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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP\ALPPR612.D4
TEMPERATURE DATA FILE:        C:\HELP\ALPTE612.D7
SOLAR RADIATION DATA FILE:    C:\HELP\ALPSR612.D13
EVAPOTRANSPIRATION DATA:      C:\HELP\ALPEV612.D11
SOIL AND DESIGN DATA FILE:    C:\HELP\INPUTS\OGE3R003.D10
OUTPUT DATA FILE:             C:\HELP\OUT\OGE3R003.OUT


TIME:  19:19      DATE:  10/30/2012


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     TITLE:  Ameren Missouri Labadie Proposed Utility Waste Landfill

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   9
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.5010 VOL/VOL
          FIELD CAPACITY               =      0.2840 VOL/VOL
          WILTING POINT                =      0.1350 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3062 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.190000006000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.34
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 30

THICKNESS	=	240.00	INCHES
POROSITY	=	0.5410	VOL/VOL
FIELD CAPACITY	=	0.1870	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1947	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.499999987000E-04	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4170	VOL/VOL
FIELD CAPACITY	=	0.0450	VOL/VOL
WILTING POINT	=	0.0180	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0455	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.500000007000E-01	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.69	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0103	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	1.28999996000	CM/SEC
SLOPE	=	1.00	PERCENT
DRAINAGE LENGTH	=	627.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 9 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 720. FEET.

SCS RUNOFF CURVE NUMBER	=	91.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	31.400	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.675	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.012	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	61.200	INCHES
TOTAL INITIAL WATER	=	61.200	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ST. LOUIS MISSOURI

STATION LATITUDE	=	38.70 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.50
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	300
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	10.40 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.72	2.14	3.28	3.55	3.54	3.73
3.63	2.55	2.70	2.32	2.53	2.22

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	33.80	43.20	56.10	65.60	74.80
78.90	77.00	69.70	57.90	44.60	34.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ST. LOUIS MISSOURI
AND STATION LATITUDE = 38.70 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 25

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.48	2.08	3.12	3.53	3.24	4.61
	3.36	2.45	2.96	2.30	2.13	2.18
STD. DEVIATIONS	0.86	1.11	0.97	1.36	1.58	2.13
	1.90	1.28	1.45	1.31	1.49	1.09
RUNOFF						
TOTALS	0.391	0.787	0.587	0.212	0.265	0.654
	0.392	0.109	0.234	0.151	0.218	0.161
STD. DEVIATIONS	0.452	0.654	0.824	0.222	0.351	0.754
	0.548	0.144	0.217	0.199	0.266	0.215
EVAPOTRANSPIRATION						
TOTALS	0.569	0.697	2.472	3.494	2.909	3.987
	3.079	2.410	2.233	1.795	1.364	0.859
STD. DEVIATIONS	0.318	0.474	0.492	0.953	1.133	1.415
	1.345	1.087	1.145	0.670	0.512	0.255
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.2934	0.2093	0.2037	0.2101	0.1532	0.1068
	0.1577	0.2502	0.2796	0.3140	0.3139	0.3278
STD. DEVIATIONS	0.1409	0.1104	0.1354	0.1173	0.0871	0.0799
	0.1512	0.1685	0.1654	0.1657	0.1378	0.1334
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5						
AVERAGES	0.0812	0.0634	0.0563	0.0600	0.0424	0.0305
	0.0436	0.0692	0.0799	0.0868	0.0897	0.0907
STD. DEVIATIONS	0.0390	0.0332	0.0375	0.0335	0.0241	0.0228
	0.0418	0.0466	0.0473	0.0458	0.0394	0.0369

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 25

	INCHES		CU. FEET	PERCENT
PRECIPITATION	33.44	(4.389)	3812059.7	100.00
RUNOFF	4.161	(1.6271)	474230.69	12.440
EVAPOTRANSPIRATION	25.868	(3.1274)	2948536.00	77.348
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.81969	(1.20674)	321394.000	8.43098
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00006	(0.00002)	6.895	0.00018
AVERAGE HEAD ON TOP OF LAYER 5	0.066	(0.028)		
CHANGE IN WATER STORAGE	0.596	(2.1473)	67891.99	1.781

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 25

	(INCHES)	(CU. FT.)
PRECIPITATION	3.44	392098.094
RUNOFF	1.975	225122.4840
DRAINAGE COLLECTED FROM LAYER 4	0.02255	2570.84790
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.05047
AVERAGE HEAD ON TOP OF LAYER 5	0.193	
MAXIMUM HEAD ON TOP OF LAYER 5	0.378	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	13.6 FEET	
SNOW WATER	2.22	252528.0310

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4152

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1350

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 25

LAYER	(INCHES)	(VOL/VOL)
1	2.6733	0.2228
2	61.7891	0.2575
3	1.0614	0.0885
4	0.1182	0.1713
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.201	

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Appendix O-12

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP\ALPPR612.D4
TEMPERATURE DATA FILE:       C:\HELP\ALPTE612.D7
SOLAR RADIATION DATA FILE:   C:\HELP\ALPSR612.D13
EVAPOTRANSPIRATION DATA:     C:\HELP\ALPEV612.D11
SOIL AND DESIGN DATA FILE:   C:\HELP\INPUTS\CAM1R002.D10
OUTPUT DATA FILE:            C:\HELP\OUT\CAM1R002.OUT


TIME:  10:41     DATE:  11/ 6/2012


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     TITLE:  Ameren Missouri Labadie Proposed Utility Waste Landfill

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   9
           THICKNESS                   =      24.00   INCHES
           POROSITY                    =       0.5010 VOL/VOL
           FIELD CAPACITY              =       0.2840 VOL/VOL
           WILTING POINT               =       0.1350 VOL/VOL
           INITIAL SOIL WATER CONTENT  =       0.3739 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.190000006000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.34
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 30

THICKNESS	=	700.00 INCHES
POROSITY	=	0.5410 VOL/VOL
FIELD CAPACITY	=	0.1870 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1871 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.499999987000E-04 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0450 VOL/VOL
WILTING POINT	=	0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0586 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.500000007000E-01 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0333	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.250000004000E-01	CM/SEC
SLOPE	=	1.00	PERCENT
DRAINAGE LENGTH	=	541.0	FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 9 WITH A POOR STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 720. FEET.

SCS RUNOFF CURVE NUMBER	=	86.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	31.400	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.684	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.012	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	151.282	INCHES
TOTAL INITIAL WATER	=	151.282	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM ST. LOUIS MISSOURI

STATION LATITUDE	=	38.70	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.50	
START OF GROWING SEASON (JULIAN DATE)	=	98	
END OF GROWING SEASON (JULIAN DATE)	=	300	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.40	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.72	2.14	3.28	3.55	3.54	3.73
3.63	2.55	2.70	2.32	2.53	2.22

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	33.80	43.20	56.10	65.60	74.80
78.90	77.00	69.70	57.90	44.60	34.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ST. LOUIS MISSOURI
AND STATION LATITUDE = 38.70 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.56	2.15	3.09	3.37	3.44	4.42
	3.38	2.66	2.75	2.18	2.16	2.06
STD. DEVIATIONS	0.95	1.09	0.92	1.36	1.56	2.04
	1.87	1.38	1.45	1.28	1.38	1.14
RUNOFF						
TOTALS	0.526	1.225	0.909	0.418	0.276	0.480
	0.247	0.059	0.080	0.079	0.154	0.203
STD. DEVIATIONS	0.576	0.948	0.891	0.629	0.455	0.841
	0.428	0.136	0.108	0.278	0.318	0.442
EVAPOTRANSPIRATION						
TOTALS	0.579	0.686	2.414	3.399	3.192	4.117
	3.512	3.155	2.504	1.805	1.402	0.887
STD. DEVIATIONS	0.344	0.463	0.611	0.935	1.054	1.402
	1.294	1.039	1.067	0.693	0.423	0.239
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.0692	0.0606	0.0887	0.0863	0.0837	0.0804
	0.0777	0.0700	0.0627	0.0653	0.0669	0.0769
STD. DEVIATIONS	0.0184	0.0152	0.0147	0.0121	0.0099	0.0108
	0.0088	0.0070	0.0078	0.0098	0.0162	0.0174

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0153	0.0134	0.0155	0.0149	0.0146	0.0147
	0.0166	0.0179	0.0182	0.0190	0.0181	0.0180
STD. DEVIATIONS	0.0150	0.0131	0.0150	0.0144	0.0143	0.0140
	0.0153	0.0164	0.0167	0.0177	0.0172	0.0174

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	14.2640	13.7198	18.3089	18.4126	17.3077	17.1844
	16.0783	14.4826	13.3825	13.4937	14.2739	15.8825
STD. DEVIATIONS	3.7982	3.4051	3.0151	2.5653	2.0399	2.3181
	1.8348	1.4688	1.6871	2.0460	3.4631	3.5892

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.1884	0.1819	0.1911	0.1893	0.1803	0.1872
	0.2049	0.2201	0.2310	0.2343	0.2300	0.2222
STD. DEVIATIONS	0.1851	0.1768	0.1850	0.1829	0.1764	0.1785
	0.1889	0.2025	0.2130	0.2178	0.2185	0.2149

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.21 (4.731)	3785646.0	100.00
RUNOFF	4.657 (2.0919)	530826.37	14.022
EVAPOTRANSPIRATION	27.651 (3.0955)	3151747.00	83.255
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.88864 (0.09279)	101289.297	2.67561

AVERAGE HEAD ON TOP OF LAYER 2	15.566 (	1.626)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.19631 (	0.18384)	22375.322	0.59106
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00016 (	0.00014)	18.739	0.00050
AVERAGE HEAD ON TOP OF LAYER 6	0.205 (	0.192)		
CHANGE IN WATER STORAGE	0.708 (	1.5321)	80679.05	2.131

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	3.44	392098.094
RUNOFF	2.442	278376.6560
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.003767	429.34015
AVERAGE HEAD ON TOP OF LAYER 2	24.000	
DRAINAGE COLLECTED FROM LAYER 5	0.00185	210.67238
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000001	0.16320
AVERAGE HEAD ON TOP OF LAYER 6	0.706	
MAXIMUM HEAD ON TOP OF LAYER 6	1.322	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	34.3 FEET	
SNOW WATER	2.43	276996.6250

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5010
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1350

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	9.4425	0.3934
2	0.0000	0.0000
3	151.3888	0.2163
4	0.8053	0.0671
5	0.6318	0.0527
6	0.0000	0.0000
7	10.2480	0.4270
SNOW WATER	0.000	

****
****

Appendix O-13

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP\ALPPR612.D4
TEMPERATURE DATA FILE:       C:\HELP\ALPTE612.D7
SOLAR RADIATION DATA FILE:   C:\HELP\ALPSR612.D13
EVAPOTRANSPIRATION DATA:     C:\HELP\ALPEV612.D11
SOIL AND DESIGN DATA FILE:   C:\HELP\INPUTS\CGE1R003.D10
OUTPUT DATA FILE:            C:\HELP\OUT\CGE1R003.OUT


TIME: 10:46     DATE: 11/ 6/2012


******************************************************************************

     TITLE:  Ameren Missouri Labadie Proposed Utility Waste Landfill

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   9
           THICKNESS                  =      24.00    INCHES
           POROSITY                   =       0.5010 VOL/VOL
           FIELD CAPACITY             =       0.2840 VOL/VOL
           WILTING POINT              =       0.1350 VOL/VOL
           INITIAL SOIL WATER CONTENT =       0.3739 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.190000006000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.34
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

```
                          LAYER  2
                          --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
THICKNESS                     =       0.06   INCHES
POROSITY                      =       0.0000 VOL/VOL
FIELD CAPACITY                =       0.0000 VOL/VOL
WILTING POINT                 =       0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT    =       0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY           =       2.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =       2.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD


                          LAYER  3
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  30
THICKNESS                     =     700.00   INCHES
POROSITY                      =       0.5410 VOL/VOL
FIELD CAPACITY                =       0.1870 VOL/VOL
WILTING POINT                 =       0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT    =       0.1871 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.499999987000E-04 CM/SEC


                          LAYER  4
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                     =      12.00   INCHES
POROSITY                      =       0.4170 VOL/VOL
FIELD CAPACITY                =       0.0450 VOL/VOL
WILTING POINT                 =       0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT    =       0.0586 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.500000007000E-01 CM/SEC
```

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.69	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0143	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	1.29999995000	CM/SEC
SLOPE	=	1.00	PERCENT
DRAINAGE LENGTH	=	541.0	FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 9 WITH A POOR STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 720. FEET.

SCS RUNOFF CURVE NUMBER	=	86.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	31.400	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.684	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.012	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	150.892	INCHES
TOTAL INITIAL WATER	=	150.892	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM ST. LOUIS MISSOURI

STATION LATITUDE	=	38.70	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.50	
START OF GROWING SEASON (JULIAN DATE)	=	98	
END OF GROWING SEASON (JULIAN DATE)	=	300	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.40	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.72	2.14	3.28	3.55	3.54	3.73
3.63	2.55	2.70	2.32	2.53	2.22

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ST. LOUIS MISSOURI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	33.80	43.20	56.10	65.60	74.80
78.90	77.00	69.70	57.90	44.60	34.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ST. LOUIS MISSOURI
AND STATION LATITUDE = 38.70 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.56	2.15	3.09	3.37	3.44	4.42
	3.38	2.66	2.75	2.18	2.16	2.06
STD. DEVIATIONS	0.95	1.09	0.92	1.36	1.56	2.04
	1.87	1.38	1.45	1.28	1.38	1.14
RUNOFF						
TOTALS	0.526	1.225	0.909	0.418	0.276	0.480
	0.247	0.059	0.080	0.079	0.154	0.203
STD. DEVIATIONS	0.576	0.948	0.891	0.629	0.455	0.841
	0.428	0.136	0.108	0.278	0.318	0.442
EVAPOTRANSPIRATION						
TOTALS	0.579	0.686	2.414	3.399	3.192	4.117
	3.512	3.155	2.504	1.805	1.402	0.887
STD. DEVIATIONS	0.344	0.463	0.611	0.935	1.054	1.402
	1.294	1.039	1.067	0.693	0.423	0.239
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.0692	0.0606	0.0887	0.0863	0.0837	0.0804
	0.0777	0.0700	0.0627	0.0653	0.0669	0.0769
STD. DEVIATIONS	0.0184	0.0152	0.0147	0.0121	0.0099	0.0108
	0.0088	0.0070	0.0078	0.0098	0.0162	0.0174

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0109	0.0127	0.0198	0.0117	0.0128	0.0188
	0.0231	0.0227	0.0215	0.0191	0.0160	0.0150
STD. DEVIATIONS	0.0110	0.0127	0.0210	0.0144	0.0145	0.0167
	0.0210	0.0217	0.0209	0.0201	0.0179	0.0169

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	14.2640	13.7198	18.3089	18.4126	17.3077	17.1844
	16.0783	14.4826	13.3825	13.4937	14.2739	15.8825
STD. DEVIATIONS	3.7982	3.4051	3.0151	2.5653	2.0399	2.3181
	1.8348	1.4688	1.6871	2.0460	3.4631	3.5892

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0026	0.0033	0.0047	0.0029	0.0030	0.0046
	0.0055	0.0054	0.0052	0.0045	0.0039	0.0036
STD. DEVIATIONS	0.0026	0.0033	0.0050	0.0035	0.0034	0.0041
	0.0050	0.0052	0.0051	0.0048	0.0044	0.0040

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	33.21	(4.731)	3785646.0	100.00
RUNOFF	4.657	(2.0919)	530826.37	14.022
EVAPOTRANSPIRATION	27.651	(3.0955)	3151747.00	83.255
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.88864	(0.09279)	101289.297	2.67561

AVERAGE HEAD ON TOP OF LAYER 2	15.566 (	1.626)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.20399 (	0.19117)	23251.387	0.61420
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00001 (	0.00000)	0.773	0.00002
AVERAGE HEAD ON TOP OF LAYER 6	0.004 (	0.004)		
CHANGE IN WATER STORAGE	0.700 (	1.5276)	79820.97	2.109

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	3.44	392098.094
RUNOFF	2.442	278376.6560
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.003767	429.34015
AVERAGE HEAD ON TOP OF LAYER 2	24.000	
DRAINAGE COLLECTED FROM LAYER 5	0.00303	345.25888
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00762
AVERAGE HEAD ON TOP OF LAYER 6	0.022	
MAXIMUM HEAD ON TOP OF LAYER 6	0.044	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	1.3 FEET	
SNOW WATER	2.43	276996.6250
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5010	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1350	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	9.4425	0.3934
2	0.0000	0.0000
3	151.3888	0.2163
4	0.8053	0.0671
5	0.0164	0.0237
6	0.0000	0.0000
7	10.2480	0.4270
SNOW WATER	0.000	

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Appendix P

Construction Quality Assurance Plan

Ameren Missouri Labadie Energy Center

Construction Quality Assurance Plan for a Utility Waste Landfill

Franklin, Missouri

Ameren Missouri
Power Operation Services
3700 South Lindbergh Blvd.
St. Louis, Missouri 63127

December 2012

GREDELL Engineering Resources, Inc.
1505 East High Street
Jefferson City, Missouri 65101
Phone: (573) 659-9078
Fax: (573) 659-9079

Ameren Missouri Labadie Energy Center
Construction Quality Assurance Plan
Utility Waste Landfill
Franklin County, Missouri

December 2012

Table of Contents

Appendices

1.0 INTRODUCTION

The Missouri Department of Natural Resources Solid Waste Management Program (MDNR-SWMP) requires construction quality assurance (CQA) and construction quality control (CQC) on landfill components to ensure quality landfill construction. Manufacturing Quality Control (MQA) and Manufacturing Quality Assurance (MQA) are also typically completed for the manufactured components of a landfill such as HDPE liners and pipe. CQA is typically performed by a party independent of the Owner/Operator (Owner) and contractor to document the quality of construction on key landfill components. CQC procedures are typically performed by the contractor and/or owner throughout construction to ensure that landfill components are constructed in accordance with applicable construction standards and specifications. MQA is typically performed by the contractor and may also be performed by a party independent of the Owner, while MQC is typically performed by the manufacturer. The technical guidance document entitled Quality Assurance and Quality Control for Waste Containment Facilities (EPA/600/R-93/182) produced by the U.S. Environmental Protection Agency specifically defines the roles that CQA, CQC, MQA, and MQC play during landfill construction:

- CQA: Construction Quality Assurance is a planned system of activities that provides the owner and permitting agencies assurance that the facility was constructed as specified in the design. CQA includes field inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA refers to the measures taken by the CQA agent to assess if the contractor or installer is in compliance with the plans and specifications for a project.

- CQC: Construction Quality Control is a planned system of inspections and materials testing that are used to directly monitor and control the quality of a construction project. CQC is frequently performed by the owner, earthwork contractor and/or geosynthetics installer and is necessary to achieve quality in the constructed or installed system. CQC refers to measures taken to determine compliance with the requirements for material and workmanship as stated in the plans and specifications for the project.

- MQC: Manufacturing Quality Control is a planned system of inspections that is used to directly monitor and control the manufacture of a material. MQC is normally performed by the manufacturer of geosynthetic materials to determine compliance with the requirements for materials and workmanship.

- MQA: Manufacturing Quality Assurance is a planned system of activities that provides assurance that the materials were constructed as specified, and refers to measures taken by the MQA organization, such as manufacturing facility inspections, verifications, audits, and evaluation of raw materials and geosynthetic products.

Typical landfill components that require CQA and/or CQC procedures are:

- Subgrade Excavation and/or Backfilling

- Low Permeability Soil Liner/Cover
- Geomembrane Liner
- Geotextiles and/or Geocomposites
- Drainage Materials

The manufacturer(s) of geosynthetic materials will be required to furnish with their bids documentation of a written, effective MQC program. One component of the manufacturer's MQC program will be a MQA program by an independent, qualified testing agency that will provide documentation with certifications that the manufactured products comply with the requirements for material and workmanship as stated in the plans and specifications for the project.

This Plan is specific to the CQA activities to be completed by an independent third-party and addresses the soil, geosynthetic, and drainage components of the composite liner, leachate drainage and collection and final cover systems to be constructed for the Utility Waste Landfill (UWL) at the Ameren Missouri Labadie Energy Center site in Franklin County, Missouri. This plan has been prepared in general conformance with the State of Missouri Solid Waste Management Rules, and Franklin County Regulations.

This document outlines methods of construction, quality assurance testing procedures, safety and reporting requirements to be followed during construction of the earthwork, liner, and final cover systems at the Labadie UWL. The specific CQC program that will be followed during installation of the landfill components is not included with this document. However, the CQA agent for earthwork, liner and final cover construction for the UWL will coordinate with the contractor(s) and CQC personnel to ensure that construction is in accordance with the approved permit documents, materials' manufacturers and suppliers standards and specifications and other available plans and specifications. If the CQC efforts appear to be insufficient, the CQA agent will coordinate with the contractor(s) to ensure that the permit documents, and plans and specifications are adhered to. The CQA procedures outlined in this document fulfill all requirements of the Missouri Solid Waste Management and Franklin County Regulations and will, by themselves, provide the information and documentation necessary to certify that landfill components were constructed in accordance with the approved permit documents.

A copy of this plan will be maintained at the UWL for use during landfill phase development and final cover construction. Any revisions to the CQA Plan shall require a permit modification to be reviewed by the MDNR-SWMP. The MDNR-SWMP must be kept informed throughout all phases of construction. The MDNR-SWMP and Franklin County Independent Registered Professional Engineer (IPRE) will review all records and results from the implementation of the CQA Plan as part of any Operating Permit Application and Request for Authorization to Operate any area or phase of the UWL.

2.0 GENERAL CONDITIONS

2.1 Responsibility and Authority

Ameren Missouri is ultimately responsible for the implementation of this CQA Plan. The following is a list of responsible personnel:

Owner's Representative

A representative of Ameren Missouri shall be responsible for coordination between the Owner, the construction crew, and the third party CQA Engineer. With the MDNR-SWMP's prior approval, the Owner may delegate this authority, and correspondingly, be responsible to see that the CQA Plan is followed.

CQA Engineer

A professional engineer licensed to practice in Missouri shall be retained by the Ameren Missouri to provide on-site Construction Quality Assurance observations and testing. The CQA Engineer will prepare a final report demonstrating that the substantial requirements of this CQA Plan were implemented. The final report will include the MQC submittals from the manufacturer(s) and the MQA submittals from the independent MQA agencies. In addition, the CQA Engineer or his designee will coordinate, through Ameren Missouri, with the contractor(s) and/or installer(s) and their CQC personnel for the purposes of sharing MQC, MQA, CQA and CQC information. Should it become apparent to the CQA Engineer or his designee that construction quality does not meet the standards established in the Construction Permit; the CQA Engineer will inform the Owner's Representative of the apparent deficiencies so appropriate adjustments can be made. The CQA Engineer will be employed by an organization that operates independently of the Owner, construction contractor(s), landfill operator, and/or permit holder. The CQA Engineer will be responsible for certifying that construction was completed in substantial compliance with the engineering plans and specifications approved by the Construction Permit. Components of the bottom composite liner system, leachate drainage and collection system or final cap system will be not constructed unless the CQA Engineer or the CQA Inspector is present.

CQA Inspector

The CQA Engineer will designate one or more CQA Inspector(s) to perform the duties of the CQA Engineer when they are not present on site or when the extent of the project requires inspection by more than one person. A CQA Inspector shall be a qualified, experienced individual who is able to act for the CQA Engineer to provide necessary on-site CQA observations and testing. The CQA Inspector will document on-site construction activities in a Daily Field Activities Report. An example of this report is included in Appendix A. No component of the bottom composite liner system, leachate drainage and collection system or final cover system will be constructed unless the CQA engineer or CQA inspector is present.

2.2 Inspection and Testing

This CQA Plan describes the inspection and testing of eight critical components of the landfill containment system:

1. Test pad construction and testing
2. Subgrade preparation
3. Compacted soil liner (bottom)
4. Geomembrane liner
5. Geotextile
6. Leachate Drainage and collection system components
7. Geocomposites
8. Protective Aggregate Layer
9. Final Cover system

The following sections outline minimum requirements and guidelines to be followed during execution of the CQA Plan. Information pertaining to the specific tests, testing frequency, level of detail and consistency in reports is presented in each section.

Throughout the construction activities, communication will play a major role in completing a successful construction project and achieving the requirements of the approved plans, specifications, and permit documents. At a minimum, the following communications guidelines will be met:

- **Pre-Construction Meeting:** A meeting involving the Owner, CQA personnel, and the contractor(s) will take place prior to the start of construction. This meeting should include discussion of each party's responsibilities, lines or means of communication, procedures for changes or problems, CQA procedures and requirements, level of the MDNR-SWMP and IPRE involvement, and other issues as they pertain to the construction project.

- **Weekly Progress Meetings:** Regularly scheduled meetings between CQA personnel and the contractor(s) will take place during project construction to review and discuss such topics as previous work, future work, construction problems, schedule revisions, and other issues that require attention.

- **Other Meetings:** Unscheduled meetings will take place as required to address issues such as construction progress and changed conditions as circumstances dictate.

Under all circumstances, the MDNR-SWMP and the IPRE will be given seven days advance notification prior to the start of any test pad construction; excavation of subgrade; placement of soil liner components; and placement of geosynthetic materials. It is understood that the MDNR-SWMP reserves the right to inspect the compacted soil liner during the initial placement of liner and during placement of the geomembrane.

2.3 Floodplain Issues Related to Construction

If a flooding event occurs during cell liner construction, the contractor will be required to monitor the flood conditions and levels outside the cell being constructed. The contractor will be required to monitor the excess hydrostatic uplift pressures on the composite liner. If required by the Owner's Representative, the contractor will be required to mitigate heave due to excess hydrostatic uplift pressures on the composite liner either by placing ballast material on the liner or by flooding the lined area as directed by the Owner's Representative. The contractor will be required to remove the ballast material or water and to restore the Work to the pre-flood condition prior to continuing with construction.

3.0 SOIL LINER CONSTRUCTION

The compacted soil portion of the UWL composite bottom liner system is to be constructed and tested in accordance with the approved permit documents and this CQA Plan. This section covers material conformance testing, general construction procedures, testing during construction, and frequency requirements.

- A test pad will be constructed for soils that will be used for liner construction. For the Ameren Missouri Labadie Energy Center utility waste landfill conformance testing of available soil materials will be performed prior to test pad construction to demonstrate that the soils meet the required specifications.

3.1 Materials Conformance Testing

Soils to be used for liner construction will be classified, excavated, segregated, and stockpiled under the observation of an experienced soils technician.

Prior to construction of the compacted soil component of the liner system, representative samples of the stockpiled materials proposed for use will be collected and tested. This testing will verify that the soils to be used for construction meet project specifications as determined by this pre-qualification testing. The following tests may be performed as prescribed by the CQA Engineer (ASTM standards and tests designations refer to the latest approved version):

Test Method	Test Description
ASTM D 2216	Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 2487	Standard Practice for Classification of Soils for Engineering Purposes
ASTM D 4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils (Atterberg Limits)
ASTM D 422	Particle Size Analysis of Soils
ASTM D 1140	Amount of Soils Finer than the No. 200 Sieve
ASTM D 698	Laboratory Compaction Characteristics of Soil using Standard Effort (Note: The Modified or Reduced Proctor Tests may be substituted or added to the Standard Proctor Test as necessary.)
ASTM D 4767	Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
ASTM D 5084	Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)

Soil selected for liner construction must have a group symbol of CL, CH, or SC according to the Unified Soil Classification System. In addition, each soil used for construction must meet the following criteria:

- Allow more than 30 percent passage through a No. 200 sieve
- Have a liquid limit equal to or greater than 20
- Have a plasticity index equal to or greater than 10
- Have a coefficient of permeability equal to or less than that specified in the Project documents, that is $1x10^{-5}$ or $1x10^{-7}$ centimeters per second (cm/sec) or less when compacted to a density and moisture content deemed acceptable by preconstruction testing and test pad construction
- Shall meet or exceed the minimum shear strength properties, both internal and interface with other materials, utilized in the geotechnical design (reference Appendix J of the Construction Permit Application).

Soils meeting all of the above requirements will be used to construct a test pad in accordance with Section 3.2 of the CQA Plan.

After completing the conformance testing described above, the CQA Engineer will complete the appropriate testing and data evaluation needed to develop a compacted soil placement range for the selected borrow material. The placement range will be developed based on previous laboratory testing of the borrow material, if available, as well as the test results obtained from preconstruction testing. The placement range (i.e., "acceptable zone") shall be developed in accordance with the method developed by D.E. Daniel and C.H. Benson (1990), "Water content-density criteria for compacted soil liners", *J. Geotech. Engrg*. ASCE, 116 (12), 1811-130, and soil placement based on the appropriate moisture and dry unit weight values related to the maximum specified hydraulic conductivity. It will be used in conjunction with quality assurance testing during soil liner/final cover construction to achieve the required permeability.

3.2 Test Pad

10 CSR 80-4.010 (10) (C) of the Missouri Solid Waste Regulations requires that a test pad be constructed prior to compacted soil liner construction. Test pad(s) will be constructed following the bottom liner construction techniques. The test pad(s) will verify that the construction and CQA procedures to be used for actual compacted soil liner will provide an adequate liner system. Tests will be completed in a manner that allows evaluation of soil types, construction methods, and/or soil amendments required to achieve the installed liner characteristics approved in the construction permit. Results from test pad construction and changes to proposed construction methods will be submitted to the MDNR-SWMP and IPRE as a Test Pad Construction Report.

MDNR-SWMP and the IPRE will be notified at least 7 days prior to commencing test pad construction activities. Construction procedures for the test pad shall be in accordance with Section 3.4 of this CQA Plan. The test pad will be constructed using the same methods and with the same equipment that will be used to construct the compacted soil liner. The test pad will be large enough to allow construction equipment the room to successfully complete required passes and compaction. Since the test pad will evaluate the construction means and methods to be used during compacted soil liner construction, the procedures used to construct the test pad must be thoroughly documented. The CQA Engineer or their designee will observe all activities completed during test pad construction. Documentation information will include at least the following:

- Source of liner material and associated prequalification testing data
- Make, model, weight, and any other unique information (e.g., compactor pad foot height) for the equipment used during test pad construction (e.g., CAT 815F compactor)
- Methods of soil material placement and compaction including soil hauling and unloading operations, soil spreading, and number of compactor passes
- Description of scarification methods, if utilized
- Moisture conditioning methods used, including equipment, frequency of procedures, and apparent results
- Survey control methods for documenting compacted lift thickness and final pad thickness
- Methods used to prevent damage to completed lifts
- Methods used to prevent placement of deleterious materials
- Methods used to prevent placement of frozen material or the placement of material on frozen ground, if appropriate
- Frequency and methods used for calibrating testing equipment
- Testing results including test pad location, test locations, moisture and density results, and their relationship to hydraulic conductivity based on prequalification testing

At the completion of test pad construction, verification testing will be completed in accordance with the following testing schedule:

- Two laboratory hydraulic conductivity tests will be performed utilizing the Flexible Wall Permeameter Test (ASTM D 5084) on undisturbed samples obtained from the completed test pad. Soil samples will be collected by pushing Shelby tubes at random locations on the test pad
- Bulk samples will be taken to the laboratory for Liquid Limit (LL) and Plasticity Index (PI) and Standard Proctor Compaction tests
- One in-situ hydraulic conductivity test will be performed on the completed test pad using a Sealed Double Ring Infiltrometer Test (ASTM D 5093) or a series of 5 Boutwell Permeameter Tests (ASTM D 6391-99)

- Two test pits will be excavated in the test pad to observe interlift bonding of the test pad. The test pits will be located at random locations in an effort to view representative test pad soil profiles
- Laboratory consolidated-undrained triaxial compression tests will be performed on Shelby tube samples obtained from the test pad to verify the shear strength properties.

Photographs of the verification testing procedures and locations will be taken for visual documentation of the testing.

Should the tests described above indicate that the construction procedures resulted in an insufficient liner system, a new test pad will be constructed using modified procedures and/or materials as agreed to by the CQA Engineer and contractor, and approved by the MDNR-SWMP and the IPRE.

Should the tests described above indicate that the construction procedures resulted in an acceptable liner system; a summary report shall be prepared and submitted to the MDNR-SWMP and IPRE that describes the construction and testing procedures that were used. The report will include the documentation information described above as well as related test results and photographs. The CQA Engineer will certify the report prior to submittal to the MDNR-SWMP. The report will be approved by the MDNR-SWMP and IPRE prior to the construction of additional portions of the liner system.

3.3 Compacted Soil Liner Subgrade Preparation

The CQA Engineer and/or designated CQA Inspector will ensure that the compacted soil liner subgrade preparation/construction is completed in accordance with the approved plans and specifications. In addition, the CQA Inspector will identify unexpected conditions encountered during subgrade construction/preparation and record changes to the plans and construction procedures on the as-built drawings. At a minimum, the designated personnel will complete the following:

- Observe and record the placement of subgrade fill on a regular basis
- Verify that soft, organic or other unacceptable materials are removed prior to fill placement
- Verify that subgrade construction is in accordance with the applicable sampling, testing, and survey program(s)
- Prior to soil liner placement, inspect the subgrade for soft spots, pumping, or deleterious materials and verify recompaction or removal and replacement of identified areas
- Verify that all debris, including plant materials such as trees, stumps, and roots, and rocks of size large enough to interfere with proper placement/compaction are removed prior to subgrade construction and preparation
- Prevent the placement of frozen material or the placement of material on frozen ground
- Record the types of compaction equipment utilized for subgrade construction
- Periodically photograph the subgrade construction and finished subgrade surface

- Verify that prior to compacted soil liner placement, the upper 6 inches of subgrade material is disked, recompacted, and graded to provide a workable surface
- Ensure the finished subgrade is surveyed on a maximum interval of 100 feet center to center, and a maximum interval of 100 feet along each line where a break in slope occurs. Sumps or other similar features shall also be identified. The survey shall be completed by a Missouri registered surveyor to confirm and document subgrade elevations and to establish break-line and other design features of the landfill. The purpose is to ensure that the soil liner, when constructed, is continuous over the bottom footprint of the permitted waste disposal boundary and meets the minimum thickness specified for the project.

3.4 Compacted Soil Liner Construction Procedures

Prior to construction of the soil liner, the subgrade will be graded to the elevations specified on the project plans +/- 0.1 foot. The soil liner material will be placed in accordance with the criteria and procedures developed during preconstruction soil testing, test pad construction, and/or in accordance with project specific guidelines. Construction progress shall be monitored with the initial subgrade survey in combination intermediate surveying during construction, as necessary.

The liner will be placed in accordance with the project specifications, geotechnical report, and approved test pad procedures. Generally, soils will be placed in 6" to 8" thick lifts and compacted to the approved moisture and density tolerances. The soils will be compacted with equipment that kneads, compacts, and interbonds the soil from the bottom of the lift up. Material conditioning procedures and compaction equipment rolling patterns will be consistent with those used in the approved test pad construction, but may be evaluated and modified as necessary to yield a workable, consistent, and suitable liner material placement.

3.5 Quality Assurance Monitoring and Testing

A CQA Inspector, under the supervision of the CQA Engineer, will be present on site to monitor the placement and compaction of the soil liner. A qualified CQA Inspector or CQA Engineer will provide visual classification of borrow soils during landfill construction.

Field moisture and density tests will be performed at a minimum frequency of one per 10,000 square feet per lift and will be completed with a nuclear density gauge in substantial compliance with ASTM D 2922 and 3017. Moisture and density test locations will be selected randomly; however, tests will not be grouped together horizontally or vertically from one lift to another. Results of the moisture and density tests will be recorded on a Nuclear Density Gauge Test Record, similar to the one provided in Appendix A. The nuclear density gauge shall be calibrated in accordance with manufacturer's instructions and ASTM 3017-88 requirements. Nuclear density gauges will be standardized in accordance with manufacturer's recommendations daily or more frequently. Unstable or erratic gauges will not be used for quality assurance testing.

Should the results of field moisture and density tests fall outside the placement range or "acceptable zone", as determined in the test pad construction report, the lift in question will be reworked and retested. The area to be reworked will be bounded by the nearest passing moisture/density test locations as delineated by the CQA Inspectors. Drying, wetting, additional compaction, or a combination thereof will be used to bring the nonconforming area to an acceptable level.

The final liner surface will be smooth and free of large angular particles or foreign objects that may damage the geomembrane liner or prevent contact between the geomembrane and soil liner. The final liner surface will also meet other conditions required by the geomembrane manufacturer or installer for installation of the geomembrane component of the composite liner system.

During soil liner construction, verification testing will be completed to ensure that the borrow material being used for construction has not changed in a manner that greatly affects its engineering properties. The following table indicates the prescribed tests and their approximate frequencies for completion during construction.

Test Method	**Frequency**
Atterberg Limits (ASTM D 4318)	1 test per 5,000 cubic yards of material placed and for each change of material type
Particle Size (ASTM D 422)	1 test per 5,000 cubic yards of material placed and for each change of material type
Moisture-Density Relationship (ASTM D 698)	1 test per 10,000 cubic yards of material placed and for each change of material type
Hydraulic Conductivity (ASTM D 5084)	1 test per 5,000 cubic yards of material placed and for each change of material type.

If the borrow material does not meet the criteria for the testing described in the table above, additional laboratory soil tests will be completed to define an acceptable placement range for the non-conforming material. Alternatively, a new test pad can be constructed as described in Section 3.2 to verify that the soils are liner grade materials and the proper placement range. If liner quality soils are stockpiled on site prior to the beginning of placement, a reduced frequency of verification testing will be requested.

To maintain the integrity of the compacted soil component of the liner or final cover system, thin walled steel tube samples (e.g., Shelby tube) for laboratory hydraulic conductivity testing through the completed liner will be avoided whenever possible. Instead, documentation of the required hydraulic conductivity will be provided by the initial materials conformance testing, including development of an acceptable placement range, and quality control/quality assurance monitoring, observation, and testing during construction, most notably moisture and density testing.

Prior to geomembrane installation over the compacted bottom soil liner or final cover, the moisture content of the compacted soil will be maintained to control desiccation cracking. If desiccation cracks are observed in excess of 1 inch deep, the surface will be lightly scarified, moisture conditioned, recompacted, regraded, and rolled to provide a smooth surface for geomembrane installation.

3.6 Thickness Verification

An independent surveyor licensed to practice in the State of Missouri will verify the thickness of the compacted soil portion of the liner after completion. The independent surveyor will operate independently of the landfill operator, construction contractor, Owner, and permit holder. The surveyor may be employed by the CQA Engineer. Prior to construction of the compacted soil liner, a survey will be completed on a minimum of 100-foot grid system. Additional survey shots will be taken at 100-foot intervals along each line where a break in slope occurs to document the top of subgrade elevations. At the completion of compacted soil liner construction, a survey will be completed at the same approximate locations to verify the required soil component thickness was achieved. Acceptable tolerances for surveying shall be ±0.1 foot for elevations and ±1.0 foot for horizontal coordinates. All results must indicate a liner thickness equal to or greater than that required by the plans and specifications.

4.0 FLEXIBLE MEMBRANE LINER

The geomembrane portion of the composite liner and final cover systems will be constructed and tested in accordance with the approved permit documents, this CQA Plan, and the manufacturer's recommendations and specifications. This section covers material conformance testing, construction methods, and testing requirements.

4.1 Materials Conformance Testing

Prior to construction of the geomembrane portion of the bottom liner or final cover system, the CQA Engineer will obtain one geomembrane sample per 100,000 square feet of geomembrane to be installed. The following tests will be performed by the CQA Engineer to verify that the geomembrane conforms to the project specifications and the manufacturer's MQC/MQA documentation:

- Thickness (ASTM D 5199)
- Density (ASTM D 1505)
- Tensile Properties (e.g., strength, elongation) (ASTM D 638, Type IV)
- Tear Resistance (ASTM D 1004)
- Puncture Resistance (ASTM D 4833)
- Notched Constant Tensile Load (ASTM D 5397)
- Carbon Black Dispersion (ASTM D 5596)
- Carbon Black Content (ASTM D 1603).

For each of the properties listed above, the material will meet current industry standards for the geomembrane material type (e.g., HDPE, smooth) and thickness. Deviations from this testing protocol due to changes in test methods or industry standards may be approved by the CQA Engineer with prior approval by the MDNR-SWMP and IPRE.

For the bottom liner system in the Labadie UWL (Cells I through 4), 60-mil textured (both sides) HDPE will be used for the bottom inside slopes of the perimeter and interior berms. Smooth 60-mil HDPE will be used in the center of each cell from the interior toe of the perimeter berm of each disposal area.

For the final cover system construction, 40-mil smooth HDPE will be used on the top or crown of the landfill. Textured (both sides) 40-mil HDPE will be used on the side slopes.

The CQA Engineer or their representative will log all rolls of geomembrane material that arrive on site and review the manufacturer's MQC certification documentation. Each roll will be documented on a Material Inventory Log similar to that found in Appendix A. Storage of geomembrane material will be in a manner that reasonably protects the material from puncture, denting, deformation of rolls, and other damaging situations, in accordance with the manufacturer's recommendations, prior to its deployment. UV sensitive geosynthetics should be stored in undamaged opaque coverings and protected from standing water during storage.

4.2 Construction Procedures

At the conclusion of soil liner or cover construction, the geomembrane liner will be installed by a third-party geosynthetics contractor in accordance with acceptable industry standards and the manufacturer's recommendations, standards, guidelines, and specifications. The geomembrane supplier or installer will develop a panel layout diagram in accordance with industry standards. The panel layout diagram will be designed so that the majority of the geomembrane seams run perpendicular not parallel with the side slopes, so that no horizontal (parallel with slopes) geomembrane seams are within five (5) feet of grade breaks, such as the toe and top of slopes. The manufacturer will provide the panel diagram to the CQA Engineer.

The subgrade will be compacted to provide a firm, unyielding foundation sufficient for all deployment vehicles to move about the construction area without rutting and pumping. The geomembrane installer will complete a Subgrade Acceptance Form for inclusion in the construction documentation report.

Anchor trenches will be excavated to the lines and widths shown on the construction documents developed in accordance with the approved permit documents. Sharp bends and edges in the anchor trench will be minimized to avoid potential stresses to the geomembrane.

Geomembrane panels will be installed and immediately assigned a number according to a panel numbering system. Panels will be physically identified in the field with a grease pencil or other durable material for reference during seaming and testing operations and project records. Destructive and nondestructive test locations as well as repair locations will be appropriately identified for documentation purposes. Panels will be deployed with a rubber-tired, front loader and special roller bar to assist with unrolling the geomembrane panels at specified locations. Care will be taken to minimize traffic and prevent equipment from damaging the geomembrane or supporting subgrade surface. Sandbags or other approved loading shall be used as necessary to prevent uplift of panels by the wind. Panels will not be deployed in areas of standing water or on frozen subgrade. Any damage to panels during deployment will be noted and repaired by patching and/or spot welding as approved by the CQA Engineer. No more panels will be deployed than can be seamed during that day, unless securely ballasted to prevent movement prior to seaming. A Panel Placement Form will be completed by the CQA Inspector for all panels deployed (see Appendix A).

Steps will be taken to prevent water from getting under the geomembrane during and after deployment. "Shingling" of the panels or completion of seaming for those panels deployed prior to the end of the workday will be used as appropriate to minimize the potential for such occurrence. Additionally, temporary or permanent berms will be constructed where necessary to redirect surface water away from the construction area.

4.3 Quality Assurance Monitoring and Testing

The CQA Inspector will visually inspect the panels for direct contact between the clay liner and the panel surface. It is imperative that the geomembrane maintain intimate contact with the compacted soil liner surface. The CQA Inspector will monitor for panel and seam defects or damage and mark any location of concern for follow-up repair. The geomembrane panels will be seamed together using double wedge fusion welding equipment supported by extrusion welding equipment where conditions make fusion welding impractical. Photo documentation of geomembrane installation and repair procedures will be included in the final CQA Report. Quality assurance monitoring and testing will follow the manufacturer's recommendations or industry standards for installation and seaming.

4.3.1 Trial Welds

Prior to seaming the geomembrane panels, trial welds will be made by the welding equipment to be used during that day's work and tested. The trial welds will be made by the same machine/operator combination and under the same conditions as will be encountered during actual seaming operations for that day. Trial welds will be made at the beginning of each workday, at approximately 4 to 5 hour intervals thereafter, and whenever a new welding machine/operator combination begins work.

For fusion trial welds, testing will include "shear" tests on five samples and top and bottom "peel" tests on five samples each. For extrusion trial welds, five samples will be tested for shear strength and five samples shall be tested for bottom peel strength.

Four out of each five samples tested must meet the following criteria for the test weld to be considered acceptable:

Shear Test

- Exhibit elongation of the parent material prior to parent material failure
- Meet or exceed the required bonded seam strength for either fusion or extrusion welds, whichever is applicable

Peel Test

- Exhibit film tear bond with less than 10 percent separation of the seam
- Meet or exceed the required bonded seam strength for both fusion and extrusion welds

Should trial welds fail, adjustments will be made to the welder, as necessary, and new specimens will be welded and tested. If repeat tests also fail, the subject welding machine will not be used for seaming until deficiencies are corrected and passing trial welds are achieved. All trial welds will be documented by the CQA Inspector on a Trial Weld Log. An example of a Trial Weld Log is included in Appendix A.

4.3.2 Panel Seaming

The CQA Inspector will observe typical panel welding to assure the welding area is kept generally clean and free of moisture, dirt, and debris. "Fish mouths" and wrinkles at seam overlaps that cannot be welded will be cut out and patched with an extrusion welded patch that is approximately round or rectangular with rounded corners. A seam number will be assigned to each seam that reflects the two panels being joined. The CQA Inspector will measure the seams and record the measurements on a Panel Seaming Form similar to the one found in Appendix A. Alternatively, seam layout and dimensions may be determined by locating the corners with Global Positioning System (GPS) equipment capable of identifying locations to an accuracy of ± 1-foot. Additional information to be documented includes date and time of seaming, the welder's initials, machine number, machine speed, and set temperature.

4.3.3 Non-Destructive Testing

All seams that are welded during installation of the geomembrane liner will be non-destructively tested by the Geomembrane Contractor and overseen by the CQA Inspector to check the integrity of the seams. Non-destructive tests will be conducted using the air pressure test or the vacuum test.

Air Pressure Test

Air pressure testing will be completed on seams that have been welded with a fusion welder (wedge welder) using an air pump capable of sustaining 25 to 30 pounds per square inch (psi) of pressure. The Geomembrane Contractor will follow the following procedures:

- Seal one end of the seam channel to be tested
- Insert sharp, hollow needle or other approved pressure feed device with a pressure gauge into the sealed end of the seam
- Energize the air pump to verify the unobstructed passage of air through the seam channel. Should the verification fail, locate the obstruction and test the seam on both sides of the obstruction
- Seal the other end of the seam channel
- Energize the air pump to a pressure of between 25 and 30 psi, close valve, and allow 2 minutes for the injected air to reach equilibrium in the channel prior to recording the initial pressure reading
- Sustain pressure for 5 minutes and note the final pressure reading
- If the air pressure decreases by more than 4 psi during the initial 5-minute test period, locate the faulty area of the seam, make repairs, and retest
- If the air pressure test passes, the air channel should be cut at the opposite end of the seam from the gauge to deflate the seam channel. Keep a record of appropriate test information on a Non-Destructive Test Log similar to the one included in Appendix A.

Vacuum Test

Vacuum testing will be completed on seams that have been welded with an extrusion welder or when the geometry of a seam makes it impossible or impractical to test using the air pressure test. The Geomembrane Contractor shall follow the following procedures:

- If testing a fusion weld trim excess overlap from the seam edges
- Wet the area to be tested with a soapy liquid solution
- Place the vacuum box assembly over the wetted area and apply sufficient pressure to "seat" the box on the test area
- Create a vacuum of 3 to 5 psi to the box, using the pressure gauge on the box to observe pressure readings
- Once a tight seal is verified, observe the area for approximately 15 seconds looking for recurring soap bubbles on the seam
- If leaks (bubbles) are observed, mark the location of each leak for repair
- If no leaks are detected, release the pressure on the vacuum box and move to the next adjacent test location maintaining a minimum 3-inch overlap if applicable
- Maintain a record of appropriate test information on a Non-Destructive Test Log similar to the one included in Appendix A

If specific locations exist where non-destructive testing is not possible or practical, seams will be tested by an alternate method accepted by the CQA Engineer.

4.3.4 Destructive Testing

Destructive testing is conducted to evaluate the strength of welded seams. Destructive testing should be minimized to preserve the integrity of the liner system. Destructive test samples will be taken at an average of once per 500 feet of seam length. The Geomembrane Contractor will follow the following procedures:

- The CQA Inspector will identify seam locations to be sampled and tested. All destructive sample locations will be marked on the geomembrane liner, indicating appropriate information including test number, seams tested and date.
- The Geomembrane Contractor will cut three samples at the selected location: one each for the Geomembrane Contractor, the CQA Inspector, and the Owner's archive. Each sample will be a minimum of 12 inches wide by 18 inches long (or according to minimum laboratory requirements) with the seam centered lengthwise. For fusion welded seams the geomembrane contractor will field test fifteen (15) 1-inch wide test specimens, ten (10) for peel strength and five (5) for shear strength per UWL cell. Five (5) of the peel specimens must come from the top weld, and five (5) must come from the bottom weld. For extrusion welded seams the geomembrane contractor will field test ten (10) 1-inch wide test specimens, five (5) for peel strength and five (5) for shear strength. Welded seam tested strengths must equal or exceed the requirements of the Geosynthetic Institute (GSI) Test Method GM19 (10/3/2011) for 60-mil HDPE component of the composite liner and the 40 mil HDPE component of the final cover system.

  Shear Test

  - All five test specimens must meet or exceed the required bonded seam strength for either hot wedge seams or extrusion fillet seams, whichever is appropriate
  - Shear percent elongation should exceed 50% at break

Peel Test

- All ten (or five out of five) test specimens must meet or exceed the required bonded seam strength for either hot wedge seams or extrusion fillet seams, whichever is appropriate
- Peel separation (incursion depth) should not exceed 25%

- The Owner or CQA Inspector will coordinate with an independent third-party laboratory to perform the same test procedures on the samples retained by the CQA Inspector.
- Failing tests will be addressed by the procedures outlined below. Such criteria will apply to both the field tests and the third-party laboratory tests. Should environmental conditions during testing detrimentally affect field test results, the laboratory tests will govern
- The CQA Inspector will document pertinent destructive test information on a Destructive Test Log similar to the one in Appendix A

Procedures for Destructive Test Failure:

- Two additional destructive samples will be taken one on each side of the failed test location at least 10 feet from its location
- The same testing procedures as described above will be followed to determine whether the additional samples pass or fail
- If the additional tests pass, the portion of the seam between two passing test locations will either be reconstructed or cap stripped
- If either of the additional tests fails, the process will be repeated until a seam length is bounded by two passing tests. At that point, the seam between the two passing test locations will either be reconstructed or cap stripped
- All repaired or replaced seams will be non-destructively tested to verify their integrity. Repairs will be noted on a Repair Report Form similar to the one found in Appendix A

4.3.5 Defects and Repairs

The CQA Inspector and Geomembrane Contractor will monitor the geomembrane liner and seams for defects, holes, blisters, and signs of damage during installation. Portions of the geomembrane or seams that show flaws, destructive test locations, and portions of seams that fail destructive or non-destructive tests will be repaired. Repairs will be completed using patching, extrusion welding, cap stripping, or other means approved by the CQA Inspector. Repairs will be non-destructively tested using methods described in Section 4.3.3 and documented on a Repair Report Form similar to the one in Appendix A.

5.0 GEOTEXTILE

Geotextile fabric required for the project will be installed by a qualified third-party contractor.

Geotextile fabric required for the project will be installed and tested in accordance with the approved permit documents and the manufacturer's guidelines, standards and specifications. Care will be used during construction to ensure that geotextile materials are not damaged. Geotextile filter fabric panels that are placed will be overlapped and bonded together to maintain placement in accordance with the manufacturers or suppliers standard for bonding of adjacent panels of geotextile.

The CQA Engineer or his representative will log all rolls of geotextile material that arrives on site and review the manufacturer's QC certification documentation. Each roll will be documented on a Material Inventory Log similar to that found in Appendix A. Storage of geotextile material will be in a manner that reasonably protects the material from puncture, denting, deformation of rolls, and other damaging situations prior to its deployment. UV sensitive geosynthetics will be stored in undamaged opaque coverings and protected from standing water during storage. Photo documentation of geotextile storage, installation, and repair procedures will be included in the final CQA Report.

5.1 Materials Conformance Testing

Prior to installation the contractor will supply the CQA Engineer with MQC and MQA information and testing documentation on the supplied materials conformance with the design specifications for geotextiles or the CQA Engineer shall obtain one geotextile sample per 100,000 square feet of material to be installed for MQA testing. The following MQC and MQA tests will be performed to verify that the geotextile conforms to the project specifications:

- Mass per unit area (ASTM D 5261/ASTM D 3776); Thickness (ASTM D 5199)
- Grab Tensile (ASTM D 4632)
- Permittivity (ASTM D 4491) (if material is to be used as a filter layer)
- Apparent Opening Size (ASTM D 4751) (if material is to be used as a filter layer)
- Shear strength properties of interface with other geosynthetics, CCPs and soils

For each of the properties listed above, the material shall meet current industry standards for the geotextile material type (e.g., woven, non-woven) and unit weight. Deviations from this testing protocol due to changes in test methods or industry standards shall be allowed with the approval of the CQA Engineer.

5.2 Construction Procedures

In general, the geotextile will be installed according to the manufacturer's recommendations and the project specifications. Proper documentation of the installation will be provided. At a minimum, the following guidelines shall be followed:

- Deployed geotextile will be weighted at its edges during times of excessive wind
- Care will be taken when cutting geotextile in place to not cut or damage other associated geosynthetic materials
- Care will be taken to avoid trapping rocks or other sharp objects between geotextile and geomembrane layers
- Tears or rips in geotextile materials will be patched with like geotextile material
- Geotextiles may be overlapped, stapled, sewn or fusion welded in accordance with the manufacturer's instructions and project specifications

6.0 LEACHATE COLLECTION SYSTEM

The two primary components of the leachate collection system include the aggregate drainage layer or geocomposite drainage net and associated leachate collection pipes. This section covers material conformance testing and general CQA requirements to ensure the leachate collection system is constructed in accordance with the construction and permit documents. Material conformance testing and general CQA observations required for the geocomposite drainage net are discussed in Section 7.0 of this report.

6.1 Aggregate Drainage Layer

Aggregate to be used in the drainage layer will be non-carbonate, well-graded aggregate with a minimum permeability of 0.25 cm/sec and particle diameter of 0.425 mm to13.0 mm. Aggregate placement/spreading techniques that minimize the potential for damage to the underlying geomembrane liner will be used. Specifically, aggregate will be placed by advancing the aggregate in fingers across the geotextile cushion layer overlying the geomembrane. Low ground pressure equipment such as a lightweight, wide-tracked dozer will be used for spreading the aggregate. During aggregate drainage layer installation, periodic visits to the site will be made by the CQA Inspector to observe and document installation procedures.

Prior to placement of the aggregate, representative samples of the stockpiled materials proposed for use will be collected and tested. One sample shall be taken from for every 5,000 CY of aggregate. This testing shall verify that the aggregates to be used for construction meet project specifications as determined by this pre-qualification testing. The following tests may be performed as prescribed by the CQA Engineer:

Test Method	Test Description
ASTM C 136	Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 117	Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
ASTM D 5084	Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

An independent surveyor licensed to practice in the state of Missouri will verify the thickness of the aggregate drainage layer. The surveyor will be independent of the landfill contract operator, construction contractor, Owner, or permit holder. The surveyor may be employed by the CQA Engineer. Following completion of the aggregate drainage layer, a final survey shall be completed on a minimum 100-foot grid system and at 100 foot intervals at along the perimeter to document the top of aggregate elevations. These survey points will be in the same general locations as the subgrade and top-of-clay-liner surveys to allow calculation of drainage layer thickness. Acceptable tolerances for surveying shall be ±0.1 foot for elevations and ±1.0 foot for horizontal coordinates. All results must indicate an aggregate drainage layer thickness equal to or greater than that required by the plans and specifications.

Once the non-carbonate gravel is in place, a geotextile filter will be laid over the top of the gravel and then covered with a single 12 inch layer of aggregate protective cover, to protect the liner, drainage layer, and pipes from damage during construction and initial filling operations.

6.2 Leachate Collection Piping

Leachate collection piping will be installed in accordance with the approved permit documents. The CQA Inspector will observe the placement of the piping to verify that the appropriate slope on the pipe has been achieved. Additionally, visual observation of piping connections will be made to document proper connection of pipe segments and orientation of perforated pipe, where applicable. The placement location of the leachate collection system piping will be documented by a survey by the CQA Engineer or Independent Surveyor at minimum intervals of 100 feet laterally along the pipe length and at changes in horizontal or vertical direction. Acceptable tolerances for surveying shall be ±0.1 foot for elevations and ±1.0 foot for horizontal coordinates. The survey locations will be used to verify the pipe has the appropriate slope.

7.0 GEOCOMPOSITE

Geocomposite material may be installed as an alternate leachate drainage layer instead of the aggregate drainage layer over the geomembrane liner. Geocomposite material will be installed by a qualified contractor. The geocomposite manufacturer will develop a panel layout diagram in accordance with industry standards for the leachate drainage layer as shown on the plan sheets. The manufacturer will provide the panel layout diagram of the geocomposite drainage layer to the CQA Engineer.

Geocomposite material will be tested and installed in accordance with the approved permit documents and manufacturer's installation instructions. Care must be used during construction to ensure that geocomposite materials and geomembrane layer are not damaged.

The CQA Engineer or his representative will log all rolls of geocomposite material that arrive on site and review the manufacturer's QC certification documentation. Each roll will be documented on a Material Inventory Log similar to that found in Appendix A. Storage of geocomposite material will be in a manner that reasonably protects the material from puncture, denting, deformation of rolls, and other damaging situations prior to its deployment. UV sensitive geosynthetics will be stored in undamaged opaque coverings and protected from standing water during storage. Photo documentation of the geocomposite drainage layer storage, installation, and repair procedures will be included in the final CQA Report.

7.1 Materials Conformance Testing

Prior to installation of the geocomposite, the CQA Engineer shall obtain one geocomposite sample per 100,000 square feet of material to be installed for materials conformance testing or obtain equivalent MQA and MQC materials conformance testing from the supplier or installer. The following materials conformance tests and results shall verify that the geocomposite material conforms to the project specifications:

- Ply Adhesion (ASTM D 413)
- Thickness (ASTM D 5199)
- Transmissivity (every fifth sample) (ASTM D 4716)

For each of the properties listed above, the material shall meet current industry standards for the geocomposite material type. Deviations from this testing protocol due to changes in test methods or industry standards will be approved by the CQA Engineer.

7.2 Construction Procedures

In general, the geocomposite will be installed in compliance with the manufacturer's requirements and the project specifications. Proper documentation of the installation will be required. At a minimum, the following guidelines will be followed:

- Deployed geocomposite will be weighted at its edges during times of excessive wind

- Geocomposite to be deployed on slopes will first be anchored and rolled down the slope in a controlled manner
- Geocomposite will not be deployed horizontally across slopes unless approved by the CQA Engineer
- Care will be taken when cutting geocomposite in place to not cut or damage other associated geosynthetic materials
- Care will be taken to avoid trapping rocks or other sharp objects between geocomposite and geomembrane layers
- Tears or rips in the geotextile portion of the geocomposite will be patched with like geocomposite material. Patches will be a minimum of 2 feet beyond the edges of the hole or tear

Adjacent geocomposite rolls will be joined according to project specifications and manufacturer's instructions. At a minimum the following procedures will be followed:

- Tears or rips in geotextile portion of the geocomposite will be patched with like geocomposite material
- Adjacent edges of the geonet along the length of the geocomposite roll will be placed with the edges of each geonet overlapping each other by 4 inches minimum
- The adjacent edges will be joined by tying the geonet structure with plastic (not metal) cable ties spaced every 5 feet along the roll length
- Adjoining geocomposite rolls (end to end) across the roll width should be shingled down in the direction of the slope, with the geonet portion of the top overlapping the geonet portion of the bottom geocomposite a minimum of 12 inches across the roll width
- Where the geocomposite is anchored in an anchor trench, the geonet portion should be tied every 6 inches along the geocomposite edges

8.0 PROTECTIVE COVER

This section covers material conformance testing and general CQA requirements to ensure the aggregate protective cover layer is constructed in accordance with the construction and permit documents.

8.1 Aggregate Protective Cover Layer

The aggregate protective cover layer shall consist of well-graded non-carbonate aggregate with a particle size between 9.5 mm and 0.075 mm, with 0 to 10 percent passing the No. 100 U.S. Sieve, a d_{50} particle size of approximately 0.5 to 0.9 mm, and a d_{15} particle size of approximately 0.2 to 0.4 mm. Aggregate protective cover placement/spreading techniques that minimize the potential for damage to the underlying geotextile layer and aggregate drainage layer will be used. Specifically, aggregate protective cover will be placed by advancing the aggregate in fingers across the underlying geotextile filter layer. Low ground pressure equipment such as a lightweight, wide-tracked dozer will be used for spreading the aggregate. During aggregate protective cover layer installation, periodic visits to the site will be made by the CQA Inspector to observe and document installation procedures.

Prior to placement of the protective cover layer aggregate, representative samples of the stockpiled materials proposed for use will be collected and tested. One sample will be taken from for every 5,000 CY of aggregate. Testing will verify that the aggregates meet project specifications as determined by this pre-qualification testing. The following tests may be performed as prescribed by the CQA Engineer:

Test Method	Test Description
ASTM C 136	Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 117	Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
ASTM D 5084	Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

An independent surveyor licensed to practice in the state of Missouri will verify the thickness of the aggregate protective cover layer. The surveyor will be independent of the landfill contract operator, construction contractor, Owner, or permit holder. The surveyor may be employed by the CQA Engineer. Following completion of the aggregate protective cover layer, a final survey will be completed on a minimum 100-foot grid system and at 100 foot intervals along the perimeter to document the top of aggregate protective cover layer elevations. These survey points will be in the same general locations as the subgrade and top-of-clay-liner surveys to allow calculation of protective cover layer thickness. Acceptable tolerances for surveying shall be ±0.1 foot for elevations and ±1.0 foot for horizontal coordinates. . All results should show an aggregate protective layer thickness equal to or greater than that required by the plans and specifications.

9.0 FINAL COVER CONSTRUCTION

The final cover system will consist of two (2) feet of soil cover overlying a geotextile layer overlying a 40 mil thick HDPE geomembrane layer on the final top and side slopes of the UWL. The two feet of nominally compacted soil of the final cover system will be constructed and tested in accordance with the approved permit documents and this CQA Plan. This section covers material conformance testing, general construction procedures, and testing requirements.

9.1 Materials Conformance Testing

Prior to construction of the nominally compacted soil component of the side slope final cover system, representative samples of the soil materials proposed for use will be collected and tested to verify that the soils meet the project specifications determined by the pre-qualification testing. The soils utilized for the final cover system shall consist of soils classified as CH, CL, ML, SC, and MH soils types according to the Unified Soil Classification System. The CQA Engineer will verify that the soil selected for use in the final cover and the associated placement ranges are capable of meeting the minimum shear strength properties, both internal and interface with geosynthetics and soils, utilized in the geotechnical design (reference Appendix J of the Construction Permit Application). Soil used for the nominally compacted soil layer on the side slopes and top should be adequate to establish and support vegetation.

9.2 Nominally Compacted Soil Construction Procedures

The nominally compacted soil layer of the final cover system will be placed over the geotextile cushion layer above the 40-mil smooth and textured HDPE geomembranes on the final top portion and the side slopes of the UWL. The soil used for the nominally compacted layer should be adequate to establish and support vegetation.

9.3 Quality Assurance

The quality assurance monitoring and testing program for the nominally compacted layer of the final cover system utilizes the same program as that of the compacted clay liner (see Section 3.5). Thickness verification will be completed for the nominally compacted soil portions of the final cover as described in Section 3.6.

10.0 MISCELLANEOUS HDPE PIPING

This section applies to miscellaneous HDPE piping, including stormwater and leachate transport lines and pump intake lines.

10.1 Butt, Heat Fusion Welds

All HDPE pipe and fittings shall be joined using butt, heat fusion welds. All joints will be made in compliance with the manufacturer's recommended practice for heater surface temperature, heating time, applied pressure and cooling time, subject to the CQA Engineer's approval. All joints will be made by trained technicians qualified by the manufacturer and using equipment and controlled procedures approved by the manufacturer.

Pipe joints will be stronger than the pipe itself under both tension and hydrostatic loading conditions. The joints will be leak-tight, homogeneous and uniform throughout. The contractor will submit written documentation certifying compliance with the manufacturer's standard specifications and CQA plan for the butt, heat fusion technique.

11.0 REPORTING

Proper documentation of the CQA process is an important aspect of construction documentation. In addition to the completion of the forms and logs mentioned previously, the following reports will be completed.

11.1 Daily Reports

The CQA Inspector will provide daily written reports to the CQA Engineer during the days when inspections are made. These reports will include information about the work accomplished each day; tests and observations that were made; and descriptions of the adequacy of the work performed. The reports will include the following as appropriate:

- Date, project name, location, cell involved in construction, equipment utilized, and personnel involved in major activities
- Description of weather conditions, including temperature, cloud cover, and precipitation
- Description of the type of construction, inspection, and testing activity for the day
- Location of construction activity for the day
- Location of tests completed
- Discussion of construction methods (i.e., equipment make/model, number of compactor passes, etc.) as they relate to the previous cell or test pad construction
- Results of construction activity (i.e., first lift completed, sump completed, etc.)
- Description of construction materials used including reference to certifications, test results, etc.
- Location of observation activity or location from which the sample(s) were obtained; Standard methods and frequency used for tests
- Results of testing performed (passing or failing); Equipment calibration results
- Construction or testing problems and required actions
- Photographic documentation of construction progress including time, date, location, and name of photographer
- Signature of the CQA Inspector

Appendix A includes example CQA forms, which provide an acceptable format the required information that may be used by the CQA Engineer, including:

- Daily Activities Field Report
- Nuclear Density Gauge Test Record
- Material Inventory Log
- Panel Placement Log
- Trial Weld Log
- Panel Seaming Log
- Non-Destructive Test Log
- Destructive Test Log

- Repair Log

These forms may be modified based on the final project features requiring CQA/CQC oversight.

11.2 Design Change Documentation

On occasion it may be necessary to modify the design during construction activities. The Owner, MDNR-SWMP, and IPRE must approve changes to the design or deviation from the permit documents.

11.3 Deviation from CQA Plan

During the course of construction, deviations from the CQA Plan may be necessary due to various construction issues, permit modifications, regulatory changes, new technology, or changes to accepted standards. Deviations from this CQA Plan will be documented and approved by the Owner and the CQA Engineer.

11.4 Final Documentation Report

At the completion of each cell's liner and leachate collection system construction, or closure of specified area of the landfill, the CQA Engineer will prepare a final CQA Report for submittal with the initial cell's Operating Permit Application (or the Request for Authorization to Operate for subsequent cells) to the MDNR-SWMP and Franklin County. This report will bear the CQA Engineer's Missouri Professional Engineer's seal and date. The CQA Report will contain the following information:

- A certification (signed, sealed, and dated) by the CQA Engineer stating that the construction of the cell has been completed in substantial compliance with the engineering design, CQA Plan and the facility Construction Permit
- As-built drawings (signed, sealed, and dated) by the CQA Engineer or the licensed survey certification (signed, sealed, and dated) by a Missouri registered land surveyor or a Missouri Professional Engineer
- CQA field data and laboratory test results
- CQA inspection records and photographs

The final CQA Report and Operating Permit Application will be submitted to the MDNR-SWMP prior to the cell receiving its first load of waste.

APPENDICES

APPENDIX A

Example CQA Forms

DAILY FIELD ACTIVITIES REPORT

Client Name: ______________________ Date: ____________

Start Time: ____________

Stop Time: ____________

Project Location: ______________________

Task: ______________________

Weather Information

Contractors, Personnel, and Equipment On Site

Work Areas/Boundaries

Testing Equipment Used/Observed and Calibration/Re-Calibration Documentation

Tests Completed/Observed

Work Comments/Observations and Test Results

Material(s) Delivered to Site

____

CQA Monitoring Technician

Nuclear Density Gauge Test Record

Date ____________ Page ______ of ________
CQA Technician ______________________

Client Name: ______________________
Project Name: ______________________
____
Project Number: ______________________
Project Location: ______________________
____

Material Designation: ________ ________
Target Dry Density: ________ ________
Target Moisture Range: ________ ________
Target Percent Compaction: ________ ________

Standard Density: ________
Standard Moisture: ________

Test-Lift Number	Material Designation	Lift Range (in.)	Location	Probe Depth (in.)	Wet Density (pcf)	Water Weight (lbs.)	Dry Density (pcf)	Water Content (%)	Percent Compaction (%)	Pass/ Fail

Material Inventory Record

Date ______ Page ______ of ______
CQA Technician ______

Client Name: ______
Project Location: ______
______

Material Type: ______

Project Name: ______
______
Project Number: ______

Date Received	Roll No.	Lot/ Batch	Roll Size			QC Docs Received	Date Used	Remarks
			Width (ft)	Length (ft)	Area (sq. ft)			

Panel Placement Record

Date ____________ Page _____ of _______
CQA Technician ____________________

Client Name: ______________________________

Project Location: ______________________________

____

Project Name: ______________________________

____

Project Number: ______________________________

Time	Panel Number	Roll Number	Panel Length (ft)	Panel Width (ft)	Panel Location/Comments

Trial Weld Record

Date ____________ Page ______ of ________
CQA Technician ____________________

Client Name: ______________________________
Project Name: ______________________________
____
Project Number: ______________________________
Project Location: ______________________________
____

Specifications: __________ mil

	Wedge	Extrusion
Peel (P)	≥ ______	≥ ______
Shear (S)	≥ ______	≥ ______
	______ of	______ bones

Trial Weld Number	Time	Ambient Temp	Installer's QC	Machine Number	Machine Properties	Weld Type	Seamer Initials	Test Values lbs/inch						Pass/ Fail	Type of Material	Comments
								P								
								S								
								P								
								S								
								P								
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SAMPLE

Seam/Non-Destructive Test Record

Date ____________ Page ______ of ________
CQA Technician ____________________

Client Name: ______________________________
Project Location: ______________________________
____

Project Name: ______________________________
____
Project Number: ______________________________

Seaming Information										Non-Destructive Testing Information										
Time	Seam Number	Seam Length	Seamer Initials	Machine Number	Trial Weld #	Direction Seamed	Weather/ Temp	Destruct Number	Comments	Date Tested	Addn'l Test #'s	Tester Initials	Pressure			Time		P/F	Vacuum Box P/F	Location/ Comments
													Start	End	+/-	Start	End			

Non-Destructive Test Record

Date ____________ Page _____ of _______
CQA Technician ____________________

Client Name: ______________________________
Project Location: ______________________________
____

Project Name: ______________________________
____
Project Number: ______________________________

Test Number	Seam Number	Tester Initials	Pressure			Time		P/F	Vacuum Box P/F	Location/Comments
			Start	End	+/-	Start	End			

Destructive Test Record

Date ____________ Page ______ of ________
CQA Technician ________________

Client Name: ______________________________
Project Name: ______________________________
____
Project Number: ______________________________
Project Location: ______________________________
____

Specifications: ________ mil

	Wedge	Extrusion
Peel (P)	≥	≥
Shear (S)	≥	≥

__________ of __________ bones

Sample ID	Installer's QC	Seam Number	Weld Type	Machine Number	Seamer Initials	Test Values lbs/inch						Field Pass/Fail	Lab Pass/Fail	Location
						P								
						S								
						P								
						S								
						P								
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Repair Record

Date ________ Page ____ of ____
CQA Technician ____________

Client Name: ____________________

Project Location: ____________________

____

Project Name: ____________________

____

Project Number: ____________________

Repair Number	Panel/ Seam	Repair Crew	Machine Number	Repair Type	Repair Size	Test Date	Trial Weld Number	Tester Initials	Test P/F	Location/Comments

Appendix Q

Groundwater Sampling and Analysis Plan

Ameren Missouri Labadie Energy Center
Proposed Utility Waste Landfill
Franklin County, Missouri

Groundwater Sampling and Analysis Plan

Ameren Missouri
Power Operation Services
3700 South Lindbergh Blvd.
St. Louis, Missouri 63127

December 2012

GREDELL Engineering Resources, Inc.
1505 East High Street
Jefferson City, Missouri 65101
Phone: (573) 659-9078
Fax: (573) 659-9079

Ameren Missouri Labadie Energy Center
Groundwater Sampling and Analysis Plan
Proposed Utility Waste Landfill
Franklin County, Missouri

December 2012

Table of Contents

List of Figures

List of Tables

List of Appendices

1.0 INTRODUCTION

This sampling and analysis plan (SAP) has been prepared by GREDELL Engineering Resources, Inc. for the proposed Ameren Missouri Labadie Utility Waste Landfill, located adjacent to the Labadie Energy Center and approximately two and one-half miles northeast of the town of Labadie and immediately southeast of the Missouri River in northeast Franklin County, Missouri. The proposed utility waste disposal area and surrounding areas to the north, south, and east are currently used primarily for agricultural (row-crop) production. The Labadie Energy Center is located immediately to the west. Labadie Bottom Road marks the approximate western boundary of the site and Davis Road marks the eastern boundary of the site. The general location is shown on Figure 1.

The SAP has been prepared consistent with the rules and regulations promulgated by the Missouri Department of Natural Resources Solid Waste Management Program (SWMP) and the Division of Geology and Land Survey (DGLS), found under 10 CSR 80-11.010(11)(C)2. through 10 CSR 80-11.010(11)(C)6. and 10 CSR 23-4, respectively. This SAP includes the following information: QA/QC procedures to be followed during both field sampling and laboratory analyses; groundwater sample preservation and shipment procedures; a chain-of-custody procedure; and discussion of statistical methods to be followed in the evaluation of groundwater samples gathered in accordance with this plan. Site-specific technical reports were also consulted during development of this plan. They include:

> *Detailed Site Investigation Report for Ameren Missouri Labadie Power Plant Proposed Utility Waste Disposal Area, Franklin County, Missouri*, dated February 4, 2011, revised March 30, 2011 by GREDELL Engineering Resources, Inc. and Reitz & Jens, Inc.
>
> *Construction Permit Application for Utility Waste Landfill, Ameren Missouri Labadie Energy Center*, prepared by Reitz & Jens, Inc. and GREDELL Engineering Resources, Inc.

This SAP is being submitted as an appendix to the solid waste disposal area construction permit application referenced above. The SAP focuses on the implementation of appropriate sampling and analysis procedures for the establishment of a groundwater detection monitoring system at the proposed utility waste landfill. This SAP will help ensure that the landfill development proceeds in an environmentally sound fashion, consistent with Solid Waste Management Law and Rules.

2.0 FACILITY LOCATION

The proposed Labadie UWL is located within the alluvial floodplain of the Missouri River in northeastern Franklin County approximately two and one-half miles northeast of the town of Labadie and six miles north of intersection of State Hwy 100 and Interstate 44 (Figure 1). The National Geodetic Survey indicates the site lies within the northwestern part of Township 44 North, Range 2 East. Portions of the area are part of the "historic" Spanish Land Grant survey system identified as "SUR". The site is located within sections 17 and 20, SUR 384, and SUR 1735. The site has had a historical land use of agriculture.

Groundwater levels are largely influenced by fluctuations in Missouri River level. Depth to groundwater is relatively shallow and varies from two to 13 feet, but levels were noted in some instances to rise up to, and during infrequent high-river stages, may slightly exceed ground surface elevation. Hydraulic gradients are also shallow. Minimum values range from 1.990×10^{-6} ft/ft to 6.161×10^{-5} ft/ft (0.015 to 0.33 ft/mi). Maximum values range from 3.517×10^{-3} ft/ft to 5.534×10^{-4} ft/ft (3 to 18 ft/mi). Calculated hydraulic conductivity values range from 9.47×10^{-2} to 2.15×10^{-2} feet per minute (ft/min), and average 4.91×10^{-2} ft/min. These values fall within the range of hydraulic conductivity values typically ascribed to coarse and medium sand deposits.

3.0 FACILITY BACKGROUND

The Ameren Missouri Labadie Utility Waste Landfill is being proposed as a landfill site to accommodate the waste generated from the flue gas desulfurization units, fly ash, and bottom ash.

The proposed UWL covers a waste boundary area of approximately 166.5 acres of the 813-acre landfill permit boundary within the Ameren Missouri Labadie Energy Center Property. The entire site is zoned by Franklin County as Agricultural Non-Urban (ANU). Improvements within the Labadie UWL permit boundary include the 166.5-acre waste disposal area, stormwater management ponds permitted separately as no discharge wastewater facilities under Missouri Clean Water Law, soil stockpile areas, flood protection berms, perimeter stormwater control structures, site access roads, perimeter security fencing, buffer zones, and groundwater monitoring.

In order to ensure that groundwater is protected a series of groundwater monitoring wells are proposed for installation both upgradient and downgradient of the UWL. Periodic sampling of the groundwater monitoring well system is required under Missouri's Solid Waste Management Regulations, 10 CSR 80-11.010(11).

4.0 PROPOSED GROUNDWATER MONITORING SYSTEM

The proposed groundwater monitoring system consists of 28 permanent wells and one temporary well (Figure 2). Each well will monitor shallow groundwater contained within the unconfined alluvial aquifer that underlies the site as recommended in the Detailed Site Investigation. The wells that generally are downgradient from waste disposal boundaries are designated MW-1 through MW-21. The wells that generally are upgradient from waste disposal boundaries are designated MW-22 through MW-28. Individual well location and depth information is summarized in Table 1. The table also lists a temporary monitoring well (TMW-1) that will serve as a "sentry" for the initial operations within Cell 1. It will be used to supplement water quality data derived from the permanent downgradient wells located along the eastern perimeter of Cell 3.

Justification for the location of the proposed permanent well system is presented in Appendix X of the Construction Permit application. The proposed wells will be installed prior to acceptance of waste. TMW-1 will be removed when Cell 3 becomes operational.

4.1 Well Construction

All monitoring well drilling and construction will be completed in accordance with the Missouri Monitoring Well Construction Code of regulations found in 10 CSR 23-4. A typical monitoring well construction detail for the proposed well installation is provided as Figure 3. Well depths will be in general accordance with Table 1 to ensure full submersion of each 10-ft screen interval. Some allowances may have to be made in actual well location to ensure they do not conflict with planned landfill development, terrain or subsurface irregularities, overhead power lines, or similar encumbrances. This in turn will affect actual well depths, which are based on ground surface elevations.

Drilling and well construction will be completed by a properly permitted monitoring well installation contractor. Drilling logs and monitoring well construction details will be completed subsequent to installation activities and inserted into Appendix 1 of this SAP at a later date.

Proposed monitoring wells will be located such that reasonable access can be gained for the purpose of maintenance and repairs. The surrounding natural drainage will not be impaired. Each well will be placed so as to facilitate surface water drainage surrounding the well.

4.2 Well Development or Redevelopment

Each well will be developed with the use of either disposal bailers or a non-dedicated, submersible pump. In no event will the method used introduce any contaminants into the wells. A minimum of three well volumes of water will be removed or until the well is effectively "dry". A "well volume" includes both the filter pack and casing, as measured from the base of the well to the initial static water level. In addition, the volume of potable water introduced into the well bore while drilling and/or constructing the well, if any, will be removed.

Field measurements of groundwater temperature, pH, and specific conductivity will be recorded during the development process. Field measurements will continue until both temperature and specific conductivity have stabilized to within ten percent between three successive readings. Similarly, pH readings should stabilize within 0.2 pH units.

In addition to the above, development records will include documentation of both pre- and post-development water levels. Final clarity of the water will also be noted.

Redevelopment will be undertaken when 20 percent of the well screen is occluded by sediments, as determined during routine measurements of the depth of the well taken during field sampling events.

5.0 SAMPLING FREQUENCY - DETECTION MONITORING

Detection monitoring is required at all monitoring wells. The sampling frequency required by 10 CSR 80-11.010(11)(C) is twice yearly during the months of May and November, except for initial background water quality monitoring following well installation and prior to operation. The rule requires a minimum of four independent samples to be collected from each well. This requirement allows identification of background concentrations contained in the shallow alluvial aquifer using a statistically valid number of sampling events. Background water quality data are critical to identify in order to allow comparison with subsequent sample analysis to determine if statistically significant increases in target contaminants are present within the groundwater.

The proposed schedule for background water quality sampling at the Ameren Missouri Labadie Utility Waste Landfill is presented in Table 2. The intent of the schedule is to provide eight independent rounds of background data prior to the start of operations. The eight sets of data (from the four minimum sampling events required by the rule plus four additional sampling events) will better define the spatial variability of groundwater quality across the footprint of the disposal area. The degree of spatial variability will ultimately determine the statistical approach to be used in the evaluation of detection monitoring results.

Detection Monitoring will include analysis of the parameters listed in Appendix I of 10 CSR 80-11.010. Those parameters are listed for reference in Appendix 2.

6.0 FIELD SAMPLING EQUIPMENT - QA/QC PROCEDURES

All field personnel must read and familiarize themselves with the protocol established in this section. All personnel involved in the sampling process must wear Level D Protective clothing as defined by OSHA. This includes, but is not limited to, safety boots/shoes, safety glasses, and disposable gloves. No smoking is allowed during sampling. A first aid kit must be accessible to field personnel during each well sampling event.

The following equipment, at a minimum, will be available in the field during each sampling event: purging and sampling equipment, both dedicated and non-dedicated; an electronic water level measurement device; pH, temperature, specific conductivity, oxidation-reduction potential (ORP), and turbidity meters; sample containers, and coolers.

The probes and attachments of each pH, temperature, specific conductivity, oxidation-reduction potential (ORP), and turbidity meter will be hand washed in a laboratory grade, non-phosphate detergent, followed by a triple rinse in distilled water. The meters will then be calibrated in accordance with manufacturer's recommendations or as otherwise specified in the *Field Equipment Calibration Forms and Procedures* included in Appendix 3. Any malfunction will be corrected or the meter will be replaced.

Sample containers will be pre-cleaned by the contract laboratory by washing in a laboratory grade, non-phosphate detergent, triple rinsed in distilled water, and sufficiently dried to remove all moisture. The sample containers will be checked/inventoried for proper container volume, material, preservatives, labels and any observed defects (e.g., preservative leakage) at the time of receipt from the laboratory and documented on the *Groundwater Sampling Bottle Inventory* form (Appendix 4).

Prior to collecting a sample, the following decontamination procedures will be implemented.

1. Purging and Sampling Equipment will be handled and decontaminated as necessary to prevent contamination of the wells.

    a. If non-dedicated purging and sampling equipment is used, it will be thoroughly decontaminated and tested by collecting an equipment blank prior to use (see Section 7.4 Equipment Blank).
    b. If disposable bailers are used in the purging and sampling of the wells, they will be new, single-use bailers for each well and purging/sampling event. Used disposable bailers, even if decontaminated, are not acceptable.
    c. If dedicated pumps or bailers are used, care will be taken to prevent cross contamination.

2. Water level measuring device, including sensor probe and the entire length of graduated tape will be washed in laboratory grade, non-phosphate detergent followed by a triple rinse in distilled water.

    a. As the tape is reeled back onto the carrying spool, it will be wiped and dried using clean, dry paper towels.

3. During sampling, carefully lower the purging and sampling equipment into the well, handling it only with clean, disposable gloves. Do not drop any equipment into the well. The intake of the sampling equipment should be suspended above the base of the well to avoid churning of particulate matter within the sump.

4. After each well is sampled or during sampling events, as necessary, disposable gloves should be discarded, hands washed with soap and water, and fresh disposable gloves applied before the next sampling.

5. After use, the purging and sampling equipment will be washed in laboratory grade, non-phosphate detergent followed by a triple rinse with distilled water, prior to any further use.

6. Should purging and sampling equipment malfunction or not be available for use during the sampling event, substitute equipment or a bailer may be used.

7. All handling of the bailer will be with clean disposable gloves. Gloves must be changed as often as necessary, particularly if contact is made with other substances during the bailing process. The bailer must not be allowed to contact any foreign substance, in which case the bailer will be promptly replaced, regardless of condition.

8. Lightweight, high tensile strength line or a similar product used in conjunction with the disposable bailers or reel systems will be discarded and replaced each time a well is sampled.

If dedicated pumps are used, care should be taken to prevent any foreign objects from being part of the sample. The outside of the sample discharge tubing should be cleaned to prevent introduction of foreign objects into the sample container.

7.0 GROUNDWATER SAMPLES - QA/QC PROCEDURES

7.1 General

Precautions must be taken during both sampling and shipping procedures to ensure representative groundwater is obtained. Sample blanks and sample duplicates are therefore required to guard against and/or identify accidental, "induced" contamination from these sources. Sample blanks include trip blanks, field blanks, and equipment blanks. Sample duplicates are self-explanatory, but can include both matrix spike and matrix spike duplicates. Each of these quality control features is explained more fully as follows.

7.2 Trip Blanks

Trip blanks are prepared in the laboratory. They are designed to detect contamination resulting from improper or inadequately cleaned containers, sample coolers used for transport, or from chemical preservatives. A trip blank is prepared by filling an appropriately sized container with distilled water and any applicable chemical preservative. It is then shipped to the sample site and subsequently accompanies groundwater samples on the "trip" back to the laboratory. Trip blanks must be clearly identified as such along with the analyses to be performed on them. At a minimum, one trip blank per sampling event will be collected.

7.3 Field Blanks

Field blanks are prepared in the field. A field blank is prepared by directly filling an appropriately sized container with laboratory-supplied deionized water. Field blanks are used to detect contamination resulting from changed ambient air conditions. They also serve as a check against trip blanks. Field blanks should be clearly identified in the sampler's field notes and appropriately labeled to ensure its later identification in laboratory analytical results. One field blank will be collected per sampling event.

7.4 Equipment Blanks

Equipment blanks are prepared in the field when non-dedicated sampling equipment is used. They are used to ensure that non-dedicated equipment is properly decontaminated. This is accomplished by collecting a sample of distilled water passed through non-dedicated equipment after they have been decontaminated. Equipment blanks should also be collected anytime new, dedicated equipment is introduced into the water sampling process. Equipment blanks should be clearly identified in the sampler's field notes and appropriately labeled to ensure its later identification in laboratory analytical results. At a minimum, one equipment blank per sampling event will be collected.

7.5 Sample Duplicates

Sample duplicates are independent samples collected as close in time as possible as the original sample from any given well. They are stored and analyzed separately from the original sample and are a check on the precision of the sampling and analytical process.

Sample duplicates must immediately follow original sample collection of any given chemical parameter. Because they serve as a check on the reproducibility of data generated by the analytical laboratory, labeling should follow a format that does not overtly divulge the true identity of the sample on the sample labels or on the chain-of-custody sheet. It should be clearly identified in the sampler's field notes and appropriately labeled to ensure its later identification in laboratory analytical results. One sample duplicate will be collected for every 20 samples. At a minimum, one sample duplicate per sampling event will be collected.

7.6 Matrix Spikes

Matrix spikes are prepared in the laboratory by adding a known amount of target analyte to a sample prior to preparation and analysis. They are used to determine the bias of a method in a given sample matrix.

7.7 Matrix Spike Duplicates

Matrix spike duplicates are intra-laboratory split samples containing identical concentrations of target analytes. They are used to substantiate matrix spike samples.

8.0 FIELD SAMPLING PROCEDURES

8.1 General

Upon arrival at each monitoring well, its physical condition must be documented. Appendix 5 contains a *Monitoring Well Field Inspection* form that must be filled out for each well each time it is sampled. Any irregularities in the condition of the well must be immediately reported and corrective action implemented prior to the next sampling event.

8.2 Water Level Measurements

The next procedure is to obtain water level measurements. They must be obtained immediately prior to any attempt to purge the well. All water levels measuring equipment will be thoroughly decontaminated as previously described and checked for wear and abrasion prior to use. Clean, disposable gloves will be worn. All measurements must be recorded to ±0.01 foot and should be based on a permanent reference point located at the top of the well, the elevation of which is established by a licensed surveyor.

Once the sample is collected, it is also necessary to measure the depth of the well. This is required to determine if the well screen is partially blocked by sediment, thus inhibiting recharge. If accumulated sediment obstructs more than twenty percent of the well screen height, it will be reported and arrangements made to redevelop the well prior to the next sampling event. Record all data gathered during water level measurements on the *Field Sampling Log* form provided in Appendix 6.

Ensure the well cap is clean prior to replacing after measurements are complete. Do not leave the well cap off for any reason, even for brief periods, unless purging immediately commences.

8.3 Purging

The next procedure is to purge the wells. There are two potential methods for purging the wells: Purge/Recover Sampling method; and Low-Flow Sampling method. Each method is acceptable, if the procedures are diligently followed. Each method is described separately below. All purge volumes must be documented on the *Volume Tracking Log* form provided in Appendix 6.

Purge/Recover Sampling: If using dedicated purge and sampling equipment, the following paragraph does not apply. If non-dedicated purge and sampling equipment is used, the wells should be purged in an order that precludes any potential cross-contamination. Typically, the upgradient wells are purged prior to the downgradient wells.

Purging must occur prior to any sampling, because water standing in the well may be unrepresentative due to physical and/or chemical alteration. Each well will be purged by removing at least three well volumes of water or until purge parameters stabilize. A well volume is considered the sum of the saturated portion of the well casing plus the saturated portion of the filter pack, which is roughly equivalent to an effective pore volume of 30 percent. The calculated volumes are based on the height of the water column above the established base of the well as measured immediately prior to purging. Filter pack heights must also be known. Well construction information for this facility will be placed in Appendix 1 following construction of the wells.

Wells will be purged using either dedicated bailers or other suitable purging and sampling equipment. All handling of purging equipment will be done wearing clean disposable gloves. Purge water will be poured into a graduated container sufficient to allow accurate measurement of the volume of water obtained. Once a well volume is obtained, temperature, specific conductivity, pH, oxidation-reduction potential (ORP) and turbidity will be recorded. Temperature must be measured first, followed by specific conductance ORP, pH, and lastly by turbidity. It is important to measure specific conductance and ORP prior to pH due to the potential presence of salts on the pH probe unit. All meters will be calibrated and checked for proper operation following manufacturer's recommendations or as otherwise outlined in Appendix 3. The clarity (turbidity) of the water will be noted. Cloudy, turbid water must be minimized.

Low–Flow Sampling Method: When using dedicated low flow pumps and automatic purge parameter sensors, such as the YSI 5083 Flow Cell, the following procedures will be followed to assess the stability of a water sample. At a minimum, all water will be purged from the line between the low-flow pump and the automatic sensors. This will be done by allowing a minimum of one volume within the connecting sampling tubing to flow from the well before assessing the stability of the water sample.

To be considered stable, the reading from each respective purge parameter sensor will be compared to the previous two values (collected at least one minute apart), and will be within the following limits:

- pH +/- 0.2 S.U.
- Specific Conductance +/- 20 umhos/cm
- Temperature +/- 1 C
- Oxidation-Reduction Potential +/- 20 millivolts
- Turbidity +/- 1 NTU (optional)

or

- 10 percent for SC, temperature, ORP and turbidity and +/- 0.2 S.U. for pH

If one-quarter inch (¼") tubing is used to connect the low flow pump to the automatic sensor, it takes one minute to purge 26 feet of tubing at 250 ml/minute.

Once sampling is complete, properly dispose of all purge water. Record all purge data on the *Field Sampling Log* form provided in Appendix 6.

8.4 Sampling

The next procedure is the actual sampling of the well. As much as practical, sampling should take place within two hours of the final purge event. In some instances, the recharge characteristics of the screened interval may be such that the two-hour stipulation is not feasible. In that event, sampling should be performed no later than 24 hours after final purging. Wells should be sampled in the order that precludes as much, to the extent practical, any potential cross-contamination. Typically, the upgradient wells are purged prior to the downgradient wells. Samples from each well will be collected in the following order, based on their sensitivity to volatilization:

- TOX
- TOC
- TDS
- Metals
- Non-metals
- COD

Samples must be carefully decanted into the appropriate sample container. Agitation must be minimized to avoid altering the chemical makeup of the sample. If well pumps are being used, care should be taken to prevent any contaminant from the exterior of the sample tubing from contaminating the water sample. Field filtration of samples is not allowed under 10 CSR 80-11.010(11)(C)2.B. Consequently, sample clarity must be documented and efforts made to minimize increasing turbidity beyond what naturally occurs in the well environment. Once a sample is retrieved, it will be preserved according to the guideline provided in Appendix 4. Samples requiring storage at low temperature will be immediately placed in coolers packed with ice. The temperature of the storage coolers will be monitored to ensure appropriate temperatures are maintained. All sampling data will be documented on the *Field Sampling Log* form provided in Appendix 6.

9.0 SAMPLE TRANSPORT AND DELIVERY, CHAIN-OF-CUSTODY

A chain-of-custody procedure is necessary to ensure the integrity of samples from the time of collection through delivery and final analysis. A sample is considered in someone's custody if:

1. It is in that person's physical possession;
2. In view of that person once he/she has taken possession;
3. Has been secured by that person so as to prevent tampering, or;
4. Has been placed by that person in an area restricted to authorized personnel.

Any person with custody as defined above must comply with the procedures established herein.

Prior to transport, the person collecting the samples must properly label each sample container and complete a *Chain-of-Custody Field Record* form. An example chain-of-custody field record form is provided in Appendix 7. Each label must be secured to the container and the following information clearly described on the label in indelible marker or pen:

- Collector's name
- Date and time of sampling
- Monitoring Well ID
- Sample ID
- Preservative(s) used, if any
- Required analytical test(s)

If the sample cooler(s) used for transport is not tamper proof, each sample container must also have a tamper proof seal affixed by the collector across the lid. A chain-of-custody summarizing the samples to be transported is also required. This form should be prepared by the collector and completed upon final sampling. A copy of the form(s) should accompany the person responsible for transporting the samples so that it can be included with the final analytical report as support documentation. The sample collector also initializes the chain-of-custody record process. It is his/her responsibility to ensure that the record is maintained upon relinquishment of the samples for transport to the laboratory.

When samples are transported, the carrier assumes responsibility for the chain-of-custody record and for ensuring safe transport of the samples to the laboratory. The carrier must recognize the contents of the shipment, the potential hazards they entail, and demonstrate an understanding of the proper handling precautions to be used during transport. The carrier is responsible for ensuring that all samples are properly stored to avoid leakage or breakage. Sample coolers should be checked to ensure required temperatures are maintained and any additional ice is added as necessary. Do not use dry ice during transport. The carrier must also ensure that all relevant shipping manifests are properly and fully completed. Other individuals who might accompany the carrier must be advised of the nature of the shipment and must not be allowed direct contact with any of the samples.

Any transfer of samples from one carrier to another must be accompanied by the chain-of-custody record and the above process repeated prior to relinquishment of the samples. The carrier must deliver the samples to the laboratory as soon as practicable after sampling, generally no later than 48 hours. The carrier should ensure that the samples are delivered to the person in the laboratory qualified to receive samples prior to relinquishment of the chain-of-custody record to that individual.

The laboratory should assign a specific individual to be responsible for the samples. This individual should first inspect the condition of the sample containers and any seals, and then reconcile the information on sample labels with that listed on the chain-of-custody record prior to signing the record. This individual should then assign laboratory numbers to each sample, enter these numbers on the laboratory logbook and on each sample container label, and should store the samples in a secured storage area until ready for analysis. This individual is ultimately responsible for completion of the chain-of-custody record and for ensuring that it forms part of the final analytical report.

10.0 ANALYTICAL LABORATORY - REPORTING AND QA/QC PROCEDURES

The contract laboratory must have the ability to produce reliable quantitative results in accordance with established protocol. At a minimum, the laboratory must use analytical methods that will achieve the nominal target reporting limits for the MDNR Appendix I groundwater monitoring parameters listed in Appendix 2. Adequate levels of accuracy, precision, and completeness must be maintained.

10.1 Accuracy

Accuracy is defined as the degree of agreement between the measured amount of a species and the amount actually known to be present, expressed as a percentage. To achieve an adequate appraisal of accuracy, spikes and/or control samples should be made for one of every twenty samples analyzed. Minimum levels for accuracy should be listed in specific laboratory quality assurance plans.

10.2 Precision

Precision is a measure of the reproducibility of analytical results, generally expressed as a *Relative Percent Difference.* To achieve an adequate appraisal of precision, duplicate analyses should be performed for every one in twenty samples. Minimum levels for precision should be listed in specific laboratory quality assurance plans.

The relative standard deviation is a measure of the variability of the results from an analytical procedure. The relative standard deviation is calculated by taking the difference between a sample result, x, and the average of sample results from numerous laboratories, x_{bar}, for each analyte divided by x_{bar} [$(x-x_{bar})/x_{bar}$ expressed as a percentage].

The relative percent difference is the difference, by analyte, between the results of duplicate sample divided by the average value for those samples [$(x_1-x_2)/((x_1+x_2)/2)$ expressed as a percentage]. It is a measure of the variation in the results of an analyte for duplicate samples.

If the results for duplicate samples of an analyte for relative percent difference are within 2.5 times the percent relative standard deviation, the analytical data for the parameter may be accepted as being comparable results. If the results of an analyte for duplicate samples for relative percent difference are not within 2.5 times the percent relative standard deviation, the results of the analyte should be checked for comparability.

10.3 Completeness

Completeness is a comparison of the amount of valid data acquired to the amount of valid data planned to be obtained, expressed as a percentage. Should the percentage of completeness fall below 90 percent for the analytical results of any given sampling event, the laboratory should be prepared to present a corrective action narrative prior to receiving further groundwater samples.

10.4 Reporting Requirements

Minimum reporting requirements for the laboratory responsible for analytical results of groundwater monitoring well samples are as follows:

1. A table summary of all analytical test methods used in the analysis, including references for each to the method manual and test method number.

2. A summary of all analytical results. This must include use of appropriate units, reporting Practical Quantitation Limit (PQL), and appropriate signature on all data sheets. Units must be shown for each analyte. Data cannot be method blank corrected. Data must be appropriately flagged.

3. A complete chain-of-custody form(s). A complete form includes name and affiliation of sample collector, time and date of sampling, and all appropriate signatures denoting custody changes. The chain-of-custody form should be an original or a highly legible copy.

4. A completed copy of the field sampling log(s) contained in Appendix 6 of this Sampling and Analysis Plan.

5. Method detection limits must be established for all metals analysis. Method blank results are required.

6. All inorganic results will be accompanied by a Quality Assurance data form that includes minimum detection limits, method blanks, field or trip blanks, and lab replicate. If spiked samples are used, these data will also be included.

Supplemental laboratory data will include a summary that chronicles laboratory procedures, including date of sampling, sample receipt, preservation, preparation, analysis, and approval signature of the results.

Once laboratory analytical data are received, facility personnel must in turn submit the data to MDNR-SWMP in report form for review and comment within 90 days of the date of sampling. Information to be contained in the report should include the following:

1. Clearly state the purpose of the submittal (i.e. either detection or assessment monitoring).

2. Supply a copy of field notes, including all field data sheets.

3. Provide unaltered copies of the "raw" analytical data. A summary table is also recommended, but cannot take the place of the "raw" data.

4. Include the completed chain-of-custody form(s).

5. Summarize the data validation procedures.

6. Summarize groundwater flow direction and hydraulic gradient. Compare and contrast with previous data. Supply an updated water table (potentiometric) map prepared by a properly qualified individual.

7. Provide a statistical analysis summary using approved methods, including discussion of any statistically significant increase over established background values.

8. Note any deviations from the Sampling and Analysis Plan that may have taken place during the sampling event.

9. Provide electronic submission of groundwater data in a format and method prescribed by the MDNR-SWMP.

11.0 STATISTICAL ANALYSIS

The statistical analysis procedure(s) used for the Ameren Missouri Labadie Utility Waste Landfill (UWL) were selected to be consistent with the requirements of 10 CSR 80-11.010(11)(C)5. The statistical analysis plan below was developed for this facility and is submitted for review and approval.

This section contains a general discussion of the type of statistics chosen for the facility. The type of statistics chosen reflects the understanding that the site is located in a flood plain, and the shallow alluvial groundwater will be monitored.

11.1 Characterization of Well Network and Selection of Statistics

Upon installation of permanent groundwater monitoring wells, the Labadie Energy Center will follow the schedule for sampling shown in Table 2. After eight rounds of background sampling, a report will be prepared comparing the distribution of data for each parameter in both the upgradient and downgradient wells. Comparisons may include Box Plots for median, quartile and extreme values and Kruskal Wallis tests for comparison of populations at a 0.05 level of significance or other tests as appropriate. If downgradient well data are not comparable to upgradient well data, intra-well statistics will be considered for future comparisons. If data from one or more upgradient wells are comparable to the downgradient well(s) data, inter-well statistics will be considered for future comparisons.

11.2 Prediction Intervals or Other Statistical Tools

Parametric and non-parametric prediction intervals will be used as discussed below. The types of statistics to be used include parametric and non-parametric prediction intervals. For intra-well comparisons, the parametric and non-parametric prediction intervals will be defined by the data from previous samples collected at the well being reviewed. For inter-well comparisons, the parametric and non-parametric prediction intervals will be defined by the data from previous samples collected at the upgradient well(s).

Below is a specific discussion on the implementation for the statistics listed above. Prediction intervals for parametric and non-parametric distributions are recommended. Most computer statistical software programs include distribution testing with the appropriate selection of normal, log normal or non-parametric distribution. Some statistical software programs use the Ladder of Powers concept in an attempt to normalize data. Prediction intervals may include samples with results below detection limits by using either the Cohen or Aitchison approximations for a limited number of non-detects.

11.3 Choice of Statistical Test for Limited Data

The following restrictions apply to these statistical methods recommended in Section 11.2 depending on the number of samples that have been collected:

- Sample size < 4 – do not run statistics
- Sample size ≥ 4 but ≤ 8 – may use Poisson Prediction Limit Test or similar tests as a cursory review of parameter concentrations. Elevated parameters from this test are not Statistically Significant Increases (SSIs), but are parameters that will need to be looked at more closely when the sample size is greater than 12
- Sample size > 8 – use recommended Statistical methods

11.4 Non-Detects

There are limitations on the use of statistical procedures if analytical results do not detect a parameter. Examples are as follows:

- For non-detects ≥ 76 percent and < 100 percent, use a non-parametric inter-well prediction interval testing with the Upper Prediction Limit (UPL) = to the largest non-outlier value.
- For non-detects equal to 100 percent, use a non-parametric prediction interval testing with the Upper Prediction Limit (UPL) = the Practical Quantitation Limit (PQL). The analytical laboratory will maintain the lowest PQL practicable. Significant changes in PQL (± 25 percent) will be avoided as much as practicable.
- For non-detects < 25 percent, use PQL divided by two, or Cohen's Adjustment, and check for normality. The SWMP may approve use of a median PQL.
- For non-detects ≥ 25 percent and < 75 percent, use Cohen's Adjustment or a modified Aitchison's Adjustment (also known as the modified delta method), and check for normality.

11.5 Normality Testing

The purpose of normality testing is to determine whether the background data is normally distributed or if it can be normalized through transformation. Data that is normally distributed or that can be normalized will be evaluated using a parametric statistical tool. Data that is not normal will be evaluated using a non-parametric statistical tool. Examples of normality testing include:

- For sample population ≤ 50 – Shapiro-Wilk Test or equivalent
- For sample population > 50 – Shapiro-Francia Test or equivalent

Show normality testing on at least the original data, data residuals, and natural logarithmically transformed data or data transformed by the Ladder of Powers concept.

11.6 Outlier Testing

Since most of the software packages available use either the t-test or Dixon's method for determining outliers and neither of these methods can determine multiple outliers the SWMP has developed the following procedure to be used in determining outliers.

Screen data first by using Probability Plots and Time Series Plots. The Time Series Plot and the Probability Plots will aid in determining whether there are multiple possible outliers or a single possible outlier. The time Series Plot is used along with the Probability Plots to screen for possible outliers, a screening tool. The possible outliers are the points on the Probability Plots that appear out of alignment with the rest of the data. Care should be taken when using Probability Plots because non-normal data will also have points out of alignment as compared to the rest of the data. In addition, the Probability Plots will help determine if the numerical tests should be evaluated using log-transformations or transformed by the Ladder of Powers concept.

Determine the Median value for the Data to be processed. The median was chosen because the median value is not changed by either high or low values. This value is the *screening tool* to be used in the steps listed below:

- Use the screening tool to determine what values are possible outliers. The Time Series Plots could aid in the identification. If the number of possible outliers is equal to one, run the outlier test on that one value. If there are no possible outliers identified, do not screen for outliers. If there is more than one possible outlier proceed to the next step.

- Determine if one or more of the possible outliers could mask the other outliers. For example, for possible outlier values of 194, 290, 332, 838 and 1630, 1630 could mask 838 as an outlier. When masking can occur, each possible outlier should be tested with the other possible outliers not used in the calculations. In the example given, tag the value of 1630 and then run the outlier test on the value of 838. If the value 838 is an outlier then the value 1630 would also be an outlier and removed from the data set as confirmed outlier.

- If the outlier test would be run on the complete data set of 194, 290, 332, 838 and 1630, to determine if 1630 was an outlier, the value of 838 would not be an outlier if the value 1630 were not an outlier.

Also, when looking at the initial sample values, use the time series plots to determine if these initial values are within reasonable limits as compared to the other early samples. Some parameters have high readings the first few times a well is tested and these higher readings could mask a trend if they are not removed early in the monitoring program. Simply relying on a computer program to determine outliers without looking at the data through a visual means can give erroneous results.

There are different outlier tests depending on the number of samples:

- Use only Dixon's Test if the sample size is ≤ 25.

- Use Rosner's Test, if available, only if the sample size is ≥ 20. Rosner's Test is able to test for either single or for multiple outliers. Although Rosner's test avoids the problem of masking when multiple outliers are present in the same data set, it is not immune to the related problem of *swamping*. Swamping refers to a block of measurements all being labeled as outliers even though only some of the observations are actually outliers. This potential pitfall seems to be in properly identifying the total number of possible outliers. Following the screening procedure above should minimize the problem of *swamping*:

  - Outliers can only be excluded for the analytical event in which they are determined.

  - Previously determined outlier results will be re-checked when background is updated to confirm that these results are still outliers and not included in the background database.

  - Last date outliers of compliance well comparisons must not be excluded from current analysis.

  - Outlier screening will never be applied to the current (future values) monitoring data of control charts.

Other types of outlier test, besides those mentioned previously, may be used.

11.7 Prediction Interval Testing

When inter-well comparisons are being used, compare inter-well Upper Prediction Limit (UPL) to each downgradient well's last date value. Inter-well UPL is calculated from all dates of upgradient well background data.

When using intra-well comparisons, compare the UPL from previous sampling to the results by constituent of the current round of sampling results by constituent.

11.8 Procedures for Response to Future SSI's

This section contains a general discussion on the re-sampling strategy for any parametric or non-parametric inter-well prediction interval methods, re-sampling used to verify SSI's. An SSI is not proven:

- If the pooled background sample size (n) is ≤ 10, there is one resample out of two samples that does not show an SSI for the parameter; or

- If the pooled background sample size (n) is > 10, the single resample does not show an SSI for the parameter

This sampling strategy is identified in flow charts provided in Appendix 8.

If an SSI is confirmed, current (1997) Missouri Solid Waste Management Rules require the following procedures [Reference 10 CSR 80-11.010(11)(C)6].

"6. Response to statistical analysis.

A. *If the comparison for the upgradient wells shows a statistically significant increase (or pH change) over background, the owner/operator shall submit this information to the department.*
B. *If the comparisons for downgradient wells show a statistically significant increase (or pH change), resulting from the landfill, over background, the owner/operator shall within ninety (90) days of the last sampling event obtain additional groundwater samples from those downgradient wells where a statistically significant difference was detected, split the samples in two (2), and obtain analyses of all additional samples to determine whether the significant statistical difference was a result of laboratory error.*
C. *If the additional samples show a statistically significant increase (or pH change) over background, the owner/operator must demonstrate to the department within ninety (90) days that a source other than the utility waste landfill caused the contamination or that the statistically significant increase resulted from an error in sampling, analysis, statistical evaluation or natural variation. If the owner/operator cannot make this demonstration to the department, the owner/operator shall submit a plan to the department for a groundwater assessment monitoring program and implement the program as described in subparagraphs (11)(C)6.D. through H. of this rule. The plan shall specify the following:*
   (I) The number, location and depth of wells;
   (II) Sampling and analytical methods for the monitoring parameters listed in Appendix I of this rule on a quarterly basis;
   (III) Evaluation procedures, including any use of previously gathered groundwater quality information;
   (IV) The rate and extent of migration of the contaminant plume in the groundwater; and
   (V) The concentrations of the contaminant plume in the groundwater.
D. *After obtaining the results from the initial or subsequent sampling events required in subparagraph (11)(C)6.B. the owner/operator shall -*
   (I) Within fourteen (14) days, notify the department and place a notice in the operating record identifying the constituents that have been detected;

(II) Within ninety (90) days, and on a quarterly basis after that, resample all wells and conduct analysis for all constituents listed in Appendix I to this rule and notify the department of the constituent concentrations. A minimum of one (1) sample from each well sampled (background and downgradient) shall be collected and analyzed during these sampling events;

(III) Establish background concentrations for any new constituents detected during subsequent monitoring events; and

(IV) Establish groundwater protection standards for all newconstituents detected during subsequent monitoring events.

E. *If the concentration of all constituents listed in Appendix I to this rule are shown to be at or below background levels as established in paragraph (11)(C)3. of this rule for two (2) consecutive sampling periods, the owner/operator may reinstate detection monitoring at the utility waste landfill as specified under subparagraph (11)(C)3.C. of this rule.*

F. *If the concentrations of any constituents listed in Appendix I of this rule are above background values, but all concentrations are below the groundwater protection standard established under subparagraph (11)(C)6.D. of this rule using the statistical procedures in paragraph (11)(C)5. of this rule, the owner/operator shall notify the department and the department may require the owner/operator to--*

(I) Continue assessment monitoring; or

(II) Develop a corrective measures assessment, or both.

G. *If one (1) or more constituents listed in Appendix I of this rule are detected at levels above the groundwater protection standard as established under subparagraph (11)(C)6.D., the owner/operator shall--*

(I) Provide the department with a report assessing potential corrective measures;

(II) Characterize the nature and extent of the release by installing additional monitoring wells as necessary; install at least one (1) additional monitoring well at the facility boundary in the direction of contaminant migration and sample this well in accordance with paragraph (11)(C)6. of this rule and, if required by the department, notify all persons who own the land or reside on the land that directly overlies any part of the plume of contamination if contaminants have migrated off-site if indicated by sampling of wells; and

(III) Continue assessment monitoring as per the groundwater quality assessment plan, and implement the approved corrective action program specified in part (11)(C)6.G.(I) of this rule.

H. *The results of implementation of the assessment monitoring program shall be submitted to the department at the end of each year or an alternate time period approved by the department."*

Prior to implementing a response to a future SSI, it is recommended that the Missouri Code of State Regulations be reviewed to determine if the Solid Waste Management Rules regarding Response to Statistical Analysis have been revised.

11.9 Current MDNR Protocols

The following protocols are currently used by MDNR's Solid Waste Management Program in managing groundwater monitoring data for solid waste disposal areas and in evaluating that data for statistically significant increases (SSI's)

The SWMP has previously not allowed a verified SSI or its verification resample value(s) to be excluded as outliers from the database for control charts if the previously specified resample strategy shows that only the "future measurements" plot, including resample(s) measurement(s), does not exceed the "SCL - limit" line.

- Re-sampling SSI's must be conducted a minimum of one quarter later from the previous sampling event. MDNR's in-house laboratory or subcontractor will be given the option to split samples for each re-sampling event.

- If a subset of background data is to be excluded, or if a previous excluded subset of background data is to be re-included for statistical analysis, a request for modification to the approved statistical analysis plan must be submitted to and approved by the SWMP before implementation. This requirement does not include the data that would be temporarily excluded because of outlier testing during a single statistical analysis event.

- See Appendix 8, Attachment 1 for a flow diagram for implementing Prediction Intervals.

- See Appendix 8, Attachment 2 for a flow diagram for Non-Parametric Prediction Intervals for data that is non-normal or for data that cannot be normalized.

Prior to utilizing various MDNR protocols for statistical analysis of groundwater monitoring data, it is recommended that the SWMP be contacted to obtain updated recommendations on current protocols and/or policies.

12.0 REFERENCES

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