusters may be necessary when contaminants both denser and lighter than water are anticipated in the same aquifer.

4.2 Casing and Screen Materials

Monitoring well casing is specified by diameter, thickness, and type of material. Well screens also require that slot size be specified. Casing thickness is referred to as "schedule." Polyvinyl chloride (PVC) is usually Schedule 40 (thinner wall), although Schedule 80 (thicker wall) is sometimes used for deep wells. Steel casing is typically Schedule 5 or 10.

Selection of casing and screen material must be based on three primary characteristics: chemical interference potential, chemical resistance, and physical strength. The materials must not assimilate chemicals either by adsorption onto the material surface or absorption into the material matrix or pores; they must be durable enough to withstand potential chemical attacks either from natural chemical constituents or groundwater contaminants; and they must have the structural strength to withstand the forces exerted on them by the surrounding geologic materials and during installation. The three components of casing and screen structural strength are tensile strength, compressive (column) strength, and collapse strength.

Casing and screen materials generally available are Teflon, PVC, stainless steel, galvanized steel, carbon steel, and low-carbon steel. Teflon materials are extremely expensive and of comparatively low strength. Although relatively inert, recent studies have shown that Teflon is prone to sorption of selected organic compounds.

The two most commonly used materials are PVC and stainless steel. PVC is inexpensive, widely available, lightweight, and easy to work with. However, the column strength of PVC may limit the depth of installation. Schedule 80 PVC may be used for deeper wells; however, the reduced inside diameter should be taken into account when designing the well. Many studies have been conducted concerning the effect of PVC on water quality data. Whereas adsorption of some chlorinated species to PVC was documented, the adsorption rate was found to be very slow. Because a sample is generally taken shortly after the purging of stagnant water in contact with the casing, the contaminants in the water will have minimal time to be influenced by sorption or leaching effects. Therefore, potential sample bias effects due to interactions with PVC appear to be negligible.

Steel well materials are stronger, more rigid, and less temperature sensitive than PVC or Teflon. Stainless steel has the highest corrosion resistance of the various types of steel. Type 304 and Type 316 are the most commonly used stainless steels. Both are available in low-carbon forms, which are more easily welded than the normal carbon steel. Low-carbon steel is designated by an "L" after the number (e.g., Type 304L). Type 304 stainless steel is superior to Type 316 from a corrosion resistance and cost standpoint. Type 316 is preferred to Type 304 under reducing conditions. For either type of stainless steel, long-term exposure to corrosive conditions may result in chromium or nickel contamination of groundwater samples. Insoluble halogen and sulfur compounds may also form as a result of corrosion of stainless steel.

Threaded, flush-joint casing is preferred for monitoring well applications. Welded-joint steel casing may also be acceptable, but is typically more expensive and inconvenient. Glued PVC should never be used for monitoring wells since the glue may release organic contamination into the well. The casing should have a well cap that is vented to prevent the accumulation of gases and to allow water levels in the well to respond to barometric and hydraulic pressure changes.

The hydraulic efficiency of a well screen depends primarily upon the amount of open area available per unit length of screen. The two screen types commonly used for monitoring wells are machine-slotted, and continuous-slot wire-wound. Hand-slotted, drilled, or perforated casings should not be used as well screens. Slotted casing is manufactured from a variety of materials, including PVC and stainless steel.

Slot openings are designated by numbers that correspond to the widths of the openings in thousandths of an inch (e.g., number 10 slot refers to 0.010-inch slot size). The slots have a consistent width for the entire wall thickness of the casing, which can result in clogging if irregularly shaped formation particles are brought through the screen during well development and sampling.

The continuous-slot, wire-wound screen has a greater area per opening per length and diameter than is available with any other screen type. The percentage of open area in continuous-slot screen is often more than twice that provided by standard slotted well screen. The triangular shaped wire makes these screens non-clogging. They are fabricated in PVC and a variety of metals and are used when high pumping rates are anticipated.

If a monitoring well will also be used for hydraulic testing, the well screen open area should equal or exceed the formation's effective porosity so that the screen is not the limiting factor in formation hydraulic testing. In most cases, this amount of open area can only be achieved through the use of continuous-slot wire-wound well screen. In choosing between types of well screens, another factor is the speed and effectiveness of well development. Screens with a high percentage of open area greatly reduce the time and effort required for well development.

The bottom of the screen must be sealed by an endcap consisting of the same material as the screen. The use of a sediment sump or trap below the well screen is not appropriate for monitoring wells.

In the case of wells deeper than 150 feet deep, schedule-80 PVC will be used to minimize the potential for casing blistering when grout cures. The diameter of the screen and casing will be a maximum of 4-inches less than the diameter of the borehole. Stainless steel centralizers will be placed at the top and bottom of the well screen and every 40 feet along the blank casing. The bottom of each well will consist of a slip cap mounted with stainless steel screws to a flush-threaded end-cap. Holes of 1/16-inch diameter will be drilled through both caps prior to installation to prevent water from sitting in the bottom of the well if the static water level drops below the bottom of the well. A locking cap or dedicated pump assembly will be used to secure the top of the well.

4.3 Decontamination of Casing and Screen Materials

During the production of PVC casing, a wax layer can develop on the inner wall of the casing; protective coatings may also be added to enhance casing durability. Considerable quantities of oils and solvents are used during the manufacturing and machining of threads during the production of steel casing. All of these represent potential sources of chemical interference and must be removed either with a laboratory-grade nonphosphate solution or by steam cleaning prior to installation. Factory cleaning of casing and screen in a controlled environment by standard detergent washing, rinsing, and air-drying procedures is superior to any cleaning efforts attempted in the field. Factory cleaned and sealed casing and screen can be certified by the supplier.

4.4 Filter Pack and Well Screen Design

A properly designed monitoring well requires that a well screen be placed opposite the zone to be monitored and be surrounded by materials that are coarser and of greater hydraulic conductivity than the natural formation material. Naturally developed wells and wells with artificially introduced filter pack are the two basic types of well intake designs for unconsolidated or poorly consolidated materials.

4.4.1 Naturally Developed Wells

In naturally developed wells, the formation materials are allowed to collapse around the well screen. Naturally developed wells can be installed in which natural formation materials are relatively coarse grained, permeable, and of uniform grain size. It is essential that the grain-size distribution of the formation to be monitored is accurately determined by conducting a mechanical (sieve) analysis of samples taken from the interval to be screened. After sieving, a plot of grain size versus cumulative percentage of sample retained on each sieve is made. Well screen slot sizes are based on the grain-size distribution, specifically the effective size (the sieve size that retains 90 percent of the formation material, referred to as D10) and the uniformity coefficient (the ratio of the sieve size that retains 40 percent of the material or D60, to the effective size). A naturally developed well can be justified if the effective grain size is greater than 0.010 inch and the uniformity coefficient is greater than 3.0. Various state agencies (e.g., the California Department of Toxic Substances Control [DTSC]) recommend that an artificial filter pack be used if sieve analysis indicates that a screen slot size of 0.020 inches or less is required to retain 50 percent of the natural formation. The biggest drawback for naturally developed wells is the time required for well development to remove fine-grained formation material.

4.4.2 Artificial Filter-Packed Wells

Filter packs are installed to create a permeable envelope around the well screen. The use of an artificial filter pack in a fine-grained formation material allows the screen slot size to be considerably larger than if the screen were placed in the formation material without the filter pack. The selection of the filter pack grain size should be based on the grain size of the finest layer to be screened.

Filter pack grain size and well screen slot size should be determined by the grain size distribution of the formation material. The filter pack should be designed first. It is recommended to use a filter pack grain size that is three to five times the average (D50) size of the formation materials. However, this method may be misleading in coarse, well-graded formation materials. Another way to determine filter pack grain size is to take the D30 grain size of the formation materials and multiplying it by a factor of between three and six, with three used if the formation is fine and uniform and six used if the formation is coarse and non-uniform. For both methods, the uniformity coefficient of the filter pack materials should be as close to 1.0 as possible (2.5 maximum) to minimize particle size segregation during filter pack installation.

The filter pack should extend from the bottom of the well screen to approximately two to five feet above the top of the screen to account for settlement of the pack material during development and to act as a buffer between the well screen and the annular seal. A secondary filter pack (transitions sand) is sometimes used to prevent annular grout seal materials from migrating into the primary filter pack. The secondary filter pack should extend at least one foot above the top of the primary filter pack. It should consist of a uniformly graded fine sand with 100 percent passing a No. 30 U.S. Standard sieve and less than 2 percent by weight passing the 200 sieve.

Filter pack thickness must be sufficient to surround the well screen but thin enough to minimize resistance to the flow of fine-grained formation material and water into the well during development. American Society of Testing and Materials (ASTM), Designation D 5092-90, recommends that a minimum of two-inch thick filter pack between the borehole well and the well casing (ASTM 1995).

The materials comprising the filter pack should be as chemically inert as possible. It should be comprised of clean quartz sand or glass beads. Filter pack materials usually come in 100-pound bags; these materials are washed, dried, and factory packaged.

The size of well intake openings can only be selected after the filter-pack grain size is specified. The slot size should be such that 90 to 100 percent of the filter-pack material is held back by the well screen.

The casing string should be installed in the center of the borehole. This will allow the filter-pack materials to evenly fill the annular space around the screen and ensure that annular seal materials fill the annular space evenly around the casing. If a hollow-stem auger or dual-tube rig is used, the auger or inner tube of the dual tube will adequately centralize the casing string. For other types of drilling, centralizers should be used to ensure the casing string is positioned in the center of the borehole. Centralizers are typically expandable stainless steel metal or plastic that attach to the outside of the casing and are adjustable along the length of the casing. Centralizers are generally attached at the bottom and immediately above the well screen and at 10- or 20-foot intervals along the casing to the surface.

Methods for filter pack emplacement include gravity (free-fall), tremie pipe, reverse circulation, and backwashing. The latter two techniques are not commonly used for monitoring well construction, since they require the introduction into the borehole of water from a surface source.

Gravity emplacement is only possible in relatively shallow wells with an annular space of more than 2 inches, where the potential occurrence of bridging is minimized. Bridging can result in the occurrence of large unfilled voids in the filter pack or the failure of filter pack materials to reach their intended depth. Gravity emplacement may also cause filter pack gradation. Additionally, formation materials from the borehole wall can become incorporated into the filter pack, potentially contaminating it.

With the tremie emplacement method, the filter pack is poured or slurried into the annular space adjacent to the well screen through a rigid pipe, usually 1.5 inches in diameter. Initially the pipe is positioned so that its end is at the bottom of the annulus. If the filter pack is being installed in a temporarily cased borehole (hollow-stem auger , dual-tube percussion, or air rotary casing hammer) the temporary casing is pulled to expose the screen as the filter-pack material builds up around the well screen. In unconsolidated formations the temporary casing should only be pulled out one to two feet at a time to prevent caving. In consolidated or well-cemented formations or in cohesive unconsolidated formations, the temporary casing may be raised well above the bottom of the borehole prior to filter pack emplacement. For deep wells and/or non-uniform filter pack materials, the filter pack may be pressure fed through a tremie pipe with a pump. Emplacement should be continuously monitored with a weighted measuring tape accurate to the nearest 0.1 foot to determine when the filter pack has reached the desired height. After reaching the desired height, the well should be surged for 10-15 minutes, then checked for settling. Add more filter pack as necessary. Record the volume of filter pack used and check against calculated volume of annular space. Most well designs also employ a “secondary” filter pack (transition sand) above the primary filter pack for purposes of reducing bentonite seal and grout migration into the primary filter pack. If applicable, care must be taken that the filter pack materials are not installed into a hydrostratigraphic unit above or below the specific zone that is targeted for monitoring.

4.5 Annular Seal

Proper annular seal formulation and placement results in the complete filling of the annular space and envelopes the entire length of the well casing to ensure that no vertical migration can occur within the borehole.

Annular seal materials may include bentonite, neat cement grout, or variations of both. Typically, a bentonite seal from 2 to 5 feet thick is emplaced immediately above the filter pack. The use of bentonite as a sealing material depends on its efficient hydration following emplacement. Expansion of bentonite in water can be on the order of eight to 10 times the volume of dry bentonite. This expansion causes the bentonite to provide a tight seal between the casing and the adjacent formation and between the grout and filter pack. Bentonite is available as pellets, granules, chips, chunks, or powder. The dry bentonite should be less than one-fifth the width of the annular space between casing and borehole (ASTM 1995). If the bentonite seal will be above the saturated zone, several gallons of clean water must be poured down the annulus to begin the hydration process. A minimum of 30 minutes should pass to allow for hydration before additional annular seal materials are placed above the bentonite. Bentonite pellets having a coating to slow the hydration process are not recommended as they have been found to contain chemicals that may impact water quality.

Powdered bentonite is generally made into a grout slurry to allow emplacement as a bentonite seal. This grout slurry is prepared by mixing about 15 pounds of a high-solids, low-viscosity bentonite with seven gallons of water to yield one cubic foot of grout. Once the grout is mixed, it should remain workable for 15 to 30 minutes. During this time the grout is pumped through a tremie pipe with a mud or grout pump. Once in place, the bentonite grout requires a minimum of 24 hours to strengthen. In water with a high total dissolved solids (TDS) content (>5,000 parts per million [ppm]) or a high chloride content, the swelling of bentonite is inhibited.

A neat cement is commonly used to seal the remainder of the annulus. Neat cement is made up of one 94-pound bag of Portland cement and six gallons of water. The water used to mix the neat cement should be clean with a TDS less than 500 ppm. Bentonite powder is often added to neat cement to improve workability and reduce slurry weight and density and to reduce grout shrinkage. The proportion of bentonite by volume should be three to five percent.

The cement-bentonite grout should be mechanically blended in an aboveground rigid container and pumped through a tremie pipe to within a few inches of the bottom of the space to be sealed. This allows the grout to displace groundwater and loose formation materials up the hole. The end of the tremie pipe should always remain in the grout without allowing air spaces. After emplacement, the tremie pipe should be removed immediately. The grout should be placed in one continuous mass before initial setting of the cement or before the mixture loses its fluidity.

Cement is a highly alkaline substance (pH from 10 to 12) and introduces the possibility of altering the chemistry of the water it contacts. Thinner slurries may infiltrate an unprotected filter pack. After a borehole annulus is filled with grout a sample of water may be obtained and the pH determined in the field. A pH reading of 12 or higher may indicate an invasion of cement grout into the well.

4.6 Surface Completions

Two types of surface completions are common for groundwater monitoring wells: aboveground and flush-mounted. Aboveground completions are preferred wherever practical. The primary purpose of either type of completion is to prevent surface runoff from entering and infiltrating down the annulus of the well, and to protect the well from accidental damage or vandalism. The surface seal may be an extension of the annular seal installed above the filter pack, or a separate seal emplaced atop the annular seal.

For aboveground completions, the drilling subcontractor will construct a concrete apron (3 feet x 3 feet x 0.5 feet) around each well. A protective steel casing fitted with a locking cover is set into the uncured concrete apron. Concrete aprons will be crowned to provide positive runoff away from the well. Concrete pads may be constructed within three days after wells have been installed. If necessary steel guard posts 4-inches in diameter and filled with concrete will be installed around the pads. Posts will be five feet long and will have a stickup of 2.5 feet above ground surface and 2.5 feet below ground surface. In a flush-to-ground surface completion, a water-tight monitoring well Christy box or its equivalent is set into the cement surface seal before it has cured. This type of completion is used in high-traffic areas. A low, gently sloping mound of cement will discourage surface runoff. A locking well cap must be used to secure the inner well casing.

5.0 REFERENCES

American Society of Testing and Materials (ASTM), 1995. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers*, Designation D 5092-90.

STANDARD OPERATING PROCEDURES

SOP-03

GROUNDWATER MONITORING WELL DEVELOPMENT

STANDARD OPERATING PROCEDURES

SOP-03
GROUNDWATER MONITORING WELL DEVELOPMENT

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

The goal of monitoring well development is to remove fines and drilling fluid residue from the gravel pack and the natural formation in the vicinity of the screened interval, thus assuring good communication between the aquifer and the well. Well development assures that a sample collected will be a true representative of the quality of water moving through the formation.

The well development process is composed of the following:

- The application of sufficient energy in a monitoring well to create groundwater flow reversals (surging) in and out of the well and the gravel pack to release and draw fines into the well

- Pumping or bailing to draw drilling fluids out of the borehole and adjacent natural formation, along with fines that have been surged into the well.

2.0 DEFINITIONS

Fines	Silt, clay, fine sand.
Parameters	Groundwater variables (i.e., pH, specific conductivity, temperature, turbidity).
Annulus	The gap between the well and borehole where the sand, seal, and grout are installed.
Saturated Annulus	The portion of the annulus that is below the aquifer.
Drilling Fluid	Any fluid the driller may have added during the drilling of the borehole.
Purge Water	Any water removed from the well via bailing, pumping, or airlift.
Drawdown	Distance between the static water level and water level while the well is being pumped or bailed at a constant rate.
Bridge	A wedge or buildup of sand that occurs when the driller is pouring the sand pack around the screened interval, thus leaving a gap or "open zone" where the natural formation could possibly clog the screen.
Yield	The rate at which a well will produce water.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** will select the site-specific development methods, with input from the site geologist or hydrogeologist and Field Team Leader, and will maintain close supervision of the activities and progress.

The **Field Team Leader/Geologist** implements the selected development program and assists in the selection of development methods.

The **Field Technician/Staff** carries out the actual well development.

4.0 WELL DEVELOPMENT

4.1 General

The following general guidelines are applicable to well development regardless of method.

4.1.1 Decontamination

Every effort must be made to avoid outside contamination and the cross-contamination of monitoring wells. This can best be done by ensuring that all equipment to be introduced into a well is clean. The level of effort for decontamination is a site- and project-specific issue to be resolved individually for each project.

4.1.2 Documentation

A critical part of monitoring well development is recording significant details and events in either a field logbook or on a well development log (Attachment 1). It is important that the following details be documented.

- Well identification number
- Installation date
- Date and time of development
- Quantity of drilling fluid lost during well installation
- All photoionization detector (PID) readings (Note: see SOP-39 for additional information on PID principles and procedures.)
- Measured well depth (pre-development and post-development)
- Water level
- Height of water column
- Pumping rate and water level drawdown (if applicable)
- Recharge rate (poor, good, excellent)

- Periodic parameter readings
- Sample observations
- Type of equipment used
- Total amount of water removed
- Completion time

4.1.3 Calculating Purge Volume

The minimum number of gallons to be removed must be calculated before the development process begins.

Information needed to calculate purge volume:

- Total depth of well (TD)
- Measured static water level (WL)
- Screen length (SL)
- Well casing inner diameter (ID)
- Borehole Diameter (BD)
- Number of gallons of water used during well drilling/construction
- Number of feet of filter pack installed above the screen, if the standing water column (SWC) is longer then the screen length

To calculate one well volume:

- Calculate the standing water column (SWC). TD - WL = SWC.
- Use a well volume chart (Attachment 2) to find a multiplier in the volume per linear foot column that coincides with the well's ID.
- SWC times ID multiplier equals gallons of water in one well volume

To calculate one annulus volume (two options):

Option 1 (if the SWC is shorter than the screen length):

- Portion of saturated annulus equals SWC
- Use a volume chart to find a multiplier in the volume per linear foot column that coincides with the well's BD

- BD multiplier minus ID multiplier equals annulus multiplier
- Feet of saturated annulus times annulus multiplier times 30 percent (assumed porosity) equals gallons of water in one annulus volume

Option 2 (if the SWC is longer than the screen length):

- Portion of saturated annulus is equal to the screen length plus the number of feet of sand above the top of the screen
- Use a volume chart to find a multiplier in the volume per linear foot column that coincides with the well's BD
- BD multiplier minus ID multiplier equals annulus multiplier
- Feet of saturated annulus times annulus multiplier times 30 percent (assumed porosity) equals gallons of water in one annulus volume

To calculate the minimum gallons to be removed:

- Well volume plus annulus volume plus number of gallons lost during well drilling/construction equals one purge volume

Example for the Development of a 4-inch Well

The Well Construction Log notes that the borehole diameter is 10.25 inches, the screen is 15 feet long, and the driller used 75 gallons of water during well construction. Measured with a water level indicator, the static water level is 59.45 feet. Measured with a well tagger, the well depth is 71.21 feet.

Record in logbook, TD = 71.25 feet
WL = 59.45 feet

TD - WL = SWC
Logbook, SWC = 11.8 feet

From Chart 1 (Attachment 2), the gallons per linear foot multiplier for a 4-inch well is 0.66. Thus, 11.8 × 0.66 = 7.79 (gallons of water in one well volume).

Logbook, one well volume = 7.79 gallons

From Chart 2 (Attachment 2), the gallons per linear foot for a 10.25-inch borehole is 4.29. Therefore, 4.29 (BD multiplier) minus 0.66 (ID multiplier) equals 3.63 (annulus multiplier). Thus, 11.8 × 3.63 × 30 percent = 12.89 (gallons of water in one annulus volume).

Logbook, one annulus volume = 12.89 gallons
drilling fluid lost = 75 gallons

7.79 (one well volume) plus 12.89 (one annulus volume) plus 75 (fluid lost) equals 95.7 gallons (one purge volume). The work plan states that a minimum of three well volumes must be removed during development. Additional water may need to be purged to allow the parameters to stabilize and the water to clear up.

Logbook, one purge volume = 95.7 gallons
95.7 × 3 = 287 (minimum number of gallons to be purged).
Logbook, minimum gallons to be purged = 287 gallons

4.2 Development Methods

4.2.1 Bailing, Surging, and Pumping

In relatively clean, permeable formations where water flows freely into the borehole, bailing, surging, and pumping is an effective development technique. The bottom of the well is first tagged to measure the amount of sand and silt before and after surging. Then a bailer (Figure 1) is lowered into the well to clean out any fines that have settled on the bottom. Then a surge block (Figure 2), approximately the same diameter as the well casing, is used to agitate the water, causing it to move in and out of the screen, which draws in fines from the gravel pack and surrounding formation, and breaks up any bridges that may have formed during the placement of the gravel pack. After surging for a few minutes (depending on the height of the water column and length of screen), the bailer is again lowered to clean out any fines that were drawn into the casing as a result of surging. This surge/bail technique should continue until minimal fines are being pulled out with the bailer. A submersible pump (Figure 3) is then lowered down the well. Pumping should begin at the top of the saturated portion of the screened interval to prevent sand locking. The pump should be lowered at intervals of five feet or less until the pump is resting approximately one foot from the bottom of the casing. The water level must be monitored continuously during the first few minutes of pumping to prevent drawing the water level below the pump intake and breaking the suction. If possible, the discharge flow rate should be increased until the well is pumping at its maximum yield without a drawdown beneath the pump.

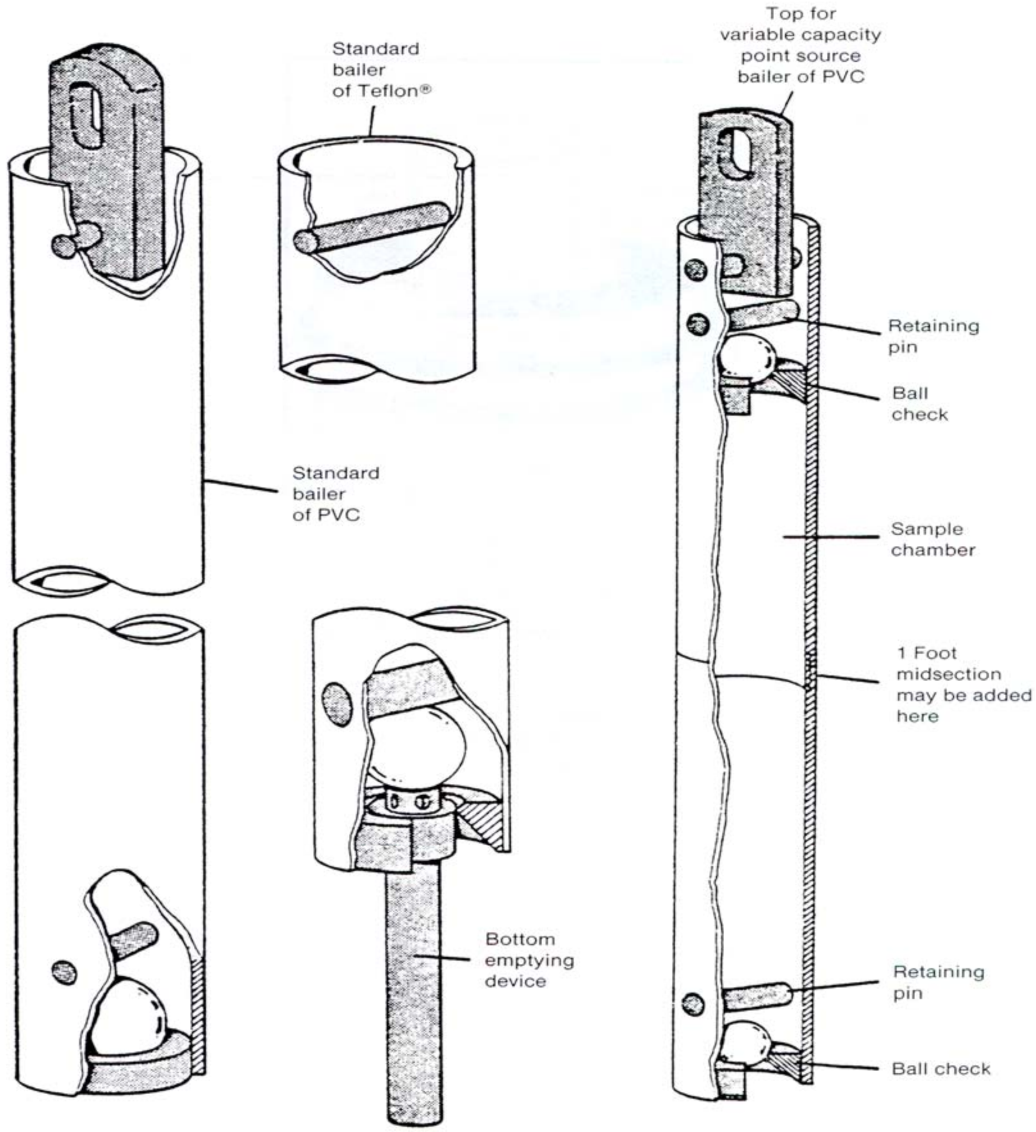

Figure 1 Bottom Discharge Bailer

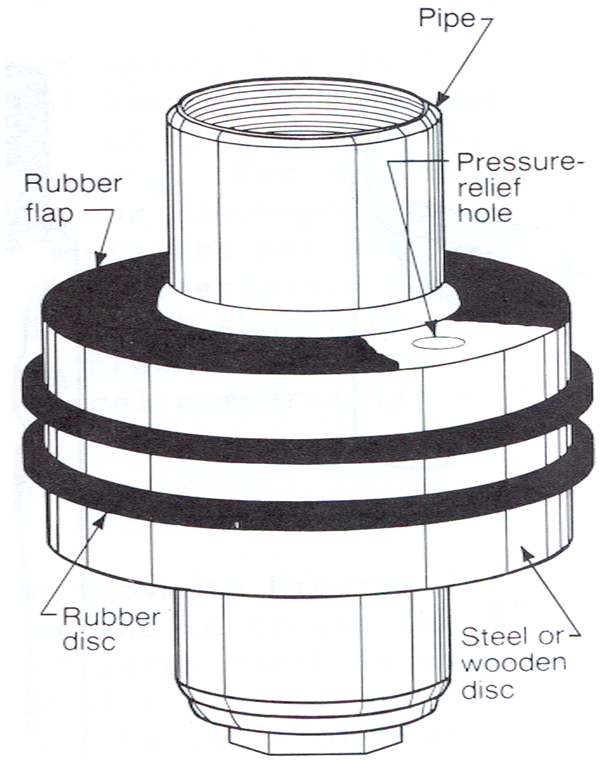

Figure 2 Surge Block

Figure 3 Submersible Pump

4.2.2 Overpumping and Backwashing

Wells may be developed by overpumping (pumping or bailing the well at a rate that exceeds the ability of the formation to deliver water) and then reversing the flow direction (backwashing) so that the water is passing from the well into the gravel pack and formation. This back and forth movement of water through the well screen and gravel pack removes fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods including pouring water into the well and then bailing, or forcing water into the well under pressure through a water-tight fitting. Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen. Where no backflow prevention valve is installed, a pump can be alternately started and stopped. This starting and stopping allows the column of water that is initially picked up by the pump to be alternately dropped and raised in a surging action. This surge tends to loosen the bridging of the fine particles, drawing them into the well where they are pumped out.

4.2.3 Compressed Air

Compressed air can be used to develop a well by either backwashing or surging. Backwashing forces water out through the screens, using increasing air pressure inside a sealed well, then releases the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. The well is subsequently pumped using the air lift method.

4.2.4 Developing Wells with Floating Product

It is important to disturb the formation as little as possible in wells that contain floating product. Surge blocks should not be used as they may smear the screen and the casing when the block is being withdrawn, potentially leaving evidence of product and increasing the risk of faulty data. Product wells should be developed using a bail/pump method. A bailer should be lowered gently into the well, without agitating the water column, to remove any fines that have settled on the bottom. If the well produces sufficient water, a pump is lowered into the well and pumping started at a slow flow rate. The product/water level is manually monitored constantly for the first few minutes to prevent the product level from coming within 2 feet of the pump intake. Pumping is continued until at least the quantity of drilling fluid lost has been purged, the parameters have stabilized, and the discharge water is visibly clear.

4.2.5 Developing Wells in Tight Formations

Developing low-yield wells is a very lengthy process; the amount of time spent developing a low yield well is project-specific and should be resolved individually for each project. For wells installed in clay or fine-grained silt, the method of development should be bailing only. Surging of such wells has been found to substantially increase the turbidity of the water and does not significantly improve hydraulic well response. These wells should be bailed dry and a record kept of the time it takes for the well to recharge 80 percent.

ATTACHMENT 1

WELL DEVELOPMENT LOG

WELL DEVELOPMENT LOG

Well ID:		**Screened Interval (ft):**		**Well Diameter (in)**	
Date:		**Pump Depth (ft):**		**Static Water Level (ft):**	
Sample ID:		**Flow Rate (gpm)**		**Standing Water (ft):**	
Time:		**Purging Device:**		**One Well Volume (gal):**	
Method:		**Water Level Instrument:**		**OVA Reading at TOC:**	
Technician:		**Water Quality Meter(s):**		**OVA Reading in BZ:**	

Time	Volume Purged (gal)	Flow Rate (gpm)	Water Level (feet - TOC)	SC (µS/cm)	pH	Temp	ORP (mV)	Turbidity (NTU)	Other	Comments
			± 0.1 ft	5%	± 0.1	± 0.1 ºC	5%	< 10 NTU		
Final Field Parameter Measurements										

Comments:

ATTACHMENT 2

VOLUME CHARTS

Chart 1 — Volume of PVC Casing

Schedule	Diameter (inches)	OD (inches)	ID (inches)	Volume/LF (gallons)
40	1.25	1.660	1.380	0.08
40	2	2.375	2.067	0.17
40	3	3.500	3.068	0.38
40	4	4.500	4.026	0.66
40	6	6.625	6.065	1.50
40	8	8.625	7.981	2.60
40	12	12.750	11.938	5.82
80	2	2.375	1.939	0.15
80	4	4.500	3.826	0.60
80	5			0.00

Chart 2 — Volume of Open Borehole and Annulus Between Casing and Hole

Hole Diameter	Volume/Linear Feet of Hole		Nominal Casing Diameter	4.2.5.1 Volume/Linear Feet of Annulus	
(inches)	(gallons)	(cubic feet)	(inches)	(gallons)	(cubic feet)
7.25	2.14	0.29	1.3	2.08	0.28
7.25	2.14	0.29	2.0	1.98	0.26
7.75	2.45	0.33	2.0	2.29	0.31
8.25	2.78	0.37	2.0	2.61	0.35
10.25	4.29	0.57	2.0	4.12	0.55
8.25	2.78	0.37	3.0	2.41	0.32
10.25	4.29	0.57	3.0	3.92	0.52
12.25	6.12	0.82	3.0	5.76	0.77
8.25	2.78	0.37	4.0	2.12	0.28
10.25	4.29	0.57	4.0	3.63	0.49
12.25	6.12	0.82	4.0	5.47	0.73
12.25	6.12	0.82	6.0	4.65	0.62

STANDARD OPERATING PROCEDURES

SOP-05

WATER SAMPLING AND FIELD MEASUREMENTS

STANDARD OPERATING PROCEDURES

SOP-05
WATER SAMPLING AND FIELD MEASUREMENTS

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Attachment 3 Chain-of-Custody Record

DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This guideline is a general reference for the proper equipment and techniques for groundwater sampling. The purpose of these procedures is to enable the user to collect representative and defensible groundwater samples and to facilitate planning of the field sampling effort. These techniques should be followed whenever applicable, although site-specific conditions or project-specific plans may require adjustments in methodology.

To be valid, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from time of collection to time of analysis in order to minimize changes in water quality parameters. Acceptable equipment for withdrawing samples from completed wells includes bailers and various types of pumps. The following are primary considerations in obtaining a representative sample of the groundwater:

- Avoid collecting stagnant (standing) water in the well.
- Avoid physically or chemically altering the water by improper sampling techniques, sample handling, or transport.
- Document that proper sampling procedures have been followed.

This guideline describes suggested well evacuation (or purging) methods, sample collection and handling, field measurement, decontamination, and documentation procedures. Examples of sampling and chain-of-custody (COC) forms are attached.

2.0 DEFINITIONS

Annular Space	The space between casing or well screen and the wall of the drilled hole, or between drill pipe and casing, or between two separate strings of casing. Also called annulus.
Aquifer	A geologic formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring.
Bailer	A long narrow tubular device with an open top and a check valve at the bottom that is used to remove water from a well during purging or sampling. Bailers are available in many widths and lengths, and may be made of Teflon, polyvinyl chloride (PVC), polyethylene (PE), or stainless steel. Disposable bailers are widely used, and are available in Teflon and PE.
Bladder Pump	A pump consisting of flexible bladder (usually made of Teflon) contained within a rigid cylindrical body (commonly made of PVC or stainless steel). The lower end of the bladder is connected through a check valve to the intake port, while the upper end is connected to a sampling line

that leads to the ground surface. A second line, the gas line, leads from the ground surface to the annular space between the bladder and the outer body of the pump. After filling, under hydrostatic pressure, application of gas pressure causes the bladder to collapse, closing the check valve and forcing the sample to ground surface through the sample line. Gas pressure is often provided by a compressed air tank, and commercial models generally include a control box that automatically switches the gas pressure off and on at appropriate intervals.

Centrifugal Pump — A pump that moves a liquid by accelerating it radially outward in an impeller to a surrounding spiral-shaped casing.

Chain of Custody — Method for documenting the history and possession of a sample from the time of its collection through its analysis and data reporting to its final disposition.

Check Valve — Ball and spring valves on core barrels, bailers, and sampling devices that are used to allow water to flow in one direction only.

Conductivity (electrical) — A measure of the quantity of electricity transferred across a unit area, per unit potential gradient, per unit time. It is the reciprocal of resistivity.

Datum — An arbitrary surface (or plane) used in the measurement of heads (i.e., National Geodetic Vertical Datum, commonly referred to as mean sea level).

Direct-Push Technology — A method of soil boring installation involving pushing a sampling device into the ground and retrieving it for soil description and collection (Geoprobe® is a common trademark name). Groundwater samples can be collected from the borehole by inserting a screen point into the hole and removing groundwater via peristaltic pump or small-diameter bailer. Similar to Hydropunch® (see below).

Decontamination — A variety of processes used to clean equipment that contacted formation material or groundwater that is known to be or suspected of being contaminated.

Downgradient — In the direction of decreasing potentiometric head.

Drawdown — The lowering of the water level or potentiometric surface in a well and aquifer due to the discharge of water from the well.

Electric Submersible Pump — A pump that consists of a rotor contained within a chamber and driven by an electric motor. The entire device is lowered into the well with the electrical cable and discharge tubing attached. A portable power source and control box remain at the surface. Electrical submersible pumps used for groundwater purging are constructed of inert materials such as stainless steel, and are well sealed to prevent sample contamination by lubricants.

Filter Pack — Sand or gravel that is generally uniform, clean, and well rounded that is placed in the annulus between the borehole wall and the well screen to prevent formation material from entering through the well screen and to stabilize the adjacent formation.

Headspace	The empty volume in a sample container between the water level and the cap.
HydroPunch®	An *in situ* groundwater sampling system in which a hollow steel rod is driven into the saturated zone that allows for the collection of a groundwater sample.
In Situ	In the natural or original position; in place.
Monitoring Well	A well that is constructed by one of a variety of techniques for the purpose of extracting groundwater for physical, chemical, or biological testing, or for measuring water levels or potentiometric surface.
Packer	A transient or dedicated device placed in a well or borehole that isolates or seals a portion of the well, well annulus, or borehole at a specific level.
Peristaltic Pump	A low-volume suction pump. The compression of a flexible tube by a rotor results in the development of suction.
pH	A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. (Original designation for potential of hydrogen.)
Piezometer	An instrument used to measure water level or potentiometric head at a point in the subsurface; a non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface.
Preservative	An additive (usually an acid or a base) used to protect a sample against decay or spoilage, or to extend the holding time for a sample.
Static Water Level	The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumping.
Turbidity	Cloudiness in water due to suspended and colloidal organic and inorganic material.
Upgradient	In the direction of increasing potentiometric head.

3.0 RESPONSIBILITIES

The **Project Manager** selects site-specific water sampling methods, locations for monitoring well installations, monitoring wells to be sampled and analytes to be analyzed (with input from the Field Team Leader and Project Geologist), and is responsible for project quality control and field audits.

The **Field Team Leader/Geologist** implements the water sampling program; supervises the Project Geologist/Hydrogeologist and Sampling Technician; ensures that proper COC procedures are observed and that samples are sampled, transported, packaged, and shipped in a correct and timely manner.

The **Project Geologist/Hydrogeologist** ensures proper collection, documentation, and storage of groundwater samples prior to shipment to the laboratory, and assists in packaging and shipment of samples.

The **Field Sampling Technician** assists the Project Geologist/Hydrogeologist in the completion of tasks and is responsible for the proper use, decontamination, and maintenance of groundwater sampling equipment.

4.0 WATER SAMPLING GUIDELINES

4.1 Equipment

There are many methods available for well purging (evacuation) and sampling. A variety of issues must be considered when choosing purging and sample collection equipment. These issues include the following:

- Depth and diameter of the well
- Recharge capacity of the well
- Analytical parameters that will be tested
- Governing regulatory requirements

Few sampling devices are suitable for the complete range of groundwater analytical parameters. For example, a bailer is acceptable for collecting major ion and trace metal samples (if turbidity is not a factor), but analytical results may be incorrect if used for the collection of samples that are analyzed for volatile organics, dissolved gases, or even pH. Generally, the best pumps are positive displacement pumps, such as bladder and helical rotor pumps, which minimize the aeration of the groundwater as it is sampled, and therefore yield the most representative groundwater samples. Although it is possible to use different equipment to purge the well and to sample the well, this is not recommended because of the increased decontamination requirements and possibilities for cross contamination. It is recommended that a flow rate as close to the actual groundwater flow rate should be employed to avoid further development, well damage, or the disturbance of accumulated corrosion or reaction products in the well (Puls and Barcelona, 1989).

Positive displacement pumps, such as bladder pumps, are generally recommended for both well evacuation and sample collection. Disposable bailers are also commonly used for well development and evacuation, as well as sample collection in certain cases. Other types of sample collection such as gas lift pumps should be avoided, especially when analyzing for sensitive parameters, because of the geochemical changes that can occur due to the aeration of the water within the well. Also, the use of certain sample devices (e.g., bailers or high-rate centrifugal pumps) may entrain suspended materials, such as fine clays and colloids, which are not representative of mobile chemical constituents in the formation of interest (Puls and Barcelona, 1989).

Specific instructions for the use of several of the sampling devices are discussed in the next sections. All purging and sampling equipment should be decontaminated before beginning work and between wells, in accordance with Section 4.5.

4.1.1 Bailers

Bailers represent the simplest and least expensive method of collecting the sample from a well. However, they may not be suitable for all analyses. Bailers are available as permanent (re-usable or dedicated) and disposable. Permanent bailers are usually constructed of Teflon or stainless steel. Disposable bailers are usually constructed of PE or Teflon.

The advantages to using permanent bailers are:

- Inexpensive
- Easy to use and maintain

The disadvantages to using permanent bailers are:

- Disturb sediment while sampling
- Require decontamination and risk of cross-contamination
- Require disposal of contaminated purge water
- Possibility of splashing (health and safety issue)

The advantages of using disposable bailers are:

- No need for decontamination between.
- Inexpensive
- Easy to use

The disadvantages to using disposable bailers are:

- Disturb sediment while sampling

- Require disposal of contaminated purge water
- Possibility of splashing (health and safety issue)

Disposable bailers are preferred. Since there is no cross- contamination between samples, there is no need for time-consuming decontamination.

Bailers can be lowered and raised using stainless steel wire or polypropylene cord. Polypropylene cord is recommended since it is inexpensive, light, and strong, however it should be discarded after one use to prevent cross-contamination. At no time should the bailer or the line touch the ground during the sampling process. This can be done by coiling the line around one's hands while pulling the bailer out of the well. For deep wells, the line may be coiled into a bucket or on a clean plastic sheet.

During bailing, the purge water is poured out of the top of the bailer into a 5-gallon bucket, 55-gallon drum, or equivalent. Most groundwater sampling protocols require that the amount of water purged be recorded; thus, a 5-gallon bucket with 1-gallon markings is recommended. During sampling, the water can be poured out of the top of the bailer. This should not be done for volatile analyses. Water can also be removed from the bottom of the bailer using a small tube or sampling device that comes with most disposable bailers. This device essentially pushes the ball out of the valve, allowing water to slowly flow out of the bottom of the bailer. This is the recommended method for volatile organic compound (VOC) sampling.

4.1.2 Peristaltic Pumps

Peristaltic and centrifugal pumps are widely used for purging wells with water levels close to the surface (less than 30 feet). They are light, reasonably portable, and easily adaptable to ground level monitoring of field parameters by attaching a flow-through cell. These pumps require minimal downhole equipment. The tubing can easily be cleaned in the field; however, more often dedicated tubing is left in each well, or tubing is replaced after each well. The following procedures should be considered when using these pumps:

- Unless dedicated tubing is used, the interior and exterior of all intake tubing used with the peristaltic/centrifugal pump should be thoroughly washed with a detergent wash, flushed with tap water, and then double rinsed with distilled water prior to use.
- Peristaltic pumps typically run on batteries. However, if a gas-powered generator is used, it should be downwind of the well.
- The intake of the tubing should be lowered to the midpoint of the well screen. Alternatives to this procedure may be necessary if the drawdown from the purging operations causes the water level to fall and begin to pump air. Because of accumulated sediment at the well bottom, the intake should be at least 1 foot above the bottom of the well.

- If parameters are to be monitored continuously, it is recommended that an in-line “flow-through” cell with a multi-parameter water quality meter be used. Connect the discharge tubing from the pump to the “in” port of the flow-through cell and begin evacuating the well (make sure to have the “out” port connected to a bucket or some sort of water containment). Continuously monitor the parameters (typically pH, oxidation reduction potential (ORP or redox), dissolved oxygen (DO), turbidity, temperature, and specific conductivity) and measure the volume of groundwater being pumped.

- After purging is complete (stabilization of parameters), disconnect the discharge tubing from the flow through cell prior to sampling. Do not collect water that has flowed through the flow-through cell.

The advantages of using peristaltic pumps are:

- Typically less purge water to collect and dispose (if low-flow sampling)
- Relatively easy to use
- Very little disturbance of sediment; easy to achieve low turbidity samples
- Low health and safety risk (low splash possibility)

The disadvantages to using peristaltic pumps are:

- Possibly expensive, depending on tubing and pump used.
- Sampling time can be 1 hour or more per well.
- Limited depth applicability; can pump only from depths less than 32 feet.
- Vacuum or negative pressure can potentially alter the geochemistry (VOCs, pH, alkalinity).

4.1.3 Submersible Pumps

Submersible pumps take in water and push the sample up a tube to the surface. The power sources for these pumps may be compressed gas or electricity. The operation principles vary, and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Bladder or helical rotor pumps are recommended for sampling for sensitive parameters. Bladder pumps are available for .05-inch diameter wells and larger, and these pumps can lift water up to several hundred feet. For large sampling projects, dedicated tubing is recommended, as tubing for bladder pumps is typically very expensive ($10 per foot), thus making disposable tubing not efficient. The entire pump assembly (and tubing, if applicable) should be decontaminated before purging and between wells, as described in Section 4.5.

The advantages of using submersible pumps are:

- Less purge water to collect and dispose (if low-flow sampling).

- Very little disturbance of sediment; easy to achieve low turbidity samples.
- Adjustable to very low flow rates.
- Can be used to sample wells 300 or more feet deep.
- Dedicated systems can lower costs over time.
- Low health and safety risk (low splash possibility).
- Some types (e.g., bladder pumps) can be easily disassembled for decontamination.

The disadvantages of submersible pumps are:

- Need power source or gas source, which can be hard to transport to remote well locations.
- High start-up costs; Many models of these pumps are expensive, as is the tubing.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components of some types is difficult and time consuming.

4.1.4 Other Pumps

Gas-Lift Pumps

A pressure displacement system consists of a chamber equipped with a gas inlet line, a water discharge line, and two check valves. When the chamber is lowered into the casing, water floods it from the bottom through the check valve. Once full, a gas (e.g., nitrogen or air) is forced into the top of the chamber in sufficient amounts to displace the water in the discharge tube. The check valve in the bottom prevents water from being forced back into the casing, and the upper check valve prevents water from flowing back into the chamber when the gas pressure is released. This cycle can be repeated as necessary until purging is complete. The potential for increased gas diffusion into the water (and thus loss of volatiles) makes this system unsuitable for sampling volatile organic or most pH critical parameters. This method is not recommended for groundwater sampling, but may be useful for development or evacuation of a well.

Direct-Push Technology Groundwater Sampling

Direct Push Technology (DPT) provides *in situ* groundwater samples by using a specially designed sample tool to provide a hydraulic connection with the water table. When used with a mobile laboratory, DPT groundwater sampling can be useful for such applications as relatively rapid delineation of groundwater plumes. It is also ideal for screening for contaminants. Both groundwater and floating layer hydrocarbons may be sampled using this method.

The DPT method utilizes a sampler containing a stainless steel screen point, which is attached to the DPT rods and is inserted into the DPT borehole. When the screen is at the desired depth, the sampler is pulled back, exposing the screen to the formation. Groundwater can then be sampled used a peristaltic pump or a small diameter bailer.

This method may be used to sample groundwater up to approximately 60 feet of soft sediments. In coarse sand, gravel, consolidated rock, or at depths greater than 60 feet, a pilot hole must be drilled prior to using this method.

The advantages of using DPT groundwater sampling techniques are:

- Low cost (relative to installing monitoring wells)
- Able to collect a relatively undisturbed *in situ* groundwater sample
- The relative speed with which a sample can be collected when compared to drilling, installing, developing, purging, and sampling a monitoring well

The disadvantages of using DPT groundwater sampling techniques are:

- Accurate water levels can not be obtained
- Sampling cannot be repeated if problems occur with the samples after they are collected
- Does not allow for long-term groundwater monitoring

4.2 Well Purging Methods

Well development procedures are covered in SOP-03, “Groundwater Monitoring Well Development.”

4.2.1 Calculation of Casing Volume

To ensure that an adequate volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well and the volume of water in the filter pack below the well seal. The volume can be easily calculated by the following method (calculations should be entered in the field logbook):

1. Obtain all available information on well construction (e.g., location, casing, screen, depth).
2. Determine well or casing diameter.
3. Measure and record static water level using an electronic water level meter (depth below top of casing reference point).

4. Use a pre-determined total depth of the well to calculate the water column. Measuring total depth prior to sampling will disturb sediment that has accumulated at the bottom of the well, which will affect sample results.

5. Calculate the volume of water in the casing using the following formula:

$$V = 7.481\ (\pi r^2 h)$$

where:

V	=	Casing volume (gal)
r	=	Well radius (ft)
h	=	Linear feet of water in well = total well depth (ft) - static water depth (ft)

Alternatively, the casing volume can be calculated by multiplying the linear feet of water in the well by the volume per linear feet taken from Attachment 1 or other similar tables. Always be sure that the units in your calculation are consistent. In the equation above, 7.481 is the conversion factor from cubic feet to gallons.

4.2.2 Calculation of Annulus Volume

Some groundwater sampling protocols require the purging of casing and annulus volumes prior to sampling. In these cases the volume of water contained in the annular space between the casing and the borehole wall is calculated by the following formula:

$$Va = (Cb - Cc) \times (h) \times (0.30)$$

where:

Va	=	Volume of water in annulus (gal)
Cb	=	Borehole capacity (gal/ft)
Cc	=	Casing capacity (gal/ft)
h	=	Amount of standing water in the well or total linear height of the sand pack, whichever is less (ft)
0.30	=	Average porosity of typical sand pack

The values for Cb and Cc can be calculated by the formula πr^2. The annulus volume is added to the casing volume prior to multiplying by the number of volumes to be purged.

4.2.3 Purging Requirements

The composition of the water within the well casing and in close proximity to the well is probably not representative of the overall groundwater quality in the target aquifer. This is because important environmental conditions such as the ORP may differ drastically near the well from the conditions in the surrounding water-bearing materials. For this reason it is necessary to either purge the well until it is thoroughly flushed of standing water and contains fresh water from the aquifer, or sample from discrete intervals in the screened interval at low flow rates in order to collect undisturbed aquifer water (Puls and Barcelona, 1996).

Full Well Purging

When full purging is required, the recommended amount of purging before sampling depends on many factors, including the characteristics of the well, the hydrogeological nature of the aquifer, the type of sampling equipment being used, the parameters that are to be analyzed, and the regulatory requirements of the project. The number of casing volumes that should be removed prior to sample collection has been a matter of debate in the groundwater community for some time. However, it is recommended that where possible, between three and five casing volumes should be purged prior to sampling.

Low-Flow Sampling

Many groundwater scientists and regulatory departments have accepted and prioritized the use of low-flow purging and sampling of groundwater. Low-flow purging is defined as pumping rates between 0.1 and 0.5 liters per minute (L/min). Also, rather than relying on the removal of a specific volume of water prior to sample collection, physical parameters, such as pH, DO, ORP, turbidity, specific conductivity, and temperature, are collected at certain intervals (usually every 2 to 5 minutes). In order to minimize contact with the atmosphere, these parameters are typically measured using a multi-parameter meter inside a closed “flow-through” cell attached to the discharge side of a pump system. Once the parameters have stabilized, the groundwater is considered representative of the aquifer and is ready for sample collection. Determining *when* the parameters have stabilized, however, may differ between regulatory agencies. Per the U.S. Environmental Protection Agency (EPA) document *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures* (Puls and Barcelona, 1996), the parameters are considered stabilized when three consecutive measurements are within the following constraints:

- Temperature ± 10 %
- Conductivity ± 3 %
- pH ± 0.1
- DO ±10 %
- ORP ±10 mV
- Turbidity ±10 % or <10 nephelometric turbidity units (NTUs)

During purging, water levels should be monitored to ensure that drawdown does not exceed 0.1 m (0.3 ft). If the water level drop exceeds this, the flow rate should be decreased until the water level stabilizes. If water levels in low yield wells do not stabilize at flow rates near 0.1 L/min, the well should be purged to dryness once and then sampled (EPA, 1986). Samples should be collected when the well has recovered to 80 percent of its original capacity or at 24 hours from being purged to dryness, whichever comes first. At no time should the well be pumped to dryness if the recharge rate causes the formation water to vigorously cascade down the sides of the screen and cause an accelerated loss of volatiles. In this case, samples should be collected at a rate slow enough to maintain the water level at or above the top of the screen to prevent cascading.

4.2.4 Purge Water Handling and Disposal

Because of the potential for spreading environmental contamination, planning for purge water disposal is a necessary part of well monitoring. Alternatives range from releasing it on the ground (<u>not</u> back down the well) to full containment, treatment, and disposal. If the well is believed to be contaminated, the best practice is to contain the purge water and store it in drums labeled "purge water" or in aboveground portable storage tanks (i.e., Baker Tanks) until the water samples have been analyzed. Include the date that the waste was generated on the container. Once the contaminants are identified, appropriate treatment or disposal requirements can be determined.

4.3 Field Measurements

A variety of field measurements are commonly made during the sampling of groundwater including water level, pH, conductivity, turbidity, temperature, DO, and ORP. The accuracy, precision, and usefulness of these measurements are dependent on the proper use and care of the field instruments. Valid and useful data can only be collected if consistent practices (in accordance with recommended manufacturer's instructions) are followed. The instruments should be handled carefully at the well site and during transportation to the field and between sampling sites.

4.3.1 Water Level

Water levels can be measured by several techniques, but the most common method is using an electronic water level meter. The proper sequence is as follows:

1. Check operation of measurement equipment aboveground. Prior to opening the well, don personal protective equipment as required.

2. Record the following information on a sampling form or in the field notebook if a form is not available:

- Well number
- Top of casing elevation
- Surface elevation, if available.

3. After opening the well, observe any pressure in the well. Allow 10-30 seconds for the water levels to equilibrate and stabilize. Repeat measurement after 30 seconds to assure the water level has stabilized.

4. Measure and record static water level and total depth (only if necessary) to the nearest 0.01 foot (0.3 cm) from the surveyed reference mark on the top edge of the inner well casing. If no reference mark is present, record in the log book where the measurement was taken (e.g., from the north side of the inner casing).

5. Record the time and day of the measurement.

Electric Water Level Indicators

These devices consist of a spool of small-diameter cable or tape and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact. For accurate readings, the probe should be lowered slowly into the well.

Oil/Water Interface Probes

If oil or free product is encountered in the well, an oil/water interface probe can be used to measure the thickness of the product on top of the water. Most models exhibit two distinct electronic sounds for oil (usually a solid beep) and water (an intermittent beep). The most accurate method for measuring the oil/water interface is to first measure the top of the free product, then go through the product until the probe registers water, and then slowly raise the probe until a solid beep is encountered. This prevents a false thickness of product being measured, since product may stick to the probe causing the probe to read product when it really is in water.

4.3.2 Multi-Parameter Probes

Typically, groundwater parameters such as pH, temperature, and DO are measured in a flow-through cell using a probe that measures several parameters at once. Certain sampling techniques may preclude the use of these probes, and individual probes may need to be used instead.

Instruments should be calibrated at the beginning of every day, and if readings become suspect. Most instruments claim to hold their calibration longer than a day; if so, their calibration can be checked every morning. If the values do not match the expected numbers, the instrument should be calibrated again. The manufacturer's directions for calibration, maintenance, and use should be read and closely followed.

Any problems with the functioning of the meter should be noted in the field log and reported to the office equipment manager.

4.4 Sample Collection Methods

4.4.1 Sample Containers

A complete set of sample containers should be prepared by the laboratory prior to going into the field. The laboratory should provide the proper containers with the required preservatives. The laboratory's quality assurance manual should provide a complete description of the procedures used to clean and prepare the containers. The containers should be labeled in the field with the date, well designation, project name, collectors' name, time of collection, and parameters to be analyzed. The sample containers should be kept in a cooler (at 4 degrees centigrade) until they are needed (i.e., not left in the sun during purging). One cooler should be used to store the unfilled bottles and another to store the samples.

The sample bottles should be filled in order of the volatility of the analytes so that the containers for volatile organics will be filled first, and samples that are not pH-sensitive or subject to loss through volatilization will be collected last. A preferred collection order (EPA, 1986) is as follows:

- VOCs
- Total petroleum hydrocarbons
- Total organic halogens
- Total organic carbon
- Extractable organics (e.g., pesticides, herbicides)
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride
- Nitrate and ammonia
- Radionuclides

Field measurements, such as temperature, pH, and specific conductance, should be measured and recorded in the field before and after sample collection to check on the stability of the water samples over time.

4.4.2 Field Filtration for Dissolved Metals

Filtering groundwater samples has been a subject of considerable debate in recent years. In many cases, samples passing a 0.45-micron filter were used to provide an indication of dissolved metals concentrations in groundwater. Puls and Barcelona (1989) report that the use of a 0.45-micron filter was not useful, appropriate, or reproducible in providing information on metals mobility in groundwater systems, nor was it appropriate for determination of truly “dissolved” constituents in groundwater. A dual sampling approach is recommended to collect both filtered and unfiltered samples.

Any filtration for estimates of dissolved species loads should be performed in the field with no air contact and immediate preservation and storage. In-line pressure filtration is best with as small a filter pore size as practically possible (e.g., 0.45, 0.10 micron). Disposable, in-line filters are recommended for convenience and avoiding cross-contamination. The filters should be pre-rinsed with distilled water; work by Jay (1985) showed that virtually all filters require pre-washing to avoid sample contamination.

In the absence of filters, low-flow sampling techniques can reduce turbidity to values less than 10 NTUs.

4.4.3 Methyl Mercury “Clean Hands/Dirty Hands” Collection Method

Sample bottles may be either Teflon, which has been cleaned, tested, filled with dilute HCl, and double bagged in a laboratory clean-room, or borosilicate glass obtained from a supplier which certifies cleanliness for metals sampling (e.g., I-Chem, Series 200 or equivalent). In general, a sample kit should be obtain from the laboratory consisting of proper containers, bags, gloves, and instructions. The use of locally obtained or untested containers is strongly discouraged as they may be the source of possible contamination. At the site the bottle is filled with water sample using an abbreviated version of the “clean –hands – dirty –hands” technique described in EPA Method 1669. Bottles are sealed tightly and re-bagged using the opposite series of steps as were used to open them. Bottles are shipped to the analytical laboratory via overnight courier for preservation and analysis.

<u>Sample Collection</u>

Samples should be collected only into rigorously cleaned and tested (for mercury) Teflon bottles or borosilicate glass bottles with Teflon-lined caps.

Samples are collected using rigorous ultra-clean protocols which are summarized as follows.

1. Ideally, at least two persons wearing fresh clean-room gloves at all times are required on a sampling crew.

2. One person ("dirty hands") pulls a bagged bottle from the cooler and opens the outer, dirty bag, avoiding touching inside that bag.

3. The other person ("clean hands") reaches in, opens the inner bag (if present), and pulls out the sample bottle. "Clean hands" should not touch anything but the sample bottle, its cap, and the water being sampled.

4. This bottle is opened and the acidified water (if present) is discarded. Under no circumstance should the bottle cap be placed on any surface while it is removed from the bottle.

Note: the sampler should be wary of disturbing the flow upstream of the sampling point. Often the insertion of the bottle into a flowing stream, or simply standing in the flow downstream of the sampling point, creates eddies (upstream flow) which can re-suspend solids near the sampling point. Entry of such re-suspended solids into samples for analysis of mercury will produce a non-representative sample and very likely increase the mercury concentration.

For Aqueous Sampling

5a. The bottle (including its cap) is rinsed three times with the sample water, and then filled almost completely. Leaving a small headspace (e.g. 1% of bottle volume) is acceptable and provides space for subsequent acid preservation at the laboratory.

Note: If the sampler cannot directly reach the water to be sampled, a pole-type sampler may be used to fill the bottle. The pole and bottle clamp should be made of plastic and/or stainless steel and the mouth of the bottle should be held facing upstream of the pole. Again, the use of a transfer vessel should be avoided.

For Sediment Sampling

5b. The bottle is then filled almost completely with sediment using a utensil known to be free from trace metal contamination. The sampler should ensure that the sampling site is representative of the immediate area.

6. The cap is replaced and the bottle re-bagged in the opposite order from which it was removed.

7. Clean-room gloves are changed between samples and whenever anything not known to be trace metal cleaned is touched.

Samples should be sent to the analytical laboratory unpreserved. The sample should be preserved as required by the method soon after arrival at the laboratory (within 48 hours). Unpreserved samples have been found stable for at least 1 week, when stored in Teflon or borosilicate glass bottles.

4.4.4 Sampling from Non-Monitoring Wells and Springs/Seeps

Municipal/Residential Wells

Residential water supply wells should be sampled in a similar manner to monitoring wells, although allowances must be made for the type of pumping equipment already installed in the well. In most cases, this will involve sampling directly from the tap on each well and before the water has gone through any chlorination or treatment system. The sampling point should be a cold-water tap located as close to the pump as practical. Domestic supply samples should not be taken from taps delivering chlorinated, aerated, softened, or filtered water. Faucet aerators should be removed if possible before sampling. Outdoor spigots are generally preferable, since they are usually provide untreated water and are less of an intrusion into the residence. Field parameters (temperature, DO, ORP, etc.) can be measured in a flow-through cell connected via hose to an outside spigot. The water sample can be collected after parameters stabilize. For sampling, the flow rate should be set to low flow sampling rates (or approximately 0.1 L/min). If field parameter measurement is not possible, the water tap should be turned on and run for at least 30 minutes unless the water tap is directly adjacent to the well head, and then the water should be allowed to run for no less than 10 minutes before the samples are collected to flush stagnant water from the system. All sample containers should be filled with water directly from the tap and the samples processed as described for monitoring well samples. Components of the plumbing system should be noted to assist in data interpretation.

Spring and Seep Sampling

Samples from springs or seeps should be collected directly into the sample bottles without using any special sampling equipment. The sample will be collected as close as possible to where the spring emanates from the soil or rock. The sampler should always stand downstream of the spring or seep to avoid disturbing sediment or clouding the water.

4.5 Decontamination

Decontamination procedures will vary from project to project based on the regulations and project-specific Field Sampling Plan (FSP). Generally, decontamination procedure for non-dedicated groundwater sampling equipment (bailers, pumps, water-level probes) consists of the following steps:

1. Scrub and wash with laboratory-grade detergent (such as Alconox™) and tap water.
2. Triple rinse with deionized water.

If equipment is highly contaminated, it may be rinsed with reagent-grade isopropanol alcohol or methanol and allowed to air dry prior to Step 2 above. A hot water pressure washer can also be used for decontaminating sampling equipment. However, dedicated or disposable equipment is preferable since it eliminates any possible cross-contamination pathway that incomplete decontamination may cause. As with other procedures documented in this Standard Operating Procedure (SOP), decontamination procedures may be determined by the client or regulatory agency involved in the project.

4.6 Records and Documentation

4.6.1 Sample Designation

Sample names vary from project to project, and further instructions are typically described in the project Quality Assurance Project Plan (QAPP) or FSP. Typically, the site name or an abbreviation or acronym of the site name is included along with the well identification. Blind duplicate samples should be labeled with the number of a non-existent well, and should not include a sample time on the label. Equipment and trip blanks, collected when non-dedicated equipment is used, may also be labeled with a fictitious well name in a similar manner to the blind duplicate samples.

4.6.2 Sample Label

Sample containers should be labeled using waterproof ink before a sample is obtained. A sample label should be affixed to all sample containers. This label identifies the sample by documenting the sample type, sampler(s) initials, sample location, time, date, analyses requested, and preservation method. A unique sample designation as discussed above is assigned to each sample collected. This sample identification is also noted on the sample label.

4.6.3 Field Notebooks and Sampling Forms

A field notebook should be prepared prior to beginning sampling activities and should be maintained throughout the sample round. The notebook should contain pertinent information about the monitoring wells, such as depth of casing and water levels. During sampling, all the activities should be recorded on a groundwater sampling log (see Attachment 2) and/or in the field notebook. All forms used during sampling should be referenced in the field notebook. A brief description of weather conditions should also be noted as weather can sometimes affect samples. Any deviation from the sampling procedure described in the project work plan or SOP should be outlined in detail and justified in the field notebook.

Specialized sampling forms can also be used to record the field measurements and other conditions observed.

4.6.4 Chain-of-Custody

The COC form (see Attachment 3) should be used to record the number of samples collected and the corresponding laboratory analyses. Information included on this form consists of time and date sampled, sample number, type of sample, sampler's name, preservatives used, and any special instructions. The project QAPP will detail the procedure for completing the COC form. A separate COC form may be completed for each cooler, or copies of the completed COC may be placed in every cooler. A copy of the COC form should be retained by the sampler prior to shipment (forms with multiple carbon copies are recommended). The original COC form should accompany the sample to the laboratory and provide a paper trail to track the sample. When transferring the possession of samples, the individuals relinquishing and receiving the samples should sign, date, and note the time on the COC form. Frequent communication with the laboratory after shipment is recommended to assure proper handling and adherence to holding times.

4.7 Sample Handling and Shipping

4.7.1 Sample Handling

The samples will be kept cool during collection and shipment with wet ice in double Ziploc™ bags (to prevent leakage). Frozen “blue ice” is not recommended. The samples should be stored in a durable, appropriately sized ice chest. The samples should be placed upright on a 1- to 3-inch layer of packing materials, such as vermiculite or bubble packaging, and kept separated, with the intervening voids filled with the packing material more than halfway to the top of the bottles or containers. The ice should be placed above and about the tops of the containers. The COC record should be sealed in a Ziplock plastic bag and affixed to the inside of the top lid of the cooler. The remaining space should be filled with packing material. The cooler should be secured by completely wrapping with strapping tape around both ends and around the lid. If there is a drain on the cooler, it should be taped shut. COC seals should be affixed across the seal between the lid and body of the cooler.

4.7.2 Shipping Instructions

All samples should be shipped overnight delivery through a reliable commercial carrier, such as FedEx. If shipment requires more than a 24-hour period, sample holding times can be exceeded, or the samples may get warm, compromising the integrity of the sample analysis. The sampler should call the laboratory to alert them when the samples will arrive on the following day.

5.0 REFERENCES

Jay, P.C., 1985. *Anion Contamination of Environmental Water Samples Introduced by Filter Media*. Analytical Chemistry 57(3): 780-782.

Puls, R.W. and M.S. Barcelona, 1989. *Ground Water Sampling for Metals Analyses*, Superfund Ground Water Issue, EPA/540/4-89/001, March.

Puls, R.W. and M.S. Barcelona, 1996. *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, U.S. Environmental Protection Agency document EPA/540/S-95/504, April.

U.S. Environmental Protection Agency (EPA), 1986. *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document*, OSWER-9950.1, September.

ATTACHMENT 1

MONITORING WELL DEVELOPMENT FORM

WELL DEVELOPMENT LOG

Well ID:	______	**Screened Interval (ft):**	______	**Well Diameter (in)**	______
Date:	______	**Pump Depth (ft):**	______	**Static Water Level (ft):**	______
Sample ID:	______	**Flow Rate (gpm)**	______	**Standing Water (ft):**	______
Time:	______	**Purging Device:**	______	**One Well Volume (gal):**	______
Method:	______	**Water Level Instrument:**	______	**OVA Reading at TOC:**	______
Technician:	______	**Water Quality Meter(s):**	______	**OVA Reading in BZ:**	______

Time	Volume Purged (gal)	Flow Rate (gpm)	Water Level (feet - TOC)	SC (µS/cm)	pH	Temp	ORP (mV)	Turbidity (NTU)	Other	Comments
			± 0.1 ft	5%	± 0.1	± 0.1 ºC	5%	< 10 NTU		
Final Field Parameter Measurements										

Comments: ______

ATTACHMENT 2

GROUNDWATER FIELD SAMPLING DATA RECORD

Well/Piezo ID:

Ground Water Sample Collection Record

Client: ______________________ Date: ________
Project No: ______________________ Time: Start ________ am/pm
Site Location: ______________________ Finish ________ am/pm
Weather Conds: ____________ Collector(s) ____________

WATER LEVEL DATA: (measured from Top of Casing) Well ☐ Piezometer ☐

a. Total Well Length ________
b. Water Table Depth ________
c. Casing Material ________
d. Casing Diameter ________
r = casing radius (ft)
L= length of water column (ft)
e. Length of Water Column ________
f. Calculated Well Volume ________ gal
(WV) = 3.14 * r^2 * L * 7.48 gal./ft^3 =

WELL PURGING DATA

a. Purge Method ______________________

b. Acceptance Criteria defined (from workplan)
- Minimum Required Purge Volume (@ _______ well volumes) ____________
- Maximum Allowable Turbidity ________ NTUs
- Stabilization of parameters ________ %

c. Field Testing Equipment Used: Make Model Serial Number

d. Field Testing Equipment Calibration Documentation Found in Field Notebook # _______ Page #_______

Time	Volume Removed (gal)	T° (C/F)	pH	Spec. Cond (umhos)	Turbidity (NTUs)	DO	Color	Odor	Other

e. Acceptance criteria pass/fail

	Yes	No	N/A
Has required volume been removed	☐	☐	☐
Has required turbidity been reached	☐	☐	☐
Have parameters stabilized	☐	☐	☐

If no or N/A - Explain below.

SAMPLE COLLECTION: Method: ______________________

Sample ID	Container Type	No. of Containers	Preservation	Analysis	Time

Comments ______________________

Signature ______________________ Date ______________________

ATTACHMENT 3

CHAIN-OF-CUSTODY RECORD

Water & Soil - Chain of Custody Record & Analytical Service Request

Requested Turnaround Time in Business Days (Surcharges) please circle
1 Day (100%) 2 Day (75%) 3 Day (50%) 4 Day (35%) 5 Day (25%) 10 Day-Standard

CAS Project No.

CAS Contact:

Company Name & Address (Reporting Information)

Project Name

Project Number

Project Manager

P.O. # / Billing Information

Phone

Fax

Email Address for Result Reporting

Sampler (Print & Sign)

Analysis Method and/or Analytes

Preservative Code

Client Sample ID	Laboratory ID Number	Date Collected	Time Collected	Matrix	Number of Containers	Volatile Organics GC/MS 624 ☐ 8260B ☐ Oxygenates ☐ TPH Gas ☐	TPH Gas 8015B ☐ BTEX 8021B ☐ MTBE 8021B ☐	TPH Diesel 8015B ☐ (Subcontracted)	TPH Diesel Low Level 8015B ☐ (Subcontracted)	TPH FC ☐ 8015M (Subcontracted)	Semi-Volatile Organics GC/MS 625 ☐ 8270C ☐ (Subcontracted)											Remarks

Preservative Key

0	**None**
1	**HCL**
2	**HNO_3**
3	**H_2SO_4**
4	**NaOH**
5	**Zn Acetate**
6	**Asc Acid**
7	**Other**

Report Tier Levels - please select

Tier I - (Results/Default if not specified) _____
Tier II (Results + QC) _____
Tier III (Data Validation Package) 10% Surcharge _____
Tier V (client specified) ________
MRL required Yes / No
MDL / PQL / J required Yes / No
EDD required Yes / No
Type: _______________

Project Requirements (MRLs, QAPP)

Reliquished by: (Signature)	Date:	Time:	Received by: (Signature)	Date:	Time:
Reliquished by: (Signature)	Date:	Time:	Received by: (Signature)	Date:	Time:
Reliquished by: (Signature)	Date:	Time:	Received by: (Signature)	Date:	Time:

Cooler / Blank / Ice / No Ice

Temperature __________ ^{o}C

STANDARD OPERATING PROCEDURES

SOP-14

FIELD DOCUMENTATION

STANDARD OPERATING PROCEDURES

SOP-14
FIELD DOCUMENTATION

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) is a general reference for the required documentation to be completed by company personnel during field investigations. Subject to the requirements of the contract, records in the form of field logbooks, reports, and forms should normally be completed for the various field activities. Records should be maintained on a daily basis as the work progresses, and should contain enough information to allow the Field Event to be completely reconstructed. All field records must be accurate, objective, and legible, because it is part of the client's product and may potentially serve as a legal document. As the field logbook is often the only record of the work conducted during the Field Event, it should normally be photocopied at least every week.

Sample field documentation forms are attached.

2.0 DEFINITIONS

None

3.0 RESPONSIBILITIES

All field team members are responsible for recording daily activities. An in-depth description of the documentation mentioned below is given in later sections.

The **Field Team Leader** (FTL) is responsible for completing the FTL logbook, Daily Quality Control Reports (DQCRs), documentation concerning supervision of team members, and duplication and distribution of applicable records. The FTL will be supervised by a qualified Nevada Certified Environmental Manager [C.E.M.]).

The **Rig Geologist/Sampling Team** is responsible for completing the drilling logbook; lithologic logs; well construction diagrams; sampling documentation such as sample labels, sample register, and chain-of-custody (COC) forms.

The **Water Sampling/Development Team** is responsible for completing the water sampling/development logbook; groundwater sampling/development logs; and sampling documentation such as sample labels, sample register, and COC forms.

The **Aquifer Data Collection Team** is responsible for completing the aquifer logs (e.g., slug tests, step-drawdown tests, pump tests), water level records, and data organization/tracking (e.g., downloading of data from data loggers).

4.0 FIELD DOCUMENTATION GUIDELINES

Field documentation serves as the primary foundation for all field data collected that will be used to evaluate the project site. Field documentation must be accurate, legible, and written in indelible ink. Absolutely no pencils or erasures are to be used. Mistakes are to be crossed out with one line, dated, and initialed. Skipped pages or blank sections at the end of a page should be crossed out with an "X" covering the entire page or blank section, dated and initialed. The person making the correction should write "No Further Entries," and date and initial the page. The responsible field team member should sign and log the date and time after the last entry for the day. To further assist in the organization of the field books, logs, or forms, the date and the significant activity description (e.g., boring or well number) should be written at the top of each page. Each project job number should have its own field book. In addition, all original field documentation should be included with the project files.

The descriptions of field data and documentation given below serve as a guideline; individual projects will vary in documentation needs, depending on the circumstances surrounding the project and the needs of the client.

4.1 Field Logbooks

The field logbook should be a bound, weatherproof book with consecutively numbered pages that serves primarily as a daily log of the activities carried out during the investigation. All entries should be made in indelible ink. A field logbook should be completed for each operation undertaken during the investigation, such as field team leader notes, drilling, groundwater sampling/development, and site visitors. The logbook serves as a diary of the events of the day.

Field activities will vary from project to project; however, the concept and general information to be recorded will be generally consistent. The following sections describe the minimum information that should normally be recorded in the three logbooks in which field activities are documented.

FTL Logbook

The FTL's responsibilities include the general supervision, support, assistance, and coordination of the various field investigation activities. A large portion of the FTL's day is spent rotating between operations in a supervisory role. Records of the FTL's activities, as well as a summary of the field team's activities, are maintained in a logbook. The FTL's logbook will be used to fill out DQCRs, and as such should contain all information required in these reports (Section 3.3). Items to be documented include the following:

- Record of tailgate meetings
- Personnel and subcontractors on job site and time spent on the site

- Field operations and personnel assigned to these activities
- Site visitors
- Log of the FTL's activities—time spent supervising each operation and summary of daily operations as provided by field team members
- Problems encountered and related corrective actions
- Deviations from the sampling plan
- Records of communications—discussions of job-related activities with the client, subcontractor, field team members, and project manager
- Information on addresses and contacts
- Record of invoices signed and other billing information
- Field observations

Rig Geologist/Sampling Team Logbook

The rig geologist or sampling team leader is responsible for recording the following information:

- Health and safety activities
  - Calibration records for health and safety equipment (type of photoionization detector (PID), calibration gas used and associated readings, noise dosimeters, etc.)
  - Personnel contamination prevention and decontamination procedures
  - Record of daily tailgate safety meetings
- Weather
- Calibration of field equipment
- Equipment decontamination procedures
- Personnel and subcontractors on the job site and time spent on the site
- Site name and well or soil boring number
- Drilling activities
  - Sample location (sketch)
  - Drilling method and equipment used
  - Borehole diameter
  - Drill cuttings disposal/containerization (number of drums, roll off-bins, etc.)
  - Type and amount of drilling fluids used (mud, water, etc.)
  - Depth and time at which first groundwater was encountered, depth to water at completion of drilling, and the stabilized depth to water—absence of water in the boring should also be noted
  - Total drilling depth of well or soil boring

  - Type and amount of materials used for well installation
  - Well construction details—depth of grout (mixture, weight), bentonite seal, filter pack, etc. (include type and amount used, calculate estimated amount that should be used)
  - Type and amount of material used to backfill soil borings
  - Time and date of drilling, completion, and backfilling
  - Name of drilling company, driller, and helpers

- Sampling
  - Date and time of sample collection
  - Sample interval
  - Types of samples taken
  - Number of samples collected
  - Analyses to be performed on collected samples

- Disposal of contaminated wastes (personal protective equipment, paper towels, Visqueen®, etc.)
- Field observations
- Problems encountered and corrective action taken
- Deviations from the sampling plan
- Site visitors

Groundwater Sampling/Development Logbook

The groundwater sampling and development team members are responsible for recording the following information:

- Health and safety activities
  - Calibration records for health and safety equipment (i.e., type of PID, calibration gas used and readings, noise dosimeters etc.)
  - Personnel contamination prevention and decontamination procedures
  - Record of daily tailgate safety meetings

- Weather
- Calibration of field equipment
- Equipment decontamination procedures
- Personnel and subcontractors on job site and time spent on the site
- Equipment decontamination procedures
- Disposal of contaminated wastes (personal protective equipment, paper towels, Visqueen®, etc.)
- Site name and well number

- Water levels and product levels—time and datum that water levels are measured (i.e., top of casing); purging of the well (include calculations, well volumes) with the following information:
  - Measured field parameters (temperature, pH, conductivity, odor, color, cloudiness, etc.)
  - Amount of water purged
  - Purge method—indicate bailer/pump, diameter and length of bailer, material that the bailer is composed of, type of pump, new nylon rope, etc.
- Purge water disposal and containment (Baker tank/ drums, number used, identification, etc.)
- PID readings from inside of well, purged water, and breathing zone (Note: see SOP-39 for additional information on PID principles and procedures.)
- Background PID readings
- Well sampling
  - Number of samples collected and type of containers used
  - Date and time of sample collection
  - Type of analyses
  - Quality assurance/quality control (QA/QC) samples collected; names given to blind samples
- Field observations
- Problems encountered and corrective actions taken
- Deviations from the sampling plan
- Site visitors

4.2 Tailgate Safety Meetings

Tailgate safety meetings are held at the beginning of each day before the start of work. All personnel, subcontractors, and others who will be on the job site are required to attend. The meetings are usually conducted by the FTL, on-site safety officer, or other qualified team member. The topics discussed at the meeting include the following:

- Directions to the hospital
- Protective clothing and equipment
- Chemical hazards
- Physical hazards
- Special equipment
- Emergency procedures

- Emergency phone numbers

All site personnel are required to sign the tailgate safety meeting form (Attachment 1). The original form is kept on site, and a copy sent to the home office.

4.3 Daily Quality Control Reports

The preparation of DQCRs (Attachment 2) is the responsibility of the FTL. DQCRs are completed on a daily basis to summarize the events of the day and supplement the information that is already recorded in the field logbook. DQCRs should be completed regardless of the duration of the field effort. Copies of the report are distributed to the Tronox Project Manager, Project Geologist, field office file, and home office file. Information recorded in this report should include the following.

- Date and weather information—date, daily temperatures, wind speed and direction, humidity
- Personnel and time spent on site
- Subcontractors and time spent on site
- Special equipment on site—PID, Smeal water sampling rig, hollow-stem auger Rig, pH meter, conductivity meter, etc.
- Work and sampling performed—personnel performing specific site activities, a summary of samples collected, and a thorough explanation of the work completed
- Quality control activities—e.g., decontamination procedures, QA/QC samples taken, calibration of field equipment
- Health and safety levels and activities—field parameter measurements, including calibration of equipment; daily tailgate safety meetings, level of protection used, etc.
- Problems encountered/corrective actions taken—any technical difficulties (e.g., problems encountered during drilling or equipment breakdowns); any problems that could potentially affect the quality of the samples should be included
- Special notes—any information that does not fit under the categories listed above, but is important to record; information that would be useful for future sampling, (e.g., base contacts made, visitors on site, etc.)
- Next day activity expectations
- Date/Signature of individual completing the report

4.4 Boring Logs

The preparation of drill logs is the responsibility of the field team members assigned to the drill rig. A detailed description of well logging is provided in the SOP for Lithologic Logging, SOP-17. Several examples of drilling logs are given in the attachments for SOP-17. An example lithologic log form is shown in Attachment 3. The exact format depends on the job and the client; however, the following basic information should normally be recorded on the log regardless of the format:

- Project and site name
- Name of driller and drilling company
- Type of drill rig used
- Drill rig contamination procedures
- Well/soil boring ID and location (sketch)
- Drilling and backfilling dates and times
- Reference elevation for all depth measurements
- Total depth of completed soil boring/well
- Depth of grouting, sealing, and grout mixes
- Signature of the logger.
- Description of unconsolidated materials
  - Geologic lithology description
  - Descriptive Unified Soil Classifications System (USCS) classification
  - USCS symbol
- Color (use appropriate soil color chart)
  - Penetration resistance (consistency or density)
  - Moisture content
  - Grain size information
  - Miscellaneous information (odor, fractures, visible contamination, etc.)
- Description of consolidated materials
  - Geologic rock description
  - Rock type
  - Relative hardness
  - Density
  - Texture
  - Color (use appropriate rock color charts)
  - Weathering
  - Bedding
  - Structures (fractures, joints, bedding, etc.)
  - Miscellaneous information (presence of odor, visible contamination, etc.)

- Stratigraphic/lithologic changes; depths at which changes occur
- Depth intervals at which sampling was attempted and amount of sample recovered
- Blow counts
- Depth intervals from which samples are retained
- Analyses to be performed on collected samples
- Depth at which first groundwater was encountered, depth to water at completion of drilling, and the stabilized depth to water. The absence of water in the boring should also be noted.
- Loss and depth of drilling fluids, rate of loss, and total volume of loss
- Use of drilling fluids
- Drilling and sampling problems
- PID readings

4.5 Well Construction Diagrams

The preparation of well construction diagrams is also the responsibility of field team members assigned to the drilling operations. This topic is further discussed in the SOP for Well Installation, SOP-02. An example well construction log form is shown in Attachment 4. The exact format of the diagram is dependent on the job and the client; however, the following basic information should be recorded and/or illustrated on the diagram regardless of the format.

- Project and site name
- Well identification number
- Name of driller and drilling company
- Depth and type of well casing
- Description of well screen and casing
- Borehole diameter
- Any sealing off of water-bearing strata
- Static water level upon completion of the well and after development
- Drilling and installation dates
- Type and amount of annulus materials used; depth measurements of annulus materials
- Other construction details (filter pack type and interval, location of centralizers, etc.)

- Surface elevation and reference elevation of all depth measurements

4.6 Groundwater Sampling and Development Logs

The groundwater sampling and development log should be used any time a well is developed or sampled (Attachment 5). The following information should be recorded on the log.

- Project name and site
- Well identification number
- Equipment decontamination procedures
- The date and time of sampling or development
- The water level and reference elevation
- Volume of water to be purged
- Pertinent well construction information (total depth, well diameter, etc.)
- Measurement of field parameters such as pH, turbidity, conductivity, and temperature, as well as the times at which the readings were taken.
- Type of purging and sampling equipment used
- Type of samples collected
- Sampler's initials

4.7 Aquifer Testing Logs

The aquifer testing team is responsible for setting up, collecting, tracking, and organizing data. The information listed below should normally be included. An example aquifer testing log form is shown in Attachment 6. The Aquifer Testing SOP-04 contains more details and the various book references related to the project site.

- Well number/identification (data logger identification)
- Data logger information/parameter setup
- Water level (include date, time, and measurement reference (such as top of casing)
- Type of aquifer test (slug, step-drawdown, pump test, etc.)
- Slug test (include length and diameter of slug for volume calculations)
- Start time of test
- Duration of test

- Pump tests (include disposal/containment of water information)
- Field observations and problems
- Tester's name

4.8 Documentation of Sampling Activities

Documentation to be made during sampling activities includes sample labels, sample seals, COC records, airbill and identification of courier, and sample register. An example sampling documentation and tracking form is shown in Attachment 7.

4.8.1 Sample Labels

A sample label, written in indelible ink, should be affixed to all soil and water sample containers. Required information on sample labels may vary from job to job; however, the following should be included at a minimum:

- Sample number
- Type of sample (grab or composite)
- Type of preservative, if applicable
- Date and time of collection
- Project location
- Analyte(s)
- Initials of sampling personnel

4.8.2 Custody Seals

Custody seals consist of security tape with the initials of the sampler and the date placed over the lid of each cooler containing samples. The tape should be placed such that the seal must be broken to gain access to the contents. Custody seals should not be placed directly onto the volatile organic compound (VOC) sample bottles. Custody seals should be placed on coolers prior to the sampling team's release to a second or third party (e.g., shipment to the laboratory).

4.8.3 Chain-of-Custody Records

COC procedures allow for the tracing of possession and handling of individual samples from the time of field collection through laboratory analysis. The COC is documented through a record that lists each sample and the individuals responsible for sample collection, shipment, and receipt. A sample is considered in custody if it is any of the following:

- In a person's possession.
- In view after being in physical possession.
- Locked or sealed so that no one can tamper with it after it has been in an individual's physical custody.
- In a secured area, restricted to authorized personnel.

A COC record is used to record the samples taken and the analyses requested. It is the legal record for maintaining accountability of control over the sample. Information recorded includes time and date of sample collection, sample number, and the type of sample, the sampler's signature, the required analysis, and the type of containers and preservatives used. A copy of the COC record should be retained by the sampler prior to release to a second or third party. Shipping receipts should be signed and filed as evidence of custody transfer between field sampler(s), courier, and laboratory.

The COC record will be properly signed and the date of collection and shipment recorded, along with the sample site identifications and requested analyses for each sample.

4.8.4 Sample Register

The sample register is a field record book with consecutive prenumbered pages. A full description of each sample is recorded in the book. The information included in the sample register should include the following:

- Sample number (identification)
- Duplicate and split sample numbers (identification)
- Location of sample
- Client
- Project number
- Collection method
- Number and size of bottles for each analysis
- Destination of the sample
- Type of analysis
- Date and time of collection
- Name of sampler

Other observations may be included as the situation dictates for a thorough record that could be used to reconstruct the events concerning that sample. All information must be recorded in indelible ink. Mistakes are to be crossed out with one line, dated, and initialed. Skipped pages or blank sections at the end of a page should be crossed out with an “X” covering the entire page or blank section, dated and initialed.

ATTACHMENT 1

TAILGATE SAFETY MEETING FORM

HEALTH AND SAFETY PRE-ENTRY BRIEFING ATTENDANCE FORM

Conducted by:		**Date Performed:**	
Topics Discussed:	1. Review of the content of the HASP (Required)		
	2.		
	3.		
	4.		

Printed Name	Signature	Representing

ATTACHMENT 2

DAILY QUALITY CONTROL REPORT

DAILY QUALITY CONTROL REPORT

Date:	Report No.:
PM:	Day:
Location:	Weather:
Project:	
Job No.:	Wind:
	Humidity:

Personnel Onsite:

Equipment Onsite:

Work Performed (including sampling):

QC Activities (including field calibrations):

DAILY QUALITY CONTROL REPORT (continued)

H&S Levels and Activities:

Problems Encountered and Corrective Action Taken:

Special Notes:

Tomorrow's Expectations:

Prepared by: ______________________ Title: ______________________

Distribution:
1. Project Manager (via email)
2. Project Manager
3. Field Office
4. Project File

ATTACHMENT 3

EXAMPLE LITHOLOGIC LOG FORM

	Client:	**BORING ID:**
	Project Number:	
	Site Location:	
	Coordinates: *Elevation:*	*Sheet: 1 of 1*
	Drilling Method:	*Monitoring Well Installed:*
	Sample Type(s): *Boring Diameter:*	*Screened Interval:*

Weather:	*Logged By:*	*Date/Time Started:*	*Depth of Boring:*
Drilling Contractor:	*Ground Elevation:*	*Date/Time Finished:*	*Water Level:*

Depth (ft)	Geologic sample ID	Sample Depth (ft)	Blows per 6"	Recovery (inches)	Headspace (ppm)	U.S.C.S	**MATERIALS: Color, size, range, MAIN COMPONENT, minor component(s), moisture content, structure, angularity, maximum grain size, odor, and Geologic Unit (If Known)**	Lab Sample ID	Lab Sample Depth (Ft.)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

NOTES:

Checked by ___________________________ Date:________________

Date	Time	Depth to groundwater while drilling

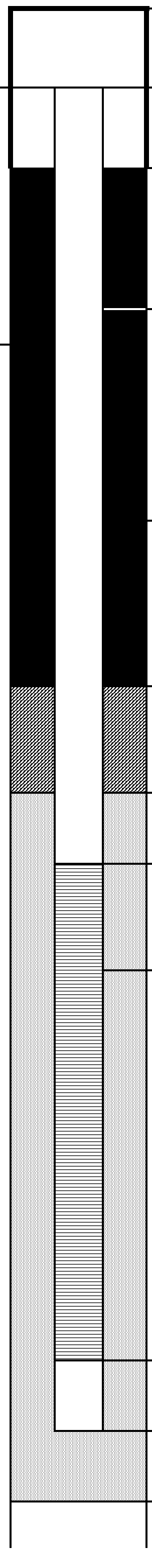
ATTACHMENT 4

EXAMPLE WELL CONSTRUCTION LOG FORM

	Client:	***WELL ID:***
	Project Number:	
	Site Location:	*Date Installed:*
	Well Location: *Coords:*	*Inspector:*
	Method:	*Contractor:*

MONITORING WELL CONSTRUCTION DETAIL

	Depth from G.S. (feet)	Elevation(feet) Datum ______
Top of Steel Guard Pipe	______	______
Top of Riser Pipe	______	______
Ground Surface (G.S.)	0.0	______
Bottom of Steel Guard Pipe	______	______
Top of Bentonite	______	______
Top of Sand	______	______
Top of Screen	______	______
Stabilized Water Level	______	______
Bottom of Screen	______	______
Bottom of Tail Pipe:	______	______
Bottom of Borehole	______	______



Measuring Point for Surveying & Water Levels

Cement, Bentonite, Bentonite Slurry Grout, or Native Materials

______ % Cement

______ % Bentonite

______ % Native Materials

Riser Pipe:

Length ______

Inside Diameter (ID) ______

Type of Material ______

Bentonite Seal Thickness ______

Screen:

Length ______

Inside Diameter (ID) ______

Slot Size ______

Type of Material ______

Type/Size of Sand ______

Sand Pack Thickness ______

Borehole Diameter: ______

Approved:

______ Signature

______ Date

Describe Measuring Point:

______

ATTACHMENT 5

GROUNDWATER SAMPLING AND WELL DEVELOPMENT FORMS

Well/Piezo ID:

Ground Water Sample Collection Record

Client: ______________________ Date: ________
Project No: ______________________ Time: Start ________ am/pm
Site Location: ______________________ Finish ________ am/pm
Weather Conds: ______________ Collector(s) ______________

WATER LEVEL DATA: (measured from Top of Casing) Well ☐ Piezometer ☐

a. Total Well Length ________
b. Water Table Depth ________
c. Casing Material ________
d. Casing Diameter ________
r = casing radius (ft)
L= length of water column (ft)
e. Length of Water Column ____________
f. Calculated Well Volume ________ gal
(WV) = 3.14 * r^2 * L * 7.48 gal./ft^3 =

WELL PURGING DATA

a. Purge Method ______________________

b. Acceptance Criteria defined (from workplan)
- Minimum Required Purge Volume (@ _______ well volumes) ____________
- Maximum Allowable Turbidity ________ NTUs
- Stabilization of parameters ________ %

c. Field Testing Equipment Used: Make Model Serial Number

d. Field Testing Equipment Calibration Documentation Found in Field Notebook # _______ Page #_______

Time	Volume Removed (gal)	T° (C/F)	pH	Spec. Cond (umhos)	Turbidity (NTUs)	DO	Color	Odor	Other

e. Acceptance criteria pass/fail

	Yes	No	N/A
Has required volume been removed	☐	☐	☐
Has required turbidity been reached	☐	☐	☐
Have parameters stabilized	☐	☐	☐

If no or N/A - Explain below.

SAMPLE COLLECTION: Method: ______________________

Sample ID	Container Type	No. of Containers	Preservation	Analysis	Time

Comments ______________________

Signature ______________________ Date ______________________

WELL DEVELOPMENT LOG

Well ID:	______	**Screened Interval (ft):**	______	**Well Diameter (in)**	______
Date:	______	**Pump Depth (ft):**	______	**Static Water Level (ft):**	______
Sample ID:	______	**Flow Rate (gpm)**	______	**Standing Water (ft):**	______
Time:	______	**Purging Device:**	______	**One Well Volume (gal):**	______
Method:	______	**Water Level Instrument:**	______	**OVA Reading at TOC:**	______
Technician:	______	**Water Quality Meter(s):**	______	**OVA Reading in BZ:**	______

Time	Volume Purged (gal)	Flow Rate (gpm)	Water Level (feet - TOC)	SC (µS/cm)	pH	Temp	ORP (mV)	Turbidity (NTU)	Other	Comments
			± 0.1 ft	5%	± 0.1	± 0.1 ºC	5%	< 10 NTU		
Final Field Parameter Measurements										

Comments: ______

ATTACHMENT 6

AQUIFER TESTING FORM

AQUIFER TEST DATA SHEET
(OBSERVATION WELLS)

Page ___ of ___

PROJECT NAME: ______________ PROJECT NO: ______________________ PIEZO NO: ______________________

DATE: ______________________ PUMP DEPTH: ______________________ TEST NO: ______________________

TYPE OF TEST: ______________ PUMPED WELL NO: ______________________ DISTANCE FROM PUMPING WELL: ______________

MEASURING EQUIPMENT: ______________________ HYDROGEOLOGIST: ______________________

Time Data Pump On: Date/Time_________ Pump Off: Date/Time_________ Duration of Aquifer Test: Pumping:_________ Recovery:________		Water Level Data Pretest Water Level_______________ Static Water Level:_______________ Measuring Point:_________________ Elevation of Measuring Point:__________			Time Data Continuation		Water Level Data Continuation		
Date	Time	Depth to Water (ft)	Pressure Transducer (XD)	Flow Rate (gpm)	Date	Time	Depth to Water (ft)	Pressure Transducer (XD)	Flow Rate (gpm)

Conversion Factors: 1 PSI = 2.31 feet 1 cubic foot = 7.48 gallons

ATTACHMENT 7

SAMPLING DOCUMENTATION AND TRACKING FORM

Sample Tracking and Documentation Form

Project: ______________________________ **Site:** ______________________________

Location ID	Sample ID	Method	Matrix	Date Sampled	Time Sampled	Date Shipped	Cooler No.	Lab Dest.	Fedex Tracking No.	QA/QC Samples

Field Duplicates:

Splits (LIMS # _______________):

STANDARD OPERATING PROCEDURES

SOP-15

FIELD LOGBOOK

STANDARD OPERATING PROCEDURES

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FIELD LOGBOOK

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

The field logbook is a controlled document that contains information about all major on-site activities associated with investigation and remediation projects. The field logbook serves as the primary documentation of all field activities and events. Information recorded in the field logbook is described in Section 4.0, Methods. Site-specific procedures described in project work plans supersede this Standard Operating Procedure (SOP). Some site conditions and/or client requirements may necessitate deviations from this SOP.

The site logbook is initiated at the start of the first on-site activity (e.g., initial reconnaissance survey or site walk). Entries are made each day field activities occur. The site logbook is part of the permanent project file maintained by AECOM, and is submitted to the project manager, who sends it to the project file at the completion of field activities. The site logbook may be admitted as evidence in cost recovery or other legal proceedings, so it is critical that this document be properly maintained.

2.0 DEFINITIONS

Field Logbook	The field logbook (also called field notebook) is a bound, waterproof notebook with consecutively numbered pages that cannot be removed.

3.0 RESPONSIBILITIES

Field logbooks are issued to field team members by the field team leader (FTL) or Project Manager. Each field team member in possession of a field logbook is responsible for keeping it current, accurate, straightforward, and relevant (see Section 4.0, Methods), and for submitting the field logbook to the FTL or Project Manager when the field work is completed. The Project Manager or designee reviews the field logbook for completeness, legibility, and relevance at the end of the field effort.

4.0 METHODS

During each field day, all site activities, personnel, visitors, and problems are recorded in the field logbook. The following paragraphs include lists of types of information included, when applicable, and methods for maintaining the field logbook.

The cover of each site logbook contains the following information:

- project name

- client name (Tronox)
- Tronox Contractors project number
- project manager's name
- applicable work plan (s)
- sequential book number
- start date
- end date

The beginning of each daily entry includes the following:

- date
- day of week
- location
- personal protective equipment (PPE) level
- start time
- weather
- personnel
- subcontractors
- visitors
- equipment
- Tronox Contractors job number and cost code for that day's activities

Daily site logbook entries include but are not limited to the following, as applicable:

- arrival and surveying, decontamination, inspection, or other field activity

- equipment calibration
- materials used
- sampling activities and methods
- sample numbers, dates, times, locations, and analyses
- sketches of work locations, sample locations, excavations, etc.
- sketches of well construction details
- sample shipment information (chain-of-custody form numbers, carrier, time)
- start and completion times of each work activity
- storage and disposal of wastes
- field measurements
- health and safety issues (PPE level, time of tailgate safety meeting, etc.)
- unusual events
- accidents and near misses
- work progress
- work problems
- corrective actions
- variations from project plans or standard procedures
- communication with the client or others
- communication with the project manager or other Tronox Contractors staff
- references to other project logs (purge, sample, equipment calibration, quality control, photograph, equipment, borehole, construction, development, etc.)

Because the site logbook and its contents are admissible as evidence in legal proceedings, the following guidelines are also important:

- Unnecessary or irrelevant information or opinions are not recorded.
- Language used in the site logbook is always professional.
- Pages are not removed from the site logbook.
- All entries are in waterproof blue or black ink.
- The person entering information signs each page on which information is recorded.
- Blank portions of pages, and pages that have been inadvertently left blank, are crossed out and signed.
- The words “End of Day” and the signature of the person making the entry appear at the end of each daily entry.
- The field logbook is reviewed and signed by the FTL or Project Manager when the field work is completed.

STANDARD OPERATING PROCEDURES

SOP-17

SOIL LOGGING

STANDARD OPERATING PROCEDURES

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SOIL LOGGING

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) is applicable to logging soils at all sites requiring soil investigation by AECOM personnel. The SOP is based on the Unified Soils Classification System (USCS) and the American Society for Testing and Materials (ASTM) Standard D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM, 2000). Variance from the logging procedures described herein shall be warranted only if specifically required in writing by a particular client or regulatory agency. A solid working knowledge of this SOP is important for Tronox Contractors field personnel to standardize logging procedures and to enable subsequent correlations between borings at a site, allowing for accurate and thorough site characterization.

The information in this SOP is summarized in two soil logging field guides (attached). Laminated copies of these guides are available for field personnel; use of the field guides is strongly recommended. Other field guidance references may also be used according to personal preference; however, such references should be based on the USCS. Note that many references (for example, AGI Data Sheet grain-size scales) base soil classifications on the Wentworth Scale. Such scales may vary significantly from the USCS and may lead to inaccurate or inconsistent soil descriptions.

2.0 DEFINITIONS

Use of the USCS requires familiarity with the grain size ranges that define a particular type of soil, as well as several other physical characteristics. The grain size definitions and physical characteristics upon which soil descriptions are based are presented below. This information is also presented in tabular format on the field guides.

2.1 GRAIN SIZES

USCS grain sizes are based on U.S. standard sieve sizes, which are named as follows:

- Standard sieves with larger openings are named according to the size of the openings in the sieve mesh. For example, a "3-inch" sieve contains openings that are 3 inches square.

- Standard sieves with smaller openings are given numbered designations that indicate the number of openings per inch. For example, a "No. 4" sieve contains 4 openings per inch.

The following grain size definitions are paraphrased from the ASTM Standard D2488-00. Field personnel should familiarize themselves with the grain size definitions and refer to the appropriate field guide for a visual reference.

Boulders	Particles of rock that will not pass a 12-inch (300-mm) square opening
Cobbles	Particles of rock that will pass a 12-inch (300-mm) square opening and be retained on a 3-inch (75-mm) sieve
Gravel	Particles of rock that will pass a 3-inch (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions: – Coarse gravel passes a 3-inch (75-mm) sieve and is retained on a 3/4-inch (19-mm) sieve – Fine gravel passes a 3/4-inch (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve
Sand	Particles of rock that will pass a No. 4 (0.19-inch or 4.75-mm) sieve and be retained on a No. 200 (0.003-inch or 75-µm) sieve with the following subdivisions: – Coarse sand passes a No. 4 (0.19-inch or 4.75-mm) sieve and is retained on a No. 10 (0.08-inch or 2-mm) sieve – Medium sand passes a No. 10 (0.08-inch or 2-mm) sieve and is retained on a No. 40 (0.017-inch or 425-µm) sieve – Fine sand passes a No. 40 (0.017-inch or 425-µm) sieve and is retained on a No. 200 (0.003-inch or 75-µm) sieve
Silt	Soil passing a No. 200 (0.003-inch or 75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dried. Individual silt particles are not visible to the naked eye.
Clay	Soil passing a No. 200 (0.003 inch or 75-µm) sieve that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air-dried. Individual clay particles are not visible to the naked eye.

2.2 PHYSICAL CHARACTERISTICS

The following physical characteristics are used in the USCS classification for fine-grained soils. A brief definition of each physical characteristic is presented below. Tables 1 through 4 present descriptions of field tests that may be performed to estimate these properties in a field sample. However, with the exception of plasticity, the tests are generally too time consuming to perform regularly in the field. A determination of the type of fine-grained soil present in the sample can generally be made on the basis of plasticity, as described in Section 4.1.2.

Dry Strength	The ease with which a dry lump of soil crushes between the fingers (Table 1).
Dilatancy Reaction	The speed with which water appears in a moist pat of soil when shaking in the hand, and disappears while squeezing (Table 2).
Toughness	The strength of a soil, moistened near its plastic limit, when rolled into a 1/8-inch diameter thread (Table 3).

Plasticity	The extent to which a soil may be rolled into a 1/8-inch. thread, and re-rolled when drier than the plastic limit (Table 4).

Table 1. Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

Table 2. Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

Table 3. Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

Table 4. Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

3.0 RESPONSIBILITIES

This section presents a brief definition of field roles and the responsibilities generally associated with them. This list is not intended to be comprehensive; additional personnel may be involved in other aspects of the project. Project team member information is usually included in project-specific plans (e.g., work plan, field sampling plan, quality assurance plan), and field personnel should always consult the appropriate documents to determine project-specific roles and responsibilities. In addition, one person may serve in more than one role on any given project.

The **Project Manager** or **Task Leader** defines the objectives of field work; selects site-specific monitoring well design and installation methods with input from the Project Hydrogeologist and Field Team Leader; and maintains close supervision of activities and progress.

The **Project Hydrogeologist** selects site-specific drilling/sampling options, helps prepare technical provisions for drilling.

The **Field Team Leader** implements the selected drilling program and may also review boring logs.

The **Drilling Rig Geologist** records the boring logs and supervises the drilling subcontractor.

The **Quality Manager** performs field and logging process audits.

4.0 SOIL LOGGING PROCEDURES

The following aspects of a project must be considered before sampling and soil logging commences. This information is generally summarized in a project-specific work plan or field sampling plan, which should be thoroughly reviewed by field personnel prior to the initiation of work.

- Purpose of the soil logging (e.g., initial investigation, subsequent investigation, remediation)
- Known or anticipated hydrogeologic setting including lithology (consolidated/unconsolidated, depositional environment, presence of fill material), physical characteristics of the aquifer (porosity/permeability), type of aquifer (confined/unconfined), recharge/discharge conditions, aquifer thickness and ground water/surface water interrelationships
- Drilling conditions
- Previous soil boring or borehole geophysical logs
- Soil sampling and geotechnical testing program

- Characteristics of potential chemical release(s) (chemistry, density, viscosity, reactivity, and concentration)
- Health and Safety protection requirements
- Regulatory requirements

The procedures used to determine the correct soil sample classification are described below. These procedures are presented in tabular and flow chart form on the field guides.

4.1 Field Classification of Soils

The following soil classification procedures are based on the ASTM Standard D2488-00 for visual-manual identification of soils (ASTM, 2000). The flow chart is Attachment 1 to this SOP and presented in the field guide can be used to assign the appropriate soil group name and symbol. When naming soils, the proper USCS soil group name is given, followed by the group symbol. For clarity, it is recommended that the group symbol be placed in parentheses after the written soil group name.

Soil identification using the visual-manual procedures is based on naming the portion of the soil sample that will pass a 3-inch (75-mm) sieve. Therefore, before classifying a soil, any particles larger than 3 inches (cobbles and boulders) should be removed, if possible. Estimate and note the percentage of cobbles and boulders.

Using the remaining soil, the next step is to estimate the percentages, by dry weight, of the gravel, sand, and fine fractions (particles passing a No. 200 sieve). The percentages are to be estimated to the closest 5 percent. In general, the soil is *fine-grained* (e.g., a silt or a clay) if it contains 50 percent or more fines, and *coarse-grained* (e.g., a sand or a gravel) if it contains less than 50 percent fines. If one of the components is present but estimated to be less than 5 percent, its presence is indicated by the term *trace*. For example, “trace of fines” would be added as additional information following the formal USCS soil description.

4.1.1 Procedure for Identifying Coarse-Grained Soils

Coarse-grained soil contains less that 50 percent fines. If it has been determined that the soil contains less than 50 percent fines, the soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand. The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

If the soil is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse-grained constituent, the words "with gravel" or "with sand" is added to the group name. For example: "gravel with sand (GP)." If the sample contains any cobbles or boulders, the words “with cobbles” or “with cobbles and boulders” are added to the group name. For example: "silty gravel with cobbles (GM)."

5 Percent or Less Fines

The soil is a “clean gravel” or “clean sand” if the percentage of fines is estimated to be 5 percent or less. “Clean” is not a formal USCS name, but rather a general descriptor for implying little to no fines. Clean sands and gravels are given the USCS designation as either *well-graded* or *poorly-graded*, as described below.

Identify the soil as a *well-graded gravel* (GW) or as a *well-graded sand* (SW) if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes. Identify the soil as a *poorly-graded gravel* (GP) or as a *poorly-graded sand* (SP) if it consists predominantly of one grain size (uniformly graded), or has a wide range of sizes with some intermediate sizes obviously missing (gap- or skip-graded).

Note: When using the USCS designation, keep in mind the difference between grading and sorting. The term grading is used to indicate the range of particles contained in the sample. For example, a poorly-graded sand containing predominantly one grain size would be considered well-sorted, and vice-versa. One notable exception to this general rule is a skip-graded (bimodally distributed) sample; a sand containing two distinct grain sizes would be considered both poorly-sorted and poorly-graded. The USCS uses only the *grading* descriptor in soil naming, not the sorting descriptor.

≥ 15 Percent Fines

The soil is a *silty* or *clayey gravel* or a *silty* or *clayey sand* if the percentage of fines is estimated to be 15 percent or more. For example, identify the soil as *clayey gravel* (GC) or a *clayey sand* (SC) if the fines are clayey. Identify the soil as a *silty gravel* (GM) or a *silty sand* (SM) if the fines are silty. The coarse grained descriptor "poorly-graded" or "well-graded" is not included in the soil name, but rather, should be included as additional information following the formal USCS soil description.

>5 Percent but <15 Percent Fines

If the soil is estimated to contain greater than 5 percent but less than 15 percent fines, give the soil a dual identification using two group symbols. The first group symbol corresponds to a clean gravel or sand (GW, GP, SW, SP) and the second symbol corresponds to a clayey/silty gravel or sand (GC, GM, SC, SM). The group name corresponds to the first group symbol, and include the words "poorly-graded" or "well-graded", plus the words "with clay" or "with silt" to indicate the character of the fines. For example, "poorly-graded gravel with silt (GP-GM)".

4.1.2 Procedure for Identifying Fine-Grained Soils

Fine-grained soil contains 50 percent or more fines. The USCS classifies inorganic fine-grained soils according to their degree of plasticity (no or low plasticity, indicated with an "L"; or high plasticity, indicated with an "H") and other physical characteristics (defined in Section 2.2 and Tables 1 through 4). As indicated in Section 2.2, the field tests used to determine dry strength, dilatancy, and toughness are generally too time consuming to be performed on a routine basis. Field personnel should be familiar with the definitions of the physical characteristics and the concepts of the field tests; however, field classifications will generally be based primarily on plasticity. If precise engineering properties are necessary for the project (i.e., construction, modeling, etc.), geotechnical samples should be collected for laboratory testing. The results of the laboratory tests should be compared to the field logging results. Soil classifications based on plasticity are as follows:

- Lean clay (CL) soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity.
- Fat clay (CH) soil has high to very high dry strength, no dilatancy, and high toughness and plasticity.
- Silt (ML) soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic.
- Elastic silt (MH) soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity. They will air dry more quickly than lean clay and have a smooth, silky feel when dry.
- Organic soil (OL or OH) soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Organic soils will often change color, from black to brown for example, when exposed to the air. Organic soils normally will not have a high toughness or plasticity.

4.1.3 Other Modifiers For Use With Fine-Grained Soils

15 percent to 25 percent coarse-grained material

If the soil is estimated to have 15 percent to 25 percent sand or gravel, or both, the words "with sand" or "with gravel" (whichever is predominant) is added to the group name. For example: "lean clay with sand (CL)" or "silt with gravel (ML)". If the percentage of sand is equal to the percentage of gravel, use "with sand."

≥30 percent coarse-grained material

If the soil is estimated to have 30 percent or more sand or gravel, or both, the words "sandy" or "gravelly" is added to the group name. Add the word "sandy" if there appears to be the same or more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy silt (ML)", or "gravelly fat clay (CH)".

4.1.4 Procedure for Identifying Borderline Soils

To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example, a soil containing an estimated 50 percent silt and 50 percent fine grained sand may be assigned a borderline symbol "SM/ML". Borderline symbols should not be used indiscriminately. Every effort should be made to first place the soil into a single group and then to estimate percentages following the USCS soil description.

4.2 Descriptive Information for Soils

After the soil name and symbol are assigned, the soil color, consistency/density, and moisture content is to be described <u>in that order</u>. Other information is presented later in the description, as applicable.

4.2.1 Color

Color is an important property in identifying organic soils, and may also be useful in identifying materials of similar geologic or depositional origin in a given location. The Munsell Soil Color Charts should be used, if possible.

When using the Munsell Soil Color Charts, a general color, such as brown, gray, red, is first assigned to the soils. Then go to the correct area in the charts and assign the applicable color name and Munsell symbol. The ability to detect minor color differences varies among people, and the chance of finding a perfect color match in the charts is rare. Keeping this in mind should help field personnel avoid spending unnecessary time and confusion going through the chart pages. In addition, attempting to describe detail beyond the reasonable accuracy of field observations could lead to making poorer soil descriptions than by simply expressing the dominant colors (Munsell Soil Color Chart, 1992).

If the color charts are not being used or are unavailable, again attempt to assign general colors to soils. Comparing a particular soil sample to samples from different locations in the borehole will help keep the eye "calibrated". For example, by holding two soils together, it may become evident that one is obviously greenish-brown, while another is reddish.

4.2.2 Consistency/Density

For intact fine-grained soil, describe consistency as very soft, soft, medium stiff, stiff, very stiff, or hard, based on the blows per foot using a 140 pound hammer dropped 30 inches (Table 5). If blow counts are not available, perform the field test described in Table 6 to determine consistency.

For coarse-grained soils, describe density based on blows per foot as very loose, loose, medium dense, dense, and very dense (Table 5). If blow counts are not available, attempt to estimate the soil density by observation, since a practical field test is not available. Be sure to clearly indicate on the field boring log if blow counts could not be obtained.

Table 5. Density/Consistency Based on Blow Counts

Density (Sand and Gravel) Blows/ft[a]				Consistency (Silt and Clay) Blows/ ft[a]			
Term	**1.4" ID**	**2.0" ID**	**2.5" ID**	**Term**	**1.4" ID**	**2.0" ID**	**2.5" ID**
Very Loose	0 – 4	0 – 5	0 – 7	Very Soft	0 – 2	0 – 2	0 – 2
Loose	4 – 10	5 – 12	7 – 18	Soft	2 – 4	2 – 4	2 – 4
Medium Dense	10 – 29	12 – 37	18 – 51	Medium Stiff	4 – 8	4 – 9	4 – 9
Dense	29 – 47	37 – 60	51 – 86	Stiff	8 – 15	9 – 17	9 – 18
Very Dense	>47	>60	>86	Very Stiff	15 – 30	17 – 39	18 – 42
				Hard	30 – 60	39 – 78	42 – 85
				Very Hard	>60	>78	>85

[a] 140 lb. Hammer dropped 30 inches

Table 6. Criteria for Describing Consistency

Description	Criteria
Very Soft	Thumb will penetrate soil more than 1 inch (25 mm)
Soft	Thumb will penetrate soil about 1 inch (25 mm)
Firm	Thumb will indent soil about ¼ inch (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very Hard	Thumbnail will not indent soil

4.2.3 Moisture

Describe the moisture condition of the soil as dry (absence of moisture, dusty, dry to the touch), moist (damp but no visible water), or wet (visible free water, saturated).

4.2.4 Grain Size

Describe the maximum particle size found in the sample in accordance with the following information:

- Sand-size—describe as fine, medium, or coarse. (See Section 2 for sand size definitions.)

- Gravel-size—describe the diameter of the maximum particle size in inches.
- Cobble or boulder-size—describe the maximum dimension of the largest particle.

For gravel and sand components, describe the range of particle sizes within each component. For example, "about 20 percent fine to coarse gravel, about 40 percent fine to coarse sand".

4.2.5 Odor

Due to health and safety concerns, **NEVER** intentionally smell the soil. This could result in exposure to volatile contaminants that may be present in the soil. If, however, an odor is noticed, it should be described if organic or unusual (e.g., petroleum product or chemical). Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation (sometimes a hydrogen sulfide [rotten egg] smell). Organic vapor readings from a photoionization detector (PID) or similar instrument should be noted on the field boring log (Note: see SOP-39 for additional information on PID principles and procedures.). The project-specific health and safety plan should then be consulted to determine the appropriate level of protection necessary to continue field work.

4.2.6 Cementation

Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the following criteria:

- Weak—crumbles or breaks with handling or little finger pressure
- Moderate—crumbles or breaks with considerable finger pressure
- Strong—will not crumble or break with finger pressure

The presence of calcium carbonate may be confirmed on the basis of effervescence with dilute hydrochloric acid (HCl) if calcium carbonate or caliche is believed to be present in the soil. Proper health and safety precautions must be followed when mixing, handling, storing, or transporting HCl. For further information, see I/HW Health and Safety Procedure 630.24, "Procedure for Hydrochloric Acid Handling for Soil Logging."

4.2.7 Angularity

The angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded are described in accordance with the following criteria:

- Angular particles have sharp edges and relatively planar sides with unpolished surfaces.

- Subangular particles are similar to angular description but have rounded edges.
- Subrounded particles have nearly plane sides but have well-rounded corners and edges.
- Rounded particles have smoothly curved sides and no edges.

A range of angularity may be stated, such as "subrounded to rounded."

4.2.8 Structure

Describe the structure of intact soils in accordance with the criteria in Table 7.

Table 7. Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying materials or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying materials or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down in small angular lumps that resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogenous	Same color and appearance throughout

4.2.9 Lithology

Describe the lithology (rock or mineral type) of the sand, gravel, cobbles, and boulders, if possible. It may be difficult to determine the lithology of fine and medium-grained sand or particles that have undergone alteration.

4.2.10 Additional Comments

Additional comments may include the presence of roots or other vegetation, fossils or organic debris, staining, mottling, or oxidation; difficulty in drilling, and caving or sloughing of the borehole walls. Also, when drilling in an area known or suspected to contain imported fill material, every effort should be made to identify the contact between fill and native soils. If a soil is suspected to be fill, this should be clearly indicated on the log following the soil description. Stratigraphic units and their contacts should be noted wherever possible.

4.2.11 Bedrock Descriptions

If the soil boring penetrates bedrock, the boring log should indicate the rock type, color, weathering, fracturing, competency, mineralogy, age (if known), and any other miscellaneous information available. Definitions of these terms are not included in this SOP, because only a small percentage of drilling activities conducted by Tronox Contractors for Tronox penetrate bedrock. If bedrock drilling is planned, the field team leader, with the concurrence of the project manager, makes arrangements to provide the field team with appropriate definitions and indicate the types with information that should be collected.

4.3 Additional Boring Log Information

The boring log form (example shown in Attachment 2) should be used unless a different form is required by the client. Information in the log heading should be complete and accurate. In addition to soil descriptions, the following information should be included, at a minimum:

- Boring or monitoring well number
- Project name and job number
- Site name
- Name of individual who logged the boring
- Name of boring log reviewer
- Drilling contractor
- Drill rig type and method of drilling (for example, "CME 75, hollow stem auger")
- Name of drilling company
- Name of driller and helper
- Borehole diameter and drill bit type
- Type of soil sampler (for example, Modified California, continuous core, etc.)
- Time and date that drilling started and finished
- Time and date that the well was completed or the soil boring backfilled, as appropriate
- Method of borehole abandonment
- Sketch map of boring or well location with estimated distances to major site features such as property lines or buildings, and north arrow

Soil sample information should include the depth interval that was sampled, the blow counts per 6 inches, the amount of soil recovered, and the portion submitted for analysis or testing, if any. The sample identification number may also be noted on the log.

The degree to which soil samples are collected during a field effort depends on the overall scope and purpose of the investigation, which should be clearly defined before the field effort commences. Additional soil samples may need to be collected if, for example, soils are very heterogeneous or unexpected conditions such as perched water zones or zones of contamination are encountered.

If groundwater is encountered during drilling, the depth to water and the time and date of the observation should be recorded. If the first water encountered is a perched zone, the depth, time, and date that any additional groundwater zones are encountered should also be recorded. Depth to water after drilling, the measuring point, and the date and time of the measurement(s) must be noted. Additional measurements of depth to groundwater, including depth and time, may be beneficial.

If a monitoring well is installed, the construction details such as casing material type, screen length and slot size should be noted on the boring log. The annulus fill material (sand pack, bentonite, grout, etc.) should also be recorded.

If the soil boring is abandoned, the backfill material used (e.g., grout, bentonite, etc.) and volume used, should be recorded on the boring log.

5.0 OTHER APPLICABLE SOPs

Several other AECOM SOPs contain information related to soil boring and logging activities. The following is a list of these SOPs:

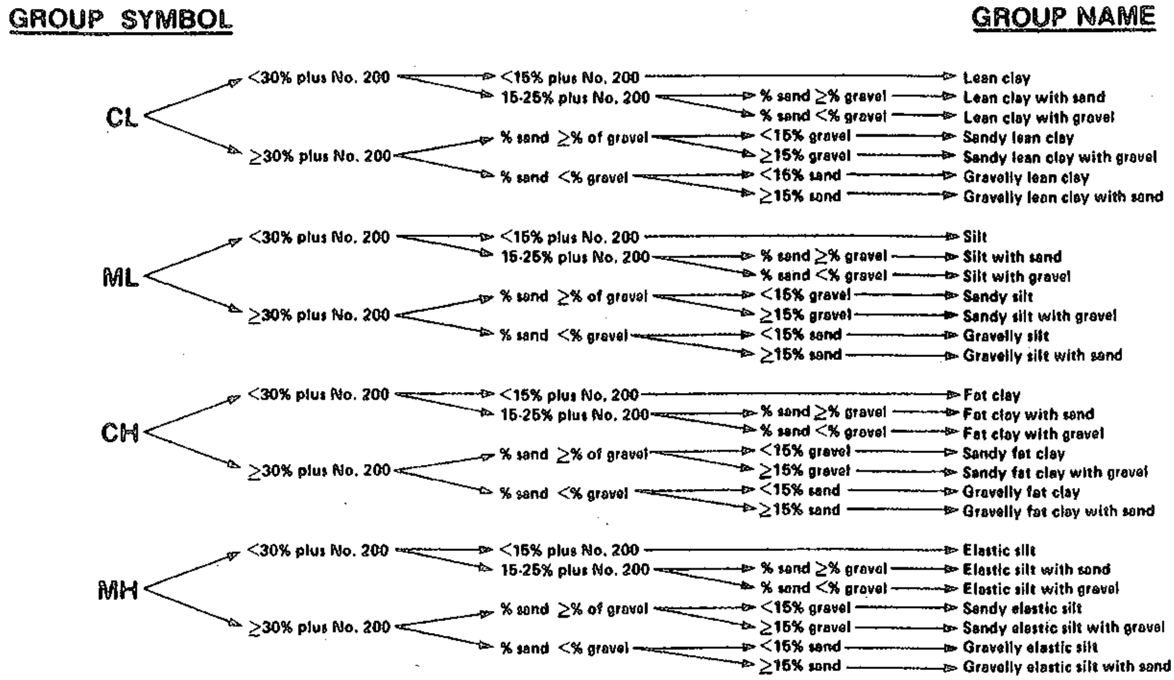
- Drilling Methods
- Monitoring Well Design and Installation
- Sample Management/Preservation
- Soil Sampling
- Trenching and Test Pitting
- Field Documentation
- Site Logbook

6.0 REFERENCES

ASTM, 2000, Standard D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

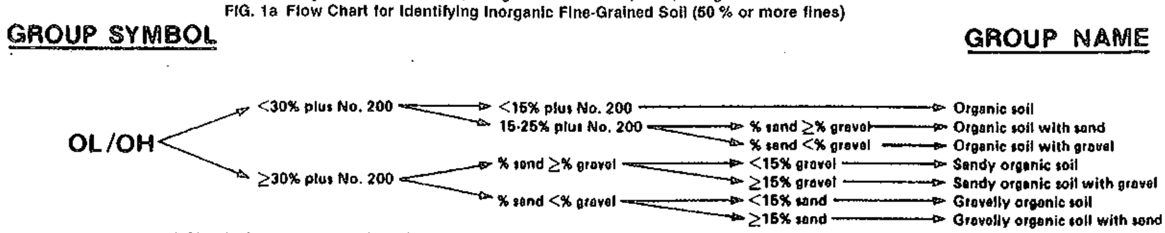
ATTACHMENT 1

FIELD CLASSIFICATION GUIDES

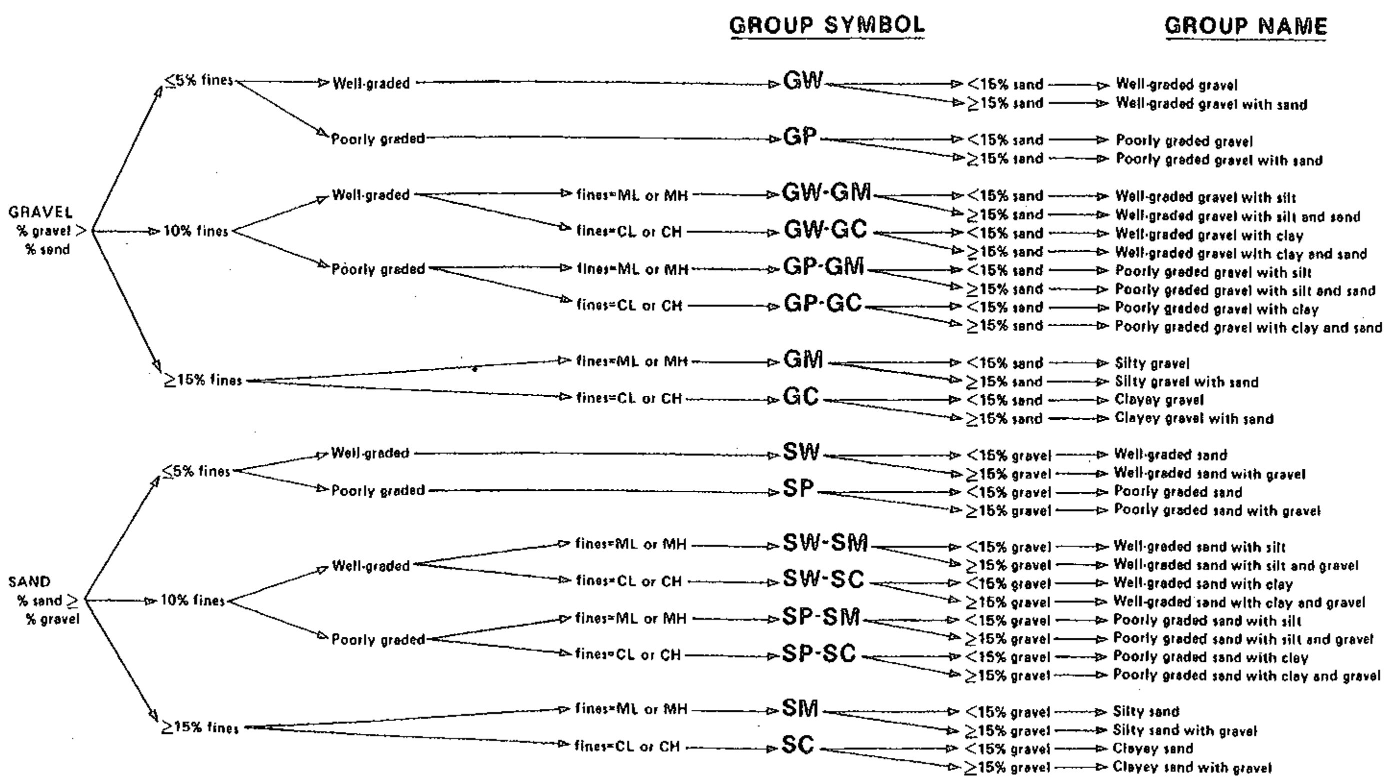


NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.



ATTACHMENT 2

EXAMPLE BORING LOG FORM

	Client:	**_BORING ID:_**
	Project Number:	
	Site Location:	
	Coordinates: *Elevation:*	*Sheet: 1 of 1*
	Drilling Method:	*Monitoring Well Installed:*
	Sample Type(s): *Boring Diameter:*	*Screened Interval:*
Weather:	*Logged By:* / *Date/Time Started:*	*Depth of Boring:*
Drilling Contractor:	*Ground Elevation:* / *Date/Time Finished:*	*Water Level:*

Depth (ft)	Geologic sample ID	Sample Depth (ft)	Blows per 6"	Recovery (inches)	Headspace (ppm)	U.S.C.S	**MATERIALS: Color, size, range, MAIN COMPONENT, minor component(s), moisture content, structure, angularity, maximum grain size, odor, and Geologic Unit (If Known)**	Lab Sample ID	Lab Sample Depth (Ft.)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

NOTES:

Date	Time	Depth to groundwater while drilling

Checked by ___________________________ Date:________________

STANDARD OPERATING PROCEDURES

SOP-20

FILTER PACK AND WELL SCREEN SLOT SIZE DETERMINATION

STANDARD OPERATING PROCEDURES

SOP-20
FILTER PACK AND WELL SCREEN SLOT SIZE DETERMINATION

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DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDES GENERAL GUIDANCE FOR AECOM PERSONNEL FOR TECHNICAL ISSUES ADDRESSED DURING ENVIRONMENTAL SITE INVESTIGATION AND REMEDIATION ACTIVITIES. IT IS NOTED, HOWEVER, THAT EACH SITE IS UNIQUE AND THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THIS STANDARD OPERATING PROCEDURE. AECOM PERSONNEL RESERVE THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN THEIR SOLE, COMPLETE, AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS, OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This guideline is applicable to the design and installation of permanent monitoring wells. Details regarding design, construction, and installation of monitoring wells are provided in SOP-2, "Groundwater Monitoring Well Design and Installation." Each monitoring well must be designed to suit the hydrogeologic setting, the type of contaminants to be monitored, the overall purpose of the monitoring program, and other site-specific variables. Site-specific objectives for each monitoring well and its respective intended use must be clearly defined before the monitoring system is designed. Additionally, different monitoring wells may serve different purposes and thus require different types of construction. Therefore, attention must be given during all phases of well design to clear documentation of the basis for design decisions, the details of well construction, and the materials to be used. At many sites, there is a precedence as to well slot size and filter pack materials that have been used, and the time consuming process of performing a sieve analysis is not necessary for determining well design details.

2.0 DEFINITIONS

Absorption	The penetration or apparent disappearance of molecules or ions of one or more substances into the interior of a solid or liquid.
Adsorption	A process by which atoms, ions, or molecules are assimilated to the surface of a material Ion-exchange processes involve adsorption.
Annular Sealant	Material used to provide a positive seal between the borehole and the casing of the well. Annular sealants should be impermeable and resistant to chemical or physical deterioration.
Annular Space	The space between the borehole wall and the well casing, or the space between a casing pipe and a liner pipe.
Aquifer	A geologic formation, group of formations, or part of a formation that can yield water to a well or a spring.
Backwashing	A method of filter pack emplacement whereby the filter pack material is allowed to fall freely through the annulus while clean fresh water is simultaneously pumped down the casing.
Bentonite	Hydrous sodium montmorillinite mineral available in powder, granular, or pellet form. It is used to provide a tight seal between the well casing and the borehole.
Bridging	The development of gaps or obstructions in either grout or filter pack materials during emplacement.

Continuous Slot Wire-Wound Well Screen	A well intake that is made by winding and welding triangular-shaped, cold-rolled wire around a cylindrical array of rods. The spacing of each successive turn of wire determines the slot size of the well.
Corrosion	The adverse chemical alteration that reverts elemental metals back to more stable mineral compounds and that affects the physical and chemical properties of the metal.
Filter Pack	Sand, gravel, or glass beads that are uniform, clean, and well-rounded that are placed in the annulus of the well between the borehole wall and the well screen to prevent formation material from entering through the well intake and to stabilize the adjacent formation.
Grout	A fluid mixture of neat cement and water with various additives or bentonite of a consistency that can be forced through a pipe and emplaced in the annular space between the borehole and the casing to form an impermeable seal.
Monitoring Well	A well that is capable of providing a groundwater level and sample representative of the zone being monitored.
Naturally Developed Well	A well construction technique whereby the natural formation materials are allowed to collapse around the well intake and fine formation materials are removed using standard development techniques.
Neat Cement	A mixture of Portland cement and water in the proportion of 5 to 6 gallons of clean water per bag (94 pounds) of cement.
Piezometers	A small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface.
Sieve Analysis	Determination of the particle-size distribution of soil, sediment, or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.
Slurry	A thin mixture of liquid, especially water, and any of several finely divided substances such as cement or clay particles.
Tremie Pipe	A device, usually a small-diameter pipe, which carries grouting materials or filter pack to the bottom of the borehole and that allows pressure grouting from the bottom up without introduction of appreciable air pockets.
Well Cluster	Two or more wells completed (screened) to different depths in a single borehole or in a series of boreholes in close proximity to each other. From these wells, water samples that are representative of different horizons within one or more aquifers can be collected.

Well Point	A sturdy, reinforced well screen or intake that can be installed by being driven into the ground.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** selects the site-specific monitoring well design and installation methods, with input from the site hydrogeologist and field team leader, and maintains close supervision of activities and progress.

The **Site Hydrogeologist/Geologist** selects the site-specific drilling/sampling options and helps prepare technical provisions for the drilling.

The **Field Team Leader** implements the selected drilling program.

The **Drilling Rig Geologist** supervises and/or performs actual monitoring well installation.

4.0 FILTER PACK AND WELL SCREEN DESIGN

A properly designed monitoring well requires that a well screen be placed opposite the zone to be monitored and be surrounded by materials that are coarser and of greater hydraulic conductivity than the natural formation material. Naturally developed wells and wells with artificially introduced filter pack are the two basic types of well designs for unconsolidated or poorly consolidated materials.

4.1 Naturally Developed Wells

In naturally developed wells, the formation materials are allowed to collapse around the well screen. Naturally developed wells can be installed in which natural formation materials are relatively coarse grained, permeable, and of uniform grain size. It is essential that the grain-size distribution of the formation to be monitored is accurately determined by conducting a mechanical (sieve) analysis of samples taken from the interval to be screened. After sieving, a plot of grain size versus cumulative percentage of sample retained on each sieve is made. Well screen slot sizes are based on the grain-size distribution, specifically the effective size (the sieve size that retains 90 percent of the formation material, referred to as D10) and the uniformity coefficient (the ratio of the sieve size that retains 40 percent of the material or D60, to the effective size). A naturally developed well can be justified if the effective grain size is greater than 0.010 inch and the uniformity coefficient is greater than 3.0. The California Department of Toxic Substances Control recommends that an artificial filter pack be used if sieve analysis indicates that a screen slot size of 0.020 inches or less is required to retain 50 percent of the natural formation. The biggest drawback for naturally developed wells is the time required for well development to remove fine-grained formation material.

4.2 Artificially Filter-Packed Wells

Filter packs are installed to create a permeable envelope around the well screen. The use of an artificial filter pack in a fine-grained formation material allows the screen slot size to be considerably larger than if the screen were placed in the formation material without the filter pack. The selection of the filter pack grain size should be based on the grain size of the finest layer to be screened.

Filter pack grain size and well screen slot size should be determined by the grain size distribution of the formation material. The filter pack should be designed first. It is recommended to use a filter pack grain size that is three to five times the average (D50) size of the formation materials. However, this method may be misleading in coarse, well-graded formation materials. Another way to determine filter pack grain size is to take the D30 grain size of the formation materials and multiplying it by a factor of between 3 and 6, with 3 used if the formation is fine and uniform and 6 used if the formation is coarse and nonuniform. For both methods, the uniformity coefficient of the filter pack materials should be as close to 1.0 as possible (2.5 maximum) to minimize particle size segregation during filter pack installation.

The filter pack should extend from the bottom of the well screen to approximately 2 to 5 feet above the top of the screen to account for settlement of the pack material during development and to act as a buffer between the well screen and the annular seal. A secondary filter pack (transitions sand) is sometimes used to prevent annular grout seal materials from migrating into the primary filter pack. The secondary filter pack should extend at least 1 foot above the top of the primary filter pack. It should consist of a uniformly graded fine sand with 100% passing a No. 30 U.S. Standard sieve and less than 2 percent by weight passing the 200 sieve.

Filter pack thickness must be sufficient to surround the well screen but thin enough to minimize resistance to the flow of fine-grained formation material and water into the well during development. American Society of Testing and Materials (ASTM), Designation D 5092-90, recommends a minimum 2-inch thick filter pack between the borehole well and the well casing (ASTM, 1995).

The materials comprising the filter pack should be as chemically inert as possible. It should be comprised of clean quartz sand or glass beads. Filter pack materials usually come in 100-pound bags; these materials are washed, dried, and factory packaged.

The size of well intake openings can only be selected after the filter-pack grain size is specified. The slot size should be such that 90 percent to 100 percent of the filter-pack material is held back by the well screen.

The casing string should be installed in the center of the borehole. This will allow the filter-pack materials to evenly fill the annular space around the screen and ensure that annular seal materials fill the annular space evenly around the casing. If a hollow-stem auger or dual-tube rig is used, the auger or inner tube of the dual tube will adequately centralize the casing string. For other types of drilling, centralizers should be used to ensure the casing string is positioned in the center of the borehole. Centralizers are typically expandable stainless steel metal or plastic that attach to the outside of the casing and are adjustable along the length of the casing. Centralizers are generally attached at the bottom and immediately above the well screen and at 10- or 20-foot intervals along the casing to the surface.

Methods for filter pack emplacement include: 1) gravity (free-fall), 2) tremie pipe, 3) reverse circulation, and 4) backwashing. The latter two techniques are not commonly used for monitoring well construction, since they require the introduction into the borehole of water from a surface source.

Gravity emplacement is only possible in relatively shallow wells with an annular space of more than 2 inches, where the potential occurrence of bridging is minimized. Bridging can result in the occurrence of large unfilled voids in the filter pack or the failure of filter pack materials to reach their intended depth. Gravity emplacement may also cause filter pack gradation. Additionally, formation materials from the borehole wall can become incorporated into the filter pack, potentially contaminating it.

With the tremie emplacement method, the filter pack is poured or slurried into the annular space adjacent to the well screen through a rigid pipe, usually 1.5 inches in diameter. Initially the pipe is positioned so that its end is at the bottom of the annulus. If the filter pack is being installed in a temporarily cased borehole (hollow-stem auger , dual-tube percussion, or air rotary casing hammer) the temporary casing is pulled to expose the screen as the filter-pack material builds up around the well screen. In unconsolidated formations, the temporary casing should only be pulled out 1 to 2 feet at a time to prevent caving. In consolidated or well-cemented formations or in cohesive unconsolidated formations, the temporary casing may be raised well above the bottom of the borehole prior to filter pack emplacement. For deep wells and/or nonuniform filter pack materials, the filter pack may be pressure fed through a tremie pipe with a pump. Emplacement should be continuously monitored with a weighted measuring tape accurate to the nearest 0.1 foot to determine when the filter pack has reached the desired height. After reaching the desired height, the well should be surged for 10-15 minutes, then checked for settling. Add more filter pack as necessary. Record the volume of filter pack used and check against calculated volume of annular space. Most well designs also employ a “secondary” filter pack (transition sand) above the primary filter pack for purposes of reducing bentonite seal and grout migration into the primary filter pack.

If applicable, care must be taken that the filter pack materials are not installed into a hydrostratigraphic unit above or below the specific zone that is targeted for monitoring.

5.0 REFERENCES

American Society for Testing and Materials, 1995. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers*, Designation D 5092-90.

STANDARD OPERATING PROCEDURES

SOP-30

FIELD ANALYTICAL PROCEDURES

(pH, CONDUCTIVITY, TEMPERATURE, ORGANIC VAPOR, AND TURBIDITY)

STANDARD OPERATING PROCEDURES

SOP-30
FIELD ANALYTICAL PROCEDURES
(pH, CONDUCTIVITY, TEMPERATURE, ORGANIC VAPOR, AND TURBIDITY)

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1.0 INTRODUCTION

This Standard Operating Procedure (SOP) is a general reference for the proper equipment and techniques for analytical field screening.

2.0 DEFINITIONS

Chain of Custody	A method for documenting the history and possession of a sample from the time of its collection through its analysis and data reporting to its final disposition.
Conductivity (electrical)	A measure of the quantity of electricity transferred across a unit area, per unit potential gradient, per unit time. It is the reciprocal of resistivity.
pH	A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. (Original designation for potential of hydrogen.)
Turbidity	Cloudiness in water due to suspended and colloidal organic and inorganic material.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** selects site-specific water sampling methods, locations for sampling and analytes to be screened (with input from the Field Team Leader or Superintendent and project geologist), and is responsible for project quality control and field audits.

The **Field Team Leader** implements the water sampling program; supervises the project geologist/hydrogeologist and sampling technician; ensures that proper chain-of-custody procedures are observed; and that samples are sampled, transported, packaged, and shipped in a correct and timely manner.

The **Project Geologist/Hydrogeologist** ensures proper collection, documentation, and storage of groundwater samples prior to shipment to the laboratory, and assists in the packaging and shipment of samples.

The **Field Sampling Technician** assists the project geologist/hydrogeologist in the completion of tasks and is responsible for the proper use, decontamination, and maintenance of groundwater sampling equipment.

4.0 FIELD ANALYTICAL PROCEDURES

The pH, specific conductance, water temperature, and turbidity (in accordance with American Society for Testing Materials [ASTM] D-1889) will be periodically measured and recorded on a log sheet. The following sections briefly outline the procedures for measuring these parameters. This SOP is not intended to be all-inclusive, but is intended to provide general guidance regarding these procedures. Specific SOPs have applicable measurements for the type of field activity and will contain any deviations or amendments to these procedures. All field instruments shall be calibrated according to manufacturer's instructions. All field instruments will be calibrated prior to use. Calibration information shall be recorded in the field logbook. Detailed information regarding maintenance and servicing is available in the operation manual for each meter used. Servicing and maintenance information will be recorded in the field logbook..

4.1 pH

Obtain a sample where pH, temperature, and specific conductance are at equilibrium. Equilibrium is established as follows: pH variation is less than 0.2 pH units, temperature variation is less than 0.5 degrees Celsius (C), and less than 10 percent variation in specific conductance. Equilibrium will be established by three consecutive readings.

4.2 Conductivity

Obtain a sample where equilibrium is as follows: pH variation is less than 0.2 pH units, temperature variation is less than 0.5 C, and less than 10 percent variation in specific conductance. Equilibrium will be established by three consecutive readings.

4.3 Temperature

Obtain a sample where equilibrium is as follows: pH variation is less than 0.2 pH units, temperature variation is less than 0.5 C, and less than 10 percent variation in specific conductance. Equilibrium will be established by three consecutive readings.

4.4 Organic Vapor

A photoionization detector (PID) will be used to field-screen soil to determine if volatile organic compounds are present. Field screening will be performed by placing the detector within one inch of recently excavated or exposed in-place soil. The highest concentration detected will be recorded on the field notebook.

Three PID probes, each containing a different ultraviolet (UV) light source, are available for use: 9.5, 10.2, and 11.7 electron volt (eV). Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials higher than that of the lamp will not be detected. All three detect many aromatic and large molecular hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe.

The 11.7 eV lamp measures the broadest range of compounds, while the 10.6 eV lamp is somewhat more selective. However, the 11.7 eV lamp provides lower resolution; that is, the lithium fluoride crystal in the 11.7 eV lamp does not allow as much light energy through, effectively making the 11.7 eV lamp “dimmer” than the 10.6eV lamp. Less energy transmitted means less ionization taking place, which reduces the potential resolution. Essentially a 10.6 eV lamp is 10 times more powerful than an 11.7 eV lamp. Therefore, for best accuracy, it is not recommended to use 11.7 eV lamps for applications requiring very high sensitivity. The 11.7 eV lamp should only be used when compounds with ionization potentials over 10.6 eV are expected. Examples include methylene chloride, chloroform, and carbon tetrachloride. (Note: see SOP-39 for additional information on PID principles and procedures.)

Flame ionization detectors (FIDs) will be used only as field screening tools, since they have the following limitations:

- FIDs measure the concentration of total organic vapors and serve as a general indicator of the level of contamination in soil.
- FIDs are not compound-specific and can detect the presence of a wide range of volatile organic compounds (e.g., the PID detects ammonia compounds and the FID detects methane).
- FIDs read in parts per million equivalent units. The readings must be adjusted based on the instrument sensitivity correction factors, calibration gas span, and estimate of the type of contaminants being measured.
- Moisture and cold temperatures can cause inaccurate meter readings during field screening.

If more accurate field-screening data are required, a headspace sample can be collected by placing soil material (in-place or recently excavated soil) into a sample container. The container is partially filled (50 to 75 percent), leaving an excess space or “headspace” above the soil. The top of the container is covered with aluminum foil and sealed with the lid. The sample is heated by placing it in the sun or near a heat source. The foil is pierced with the detector probe to determine the concentration of the organic compounds, which have volatilized from the soil and into the container headspace. The highest concentration detected is recorded on the field log.

4.5 Turbidity

Obtain a sample where equilibrium is as follows four consecutive turbidity readings with 10 percent of each other. Sample measurements will be collected using a turbidimeter that detects sample opacity. Gross turbidity measurements may be collected using an Imhoff cone.

STANDARD OPERATING PROCEDURES

SOP-31

DRILLING EQUIPMENT DECONTAMINATION

STANDARD OPERATING PROCEDURES

SOP-31
DRILLING EQUIPMENT DECONTAMINATION

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1.0 INTRODUCTION

Drilling is a common activity associated with all phases of environmental investigations. Drilling methods are most commonly used to collect site data during site investigations and remedial investigations, but are also used to install vapor extraction or water wells associated with remedial actions.

Field investigations usually require invasive types of activities to gather information to evaluate the site. The investigation may require the analysis of soil and/or groundwater samples, which would be accomplished by drilling a borehole. The borehole is often converted into a well for the evaluation of vapor or groundwater conditions over time. In addition to the collection of samples for analyses, other data such as physical parameters of soils can be obtained from boreholes.

For determining the most appropriate drilling method for a site investigation, primary consideration must be given to obtaining information that is representative of existing conditions and the collection of samples that are valid for chemical analysis. The samples must not be contaminated or adversely affected by the drilling method.

Drilling associated with remedial actions may include the installation of vapor or water extraction and/or injection wells. In selecting the most appropriate drilling method for remedial actions, primary consideration must be given to completion of a well that will perform as designed.

This Standard Operating Procedure (SOP) provides a description of the decontamination procedures used during field investigations for typical drilling equipment. It is intended to be used by the Project Manager, Project Engineer, Field Team Leader, and site hydrogeologist to develop as general guidance for decontamination procedures for environmental work. The project specific sampling and analysis plans may have site-specific concerns, which would require an addition or adjustment to these procedures.

This document focuses on methods and equipment that are readily available and typically applied. It is not intended to provide an all-inclusive discussion of decontamination methods.

2.0 DEFINITIONS

Bailer	A cylindrical tool designed to remove material, both solid and liquid, from a well or borehole. A valve at the bottom of the bailer retains the material in the bailer. The three types of bailers are flat-valve bailer, a dart-valve bailer, and the sand pump with rod plunger.
Cone Penetrometer	An instrument used to identify the underground conditions by measuring the differences in the resistance and other physical parameters of the strata. The cone penetrometer consists of a conical point attached to a

	drive rod of smaller diameter. Penetration of the cone into the formation forces the soil aside, creating a complex shear failure. The cone penetrometer is very sensitive to small differences in soil consistency.
Cuttings	Formation particles obtained from a borehole during the drilling process.
Drilling Fluids or Muds	A water-based or air-based fluid used in the well drilling operation to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill string and the sides of the borehole, and to seal the borehole.
Dual-Purpose Well	A well that can be used as both a monitoring and extraction or injection well.
Flight	An individual auger section, usually 5 feet in length.
Heaving Formation	Unconsolidated saturated substrate encountered during drilling where the hydrostatic pressure of the formation is greater than the borehole pressure causing the sands to move up into the borehole.
Kelly Bar	A hollow steel bar or pipe that is the main section of drill string to which the power is directly transmitted from the rotary table to rotate the drill pipe and bit. The cross section of the kelly is square, hexagonal, or grooved. The kelly works up and down through drive bushings in the rotary table.
Pitch	The distance along the axis of an auger flight that it takes for the helix to make one complete 360 degree turn.
Rotary Table	A mechanical or hydraulic assembly that transmits rotational torque to the kelly, which is connected to the drill pipe and the bit. The rotary table has a hole in the center through which the kelly passes.
Split-Spoon Sampler	A thick-walled steel tube split lengthwise used to collect soil samples. The sampler is commonly lined with metal sample sleeves and is driven or pushed downhole by the drill rig to collect samples.
Thin-Walled Sampler	A sampling devise used to obtain undisturbed soil samples made from thin-wall tubing. The sampler is also known as a Shelby tube. The thin-wall sampler minimizes the most serious sources of disturbance: displacement and friction.

3.0 RESPONSIBILITIES

The **Project Manager** or **Task Leader** selects site-specific drilling methods, with input from the Field Team Leader and Site Hydrogeologist, and maintain close supervision of activities.

The **Site Hydrogeologist** (a California certified Professional Geologist (P.G.) selects site-specific drilling options and assists in the preparation of the technical provisions for drilling.

The **Field Team Leader** implements the selected drilling and decontamination program and assists in the selection of decontamination methods.

The **Site Safety Officer** prepares the site- and activity-specific Job Hazard Analysis and Health and Safety Plan to be followed by the drilling subcontractor; reviews subcontractor Health and Safety plans and rejects or accepts them based on contract requirements; conducts pre-job tailgate safety meetings; and performs site safety observations and inspections.

4.0 DECONTAMINATION PROCEDURES

The purpose of decontamination and cleaning procedures during excavation, drilling, and sampling is to prevent foreign contamination of the samples and cross contamination between sites. A decontamination area and clean zone will be established for the preparation and breakdown of equipment prior to each sampling task. The decontamination area will be large enough to accommodate equipment to be used for invasive work and allow decontamination rinsate to be pumped off for temporary storage and subsequent disposal. Before use, and between each site, all equipment and other non-sampling equipment will be decontaminated with high-pressure steam, or scrubbed with a non-phosphate detergent and rinsed with water from the approved water source. If appropriate, equipment will be covered in plastic to protect it from the elements.

All equipment that may directly contact samples will be decontaminated on site. The following sampling-specific decontamination procedures will be observed:

1. Wash and scrub with detergent (laboratory grade - non-phosphate detergent).
2. Rinse with tap water.
3. Rinse with deionized water.
4. Rinse with deionized water.
5. Air dry.
6. Protect from fugitive dust and vapors.

Upon completion of the project, samples will be obtained from decontamination water resulting from final decontamination and demobilization of the equipment. One water sample from the water used for final rinse for decontamination will be collected and analyzed for the contaminants of concern at the beginning of the project.

Additional solvent and/or acid rinses may be added to the procedure, depending on the site sampling objectives. Materials Safety Data Sheets must be obtained for any hazardous chemicals used for decontamination and approved by the site safety officer prior to bringing the chemicals to the worksite. Personal protective equipment specific to the decontamination chemicals in use must be used, as specified in the health and safety plan. If these additional rinses are required, the procedures for incorporation are provided below:

1. Wash and scrub with detergent (laboratory grade - non-phosphate detergent).
2. Rinse with tap water.
3. Rinse with methanol (pesticide grade).
4. Rinse with deionized water.
5. Rinse with 1:1 nitric acid.
6. Rinse with deionized water.
7. Air dry.
8. Protect from fugitive dust and vapors.

Sample Tracking and Documentation Form

Project: ______________________ **Site:** ______________________

Equipment Rinsate Blanks:

Location ID	Sample ID	Method	Matrix	Date Sampled	Time Sampled	Date Shipped	Cooler No.	Lab Dest.	Fedex Tracking No.	QA/QC Samples

Equipment Rinsate Blanks Splits (LIMS #____________):

Location ID	Sample ID	Method	Matrix	Date Sampled	Time Sampled	Date Shipped	Cooler No.	Lab Dest.	Fedex Tracking No.	QA/QC Samples

Trip Blanks

Location ID	Sample ID	Method	Matrix	Date Sampled	Time Sampled	Date Shipped	Cooler No.	Lab Dest.	Fedex Tracking No.	QA/QC Samples

QA/QC CODES:

1 = Primary Lab Duplicate
2 = Primary Lab Duplicate and QA Laboratory Split
3 = Primary Lab Rinsate Blank
4 = Primary Lab Rinsate Blank and QA Lab Rinsate Blank Split
5 = Matrix Spike and Duplicate (MS/MSD)