F.3
Appendix E Excerpt – Geomembrane Compatibility

CHEMICAL COMPATIBILITY
EPA 9090 STUDIES

FURNACE BOTTOM & FLY ASH
VS.
POLY-FLEX & DURA-FLEX

INTRODUCTION

This report contains the results of the chemical compatibility studies of municipal power plant furnace bottom ash and fly ash in contact with Poly-Flex (HDPE) and Dura-Flex (VLDPE).

Municipal power plants generate wastes of furnace bottom ash and fly ash. These wastes are collected and often times disposed of through the use of a landfill. In order to prevent chemicals, metals or other materials from leaching out of the ash and possibly contaminating the ground water, a flexible membrane liner (FML) is placed beneath the ash at the waste disposal facility.

One of the most important criteria in specifying a FML for this application is to verify that the ash does not adversely effect the liner's performance. The most widely accepted practice for assessing chemical compatibility of geomembranes is to perform and EPA 9090 study. In this study, the samples of the liner are immersed in the waste leachate or other chemicals for four months at 23° and 50° C. Once a month, the liner is removed from the waste leachate and the liner's material properties are measured. The changes in these properties over this four month period of time are compared to the liner's original values. Chemical compatibility is then determined by assessing the magnitude of changes that took place, and by looking for overall trends in these changes.

In these particular EPA 9090 studies, 60 mil Poly-Flex (HDPE) and Dura-Flex (VLDPE) were tested against furnace bottom ash and fly ash obtained by Northern States Power from a municipal power plant in North Dakota.

Since most EPA 9090 studies are conducted with liquid leachates, there is little problem in obtaining intimate contact with the liners during the immersion process. To obtain intimate contact with the solid ash, the liners had to be first buried in the ash and then water was added to make a sludge. To keep the 50° C. immersion tank at temperature, the entire tank was placed in a heated water bath.

DISCUSSION OF RESULTS

The tests which are used to evaluate the liner can be broken down into two groups. The first group of tests relates to intrinsic change in the polymer. These tests reflect whether the polymer has degraded in some form, absorbed material out of the leachate, or whether the leachate has absorbed (extracted) something out of the polymer (i.e. additive package). Even small changes in these properties can be significant. The second group of tests evaluate changes in the liner's performance by measuring changes in key physical properties. Because of the nature of the testing and sample variation, changes in these properties are harder to evaluate. Overall trends in the property changes have to be considered.

STUDY I POLY-FLEX VS BOTTOM ASH

As will be noted in the table of results, no changes were evident (within testing precision) in the polymer performance properties of gauge, dimensions, hardness, mass and density. In the case of total volatile loss, even though some values were more than twice the control result, the numbers are still so small as to be considered negligible.

With physical properties of the liner (tensile, C-tear and puncture), significant changes occurred in these values from month to month when compared to the control. For example, after three months, stress @ 100% and 200% elongation was approximately 15-20% lower than the control. However, after four months, these same properties yielded values equivalent to the control samples. Therefore, it is suspected that the low values generated at the three month mark were more likely due to sample variation or test error, rather than a real change in the liner. Similarly, a consistent 10% drop in C-tear values was experienced on samples from the 23°C immersion tank. However, if the ash had caused an actual change in the liner, a similar drop in C-tear values should be observed in the samples from the 50°C immersion tank. This was not the case.

Hence, based on the review of this data, which indicated no change in polymer performance (gauge, mass, etc.) and with no clear consistent trends showing changes in the liner's physical performance (tensile, C-tear and puncture) it is concluded that Poly-Flex is chemically compatible with furnace bottom ash.

STUDY II POLY-FLEX VS FLY ASH

The results from this study are similar to that of Poly-Flex in contact with bottom ash. No changes in polymer performance properties (mass, gauge, etc.) occurred even after four months. Changes in physical performance properties showed some variation in results. Overall, the variation in data was less than in Study I (Poly-Flex vs bottom ash) and like Study I, no consistent changes or trends were evident. Due to problems with the chart recorder, values for tensile strength at 100% and 200% elongation at three months were not available.

Since the results of this study are similar to the results previously given in Study I, it is also concluded that Poly-Flex in contact with fly ash is chemically compatible.

STUDY III DURA-FLEX VS BOTTOM ASH

All the tests performed on Dura-Flex are the same as those performed on Poly-Flex, except for tensile yield and elongation at yield, because Dura-Flex does not have a clear yield point.

As with Poly-Flex, the polymer performance property table shows Dura-Flex is unaffected by the bottom ash in both the 23° and 50° C immersion tests. The higher total volatile loss value at three months is believed to be a testing error, as it is not consistent with the results from the 1st, 2nd and 4th month tests.

The physical performance property table shows that from one month to the next, test values could flip-flop from being higher or lower than the control sample, resulting in percent change numbers being positive or negative. This lack of clear consistent trends would indicate that Dura-Flex is chemically resistant to the chemical components that constitute bottom ash.

STUDY IV **DURA-FLEX VS FLY ASH**

With the three previous studies, the percent change in gauge values were either zero or yielded values that would fall within testing error (± 1 mil). During this study the change in gauge was slightly higher than expected. As much as a 6% change occurred. However, all other polymer performance tests showed no changes. If a true change in the Dura-Flex had occurred, it should have affected some of the other tests. Since the rest of the tests indicate no change in the original value (within test error), this change in gauge is not considered critical.

Under the physical performance property table, C-tear and puncture results are all within normal test variation. Likewise, tensile break and elongation at break values all fall within this ± 10% range. Somewhat higher in variation are the results for tensile stress at 100% and 200% elongation, but this is consistent with the percent change values exhibited in the other studies.

Hence this data supports the conclusion that Dura-Flex is unaffected by fly ash.

CONCLUSIONS

With each of the four EPA 9090 studies in this report, data has been analyzed on changes that occur in the polymer structure and changes in the performance of physical properties. In all these studies, both the 23° and 50° C tanks failed to produce any change to the original properties which characterize the polymer's performance. In regards to the sheet's physical properties, changes in values from month to month did occur, but failed to produce a consistent trend which would cause concern about the liners' chemical resistance.

In conclusion, the results from these studies demonstrate that Poly-Flex and Dura-Flex are chemically compatible with furnace bottom and fly ash from municipal power plants.

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EPA 9090 with BOTTOM ASH
POLY-FLEX @ room temperature

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)	
			MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD
CONTROL 1	62	62	169	173	13	12	132	125	137	126	252	246	753	718	98000	99000
CONTROL 2	60	60	152	162	13	12	126	115	127	116	241	230	779	789	97000	97000
CONTROL AVE	61	61	161	168	13	12	129	120	132	121	247	238	766	754	97500	98000
1 MONTH	57	56	144	151	14	14	121	114	126	116	240	221	788	780	98000	105000
2 MONTHS	57	57	151	162	13	12	121	116	124	119	275	279	883	951	95000	96000
3 MONTHS	57	56	149	158	13	12	91	86	93	91	261	250	828	858	84000	98000
4 MONTHS	60	60	155	160	14	12	122	121	117	117	280	262	877	858	93000	90000
(% CHANGE)																
1 MONTH		-2	-10	-10	8	17	-6	-5	-5	-4	-3	-7	3	4	1	7
2 MONTHS		0	-6	-3	0	0	-6	-3	-6	-2	12	17	15	26	-3	-2
3 MONTHS		-2	-7	-6	0	0	-29	-28	-30	-25	6	5	8	14	-14	0
4 MONTHS		0	-3	-4	8	0	-5	1	-11	-3	14	10	14	14	-5	-8

EPA 9090 with BOTTOM ASH
POLY-FLEX @ 50 degrees centigrade

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)	
			MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD
CONTROL 1	62	62	169	173	13	12	132	125	137	126	252	246	753	718	98000	99000
CONTROL 2	60	60	152	162	13	12	126	115	127	116	241	230	779	789	97000	97000
CONTROL AVG	61	61	161	168	13	12	129	120	132	121	247	238	766	754	97500	98000
1 MONTH	61	61	161	169	13	12	130	125	134	130	243	240	733	779	84000	98000
2 MONTHS	60	60	158	171	13	19	126	124	129	128	259	286	801	933	97000	87000
3 MONTHS	60	60	165	173	14	20	101	94	102	95	296	275	880	872	82000	90000
4 MONTHS	61	61	168	177	13	13	129	119	130	125	279	269	820	865	83000	100000
(% CHANGE)																
1 MONTH		0.	0	1	0	0	1	4	2	7	-1	1	-4	3	-14	0
2 MONTHS		0	-2	2	0	58	-2	3	-2	6	5	20	5	24	-1	-11
3 MONTHS		0	3	3	8	67	-22	-22	-23	-21	20	16	15	16	-16	-8
4 MONTHS		0	5	6	0	8	0	-1	-2	3	13	13	7	15	-15	2

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EPA 9090 with BOTTOM ASH
POLY-FLEX @ room temperature

	C-TEAR (LB.) MD	C-TEAR (LB.) CD	2065 PUNC. (LB)	DIMENSIONS BEFORE (CM)	DIMENSIONS AFTER (CM)	HARDNESS BEFORE (DURO D)	HARDNESS AFTER (DURO D)	MASS BEFORE (GM)	MASS AFTER (GM)	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	54	51	109	96.30	96.30	63	63	88.5	88.5	0.950	0.00	0.04	0.04
CONTROL 2	50	49	96	96.80	96.80	63	63	83.7	83.7	0.951	0.00	0.05	0.05
CONTROL AVE	52	50	103	96.55	96.55	63	63	86.1	86.1	0.951	0.00	0.05	0.05
1 MONTH	47	45	94	96.10	96.40	63	64	78.5	78.3	0.952	0.08	0.00	0.08
2 MONTHS	47	45	90	96.35	96.45	63	64	80.2	80.0	0.951	0.04	0.02	0.06
3 MONTHS	47	44	86	96.30	96.50	63	65	79.9	79.7	0.952	0.10	0.02	0.12
4 MONTHS	48	44	93	96.40	96.30	63	64	82.6	82.6	0.953	0.05	0.00	0.05
(% CHANGE)													
1 MONTH	-10	-10	-8		0		2		0	0			
2 MONTHS	-10	-10	-12		0		2		0	0			
3 MONTHS	-10	-12	-16		0		3		0	0			
4 MONTHS	-8	-12	-9		0		2		0	0			

EPA 9090 with BOTTOM ASH
POLY-FLEX @ 50 degrees centigrade

	C-TEAR (LB.) MD	C-TEAR (LB.) CD	2065 PUNC. (LB)	DIMENSIONS BEFORE (CM)	DIMENSIONS AFTER (CM)	HARDNESS BEFORE (DURO D)	HARDNESS AFTER (DURO D)	MASS BEFORE (GM)	MASS AFTER (GM)	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	54	51	109	96.30	96.30	63	63	88.5	88.5	0.950	0.00	0.04	0.04
CONTROL 2	50	49	96	96.80	96.80	63	63	83.7	83.7	0.951	0.00	0.05	0.05
CONTROL AVG	52	50	103	96.55	96.55	63	63	86.1	86.1	0.951	0.00	0.05	0.05
1 MONTH	52	51	104	96.65	96.75	63	64	85.9	86.0	0.953	0.04	0.00	0.04
2 MONTHS	49	51	99	96.35	96.40	63	64	85.6	85.6	0.951	0.05	0.06	0.11
3 MONTHS	51	48	96	99.60	96.45	63	65	84.9	85.1	0.953	0.10	0.02	0.12
4 MONTHS	52	50	96	96.58	96.58	63	65	86.5	86.8	0.953	0.05	0.01	0.06
(% CHANGE)													
1 MONTH	0	2	1		0		2		0	0			
2 MONTHS	-6	2	-3		0		2		0	0			
3 MONTHS	-2	-4	-6		-3		3		0	0			
4 MONTHS	0	0	-6		0		3		0	0			

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)	
			MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD
ONTROL 1	47	47	NA	NA	NA	NA	53	51	57	52	200	175	926	893	28000	35000
ONTROL 2	49	49	NA	NA	NA	NA	51	49	54	50	198	162	930	859	29000	24000
ONTROL AVE	48	48	NA	NA	NA	NA	52	50	56	51	199	169	928	876	28500	29500
1 MONTH	53	53					56	58	60	60	206	175	910	822	23000	30000
2 MONTHS	54	53					53	53	59	55	188	178	901	927	34000	33000
3 MONTHS	53	53					62	59	64	61	199	183	909	907	27000	25000
4 MONTHS	49	49					50	50	56	53	187	157	941	891	31000	31000
(% CHANGE)																
1 MONTH		0					8	16	8	18	4	4	-2	-6	-19	2
2 MONTHS		-2					2	6	6	8	-6	6	-3	6	19	12
3 MONTHS		0					19	18	15	20	0	9	-2	4	-5	-15
4 MONTHS		0					-4	0	1	4	-6	-7	1	2	9	5

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)	
			MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD
ONTROL 1	47	47	NA	NA	NA	NA	53	51	57	52	200	175	926	893	28000	35000
ONTROL 2	49	49	NA	NA	NA	NA	51	49	54	50	198	162	930	859	29000	24000
ONTROL AVE	48	48	NA	NA	NA	NA	52	50	56	51	199	169	928	876	28500	29500
1 MONTH	48.0	48.0					49	50	52	52	172	196	896	933	31000	26000
2 MONTHS	54.0	54.0					53	54	55	58	187	160	919	852	33000	30000
3 MONTHS	52.0	53.0					61	58	64	59	203	172	933	891	25000	23000
4 MONTHS	52.0	51.0					62	59	64	60	189	172	917	904	27000	31000
(% CHANGE)																
1 MONTH		0					-6	0	-6	2	-14	16	-3	7	9	-12
2 MONTHS		0					2	8	-1	14	-6	-5	-1	-3	16	2
3 MONTHS		2					17	16	15	16	2	2	1	2	-12	-22
4 MONTHS		-2					19	18	15	18	-5	2	-1	3	-5	5

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature

			2065	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	C-TEAR		PUNC.	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	DENSITY	AFTER	AFTER	TOTAL
	(LB.)		(LB)	(CM)		(DURO D)		(GM)		(GM/CC)	DESIC.	105 C	VOL.
	MD	CD											
CONTROL 1	24	22	72	97.60	97.60	50	50	66.0	66.0	0.925	0.07	0.00	0.07
CONTROL 2	22	21	74	97.80	97.80	50	50	66.2	66.2	0.927	0.10	0.00	0.10
CONTROL AVE	23	22	73	97.70	97.70	50	50	66.1	66.1	0.926	0.09	0.00	0.09
1 MONTH	24	25	85	97.25	97.45	50	50	73.2	73.3	0.926	0.08	0.00	0.08
2 MONTHS	24	23	72	97.50	97.50	49	51	73.7	73.8	0.925	0.04	0.02	0.06
3 MONTHS	25	24	73	97.65	97.65	50	50	72.4	72.6	0.925	0.13	0.04	0.17
4 MONTHS	23	21	64	97.40	97.60	50	51	66.5	66.8	0.925	0.05	0.00	0.05
(% CHANGE)													
1 MONTH	4	16	16		0		0		0	0			
2 MONTHS	4	7	-1		0		4		0	0			
3 MONTHS	9	12	0		0		0		0	0			
4 MONTHS	0	-2	-12		0		2		0	0			

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature

			2065	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	C-TEAR		PUNC.	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	DENSITY	AFTER	AFTER	TOTAL
	(LB.)		(LB)	(CM)		(DURO D)		(GM)		(GM/CC)	DESIC.	105 C	VOL.
	MD	CD											
CONTROL 1	24	22	72	97.60	97.60	50	50	66.0	66.0	0.925	0.07	0.00	0.07
CONTROL 2	22	21	74	97.80	97.80	50	50	66.2	66.2	0.927	0.10	0.00	0.10
CONTROL AVE	23	22	73	97.70	97.70	50	50	66.1	66.1	0.926	0.09	0.00	0.09
1 MONTH	22	21	74	97.75	97.90	50	50	66.3	66.5	0.925	0.06	0.00	0.06
2 MONTHS	23	22	65	97.35	97.40	51	48	72.3	72.2	0.926	0.05	0.03	0.08
3 MONTHS	24	22	72	97.50	97.35	51	50	71.5	71.7	0.925	0.19	0.07	0.26
4 MONTHS	24	23	67	97.60	97.68	50	49	71.7	72.2	0.924	0.05	0.00	0.05
(% CHANGE)													
1 MONTH	-4	-2	1		0		0		0	0			
2 MONTHS	0	2	-11		0		-6		0	0			
3 MONTHS	4	2	-1		0		-2		0	0			
4 MONTHS	4	7	-8		0		-2		1	0			

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10/15/90

EPA 9090 with BOTTOM ASH
POLY-FLEX @ room temperature
POLYMER PERFORMANCE PROPERTIES

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	DIMENSIONS BEFORE (CM)	DIMENSIONS AFTER (CM)	HARDNESS BEFORE (DURO D)	HARDNESS AFTER (DURO D)	MASS BEFORE (GM)	MASS AFTER (GM)	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	62	62	96.30	96.30	63	63	88.5	88.5	0.950	0.00	0.04	0.04
CONTROL 2	60	60	96.80	96.80	63	63	83.7	83.7	0.951	0.00	0.05	0.05
CONTROL AVE	61	61	96.55	96.55	63	63	86.1	86.1	0.951	0.00	0.05	0.05
1 MONTH	57	56	96.10	96.40	63	64	78.5	78.3	0.952	0.08	0.00	0.08
2 MONTHS	57	57	96.35	96.45	63	64	80.2	80.0	0.951	0.04	0.02	0.06
3 MONTHS	57	56	96.30	96.50	63	65	79.9	79.7	0.952	0.10	0.02	0.12
4 MONTHS	60	60	96.40	96.30	63	64	82.6	82.6	0.953	0.05	0.00	0.05
(% CHANGE)												
1 MONTH		-2		0		2		0	0			
2 MONTHS		0		0		2		0	0			
3 MONTHS		-2		0		3		0	0			
4 MONTHS		0		0		2		0	0			

EPA 9090 with BOTTOM ASH
POLY-FLEX @ 50 degrees centigrade
POLYMER PERFORMANCE PROPERTIES

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	DIMENSIONS BEFORE (CM)	DIMENSIONS AFTER (CM)	HARDNESS BEFORE (DURO D)	HARDNESS AFTER (DURO D)	MASS BEFORE (GM)	MASS AFTER (GM)	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	62	62	96.30	96.30	63	63	88.5	88.5	0.950	0.00	0.04	0.04
CONTROL 2	60	60	96.80	96.80	63	63	83.7	83.7	0.951	0.00	0.05	0.05
CONTROL AVG	61	61	96.55	96.55	63	63	86.1	86.1	0.951	0.00	0.05	0.05
1 MONTH	61	61	96.65	96.75	63	64	85.9	86.0	0.953	0.04	0.00	0.04
2 MONTHS	60	60	96.35	96.40	63	64	85.6	85.6	0.951	0.05	0.06	0.11
3 MONTHS	60	60	99.60	96.45	63	65	84.9	85.1	0.953	0.10	0.02	0.12
4 MONTHS	61	61	96.58	96.58	63	65	86.5	86.8	0.953	0.05	0.01	0.06
(% CHANGE)												
1 MONTH		0		0		2		0	0			
2 MONTHS		0		0		2		0	0			
3 MONTHS		0		-3		3		0	0			
4 MONTHS		0		0		3		0	0			

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10/15/90

EPA 9090 with BOTTOM ASH
POLY-FLEX @ room temperature
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	169	173	13	12	132	125	137	126	252	246	853	813	98000	99000	54	51	109
CONTROL 2	152	162	13	12	126	115	127	116	241	250	779	789	97000	97000	50	49	96
CONTROL AVE	161	168	13	12	129	120	132	121	247	248	816	804	97500	98000	52	50	103
1 MONTH	144	151	14	14	121	114	126	116	240	221	738	780	98000	105000	47	45	94
2 MONTHS	151	162	13	12	121	116	124	119	275	279	883	951	95000	96000	47	45	90
3 MONTHS	149	158	13	12	101	103	105	103	261	250	828	856	84000	98000	47	44	86
4 MONTHS	155	160	14	12	122	121	117	117	280	262	877	858	93000	90000	48	44	93
(% CHANGE)																	
1 MONTH	-10	-10	8	17	-6	-5	-5	-4	-3	-11	-3	-3	1	7	-10	-10	-8
2 MONTHS	-6	-3	0	0	-6	-3	-6	-2	12	13	8	13	-3	-2	-10	-10	-12
3 MONTHS	-7	-6	0	0	-22	-14	-20	-15	6	1	1	7	-14	0	-10	-12	-16
4 MONTHS	-3	-4	8	0	-5	1	-11	-3	14	6	7	7	-5	-8	-8	-12	-9

EPA 9090 with BOTTOM ASH
POLY-FLEX @ 50 degrees centigrade
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	169	173	13	12	132	125	137	126	252	246	753	818	98000	99000	54	51	109
CONTROL 2	152	162	13	12	126	115	127	116	241	250	779	789	97000	97000	50	49	96
CONTROL AVG	161	168	13	12	129	120	132	121	247	248	766	804	97500	98000	52	50	103
1 MONTH	161	169	13	12	130	125	134	130	243	240	733	779	84000	98000	52	51	104
2 MONTHS	158	171	13	12	126	124	129	128	259	286	801	933	97000	87000	49	51	99
3 MONTHS	165	173	14	13	101	94	102	95	296	275	880	872	82000	90000	51	48	96
4 MONTHS	168	177	13	13	129	119	130	125	279	269	820	865	83000	100000	52	50	96
(% CHANGE)																	
1 MONTH	0	1	0	0	1	4	2	7	-1	-3	-4	-3	-14	0	0	2	1
2 MONTHS	-2	2	0	0	-2	3	-2	6	5	15	5	16	-1	-11	-6	2	-3
3 MONTHS	3	3	8	8	-22	-22	-23	-21	20	11	15	9	-16	-8	-2	-4	-6
4 MONTHS	5	6	0	8	0	-1	-2	3	13	8	7	8	-15	2	0	0	-6

9090F-ASH
START DATE: 12-8-90

EPA 9090 with FLY ASH
POLY-FLEX @ room temperature
POLYMER PERFORMANCE PROPERTIES

	GAUGE	GAUGE	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	ORIGIN (MIL)	AFTER (MIL)	BEFORE (CM)	AFTER	BEFORE (DURO D)	AFTER	BEFORE (GM)	AFTER	DENSITY (GM/CC)	AFTER DESIC.	AFTER 105 C	TOTAL VOL.
CONTROL 1	63	63	99.10	99.10	64	64	92.5	92.5	0.950	0.00	0.04	0.04
CONTROL 2	62	62	98.95	98.95	64	64	91.0	91.0	0.951	0.00	0.07	0.07
CONTROL 3	60	60	99.05	99.05	65	65	91.5	91.5	0.950	0.00	0.05	0.05
CONTROL AVE	62	62	99.03	99.03	64	64	91.7	91.7	0.950	0.00	0.05	0.05
1 MONTH	62	61	99.10	98.80	64	64	92.0	92.1	0.951	0.08	0.09	0.17
2 MONTHS	63	63	99.15	98.90	64	66	90.0	90.2	0.952	0.07	0.01	0.08
3 MONTHS	61	62	99.20	98.90	64	65	92.3	92.3	0.952	0.04	0.03	0.07
4 MONTHS	63	63	99.05	98.30	64	64	90.3	90.5	0.952	0.05	0.01	0.06
(% CHANGE)												
1 MONTH		-2		0		0		0	0			
2 MONTHS		0		0		3		0	0			
3 MONTHS		2		0		2		0	0			
4 MONTHS		0		0		0		0	0			

EPA 9090 with FLY ASH
POLY-FLEX @ 50 degrees centigrade
POLYMER PERFORMANCE PROPERTIES

	GAUGE	GAUGE	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	ORIGIN (MIL)	AFTER (MIL)	BEFORE (CM)	AFTER	BEFORE (DURO D)	AFTER	BEFORE (GM)	AFTER	DENSITY (GM/CC)	AFTER DESIC.	AFTER 105 C	TOTAL VOL.
CONTROL 1	63	63	99.10	99.10	64	64	92.5	92.5	0.950	0.00	0.04	0.04
CONTROL 2	62	62	98.95	98.95	64	64	91.0	91.0	0.951	0.00	0.07	0.07
CONTROL 3	60	60	99.05	99.05	65	65	91.5	91.5	0.950	0.00	0.05	0.05
CONTROL AVE	62	62	99.03	99.03	64	64	91.7	91.7	0.950	0.00	0.05	0.05
1 MONTH	59	61	99.10	98.80	64	64	92.0	92.1	0.951	0.06	0.07	0.13
2 MONTHS	58	57	99.00	98.60	64	66	84.3	84.6	0.953	0.06	0.00	0.06
3 MONTHS	57	57	98.50	98.30	64	64	85.0	83.7	0.952	0.07	0.07	0.14
4 MONTHS	57	58	99.00	98.60	63	64	84.3	84.5	0.951	0.06	0.01	0.07
(% CHANGE)												
1 MONTH		3		0		0		0	0			
2 MONTHS		-2		0		3		0	0			
3 MONTHS		0		0		0		-2	0			
4 MONTHS		2		0		2		0	0			

9090F-ASH
START DATE: 12/8/90

EPA 9090 with FLY ASH
POLY-FLEX @ room temperature
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	164	169	14	12	127	118	127	123	272	283	787	886	86000	88000	51	49	98
CONTROL 2	157	168	14	12	121	115	122	120	261	271	797	850	94000	90000	52	49	101
CONTROL 3	159	162	14	12	132	122	133	126	298	274	858	857	83000	97000	52	49	100
CONTROL AVE	160	166	14	12	127	118	127	123	277	276	814	864	87667	91667	52	49	100
1 MONTH	155	165	14	12	127	121	129	123	284	282	869	872	79000	85000	48	47	93
2 MONTHS	162	164	14	12	135	128	138	128	291	259	847	857	89000	94000	50	47	96
3 MONTHS	163	180	13	12					257	240	766	780	84000	90000	52	50	97
4 MONTHS	164	168	14	12	128	119	130	125	274	275	812	868	86000	87000	50	48	98
(% CHANGE)																	
1 MONTH	-3	-1	0	0	0	2	1	0	3	2	7	1	-10	-7	-7	-4	-7
2 MONTHS	1	-1	0	0	7	8	8	4	5	-6	4	-1	2	3	-3	-4	-4
3 MONTHS	2	8	-7	0					-7	-13	-6	-10	-4	-2	1	2	-3
4 MONTHS	3	1	0	0	1	1	2	2	-1	0	0	0	-2	-5	-3	-2	-2

EPA 9090 with FLY ASH
POLY-FLEX @ 50 degrees centigrade
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	164	169	14	12	127	118	127	123	272	283	787	886	86000	88000	51	49	98
CONTROL 2	157	168	14	12	121	115	122	120	261	271	797	850	94000	91000	52	49	101
CONTROL 3	159	162	14	12	132	122	133	126	298	274	858	857	83000	97000	52	49	100
CONTROL AVE	160	166	14	12	127	118	127	123	277	276	814	864	87667	92000	52	49	100
1 MONTH	155	165	14	12	127	121	129	123	284	282	869	872	79000	85000	48	47	93
2 MONTHS	153	163	15	12	129	121	131	122	254	270	796	910	90000	97000	46	43	91
3 MONTHS	162	156	14	13					245	242	760	830	84000	83000	47	44	91
4 MONTHS	158	169	14	13	130	121	131	124	271	278	797	895	96000	86000	49	46	93
(% CHANGE)																	
1 MONTH	-3	-1	0	0	0	2	1	0	3	2	7	1	-10	-8	-7	-4	-7
2 MONTHS	-4	-2	7	0	2	2	3	-1	-8	-2	-2	5	3	5	-11	-12	-9
3 MONTHS	1	-6	0	8					-12	-12	-7	-4	-4	-10	-9	-10	-9
4 MONTHS	-1	2	0	8	3	2	3	1	-2	1	-2	4	10	-7	-5	-6	-7

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	NA	NA	NA	NA	53	51	57	52	200	175	926	893	28000	35000	24	22	72
CONTROL 2	NA	NA	NA	NA	51	49	54	50	198	162	930	859	29000	24000	22	21	74
CONTROL AVE	NA	NA	NA	NA	52	50	56	51	199	169	928	876	28500	29500	23	22	73
1 MONTH					56	58	60	60	206	175	910	822	23000	30000	24	25	85
2 MONTHS					53	53	59	55	188	178	901	927	34000	33000	24	23	72
3 MONTHS					62	59	64	61	199	183	909	907	27000	25000	25	24	73
4 MONTHS					50	50	56	53	187	157	941	891	31000	31000	23	21	64
(% CHANGE)																	
1 MONTH					8	16	8	18	4	4	-2	-6	-19	2	4	16	16
2 MONTHS					2	6	6	8	-6	6	-3	6	19	12	4	7	-1
3 MONTHS					19	18	15	20	0	9	-2	4	-5	-15	9	12	0
4 MONTHS					-4	0	1	4	-6	-7	1	2	9	5	0	-2	-12

EPA 9090 with BOTTOM ASH
DURA-FLEX @ 50 degrees centigrade
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	NA	NA	NA	NA	53	51	57	52	200	175	926	893	28000	35000	24	22	72
CONTROL 2	NA	NA	NA	NA	51	49	54	50	198	162	930	859	29000	24000	22	21	74
CONTROL AVE	NA	NA	NA	NA	52	50	56	51	199	169	928	876	28500	29500	23	22	73
1 MONTH					49	50	52	52	172	196	896	933	31000	26000	22	21	74
2 MONTHS					53	54	55	58	187	160	919	852	33000	30000	23	22	65
3 MONTHS					61	58	64	59	203	172	933	891	25000	23000	24	22	72
4 MONTHS					62	59	64	60	189	172	917	904	27000	31000	24	23	67
(% CHANGE)																	
1 MONTH					-6	0	-6	2	-14	16	-3	7	9	-12	-4	-2	1
2 MONTHS					2	8	-1	14	-6	-5	-1	-3	16	2	0	2	-11
3 MONTHS					17	16	15	16	2	2	1	2	-12	-22	4	2	-1
4 MONTHS					19	18	15	18	-5	2	-1	3	-5	5	4	7	-8

EPA 9090 with BOTTOM ASH
DURA-FLEX @ room temperature
POLYMER PERFORMANCE PROPERTIES

	GAUGE	GAUGE	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	ORIGIN (MIL)	AFTER (MIL)	BEFORE (CM)	AFTER	BEFORE (DURO D)	AFTER	BEFORE (GM)	AFTER	DENSITY (GM/CC	AFTER DESIC.	AFTER 105 C	TOTAL VOL.
CONTROL 1	47	47	97.60	97.60	50	50	66.0	66.0	0.925	0.07	0.00	0.07
CONTROL 2	49	49	97.80	97.80	50	50	66.2	66.2	0.927	0.10	0.00	0.10
CONTROL AVE	48	48	97.70	97.70	50	50	66.1	66.1	0.926	0.09	0.00	0.09
1 MONTH	53	53	97.25	97.45	50	50	73.2	73.3	0.926	0.08	0.00	0.08
2 MONTHS	54	53	97.50	97.50	49	51	73.7	73.8	0.925	0.04	0.02	0.06
3 MONTHS	53	53	97.65	97.65	50	50	72.4	72.6	0.925	0.13	0.04	0.17
4 MONTHS	49	49	97.40	97.60	50	51	66.5	66.8	0.925	0.05	0.00	0.05
(% CHANGE)												
1 MONTH		0		0		0		0	0			
2 MONTHS		-2		0		4		0	0			
3 MONTHS		0		0		0		0	0			
4 MONTHS		0		0		2		0	0			

EPA 9090 with BOTTOM ASH
DURA-FLEX @ 50 degrees centigrade
POLYMER PERFORMANCE PROPERTIES

	GAUGE	GAUGE	DIMENSIONS		HARDNESS		MASS			VOLATILE LOSS		
	ORIGIN (MIL)	AFTER (MIL)	BEFORE (CM)	AFTER	BEFORE (DURO D)	AFTER	BEFORE (GM)	AFTER	DENSITY (GM/CC)	AFTER DESIC.	AFTER 105 C	TOTAL VOL.
CONTROL 1	47	47	97.60	97.60	50	50	66.0	66.0	0.925	0.07	0.00	0.07
CONTROL 2	49	49	97.80	97.80	50	50	66.2	66.2	0.927	0.10	0.00	0.10
CONTROL AVE	48	48	97.70	97.70	50	50	66.1	66.1	0.926	0.09	0.00	0.09
1 MONTH	48	48	97.75	97.90	50	50	66.3	66.5	0.925	0.06	0.00	0.06
2 MONTHS	54	54	97.35	97.40	51	48	72.3	72.2	0.926	0.05	0.03	0.08
3 MONTHS	52	53	97.50	97.35	51	50	71.5	71.7	0.925	0.19	0.07	0.26
4 MONTHS	52	51	97.60	97.68	50	49	71.7	72.2	0.924	0.05	0.00	0.05
(% CHANGE)												
1 MONTH		0		0		0		0	0			
2 MONTHS		0		0		-6		0	0			
3 MONTHS		2		0		-2		0	0			
4 MONTHS		-2		0		-2		1	0			

EPA 9090 with FLY ASH
DURA-FLEX @ room temperature
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	NA	NA	NA	NA	80	77	92	88	232	234	1003	1064	30000	34000	30	28	81
CONTROL 2	NA	NA	NA	NA	77	81	92	91	240	223	1052	1009	33000	33000	28	30	87
CONTROL 3	NA	NA	NA	NA	72	68	87	81	230	236	1009	1089	27000	32000	31	30	87
CONTROL AVE	NA	NA	NA	NA	76	75	90	87	234	231	1021	1054	30000	33000	30	29	85
1 MONTH					75	74	88	85	238	228	1006	1008	33000	33000	30	29	76
2 MONTHS					68	68	71	74	228	250	980	1112	35000	41000	30	29	79
3 MONTHS					80	75	83	76	258	214	1073	957	31000	31000	29	28	82
4 MONTHS					75	74	77	77	253	226	1068	990	26000	24000	30	29	85
(% CHANGE)																	
1 MONTH					-2	-2	-3	-2	2	-1	-2	-4	10	0	1	-1	-11
2 MONTHS					-11	-10	-21	-15	-3	8	-4	6	17	24	1	-1	-7
3 MONTHS					5	0	-8	-12	10	-7	5	-9	3	-6	-2	-5	-4
4 MONTHS					-2	-2	-15	-11	8	-2	5	-6	-13	-27	1	-1	0

EPA 9090 with FLY ASH
DURA-FLEX @ 50 degrees centigrade
PHYSICAL PERFORMANCE PROPERTIES

	STRESS @ YIELD (LB.-IN)		ELONG @ YIELD (%)		STRESS @ 100% (LB.-IN)		STRESS @ 200% (LB.-IN)		STRESS @ BREAK (LB.-IN)		ELONG @ BREAK (%)		SECANT MODULUS (PSI)		C-TEAR (LB.)		2065 PUNC. (LB)
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD	
CONTROL 1	NA	NA	NA	NA	80	77	92	88	232	234	1003	1064	30000	34000	30	28	81
CONTROL 2	NA	NA	NA	NA	77	81	92	91	240	223	1052	1009	33000	33000	28	30	87
CONTROL 3	NA	NA	NA	NA	72	68	87	81	230	236	1009	1089	27000	32000	31	30	87
CONTROL AVE	NA	NA	NA	NA	76	75	90	87	234	231	1021	1054	30000	33000	30	29	85
1 MONTH					70	73	86	86	246	230	1044	1003	28000	29000	31	29	81
2 MONTHS					73	76	77	79	239	241	1020	1031	35000	38000	31	29	79
3 MONTHS					80	79	82	84	239	245	1006	1056	30000	35000	30	29	78
4 MONTHS					75	71	79	74	250	241	1026	1065	30000	25000	30	30	78
(% CHANGE)																	
1 MONTH					-8	-3	-5	-1	5	0	2	-5	-7	-12	4	-1	-5
2 MONTHS					-4	1	-15	-9	2	4	0	-2	17	15	4	-1	-7
3 MONTHS					5	5	-9	-3	2	6	-2	0	0	6	1	-1	-8
4 MONTHS					-2	-6	-13	-15	7	4	0	1	0	-24	1	2	-8

EPA 9090 with FLY ASH
DURA-FLEX @ room temperature
POLYMER PERFORMANCE PROPERTIES

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	DIMENSIONS (CM) BEFORE	DIMENSIONS (CM) AFTER	HARDNESS (DURO D) BEFORE	HARDNESS (DURO D) AFTER	MASS (GM) BEFORE	MASS (GM) AFTER	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	61	61	99.26	99.26	54	54	85.8	85.8	0.929	0.07	0.00	0.07
CONTROL 2	61	61	99.13	99.13	54	54	85.5	85.5	0.930	0.04	0.02	0.06
CONTROL 3	62	62	99.40	99.40	53	53	86.4	86.4	0.929	0.10	0.00	0.10
CONTROL AVE	61	61	99.26	99.26	54	54	85.9	85.9	0.929	0.07	0.01	0.08
1 MONTH	63	61	99.50	99.45	53	51	89.3	90.0	0.929	0.05	0.06	0.11
2 MONTHS	62	60	100.11	100.15	54	53	87.8	88.4	0.929	0.04	0.01	0.05
3 MONTHS	62	59	99.30	99.20	53	53	85.3	85.7	0.930	0.02	0.09	0.11
4 MONTHS	63	62	99.2	99.1	53	53	86.5	87.6	0.931	0.06	0.02	0.08
(% CHANGE)												
1 MONTH		-3		0		-4		1	0			
2 MONTHS		-3		0		-2		1	0			
3 MONTHS		-5		0		0		0	0			
4 MONTHS		-2		0		0		1	0			

EPA 9090 with FLY ASH
DURA-FLEX @ 50 degrees centigrade
POLYMER PERFORMANCE PROPERTIES

	GAUGE ORIGIN (MIL)	GAUGE AFTER (MIL)	DIMENSIONS (CM) BEFORE	DIMENSIONS (CM) AFTER	HARDNESS (DURO D) BEFORE	HARDNESS (DURO D) AFTER	MASS (GM) BEFORE	MASS (GM) AFTER	DENSITY (GM/CC)	VOLATILE LOSS AFTER DESIC.	VOLATILE LOSS AFTER 105 C	VOLATILE LOSS TOTAL VOL.
CONTROL 1	61	61	99.26	99.26	54	54	85.8	85.8	0.929	0.07	0.00	0.07
CONTROL 2	61	61	99.13	99.13	54	54	85.5	85.5	0.930	0.04	0.02	0.06
CONTROL 3	62	62	99.40	99.40	53	53	86.4	86.4	0.929	0.10	0.00	0.10
CONTROL AVE	61	61	99.26	99.26	54	54	85.9	85.9	0.929	0.07	0.01	0.08
1 MONTH	66	62	99.06	99.15	53	53	88.8	89.3	0.930	0.07	0.06	0.13
2 MONTHS	64	62	99.19	99.20	53	52	89.0	89.5	0.929	0.07	0.00	0.07
3 MONTHS	61	61	99.13	98.90	54	52	89.1	89.6	0.930	0.12	0.04	0.16
4 MONTHS	63	61	100.6	99.65	53	52	87.0	87.4	0.931	0.00	0.07	0.07
(% CHANGE)												
1 MONTH		-6		0		0		1	0			
2 MONTHS		-3		0		-2		1	0			
3 MONTHS		0		0		-4		1	0			
4 MONTHS		-3		-1		-2		0	0			

F.4
Appendix H Excerpt – Piping and Permeability

Appendix H
Piping and Permeability Calculations

Table of Contents

Purpose/Methodology/Assumptions/Results/References

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
	By:	Date:	By:	Date:	
Dairyland Power Cooperative	MJA	9/18/00	BJK	10/10/00	3081.40

PIPING AND PERMEABILITY CALCULATIONS

Purpose

The purpose of the piping and permeability calculations is to demonstrate proper soil filter design by satisfying the following criteria:

1. **Piping**: The pore space in the soil filter that is in contact with the material being retained must be small enough to limit particles from being washed in or through it. Likewise, the perforation size of the collection system pipe must be designed to limit pipe bedding material from entering the pipe.
2. **Permeability**: The pore space in the soil filter must be large enough to provide sufficient permeability in order to permit seepage to escape freely.

Methodology

The piping and permeability calculations have been performed using the three piping relationships, the permeability relationship, and the pipe perforation piping relationship provided in the Naval Facilities Engineering Command (NAVFAC) Design Manual, Figure 4, pg. 7.1-273 (U.S. Navy, 1986). These relationships compare the particle sizes of given materials to one another.

To avoid movement of particles (piping criteria):

$$\frac{D15_F}{D85_B} \langle \; 5$$

$$\frac{D50_F}{D50_B} \langle \; 25$$

$$\frac{D15_F}{D15_B} \langle \; 20$$

Note: For very uniform base material ($C_U<1.5$): $D15_F/D85_B$ may be increased to 6.
For broadly graded base material ($C_U>4$): $D15_F/D15_B$ may be increased to 40.

To avoid headloss in filter (permeability criteria):

$$\frac{D15_F}{D15_B} \rangle \; 4$$

COMPUTATION SHEET

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To avoid loss of filter material into collection pipe perforations:

$$\frac{D85_F}{\text{Hole Diameter}} \rangle \ 1.2 \qquad \text{or} \qquad \frac{D85_F}{\text{SlotWidth}} \rangle \ 1.4$$

Notes: D15 = Particle size at which 15 percent of the given material passes
D50 = Particle size at which 50 percent of the given material passes
D85 = Particle size at which 85 percent of the given material passes
F = Filter Material
B = Base Material (material to be retained)

When these relationships are satisfied, effective filter designs are established.

Assumptions

Filter Applications

The graded filter design was analyzed by evaluating grain-size distributions for the leachate drainage blanket and the pipe bedding material. Pipe perforation size was also used as part of this calculation. Two filter configurations were analyzed:

- Leachate Drainage Blanket (Base)/Pipe Bedding Material (Filter)
- Pipe Bedding Material (Filter)/Pipe Perforation Size

Soil Properties

Detailed grain-size distribution information for existing material is not available; therefore, typical grain size distributions based on the proposed specification have been used in this analysis for the leachate drainage blanket and the pipe bedding material. Grain-size distribution curves for these materials are included in this section. Average values, between the high and low curves, of D85, D50, and D15 for the drainage blanket and the pipe bedding material have been used for this analysis.

Results

The results of the analysis indicate that the leachate drainage blanket and the pipe bedding material will meet the requirements for a graded filter design. The calculations indicate that the maximum hole diameter or slot size to be used in the collection pipes is 1/2 inch, therefore the proposed 3/8 inch holes shall be adequate.

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Prior to construction, the actual granular materials used for the graded filter will be tested for grain size distribution, and the ratios will be compared to the given criteria to document that the materials meet the requirements of a graded filter design.

References

U.S. Navy. 1982 Soil Mechanics. Naval Facilities Engineering Command (NAVFAC) Design Manual DM-7.1. Washington D.C.

Calculations

RMT

COMPUTATION SHEET

SHEET 1 OF 1

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Dairyland Power Cooperative	By: MJA	Date: 9/19/00	By: KAA	Date: 9/27/00	3081.40

Piping and Permeability Calculation

Input

Base (Drainage Blanket)

$D15_B$	0.2
$D50_B$	0.6
$D85_B$	2.4

Filter (Bedding Material)

$D15_F$	2.7
$D50_F$	8.4
$D85_F$	18.6

Collection Pipe

Pipe Hole Diameter 1/2 inch or Slot Width 1/2 inch

Results

Permeability Results

	Actual	Required
$D15_F / D15_B$	12.7	> 4

Perforation Size Results

	Actual	Required
$D85_F /_{HOLE}$	1.5	> 1.2
or		
$D85_F /_{SLOT}$	1.5	> 1.4

Piping Results

	Actual	Required
$D15_F / D85_B$	1.1	< 5
$D50_F / D50_B$	13.3	< 25
$D15_F / D15_B$	12.7	< 20

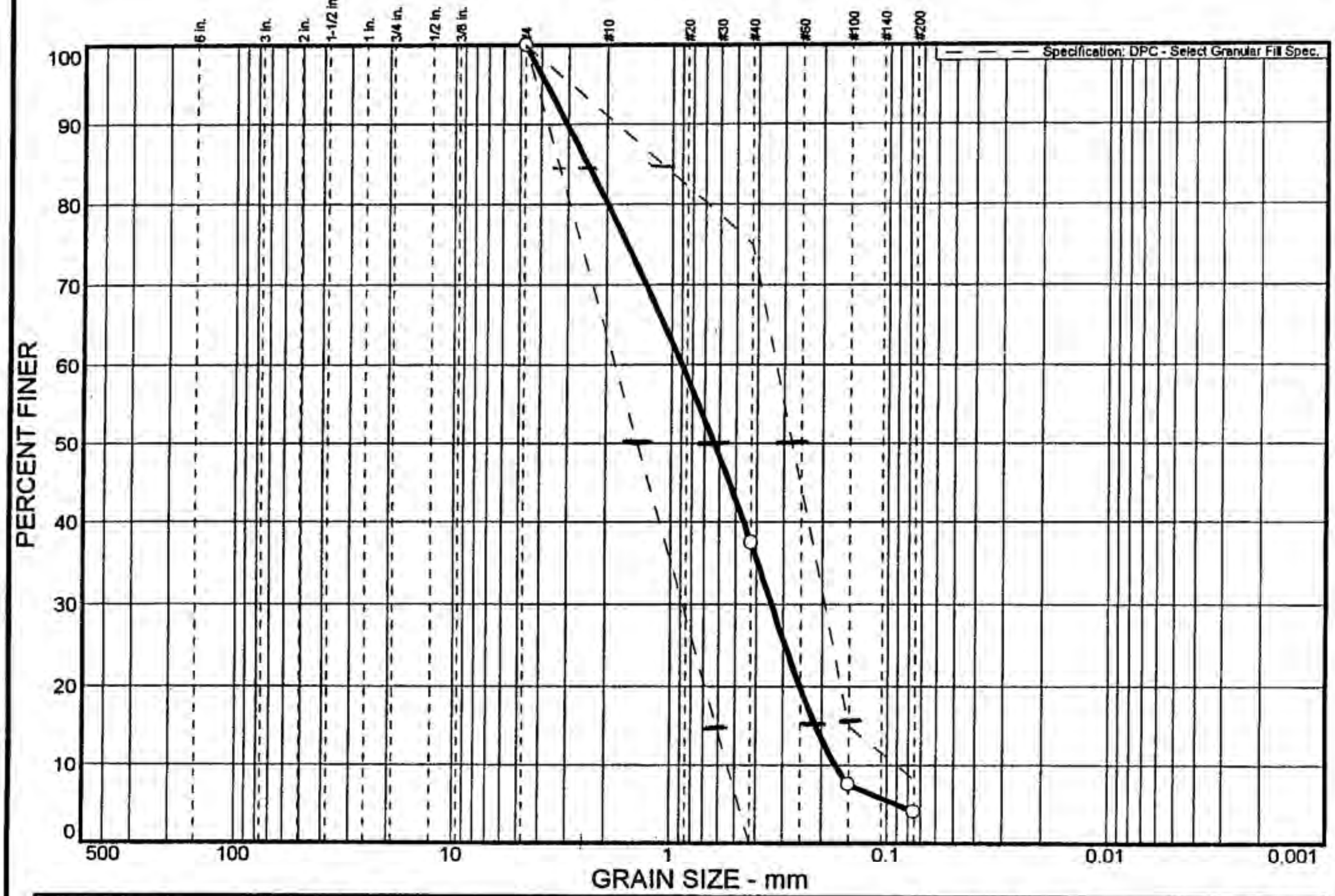
NOTES

1. All units are in millimeters unless specified.
2. For very uniform base material (Cu<1.5): $D15_F/D85_B$ may be increased to 6.
3. For broadly graded base material (Cu>4): $D15_F/D15_B$ may be increased to 40 (Piping equation only).
4. To avoid segregation, filter material should contain no sizes larger than 3 inches.
5. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve.

(NAVFAC, 1986)

✓

GRAIN SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	96.0	4.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0	100 - 100	
#40	37.5	0 - 75	
#100	7.5	0 - 15	
#200	4.0	0 - 8	

* DPC - Select Granular Fill Spec.

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.44 D_{60}= 0.896 D_{50}= 0.632

D_{30}= 0.341 D_{15}= 0.212 D_{10}= 0.172

C_u= 5.20 C_c= 0.75

Classification

USCS= SP AASHTO=

Remarks

Sample No.: Average Sample **Source of Sample:** Select Granular Fill **Date:** 9-18-00

Location: **Elev./Depth:**

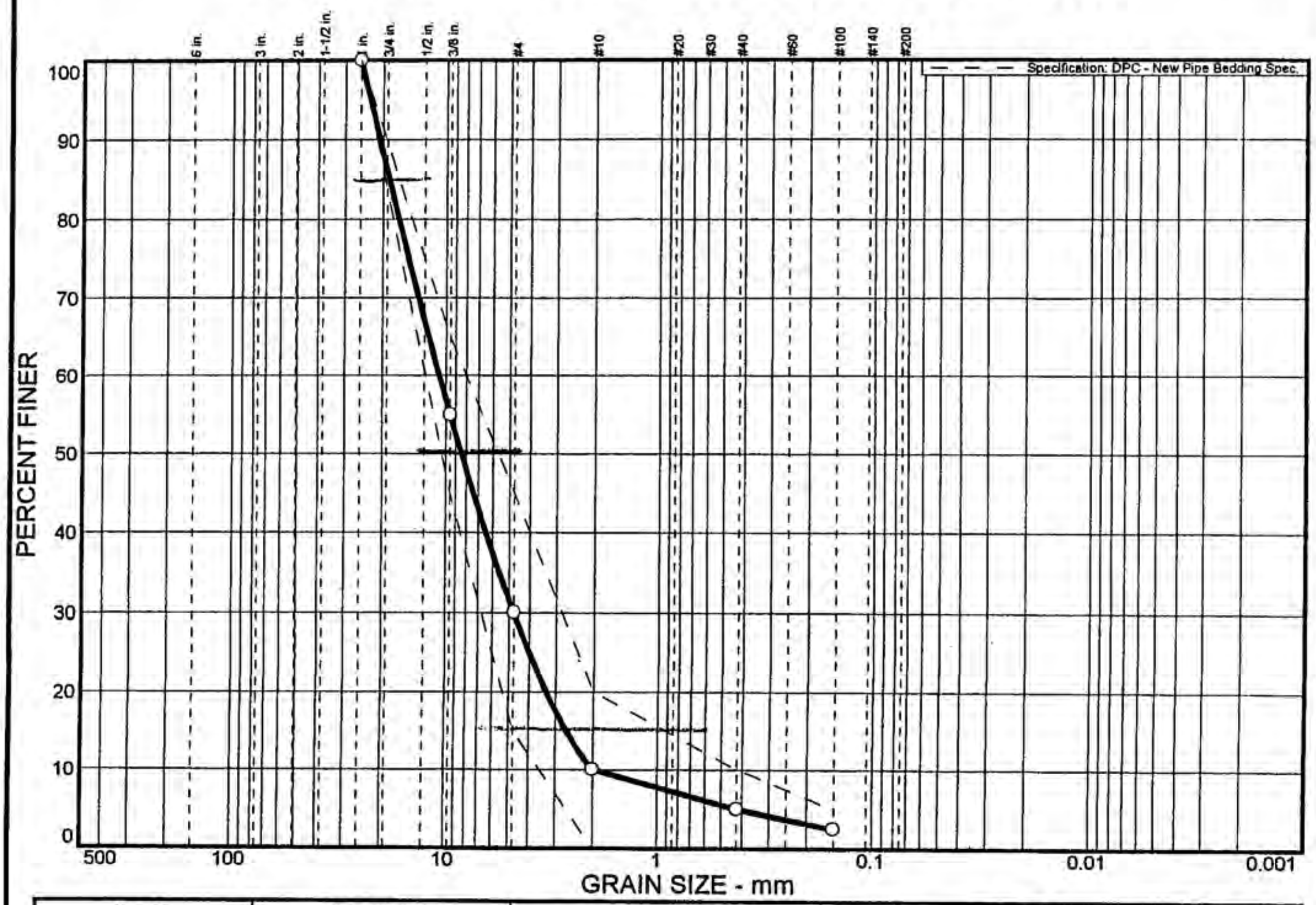
RMT, Inc.

Client:

Project: DPC

Project No: 3081.40 **Figure:**

GRAIN SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL	% SAND	% SILT	% CLAY
0.0	70.0	30.0		

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.0 in.	100.0	100 - 100	
.375 in.	55.0	45 - 65	
#4	30.0	15 - 45	
#10	10.0	0 - 20	
#40	5.0	0 - 10	
#100	2.5	0 - 5	

* DPC - New Pipe Bedding Spec.

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 18.6 D_{60}= 10.7 D_{50}= 8.41
D_{30}= 4.75 D_{15}= 2.67 D_{10}= 2.00
C_u= 5.37 C_c= 1.05

Classification

USCS= AASHTO=

Remarks

Sample No.: Average Sample #2 **Source of Sample:** Pipe Bedding **Date:** 9-19-00
Location: **Elev./Depth:**

RMT, Inc.

Client:
Project: DPC
Project No: 3081.40 **Figure:**

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Appendix F Excerpt – Saturated Head Over Liner Calculation

Saturated Depth on Landfill Liner

COMPUTATION SHEET

SHEET 1 OF 6

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	By:	Date:	By:	Date:	
Dairyland Power	BLP	6/10/97	PDC	7/29/97	3081.26

MAXIMUM SATURATED DEPTH ON LANDFILL LINER (McENROE METHOD)

Purpose:

To estimate the maximum saturated depth (i.e., leachate head) on the base liner of the landfill using the McEnroe Method.

Methodology:

NR 504.06(5)(a) of the Wisconsin Administrative Code limits the average leachate head over the liner to 12 inches or less. Factors affecting this saturated depth are the percolation rate into the drainage layer, the hydraulic conductivity of the drainage layer, the leachate flow distance from the upstream boundary to the leachate collection pipe, and the slope of the landfill liner.

The McEnroe Method uses a set of formulas for estimating the maximum saturated depth over a sloping liner. These equations were developed by Bruce M. McEnroe and published by ASCE in the Journal of Environmental Engineering, March/April 1993. These equations modify the method originally developed by McEnroe in 1989. The three equations are presented below:

For $R<1/4$,

$$Y_{max} = (R-RS+R^2S^2)^{1/2}\ \{[(1-A-2R)(1+A-2RS)]/[(1+A-2R)(1-A-2RS)]\}^{1/2A}$$

For $R=1/4$,

$$Y_{max} = R(1-2RS)/(1-2R)\ \exp\{2R(S-1)/[(1-2RS)(1-2R)]\}$$

For $R>1/4$,

$$Y_{max} = (R-RS+R^2S^2)^{1/2}\ \exp\{(1/B)\tan^{-1}[(2RS-1)/B]-(1/B)\tan^{-1}[(2R-1)/B]\}$$

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where:

$R = r/(K\sin^2 \propto)$
r = percolation rate per unit surface area ($cm^3/sec/cm^2$)
K = saturated hydraulic conductivity of the leachate drainage layer (cm/sec)
$\propto$ = slope angle, measured from horizontal
$S = \tan \propto$ = slope of liner (ft/ft)
$A = (1-4R)^{1/2}$
$B = (4R-1)^{1/2}$
L = drainage distance, measured horizontally (ft)
$y_{max} = Y_{max} (L \tan \propto)$ = maximum saturated depth (ft)

A computer spreadsheet utilizing the McEnroe Method was used to calculate the maximum leachate head on the liner for the proposed liner and leachate collection system configurations.

Assumptions:

1. The minimum liner slope, located on the base of the landfill and measured perpendicular to the leachate collection pipes, is 4 percent. The maximum flow distance associated with this minimum slope is approximately 145 feet. This occurs at the eastern end of the liner base area.

2. The maximum leachate flow distance across the base of the landfill is approximately 190 feet. This occurs at the western end of the liner base area, with a slope of 6 percent measured perpendicular to the leachate collection pipe.

3. In accordance with NR 504.06(5)(t), the drainage layer is required to have a minimum hydraulic conductivity of 1×10^{-2} cm/s.

4. Leachate generation (impingement) rates presented in NR 512.12(3) of the Wisconsin Administrative Code (WAC) were used for both open and post-closure conditions. The open conditions impingement rate is 6 inches per year, or 0.5 inches per month. The post-closure impingement rate is 1 inch per year, or 0.083 inches per month.

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Results:

Using the McEnroe Method, the maximum leachate head on the liner during landfill operations was determined to be approximately 2 inches. The post-closure maximum leachate head on the liner was determined to be 0.3 inches. Both of these values are much less than the maximum 12 inches required by NR 504.06(5) of the Wisconsin Administrative Code. The supporting computer spreadsheet calculations are attached.

References:

McEnroe, Bruce M. "Steady Drainage of Landfill Covers and Bottom Liners," Journal of Environmental Engineering. ASCE, Vol. 115, No. 6, December 1989, pg. 1114 - 1122.

McEnroe, Bruce M. "Maximum Saturated Depth Over Landfill Liner," Journal of Environmental Engineering. ASCE, Vol. 119, No. 2, March/April 1993, pg. 262-270.

COMPUTATION SHEET

SHEET 4 OF 6

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	By:	Date:	By:	Date:	
Dairyland Power	BLP	6/10/97	PDC	7/29/97	3081.26

MAXIMUM SATURATED DEPTH ON LANDFILL LINER (McENROE METHOD)

OPEN CONDITIONS

r = 0.5 in/month (from NR 512.12(3))
r = 4.83E-07 cm/sec (calculated)
K = 0.01 cm/sec
S = 4 % } longest flow distance at flattest
L = 145 ft } base slope (perpendicular to pipe)

alpha = 0.0399787 radians
alpha = 2.29 degrees
S = 0.04 ft/ft
R = 0.0303

For R < 1/4

A = 0.9375

Y_{max} = 0.03

y_{max} = 0.16 ft = 1.9 in < 12 in

For R = 1/4

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

For R >1/4

B = NOT APPLICABLE

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

COMPUTATION SHEET

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Dairyland Power	BLP	6/10/97	PDC	7/29/97	3081.26

MAXIMUM SATURATED DEPTH ON LANDFILL LINER (McENROE METHOD)

OPEN CONDITIONS

r = 0.5 in/month (from NR 512.12(3))
r = 4.83E-07 cm/sec (calculated)
K = 0.01 cm/sec
S = 6 %
L = 190 ft ← maximum flow distance to pipe along base (measured perpendicular to pipe)

alpha = 0.0599282 radians
alpha = 3.43 degrees
S = 0.06 ft/ft
R = 0.0135

For R < 1/4

A = 0.9727

Y_{max} = 0.01

y_{max} = 0.15 ft = <u>1.8</u> <u>in</u> < 12 in

For R = 1/4

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

For R >1/4

B = NOT APPLICABLE

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Dairyland Power	BLP	6/10/97	PDC	7/29/97	3081.26

MAXIMUM SATURATED DEPTH ON LANDFILL LINER (McENROE METHOD)

POST-CLOSURE CONDITIONS

r =	0.083	in/month	(from NR 512.12(3))
r =	8.02E-08	cm/sec	(calculated)
K =	0.01	cm/sec	
S =	4	%	
L =	145	ft	
alpha =	0.0399787	radians	
alpha =	2.29	degrees	
S =	0.04	ft/ft	
R =	0.0050		

For R < 1/4

A = 0.9899

Y_{max} = 0.00

y_{max} = 0.03 ft = 0.3 in < 12 in

For R = 1/4

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

For R >1/4

B = NOT APPLICABLE

Y_{max} = NOT APPLICABLE

y_{max} = N/A ft = N/A in

F.6
Appendix G Excerpt – Pipe Strength Calculations

Appendix G
Pipe Strength Calculations

Table of Contents

Pipe Strength Calculations

Purpose/Methodology/Assumptions/Results/References

Purpose

The purpose of the pipe strength calculations is to demonstrate that the proposed piping for the Phase IV disposal facility will withstand the potential worst-case loading conditions, and provide adequate factors of safety for long-term performance.

Methodology

The pipe strength analysis consists of evaluating the pipes' abilities to withstand the following:

- Excessive ring deflection
- Wall crushing (ring compression)
- Longitudinal beam deflection

For flexible pipe (e.g., PVC and HDPE), ring deflection has historically been calculated using the Modified Iowa Formula. This formula uses pipe properties, bedding conditions, and anticipated pipe loading conditions to determine pipe deflection. Recent information from Dr. Watkins of Utah State University, the developer of the Modified Iowa Formula (Harrison and Watkins, 1996) and others, however, indicates that for pipes bedded in aggregate, the Modified Iowa Formula overestimates ring deflection for flexible pipes in stiff embankments and should not be used as a limiting design criteria in landfill applications. The Modified Iowa formula is not representative of the conditions to which a landfill collection pipe is exposed for the following reasons:

- The modulus of soil reaction, E', is employed as a spring constant, whereas the soil (bedding stone) is not an elastic material (not spring-like).
- After deep burial, such as the first lift of waste, forces requiring a spring-like reaction from the sidefill soil no longer exist (i.e., the loads on the pipe will be distributed and not concentrated over the pipe like a wheel load).
- The model does not consider the behavior of the sidefill in the vertical direction (it has been reported by Watkins that the pipe cannot, and will not, deflect more than the sidefill around the pipe).

Watkins concluded that the ring compression formula is the correct fundamental design approach and should be used while also checking for other performance limits (primarily sidefill deflection).

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For this analysis, the ring compression formula recommended by Watkins has been used to check the adequacy of the piping bedded in aggregate in the disposal facility. Ring deflection has been conservatively estimated by calculating the deflection of the bedding soil on the sides of the pipe. For pipes bedded in clay (sidewall penetrations), the Modified Iowa formula was utilized.

Longitudinal strain is caused by inconsistent support by the pipe bedding (Harrison and Watkins, 1996). This condition is not applicable in landfill applications such as the disposal facility since the landfill base will be constructed on a firm foundation with pipes continuously bedded. Therefore, longitudinal strain was not calculated.

Equations

Wall Crushing (Ring Compression):

$S_A=\sigma(SDR)/2$, (Harrison and Watkins, 1996)

where,

S_A = the magnitude of the compressive force experienced by the pipe wall (psi);
σ = the maximum unit pressure expected to act on the top of the pipe (psi);
SDR = standard dimension ratio.

S_A is then compared to the design long-term compressive strength of the material (approximately 800 psi for HDPE which has a factor of safety of 2 or greater built into it [Plexco/Spirolite] and approximately 4,000 psi for PVC).

Ring Deflection (sidefill deflection):

$X = \varepsilon = \sigma$ (pipe diameter)/E,

where:

X = Deflection; conservatively assumed to equal ε (the allowable ring deflection for PVC and HDPE pipes is 7.5 percent);
ε = vertical compression of sidefill;

E = modulus of elasticity of bedding stone - Constrained Modulus (note: this value differs from the modulus of soil reaction E' used in the Modified Iowa formula). Assume E = 20,000 psi for uniform gravel at 90% relative density and subject to initial loading (Lambe and Wittmann, 1969);

σ = the maximum unit pressure expected to act on the top of the pipe (psi).

Assumptions

Piping Applications

For the disposal facility, there are three key pipes for pipe strength consideration at this time. These pipes include the following:

- 6-inch SDR 17 HDPE leachate collection pipe
- 8-inch SDR 17 HDPE secondary containment pipe
- 10-inch SDR 17 HDPE secondary containment pipe
- 3-inch SCH 120 PVC leachate head well pipe

Note that all piping situations are open-channel flow conditions without pressure (i.e., pipes do not run full). Further, these pipes will be constructed with a coarse stone aggregate bedding. An 8-inch and 10-inch leachate conveyance pipe were evaluated to allow for flexibility concerning the size of the outer pipe, which will act as secondary containment for a 6-inch leachate conveyance pipe.

Loading Conditions

The pipes' structural stabilities were analyzed for severe loading conditions. The severe loading conditions were based on the following:

- The probable maximum equipment load on the pipe for an appropriate minimum soil cover depth during construction.
- The probable prismatic static load on the pipe following closure. This loading condition is considered conservative for deep burials based on a telephone conversation with Dr. Watkins on March 18, 1998.

Vehicle specifications were determined from the Caterpillar Performance Handbook, Edition 20. To be conservative, waste and soil unit weights were 80 lbs/ft^3 and 120 lbs/ft^3, respectively, based on the soil characteristics. The maximum waste height over the piping networks is approximately 140 feet.

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In all cases, the static load on the pipe following landfill closure is the higher of the two loading conditions on the pipes; therefore, the ring compression and deflection calculation are based on these static loads.

Pipe Compressive Strength

An allowable design long-term compressive strength of 800 psi was assumed based on recommendations from Plexco/Spirolite for HDPE and 4,000 psi for PVC. The maximum allowable deflection is 7.5 percent, from the Uni-Bell Handbook (see attached references at the end of the pipe strength calculations).

For flexible pipe materials (e.g., PVC and HDPE), under conditions of constant strain (deflection), the rate of relaxation of the pipe is greater than the rate of strength regression. This means that the pipe will react relatively quickly to a compressive load by relaxing. As the pipe relaxes, the load is transferred to the surrounding bedding material (soil arch). As the load is transferred to the soil arch, the stress in the pipe will be reduced. Under these conditions, the pipe is exposed to a state of constant strain, not constant stress. If additional loads are then placed on the pipes, these additional loads will be resisted by the pipe's original compressive strength. The pipe will again relax, and the load will be taken up by the soil arch. Therefore, using the pipe's original compressive strength for this analysis is considered the correct approach.

It is noted that the compressive strength values used in this analysis are based on manufacturer's reference data from testing in which the pipe is placed in tension. Under landfill conditions, the pipe will be placed in compression. Strength for materials placed in compression are expected to be higher than for materials placed in tension. This, therefore, provides additional conservatism to this analysis.

Temperature Effects

Tests by Dr. Watkins have shown that polyethylene softens slightly at 140°F. The result is that the pipe relaxes faster and, as a result, transfers the load to the soil arch faster. For the same reasons discussed above, the pipe will be in a state of constant strain, not constant stress. Therefore, temperature is not a critical performance limit under typical landfill conditions.

Pipe Creep

Pipe creep occurs under conditions of constant stress, not conditions of constant strain. Since a condition of constant stress does not occur in landfill pipe applications, creep is not a performance limit.

Results

The results of the pipe strength calculations show that the pipes evaluated will be able to withstand the load placed on them. These pipes were analyzed at the locations where the dead loads would be the greatest. The associated factor of safety against wall crushing exceeded the minimum design value of 4.0. The allowable deflection (7.5%) was not exceeded based on the anticipated deflection of the sidefill soil. Based on these calculations, the proposed pipe designs are adequate for the anticipated loading conditions.

PIPE NUMBER	PIPE DESCRIPTION	RING COMPRESSION FORCE (psi)(1)	ESTIMATED DEFLECTION (sidefill soil compression)(2)
1	6" SDR 17 HDPE LEACHATE COLLECTION PIPE	703	0.41%
2	8" SDR 17 HDPE SECONDARY CONTAINMENT PIPE (IN AGGREGATE)	284	0.17%
3	10" SDR 17 HDPE SECONDARY CONTAINMENT PIPE (IN AGGREGATE)	283	0.17%
3A	10" SDR 17 HDPE SECONDARY CONTAINMENT PIPE (IN CLAY)	N/A	5.76%
4	3" SCH 120 PVC LEACHATE HEAD WELL PIPE	403	2.85%

(1) The allowable design long-term ring compression force is equal to 800 psi for HDPE and 4,000 psi for PVC.

(2) The allowable design estimated defection is equal to 7.5 percent.

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Dairyland Power Cooperative	BAA	8/00	MJA	10/00	3081.40

References

Driscopipe Systems Design Manual, 1991.

Harrison, S., Watkins, R.K. 1996. HDPE Leachate Collection Pipe Design by Fundamentals of Mechanics. Presented at the Nineteenth International Madison Waste Conference, Department of Engineering Professional Development, University of Wisconsin-Madison, September 25-26, 1996.

Lambe, W.T. and R.V. Whitman. 1969. Soil Mechanics. New York: John Wiley & Sons, Inc. 1969.

Plexco, Application Note No. 1, Extra High Molecular Weight. 1987. High density polyethylene PE 3408 industrial piping system pipe behavior under earth loading. Amsted Industries.

Uni-Bell PVC Pipe Association. 1982. Uni-bell handbook of PVC pipe design and construction. 2nd edition. Dallas: Uni-Bell PVC Pipe Association.

Uni-Bell PVC Pipe Association. 1991. Uni-bell handbook of PVC pipe design and construction. 3rd edition. Dallas: Uni-Bell PVC Pipe Association.

Utah State University. 1996. Procedure for structural design of HDPE pipe, DR-11, buried in waste landfills. Reynold King Watkins, Professor Emeritus, Department of Civil and Environmental Engineering, Logan, Utah. February 19, 1996.

Calculations

RMT

COMPUTATION SHEET

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DPC Phase IV	By: BAA	Aug-00	By:MJA	Date:	10/00	3081.40

PIPE STRENGTH CALCULATIONS

Piping Applications:

Pipe #	Description	Dia. (in.)	
		nomina	actual
1	SDR 17 HDPE Leachate Collection Pipe	6	6.625
2	SDR 17 HDPE Leachate Conveyance Pipe	8	8.625
3	SDR 17 HDPELeachate Conveyance Pipe	10	10.75
4	Sch.120 PVC Leachate Headwell Pipe	3	3.5
5	SDR 11 HDPE Leach.Conv. Pipe (in Clay)	10	10.75
6		0	0
7		0	0

Minimum soil cover over pipes for operation of wheeled vehicles (in.): 36

Minimum soil cover over pipes for operation of tracked vehicles (in.): 24

Calculate Equipment Loads:

From Uni-Bell Handbook of PVC Pipe Design and Construction (1982)

$W_{sc} = C_s\,(P\,F'/\,L)$ <= Concentrated Load

Where: W_{sc} = The load on the pipe, lb/unit length

P = The concentrated load, lb

F' = The impact factor <= 1.5 (From Uni-Bell Handbook)

L = The effective length of conduit (3' or less), ft

C_s = The load coefficient which is a function of $B_c/2H$ and $L/2H$,

Where:

H = The height of the fill from the top of the pipe to the ground surface, ft

B_c = The diameter of the pipe, ft

and:

$W_{sd} = C_s\,P\,F'\,B_c$ <= Distributed Load

Where: W_{sd} = The load on the pipe, lb/unit length

P = The intensity of the distributed load, lb/ft^2

F' = The impact factor <= 1.5 (From Uni-Bell Handbook)

B_c = The diameter of the pipe, ft

C_s = The load coefficient which is a function of $D/2H$ and $M/2H$,

Where D and M are the width and length, respectfully, of the area over which the distributed load acts, ft

PROJECT/PROPOSAL NAME	PREPARED		CHECKED			PROJECT/PROPOSAL NO.
DPC Phase IV	By: BAA	Aug-00	By:MJA	Date:	10/00	3081.40

Using the formulas, determine the maximum equipment loads for the pipe diameters to be used in the landfill design

Consider the following equipment:

CAT 637E Scraper
Operating weight (loaded) = 195,000 lb
50/50 weight distribution
Number of Wheels = 4
Weight per wheel = 48,750 lb = P

CAT 826C Landfill Compactor
Operating weight (loaded) = 69,700 lb
50/50 weight distribution
Number of Wheels = 4
Weight per wheel = 17,425 lb = P

CAT D4000 Articulated Dumptruck
Operating weight (loaded) = 141,700 lb
34/33/33 weight distribution (3 axels)
Number of Wheels = 6
Weight per wheel = 23,617 lb = P

=> For wheeled vehicles the CAT 637E Scraper load is the largest, thus use 48750 lb. to determine Wsc

CAT D9N Dozer
Operating weight (loaded) = 94,000 lb
Track width = 2 ft. Track length = 11.4 ft.
Ground Contact Area = 6,566 in^2
Weight per track = 47,000 lb
Force per unit area = 14 psi

=> For distributed loads use 14 psi to determine Wsd

COMPUTATION SHEET

SHEET 3 OF 6

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
DPC Phase IV	By: BAA	Aug-00	By:MJA	Date: 10/00	3081.40

6.625" Diameter Pipe

O.D. = 6.625 in.

Min. Soil Cover (wheeled) = 36 in.

Bc/2H = 0.1 L/2H = 0.5

From Table, Cs = 0.079

Wsc = 160 lbs/in

Min. Soil Cover (tracked) = 24 in.

D/2H = 0.5 M/2H = 2.9

From Table, Cs = 0.54

Wsd = 75 lb/in

Use 160 lb/in

8.625" Diameter Pipe

O.D. = 8.625 in.

Min. Soil Cover (wheeled) = 36 in.

Bc/2H = 0.1 L/2H = 0.5

From Table, Cs = 0.079

Wsc = 160 lbs/in

Min. Soil Cover (tracked) = 24 in.

D/2H = 0.5 M/2H = 2.9

From Table, Cs = 0.54

Wsd = 98 lb/in

Use 160 lb/in

COMPUTATION SHEET

SHEET 4 OF 6

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED			PROJECT/PROPOSAL NO.
DPC Phase IV	By: BAA	Aug-00	By:MJA	Date:	10/00	3081.40

10.75" Diameter Pipe

O.D. = 10.75 in.

Min. Soil Cover (wheeled) = 36 in.

Bc/2H = 0.1 L/2H = 0.5

From Table, Cs = 0.079

Wsc = 160 lbs/in

Min. Soil Cover (tracked) = 24 in.

D/2H = 0.5 M/2H = 2.9

From Table, Cs = 0.54

Wsd = 122 lb/in

Use 160 lb/in

COMPUTATION SHEET

SHEET 5 OF 6

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
DPC Phase IV	By: BAA	Aug-00	By:MJA	Date: 10/00	3081.40

3.5" Diameter Pipe

O.D. = 3.5 in.

Min. Soil Cover (wheeled) = 36 in.

Bc/2H = 0.1 L/2H = 0.5

From Table, Cs = 0.079

Wsc = 160 lbs/in

Min. Soil Cover (tracked) = 24 in.

D/2H = 0.5 M/2H = 2.9

From Table, Cs = 0.54

Wsd = 40 lb/in

Use 160 lb/in

COMPUTATION SHEET

SHEET 6 OF 6

PROJECT/PROPOSAL NAME DPC Phase IV	PREPARED By: BAA	Aug-00	CHECKED By:MJA	Date: 10/00	PROJECT/PROPOSAL NO. 3081.40

Calculate Soil and Waste Loads (Dead Loads):

Soil Type	unit wt (pcf)
Soil	120
Waste	80

Pipe #	Soil ht. (ft)	Waste ht. (ft)	0 ht. (ft)	0 ht. (ft)	0 ht. (ft)	0 ht. (ft)	0 ht. (ft)	Pipe Diam (in)	Load psi	Load lb/in
Operational										
1	3	0						6.625	2.5	17
2	4	0						8.625	3.3	29
3	4	0						10.750	3.3	36
4	2	0						3.500	1.7	6
5	4	0						10.750	3.3	36
6										
Closure										
1	6	140						6.625	83	548
2	40	0						8.625	33	288
3	40	0						10.750	33	358
4	4.5	110						3.500	65	227
5	5	68						10.750	42	451
6										

Worst Case Loading

Pipe Description	Pipe Diam (in)	Operational Load (lb/in)	Closure Load (lb/in)	Worst Case Load (lb/in)
SDR 17 HDPE Leachate Collection Pipe	6.625	177	548	548
SDR 17 HDPE Leachate Conveyance Pipe	8.625	189	288	288
SDR 17 HDPELeachate Conveyance Pipe	10.750	196	358	358
Sch.120 PVC Leachate Headwell Pipe	3.500	166	227	227
SDR 11 HDPE Leach.Conv. Pipe (in Clay)	10.750	196	451	451
0	#N/A	0	0	0
0	#N/A	0	0	0

TABLE 1 Influence Coefficients, Cs for Concentrated and Distributed Loads Vertically Centered Over Conduit (Solution of Holl's and Newmark's integration of Boussinesq Equasion)

D/2H or B_c/2H	**M/2H or L/2H**													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

Ref: Uni-bell Handbook of PVC Pipe

HDPE PIPE DESIGN BY RING COMPRESSION AND DEFLECTION

PROJECT NAME DPC
PROJECT NO. : 3081.40
USER NAME : MJA
DATE : 8/20/2000

FILE:p:\data\projects\3081\40\pipe\lcpipe1.xls
HDPE CALCLULATION ONLY

6" SDR 17 HDPE Leachate Collection Pipe

<<< VARIABLES >>>

STANDARD DIMENSION RATIO	17.0
OUTSIDE DIAMETER (inches)	6.625
PIPE LOADING (lbs/in)	548
PIPE LOADING (psi)	83
BEDDING CONSTRAINED MODULUS (psi)	20000

<<< CONSTANTS >>>

PIPE COMPRESSIVE STRENGTH, FS ≥2.0 (psi)	800

<<< CALCULATED VALUES >>>

RING COMPRESSIVE FORCE (psi)	703
IS RING COMPRESSIVE FORCE GREATER THAN PIPE COMPRESSIVE STRENGTH?	No
DEFLECTION:SIDEFILL COMP. (in)	0.027
% DEFLECTION	0.41%

HDPE PIPE DESIGN BY RING COMPRESSION AND DEFLECTION

PROJECT NAME DPC
PROJECT NO. : 3081.40
USER NAME : MJA
DATE : 8/20/2000

FILE:p:\data\projects\3081\40\pipe\lcpipe2.xls
HDPE CALCLULATION ONLY

8" SDR 17 HDPE Leachate Conveyance Pipe

<<< VARIABLES >>>

STANDARD DIMENSION RATIO	17.0
OUTSIDE DIAMETER (inches)	8.625
PIPE LOADING (lbs/in)	288
PIPE LOADING (psi)	33
BEDDING CONSTRAINED MODULUS (psi)	20000

<<< CONSTANTS >>>

PIPE COMPRESSIVE STRENGTH, FS ≥2.0 (psi)	800

<<< CALCULATED VALUES >>>

RING COMPRESSIVE FORCE (psi)	284
IS RING COMPRESSIVE FORCE GREATER THAN PIPE COMPRESSIVE STRENGTH?	No
DEFLECTION:SIDEFILL COMP. (in)	0.014
% DEFLECTION	0.17%

HDPE PIPE DESIGN BY RING COMPRESSION AND DEFLECTION

PROJECT NAME DPC
PROJECT NO. : 3081.40
USER NAME : MJA
DATE : 8/20/2000

FILE:p:\data\projects\3081\40\pipe\lcpipe3.xls
HDPE CALCLULATION ONLY

10" SDR 17 HDPE Leachate Conveyance Pipe

<<< VARIABLES >>>

STANDARD DIMENSION RATIO	17.0
OUTSIDE DIAMETER (inches)	10.750
PIPE LOADING (lbs/in)	358
PIPE LOADING (psi)	33
BEDDING CONSTRAINED MODULUS (psi)	20000

<<< CONSTANTS >>>

PIPE COMPRESSIVE STRENGTH, FS ≥2.0 (psi)	800

<<< CALCULATED VALUES >>>

RING COMPRESSIVE FORCE (psi)	283
IS RING COMPRESSIVE FORCE GREATER THAN PIPE COMPRESSIVE STRENGTH?	No
DEFLECTION:SIDEFILL COMP. (in)	0.018
% DEFLECTION	0.17%

```
***** MODIFIED IOWA FORMULA FOR PVC PIPE DESIGN BY RING DEFLECTION *****


                                                 PROJECT       : DPC
                                                 PROJECT NO.  : 3081.40
                                                 USER NAME     : MJA
                                                 DATE          : 02-Oct-00

   FILE:H:\DATA\COMMON\TEMPLATE\SC-11\IOWAPVC.XLS
   PVC CALCULATION ONLY
   PIPE DESCRIPION:    3" DIA. SCHEDULE 80 PVC HEADWELL PIPE


        <<< VARIABLES >>>

        STANDARD DIMENSION RATIO                      12.4
        OUTSIDE DIAMETER (inches)                    3.500
        MIN. WALL THICKNESS (inches)                 0.300
        WEIGHT / LINEAL INCH (lbs/in)                  227
        SOIL MODULUS (psi)                            2000

        <<< CONSTANTS >>>

        BEDDING FACTOR                                0.10
        DEFLECTION LAG FACTOR                          1.5
        FLEXURAL MODULUS (psi)                     400,000

        <<< CALCULATED VALUES >>>

        MOMENT OF INERTIA (inch^3)                   0.002
        MEAN RADII (inches)                          1.600
        PIPE STIFFNESS (psi)                         1,475

        DEFLECTION (inches)                          0.100

        % DEFLECTION                                 2.85%
```

$\left(\frac{227\#}{in}\right) \div (3.5 in) = 64.8 psi$

Wall Crushing

$S_A = \sigma (SDR)/2 = (65 psi)(12.4)/2 = 403 psi$ ✓

***** MODIFIED IOWA FORMULA FOR HDPE PIPE DESIGN BY RING DEFLECTION *****

PROJECT NAME: DPC
PROJECT NO. : 07-Jun-08
USER NAME : BJK
DATE : 05-Oct-00

FILE:H\DATA\COMMON\TEMPLATE\SC-11\IOWAHDPE.XLS
HDPE CALCLULATION ONLY
PIPE DESCRIPION: 8" SDR 17 HDPE Leachate Conveyance Pipe

<<< VARIABLES >>>

STANDARD DIMENSION RATIO	11.0
OUTSIDE DIAMETER (inches)	10.750
WEIGHT / LINEAL INCH (lbs/in)	451
SOIL MODULUS (psi)	400

<<< CONSTANTS >>>

BEDDING FACTOR	0.10
DEFLECTION LAG FACTOR	1.5
FLEXURAL MODULUS (psi)	105,000

<<< CALCULATED VALUES >>>

AVERAGE WALL THICKNESS (inches)	1.036
MOMENT OF INERTIA (inch^3)	0.093
MEAN RADII (inches)	4.857
PIPE STIFFNESS (psi)	570
DEFLECTION (inches)	0.619
% DEFLECTION	5.76%
% TANGENTIAL STRAIN	2.22%
TANGENTIAL STRAIN ALLOWABLE	4.20%
FACTOR OF SAFETY (STRAIN)	1.89

RMT INC.

COMPUTATION SHEET

SHEET ____________ OF ____________

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT / PROPOSAL NO.
DPC	BJK	10/00	MJA	10/00	3081.40

Figure 3
BUREAU OF RECLAMATION VALUES OF E' FOR IOWA FORMULA
(For Initial Flexible Pipe Deflection) (REFERENCE FLEXCO)

Soil type-pipe bedding material (Unified Classification System 1/)	E' for degree of compaction of bedding (lb/in^{2})^{4}/			
	Dumped	Slight <85% Procter <40% rel. den.	Moderate 85-95% Proctor 40-70% rel. den.	High >95% Proctor >70% rel. den.
Fine-grained Soils (LL > 50)^{2}/ Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent Soils Engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25 percent coarse-grained particles	50	200	$\boxed{400}$	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25 percent coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC3/ contains more than 12 percent fines	100	400	1,000	2,000
Coarse-grained Soils with Little or No Fines GW, GP, SW, SP3/ contains less than 12 percent fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000		

1/ ASTM Designation D-2487, USBR Designation E-3.

2/ LL = Liquid limit.

3/ Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC.).

4/ 1 lb/in^2 = 0.07 kg/cm^2.

FIGURE 2

Variation In Soil Stress With Cover Depth Below H-20 Wheel Load

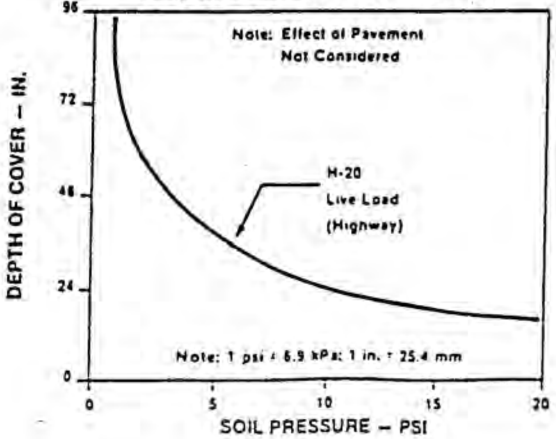
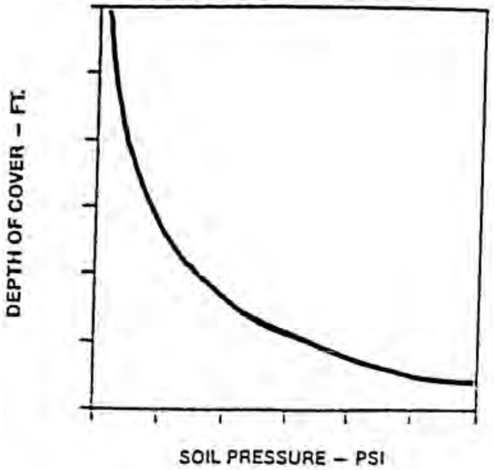


FIGURE 3

Cooper E-80 Live Loading



F.7
Appendix J Excerpt – Global Stability

Global Slope Stability

Purpose/Approach/Methodologies/Assumptions/Results/References

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
	By:	Date:	By:	Date:	
Dairyland Power Cooperative	JDH Rev. BJK	9/97 9/00	PDC	9/97	3081.40

GLOBAL SLOPE STABILITY

Purpose

To evaluate the global slope stability of the liner and final slopes.

Approach

The global stability analysis was performed by evaluating the following worst-case slope conditions:

Liner Slope

The worst-case slope of the liner consists of an 83-foot-high 3H:1V slope with a 2-foot-thick low-permeability soil layer, a GCL, a geomembrane, and a 1-foot-thick granular drainage layer (approximately Coordinate N172500, E147700, west slope [see Figure J-1]).

Final Cover Slope

The worst-case slope of the final cover consists of a 36-foot-high, 4H:1V slope (approximately Coordinate N172000, E1477000, west slope [see Figure J-2]). Conditions are modeled for ash waste.

Methodologies

- The analyses have been performed using the computer program XSTABL, which was developed at Purdue University and subsequently modified by Interactive Software Designs, Inc., of Moscow, Idaho (1994). XSTABL is used to perform the iterative task of identifying the worst-case failure scenario for each case using the Modified Bishops Method. XSTABL uses a two-dimensional static equilibrium method to determine a factor of safety against failure.
- The failure mode considered for the stability analysis was the circular or rotational failure of the waste, subgrade, natural formations, and compacted embankments (*i.e.*, perimeter berm, liner, and cover).
- The circular trial failure surface generator performs a search for the critical failure surface based on failure initiation and termination points established by the user, and is often used when no well-defined weak zone exists in the profile being evaluated. This failure mode is used in evaluating the stability of the liner and final slopes.
- The worst-case (lowest factor of safety) is identified by varying the limits of the failure generation locations. In cases where both types of failure are used to analyze the stability, the failure mode resulting in the most critical (lowest) factor of safety is presented in the results.

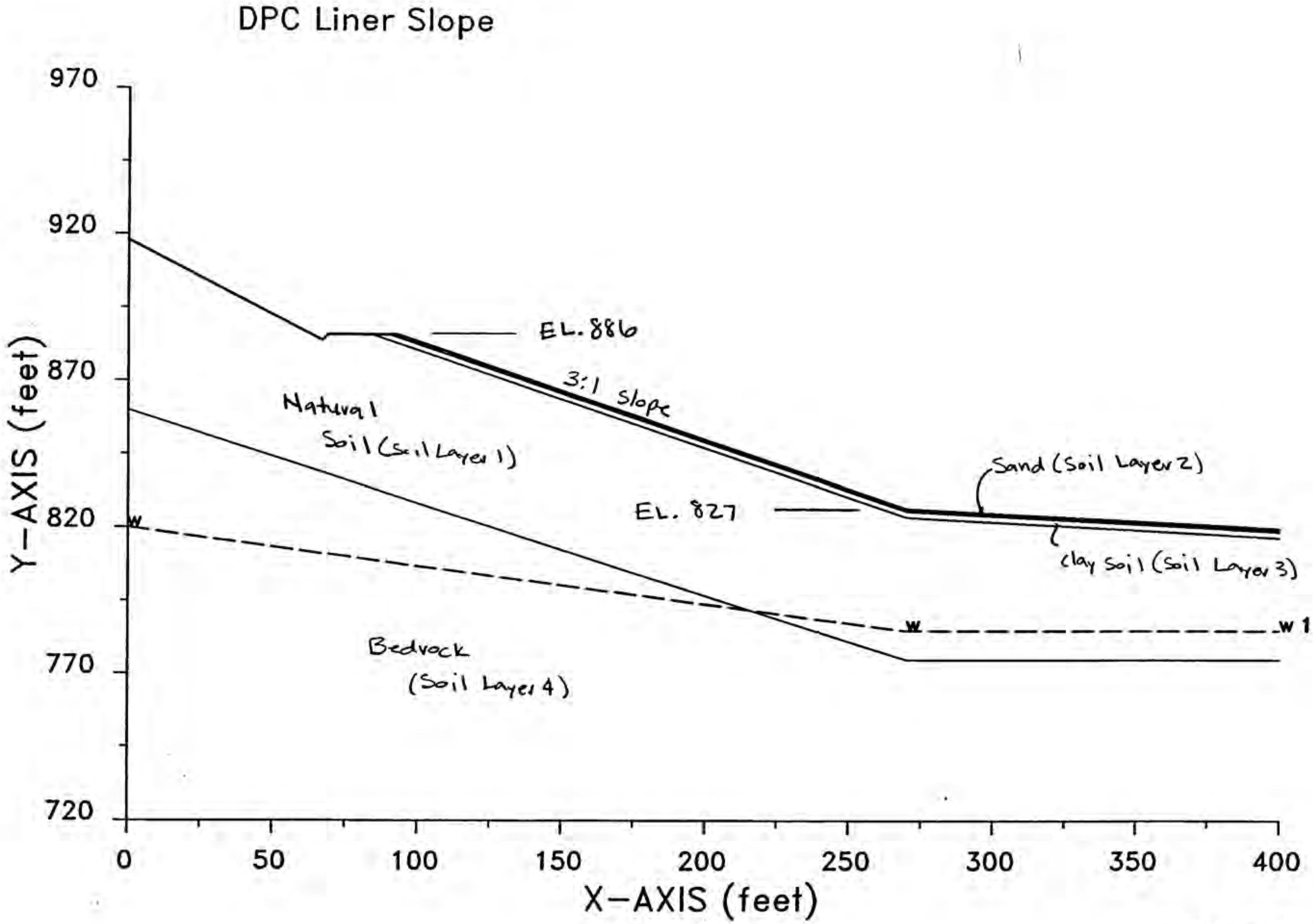

FIGURE J-1
DPC 3081.28

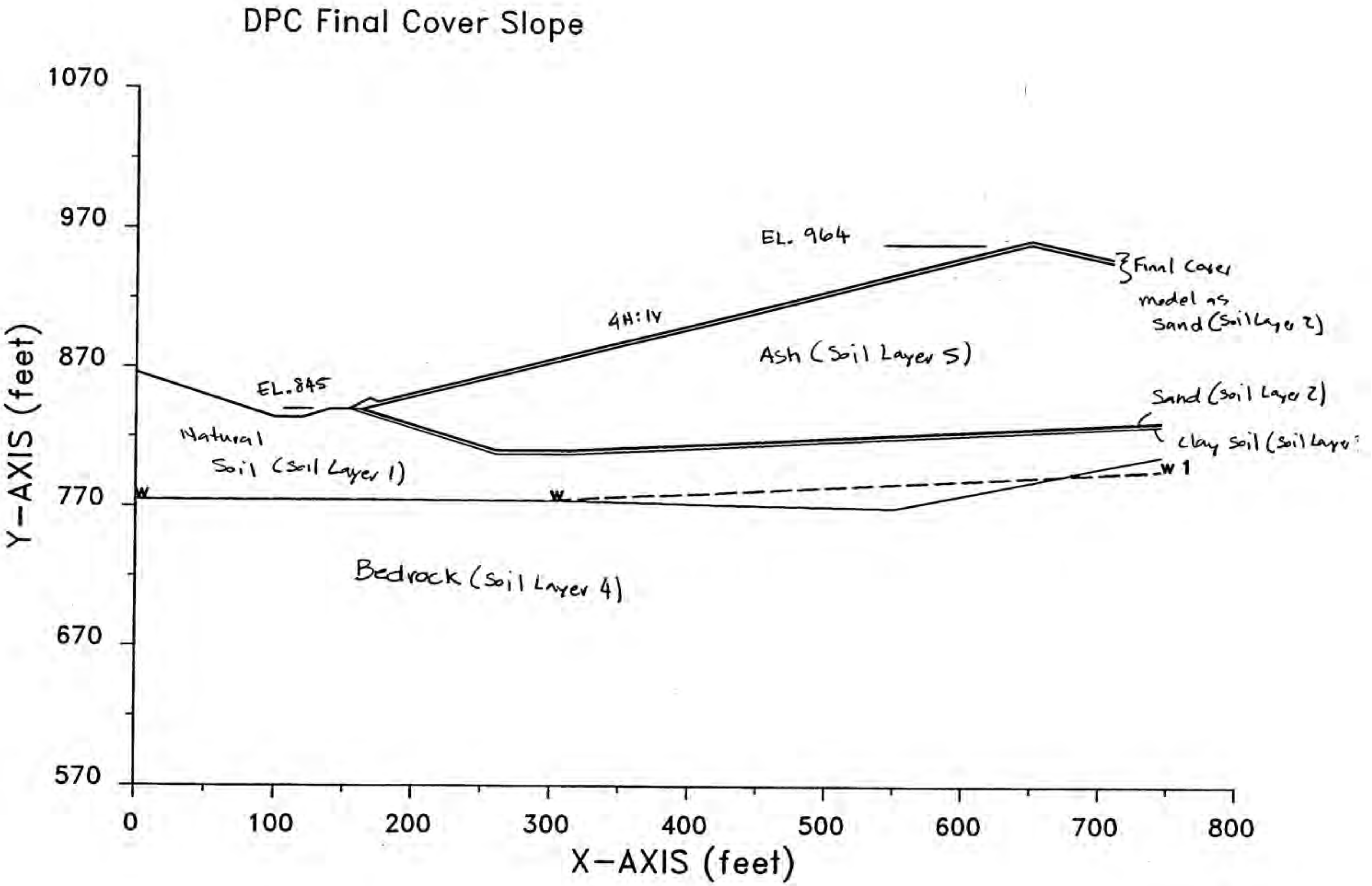

FIGURE J-2
DPC 3081.28

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Dairyland Power Cooperative	JDH Rev. BJK	9/97 9/00	PDC	9/97	3081.40

Assumptions

- Profile - The cross sections selected to be analyzed are representative of worst-case profiles with regard to slope stability. The longest and highest slopes were selected for modeling. The geologic setting and subgrade information was based on the information found on the geologic cross sections contained in this report.
- To simplify the analysis, the final cover is modeled as a single layer of soil, using sand soil characteristics. This assumption is minor due to the small thickness of the final cover relative to the thickness of waste.
- Groundwater - The water table is estimated to be at varying elevations of 775 to 799 feet through the cross section based on the groundwater elevation maps found in this report.
- A factor of safety of at least 1.3 is acceptable against global slope failures.
- The shear strength of the ash is based on published results of fly ash materials (Oweis, 1990). The results of these tests are as follows:

MATERIAL	MC (%)	γ_d (pcf)	c (psf)	ϕ (degrees)
DPC ash waste	40	50	130	20

Notes:
MC = moisture content.
γ_d = dry unit weight.
c = cohesion (psf).
ϕ = friction angle.

- Soil Parameters - Unit weight, friction angles, and cohesive strength parameters were estimated based on information gathered from boring logs contained in Appendix C of Addendum 3 for the Initial Site Report (RMT, 1995) and on geologic cross sections. Parameters were chosen based on their correlation with pocket penetration numbers and Plasticity Indices. Published values and engineering judgment were also considered to conservatively estimate the clay, soil, and waste characteristics, as presented in the following table:

MATERIAL	γ (pcf)	γ Sat (pcf)	ϕ (degrees)	c (psf)
Natural soil	120	120	20	200
Sand	110	110	30	0
Clay soil	125	125	25	400
Bedrock	145	145	45	10000
Ash waste	80	80	20	130

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Dairyland Power Cooperative	JDH Rev. BJK	9/97 9/00	PDC	9/97	3081.40

Results

- The results of the slope stability analysis are summarized below.

Factors of Safety Against Circular Failure

	FACTOR OF SAFETY
Liner slope	1.6
Final cover slope	1.8

- Based on the assumed soil strength parameters and slope conditions, the slopes of the liner and final cover will be stable under the specified modeled conditions.

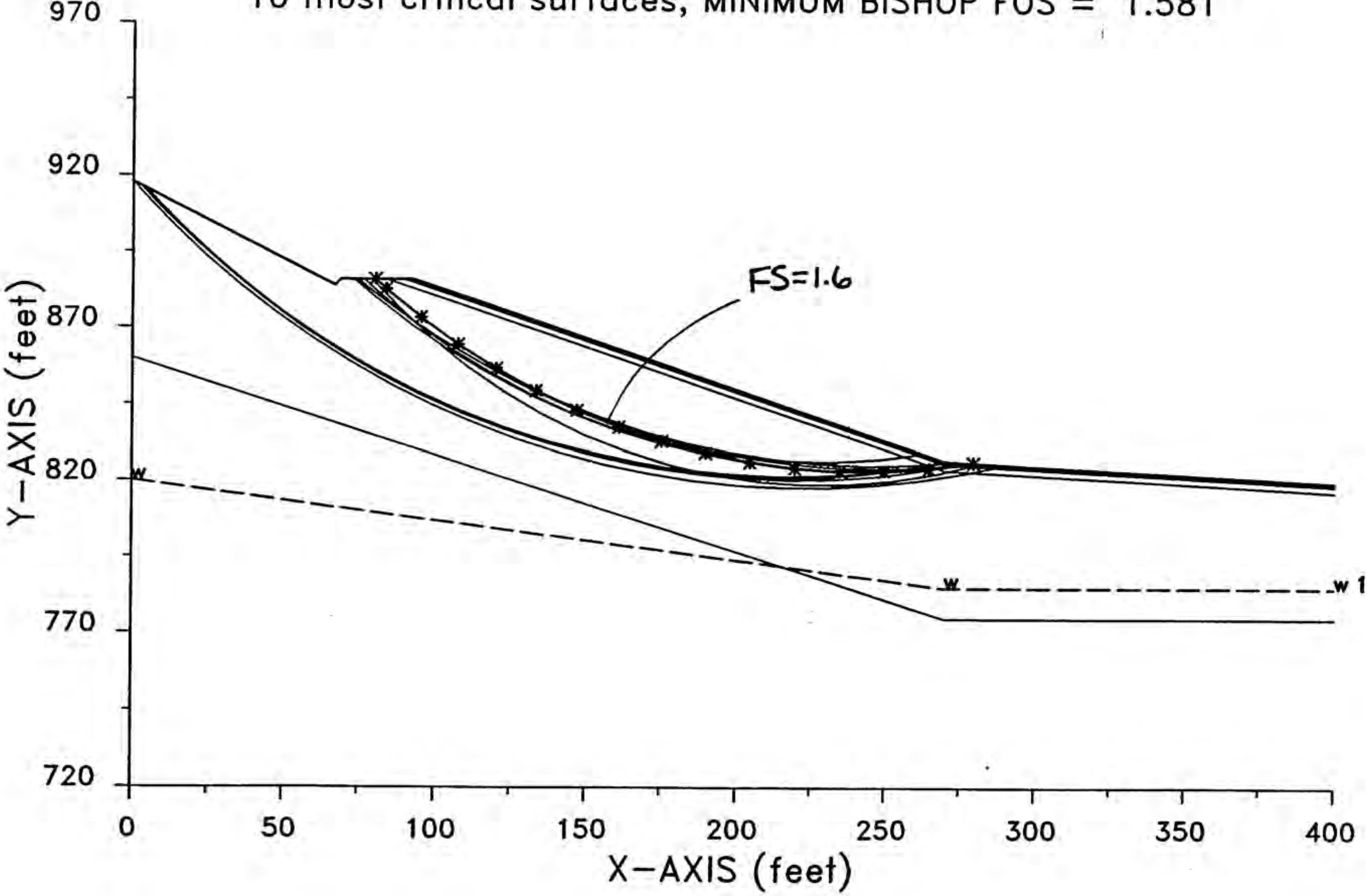
References

Oweis, I. S. and R.P. Khera. 1990. Geotechnology of waste management. Butterworths, London.

RMT, Inc. 4/1995. Initial site report for Dairyland Power Cooperative.

Interactive Software Designs. 1994. XSTABL Slope Stability Computer Program. Moscow, Idaho.

XSTABL Outputs



DPC Liner Slope
10 most critical surfaces, MINIMUM BISHOP FOS = 1.581

```
XSTABL File: LIN

          *******************************************
          *              X S T A B L                *
          *                                         *
          *        Slope Stability Analysis         *
          *               using the                 *
          *            Method of Slices             *
          *                                         *
          *         Copyright (C) 1992 - 96         *
          *   Interactive Software Designs, Inc.    *
          *        Moscow, ID 83843, U.S.A.         *
          *                                         *
          *           All Rights Reserved           *
          *                                         *
          * Ver. 5.200                  96 - 1460   *
          *******************************************


   Problem Description : DPC Liner Slope



   ----------------------------
   SEGMENT BOUNDARY COORDINATES
   ----------------------------

      7 SURFACE boundary segments

   Segment    x-left    y-left    x-right    y-right     Soil Unit
     No.       (ft)      (ft)       (ft)       (ft)     Below Segment

      1          .0     918.0       67.0      884.0          1
      2        67.0     884.0       69.0      886.0          1
      3        69.0     886.0       84.0      886.0          1
      4        84.0     886.0       90.0      886.0          3
      5        90.0     886.0       93.0      886.0          2
      6        93.0     886.0      270.0      827.0          2
      7       270.0     827.0      400.0      820.0          2


      6 SUBSURFACE boundary segments

   Segment    x-left    y-left    x-right    y-right     Soil Unit
     No.       (ft)      (ft)       (ft)       (ft)     Below Segment

      1        90.0     886.0      270.0      826.0          3
      2       270.0     826.0      400.0      819.0          3
      3        84.0     886.0      270.0      824.0          1
      4       270.0     824.0      400.0      817.0          1
      5          .0     860.0      270.0      775.0          4
      6       270.0     775.0      400.0      775.0          4


   -------------------------
   ISOTROPIC Soil Parameters
   -------------------------
```

✓ Jpa
8/97

```
 4 Soil unit(s) specified

Soil   Unit Weight   Cohesion  Friction    Pore Pressure      Water
Unit  Moist    Sat.  Intercept   Angle  Parameter  Constant  Surface
 No.  (pcf)   (pcf)    (psf)     (deg)      Ru       (psf)      No.

  1   120.0   120.0    200.0     20.00     .000         .0       1 - Natural Soil
  2   110.0   110.0       .0     30.00     .000         .0       1 - Sand
  3   125.0   125.0    400.0     25.00     .000         .0       1 - Clay Soil
  4   145.0   145.0  10000.0     45.00     .000         .0       1 - Bedrock


 1 Water surface(s) have been specified

Unit weight of water =    62.40  (pcf)

Water Surface No.  1 specified by  3 coordinate points

**********************************
         PHREATIC SURFACE,
**********************************

 Point      x-water     y-water
  No.         (ft)        (ft)

   1           .00      820.00
   2        270.00      785.00
   3        400.00      785.00


A critical failure surface searching method, using a random
technique for generating CIRCULAR surfaces has been specified.


 400 trial surfaces will be generated and analyzed.


 20 Surfaces initiate from each of  20 points equally spaced
along the ground surface between  x =     250.0 ft
                                and  x =     290.0 ft


Each surface terminates between    x =        .0 ft
                               and  x =      90.0 ft


Unless further limitations were imposed, the minimum elevation
at which a surface extends is  y =        .0 ft


  15.0 ft line segments define each trial failure surface.


--------------------
ANGULAR RESTRICTIONS
--------------------
```

```
  The first segment of each failure surface will be inclined
  within the angular range defined by :

          Lower angular limit :=   -45.0 degrees
          Upper angular limit :=  (slope angle - 5.0) degrees




Factors of safety have been calculated by the :

* * * * *   SIMPLIFIED BISHOP METHOD   * * * * *



  The most critical circular failure surface
  is specified by 16 coordinate points

        Point      x-surf       y-surf
         No.        (ft)         (ft)

          1        279.47       826.49
          2        264.59       824.66
          3        249.61       823.77
          4        234.61       823.79
          5        219.64       824.75
          6        204.76       826.63
          7        190.02       829.43
          8        175.49       833.14
          9        161.21       837.74
         10        147.25       843.21
         11        133.65       849.54
         12        120.46       856.70
         13        107.75       864.66
         14         95.55       873.39
         15         83.92       882.86
         16         80.52       886.00

****  Simplified BISHOP FOS =   1.581  ****




The following is a summary of the TEN most critical surfaces

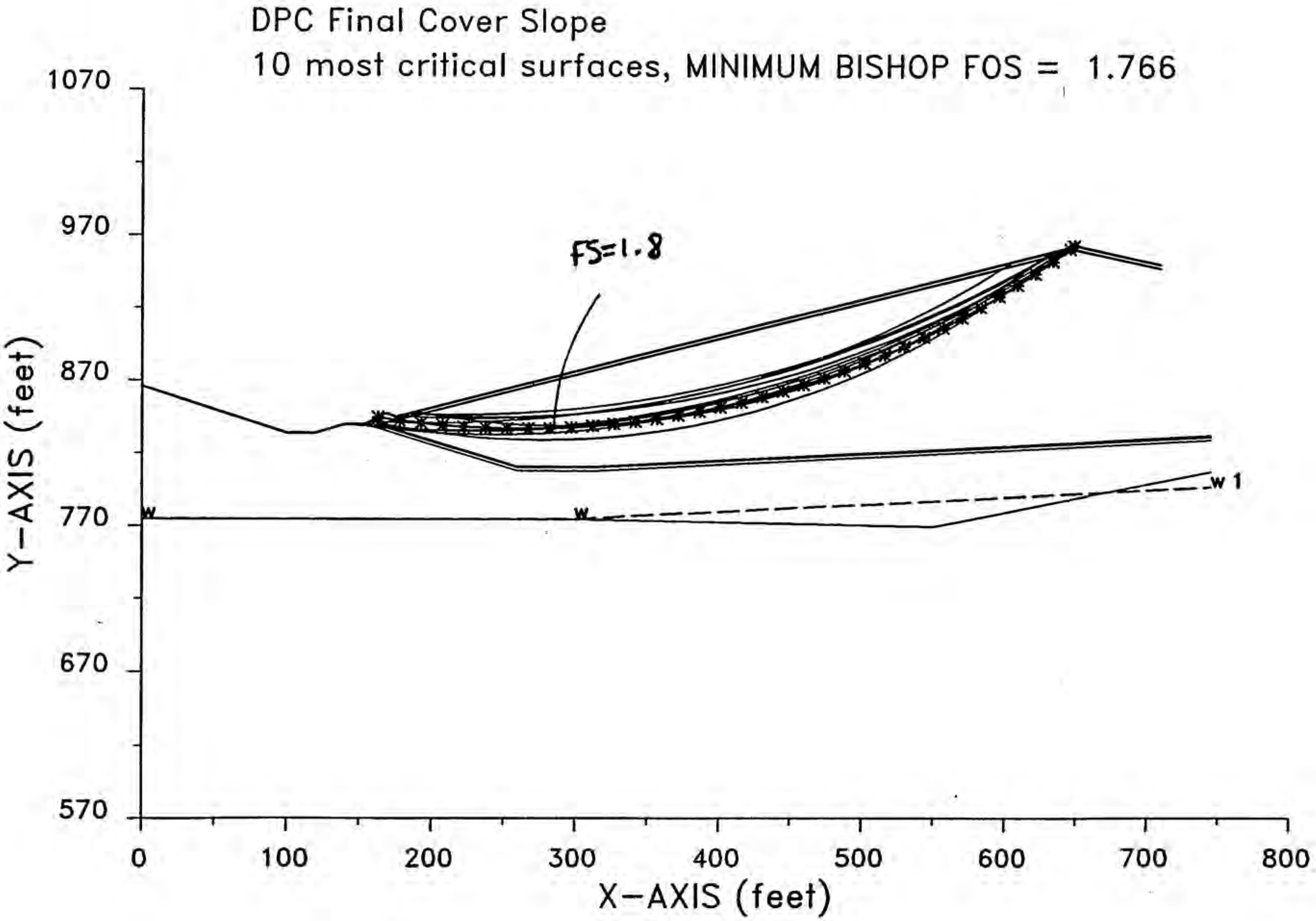
Problem Description : DPC Liner Slope

         FOS      Circle Center     Radius   Initial Terminal  Resisting
       (BISHOP)  x-coord  y-coord            x-coord  x-coord    Moment
                   (ft)     (ft)      (ft)     (ft)     (ft)     (ft-lb)

  1.    1.581    242.58  1065.87    242.21   279.47    80.52  4.571E+07
  2.    1.583    240.37  1080.10    256.18   277.37    73.34  5.172E+07
  3.    1.588    217.22  1112.22    290.31   271.05     2.88  9.804E+07
  4.    1.588    222.43  1115.96    297.80   290.00      .10  1.125E+08
  5.    1.589    245.92  1099.38    273.91   273.16    74.27  5.033E+07
```

```
  6.   1.590    228.19  1018.10   199.02   281.58     79.45  4.717E+07
  7.   1.590    246.76  1096.56   272.04   279.47     74.66  5.171E+07
  8.   1.590    219.48  1112.23   291.43   277.37      4.12  1.004E+08
  9.   1.592    215.31  1104.38   282.98   271.05      4.55  9.690E+07
 10.   1.592    227.51  1048.57   221.91   262.63     76.64  4.135E+07

                      * * *  END OF FILE  * * *
```


DPC Final Cover Slope

10 most critical surfaces, MINIMUM BISHOP FOS = 1.766

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XSTABL File: COVER      8-26-97     8:38

          ******************************************
          *               X S T A B L              *
          *                                        *
          *        Slope Stability Analysis        *
          *               using the                *
          *            Method of Slices            *
          *                                        *
          *        Copyright (C) 1992 - 96         *
          *   Interactive Software Designs, Inc.   *
          *        Moscow, ID 83843, U.S.A.        *
          *                                        *
          *          All Rights Reserved           *
          *                                        *
          *  Ver. 5.200                96 - 1460   *
          ******************************************


     Problem Description : DPC Final Cover Slope



     -----------------------------
     SEGMENT BOUNDARY COORDINATES
     -----------------------------

        9 SURFACE boundary segments

     Segment   x-left    y-left    x-right   y-right     Soil Unit
       No.      (ft)      (ft)      (ft)      (ft)     Below Segment

        1         .0     866.0     100.0     834.0           1
        2      100.0     834.0     120.0     834.0           1
        3      120.0     834.0     140.0     840.0           1
        4      140.0     840.0     154.0     840.0           1
        5      154.0     840.0     168.0     847.0           2
        6      168.0     847.0     170.0     847.0           2
        7      170.0     847.0     175.0     845.0           2
        8      175.0     845.0     650.0     964.0           2
        9      650.0     964.0     710.0     951.0           2


       17 SUBSURFACE boundary segments

     Segment   x-left    y-left    x-right   y-right     Soil Unit
       No.      (ft)      (ft)      (ft)      (ft)     Below Segment

        1      162.0     839.4     650.0     961.5           2
        2      650.0     961.5     710.0     948.5           2
        3      164.5     839.6     650.0     961.0           5
        4      650.0     961.0     710.0     948.0           5
        5      164.5     839.6     260.0     811.0           2
        6      260.0     811.0     315.0     811.0           2
        7      315.0     811.0     745.0     833.0           2
        8      154.0     840.0     160.0     840.0           3
        9      160.0     840.0     260.0     810.0           3
       10      260.0     810.0     315.0     810.0           3
```

√ JOH
8/97

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    11      315.0     810.0      745.0     832.0           3
    12      154.0     840.0      260.0     808.0           1
    13      260.0     808.0      315.0     808.0           1
    14      315.0     808.0      745.0     830.0           1
    15         .0     775.0      300.0     775.0           4
    16      300.0     775.0      550.0     770.0           4
    17      550.0     770.0      745.0     808.0           4


  -------------------------
  ISOTROPIC Soil Parameters
  -------------------------

   5 Soil unit(s) specified

  Soil   Unit Weight   Cohesion  Friction    Pore Pressure       Water
  Unit  Moist    Sat.  Intercept   Angle  Parameter  Constant  Surface
   No.  (pcf)   (pcf)    (psf)     (deg)      Ru       (psf)      No.

    1   120.0   120.0    200.0     20.00     .000         .0       1     Natural Soil
    2   110.0   110.0       .0     30.00     .000         .0       1     Sand
    3   125.0   125.0    400.0     25.00     .000         .0       1     Clay Soil
    4   145.0   145.0  10000.0     45.00     .000         .0       1     Bedrock
    5    80.0    80.0    130.0     20.00     .000         .0       1     Ash


   1 Water surface(s) have been specified

 Unit weight of water =    62.40  (pcf)

 Water Surface No.  1 specified by  3 coordinate points

 **********************************
         PHREATIC SURFACE,
 **********************************

   Point      x-water     y-water
    No.        (ft)        (ft)

     1          .00      775.00
     2       300.00      775.00
     3       745.00      797.00


 A critical failure surface searching method, using a random
 technique for generating CIRCULAR surfaces has been specified.


  400 trial surfaces will be generated and analyzed.


   20 Surfaces initiate from each of  20 points equally spaced
 along the ground surface between  x =    100.0 ft
                              and  x =    200.0 ft


 Each surface terminates between   x =    550.0 ft
```

```
                        and   x =    650.0 ft


Unless further limitations were imposed, the minimum elevation
at which a surface extends is  y =       .0 ft


   15.0 ft line segments define each trial failure surface.



---------------------
ANGULAR RESTRICTIONS
---------------------

  The first segment of each failure surface will be inclined
  within the angular range defined by :

          Lower angular limit :=   -45.0 degrees
          Upper angular limit :=  (slope angle - 5.0) degrees




Factors of safety have been calculated by the :

* * * * *   SIMPLIFIED BISHOP METHOD   * * * * *



  The most critical circular failure surface
  is specified by 36 coordinate points

        Point       x-surf       y-surf
         No.         (ft)         (ft)

          1         163.16       844.58
          2         178.01       842.44
          3         192.90       840.65
          4         207.83       839.20
          5         222.79       838.10
          6         237.77       837.34
          7         252.76       836.93
          8         267.76       836.86
          9         282.76       837.14
         10         297.75       837.77
         11         312.72       838.74
         12         327.66       840.06
         13         342.57       841.72
         14         357.43       843.72
         15         372.25       846.06
         16         387.00       848.75
         17         401.70       851.78
         18         416.31       855.14
         19         430.85       858.84
         20         445.30       862.87
         21         459.65       867.24
         22         473.89       871.94
         23         488.03       876.96
```

```
           24        502.04      882.31
           25        515.93      887.98
           26        529.68      893.97
           27        543.29      900.27
           28        556.75      906.89
           29        570.06      913.81
           30        583.20      921.04
           31        596.17      928.57
           32        608.97      936.40
           33        621.58      944.52
           34        634.00      952.93
           35        646.23      961.63
           36        649.10      963.77


  ****  Simplified BISHOP FOS =   1.766  ****




  The following is a summary of the TEN most critical surfaces

  Problem Description : DPC Final Cover Slope

         FOS      Circle Center     Radius   Initial  Terminal  Resisting
       (BISHOP)  x-coord  y-coord            x-coord  x-coord    Moment
                   (ft)     (ft)      (ft)     (ft)     (ft)     (ft-lb)

   1.    1.766   263.14  1487.27    650.42   163.16   649.10  3.560E+08
   2.    1.772   245.10  1579.89    735.11   184.21   644.14  3.177E+08
   3.    1.781   291.69  1377.57    538.73   189.47   631.14  2.805E+08
   4.    1.782   277.11  1389.77    560.64   157.89   638.35  3.532E+08
   5.    1.786   228.21  1584.42    749.38   142.11   647.53  4.003E+08
   6.    1.786   201.38  1697.08    856.23   157.89   639.17  3.588E+08
   7.    1.790   222.48  1597.73    761.99   142.11   642.84  3.896E+08
   8.    1.790   219.39  1665.49    818.94   184.21   636.06  3.063E+08
   9.    1.791   244.31  1492.11    659.28   147.37   633.16  3.638E+08
  10.    1.791   233.61  1533.39    689.57   178.95   605.85  2.576E+08

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Appendix G: Construction Quality Assurance Plan

744 Heartland Trail (53717-1934)
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Madison, WI
Telephone (608) 831-4444
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CQA Plan

July 2003
Revised February 2007

Table of Contents

List of Tables

Section 1
Introduction

1.1 Project Background

This report presents the Construction Quality Assurance (CQA) Plan for the Dairyland Power Cooperative (DPC) Phase IV Ash Disposal Facility. The landfill consists of approximately 32.1 acres and is owned by DPC. This site is located in the NE ¼ of the NE ¼ of Section 19 and portions of Sections 18 and 20, T21N, R12W Town of Belvidere, Buffalo County, Wisconsin.

This CQA Plan has been prepared for, and is included in, the submittal of the Plan of Operation for the DPC Phase IV Ash Disposal Facility. This CQA Plan is intended to be a "working" document, in other words, one that is updated to reflect changes in specific materials, in installation practices, industry standards, or in tests and test methods.

1.2 Purpose and Scope

The purpose of this CQA Plan is to address the quality assurance procedures and requirements for the construction at the proposed DPC Phase IV Ash Disposal Facility, including all earthen materials (low-permeability layer, general soil, granular soil, and topsoil) and synthetic materials (geomembrane, geotextile, geosynthetic clay liner, and piping).

This CQA Plan provides procedures that will ensure that all of the landfill components are constructed in a manner that will maximize their performance and that will safeguard components from damage during construction. The plan procedures will also ensure that the landfill (composite liner and cover) is constructed, tested, and documented in accordance with the design criteria and regulatory requirements.

The scope of this report includes general CQA requirements in regard to the roles, responsibilities, and qualifications of parties involved; the preconstruction activities; and the general inspection and documentation procedures. Specifically, this plan establishes requirements for construction procedures and observation, field and laboratory testing frequencies and methods, and acceptance criteria for each component of the composite liner and cover. Testing and acceptance criteria are based on Chapter NR 500, Wisconsin Administrative Code (WAC), requirements where applicable. Geomembrane testing and acceptance criteria are based on representative manufacturer's product data, and on current acceptable industry standards and practice.

The CQA Plan addresses the construction of the following systems within the landfill facility**:**

- Low-permeability layer
- General soil
- Granular soil
- Topsoil
- Geomembrane
- Geotextile
- Geosynthetic clay liner
- Piping

1.3 Quality Assurance and Quality Control

Quality assurance and quality control are defined as follows:

- Quality assurance - A planned and systematic pattern of all means and actions designed to provide adequate confidence that materials or services meet contractual and regulatory requirements. This is typically performed to ensure the purchaser, owner, and/or regulatory agencies that delivered materials or services are of desired quality.
- Quality control - Those actions that provide a means to measure and regulate the characteristics of a material or service to meet contractual and regulatory requirements. This typically is performed by, or for, the provider of materials or services as a control mechanism on the quality of the provider's efforts.

In the context of this manual, the terms are further defined as follows:

- Quality assurance refers to the means and actions employed by the CQA Officer to ensure conformity of the systems' installation with the CQA Plan and the construction plans and specifications. Quality assurance is primarily provided by an independent third party (consultant or laboratory) under the oversight of the CQA Officer.
- Quality control refers to those actions taken by the Manufacturer, Fabricator, or Contractor/Installer to provide materials and workmanship that meet the requirements of the CQA Plan and the construction plans and specifications. Some testing efforts required by this CQA Plan may serve as both quality control and quality assurance measures.

1.4 General Testing Requirements

This CQA Plan includes references to test procedures of the American Society for Testing and Materials (ASTM) and the Geosynthetics Research Institute (GRI). Test procedure references are always to the latest approved version up to the date of this document, unless specifically stated otherwise in this document.

Tests will be performed in strict accordance with the referenced test procedure and the description included in this plan, unless indicated otherwise. Any deviations to test procedures called out in this plan must be approved, in writing, by the CQA Officer prior to commencement of any work.

Section 2
CQA Roles, Responsibilities, and Qualifications

2.1 CQA Officer

The CQA Officer will supervise and be responsible for all observation, testing, and related construction documentation as described in this CQA Plan. The CQA Officer will be responsible for preparing the construction documentation report to certify substantial compliance with appropriate sections of Chapter NR 500. The CQA Officer will be a Professional Engineer registered in the State of Wisconsin.

The CQA Officer may delegate daily observation and documentation, testing, and sampling duties to a qualified technician or engineer with experience in the assigned aspect of construction who will serve as the Resident Project Representative (RPR). Although these duties may be delegated, the CQA Officer will retain the responsibility for these activities.

2.2 Resident Project Representative (RPR)

The RPR will carry out daily observation, testing, and sampling duties under the direct supervision of the CQA Officer as required by NR 516.04. The RPR will be a qualified technician or engineer with experience in the assigned aspect of construction. The RPR will observe and document construction and installation procedures. The RPR will prepare daily summary reports and will routinely transmit these to the CQA Officer. The RPR will immediately notify the CQA Officer of problems or deviations from the CQA Plan or construction plans and specifications. Reporting, documentation, and resolution of problems and deficiencies will be carried out as described in Section 4. The RPR will not have authority to approve design or specification changes without the consent of the CQA Officer.

2.3 Soil Testing Laboratory

The Soil Testing Laboratory retained will be experienced in landfill construction soil testing, the American Society of Testing and Materials Standards (ASTM), and other applicable standards. The selected laboratory will be required to be responsive to the project needs by providing test results within reasonable time frames. This will include providing verbal communication on the status of ongoing tests and immediate communication of test results as needed to facilitate ongoing construction. Such information may include hydraulic conductivity test data, maximum dry density and optimum moisture content values, and borrow source characterization data. Final laboratory reports will be certified by the soil testing laboratory and submitted to the CQA Officer.

2.4 Geosynthetics Testing Laboratory/Laboratories

The Geosynthetics Testing Laboratory/Laboratories will have experience in testing geosynthetics in accordance with standards developed by ASTM, Geosynthetics Research Institute (GRI), and other applicable test standards. The selected laboratory/laboratories will be required to be responsive to the project needs by providing test results within reasonable time frames. Final laboratory reports will be certified by the geosynthetics testing laboratory/laboratories and will be submitted to the CQA Officer.

2.5 Construction Contractor

The Construction Contractor's role will be to furnish earthwork, construction, and piping installation, and to provide overall construction responsibility for the completion of the landfill facility. The Construction Contractor will be experienced in solid waste landfill construction, knowledgeable about low-permeability soil liner construction techniques, and familiar with geosynthetic installations. The term "Contractor" is used interchangeably with "Construction Contractor" in this plan.

2.6 Geosynthetics Installers

The Geosynthetics Installer is the company hired by the Construction Contractor or owner to install the geosynthetic components referenced in this manual and to perform the nondestructive seam testing of the geomembrane as required by this plan. The term "Installer" is used throughout this plan when reference is made to the tasks and responsibilities of a Geosynthetics Installer.

The Installer will be trained and qualified to install the various geosynthetic components covered by this plan. The Installer of the geomembranes will be approved and/or licensed by the Manufacturer.

Prior to confirmation of any contractual agreements, the Installer of the geomembrane and geosynthetic clay liner (GCL) will provide the CQA Officer with the following written information, which must be approved by the CQA Officer:

- Corporate background information.
- Installation capabilities.
  - Information on equipment and personnel
  - Quality control manual for installation
- A list of at least 10 completed facilities, totaling a minimum of 2,000,000 square feet for which the Installer has completed the installation of polyethylene geomembrane. For each installation, the following information will be provided:

  - Name and purpose of facility, its location, and date of installation
  - Name of owner, project manager, designer, manufacturer, and fabricator (if any)
  - Thickness and type of polyethylene geomembrane and the surface area of the installed geomembrane
- A list of at least 10 completed facilities, totaling a minimum of 1,000,000 square feet for which the Installer has completed the installation of GCL. For each installation, the following information will be provided:
  - Name and purpose of facility, its location, and date of installation
  - Name of owner, project manager, designer, manufacturer, and fabricator (if any)
  - Type of GCL and the surface area of the installed GCL

All personnel performing geomembrane seaming operations will be qualified by experience or by successfully passing seaming tests for the seaming methods to be used. At least one seamer will have experience seaming a minimum of 2,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus in use at the site. The most experienced seamer, the "master seamer," will provide direct supervision, as required, over less experienced seamers. No field seaming will take place without an experienced seamer (meeting the seaming criteria stated above) being present.

The Installer will provide the CQA Officer with a list of proposed seaming and testing personnel, and their professional records, prior to installation of the geosynthetics. This document will be reviewed by the CQA Officer. Any proposed seaming personnel deemed insufficiently experienced will not be accepted by the CQA Officer or will be asked to pass a seaming test.

The Installer will designate one representative as the Superintendent, who will represent the Installer at all site meetings and who will be responsible for acting as the Installer's spokesperson on-site. This Superintendent will be prequalified for this role, on the basis of experience, management ability, and authority.

Section 3
Preconstruction Activities

3.1 Preconstruction Meeting

Prior to commencement of each phase (i.e., cell or module) of construction at the landfill facility, a preconstruction meeting will be held. This meeting will include the parties involved in the construction, including the CQA Officer or designated representative, the RPR, the Construction Contractor, the Installer, and the Owner. If the Installer does not attend the preconstruction meeting, a second meeting, the preinstallation meeting, will be conducted with the Installer.

The purpose of this meeting is to begin the planning and coordination of construction tasks; to identify potential problems that might cause difficulties and delays in construction; to properly interpret the design intent by the Contractor(s); and to present the CQA Plan to all of the parties involved. It is important that the rules regarding testing, repairs, etc., be known and accepted by each party to this plan.

Specific topics considered for this meeting include the following, but will be dependant on the presence of the Installer:

- Review critical design details of the project, including the plans and specifications.
- Review measures for surface water runoff and runon diversion control, including sump locations, siltation control, and pumping requirements.
- Make appropriate modifications to the CQA Plan; develop project-specific addendums (if necessary).
- Review the responsibilities of each party.
- Review lines of authority and communication.
- Review methods for documenting and reporting and for distributing documents and reports.
- Review requirements of the soil testing laboratory and the geosynthetics testing laboratory regarding sample sizes, methods of collection, and shipment. Also, review turn times for sample data and their implications on the construction schedule, pending receipt of acceptance data.
- Review the number and locations of the tests required for soil and geosynthetic components.

- Review precautions to be taken to maximize bonding between lifts of compacted soil.
- Review the method for splicing segments of the compacted soil liner and cover.
- Review precautions to be taken to minimize desiccation cracking of the subbase layer surfaces.
- Review methods of subbase layer surface preparation and approval prior to GCL placement.
- Establish rules for writing on the geomembrane (*i.e.*, who is authorized to write, what can be written, and in which color); and outline procedures for packaging and storing archive samples.
- Review GCL and geomembrane panel and seam layout diagrams and numbering systems.
- Establish procedures for use of the geomembrane welding apparatus.
- Establish appropriate intervals for geomembrane seamers to record operating and ambient data.
- Finalize geomembrane field cutout sample sizes.
- Review geosynthetic repair procedures.
- Review the time schedule for all operations.
- Establish procedures for deployment of materials over completed GCL and geomembranes emphasizing protection of both layers. Specific discussion will address the deployment of textured geomembrane over the GCL and the deployment of select granular fill on the sidewalls.
- Observe where the site survey benchmarks are located, and review methods for maintaining vertical and horizontal control.
- Review permit documentation requirements.
- Review the survey documentation tables and plans that identify the locations where survey documentation information is required.
- Conduct a site walk-around to review material storage locations and general conditions relative to construction.
- Set up a time and place for regular construction progress meetings.

The meeting will be documented by the RPR or CQA Officer, and minutes will be distributed to all parties involved in the construction project.

3.2 Preconstruction Submittal

Prior to installation of the geosynthetics in each landfill area, a preconstruction submittal will be prepared and submitted to the WDNR a minimum of 15 days prior to the preconstruction meeting or the preinstallation meeting, whichever is applicable, depending on the Installers attendance at the preconstruction meeting. The preconstruction submittal will include the following information required under s. NR 516.04(5).

- Identification of the fabricators and installers selected for geomembrane and other geosynthetics
- Final version of the construction quality assurance plan, incorporating input, if any, from the selected installers, and documenting qualifications of the third-party construction quality assurance organization and testing laboratories
- Any modifications to the installation plan, with the final proposed version of the panel layout diagrams and any revisions to details of seaming, patching, penetrations, use of prefabricated specialty sections, or repair methods

3.3 Preinstallation Meeting

Prior to commencement of the geomembrane installation, a preinstallation meeting will be held if the Installer is not present at the preconstruction meeting. This meeting will include the parties involved in the installation of the geosynthetics, including the RPR, the Construction Contractor, and the Installer.

The purpose of this meeting is to begin the planning and coordination of installation tasks; to identify potential problems that might cause difficulties and delays during the installation; and to present the CQA Plan to all of the parties involved. It is important that the rules regarding testing, repairs, etc., be known and accepted by each party to this plan.

Specific topics considered for this meeting include the following:

- Review critical design details of the project, including the plans and specifications.
- Make appropriate modifications to the CQA Plan; develop project-specific addendums (if necessary).
- Review the responsibilities of each party.
- Review lines of authority and communication.
- Review methods for documenting and reporting and for distributing documents and reports.
- Establish rules for writing on the geomembrane (*i.e.*, who is authorized to write, what can be written, and in which color); and outline procedures for packaging and storing archive samples.

- Review GCL and geomembrane panel and seam layout diagrams and numbering systems.
- Establish procedures for use of the geomembrane welding apparatus.
- Establish appropriate intervals for geomembrane seamers to record operating and ambient data.
- Finalize geomembrane field cutout sample sizes.
- Review geosynthetic repair procedures.
- Review the time schedule for all operations.
- Establish procedures for deployment of materials over completed GCL and geomembranes emphasizing protection of both layers. Specific discussion will address the deployment of textured geomembrane over the GCL and the deployment of select granular fill on the sideslopes.
- Review permit documentation requirements.

The meeting will be documented by the RPR or CQA Officer, and minutes will be distributed to all parties involved in the construction project.

Section 4
General Construction Observation and Documentation

This section describes progress meetings, general documentation procedures to be implemented, including the use of forms, the identification and resolution of problems or deficiencies, and photographic documentation.

4.1 Progress Meetings

Progress meetings will be held regularly at the work area. At a minimum, the meeting will be attended by field supervisory and CQA personnel. The purposes of the meeting are as follows:

- Review health and safety issues.
- Review the work activity since the last progress meeting.
- Discuss the Contractor's and Installer's personnel and equipment assignments.
- Review the work schedule.
- Discuss possible problems.
- Review any new test data.
- Review data documentation requirements.

The meetings will be documented by a person designated at the beginning of the meeting, and minutes will be transmitted to all parties.

4.2 Daily Reports

A daily summary report will be prepared by the CQA Officer, or the RPR under direct supervision of the CQA Officer, for each day of activity and will include the following information:

- Date, project name, location, report preparer's name, and the names of representatives on-site performing CQA under the supervision of the CQA Officer
- Time work starts and ends each construction work day, along with the duration and reason for work stoppages (*i.e.*, weather delay, equipment shortage, labor shortage, unanticipated conditions encountered, etc.)
- Data on weather conditions, including temperature, humidity, wind speed and direction, cloud cover, and precipitation

- Construction contractor's work force, equipment in use, and materials delivered to, or removed from, the job site
- Chronological description of work in progress, including locations and type of work performed
- Summary of meetings held and a list of those in attendance
- A description of materials used and references or results of testing and documentation
- Discussion of problems/deficiencies identified and corrective actions taken as described in Subsection 4.4. (Problem/Deficiency Identification and Corrective Action)
- Identification/List of laboratory samples collected, marked, and delivered to laboratories, or clear reference to the document containing such information
- An accurate record of calibrations, recalibrations, or standardizations performed on field testing equipment, including actions taken as a result of recalibrations, plus the results of other data recording, such as geomembrane seam barrel temperature.

Field data sheets containing the following information, as necessary, will be prepared daily by each representative:

- Test or sample location and elevation
- Type of documentation (e.g., field moisture/density test, etc.)
- Procedures used
- Test data (e.g., proctor value, etc.)
- Results
- Personnel involved in the documentation and sampling activities
- Signature of the person performing the documentation

4.3 Forms, Checklists, and Data Sheets

Additional forms may be developed during the course of the project to provide specific needs, such as geomembrane or GCL CQA documentation, or simply to improve the efficiency of data collection. New forms will be approved by the CQA Officer prior to their use.

4.4 Problem/Deficiency Identification and Corrective Action

Problem and/or deficiency identification and corrective action will be documented in the daily report when a construction material or activity is observed or tested that does not meet the requirements set forth in this plan. The daily report should clearly reference other reports, photographs, or forms that contain data or observations leading to the determination of a problem or deficiency. Problem and/or deficiency identification and corrective action documentation may include the following information:

- A description of the problem or deficiency, including reference to supplemental data or observations responsible for determining the problem or deficiency.
- The location of the problem or deficiency, including how and when the problem or deficiency was discovered, and an estimate of how long the problem or deficiency has existed.
- An opinion as to the probable cause of the problem or deficiency.
- A recommended corrective action for resolving the problem or deficiency. If the corrective action has already been implemented, then the observations and documentation to show that the problem or deficiency has been resolved should be included. If the problem or deficiency has not been resolved by the end of the day upon which it was discovered, then the report will clearly state that it is an unresolved problem or deficiency. Subsequent daily reports will indicate the status of problems or deficiencies until they are resolved.

If the problem or deficiency has not been resolved, then the CQA Officer and the RPR will discuss the necessary corrective actions. The CQA Officer will work with the Owner and Construction Contractor to implement actions as necessary to resolve the problem or deficiency. A description of such problems or deficiencies and corrective actions implemented will be provided in the Construction Documentation Report.

The CQA Officer, working with the Owner and Construction Contractor, will determine if the problem or deficiency is an indication of a situation that might require changes to the plans and specifications and/or the CQA Plan. Revisions to the plans or specifications or the CQA Plan must be approved by the CQA Officer and the site Owner after consultation with the WDNR. Documentation of the WDNR's concurrence and/or conditions regarding proposed changes will be incorporated into the Construction Documentation Report.

4.5 Photographic Documentation

Photographs will be taken to document observations, problems, deficiencies, corrective actions, and work in progress. Photographs will be in 35-mm slide or print format or digital and will be filed in chronological order in a permanent protective file by the CQA Officer or the RPR.

The following information will be documented in the daily report or a log book for each photograph:

- Date and time
- Information regarding the orientation of the photograph itself for proper viewing (e.g., looking south)

- Description of the subject matter
- Unique identifying number for reference in reports

4.6 Surveying

Documentation surveying requirements for each composite liner or cover component are described in their respective report sections. Required surveying will be performed by personnel experienced in construction surveying under the supervision of the CQA Officer. Surveys will be based on survey control points previously established at the site. Elevations will be based on mean sea level (M.S.L.) datum, and coordinates will be based on the Wisconsin State Plane Coordinate System. The location of field tests and samples will be recorded. Generally, these locations can be determined by reference to nearby construction stakes or markings; however, if such convenient reference is not readily available, the CQA Officer or the designated RPR will be responsible to provide or request survey control.

Section 5
Low-Permeability Layer

5.1 General

This section includes the quality assurance requirements for placement, backfilling, and compaction of the compacted select 2-foot low-permeability subbase soil layer (low-permeability layer) as part of the landfill liner. The low-permeability layer material will be obtained from on-site excavations of loess material. All field tests, soil sample types, and survey measurements will be recorded in the daily construction reports (see Subsection 4.2) as record construction data, including locations (by coordinates) and elevations of field tests and laboratory sample points.

5.2 Procedures and Observation

The RPR will observe the low-permeability layer construction activities and will document relevant observations to support certification of the following requirements:

- The RPR will confirm the uniformity of the excavated soil to be used as the low-permeability layer. Soil placement will be monitored for segregation and removal of unsuitable material and for changes in soil type, color, texture, and moisture content.
- The Construction Contractor will segregate and/or remove unsuitable materials, such as granular soil, silty or sandy clay not meeting acceptance criteria, boulders, cobbles, and organic material. Due to the thin and laterally discontinuous nature of the loess material, special care will be taken during the excavation of the low-permeability layer. As determined necessary during construction, the cleanest loess deposits will be segregated for use in the final lift (below the GCL). In addition, a provision for screening will be included in the technical specifications to allow processing of the loess material if the material specifications cannot be otherwise achieved.
- The RPR will observe the placement of the low-permeability layer and will measure field densities and moisture contents, using methods described in Subsection 5.3 (Sampling Requirements and Acceptance Criteria), to document that the soil is in substantial conformance with the placement specifications and that soil placement has been conducted in a manner to achieve a uniform, homogeneous mass.
- Voids created by nuclear density gauge (NDG) probes or as the result of Shelby tube samples will be backfilled with granular bentonite.
- Areas of unacceptable density or moisture content, as defined by Subsection 5.3 (Sampling Requirements and Acceptance Criteria), will be documented by the RPR. Corrective action will consist of moisture-conditioning of the soil and/or additional compactive effort as

necessary. Methods for moisture-conditioning soil are described below. Following corrective actions, such areas will be retested.

- If necessary, surfaces of liner to receive successive lifts of low-permeable soil will be moisture-conditioned either by scarification and addition of water where desiccated, or by discing and air drying where saturated to promote effective bonding of lifts. Following scarification, water will be applied with a spray bar applicator or equivalent method to achieve uniform distribution.
- Soil placement will be performed in a manner to achieve continuous and complete keying together of low-permeable layer construction areas. Stepped joints will be utilized to connect lateral segments of low-permeable soil layer construction.
- No frozen soil will be used to construct the low-permeability layer. Frozen soil in the compaction work area will be removed.
- Stones and other penetrating objects 1 inch or larger protruding from the surface of the final lift of low-permeability layer will be removed to avoid puncturing the GCL and/or geomembrane. The RPR will observe the liner during this process and will document the removal of stones and other objects by the Contractor. Voids made by the removal of stones will be filled with low-permeable soil or bentonite, and the entire liner surface will be rolled with a smooth-drum compactor.
- Preconstruction planning will be undertaken to sequence construction activities to minimize the length of time any portion of the low-permeability layer surface will be exposed prior to receiving protective cover. Protective cover will be provided by the installation of the GCL and the geomembrane.

5.3 Sampling Requirements and Acceptance Criteria

Field and laboratory sampling frequencies are based on the area or volume of material placed. This section describes the required analyses, methods, sample frequencies, and acceptance limits. The RPR will perform field tests and will collect soil samples for laboratory analysis.

5.3.1 Field Testing

The following field testing methods will be used by the RPR during construction:

PARAMETER	METHOD
Moisture content	ASTM D3017
Soil density	ASTM D2922 Method B

Field density and moisture content tests will be performed on a 100-foot grid pattern for each 1-foot thickness of compacted low-permeable soil placed. The testing pattern will be offset on alternate lifts. In confined areas where compaction equipment is hindered or hand compaction is necessary, a minimum of two field density and moisture content tests will be performed for each 1-foot thickness of low-permeable soil placed.

Field Testing Acceptance Criteria

Acceptance criteria for field density will require soil compaction to a minimum of 90 percent of the Modified Proctor (ASTM D1557) maximum dry density. Moisture content requirements will be at least wet of optimum. The acceptable range will be based on Proctor moisture-density relationships and compaction versus permeability relationships.

5.3.2 Laboratory Testing

Routine laboratory testing of the low-permeability layer will be performed on samples from the soil borrow area and on the in-place soil samples collected by the RPR. Samples for determining in-place properties will be collected by pushing Shelby tubes. Soil characteristics will be determined from representative samples and from Shelby tube samples.

Undisturbed Sample Analysis

One undisturbed sample will be taken for each acre or less for every 1-foot thickness of soil placed and will be submitted to the Soil Testing Laboratory.

The following analyses will be performed on all undisturbed samples obtained:

PARAMETER	TEST METHOD
Moisture content and dry density	ASTM D2216

Representative Sample Analysis

Representative (grab) samples will be obtained on the basis of three criteria. First, an initial sample will be obtained from the borrow source and analyzed prior to construction. This will confirm soil characteristics and provide an initial maximum dry density and optimum moisture content for field moisture/density testing. Second, routine samples will be obtained for every 5,000 cubic yards placed. Third, in the event that changes in physical appearance or soil characteristics are observed, a sample will be obtained and analyzed. The maximum dry density and optimum moisture content values used for compaction testing may be adjusted during the course of liner construction based on the results of the above sampling.

The following laboratory analyses will be performed on all representative samples obtained:

PARAMETER	TEST METHOD
Moisture-density relationship using Modified/Standard Proctor compaction	ASTM D1557 (a, b)/ ASTM D698 (a, b)

Notes:

(a) Five-point Proctor analysis required for first and second sampling criteria.

(b) A one-point Proctor analysis may be utilized for representative samples collected for the third sampling criteria (apparent changes in soil quality) to verify applicability of previously analyzed moisture-density relationships. If the result does not verify applicability, then a five-point analysis will be performed in accordance with the first sampling criteria.

5.4 Thickness Documentation

The top of the low-permeability layer grades will be surveyed on the same 50-foot grid pattern and key locations surveyed for the subbase grades. Key locations include breaks in grade, toes of slopes, mid-points, and tops of sideslopes. In the alignment for leachate collection lines, bottom of trench elevations will be surveyed at 25-foot intervals (or 50-foot intervals if a total station or laser equipment is used to set elevations) in the same locations surveyed for trench undercuts. The low-permeability layer thickness will be determined at surveyed locations and reported in a tabular fashion. The minimum acceptable liner thickness will be 2 feet (-0.0/+0.1 foot).

Section 6
General Soil

6.1 General

This section includes the quality assurance requirements for placement, compaction, and grading of general soil (i.e., general fill). General soil may be any inorganic soil. General soil will be used in the construction of the following landfill components:

- Final cover
- Access roads
- Berms

All field tests, soil sample types, and survey measurements will be recorded in the daily summary reports (see Subsection 4.2) as record construction data, including locations (by coordinates) and elevations of all field tests and laboratory sample points.

6.2 Procedures and Observation

The RPR will observe general soil placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will periodically observe loads of general fill for general conformance to material specifications and may randomly sample loads. The RPR will perform routine conformance sampling as defined in Subsection 6.3.2.
- General soil used as the grading layer will have no stones or other penetrating objects 1 inch or larger protruding from the surface of the final lift. The RPR will observe the grading layer during placement and will document the removal of stones and other objects by the contractor. Voids made by the removal of items will be filled with general fill or bentonite, and the entire layer will be rolled with a smooth-drum compactor.
- No frozen soil will be used for backfilling. Any frozen soil in the compaction work area will be removed.
- Loose lift thickness for general soil compaction will not exceed 18 inches.
- General soil used as structural fill (e.g., access roads and berms) will be placed with a compacted effort to achieve a minimum of 90 percent or 95 percent of the maximum dry density as determined by the modified or standard Proctor test, respectively.

- Unacceptable compaction density, as defined above, will be reported to the CQA Officer by the RPR. Corrective action will consist of moisture-conditioning of the soil and/or additional compactive effort as necessary.

Field densities using methods described in Subsection 6.3.1 will be measured to document that the in-place soil is in substantial conformance with the required density.

6.3 Sampling Requirements and Acceptance Criteria

No field or laboratory testing of general soil will be required.

Routine laboratory testing of the general soil will be performed on samples from the general soil borrow area or stockpile for general soil used as structural fill. The following laboratory test method will be performed by the Soil Testing Laboratory on samples collected by the RPR:

PARAMETER	TEST METHOD
Moisture/Density using Modified or Standard Proctor compaction	ASTM D1557 or ASTM D698

Samples of the borrow area or stockpiled soil will be collected by the RPR prior to the use of the material and whenever physical appearance or other changes are noticeable. These samples will be submitted to the Soil Testing Laboratory for the above testing.

6.4 Thickness Documentation

Base and top of subbase grades for the final cover grading layer will be documented on an approximate 100-foot grid for cells larger than 4 acres and on an approximate 50-foot grid for cells smaller than 4 acres, and at other key locations, such as breaks in grade, toes of slope, mid-points, and tops of slopes. In the alignment for leachate collection undercuts, the bottom of trench undercut elevations will be surveyed at 25-foot intervals. The minimal acceptable thickness will be 6 inches. The allowable tolerance in elevation will be ±0.1 foot.

Top of final cover rooting zone grades will be surveyed on an approximate 100-foot grid for cells larger than 4 acres and on an approximate 50-foot grid for cells smaller than 4 acres, and at other key locations, such as breaks in grade and toes of slopes. The minimum acceptable thickness will be 1.0 foot. The allowable tolerance in elevation will be ±0.1 foot

In addition to survey measurements for elevation, measurements for horizontal location will also be performed using previously established horizontal control to document the boundaries and alignment of the general soil placement.

Section 7
Granular Soil

7.1 General

Granular soil includes select granular fill and pipe bedding material. Select granular fill refers to material used for the granular drainage layer overlying the geomembrane liner and for the granular drainage layer in the final cover. The pipe bedding material refers to the gravel to be used for structural support of the leachate collection pipes. Limestone and dolomite stone will not be used in the leachate collection system unless no other suitable material is reasonably available. The gravel should be rounded to subangular.

7.2 Procedures and Observation

The RPR will observe granular soil placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will periodically observe loads of granular soil for general conformance to material specifications and may randomly sample loads. The RPR will perform routine conformance sampling as defined in Subsection 7.3.
- Guidance will be provided to the machine operators placing soil on the geomembrane by the use of an observer with an unobstructed view of the advancing lift of granular soil.
- No trucks or heavy equipment will travel directly on the geomembrane. Only low-ground pressure tracked equipment (< 5 psi) may operate over the geomembrane when there is a minimum 12-inch–thick layer of select granular fill in-place. Flotation tire-equipped vehicles and tracked vehicles may not travel over the geomembrane unless a minimum of 2 feet of select granular fill are in place. Traditional rubber-tired equipment may not travel over the geomembrane unless a minimum of 3 feet of select granular fill are in place. Procedures for deployment of pipe, sand, gravel, and/or geotextiles overlying geomembranes will be planned at the preconstruction meeting. Special requirements for geomembrane protection and equipment necessary to deploy materials must be approved by the CQA Officer.
- Care will be exercised during placement of granular soil to prevent undue damage to pipes, geomembrane, and geotextiles. Stone will not be dropped from a height greater than 3 feet above the pipe trench.
- A geotextile cushion will be placed between the geomembrane and the pipe bedding material placed in the leachate collection trenches.

- A minimum of 4 inches of pipe bedding material will be placed under leachate collection pipes prior to pipe placement, and a minimum of 12 inches of bedding material will be placed over the top of the leachate collection pipes.
- If granular soil is stockpiled on-site prior to use, measures will be taken to minimize contamination by fines such as wind-blown particles and surface soil during loading operations.

7.3 Sampling Requirements and Acceptance Criteria

Field sampling and laboratory testing frequencies are based on proportionate sampling of construction areas or volumes of material placed as specified by s. NR 516.06. This section describes the required analyses, methods, sampling frequencies, and acceptance limits. The RPR will collect soil samples for laboratory analysis.

7.3.1 Field Testing

No field testing will be required for select granular fill or pipe bedding material soil. However, as stated in Subsection 7.2 above, the RPR will perform a visual inspection of this soil for conformance to material specifications and may randomly sample deliveries.

7.3.2 Laboratory Testing

Representative (grab) samples will be obtained from the proposed select granular fill and pipe bedding material sources prior to delivery of the material. The source sampling frequency will be dependent on the apparent uniformity of the source and must be approved by the CQA Officer.

Grab samples of granular material placed will be collected and analyzed as follows:

SOIL TYPE	FREQUENCY	PARAMETER	TEST METHOD
Select granular fill	1/1,000 CY (a, b)	Grain size	ASTM D422(c)
Select granular fill	1/2,500 CY (b, d)	Remolded hydraulic conductivity	ASTM D2434
Pipe bedding material	1/1,000 LF of trench (e)	Grain size	ASTM D422(c)
Pipe bedding material (solid-wall leachate or transfer pipes)	1/1,000 LF of trench	Grain size	ASTM D422(f)

Notes:
(a) For lesser volumes, a minimum of four samples will be tested.
(b) This frequency may be reduced for uniform sources. Proposed reductions will be submitted for WDNR approval prior to implementation.
(c) Testing is required only to the #200 sieve.
(d) For lesser volumes, a minimum of two samples will be tested.
(e) For documentation areas with less than 3,000 feet of pipe trench, a minimum of three samples will be tested.
(f) Testing is required only to the #4 sieve.

Laboratory Testing Acceptance Criteria

Select granular fill material will contain no more than 5 percent by weight of fines passing the #200 sieve, will have a uniformity coefficient less than 4 for gravelly soil and less than 6 for sandy soil, and will have a remolded hydraulic conductivity of 1 x 10^{-2} cm/s or greater at the anticipated field density. Select granular fill with material retained on the #4 sieve will require a geotextile cushion between the geomembrane and select granular fill (see Section 9). Pipe bedding material will have a uniformity coefficient less than 4, will contain no more than 5 percent by weight passing the #4 sieve, will have a maximum particle diameter of ½ inch, and will have a rounded to subangular particle shape.

7.4 Thickness Documentation

The finished elevation of the select granular fill drainage layer portion of the composite liner system will be surveyed on a 50-foot grid. The finished elevation of the select granular fill drainage layer portion of the final cover system will be surveyed on a 100-foot grid (50-foot grid for areas less than 4 acres). The minimum acceptable drainage layer thickness will be 12 inches (-0.0/+0.2 foot). Gravel placed along collection pipe alignments will be surveyed for elevation prior to pipe placement and following pipe backfilling at 25-foot intervals (50-foot intervals if a total station or laser equipment is used to set elevation) to document the thickness of gravel placed below pipe inverts and above the top of pipe.

Section 8
Topsoil

8.1 General

This section includes the quality assurance requirements for the excavation and placement of the topsoil and for the fertilization, seeding, mulching, and watering of the topsoil layer for vegetation. Topsoil is the final layer of soil material installed on the final cover, along the outside slopes of the perimeter berms, along the ditches, and on other perimeter areas. Topsoil will be obtained from on-site stockpiles created by the clearing of the landfill footprint and associated disturbed perimeter areas.

8.2 Procedures and Observation

Work covered by this section will be performed in accordance with the construction plans and specifications. The RPR will observe topsoil placement activities and will document relevant observations to support certification of the following requirements:

- The RPR will confirm the source and uniformity of topsoil used. Soil excavation and placement will be monitored for minimization of inorganic soil not compatible for establishment of vegetation.
- Prior to seeding, the topsoil will be worked to prepare a suitable seedbed.
- Fertilizing, seeding, and mulching will be performed in a timely manner.

8.3 Sampling Requirements and Acceptance Criteria

The topsoil will be suitable for the establishment and long-term maintenance of the selected vegetation seed mix with appropriate fertilization. At the RPR's discretion, or if required by the construction specifications, samples will be collected for laboratory testing.

8.4 Surveying

The thickness of topsoil placement will be documented on a 100-foot grid for cells larger than 4 acres and on a 50-foot grid for cells smaller than 4 acres by surveying or by hand shoveling and measuring the observed thickness of topsoil.

Section 9
Geomembrane

9.1 General

This section of the CQA Plan applies to the high-density polyethylene (HDPE) geomembrane used in the landfill composite liner and the very flexible polyethylene (VFPE) geomembrane, or equal, used in the composite final cover.

The geomembrane will be supplied to the site in factory rolls. No factory seams will be used to prepare larger panels of geomembrane for delivery to the site. This plan, therefore, does not contain any QA/QC requirements for factory seaming.

This section is divided into four major subheadings, which cover the CQA requirements for the preinstallation (includes Resin Manufacturers and Geomembrane Manufacturers), installation, field seaming, and post-installation (includes the final examination of the geomembrane prior to placing the appropriate material above the geomembrane). The terms preinstallation, installation, field seaming, and post-installation are applicable only to the geomembrane installation and do not apply to the overall construction of the landfill facility.

9.2 Preinstallation

This section describes the quality control measures that are applicable to the polyethylene (PE) Resin Manufacturers and Geomembrane Manufacturers, and to the delivery of the finished geomembrane roll to the site.

The geomembrane must be fabricated from polyethylene resin. The resin from which the geomembrane is made will have a density range of 0.940 g/cc or higher for HDPE and 0.939 g/cc or less for VFPE. In addition, the geomembrane will have a melt index value per ASTM D1238 of less than 1.0 g per 10 minutes for HDPE and 0.6 g per 10 minutes for VFPE. The resin shall be virgin material with no more than 10 percent rework. If rework is used, it must be of the same formulation as the parent material. No post-consumer resin (PCR) of any type shall be added to the formulation.

In the event that, during the course of construction, geomembrane materials are obtained from a different manufacturer or are made from different resins, seam samples formed by joining the original and the proposed geomembrane will be tested to confirm the construction compatibility of the two geomembrane materials. Prior to the use of the new geomembrane material, a minimum of two seamed samples (as described above) will be submitted to the geosynthetics laboratory for destructive seam testing as described in Subsection 9.4.5. The CQA Officer will review the testing results prior to authorizing the use of the new geomembrane material.

9.2.1 Manufacturing

Material Specifications

The following list specifies the required membrane materials for liner and final cover construction:

Base liner sideslopes (3H:1V typical)	60-mil HDPE-textured
Base liner	60-mil HDPE (textured optional)
Final cover top (5 percent slope)	40-mil VFPE (textured optional)
Final cover sideslopes (4H:1V typical)	40-mil VFPE (textured)

Quality Control Requirements

Prior to the delivery of any geomembrane rolls to the site, the Geomembrane Manufacturer will provide the CQA Officer with the following information:

- The Resin Supplier's name, the location of the Resin Supplier's production plant(s), and the resin brand name and product number
- Any results of tests conducted by the Geomembrane Manufacturer's and/or the Resin Manufacturer's testing laboratories to document the quality of the resin used in fabricating the geomembrane
- The Quality Control Plan that the Geomembrane Manufacturer will be using for the geomembrane being supplied

Every roll of geomembrane for delivery to the site must be manufactured and inspected by the Geomembrane Manufacturer according to the following requirements:

- First quality polyethylene resin must be used.
- The geomembrane must contain no more than a maximum of 1 percent by weight of additives, fillers, or extenders, excluding carbon black.
- Carbon black for ultraviolet protection shall be added during manufacturing of the geomembrane.
- The geomembrane must be free of holes, blisters, undispersed raw materials, or any other sign of contamination by foreign matter.

The Geomembrane Manufacturer will routinely perform specific gravity (ASTM D792) and melt index (ASTM D1238) tests on the raw resin to document the quality of the HDPE and VFPE resin used to manufacture the geomembrane rolls assigned to this project. The results will be submitted to the CQA Officer, prior to the acceptance of the geomembrane.

Manufacturer's Certification

The Geomembrane Manufacturer will test the geomembrane produced for the site according to the test methods and frequencies listed in Table 9-1. The Geomembrane Manufacturer will provide certification, based on tests performed by either the Geomembrane Manufacturer's laboratory or other outside laboratory contracted by the Geomembrane Manufacturer, that the geomembrane supplied under this plan will meet the specifications presented in Tables 9-2 and 9-3. Additionally, the Geomembrane Manufacturer will provide certification that the Manufacturer's Quality Control Plan was fully implemented for the geomembrane material supplied under this plan. The Geomembrane Manufacturer will provide documentation to verify results of the Manufacturer's Quality Control Plan implementation if requested by the CQA Officer.

9.2.2 Delivery, Handling, and Storage of Geomembrane Rolls

The geomembrane will be protected during shipment from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane rolls will be stored on-site in a designated area and will be protected from long-term ultraviolet exposure prior to actual installation.

Each geomembrane roll will be marked by the Geomembrane Manufacturer with the following information (on a durable gummed label, or equivalent, on the inside of core):

- Name of manufacturer
- Product type and identification number (if any)
- Roll length and width
- Batch (or lot) number
- Nominal product thickness
- Date of manufacture
- Roll (or field panel) number

Table 9-1
HDPE and VFPE Geomembrane Tests and Test Methods

PROPERTY	TEST METHOD	MINIMUM TESTING FREQUENCY (1)
Carbon black content	ASTM D4218	1/68,000 sf
Carbon black dispersion	ASTM D5596	1/154,000 sf
Density	ASTM D792 or D1505	1/100,000 sf
Melt flow index	ASTM D1238 with load of 2.16 kg at 190°C	1/100,000 sf
Tear resistance (2)	ASTM D1004	1/154,000 sf
Puncture resistance	ASTM D4833	1/154,000 sf
Tensile properties (2) Yield stress Yield elongation Break stress Break elongation	ASTM D638 HDPE - Type IV specimen at 2 inches/minute VFPE - Type IV specimen at 20 inches/minute	1/100,000 sf
Single-point notched constant load (SPNCL)	ASTM D5397	1/resin batch
Thickness	ASTM D5199 (smooth) ASTM D5994 (textured)	5 times/roll

Notes:

(1) The Geomembrane Manufacturer will perform quality control testing at the specified frequencies (minimum) on geomembrane rolls to be supplied for this project.

(2) These tests will be performed and results will be reported for both machine and cross direction.

Table 9-2
60-mil HDPE Geomembrane Acceptance Criteria

PROPERTY	UNITS	TYPE OF CRITERION	ACCEPTABLE VALUE (1)
Carbon black content	% by weight	Range	2 - 3
Carbon black dispersion	NA	Range	Category 1, 2 or 3 (2)
Density	NA	Minimum avg.	0.940
Tear resistance (3)	lb	Minimum avg.	42
Puncture resistance	lb	Minimum avg.	108 (90) (4)
Tensile properties (3)			
Yield stress	ppi	Minimum avg.	126
Yield elongation	%	Minimum avg.	12
Break stress	ppi	Minimum avg.	228 (90) (4)
Break elongation	%	Minimum avg.	700 (100) (4)
SPNCL	hours	Minimum avg.	200
Thickness (lowest individual) (5)	mils	Minimum avg.	54 (51)(4)
Thickness (minimum average)	mils	Minimum avg.	60

Notes:
(1) Values are based on representative manufacturer's product data.
(2) For 10 different views, nine must be Category 1 or 2, and one must be Category 3.
(3) Test is performed in both machine and cross direction.
(4) Parenthetical values are for textured geomembrane.
(5) For smooth geomembrane, lowest individual value of 10 values; for textured geomembrane, lowest individual value for 8 out of 10 values.

Table 9-3
40-mil VFPE Geomembrane Acceptance Criteria

PROPERTY	UNITS	TYPE OF CRITERION	ACCEPTABLE VALUE (1)
Carbon black content	% by weight	Range	2 - 3
Carbon black dispersion	N/A	Range	Category 1, 2, or 3 (2)
Density	N/A	Maximum	0.939
Puncture resistance	lb	Minimum	52
Tear resistance (3)	lb	Minimum	22
Tensile properties (3)			
Break stress (5)	ppi	Minimum	152 (72) (4)
Break elongation	%	Minimum	625 (200) (4)
SPNCTL	hours	Minimum	200
Thickness (lowest individual) (5)	mils	Minimum	36 (34) (6)
Thickness (minimum average)	mils	Average	40

Notes:

(1) Values are based on representative manufacturer's product data.

(2) For 10 different views, nine must be Category 1 or 2, and one must be Category 3.

(3) Test performed in both machine and cross direction.

(4) Parenthetical values are for textured geomembrane.

(5) For smooth geomembrane, lowest individual value of 10 values; for textured geomembrane, lowest individual value for 8 of 10 values.

(6) For textured geomembrane, lowest individual value of any of the 10 values.

When cores are required for preparing the geomembrane for shipment, the Manufacturer will use cores with sufficient crushing strength to prevent collapse or other damage while in use.

The following practices will be used as a minimum in receiving and storing geomembrane rolls in the designated storage area at the job site:

- While unloading or transferring the geomembrane rolls from one location to another, care will be taken to prevent damage to the geomembrane itself. The preferred method involves using a spreader-bar, straps, and a loader. Rolls will not be dragged.
- Geomembrane rolls will be stored in a manner so as to ensure that they are adequately protected from the following:
  - Equipment damage
  - Strong oxidizing chemicals, acids, or bases
  - Flames, including welding sparks
  - Temperatures in excess of 160°F
  - Dust and dirt

The RPR will observe and document, throughout the preinstallation, installation, and post-installation periods that the Installer provides adequate handling equipment for moving geomembrane rolls and that the equipment and the handling methods used do not pose unnecessary risk of damage. The Installer will be responsible for the means and methods to implement the work.

The Installer will be responsible for ensuring that all materials installed meet specifications (*i.e.*, that the roll marking label information indicates required specifications and properly represents materials). The RPR will maintain a log of geomembrane roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of delivery at job site
- For each geomembrane roll, the following information:
  - Roll number
  - Batch (lot) number

9.3 Installation

This section includes discussions of geomembrane roll testing requirements, earthwork required for geomembrane placement, placement of the geomembrane, defects and repairs of geomembrane, and requirements applicable to other materials in contact with the geomembrane. Subsection 9.4 describes the installation and testing requirements for geomembrane seams.

All parties involved in the installation of the geomembrane will be familiar with geomembrane and will focus on protecting the geomembrane from damage during construction activities.

9.3.1 Testing Requirements

This subsection describes the test methods, including sampling procedures and frequencies, and the role of the geosynthetics testing laboratory in testing the geomembrane roll samples. Subsection 9.2.1, under Quality Control Requirements, describes the test methods that are performed on an infrequent basis to demonstrate the uniformity of resin used to fabricate geomembrane shipped to the job site. Seam testing is described in Subsections 9.4.4 and 9.4.5.

Test Methods

Geomembrane roll samples will be collected by the RPR at the rate of one sample per 100,000 square feet of geomembrane delivered to the site. At least one sample will also be obtained for each geomembrane production batch in each shipment. The Installer will not ship to, or receive at, the site, geomembrane from more than two production batches in any single shipment without the prior written approval of the CQA Officer.

Samples will be 3 feet long by the full width of the roll and will not include the first 3 feet of any roll. Since machine direction for geomembrane rolls is the direction in which the material comes off the roll, machine direction for any sample will always be along the 3-foot length of the sample.

Tables 9-1, 9-2 and 9-3 list the tests and the test methods to be performed on the HDPE and VFPE geomembrane roll samples. The specifications and methods used in evaluating the results are discussed below under Procedures for Determining Geomembrane Roll Test Failures. Unless specified otherwise, sample specimens will be prepared in accordance with the referenced test method. The results for tear resistance and each of the tensile property tests will be reported for both the machine and cross direction.

Role of Testing Laboratory

The geosynthetics testing laboratory will be responsible for performing the tests on samples submitted to them as described above under Test Methods. The results of the tests performed will be reported to the CQA Officer and the RPR.

Retesting of geomembrane rolls for quality assurance purposes because of failure to meet any or all of the acceptance specifications listed in Tables 9-2 and 9-3 can only be authorized by the CQA Officer.

The Geomembrane Manufacturer and/or Installer may perform their own tests according to the methods and procedures defined in Table 9-1; however, the results will only be applicable to their own quality control needs. These results will not be substituted for the quality assurance testing described herein.

Procedures For Determining Geomembrane Roll Test Failures

Tables 9-2 and 9-3 list the acceptance specifications for HDPE and VFPE geomembranes. These tables apply to both textured and smooth geomembranes. For those tests where results are reported for both machine and cross direction, each result will be compared to the listed specification to determine acceptance. The HDPE geomembrane values listed in the acceptance specifications of Table 9-3 are based on representative manufacturer's product data for smooth and textured HDPE geomembrane.

The VFPE geomembrane acceptance values listed in Table 9-3 are based on the review of product literature from several geomembrane manufacturers. Textured geomembranes will be required to meet the same specifications listed for nontextured geomembranes unless otherwise noted.

The following procedure will be used for interpreting results:

- If the test values meet the specifications stated in Tables 9-2 and 9-3, then the roll and the lot will be accepted for use at the job site. If the sample represents all rolls from an entire shipment, then the entire shipment will also be considered accepted.
- If the result does not meet the specifications, then the roll and the batch may be retested using specimens either from the original roll sample or from another sample collected by the RPR. For retesting, two additional tests will be performed for the failed test procedure. (Each additional test will consist of multiple specimen tests if multiple specimens are called for in the test procedure.) If both of the retests are acceptable, then the roll and

batch will be considered to have passed this particular acceptance test; if either of the two additional tests fail, then the roll and batch will be considered unsuitable without further recourse. The CQA Officer may obtain samples from other rolls in the batch. On the basis of testing these samples, the CQA Officer may choose to accept a portion of the batch while rejecting the remainder.

- If retesting does not result in passing test results as defined in the preceding paragraph, or if there is any other nonconformity with the material specifications, then the Installer will withdraw the rolls from use in the project at the Installer's sole risk, cost, and expense. The Installer will be responsible at his/her sole risk, cost, and expense for removing this geomembrane from the site and replacing it with acceptable geomembrane.

9.3.2 Earthwork

The Construction Contractor will be responsible for preparing the supporting soil according to the plans and specifications and Section 5 of this CQA Plan. The geomembrane will be deployed directly above the geosynthetic clay liner (GCL). Prior to the installation of the GCL, the Installer will certify in writing that the surface on which the GCL/geomembrane will be installed is acceptable. This certification of acceptance will be reported by the Installer prior to the start of GCL/geomembrane installation in the area under consideration. Unacceptable areas noted by the Installer will be immediately reported to the RPR.

The soil surface will also be examined by the RPR to evaluate any areas softened by precipitation or cracked due to desiccation. The daily observation will be documented in the daily report. Areas determined to be unacceptable will be reworked by the Construction Contractor until acceptable.

9.3.3 Placement

Location and Panel Layout Drawing

A panel layout drawing for the geomembrane installation covered by this plan will be prepared by the Installer prior to installation and submitted to the CQA Officer, showing the proposed location and orientation of geomembrane panels to be installed in relation to slope, collection trenches, anchor trench and phase boundaries, seaming methods, and phased construction. This panel layout drawing will be submitted to the WDNR in a preconstruction or preinstallation submittal prior to construction. The CQA Officer will review the panel layout drawing and document that it is consistent with accepted practice and the construction plans and specifications. Geomembrane panels and seams will be identified by the RPR by the corresponding geomembrane roll number on the layout drawing as they are installed.

Installation Techniques

Geomembrane panels will be installed by placing one at a time, and each panel will be seamed by the end of the day on which it was placed. The RPR will document that the condition of the supporting surface has not changed detrimentally during installation. The RPR will record the roll number, location, and date of each geomembrane panel installed.

The Installer will take the following precautions while installing the geomembrane:

- Ensure that the equipment used does not damage the geomembrane by the way it is handled, by excessive heat, by leakage of hydrocarbons, or by other means.
- Ensure that personnel working on the geomembrane do not smoke, wear damaging clothing, or engage in other activities that could damage the geomembrane.
- Ensure that the method used to unroll the geomembrane does not cause scratches or crimps in the geomembrane and does not damage the GCL or supporting soil.
- Ensure that the method used to place the rolls minimizes wrinkles (especially differential wrinkles between adjacent panels).
- Ensure that adequate temporary loading or anchoring (continuously placed, if necessary), which will not damage the geomembrane, is placed to prevent uplift by the wind.
- Ensure that direct contact with the geomembrane is minimized. The geomembrane will be protected by geotextile, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

Weather Conditions

Geomembrane will not be placed in an area of ponded water, during precipitation events, or in the presence of excessive winds (greater than 20 mph). The RPR will document that this condition is fulfilled. The CQA

Officer will stop or postpone geomembrane placement when conditions are unacceptable.

Damages

The RPR will examine each panel for damage after placement and will determine which panels, or panel portions, should be rejected, repaired, or accepted. Damaged panels or panel portions that have been rejected will be marked, and their removal from the site will be recorded by the RPR. Panel repairs will be made according to the procedures described in Subsection 9.3.4.

9.3.4 Defects and Repairs

This section applies to all defects and repairs resulting from examinations, tests, or visual observations performed on the geomembrane material itself and on the seams used in joining rolls in the field.

Identification

All seam and nonseam areas of the geomembranes will be examined and documented by the RPR for identification of defects, holes, blisters, undispersed raw materials, and any signs of contamination by any foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane will be clean at the time of examination. The geomembrane surface will be swept with a broom and/or washed by the Installer if the amount of dust or mud inhibits examination.

Evaluation

Each suspect area identified will be nondestructively tested using the vacuum box test method described in Subsection 9.4.4. Each location that fails the nondestructive tests will be marked by the RPR and repaired by the Installer.

Repair Procedures

Any portion of the geomembrane exhibiting a flaw or failing a destructive or nondestructive test will be repaired. Several procedures exist for the repair of these areas. The procedures available include the following:

- Patching is used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
- Grinding and rewelding are used to repair small sections of extruded seams.

- Spot welding or seaming is used to repair small tears, pinholes, or other minor, localized flaws.
- Capping is used to repair large lengths of failed seams.
- Topping is used to repair areas of inadequate seams that have an exposed edge.
- Other procedures may be used at the recommendation of the Installer if agreed upon by the CQA Officer and the RPR.

The repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQA Officer, RPR, and Installer. At a minimum, the following provisions will be satisfied:

- Patches or caps will extend at least 6 inches beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 3 inches.
- The geomembrane below large caps will be appropriately cut to avoid water or gas collection between the two sheets.

Examination of Repairs

Each repair will be numbered and logged by the RPR. Each repair will be nondestructively tested according to Subsection 9.4.4. Repairs that pass the above testing will be considered to be adequate, except that large caps may be of sufficient extent to require destructive seam sampling and testing, at the discretion of the RPR, according to the provisions of Subsection 9.4.5.

Failed tests indicate that the repair was inadequate, and the repair will be redone and retested until a passing result is obtained. The RPR will document that all repairs have been subjected to nondestructive testing and will record the number of each repair, the date, and the test outcome.

Large Wrinkles

When seaming of the geomembrane is completed, the RPR will examine the geomembrane for wrinkles and determine which wrinkles should be cut and seamed by the Installer. The wrinkle repair will be done in accordance with the equipment and procedures described in Subsections 9.4.2 and 9.4.3 (General Seaming Procedures), respectively, and it will be nondestructively tested using the vacuum box test method described in Subsection 9.4.4.

9.3.5 Materials In Contact With Geomembranes - Anchor Trench System and Backfilling

The anchor trench for the geomembrane will be excavated by the Construction Contractor, unless otherwise specified, to the lines and grades shown on the plans and specifications. The trench will use a “U” configuration. No more than the amount of trench required for the geomembrane to be anchored in 1 day will be excavated to minimize the desiccation potential of the anchor trench soil.

The anchor trench will be backfilled and compacted by the Contractor. Care will be taken when backfilling the trenches to prevent any damage to the geomembrane or other geosynthetics that may also be placed in the trench prior to backfilling. The anchor trench will be adequately drained to prevent ponding or softening of the adjacent soil while the trench is open.

The RPR will observe the backfilling and compacting operations and will advise the CQA Officer of the adequacy of the soil installation. The RPR will also advise the CQA Officer of observed problems.

9.4 Field Seaming

This section covers the quality assurance procedures on seams used to join the rolls of geomembrane into a continuous layer. The installation of each of the geomembranes at the landfill facility will include 100 percent nondestructive testing of all field seams for joining adjacent rolls of geomembranes to document that no openings or gaps exist between geomembrane sheets. In addition, destructive testing will be performed at a routine interval for determining the strength and mode of failure of field seams in both the shear and peel modes.

The allowable field seam methods, equipment, personnel qualifications, and destructive and nondestructive testing methods are described in this section.

9.4.1 Seam Layout

No horizontal seams will be allowed on slopes greater than 5 horizontal to 1 vertical. In corners and at other odd-shaped geometric intersections, the number of horizontal seams will be minimized. A seam numbering system comparable and compatible with the geomembrane roll numbering system will be agreed upon at the preconstruction/preinstallation meeting (Subsections 3.1 and 3.3).

9.4.2 Seaming Equipment

The approved process for production field seaming (panel to panel) are the dual hot wedge (fusion-type) seam method and the extrusion fillet weld process. Specialty seams and repair seams (nonproduction) will be done by the extrusion fillet weld process. No other processes can be used without prior written authorization from the CQA Officer and the RPR. Only equipment that has been specifically approved by make and model will be used.

Dual Hot Wedge Process

The Installer will meet the following requirements regarding the use, availability, and cleaning of the equipment to be used at the job site:

- An automated self-propelled type of apparatus will be used.
- The welding apparatus will be equipped to continuously monitor applicable temperatures.
- One spare operable seaming device will be maintained on-site at all times.
- Equipment used for seaming will not damage the geomembrane.
- The geomembrane will be protected in areas of heavy traffic to prevent damage as discussed in Subsection 9.3.3.
- For cross seams, the edge of the cross seams will be ground to a smooth incline (top and bottom) prior to welding.
- For cross seams, the intersecting dual hot wedge seam will be patched using the extrusion fillet process described below.
- The electric generator for the equipment will be placed on a smooth base in such a way that no damage occurs to the geomembrane. Similarly, a smooth insulating plate or fabric will be placed beneath the hot equipment after use.

The Installer will keep records for each seamer performing dual hot wedge seaming, including welding machine I.D. number, ambient air temperature, geomembrane surface temperature, and machine operating pressures and temperatures. These data will be recorded at intervals as agreed upon at the preconstruction or preinstallation meeting.

Extrusion Fillet Process

The Installer will meet the following requirements regarding the use, availability, and cleaning of extrusion welding equipment to be used at the job site:

- The welding apparatus will be equipped to continuously monitor temperature at the nozzle.

- One spare operable seaming device will be maintained on-site at all times.
- Equipment used for seaming will not damage the geomembrane.
- The geomembrane will be protected in areas of heavy traffic to prevent damage.
- The extruder will be cleaned and purged prior to beginning seaming, and at any time during which seaming operations are stopped, until all heat-degraded extrudate has been removed from the barrel.
- The electric generator for the equipment will be placed on a smooth base in such a way that no damage occurs to the geomembrane. Similarly, a smooth insulating plate or fabric will be placed beneath the hot equipment after use.
- Geomembrane surfaces will not be ground for welding preparation more than 1 hour prior to seaming.

The Installer and, if applicable, the Geomembrane Manufacturer will provide documentation to the CQA Officer regarding the quality of the extrudate used in the welding apparatus. At a minimum, the extrudate will be compatible with the base liner material and will contain the same grade and quality of polyethylene resin as used in the base material.

The Installer will keep records for each seamer performing extrusion weld seaming, including welding machine I.D. number, extrudate, and ambient air and geomembrane surface temperatures. These data will be recorded at intervals as agreed upon at the preconstruction or preinstallation meeting.

9.4.3 Initial Requirements

Personnel Qualifications

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests for the type of seaming equipment to be used. At least one seamer will have experience in seaming a minimum of 2,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at the landfill facility. The most experienced seamer, the “master seamer,” will have direct supervisory responsibility at the job site over less experienced seamers.

The Installer will provide a list of proposed seaming personnel and their experience records to the CQA Officer and the RPR for their review and approval.

Weather Conditions

The weather conditions under which geomembrane seaming can be performed are as follows:

- Unless otherwise authorized in writing by the CQA Officer, no seaming will be attempted or performed at an ambient temperature below 32° F (0°C) or above 104°F (40°C).
- Between ambient temperatures of 32°F (0°C) and 50°F (10°C), seaming will be performed only if the geomembrane is preheated by either sun or a hot air device, provided there is no excessive ambient cooling resulting from high winds.
- Above 50°F (10°C), no preheating of the geomembrane will be required.
- Geomembrane will be dry and protected from the wind.
- Seaming will not be performed during any precipitation event unless the Installer erects satisfactory shelter to protect the geomembrane areas for seaming from water and/or moisture.
- Seaming will not be performed in areas where ponded water has collected below the surface of the geomembrane.

If the Installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 104°F, the Installer will demonstrate and certify that the methods and techniques used to perform the seaming produce seams that are entirely equivalent to seams produced at temperatures above 50°F and below 104°F, and that the overall quality of the geomembrane is not adversely affected.

The RPR will document the following items:

- Ambient temperature at which seaming is performed.
- Precipitation events occurring at the site, including the time of such occurrences, the intensity, and the amount of precipitation.

The RPR will inform the CQA Officer if any of the conditions relating to the weather are not being fulfilled. The CQA Officer will stop or postpone the geomembrane seaming when weather conditions are unacceptable.

Overlapping and Temporary Bond

The Installer will be responsible for ensuring that the following requirements are met:

- Panels of geomembrane will have a finished overlap of a minimum of 3 inches for extrusion welding and 4 inches for fusion welding; but, in any event, sufficient overlap will be provided to allow peel tests to be performed on the seam.
- No solvents or adhesives will be used on the geomembrane unless the product has been approved in writing by the CQA Officer. Approval can only be obtained by submitting samples and data sheets to the CQA Officer for testing and evaluation.
- Procedures used to temporarily bond adjacent geomembrane rolls must not damage the geomembrane; in particular, the temperature of the hot air at the nozzle of any spot welding apparatus will be controlled such that the geomembrane is protected at all times against potential damage.

Trial Seams

Trial seams will be made on fragments of geomembrane to document that seaming conditions are adequate. Such trial seams will be made at the beginning of each seaming period, following work interruptions, at changes in weather, and at least once for every 5 hours of seaming activities, for each seaming apparatus used that day. A minimum of one trial seam per welding machine will be made at the start of each day by each seaming technician performing welding that day. Also, each seamer will make at least one trial seam each day. Trial seams will be made under the same conditions as actual seams.

The trial seams will be examined by the Installer for squeeze-out, foot pressure applied by seaming equipment, and general appearance. If the seam fails any of these examinations, it will be repeated until satisfactory seams are obtained.

The trial seam samples will be at least 3 feet long by 1 foot wide after seaming, with the seam centered lengthwise. Seam overlap will be as indicated above under Overlapping and Temporary Bond.

Two adjoining specimens, each 1 inch wide, will be cut from each end of the trial seam sample by the Installer. The specimens will be tested by the Installer in shear and peel, respectively, using a field tensiometer, and they should not fail in the seam. If a specimen fails, then the entire test will be repeated using two additional specimens cut from each end of the trial seam sample. If the second set of specimens also fails, then the seaming apparatus and seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.

The remainder of the trial seam sample will be identified and marked by the RPR as follows:

- The sample will be assigned a number and marked as to the welding apparatus used and the seamer's name.
- The date, time, applicable operating temperatures of the welding equipment, and ambient temperature at the time of seaming will be noted.
- Whether the sample passes or fails will be indicated.

The RPR will observe trial seam procedures. The sample itself will be cut into three pieces, one for the Owner's record, one to be retained by the RPR, and one to be made available to the Installer.

The RPR may randomly select trial seam samples for destructive testing by the geosynthetics testing laboratory according to the test procedures described in Subsection 9.4.5. The frequency for trial seam laboratory testing will be at the discretion of the RPR and the CQA Officer.

If a trial seam sample fails a destructive test performed by the geosynthetics testing laboratory, according to the acceptance criteria stated in Subsection 9.4.5, then a destructive test seam sample(s) will be taken from each of the seams completed by the seamer during the shift related to the failed trial seam test. These samples will be forwarded by the RPR to the geosynthetics testing laboratory and, if any of them fails the tests, then the procedures described in Subsection 9.4.5 will apply. The conditions of this paragraph will be considered met if a destructive seam test sample, collected and tested according to the provisions under Location and Sampling Frequency and Sampling Procedure of Subsection 9.4.5, has already been taken and has passed.

Seam Preparation

The Installer will ensure that the following conditions for each of the geomembrane installations covered by this plan are met:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.

- If seam overlap grinding is required, then the grinding process will be completed according to the Geomembrane Manufacturer's instructions within 1 hour of the seaming operation, and in a way that will not damage the geomembrane or cause excessive striation of the geomembrane surface.
- Seams will be aligned so as to minimize the number of wrinkles and "fishmouths."

General Seaming Procedure

Unless otherwise specified, the general seaming procedure to be used by the Installer for each of the geomembrane installations covered by this plan, and observed by the RPR, will be as follows:

- A firm substrate will be provided to achieve proper support for seaming.
- Fishmouths or wrinkles at the seam overlaps will be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles will be seamed, and any portion where the overlap is inadequate will then be patched with the same geomembrane (including thickness) extending a minimum of 6 inches beyond the cut in all directions.
- If seaming operations are to be conducted at night, adequate illumination will be provided.

9.4.4 Nondestructive Testing

Each field seam will be nondestructively tested over its full length using one of the methods described in this section. The purpose of nondestructive testing is to determine the continuity of the seams. Nondestructive testing, at this stage of development, does not provide any information on the strength of seams. Seam strengths will be determined by destructive testing methods that are described in Subsection 9.4.5. Failure of any of the nondestructive or destructive tests will require the repair of the failed section according to the procedures contained in Subsection 9.3.4.

Nondestructive testing as described in this section will be performed on seams for every geomembrane installation covered by this plan. The recommended test methods for conducting the nondestructive seam testing are the air pressure test for dual hot wedge seams and the vacuum box test for extrusion fillet welds. These two nondestructive testing methods are described below.

The RPR will perform the following documentation tasks:

- Observe nondestructive seam testing, and examine seams for squeeze-out, foot pressure, and general appearance. Failure of these criteria will be considered as failure of the seam, and repair or reconstruction will be required.
- Document location, date, test unit number, name or number of tester, and outcome of all testing.
- Inform the Installer of any required repairs.
- Document that appropriate repairs are made and that the repairs are retested nondestructively with passing results.

Air Pressure Testing

The following test procedure is applicable only to dual hot wedge seams. The equipment for performing the test should meet the following minimum requirements:

- An air compressor or hand pump equipped with a pressure gauge and regulator capable of producing and sustaining a pressure between 25 to 30 psig and mounted on a cushion to protect the geomembrane surface
- Fittings, rubber hose, valves, etc., to operate the equipment, and a sharp hollow needle or other approved pressure feed device

Air pressure testing will be performed according to the following procedure:

1. Seal both ends of the seam to be tested.
2. Insert needle or other approved pressure feed device into the air space at one end of the dual hot wedge seam.
3. Energize the air compressor or hand pump to a pressure of 25-30 psig. Close the valve, and monitor the pressure in the seam air space for approximately 7 minutes for HDPE and approximately 4 minutes for VFPE.
4. Record the pressure in the seam at the end of 2 minutes and again at the end of 7 minutes for HDPE and approximately 4 minutes for VFPE.

   Acceptable air pressure loss shall be determined in accordance with GRI GM6: for 40-mil, 4 psig; 60-mil, 3 psig.
5. If the pressure difference between the 2-minute and 7-minute or 4-minute readings exceeds 3 psi for HDPE or 4 psi for VFPE, or if the pressure does not stabilize within the 7-minute or 4-minute period, then allow for one more pressure monitoring interval.

6. If the pressure loss over both intervals exceeds the allowable pressure drop or if the pressure does not stabilize, then consider the seam as having failed the test.
7. If the pressure loss over either interval does not exceed the allowable pressure drop, then consider the seam as having passed the test.
8. The Installer must verify that the air channel tested was not obstructed by noting a release of air pressure at the end of the tested seam interval opposite the pressure gauge.

For any seam interval that fails the air pressure nondestructive test, additional nondestructive testing or visual inspection will be used to identify, if possible, the faulty area of the seam. The faulty area will be repaired and retested. If the faulty area cannot be identified, then the entire seam will be repaired and retested.

Vacuum Box Test

Vacuum box testing is to be used on those seams made by the extrusion fillet process, to locate precisely the defects identified from air pressure testing, or to evaluate suspect seam and nonseam areas as discussed in Subsection 9.3.4.

Vacuum box testing equipment must meet the following minimum standards:

- A five-sided vacuum box with an open bottom, a clear viewing panel on top, and a pliable gasket attached to the bottom
- A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections capable of achieving a vacuum of 26 inches of mercury (Hg) (or approximately 2 psia)
- A vacuum gauge on the tank with an operating range from 0 to 26 inches of vacuum, and a vacuum gauge on the vacuum box with an operating range from 0 to 10 inches of vacuum

The following procedure will be used in performing the vacuum box test:

1. Clean the seams to be tested so that they are relatively free from soil or foreign objects that might prohibit a good seal from being formed between the vacuum chamber and the geomembrane.
2. Energize the vacuum pump, and reduce the tank pressure to approximately 24 inches of vacuum (or approximately 3 psia).

3. Wet a strip of geomembrane approximately twice the size of the vacuum box with the soapy solution.
4. Place and center the vacuum box with the gasket in contact with the geomembrane surface over the wetted area of the seam.
5. Applying a normal force to the top of the vacuum box, close the bleed valve and open the vacuum valve. Check to make certain that a tight seal is created between the geomembrane and the vacuum box. A minimum vacuum of 5 inches will be used for testing with the maximum allowable testing pressure never exceeding 10 inches of vacuum.
6. With the vacuum drawn, use the viewing panel to examine the geomembrane seam for bubbles resulting from the flow of air through the seam. Continue this examination for not less than 10 seconds.
7. Remove the vacuum box by first closing the vacuum valve and then opening the bleed valve. Proceed to Step 8 if bubbles appear in Step 6. If no bubbles appear in Step 6, then proceed directly to Step 9.
8. If bubbles appear through the geomembrane, mark the defective area for repair according to the provisions of Subsection 9.3.4. All repairs will be tested until nondestructive results are passing.
9. Move the vacuum box along the seam to be tested, overlapping the previously tested area by no less than 3 inches.

9.4.5 Destructive Seam Testing

Destructive seam testing will be performed on the geomembrane seams covered by this plan. Destructive seam testing is performed to determine the strength of the seam in both shear and peel failure modes. Destructive seam testing will be performed within 48 hours of sampling either in an on-site laboratory by personnel under the direction of the CQA Officer or at the geosynthetics testing laboratory.

Location and Sampling Frequency

The RPR will select locations where seam samples will be cut out for the destructive testing. Test locations will be determined during seaming at the RPR's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential causes of an imperfect seam. The Installer will not be informed in advance of any location where seam samples will be taken.

The minimum frequency of sample collection will be one test location per every 500 linear feet of seam length. This minimum frequency will be taken as an average for the entire installation area.

Sampling Procedure

Samples will be cut under the direction of the RPR as the seaming progresses. For each sample location, the following information will be documented:

- Assigned sample number.
- Sample location on layout drawing.
- The reason for collecting the sample (*e.g.*, as part of statistical testing program, suspicious seam, etc.). Record this by the sample number.
- For the peel test, which geomembrane is the top and which is the bottom with respect to seams performed using dual hot wedge (fusion) weld techniques.

Specimens for qualitative field testing will be taken prior to removal of the laboratory sample. Samples for field tensiometer testing will be 1 inch wide by 12 inches long with the seam centered parallel to the width. The distance between the two samples will be 42 inches measured from inside edge to inside edge. If both samples pass the field tensiometer test described below under Field Test Methods, then the sample for laboratory testing will be taken according to the procedure described below.

The sample for laboratory testing will be located between the two samples used for field testing. Therefore, the laboratory sample will be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample will be cut by the Installer into three parts and distributed as follows:

- A sample, 12 inches by 12 inches, will be kept by the Installer for testing if so desired.
- A sample, 12 inches by 12 inches, will be given to the Owner for record storage.
- A sample, 18 inches by 12 inches, will be transmitted to the geosynthetic testing laboratory or on-site testing laboratory by the RPR.

All holes cut into the geomembrane resulting from destructive seam sampling will be immediately repaired by the Installer in accordance with the repair procedures described in Subsection 9.3.4. The repaired area will be nondestructively tested in accordance with the requirements of Subsection 9.4.4.

End-of-Seam Sampling

In addition to the 42-inch sample cut for laboratory testing, an additional sample will be cut from each end of each continuous production field seam for field testing as described below. These samples, often referred to as bones, need to be only 1 inch wide and can be cut from the portion of the seam that extends into/past the anchor trench so as not to require an additional repair.

Field Test Methods

The two 1-inch–wide samples described above under Sampling Procedure as well as the end-of-seam samples described above under End-of Seam Sampling will be field-tested for both peel and shear. Testing will be performed using a field tensiometer or equivalent device to qualitatively determine the mode of failure. The seam will be considered as having passed if the failure in both peel and shear does not occur within the seam. If the samples fail the field tensiometer test, then the repair procedures of Subsection 9.3.4 for the holes left by the cut-out samples, and the seam reconstruction procedures for the repair of the defective seam, discussed later in this subsection, will be implemented.

Laboratory Test Methods

Laboratory testing of the destructive seam samples will be performed by the geosynthetics testing laboratory or an on-site testing laboratory under the direction of the CQA Officer. All destructive seam tests, whether performed on trial seam samples (as described above) or on samples cut out from production seams, will be performed in general accordance with the methodology of ASTM D4437, which stipulates that at least five specimens will be tested in shear and five in peel. Samples will be cut in alternating order (*e.g.*, shear and peel, peel and shear) and will also be tested in the order of cutting, to determine if any trend in seam quality along the length of the sample exists. All specimens will be cut as 1-inch–wide strips to ensure that the seam does not exceed the test gauge length of the specimen.

The following tests will be performed on each seam sample submitted for laboratory testing:

- <u>Shear and peel maximum tension</u> is the maximum load per unit width of a 1-inch–wide specimen expressed in pounds per inch of width in both the shear and peel mode, according to ASTM D4437 as modified by NSF Standard 54.

- Shear elongation at break is the extension at break expressed as a percentage of the initial distance between the edge of the fused track and the nearer grip. This distance should be the same on both sides of the seam and is usually 2 inches. No referenced ASTM test exists for this procedure as defined; however, the specimen will be elongated to a maximum of 100 percent with any failures of individual specimens noted. For specimens that fail below 100 percent elongation, the value at which failure occurred will be noted on the results.
- Peel seam separation estimates the area of seam interface separation expressed as a percentage of the original area.

Also, for both the seam shear and peel tension tests, an indication will be given for each specimen tested that defines the locus of the failure.

For shear tests, the following values will be reported for each specimen tested:

- Maximum tension in pounds per inch
- Elongation at break indicating at what percentage the specimen failed (up to a tested maximum of 100)
- The locus of failure using the above designations

For peel tests, the following values will be reported for each specimen tested:

- Maximum tension in pounds per inch
- Seam separation expressed as percent of original seam area
- Locus of failure

Role of Testing Laboratory

The geosynthetics testing laboratory or on-site testing laboratory will be responsible for performing the tests on samples submitted to them as described above. The results of tests performed will be reported to the CQA Officer and the RPR. Retesting of seams, because of failure to meet any or all of the specifications listed below, can only be authorized by the CQA Officer.

The Geomembrane Manufacturer and/or the Installer may perform their own quality control testing in accordance with the methods and procedures defined above under Laboratory Test Methods; however, the results, if substantially different from those obtained by the geosynthetics testing laboratory or on-site laboratory, may only be used to request a retesting by the geosynthetics testing laboratory or on-site testing laboratory. All quality assurance test results from the geosynthetics testing laboratory or on-site laboratory govern over any test results from the Geomembrane Manufacturer or Installer. Only the CQA Officer is authorized to approve a retesting request.

Procedures For Determining Destructive Seam Test Failures

The procedures described in this section apply to the procedures for destructive testing defined above under Field Test Methods and Laboratory Test Methods. Procedures for repairing failed seams are given in Subsection 9.3.4 of this plan.

The results from the shear and peel tests for the HDPE geomembranes will be evaluated against the criteria tabulated in Table 9-4, and the VFPE geomembrane will be evaluated against the criteria presented in Table 9-5.

All of the tabular criteria for each respective geomembrane type must be met for a given seam to be considered acceptable.

Table 9-4
60-mil HDPE Geomembrane Seam Acceptance Criteria

PROPERTY	TEST METHOD	UNITS	TYPE OF CRITERION	ACCEPTANCE VALUES	
				NON-TEXTURED	TEXTURED (1)
Shear strength (2)	ASTM D6392	ppi	Minimum	120	120
Shear elongation	--	percent	Minimum	50	50
Peel strength (2) - Fusion	ASTM D6392	ppi	Minimum	78	78
Peel strength (2) - Extrusion	ASTM D6392	ppi	Minimum	78	78
Peel separation	--	percent	Maximum	25	25

Notes:

(1) If the lengthwise edges of the textured geomembrane panels are nontextured, then the nontextured specifications will apply for the testing of seams made along these edges.

(2) Four out of the five specimens must meet these requirements. The fifth specimen must achieve 80 percent of the listed peel strength.

Table 9-5
40-mil VFPE Geomembrane Seam Acceptance Criteria

PROPERTY	TEST METHOD	UNITS	MINIMUM AVERAGE VALUE	
			NON-TEXTURED	TEXTURED [1]
Shear strength [2]	ASTM D4437	ppi	44	44
Shear elongation [2]	--	percent	50	50
Peel strength [3],[4] - Fusion	ASTM D4437	ppi	40	40
Peel strength [3],[4] – Extrusion	ASTM D4437	ppi	40	40
Peel separation [5]	--	percent	10	10

Notes:

[1] If the lengthwise edges of the textured geomembrane panels are nontextured, then the nontextured specifications shall apply for the testing of seams made along these edges.

[2] Five out of the five test specimens must meet these requirements. In addition, failure type must be film-tear bond (FTB) for all five specimens.

[3] Four out of the five specimens must meet these requirements. The fifth specimen must achieve 90 percent of the listed peel strength.

[4] Failure type must be film-tear bond (FTB) for 4 out of 5 test specimens.

[5] Maximum Acceptance Value for four out of five test specimens. The fifth specimen must have no more than 50 percent peel separation.

The Installer has the following two options in determining the repair boundary whenever a seam has failed either the field tensiometer testing or laboratory destructive testing:

- The seam can be reconstructed between any two previously tested and passed destructive seam test locations.
- The Installer can trace the welding path to an intermediate location (at a 10-foot minimum from the point of the failed test in each direction) and request that field tensiometer tests be performed at these intermediate locations. If the field tensiometer sample results are acceptable, then full laboratory samples will be taken and tested. If the laboratory tests are acceptable, then the seam will be reconstructed between these intermediate locations. If either sample fails, then the process will be repeated until acceptable destructive seam tests have been performed in both directions away from the original failed sample location. For all retesting of seams, according to this procedure, the sampling methodology described earlier in this plan under Sampling Procedure will be used.

For seams reconstructed due to a failing destructive seam sample that are in excess of 150 feet long, an additional sample taken from the reconstructed zone must pass destructive seam testing.

The RPR will be responsible for documenting all actions, including test results submitted by the geosynthetics testing laboratory, taken in conjunction with seam testing. The RPR will also be responsible for keeping the CQA Officer informed on seam testing results and seaming progress.

9.5 Post-installation

Each geomembrane covered by this plan will be examined by the RPR. Any defects, whether due to failed seams, pinholes, or other penetrations, will be repaired.

Placement of the select granular fill drainage layer material will proceed as soon as practical following the RPR's testing and acceptance of completed geomembrane areas. The granular layer will provide ultraviolet protection, thermal insulation, and protection from physical damage.

Low-ground pressure tracked equipment (< 5 psi) will be used to place the drainage layer material over the geomembrane. At a minimum, 1 foot of cover material is required between the geomembrane and low-ground pressure equipment, 2 feet of cover soil are required between the geomembrane and all other tracked or floatation wheeled equipment, and 3 feet of cover soil are required between the geomembrane and all rubber-tired vehicles.

Following the installation of the select granular fill drainage layer material over the geomembrane liner, electrical resistivity testing will be conducted over the entire lined area. Detected defects will be uncovered and repaired in accordance with industry standards and manufacturer's recommendations.

Section 10
Geotextile

10.1 General

This section of the CQA Plan applies to nonwoven geotextile used throughout the landfill facility. Geotextile will be installed in the following systems of the landfill facility:

- Leachate collection system (LCS)

This section is divided into three major subheadings, which cover the quality assurance requirements for preinstallation (which includes Geotextile Manufacturers), installation, and post-installation (which includes the final examination of the geotextiles prior to placing the appropriate material above the geotextile). The terms preinstallation, installation, and post-installation are applicable only to the geotextile and do not apply to the overall construction of the landfill facility.

10.2 Preinstallation

10.2.1 Manufacturing

The geotextile will be supplied to the site in factory rolls. Prior to the delivery of any geotextile rolls to the site, the Geotextile Manufacturer will provide the CQA Officer with the Manufacturer's Quality Control Plan used for production of the geotextile rolls.

Every roll of geotextile for delivery to the site will be manufactured and inspected by the Geotextile Manufacturer, according to the following requirements:

- The geotextile must contain no needles used for punching.
- The geotextile must be free of holes and any other sign of contamination by foreign matter.

The Geotextile Manufacturer will provide certification, based on tests performed in accordance with the methods listed in Table 10-1 that the geotextile cushion supplied under this plan will meet the material specifications listed in Table 10-2. These tests may be performed by the Geotextile Manufacturer's laboratory or a laboratory

Table 10-1
Geotextile Material Acceptance Criteria
(minimum average roll values)

PROPERTY	TEST METHOD	UNITS	GEOTEXTILE TYPE AND FUNCTION	
			A	B
			NONWOVEN FABRIC CUSHION FOR LEACHATE COLLECTION TRENCHES	NONWOVEN FABRIC BELOW GROUTED RIPRAP
Mass per unit area	ASTM D5261	oz/yd^2	12	—
Apparent opening size (maximum)	ASTM D4751	mm	0.15	0.21
Permittivity(1)	ASTM D4491	1/s	0.9	1.5
Grab strength	ASTM D4632	lb	300	160
Tear strength	ASTM D4533	lb	115	60
Puncture strength	ASTM D4833	lb	190	80
Wide-width tensile strength	ASTM D4595	lb/in	—	—
Elongation at ultimate strength(2)	ASTM D4595	%	—	—

Notes:
(1) Assumed geotextile thickness of 0.1 cm to estimate minimum permittivity.
(2) Measured in machine and cross-machine direction.

contracted by the Geotextile Manufacturer. Additionally, the Geotextile Manufacturer will provide certification that the Manufacturer's Quality Control Plan was fully implemented for the geotextile materials supplied under this plan. The Geotextile Manufacturer will provide documentation to verify the results of the Manufacturer's CQA Plan implementation if required by the CQA Officer.

The geotextile rolls will be tested and evaluated prior to acceptance. The CQA Officer may perform/require additional testing (*i.e.*, conformance testing) as required by detailed specifications or as required in the judgment of the CQA Officer to verify that the geotextile meets the specifications.

10.2.2 Delivery, Handling, and Storage of Geotextile Rolls

Each geotextile roll to be used at the landfill facility will be marked by the Geotextile Manufacturer with the following information and in the following manner:

- When fabric is rolled on a core, each roll will be identified with a durable gummed label, or an equivalent, on the inside of the core and on the outside of the protective wrapping for the roll.
- Each roll label will contain the following information at a minimum:
    - Name of manufacturer (or supplier)
    - Style and type number
    - Roll length and width
    - Batch (or lot) number
    - Nominal product thickness
    - Date of manufacture
    - Roll number

The Geotextile Manufacturer will use the following guidelines in packaging, wrapping, and preparing all geotextile rolls for shipment:

- When cores are required, those that have a crushing strength sufficient to avoid collapse or other damage while in use will be used.
- Each roll will be covered with a wrapping material that will protect the geotextile from damage due to shipment, water, sunlight, or contaminants.

The following practices will be used as a minimum in receiving and storing geotextile rolls in the designated storage area at the job site:

- While unloading or transferring the geotextile rolls from one location to another, care will be taken to prevent damage to the wrapping or to the geotextile itself. If practicable, the Installer may use fork lift trucks fitted with poles that can be inserted into the cores of rolls. The poles will be at least two-thirds the length of the rolls, to prevent breaking the cores and possibly damaging the geotextile. Rolls will not be dragged.
- The geotextile rolls will be stored in such a manner so as to ensure that they are adequately protected from the following:
    - Precipitation
    - Ultraviolet radiation, including sunlight
    - Strong oxidizing chemicals, acids or bases
    - Flames, including welding sparks
    - Temperatures in excess of 160°F
    - Soiling

Throughout the preinstallation, installation, and post-installation periods, the RPR will observe and document that the Installer provides adequate handling equipment for moving geotextile rolls and that the equipment and handling methods do not pose unnecessary risk of damage. The Installer will be responsible for the means and methods to implement the work.

The Installer will be responsible for ensuring that all materials installed meet specifications (*i.e.*, the roll marking label information indicates required specifications and properly represents materials). The RPR will maintain a log of geotextile roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of delivery at job site
- For each geotextile roll, the following information:
    - Roll number
    - Batch (lot) number

10.3 Installation

This section describes the quality assurance requirements applicable to the installation, observation, and documentation of geotextile.

10.3.1 Placement

The Installer will install all geotextile in such a manner as to ensure that it is not damaged and in a manner that complies with the following requirements:

- On sideslopes, the geotextile will be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile in tension.
- In the presence of wind, all geotextile will be secured by suitable methods. The temporary securing material will be left in place until replaced with cover material as shown on the design plans and specifications.
- In-place geotextile will be cut with special care to protect other materials from damage that could be caused by the cutting of the geotextile.
- The Installer will take necessary precautions to prevent damage to any underlying layers during placement of the geotextile.
- During placement of geotextile, care will be taken not to entrap in the geotextile any stones, excessive dust, or moisture that could damage the geotextile, or generate clogging of drains or filters.
- A visual examination of the geotextile will be carried out over the entire surface after installation by the Installer to ensure that no potentially harmful foreign objects, such as needles, are present.
- The edges of the geomembrane between phases will be protected with a geotextile wrap and/or an overlying protective material until the edges are spliced together with the liner system of the adjacent phase.

10.3.2 Seams and Overlaps

The following requirements will be met with regard to seaming and overlapping of geotextile rolls:

- Geotextile seams will be continuously heat-bonded or sewn (spot heat bonding or sewing will not be allowed). Geotextile will be overlapped 6 inches prior to seaming. The sewing method and stitch type will be per the Manufacturer's recommendation, but must be approved by the CQA Officer. Overlapping of geotextile without sewing may be acceptable for certain applications (e.g., under riprap emergency spillways) with approval from the CQA Officer.
- No horizontal seams will be allowed on slopes steeper than 5 horizontal to 1 vertical (*i.e.*, seams will be along, not across, the slope), except as part of a geotextile repair.
- Sewing will be performed with thread made from the same base material as the geotextile, or suitable equivalent.

- The Installer will pay particular attention to seams to ensure that no earthen materials could be inadvertently trapped beneath the geotextile.

The RPR will be responsible for observing and documenting that the above provisions are performed by the Installer in an acceptable manner.

10.4 Post-installation

10.4.1 Final Examination

The RPR will perform a final geotextile examination after the installation of each geotextile layer has been completed. The objectives of the final examination are as follows:

- To examine for the presence of holes, tears, or other deterioration
- To examine geotextile for excessive tension due to stretching of the fabric during installation

If there will be an extended time delay between completion of the geotextile and the start of the installation of any overlying cover, then the Installer will make provisions, by temporarily covering or using other suitable methods, to protect the geotextile against exposure to sunlight and ultraviolet radiation.

10.4.2 Placement of Soil Materials

The Construction Contractor will place all soil materials located on top of a geotextile in such a manner as to minimize the following:

- Damage to the geomembrane
- Slippage of the geotextile on underlying layers
- Excessive tensile stresses imposed on the geotextile

Section 11
Geosynthetic Clay Liner

11.1 Introduction

This section is divided into three major subheadings, which cover the quality assurance requirements for preinstallation (includes the GCL Manufacturer), installation, and post-installation (includes the final examination of GCL prior to the placement of the geomembrane). The terms preinstallation, installation, and post-installation are applicable only to the GCL installation and do not apply to the overall construction of the landfill facility.

11.2 Preinstallation

Preinstallation activities are designed to help ensure that a high-quality product is being manufactured and that it is properly delivered, handled, and stored to maintain its quality.

11.2.1 Manufacturer's Quality Control Plan (MQCP)

The manufacturer of each component of the GCL and the GCL itself will have a Manufacturer's Quality Control Plan (MQCP) to ensure that their product meets all of the stated minimum properties. These manufacturers include the Bentonite Supplier, the Geotextile Manufacturer, and the GCL Manufacturer.

Bentonite Supplier

The Bentonite Supplier will have a MQCP that will be adhered to in the manufacturing process. This plan will include the following information:

- Documentation that the bentonite is sodium bentonite
- Testing that demonstrates that the bentonite meets specified gradation requirements
- Testing that demonstrates that the bentonite meets specified index test requirements
- Testing that demonstrates that the bentonite has not been treated with synthetic chemicals or polymers

Geotextile Manufacturer

The Geotextile Manufacturer will have an MQCP that will be adhered to in their manufacturing process. This plan will include the following provisions:

- Testing that demonstrates that the product is made of specified polymers
- Testing that demonstrates that the product meets certain minimum average roll values (for geotextiles)

GCL Manufacturer

The GCL manufacturer will have an MQCP that describes the procedures for accomplishing quality in the final product. At a minimum, the tests shown in Table 11-1 shall be performed by the Manufacturer.

This MQCP will also dictate the following requirements:

- Overlap alignment lines are to be marked on the edges.
- Completed rolls are to be securely wrapped in plastic.
- Completed rolls are to be stored indoors, and provisions are to be in place to prevent rolls from being stacked too high, to prevent rolls from becoming too wet, and to prevent damage during handling.
- Quality control certificates are to be provided.

11.2.2 Materials

The GCL will consist of a layer of pure sodium bentonite clay encapsulated between two geotextiles, and will comply with all of the manufacturing processes and physical/chemical criteria listed in this section.

The bentonite clay utilized in the manufacture of the GCL, as well as any accessory bentonite clay (e.g., Volclay® granular sodium bentonite or approved equivalent) provided for seaming and detail work, will meet the manufacturer's minimum requirements, as specified in the MQCP.

The geotextile component of the GCL, and the geosynthetic clay liner itself, will meet the minimum requirements of the respective MQCPs.

11.2.3 GCL Delivery, Handling, and Storage

The GCL panels will be supplied to the site in factory-produced rolls, which are of standard factory roll dimensions.

Table 11-1
GCL Material Tests, Test Methods, and Acceptance Criteria

PROPERTY	TEST METHOD	UNITS	VALUE
Bentonite properties:			
Free Swell	ASTM D5890	mL/2 g	24 (MARV)$^{(1)}$
Fluid Loss	ASTM D5891	mL	18
Hydraulic properties:			
Hydraulic Conductivity	ASTM D 5887	cm/sec	5 x 10^{-9} max.
Flux$^{(2)(3)}$	ASTM 5887	m^3/m^{2-S}	1 x 10^{-8}
Physical GCL properties			
Bentonite Mass Per Unit Area	ASTM D5993	lb/sqf	0.75 (MARV)$^{(1)}$
Grab Strength	ASTM D 4632	lb	90 (MARV)$^{(1)}$
	ASTM D 6768	lb/in.	22.5 (MARV)$^{(1}$
Peel Strength	ASTM D 4632	lb	15 min.
	ASTM D 6496	lb/in.	2.5 min.
Hydrated Internal Shear Strength	ASTM D 5321	lb	15 min.
	ASTM D 6243	lb/sqf	500

Notes:

(1) Minimum average roll value (MARV).

(2) Flux is defined as “flow rate/unit area” which can be converted to permeability using the equation:

permeability = flux/hydraulic gradient

(3) Report results at a maximum confining stress of 69 Kpa (5 psi) and 34 Kpa (2 psi) head pressure.

(4) The values provided in the original table for “Fluid loss” and “Flux” shall be considered maximum permitted values.

Each roll of GCL supplied to the site will be labeled with the following information:

- Name of manufacturer
- Product type and identification number (if any)
- Lot (Batch) number
- Date of manufacture
- Roll number

The GCL Manufacturer will ensure that the crushing strength of all GCL roll cores will be sufficient to avoid collapse or other damage while in use.

The rolls of GCL will be carefully unloaded by the Contractor upon arrival at the site. At a minimum, the following practices will be followed in receiving and storing GCL rolls in the covered storage area at the job site:

- While unloading or transferring the GCL rolls from one location to another, prevent damage to the GCL.
- For standard rolls, insert a steel support pipe through the cardboard roll core. Attach the slings or lifting chains at one end to the support pipe and at the other end to the bucket of a front-end loader or lifting device. Use a spreader bar to support and spread the slings. Ensure that the bar and support pipe are long enough to prevent damage to the edges of the GCL during hoisting.
- Alternatively, modify the fork lift trucks to lift the rolls with a steel bar, securely attached to the fork lift and inserted into the roll core. Do not lift the rolls by sliding the forks under the roll.
- Store the rolls of GCL in their original, unopened, wrapped cover in a clean, dry area. Store the material off the ground on pallets or by other suitable techniques that provide continuous support over the entire length of the roll. Cover the roll with a heavy, protective tarpaulin, or store the roll beneath a roof. Care will be used to protect the GCL from the following:
  - Precipitation
  - Ultraviolet radiation, including sunlight
  - Strong oxidizing chemicals, acids or bases
  - Flames, including welding sparks
  - Temperatures in excess of 160°F

Throughout the preinstallation, installation, and post-installation periods, the RPR will be responsible for observing and documenting that the Installer provides adequate handling equipment for moving GCL rolls and that the equipment and handling methods do not pose any risk of damage.

The RPR will be responsible for making certain that the name of the manufacturer, the type, and the thickness of each roll (as noted on the roll marking label described above) are correct. The RPR will also maintain a log of GCL roll deliveries. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

- Date of receipt of delivery at job site
- For each GCL roll, the following information will be noted:
  - Roll number
  - Batch (lot) number

11.2.4 Submittals

Submittals will be made prior to installation of the GCL concerning the GCL Manufacturer/production information and the GCL installer information.

The GCL Manufacturer/production information will include the following:

- Corporate background information
- Manufacturer's Quality Control Plan (MQCP) for bentonite, geotextile, and GCL manufacturers
- Project reference list consisting of the principal details of at least 10 projects totaling at least 8 million square feet of GCL installation, if required by the RPR or CQA Officer
- Results of tests conducted by the Bentonite Supplier and Geotextile Supplier to document the quality of the materials used to manufacture the GCL rolls assigned to the project
- Copy of quality control certificates, signed by a responsible entity of the Manufacturer. Each quality control certificate will include roll identification numbers, and the results of quality control tests (refer to Subsection 11.2.3 above for minimum testing requirements)
- Manufacturer's written certification that the GCL meets the project specifications, that the GCL has been continuously inspected and found to be needle-free, that the bentonite will not shift during transportation or installation, and that the bentonite and geotextile materials meet the Manufacturer's specifications

GCL Installer information will include the following:

- Corporate background information
- Project reference list consisting of the principal details of at least five projects totaling at least 1 million square feet, if required by the RPR or CQA Officer
- List of personnel performing field operations, along with pertinent experience information, if required by the RPR or CQA Officer

Also submitted prior to the preconstruction/preinstallation meeting will be the proposed panel layout diagram identifying placement of the GCL panels and seams, as well as any variances or additional details that deviate from the engineering drawings. The layout will be drawn to scale, will include information such as dimensions and details, and will be adequate for use as a construction plan.

11.3 Installation

The following installation procedures are designed to ensure the effectiveness of the GCL in meeting its design requirements and to simplify the deployment procedures. These procedures are to be followed by the Installer, unless the Installer proposes alternative procedures in writing and the CQA Officer approves them in writing prior to installation.

11.3.1 Testing Requirements

This subsection describes the test methods, including sampling procedures and frequencies, and the role of the Geosynthetic Testing Laboratory in testing the GCL roll samples. Unless specified otherwise, all sampling procedures will be performed in accordance with the referenced test method defined in this section.

GCL roll samples will be collected by the Contractor at the discretion of, and under the direction of, the RPR, at a rate specified by the RPR.

Samples will be 3 feet long by the full width of the roll and will not include the first 3 feet of any roll.

Table 11-1 lists the tests and the test methods that may be performed on GCL roll samples. The specifications and methods used in evaluating the results are discussed later in this subsection.

Role of Testing Laboratory

The Geosynthetic Testing Laboratory will be responsible for performing the tests on samples submitted to them. The results of tests performed will be reported to the RPR and CQA Officer.

Retesting of GCL rolls for quality assurance purposes, because of failure to meet any or all of the acceptance specifications in this section, can only be authorized by the CQA Officer.

The GCL Manufacturer and/or Installer may perform their own tests according to the methods and procedures defined in Table 11-1; however, the results will only be applicable to their own quality control needs. These results will not be substituted for the quality assurance testing described herein.

Procedure For Determining GCL Roll Test Failures

Table 11-1 lists the specifications that are applicable to the GCL. For any referenced test method that requires the testing of multiple specimens, the criteria in Table 11-1 will be met based on the average results of the multiple specimen tests.

The following procedure will be used for interpreting the results relative to acceptance or rejection of rolls, lots, and shipments of GCL to the site:

1. If the test values meet the stated specifications, then the roll and batch will be accepted for use at the job site. If the sample represents all rolls from an entire shipment, then the entire shipment will also be considered accepted.
2. If the results do not meet the specification, then the roll and the batch will be retested at the Contractor's expense using specimens either from the original roll sample or from another sample collected by the RPR. For retesting, two additional tests will be performed for the failed test procedure. (Each additional test will consist of multiple specimen tests if multiple specimens are called for in the failed test procedure.) If both of the retests are acceptable, then the roll and batch will be considered as having passed this particular acceptance test; if either of the two additional tests fail, then the roll and batch will be considered as being unsuitable without further recourse. The RPR may obtain samples from other rolls in the batch. On the basis of testing these samples, the CQA Officer may choose to accept a portion of the batch while rejecting the remainder.

   If retesting does not result in passing test results as defined in the preceding paragraph, or if there is any other nonconformity with the material specifications, then the Contractor will withdraw the rolls from use in the project at Contractor's sole risk, cost, and expense. Once withdrawn, the same rolls will not be resubmitted for use. Expenses for removing this GCL from the site and replacing it with acceptable GCL will be the sole risk and responsibility of Contractor.

11.3.2 Required Equipment

The following installation equipment is required on-site:

- Front end loader, crane, or other similar equipment. The selected piece of equipment will not cause damage to the subgrade, such as rutting. The Installer will verify in the presence of the RPR that the selected piece of equipment does not damage the subgrade
- A spreader bar to prevent slings from damaging the ends of the rolls.
- Several steel pipes to be inserted into the roll's core for lifting.
- Wooden pallets for aboveground storage of the GCL rolls.
- Heavy waterproof tarps for protecting all GCL rolls.
- Sandbags for securing the GCL during installation and for securing the tarps.
- Adhesive or tape for securing patches.
- Granular bentonite for seams and patches, and for securing around penetrations and structures as shown on the drawings.

11.3.3 Surface/Subgrade Preparation

GCL liner installation will not begin until a proper subbase has been prepared to accept the bentonite liner. Base material, including material in the vee trenches constructed for the leachate collection system piping, will be fine-grained soil free from angular rocks, roots, grass, and vegetation. Foreign materials and protrusions will be removed, and all cracks and voids will be filled; the surface will be made smooth and uniformly sloping. Unless otherwise required by the contract specifications and drawings, the prepared surface will be free from excessive moisture, loose earth, rocks or clay clods larger than 1 inches in diameter, rubble, and other foreign matter. The subgrade will be uniformly compacted to ensure against localized settlement and rutting under wheel loads and will be smoothed with a smooth drum or vibratory roller. Refer to Subsection 9.3.2 for additional earthwork-related requirements.

The surface on which the liner is to be placed will be maintained in a firm, clean, and smooth condition, free of standing water, during liner installation.

11.3.4 Deployment

As each roll is moved from the storage area, the labels will be removed by the Installer or RPR for storage in the project file.

The rolls of GCL will be brought to the area to be lined with a front-end loader, and support pipe will be set up such that the roll of liner is fully supported across its length. A spreader bar or similar device will be used to prevent the lifting chains or slings from damaging the edges. Dragging of the GCL liner will be minimized.

The Contractor will ensure, and the RPR will verify, that the following criteria are being met:

- The equipment used does not damage the GCL by handling, excessive heat, leakage of hydrocarbons, or by other means.
- The prepared surface underlying the GCL has not deteriorated since previous acceptance, and it is still acceptable at the time of GCL placement.
- Personnel working on the GCL do not smoke, wear damaging clothing, or engage in other activities that could damage the GCL.
- The method used to unroll the GCL does not cause damage to the GCL, and/or the subgrade.
- The method used to place the rolls minimizes wrinkles (especially wrinkles between adjacent panels).

GCL must not be placed during precipitation events, in the presence of excessive moisture, in any area of ponded water, or during excessive winds. The GCL must be dry when installed and must be dry when covered.

The proper side of the GCL, as per the manufacturer's recommendation, will face upward (unless otherwise dictated by project requirements). The liner will be placed over the prepared surface such that material handling will be minimized.

The GCL panels will be placed in a manner that ensures sufficient overlap as described in Subsection 11.3.5. Horizontal seams will not occur on slopes steeper than 10 horizontal:1 vertical.

The cover material (i.e., geomembrane) will be placed over the bentonite liner during the same day as the placement of the GCL. Only those GCL rolls that can be covered that same day will be unpacked and placed in position.

When wind conditions could affect installation, the GCL liner installation will be started at the upwind side of the project and will proceed downwind. The leading edge of the liner will be secured at all times with sandbags or other means sufficient to hold it down during high winds.

The GCL will be installed in a relaxed condition and will be free of tension or stress upon completion of the installation. Stretching of the liner to fit will not be allowed. Deployed rolls (panels) will be straightened by the installation personnel to smooth out creases or irregularities.

The RPR will visually inspect the geotextile's quality, the bentonite uniformity, and the degree of hydration, if any, of the GCL. Any areas in need of repair will be marked.

11.3.5 Seaming

Once the first panel has been deployed, adjoining panels will be laid with a 6-inch minimum overlap on longitudinal seams, and 24 inches on the panel end seams, depending on project specifications. To assist in obtaining the proper overlap, 6-inch overlap lines will be marked on the liner. All dirt, gravel, or other debris will be removed from the overlap area of the GCL.

Seam overlaps, whenever possible, will be placed such that the direction of flow is from the top panel to the underlying panel to form a shingle effect.

If the GCL requires a granular bentonite seam, then the overlapping panel edge will be pulled back and granular Volclay® (or approved equivalent) sodium bentonite will be poured continuously along all seams and lap areas from the panel edge to the 6-inch lap line, at a minimum application rate of ¼ pound per linear foot.

11.3.6 Patches/Repairs

Irregular shapes, cuts, or tears in the installed GCL will be covered with sufficient liner to provide a 12-inch overlap in all directions beyond the damaged area. A layer of granular bentonite will be placed in the overlap zone in accordance with the Manufacturer's recommendations. An epoxy-based adhesive, or other approved method, will be used to secure the patch during backfill operations. Alternatively, the patch can be placed underneath the defective liner.

11.3.7 Penetration Seals

The GCL will be sealed around penetrations, pipes, and structures in accordance with the recommendations of the GCL Manufacturer.

Pipe penetrations will incorporate a collar of GCL wrapped around the pipe and securely fastened. A bentonite or mastic grout will be placed around the corners for additional protection.

An additional GCL skirt placed over the bentonite grout is also recommended to provide a third level of protection and to prevent the bentonite grout from being displaced.

If the seal requires granular bentonite, then a 1- to 2-inch cut will be excavated around the circumference of the pipe, into the subgrade at least 12 inches out from the pipe. Volclay® sodium bentonite (or approved equivalent) will then be packed around the pipe in the subgrade excavation and on adjacent areas so that the pipe is surrounded with granular bentonite.

The GCL panel will then be placed over the pipe by penetrating the GCL with slits in a "pie" configuration where the pipe is to protrude in a manner that will create a snug fit between the GCL and the pipe.

More sodium bentonite will then be spread around the cut edges of the GCL against the pipe and over adjacent areas.

To complete the pipe penetration seal, a collar of GCL will be cut in a manner similar to that made on the main panel and will be fit around the pipe, with additional Volclay® sodium bentonite (or approved equivalent) being applied into any gaps that may remain.

11.3.8 Covering GCL

Only the amount of GCL that can be inspected, repaired, and covered in the same day will be installed. The GCL must be covered the same day on which it is installed.

Geosynthetics

When covering the GCL, precautions will be taken to prevent damage to the GCL by restricting heavy equipment traffic. If a textured geomembrane is to be placed over the GCL, a slip sheet (such as 20-mil smooth HDPE) will be placed over the GCL to allow the textured geomembrane to slide into its proper position. The slip sheet will be removed after the geomembrane is in place.

Soil

The following requirements apply to soil placement over the GCLs:

- Equipment used for placing the soil must not be driven directly on the GCL.
- A minimum thickness of 1 foot of soil is specified between a light dozer (*i.e.*, maximum contact pressure of 8 lb/sq. inch) and the GCL.
- A minimum thickness of 3 feet of soil is specified between rubber-tired vehicles and the GCL.

Any leading edge or panels of GCL left unprotected must be covered with a heavy, waterproofing tarp that is secured and protected with sandbags or other ballast.

11.3.9 Submittals

The following will be submitted during installation:

- Daily records/logs prepared by the Installer documenting work performed, personnel involved, general working conditions, and any problems encountered or expected on the project. These records will be submitted on a weekly basis.
- Copy of subgrade acceptance forms by the Installer.
- Quality control documentation.

11.4 Post-installation

11.4.1 Final Examination

The RPR will perform a final GCL examination after portions of installation have been completed. The RPR will examine the GCL for the following:

- Tears or defects
- Proper overlaps

If any portion of the GCL requires repairs based on the above examination, it will be repaired in accordance with the procedures in Subsection 11.3.6.

11.4.2 Submittals

The following will be submitted after installation is completed:

- Installation certification prepared by the Installer certifying that the GCL was installed in substantial accordance with the specifications and the CQA Plan.

- An as-build panel layout diagram prepared by the Installer identifying the placement of panels and seams. The numbering sequence will be as agreed upon between the RPR and the Installer prior to commencing installation.
- A copy of the Warranty obtained from the Manufacturer/Installer.

Section 12
Piping

12.1 General

This section includes quality assurance requirements for piping used throughout the facility. Piping will be used in the construction of the following items:

- Leachate collection system
- Leachate conveyance (or transfer) system
- Leachate head well piping

This section is divided into three major subheadings, which cover the quality assurance requirements for the preinstallation (includes Piping Manufacturers and Fabricators), installation, and post-installation (includes the final observation and documentation of piping installations). The terms preinstallation, installation, and post-installation are applicable only to the piping installation and do not apply to the overall construction.

Individual pipe sizes and standard dimension ratios (SDRs) to be used for each individual pipe installation are not detailed in this section; the plans and specifications will be used for the determination of correct size and wall thickness.

12.2 Preinstallation

12.2.1 Manufacturing

High-Density Polyethylene Material Specifications

High-density polyethylene (HDPE) pipe must be made from extra high molecular weight (EHMW) polyethylene (PE) resin, and the manufactured piping must be classified as Type III, Class C, Category 5, Grade P34 material according to ASTM D1248 and must also have a cell classification of 345434C as defined by ASTM D3350.

Polyvinyl Chloride Material Specifications

All polyvinyl chloride (PVC) pipe fittings must be Schedule 120 PVC molded fittings. Extruded fittings may not be used unless specifically approved in writing by the CQA Officer.

Fabricator

The Piping Fabricator will be responsible for perforating the pipe delivered by the Piping Manufacturer according to the plans and specifications.

12.2.2 Delivery, Handling, and Storage of Piping

Pipe will be protected during shipment from excessive heat or cold, puncture, or other damaging or deleterious conditions. The pipe will be stored on-site in a manner suitable to protect it from long-term ultraviolet exposure prior to actual installation.

Throughout the preconstruction, construction, and post-construction periods, the RPR will be responsible for observing and documenting that the Contractor provides adequate handling equipment for moving pipe and that the equipment and handling methods do not pose any risk of damage.

The RPR will maintain a log of pipe deliveries throughout the installation. The following information, at a minimum, will be recorded on the log for each shipment received at the job site:

1. Date of receipt of delivery at job site
2. Pipe size and type

12.3 Installation

12.3.1 Connections

HDPE Pipe

Unless approved otherwise by the CQA Officer, HDPE pipe connections will be made by the butt fusion procedure. The following procedure will be used regarding butt fusion seams:

- Seams will be made at the Manufacturer's recommended temperature for fusing pipe and fittings.
- For pipe diameter sizes 4 inches (nominal) and larger, seams will be made using the hydraulic fusion machines. For pipe diameters of less than 4 inches, manual fusion equipment can be used.
- Care will be taken to make certain that adequate pressures are used for fusing pipes and that sufficient cooling periods are allowed prior to testing, bending, or backfilling of pipe sections.

PVC Pipe

Unless approved otherwise by the CQA Officer, all PVC pipe connections will be made according to the Standard Practice for Making Solvent-Cemented Joints with Polyvinyl chloride (PVC) Pipe and Fittings, ASTM D2855. Particular care will be taken regarding required set and cure times for solvent-cemented joints, which vary for ambient temperature conditions. Joints will not be subjected to stresses by moving or backfilling prior to the specified set times. ASTM D2855 Section 5.2.4 discusses shelf life and signs of deterioration of PVC solvent cements. Only original quality solvent cement may be used since expired shelf life and deteriorated cements may cause inadequate connections.

12.3.2 Placement

Pipe placement will be done in accordance with the following procedure and requirements:

- Piping will be bedded and backfilled according to the plans and specifications.
- The prepared surface underlying the piping will not show evidence of deterioration since previous acceptance and must be acceptable prior to piping placement.
- The method used to place the piping will not cause damage to the piping and will not disturb the supporting backfill.
- The pipe bedding material will be shovel-sliced, or compacted to the spring line of the pipe to ensure proper bedding.
- Observations and measurements will be made to ensure that the pipes are of the specified size and dimension ratio, manufactured of the specified material, and that pipe perforations are sized and spaced as specified.
- All piping will be located as noted in the plans and specifications. Locations, grades, and size requirements are specified on the details of the plan set. Observations and surveying measurements will be made to ensure that the pipes are placed at the specified locations and grades and in the specified configuration. Deviations from the plans and specifications will be brought to the attention of the CQA Officer for evaluation of the necessity of corrective action.

12.3.3 Damage

Damaged pipes or portions of pipes that have been rejected will be marked and removed from the installation area.

12.4 Post-Installation

The integrity of each leachate collection piping system installed will be documented by flushing with water, by pulling a mandrel, or by another equivalent method after completion of construction of the backfill/leachate drainage layer. The RPR will observe and document that this operation is carried out and that the pipes are free flowing. Any systems that do not appear to be free flowing will be immediately reported to the CQA Officer, and corrective action will be taken.

Solid-wall pipe (single- and double-walled) outside the limits of waste will be air pressure–tested to document that the piping system is airtight. The line will be air-pressurized to 5.0 pounds/square inch (gauge pressure). The valve on the pressurizing unit will be closed, and the system will be pressure-monitored. A system pressure of 4.5 psig or greater maintained for 30 minutes after the valve closing will be considered as acceptable. The RPR will observe and document that this operation is carried out and that the pipes are airtight.

Pipe invert elevations will be documented every 50 linear feet by survey, as well as at key points, including changes in grade, intersections, and end points.

Appendix H: GCL Conformance Demonstration

- H.1: Liquid Flow Rate Comparison
- H.2: GCL Compatibility Demonstration
  - H.2.1: 2009 Leaching Potential and GCL Compatibility Analysis
  - H.2.2: 2013 Plan of Operation Modification

H.1
Liquid Flow Rate Comparison

TRC *999 Fourier Drive, Suite 101, Madison, WI 53717 • www.TRCcompanies.com* SHEET 1 OF 1

PROJECT / LOCATION: Dairyland Power Cooperative 2022 Plan Modification		PROJECT / PROPOSAL NO.
SUBJECT: GCL vs. Soil Barrier Liquid Flow Rate Comparison		469888.0001.0000
PREPARED BY: Z. Bauman	DATE: 12/7/2022	FINAL ☐
CHECKED BY: B. Kahnk	DATE: 12/28/2022	REVISION ☐

In accordance to s. NR 504.12(3)(5), a liner that utilizes GCL and soil barrier shall be designed to have a liquid flow rate no greater than the liquid flow rate through 2 feet of compacted soil with a hydraulic conductivity of 1 x 10^{-7} cm/sec. The liquid flow rate comparison shall be made using Darcy's Law:

$$\frac{Q}{A} = q = k\left(\frac{h}{t} + 1\right)$$

Q = flow rate (cm^3/sec)

A = surface area of liner (cm^2)

q = flow rate per unit area (cm^3/sec/cm^2)

k = hydraulic conductivity (cm/sec)

h = hydraulic head above liner (cm)

t = thickness of liner (cm)

	2 -ft Compacted Soil				**GCL with 2 ft soil barrier**	
k	1E-07	cm/sec		k	1.23E-09	cm/sec
h	30.48	cm		h	30.48	cm
t	60.96	cm		t	0.5	cm
q	1.5E-07	cm^3/sec/cm^2	Good	q	7.62E-08	cm^3/sec/cm^2

Assumptions

1) The maximum head on the liner will be 1 ft, which is the maximum head allowed according to WDNR

2) Hydraulic Conductivity of the GCL is based on latest documentation results during the construction of Cell 3B liner (TRC, 2015).

3) GCL thickness is typically 5mm to 12 mm. 5 mm (0.5 cm) was used as the thickness to remain conservative.

Conclusion: Based on the tested hydraulic conductivity of the GCL, the flow rate of the GCL and soil barrier are not greater than that of a 2 ft compacted soil liner system with a hydraulic conductivity of 1 x 10^{-7} cm/sec and thus, satisfies s. NR 504.12(3)(5). As detailed in the Section 3.2.2.2.2 of the 2023 Plan Modification, the effect of the CCR leachate on the GCL is minimal and does not substantially impact the GCL hydraulic conductivity.

TESTING, RESEARCH, CONSULTING AND FIELD SERVICES
AUSTIN, TX - USA | ANAHEIM, CA - USA | ANDERSON, SC - USA | GOLD COAST - AUSTRALIA | SUZHOU - CHINA

July 20, 2015

Mail To:

Bill To:

Mr. Scott Solotorovsky
CETCO
2870 Forbs Avenue
Hoffman Estates, IL 60192

<= Same

email: scott.solotorovsky@cetco.com
kathy.brazeau@colloid.com

Dear Mr. Soltorovsky:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

Project:	**MQC Weston Disposl Site No. 3**
TRI Job Reference Number:	E2392-69-07
Material(s) Tested:	One Bentomat ST GCL
Test(s) Requested:	Index Flux (ASTM D5887)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

John M. Allen, P.E.
Division Director
Geosynthetic Services Division
www.GeosyntheticTesting.com

GCL TEST RESULTS
TRI Client: CETCO
Project: MQC Weston Disposl Site No. 3

Material: Bentomat ST GCL
TRI Log #: E2392-69-07

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.	PROJ. SPEC.
Index Flux (ASTM D5887) **Sample Identification: Lot 201529LO Roll 3759**													
Index Flux ($m^3/m^2/sec$)		1.5E-09									1.5E-09		
Hydraulic Conductivity (cm/sec)		9.4E-10									9.4E-10		5.3E-09 max

TESTING, RESEARCH, CONSULTING AND FIELD SERVICES
AUSTIN, TX - USA | ANAHEIM, CA - USA | ANDERSON, SC - USA | GOLD COAST - AUSTRALIA | SUZHOU - CHINA

July 29, 2015

Mail To:

Bill To:

<= Same

Terrence Halena
TRC Environmental Corporation
708 Heartland Trail, Suite 3000
Madison, WI 53717

email: thalena@trcsolutions.com
cc email: twmartin@trcsolutions.com

Dear Mr. Halena:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs.
TRI is pleased to submit this final report for laboratory testing.

Project:	**DPC Alma Off-Site Ash Disposal Facility Cell 3B**
TRI Job Reference Number:	E2392-71-05
Material(s) Tested:	Four GSE BentoLiner NSL GCL(s)
Test(s) Requested:	Mass/Unit Area (ASTM D5993) Index Flux (ASTM D5887)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

John M. Allen, P.E.
Division Director
Geosynthetic Services Division
www.GeosyntheticTesting.com

GCL TEST RESULTS
TRI Client: TRC Environmental Corporation
Project: DPC Alma Off-Site Ash Disposal Facility Cell 3B

Material: GSE BentoLiner NSL GCL
Sample Identification: 502256840 ✓
TRI Log #: E2392-71-05

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Bentonite - Mass/Unit Area (ASTM D5993, result @ 0% M.C.)												
Bentonite mass/unit area (lbs/ft^2)	0.79 ✓	0.80 ✓	0.92 ✓	0.88 ✓	0.80 ✓						0.84	0.06
Moisture Content (%)	9.8 ✓	9.9 ✓	9.8 ✓	9.7 ✓	9.7 ✓						9.8	0.1
Index Flux (ASTM D5887)												
Index Flux (m^3/m^2/sec)		3.3E-09 ✓									3.3E-09	
Hydraulic Conductivity (cm/sec)		2.8E-09 ✓									2.8E-09	

MD Machine Direction TD Transverse Direction NA Not Available

GCL TEST RESULTS
TRI Client: TRC Environmental Corporation
Project: DPC Alma Off-Site Ash Disposal Facility Cell 3B

Material: GSE BentoLiner NSL GCL
Sample Identification: 502256860
TRI Log #: E2392-71-05

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Bentonite - Mass/Unit Area (ASTM D5993, result @ 0% M.C.)												
Bentonite mass/unit area (lbs/ft^2)	0.83	0.76	0.81	0.90	0.74						0.81	0.06
Moisture Content (%)	10.3	10.5	10.6	10.8	10.6						10.6	0.2
Index Flux (ASTM D5887)												
Index Flux (m^3/m^2/sec)		3.6E-09									3.6E-09	
Hydraulic Conductivity (cm/sec)		2.8E-09									2.8E-09	

MD Machine Direction TD Transverse Direction NA Not Available

GCL TEST RESULTS
TRI Client: TRC Environmental Corporation
Project: DPC Alma Off-Site Ash Disposal Facility Cell 3B

Material: GSE BentoLiner NSL GCL
Bentonite - Mass/Unit Area (ASTM D5993, result @ 0% M.C.)
TRI Log #: E2392-71-05

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Sample Identification: 502256830												
Bentonite mass/unit area (lbs/ft^2)	0.88	0.82	0.92	0.81	0.81						0.85	0.05
Moisture Content (%)	9.5	9.6	9.7	9.6	9.7						9.6	0.1
Sample Identification: 502256850												
Bentonite mass/unit area (lbs/ft^2)	0.82	0.90	0.88	0.85	0.78						0.85	0.05
Moisture Content (%)	10.3	10.3	10.3	10.1	10.2						10.2	0.1

MD Machine Direction TD Transverse Direction NA Not Available

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TRI

July 29, 2015
September 23, 2015 Reissued to add roll number

Mail To:	**Bill To:**
Terrence D. Halena	**<= Same**

TRC Environmental Corporation
708 Heartland Trail, Suite 3000
Madison, WI 53717

email: thalena@trcsolutions.com
cc email: twmartin@trcsolutions.com
cc email: ssellner@trcsolutions.com

Dear Mr. Halena:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report of the laboratory testing for the sample listed below.

Project:	**DPC Cell 3 B Construction**
TRI Job Reference Number:	E2392-74-03
Material Tested:	One GCL
Test Requested:	Index Flux (ASTM D5887)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Richard S. Lacey

Richard S. Lacey, P.E.
Senior Engineer
Geosynthetic Services Division
www.GeosyntheticTesting.com

GCL TEST RESULTS
TRI Client: TRC Environmental Corporation
Project: DPC Cell 3 B Construction

Material: GCL
Sample Identification: 502252239
TRI Log #: E2392-74-03

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Index Flux (ASTM D5887)												
Index Flux ($m^3/m^2/sec$)		2.9E-09									2.9E-09	
Hydraulic Conductivity (cm/sec)		2.3E-09									2.3E-09	

MD Machine Direction TD Transverse Direction NA Not Available

H.2
GCL Compatibility Demonstration

H.2.1
2009 Leaching Potential and GCL Compatibility Analysis

RMT
• ENVIRONMENT • ENERGY • ENGINEERING

April 16, 2009

Mr. Bill Kowalski
Dairyland Power Cooperative
P.O. Box 817
3200 East Avenue South
La Crosse, WI 54601

Subject: Evaluation of the Leaching Potential of Sherco Unit 3 Scrubber Material for GCL Compatibility; Phase IV Disposal Area; License #4126; Alma Off-Site Disposal Facility

Dear Bill:

As directed by Dairyland Power Cooperative (DPC) RMT, Inc., (RMT) has finalized our Technical Memorandum which presented the evaluation of the leaching potential of Sherco Unit 3 scrubber material for geosynthetic clay liner (GCL) compatibility. Based on the findings presented in the Technical Memorandum dated April 14, 2009, we recommend that you submit a cover letter requesting an expedited plan modification, under NR 514.09, to the Wisconsin Department of Natural Resources (WDNR). The plan modification request will include two items. The first item will request that based on the findings contained in the Technical Memorandum dated April 14, 2009, that the Department modify the existing Conditional Plan of Operation Approval, dated May 15, 2001, for the Alma Off-Site (AOS) Phase IV Disposal Facility to allow for the disposal of coal combustion byproducts (e.g., flue gas desulfurization material) from the sulfur dioxide scrubbing unit currently under construction at Genoa Station Unit 3.

The second plan modification item will request the elimination of annual coal ash testing for GCL compatibility required by Condition No. 30.b. of the May 15, 2001, Plan of Operation Conditional Approval. This request can be justified based on the favorable findings of the annual coal ash testing for GCL compatibility for the Phase IV Disposal Area. These findings were submitted annually by RMT on behalf of DPC, for the years of 2004 through 2008, as well as the favorable findings contained in RMT's Technical Memorandum dated April 14, 2009.

Please contact Curt Madsen, at (608)662-5475, with any questions or comments.

Sincerely,

Curtis D. Madsen, P.E.
Senior Project Manager

Attachments

cc: Mike Giblin-DPC, (letter only)
Bob Stanforth-RMT

Technical Memorandum

Date: April 15, 2009

To: Project File 3081.93

cc: Bill Kowalski – DPC
Curt Madsen – RMT, Inc.

From: Robert Stanforth, Ph.D.
Consulting Chemist – RMT, Inc.

Subject: Evaluation of the Leaching Potential of Sherco Unit 3 Scrubber Material for GCL Compatibility

Introduction

Sulfur dioxide (SO_2) scrubbing equipment is currently being installed at the Dairyland Power Cooperative (DPC) Genoa Station Unit 3 (G3) power plant. The flue gas desulfurization (FGD) waste collected from the SO_2 scrubbing unit will contain both the fly ash currently collected in the baghouse as well as the product from the SO_2 scrubbing process. The FGD waste that cannot be diverted for beneficial use will be disposed of in the Phase IV Disposal Area at the Alma Off-Site Disposal Facility. The Phase IV Disposal Area is lined by a composite liner that includes a geosynthetic clay liner (GCL) of low permeability. DPC would like to place the FGD waste that cannot be beneficially used into the landfill, as well. However, the leaching characteristics of the new material (FGD waste) could potentially be sufficiently different from the material currently placed in the landfill to adversely affect the GCL, in which case it would not be appropriate to place the FGD waste in the landfill. It is therefore important to evaluate the leaching characteristics of the FGD waste to determine whether it is acceptable for placement in the landfill.

The material from the air pollution control system is not currently available, since the system will not become operational until later in 2009. However, FGD waste from a similar process is available from the Sherco power plant in Minnesota. The Sherco unit burns a coal blend (e.g., low Btu and medium Btu coal) that is similar to that burned at Genoa Unit 3, and has the same type of SO_2 scrubber system (e.g., dry scrubber process) that is currently under construction at Genoa Unit 3. Testing has been conducted on the Sherco Unit 3 product to evaluate the chemical composition and leaching characteristics for comparison with the fly ash that is currently placed in the landfill. The testing on the Sherco product consisted of the following:

1. Compositional analysis
2. ASTM Water Leaching Test

3. The DPC Leachate Generation Procedure, which is a modification of the ASTM Water Leaching Test designed to provide a more realistic simulation of the actual leachate generated by the waste in the field.

The compositional analysis and the ASTM Test were done by Pace Laboratories. The DPC Leachate Generation Procedure leaching tests were done in the RMT Applied Chemistry Laboratory, with the leachate being analyzed by Pace Laboratories.

Results

Compositional Analysis

A comparison of the Sherco Unit 3 material with the fly ash from the other DPC plants is provided in Table 1. The laboratory reports are provided in Attachment A.

The Sherco material has higher levels of aluminum, boron, calcium, and sodium, but has lower levels of arsenic, chromium, cobalt, copper, iron, and zinc. Most of the differences are likely due to the presence of the lime and calcium scrubber products (calcium sulfate and sulfite), which increase the calcium concentrations while decreasing trace metal concentrations in the fly ash. Changes in the composition of the material do not in and of themselves predict changes in leaching chemistry. For that, we need to evaluate the leaching potential of the different materials.

ASTM Water Leach Test

The results of the ASTM water leaching test run on the Sherco material are presented in Table 2. The laboratory reports are provided in Attachment A.

DPC Leachate Generation Procedure

The ASTM Water Leaching Test provides a convenient means of evaluating the leaching potential of the material being leached under conditions in which the material controls the pH of the leaching solution. However, the Leaching Tests employ a relatively small amount of solid per unit volume of leaching solution (e.g., 1 g solid per 20 mL leaching solution), which is not representative of the solid to solution ratio found as rainwater percolates through a landfill. A more realistic view of the leachate can be obtained by running a series of leaching tests using the same leaching solution and contacting fresh solid with the same batch of leachate. This approach is used in the DPC Leachate Generation Procedure. The leaching procedure is presented in Attachment B.

This procedure was utilized on the Sherco Unit 3 ash. The results are presented in Table 3, along with the results from the same test procedure run on yearly composites of the ash currently disposed in the landfill. The laboratory reports are presented in Attachment A.

The Sherco material had leachate concentrations that are in the same range as the fly ash from previous years. Calcium is slightly elevated over the previous year's results, which is not surprising, since lime (CaO) is used to "scrub" the SO_2. The key question is whether the leachate from the new material will influence the permeability of the clay liner more than the current leachate does. The effect of leachate composition on clay (benotonite) liner permeability is discussed in a paper by Kolstad *et al*. (2004) presented in Attachment C. They found that the key factors influencing the liner's permeability are the monovalent to divalent cation ratio (referenced to as RMD), and the ionic strength of the solution. The influences of both of these factors are shown on a figure in the paper, which is reproduced on Figure 1. Both ionic strength and the RMD exert significant influences on the hydraulic conductivity of the bentonite liner. The calculated ionic strengths due to the cations and RMD are shown in Table 4. The total ionic strength has a component due to both cations and anions. If we assume that the anion component equals the cation component, then the total ionic strength is in the region of between 0.02 and 0.15 M, in other words, on the left-hand side of the graph on Figure 1. Plotting the results for the current fly ash results and the Sherco results on the graph from Kolstad *et al*. shows that the Sherco ash falls at a permeability slightly above the previous results, going from a maximum hydraulic conductivity of around 8×10^{-9} cm/s for the previous results to around 4×10^{-8} cm/s (see Figure 2). The hydraulic conductivity points for the fly ash currently disposed at the site range from less than 1×10^{-9} to 8×10^{-8} cm/s. The change in hydraulic conductivity from the Sherco ash is less than the variability now seen for the fly ash.

Based on the results of the leaching study of the Sherco scrubber material and the fly ash currently disposed of in the landfill, disposal of the Sherco ash may cause a slight increase in the liner permeability, but the permeability should still be well below 1×10^{-7} cm/s.

FIGURES 1 and 2

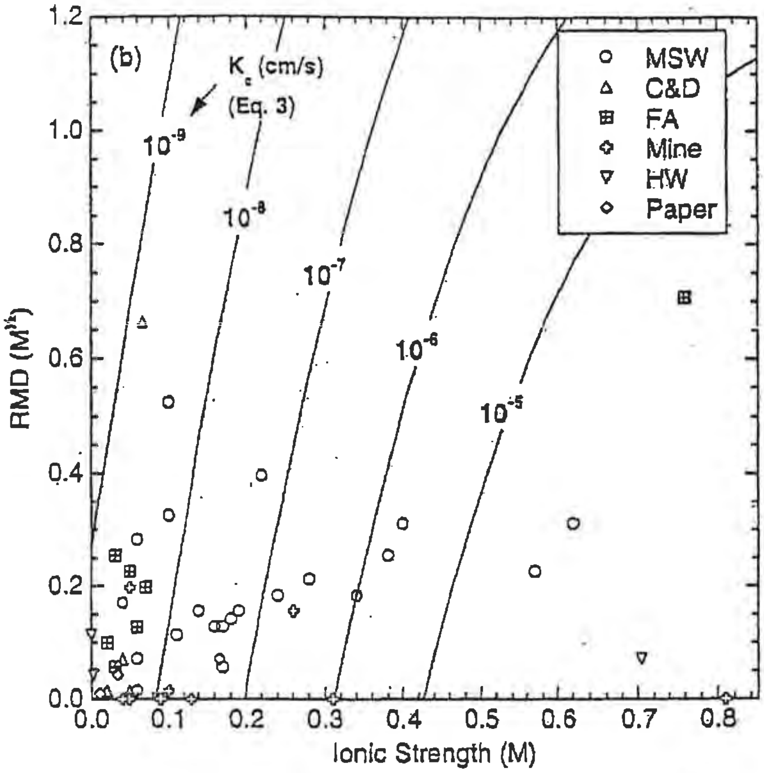

Fig. 1. Contours of hydraulic conductivity as a function of RMD and ionic strength predicted with Eq. 3 along points corresponding to ionic strength and RMD of various leachates. Data from Williams (1975) (I = 1.87 M and RMD = 0) and Kolstad (2000) (I = 1.37 M and RMD = 2.52 mM^{½}) are off the scale in (b).

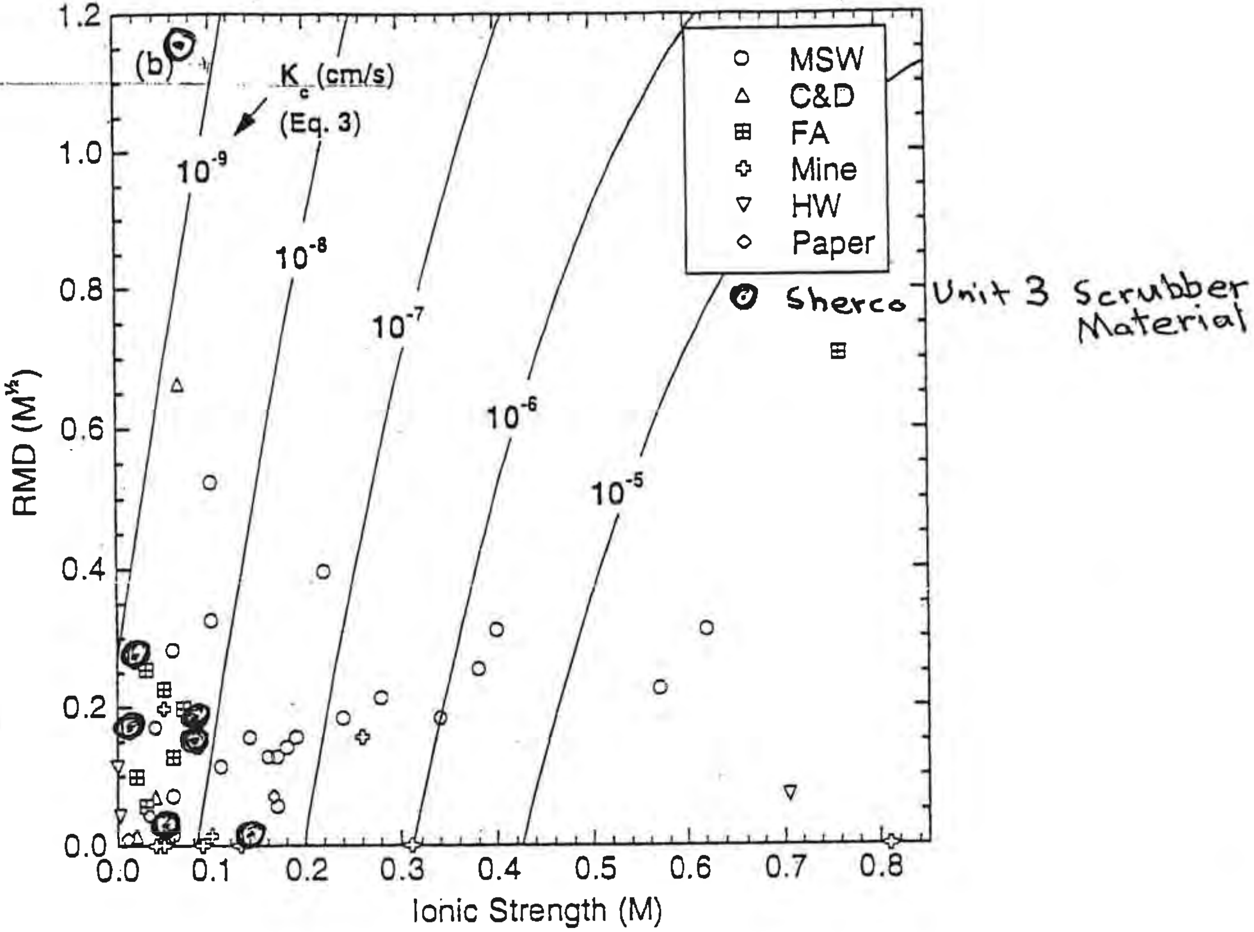

Figure 2 The graph showing the relationship of hydraulic conductivity with changes in ionic strength and RMD. The graph is from Kolstad et al. (2004) (corrected figure), with the data points for the DPC fly ash leachates shown as well.

Prepared by: R. Stanforth 3/30/09

Checked by: C. Madsen 4/1/09

TABLES 1, 2, 3 and 4

Table 1.
Compositional Analysis of Sherco Unit 3 material and Fly Ash from other DPC Units.

Parameter	Compositional Analysis of Fly Ash from, mg/kg			
	Genoa*	Alma*	JPM*	Sherco
Aluminum	32,600	37,000	59,200	69,800
Antimony	0.157	<0.146	0.078	0.74 (J)
Arsenic	109	76.2	56.0	7.7 (J)
Barium	73.1	11	113	123
Beryllium	5.07	5.0	1.60	1.3
Boron	127	110	63	701
Cadmium	1.80	2.09	2.29	0.34
Calcium	26,900	69,200	98,800	147,000
Chromium	60.7	49.5	69.2	27.2
Cobalt	9.0	10.1	7.9	2.7
Copper	73.8	88.3	156	37.6
Iron	41,300	18,500	22,700	11,000
Lead	95.3	53.8	31.4	28.4
Magnesium	6,080	10,700	23,900	7,630
Manganese	87.0	148	311	310
Molybdenum	12.1	15.0	1.46	4.2
Nickel	47.3	52.6	33.3	8.3
Selenium	1.82	5.55	1.02	3.8 (J)
Silver	0.23	0.062	0.25	0.63
Sodium	2,060	5,300	5,710	7,840
Strontium	558	1,500	1,960	2,980
Thallium	2.07	1.65	0.086	<1.9
Vanadium	155	206	24	42.8
Zinc	101	156	30.7	15.1

(J) – Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

* results from Feasibility Report - Phase IV Disposal Area Alma Off-Site Disposal Facility, September, 1997

Table 2

Analysis of Leachate from ASTM Water Leaching Test on Sherco Unit 3 Material

Parameter	Units	Leachate Concentration
pH	su	12.1
Total Dissolved Solids	µg/L	1,680,000
Specific Conductance	µmhos/cm	2490
Sulfate	µg/L	784,000
Aluminum	µg/L	630
Antimony	µg/L	1.8 (J)
Arsenic	µg/L	2.7 (J)
Barium	µg/L	2,600
Beryllium	µg/L	<0.040
Boron	µg/L	400
Cadmium	µg/L	0.21 (J)
Calcium	µg/L	483,000
Chromium	µg/L	110
Copper	µg/L	3.0 (J)
Iron	µg/L	<7.2
Lead	µg/L	2.7 (J)
Magnesium	µg/L	93 (J)
Manganese	µg/L	<0.66
Mercury	µg/L	<0.10
Nickel	µg/L	0.33 (J)
Selenium	µg/L	21
Silver	µg/L	<0.34
Sodium	µg/L	10,400
Thallium	µg/L	<1.4
Zinc	µg/L	<2.6

(J) – Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

Table 3

Results of the DPL Leachate Generation Procedure on the Sherco material and on the annual composites of the fly ash currently disposed in the landfill

Parameter		DPL Leachate Concentration in Year								
ID	units	1997	2000	2003	2004	2005	2006	2007	Sherco	
Boron	µg/L	9700	240	8100	13000	30000	73000	7630	369	
Calcium	µg/L	97000	120000	87000	200000	570000	550000	383000	1,280,000	
Chromium	µg/L		4.1	580	5900	870	980	764	988	
Potassium	µg/L	71000	16000	47000	75000	44000	81000	36600	42,300	
Sodium	µg/L	1,300,000	330,000	160,000	2,900,000	410,000	430,000	350,000	144,000	
Chloride	Mg/L	13	13	27	42	90	62	18.7	548	
Specific Conductance	µmhos/cm	10,000	3,900	2,500	9,900	3,800	3,800	3,180	8,380	
Sulfate	Mg/L	<4.9	0.38	940	7,000	2,100	1,700	1,930	1,260	
TSS	Mg/L	120	40	<2.5	100	2.2	1.8	<0.78	6.0(J)	

Table 4

Results of the DPL Leachate Genertaion Procedure presented in molar units, and the calculated ionic strength and RMD values for the leachates.

Parameter		DPL Leachate Concentration in Year								
ID	units	1997	2000	2003	2004	2005	2006	2007	Sherco	
Calcium	mM	2.43	3.00	2.18	5.0	14.3	13.8	9.58	32	
Potassium	mM	1.82	0.41	1.21	1.92	1.13	2.08	0.94	1.08	
Sodium	mM	56.5	14.3	6.96	126	17.8	18.7	15.2	6.26	
Ionic Strength (cations)	M	0.034	0.0134	0.00845	0.074	0.0381	0.038	0.0272	0.0677	
Estimated total ionic strength		0.07	0.03	0.02	0.15	0.08	0.08	0.05	0.14	
RMD	√M	1.18	0.268	0.175	1.81	0.158	0.177	0.165	0.041	

APPENDIX A

Pace Laboratory Test Results

Pace Analytical®
www.pacelabs.com

Pace Analytical Services, Inc.
1241 Bellevue Street - Suite 9
Green Bay, WI 54302
(920)469-2436

March 09, 2009

CURT MADSEN
RMT - MADISON
744 HEARTLAND TRAIL
Madison, WI 53717

RE: Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Dear CURT MADSEN:

Enclosed are the analytical results for sample(s) received by the laboratory on February 20, 2009. The results relate only to the samples included in this report. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Tod Noltemeyer

Tod Noltemeyer

tod.noltemeyer@pacelabs.com
Project Manager

Enclosures

CERTIFICATIONS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Green Bay Certification IDs
Wisconsin DATCP Certification #: 105-444
Wisconsin DATCP Certification #: 105-444
Wisconsin Certification #: 405132750
Wisconsin Certification #: 405132750
South Carolina Certification #: 83006001
South Carolina Certification #: 83006001
North Dakota Certification #: R-200
North Dakota Certification #: R-150
North Carolina Certification #: 503
North Carolina Certification #: 503
New York Certification #: 11888
New York Certification #: 11887
Minnesota Certification #: 055-999-334
Minnesota Certification #: 055-999-334
Louisiana Certification #: 04169
Louisiana Certification #: 04168
Kentucky Certification #: 83
Kentucky Certification #: 82
Illinois Certification #: 200051
Illinois Certification #: 200050
Florida/NELAP Certification #: E87951
Florida/NELAP Certification #: E87948

SAMPLE SUMMARY

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Lab ID	Sample ID	Matrix	Date Collected	Date Received
4014247001	CONC. LEACHATE-PRESERVED	Water	02/18/09 16:00	02/20/09 08:30
4014247002	CONC. LEACHATE	Water	02/18/09 16:00	02/20/09 08:30
4014247003	SHERCO #3 SCRUBBER MAT	Solid	02/18/09 16:00	02/20/09 08:30
4014247004	SHERCO #3 SCRUBBER MAT	Water	02/18/09 16:00	02/20/09 08:30

SAMPLE ANALYTE COUNT

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Lab ID	Sample ID	Method	Analysts	Analytes Reported
4014247001	**CONC. LEACHATE-PRESERVED**	EPA 6010	DLB	5
4014247002	**CONC. LEACHATE**	EPA 120.1	MY	1
		EPA 300.0	DDY	2
		SM 2540D	RRS	1
4014247003	**SHERCO #3 SCRUBBER MAT**	ASTM D2974-87	MRN	1
		EPA 300.0	DDY	1
		EPA 6010	MES	20
		EPA 6010	MES	24
		EPA 7470	LMS	1
4014247004	**SHERCO #3 SCRUBBER MAT**	EPA 120.1	DEY	1
		SM 2540C	DEY	1
		SM 4500-H+B	DEY	1

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: EPA 6010
Description: 6010 MET ICP
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 3050 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

QC Batch: MPRP/2297

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 4014313009

M0: Matrix spike recovery was outside laboratory control limits.

- MS (Lab ID: 129565)
  - Antimony
  - Chromium
  - Copper
  - Nickel
  - Thallium
  - Vanadium
- MSD (Lab ID: 129566)
  - Antimony
  - Chromium
  - Copper
  - Nickel
  - Strontium
  - Thallium
  - Vanadium

R1: RPD value was outside control limits.

- MS (Lab ID: 129565)

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **EPA 6010**
Description: 6010 MET ICP
Client: RMT - MADISON
Date: March 09, 2009

QC Batch: MPRP/2297

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 4014313009

R1: RPD value was outside control limits.

- Barium
- Lead
- Manganese
- Sodium
- MSD (Lab ID: 129566)
  - Barium
  - Lead
  - Manganese
  - Sodium
  - Zinc

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

Analyte Comments:

QC Batch: MPRP/2297

D3: Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.

- SHERCO #3 SCRUBBER MAT (Lab ID: 4014247003)
  - Arsenic
  - Antimony
  - Selenium
  - Thallium

PROJECT NARRATIVE

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Method: **EPA 6010**
Description: 6010 MET ICP, ASTM
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 3010 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

Analyte Comments:

QC Batch: MPRP/2296

2j: Analyte was detected in the associated extraction blank at 0.0026 mg/L.
- SHERCO #3 SCRUBBER MAT (Lab ID: 4014247003)
  - Copper

3j: Analyte was detected in the associated extraction blank at 0.21 mg/L.
- SHERCO #3 SCRUBBER MAT (Lab ID: 4014247003)
  - Nickel

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: EPA 6010
Description: 6010 MET ICP, Dissolved
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 6010 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **EPA 7470**
Description: 7470 Mercury, ASTM D3938
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 7470. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 7470 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **ASTM D2974-87**
Description: Percent Moisture
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for ASTM D2974-87. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Method: **EPA 120.1**
Description: 120.1 Specific Conductance
Client: RMT - MADISON
Date: March 09, 2009

General Information:
2 samples were analyzed for EPA 120.1. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

Analyte Comments:

QC Batch: WET/3138

1j: Analyte was detected in the associated ASTM blank at 1.51umho/cm.
- SHERCO #3 SCRUBBER MAT (Lab ID: 4014247004)
  - Specific Conductance

PROJECT NARRATIVE

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Method: **SM 2540C**
Description: 2540C Total Dissolved Solids
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for SM 2540C. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **SM 2540D**
Description: 2540D Total Suspended Solids
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for SM 2540D. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **SM 4500-H+B**
Description: 4500H+ pH, Electrometric
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for SM 4500-H+B. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

H6: Analysis initiated more than 15 minutes after sample collection.
- SHERCO #3 SCRUBBER MAT (Lab ID: 4014247004)

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **EPA 300.0**
Description: 300.0 IC Anions 28 Days,Diss
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 300.0. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

PROJECT NARRATIVE

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

Method: **EPA 300.0**
Description: 300.0 IC Anions ASTM 28 Days
Client: RMT - MADISON
Date: March 09, 2009

General Information:
1 sample was analyzed for EPA 300.0. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

This data package has been reviewed for quality and completeness and is approved for release.

ANALYTICAL RESULTS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Sample: CONC. LEACHATE-PRESERVED **Lab ID: 4014247001** Collected: 02/18/09 16:00 Received: 02/20/09 08:30 Matrix: Water

Parameters	Results	Units	LOQ	LOD	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP, Dissolved	Analytical Method: EPA 6010 Preparation Method: EPA 6010								
Boron, Dissolved	**369**	ug/L	100	0.36	1	03/02/09 08:30	03/03/09 22:31	7440-42-8	
Calcium, Dissolved	**1280000**	ug/L	2000	90.4	10	03/02/09 08:30	03/04/09 10:26	7440-70-2	P6
Chromium, Dissolved	**988**	ug/L	5.0	1.1	1	03/02/09 08:30	03/03/09 22:31	7440-47-3	
Potassium, Dissolved	**42300**	ug/L	2000	399	10	03/02/09 08:30	03/05/09 10:35	7440-09-7	P6
Sodium, Dissolved	**144000**	ug/L	1000	12.9	1	03/02/09 08:30	03/03/09 22:31	7440-23-5	P6

ANALYTICAL RESULTS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Sample: CONC. LEACHATE **Lab ID: 4014247002** Collected: 02/18/09 16:00 Received: 02/20/09 08:30 Matrix: Water

Parameters	Results	Units	LOQ	LOD	DF	Prepared	Analyzed	CAS No.	Qual
120.1 Specific Conductance	Analytical Method: EPA 120.1								
Specific Conductance	**8380**	umhos/cm	10.0	1.2	1		02/24/09 10:00		
2540D Total Suspended Solids	Analytical Method: SM 2540D								
Total Suspended Solids	**6.0J**	mg/L	10.0	3.1	1		02/24/09 09:08		
300.0 IC Anions 28 Days,Diss	Analytical Method: EPA 300.0								
Chloride, Dissolved	**548**	mg/L	500	106	100		03/04/09 00:17	16887-00-6	
Sulfate, Dissolved	**1260**	mg/L	400	51.0	100		03/04/09 00:17	14808-79-8	

ANALYTICAL RESULTS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Sample: SHERCO #3 SCRUBBER MAT **Lab ID: 4014247003** Collected: 02/18/09 16:00 Received: 02/20/09 08:30 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	LOQ	LOD	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**69800**	mg/kg	253	6.3	10	02/25/09 09:45	02/26/09 15:43	7429-90-5	
Antimony	**0.74J**	mg/kg	10.1	0.60	10	02/25/09 09:45	02/26/09 15:43	7440-36-0	D3
Arsenic	**7.7J**	mg/kg	10.1	0.60	10	02/25/09 09:45	02/26/09 15:43	7440-38-2	D3
Barium	**123**	mg/kg	0.25	0.053	1	02/25/09 09:45	02/25/09 22:13	7440-39-3	
Beryllium	**1.3**	mg/kg	0.20	0.0026	1	02/25/09 09:45	02/25/09 22:13	7440-41-7	
Boron	**701**	mg/kg	10.1	0.35	2	02/25/09 09:45	02/26/09 15:48	7440-42-8	
Cadmium	**0.34**	mg/kg	0.25	0.0064	1	02/25/09 09:45	02/25/09 22:13	7440-43-9	
Calcium	**147000**	mg/kg	101	23.8	10	02/25/09 09:45	02/26/09 15:43	7440-70-2	
Chromium	**27.2**	mg/kg	2.5	0.29	10	02/25/09 09:45	02/26/09 15:43	7440-47-3	
Cobalt	**2.7**	mg/kg	0.51	0.030	2	02/25/09 09:45	02/26/09 15:48	7440-48-4	
Copper	**37.6**	mg/kg	0.51	0.16	1	02/25/09 09:45	02/25/09 22:13	7440-50-8	
Iron	**11000**	mg/kg	5.1	0.37	1	02/25/09 09:45	02/25/09 22:13	7439-89-6	
Lead	**28.4**	mg/kg	5.1	0.34	10	02/25/09 09:45	02/26/09 15:43	7439-92-1	
Magnesium	**7630**	mg/kg	10.1	0.82	1	02/25/09 09:45	02/25/09 22:13	7439-95-4	
Manganese	**310**	mg/kg	0.25	0.016	1	02/25/09 09:45	02/25/09 22:13	7439-96-5	
Molybdenum	**4.2**	mg/kg	1.0	0.012	1	02/25/09 09:45	02/25/09 22:13	7439-98-7	
Nickel	**8.3**	mg/kg	0.51	0.022	1	02/25/09 09:45	02/25/09 22:13	7440-02-0	
Selenium	**3.8J**	mg/kg	10.1	0.74	10	02/25/09 09:45	02/26/09 15:43	7782-49-2	D3
Silver	**0.63**	mg/kg	0.51	0.011	1	02/25/09 09:45	02/25/09 22:13	7440-22-4	
Sodium	**7840**	mg/kg	101	2.2	2	02/25/09 09:45	02/26/09 15:48	7440-23-5	
Strontium	**2980**	mg/kg	2.5	0.14	10	02/25/09 09:45	02/26/09 15:43	7440-24-6	
Thallium	**<1.9**	mg/kg	20.3	1.9	10	02/25/09 09:45	02/26/09 15:43	7440-28-0	D3
Vanadium	**42.8**	mg/kg	0.51	0.046	2	02/25/09 09:45	02/26/09 15:48	7440-62-2	
Zinc	**15.6**	mg/kg	2.0	0.22	1	02/25/09 09:45	02/25/09 22:13	7440-66-6	
6010 MET ICP, ASTM	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Aluminum	**0.63**	mg/L	0.50	0.015	1	02/25/09 09:18	02/25/09 16:51	7429-90-5	
Antimony	**0.0018J**	mg/L	0.020	0.0010	1	02/25/09 09:18	02/25/09 16:51	7440-36-0	
Arsenic	**0.0027J**	mg/L	0.020	0.0012	1	02/25/09 09:18	02/25/09 16:51	7440-38-2	
Barium	**2.6**	mg/L	0.0050	0.00033	1	02/25/09 09:18	02/25/09 16:51	7440-39-3	
Beryllium	**<0.000040**	mg/L	0.0040	0.000040	1	02/25/09 09:18	02/25/09 16:51	7440-41-7	
Boron	**0.40**	mg/L	0.10	0.00036	1	02/25/09 09:18	02/25/09 16:51	7440-42-8	
Cadmium	**0.00021J**	mg/L	0.0050	0.00013	1	02/25/09 09:18	02/25/09 16:51	7440-43-9	
Calcium	**483**	mg/L	0.40	0.018	2	02/25/09 09:18	02/26/09 13:31	7440-70-2	P6
Chromium	**0.11**	mg/L	0.0050	0.0011	1	02/25/09 09:18	02/25/09 16:51	7440-47-3	
Copper	**0.0030J**	mg/L	0.010	0.00049	1	02/25/09 09:18	02/25/09 16:51	7440-50-8	2j
Iron	**<0.0072**	mg/L	0.10	0.0072	1	02/25/09 09:18	02/25/09 16:51	7439-89-6	
Lead	**0.0027J**	mg/L	0.010	0.0014	1	02/25/09 09:18	02/25/09 16:51	7439-92-1	
Magnesium	**0.093J**	mg/L	0.20	0.024	1	02/25/09 09:18	02/25/09 16:51	7439-95-4	
Manganese	**<0.00066**	mg/L	0.0050	0.00066	1	02/25/09 09:18	02/25/09 16:51	7439-96-5	
Nickel	**0.00033J**	mg/L	0.010	0.00015	1	02/25/09 09:18	02/25/09 16:51	7440-02-0	3j
Selenium	**0.021**	mg/L	0.020	0.0016	1	02/25/09 09:18	02/25/09 16:51	7782-49-2	
Silver	**<0.00034**	mg/L	0.010	0.00034	1	02/25/09 09:18	02/25/09 16:51	7440-22-4	
Sodium	**10.4**	mg/L	1.0	0.013	1	02/25/09 09:18	02/25/09 16:51	7440-23-5	

ANALYTICAL RESULTS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Sample: SHERCO #3 SCRUBBER MAT **Lab ID: 4014247003** Collected: 02/18/09 16:00 Received: 02/20/09 08:30 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	LOQ	LOD	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP, ASTM	Analytical Method: EPA 6010 Preparation Method: EPA 3010								
Thallium	**<0.0014**	mg/L	0.040	0.0014	1	02/25/09 09:18	02/25/09 16:51	7440-28-0	
Zinc	**<0.0026**	mg/L	0.040	0.0026	1	02/25/09 09:18	02/25/09 16:51	7440-66-6	
7470 Mercury, ASTM D3938	Analytical Method: EPA 7470 Preparation Method: EPA 7470								
Mercury	**<0.10**	ug/L	0.20	0.10	1	03/04/09 15:41	03/05/09 11:30	7439-97-6	
Percent Moisture	Analytical Method: ASTM D2974-87								
Percent Moisture	**1.5**	%	0.10	0.10	1		02/21/09 08:13		
300.0 IC Anions ASTM 28 Days	Analytical Method: EPA 300.0								
Sulfate	**784**	mg/L	200	18.0	50		03/05/09 18:30	14808-79-8	

ANALYTICAL RESULTS

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

Sample: SHERCO #3 SCRUBBER MAT **Lab ID: 4014247004** Collected: 02/18/09 16:00 Received: 02/20/09 08:30 Matrix: Water

Parameters	Results	Units	LOQ	LOD	DF	Prepared	Analyzed	CAS No.	Qual
120.1 Specific Conductance	Analytical Method: EPA 120.1								
Specific Conductance	**2490**	umhos/cm	10.0	1.2	1		04/06/09 10:00		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**1680**	mg/L	20.0	12.0	1		02/25/09 11:30		
4500H+ pH, Electrometric	Analytical Method: SM 4500-H+B								
pH at 25 Degrees C	**12.1**	Std. Units	0.10	0.010	1		02/23/09 13:00		H6

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: PMST/2240
QC Batch Method: ASTM D2974-87
Associated Lab Samples: 4014247003

Analysis Method: ASTM D2974-87
Analysis Description: Dry Weight/Percent Moisture

SAMPLE DUPLICATE: 128622

Parameter	Units	4014248001 Result	Dup Result	RPD	Max RPD	Qualifiers
Percent Moisture	%	21.5	19.7	9	10	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WET/3123
QC Batch Method: SM 4500-H+B
Associated Lab Samples: 4014247004

Analysis Method: SM 4500-H+B
Analysis Description: 4500H+B pH

SAMPLE DUPLICATE: 129074

Parameter	Units	4014247004 Result	Dup Result	RPD	Max RPD	Qualifiers
pH at 25 Degrees C	Std. Units	12.1	12.1	.2	5	H6

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WET/3126
QC Batch Method: SM 2540D
Associated Lab Samples: 4014247002
Analysis Method: SM 2540D
Analysis Description: 2540D Total Suspended Solids

METHOD BLANK: 129143
Matrix: Water
Associated Lab Samples: 4014247002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Total Suspended Solids	mg/L	<0.31	1.0	02/24/09 09:08	

LABORATORY CONTROL SAMPLE: 129144

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Suspended Solids	mg/L	459	424	92	80-120	

SAMPLE DUPLICATE: 129145

Parameter	Units	4014301001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Suspended Solids	mg/L	144	142	1	10	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WET/3133
QC Batch Method: EPA 120.1
Associated Lab Samples: 4014247002

Analysis Method: EPA 120.1
Analysis Description: 120.1 Specific Conductance

METHOD BLANK: 129474
Matrix: Water
Associated Lab Samples: 4014247002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Specific Conductance	umhos/cm	<1.2	10.0	02/24/09 10:00	

LABORATORY CONTROL SAMPLE: 129475

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Specific Conductance	umhos/cm	345	341	99	80-120	

SAMPLE DUPLICATE: 129476

Parameter	Units	4014100002 Result	Dup Result	RPD	Max RPD	Qualifiers
Specific Conductance	umhos/cm	811	813	.2	20	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: MPRP/2296
QC Batch Method: EPA 3010
Associated Lab Samples: 4014247003

Analysis Method: EPA 6010
Analysis Description: 6010 MET ASTM

METHOD BLANK: 129558

Matrix: Water

Associated Lab Samples: 4014247003

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/L	<0.015	0.50	02/25/09 16:44	
Antimony	mg/L	<0.0010	0.020	02/25/09 16:44	
Arsenic	mg/L	<0.0012	0.020	02/25/09 16:44	
Barium	mg/L	<0.00033	0.0050	02/25/09 16:44	
Beryllium	mg/L	<0.000040	0.0040	02/25/09 16:44	
Boron	mg/L	<0.00036	0.10	02/25/09 16:44	
Cadmium	mg/L	<0.00013	0.0050	02/25/09 16:44	
Calcium	mg/L	<0.0090	0.20	02/26/09 13:24	
Chromium	mg/L	<0.0011	0.0050	02/25/09 16:44	
Copper	mg/L	<0.00049	0.010	02/25/09 16:44	
Iron	mg/L	0.0092J	0.10	02/25/09 16:44	
Lead	mg/L	<0.0014	0.010	02/25/09 16:44	
Magnesium	mg/L	<0.024	0.20	02/25/09 16:44	
Manganese	mg/L	<0.00066	0.0050	02/25/09 16:44	
Nickel	mg/L	<0.00015	0.010	02/25/09 16:44	
Selenium	mg/L	<0.0016	0.020	02/25/09 16:44	
Silver	mg/L	<0.00034	0.010	02/25/09 16:44	
Sodium	mg/L	<0.013	1.0	02/25/09 16:44	
Thallium	mg/L	<0.0014	0.040	02/25/09 16:44	
Zinc	mg/L	<0.0026	0.040	02/25/09 16:44	

LABORATORY CONTROL SAMPLE: 129559

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/L	5	4.8	96	80-120	
Antimony	mg/L	.5	0.49	98	80-120	
Arsenic	mg/L	.5	0.48	95	80-120	
Barium	mg/L	.5	0.48	97	80-120	
Beryllium	mg/L	.5	0.49	98	80-120	
Boron	mg/L	.5	0.49	98	80-120	
Cadmium	mg/L	.5	0.47	94	80-120	
Calcium	mg/L	5	4.9	98	80-120	
Chromium	mg/L	.5	0.49	98	80-120	
Copper	mg/L	.5	0.48	95	80-120	
Iron	mg/L	5	5.0	100	80-120	
Lead	mg/L	.5	0.48	97	80-120	
Magnesium	mg/L	5	4.9	97	80-120	
Manganese	mg/L	.5	0.49	97	80-120	
Nickel	mg/L	.5	0.49	98	80-120	
Selenium	mg/L	.5	0.47	94	80-120	
Silver	mg/L	.25	0.25	98	80-120	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

LABORATORY CONTROL SAMPLE: 129559

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sodium	mg/L	5	5.0	101	80-120	
Thallium	mg/L	.5	0.47	94	80-120	
Zinc	mg/L	.5	0.49	99	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 129560 129561

Parameter	Units	4014247003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/L	0.63	5	5	5.6	5.6	99	100	75-125	.7	20	
Antimony	mg/L	0.0018J	.5	.5	0.53	0.53	105	105	75-125	.4	20	
Arsenic	mg/L	0.0027J	.5	.5	0.51	0.51	102	101	75-125	.4	20	
Barium	mg/L	2.6	.5	.5	3.0	3.0	82	81	75-125	.2	20	
Beryllium	mg/L	<0.000040	.5	.5	0.49	0.49	98	98	75-125	.06	20	
Boron	mg/L	0.40	.5	.5	0.90	0.90	101	101	75-125	.09	20	
Cadmium	mg/L	0.00021J	.5	.5	0.49	0.49	99	99	75-125	.1	20	
Calcium	mg/L	483	5	5	470	468	-248	-288	75-125	.4	20	P6
Chromium	mg/L	0.11	.5	.5	0.60	0.60	97	96	75-125	.4	20	
Copper	mg/L	0.0030J	.5	.5	0.50	0.50	99	99	75-125	.3	20	
Iron	mg/L	<0.0072	5	5	5.0	5.0	100	101	75-125	.3	20	
Lead	mg/L	0.0027J	.5	.5	0.48	0.49	96	97	75-125	.8	20	
Magnesium	mg/L	0.093J	5	5	4.9	4.9	96	97	75-125	.9	20	
Manganese	mg/L	<0.00066	.5	.5	0.49	0.49	98	98	75-125	.1	20	
Nickel	mg/L	0.00033J	.5	.5	0.49	0.49	98	98	75-125	.6	20	
Selenium	mg/L	0.021	.5	.5	0.53	0.53	101	101	75-125	.5	20	
Silver	mg/L	<0.00034	.25	.25	0.26	0.26	103	103	75-125	.08	20	
Sodium	mg/L	10.4	5	5	15.3	15.2	98	96	75-125	.8	20	
Thallium	mg/L	<0.0014	.5	.5	0.46	0.47	93	93	75-125	.5	20	
Zinc	mg/L	<0.0026	.5	.5	0.48	0.48	97	97	75-125	.1	20	

MATRIX SPIKE SAMPLE: 129562

Parameter	Units	4014288001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/L	21.97	5	26.7	95	75-125	
Antimony	mg/L	0.00211J	.5	0.50	99	75-125	
Arsenic	mg/L	0.002528J	.5	0.48	96	75-125	
Barium	mg/L	0.4721	.5	0.94	94	75-125	
Beryllium	mg/L	<0.000040	.5	0.49	98	75-125	
Boron	mg/L	0.625	.5	1.1	97	75-125	
Cadmium	mg/L	0.0001578J	.5	0.47	95	75-125	
Calcium	mg/L	70.97	5	75.9	99	75-125	
Chromium	mg/L	0.01262	.5	0.49	96	75-125	

QUALITY CONTROL DATA

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

MATRIX SPIKE SAMPLE: 129562

Parameter	Units	4014288001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Copper	mg/L	0.002597J	.5	0.48	96	75-125	
Iron	mg/L	<0.0072	5	5.1	101	75-125	
Lead	mg/L	0.002311J	.5	0.48	95	75-125	
Magnesium	mg/L	0.05902J	5	5.0	98	75-125	
Manganese	mg/L	<0.00066	.5	0.48	96	75-125	
Nickel	mg/L	0.0003864J	.5	0.48	96	75-125	
Selenium	mg/L	0.003411J	.5	0.48	95	75-125	
Silver	mg/L	<0.00034	.25	0.24	98	75-125	
Sodium	mg/L	123.5	5	125	38	75-125	P6
Thallium	mg/L	<0.0014	.5	0.46	91	75-125	
Zinc	mg/L	<0.0026	.5	0.49	97	75-125	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: MPRP/2297
QC Batch Method: EPA 3050
Analysis Method: EPA 6010
Analysis Description: 6010 MET
Associated Lab Samples: 4014247003

METHOD BLANK: 129563
Matrix: Solid
Associated Lab Samples: 4014247003

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/kg	<0.62	25.0	02/25/09 21:45	
Antimony	mg/kg	<0.060	1.0	02/25/09 21:45	
Arsenic	mg/kg	<0.059	1.0	02/25/09 21:45	
Barium	mg/kg	<0.053	0.25	02/25/09 21:45	
Beryllium	mg/kg	<0.0026	0.20	02/25/09 21:45	
Boron	mg/kg	1.1J	5.0	02/25/09 21:45	
Cadmium	mg/kg	<0.0063	0.25	02/25/09 21:45	
Calcium	mg/kg	<2.4	10.0	02/26/09 15:16	
Chromium	mg/kg	<0.028	0.25	02/25/09 21:45	
Cobalt	mg/kg	<0.015	0.25	02/25/09 21:45	
Copper	mg/kg	<0.16	0.50	02/25/09 21:45	
Iron	mg/kg	1.5J	5.0	02/25/09 21:45	
Lead	mg/kg	0.048J	0.50	02/25/09 21:45	
Magnesium	mg/kg	<0.81	10.0	02/26/09 15:16	
Manganese	mg/kg	0.023J	0.25	02/25/09 21:45	
Molybdenum	mg/kg	<0.012	1.0	02/25/09 21:45	
Nickel	mg/kg	<0.022	0.50	02/25/09 21:45	
Selenium	mg/kg	<0.073	1.0	02/25/09 21:45	
Silver	mg/kg	<0.011	0.50	02/25/09 21:45	
Sodium	mg/kg	4.8J	50.0	02/26/09 16:42	
Strontium	mg/kg	<0.014	0.25	02/25/09 21:45	
Thallium	mg/kg	<0.19	2.0	02/25/09 21:45	
Vanadium	mg/kg	<0.023	0.25	02/25/09 21:45	
Zinc	mg/kg	<0.22	2.0	02/25/09 21:45	

LABORATORY CONTROL SAMPLE: 129564

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	250	251	100	80-120	
Antimony	mg/kg	25	24.1	96	80-120	
Arsenic	mg/kg	25	24.2	97	80-120	
Barium	mg/kg	25	24.8	99	80-120	
Beryllium	mg/kg	25	24.6	98	80-120	
Boron	mg/kg	25	24.9	99	80-120	
Cadmium	mg/kg	25	23.9	96	80-120	
Calcium	mg/kg	250	237	95	80-120	
Chromium	mg/kg	25	24.8	99	80-120	
Cobalt	mg/kg	25	24.9	100	80-120	
Copper	mg/kg	25	24.0	96	80-120	
Iron	mg/kg	250	260	104	80-120	
Lead	mg/kg	25	24.1	96	80-120	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

LABORATORY CONTROL SAMPLE: 129564

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Magnesium	mg/kg	250	229	92	80-120	
Manganese	mg/kg	25	24.3	97	80-120	
Molybdenum	mg/kg	25	25.3	101	80-120	
Nickel	mg/kg	25	24.5	98	80-120	
Selenium	mg/kg	25	23.2	93	80-120	
Silver	mg/kg	12.5	12.0	96	80-120	
Sodium	mg/kg	250	270	108	80-120	
Strontium	mg/kg	25	24.4	98	80-120	
Thallium	mg/kg	25	23.4	93	80-120	
Vanadium	mg/kg	25	24.1	96	80-120	
Zinc	mg/kg	25	25.0	100	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 129565 129566

Parameter	Units	4014313009 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	17900	329	328	16000	13800	-577	-1250	75-125	15	20	P6
Antimony	mg/kg	0.57J	32.9	32.8	5.4	6.2	15	17	75-125	14	20	M0
Arsenic	mg/kg	9.4	32.9	32.8	36.1	35.9	81	81	75-125	.6	20	
Barium	mg/kg	308	32.9	32.8	299	406	-26	300	75-125	30	20	P6,R1
Beryllium	mg/kg	0.39	32.9	32.8	27.4	27.4	82	82	75-125	.06	20	
Boron	mg/kg	8.9	32.9	32.8	38.0	38.1	88	89	75-125	.2	20	
Cadmium	mg/kg	4.7	32.9	32.8	31.6	30.5	82	79	75-125	3	20	
Calcium	mg/kg	77100	329	328	92800	85300	4790	2500	75-125	8	20	P6
Chromium	mg/kg	23.1	32.9	32.8	43.9	40.5	63	53	75-125	8	20	M0
Cobalt	mg/kg	3.2	32.9	32.8	29.5	28.9	80	78	75-125	2	20	
Copper	mg/kg	28.6	32.9	32.8	43.9	40.0	47	35	75-125	9	20	M0
Iron	mg/kg	14000	329	328	20300	19000	1910	1530	75-125	6	20	P6
Lead	mg/kg	154	32.9	32.8	93.7	68.5	-184	-261	75-125	31	20	P6,R1
Magnesium	mg/kg	29900	329	328	34800	31700	1510	544	75-125	10	20	P6
Manganese	mg/kg	232	32.9	32.8	300	244	206	37	75-125	20	20	P6,R1
Molybdenum	mg/kg	1.0J	32.9	32.8	28.5	28.5	84	84	75-125	.2	20	
Nickel	mg/kg	10.2	32.9	32.8	34.4	32.5	74	68	75-125	6	20	M0
Selenium	mg/kg	<0.096	32.9	32.8	27.9	27.9	85	85	75-125	.08	20	
Silver	mg/kg	0.21J	16.5	16.5	15.8	15.7	95	94	75-125	.7	20	
Sodium	mg/kg	2030	329	328	2000	1550	-8	-146	75-125	25	20	P6,R1
Strontium	mg/kg	83.8	32.9	32.8	112	98.9	86	46	75-125	12	20	M0
Thallium	mg/kg	<0.25	32.9	32.8	24.1	24.1	73	73	75-125	.3	20	M0
Vanadium	mg/kg	27.5	32.9	32.8	50.9	47.9	71	62	75-125	6	20	M0
Zinc	mg/kg	203	32.9	32.8	211	270	23	206	75-125	25	20	P6,R1

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WET/3135
Analysis Method: SM 2540C
QC Batch Method: SM 2540C
Analysis Description: 2540C Total Dissolved Solids
Associated Lab Samples: 4014247004

METHOD BLANK: 129593
Matrix: Water
Associated Lab Samples: 4014247004

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	<12.0	20.0	02/25/09 11:28	

LABORATORY CONTROL SAMPLE: 129594

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	741	768	104	80-120	

SAMPLE DUPLICATE: 129595

Parameter	Units	4014247004 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	1680	1710	2	10	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WET/3138
QC Batch Method: EPA 120.1
Analysis Method: EPA 120.1
Analysis Description: 120.1 Specific Conductance
Associated Lab Samples: 4014247004

METHOD BLANK: 129717
Matrix: Water
Associated Lab Samples: 4014247004

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Specific Conductance	umhos/cm	<1.2	10.0	02/25/09 10:00	

LABORATORY CONTROL SAMPLE: 129718

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Specific Conductance	umhos/cm	345	332	96	80-120	

SAMPLE DUPLICATE: 129719

Parameter	Units	4014247004 Result	Dup Result	RPD	Max RPD	Qualifiers
Specific Conductance	umhos/cm	2.8J	2.8J		20	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: MPRP/2312
QC Batch Method: EPA 6010
Associated Lab Samples: 4014247001

Analysis Method: EPA 6010
Analysis Description: 6010 MET Dissolved

METHOD BLANK: 131035
Matrix: Water
Associated Lab Samples: 4014247001

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Boron, Dissolved	ug/L	0.85J	100	03/03/09 22:24	
Calcium, Dissolved	ug/L	9.5J	200	03/03/09 22:24	
Chromium, Dissolved	ug/L	<1.1	5.0	03/03/09 22:24	
Potassium, Dissolved	ug/L	<39.9	200	03/03/09 22:24	
Sodium, Dissolved	ug/L	<12.9	1000	03/03/09 22:24	

LABORATORY CONTROL SAMPLE: 131036

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Boron, Dissolved	ug/L	500	512	102	80-120	
Calcium, Dissolved	ug/L	5000	4900	98	80-120	
Chromium, Dissolved	ug/L	500	492	98	80-120	
Potassium, Dissolved	ug/L	5000	4970	99	80-120	
Sodium, Dissolved	ug/L	5000	5070	101	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 131037 131038

Parameter	Units	4014247001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Boron, Dissolved	ug/L	369	500	500	904	890	107	104	75-125	2	20	
Calcium, Dissolved	ug/L	1280000	5000	5000	1260000	1230000	-320	-900	75-125	2	20	P6
Chromium, Dissolved	ug/L	988	500	500	1450	1430	93	89	75-125	1	20	
Potassium, Dissolved	ug/L	42300	5000	5000	47100	45700	97	68	75-125	3	20	P6
Sodium, Dissolved	ug/L	144000	5000	5000	146000	143000	32	-20	75-125	2	20	P6

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WETA/3319
QC Batch Method: EPA 300.0
Analysis Method: EPA 300.0
Analysis Description: 300.0 IC Anions,Dissolved
Associated Lab Samples: 4014247002

METHOD BLANK: 131508
Matrix: Water
Associated Lab Samples: 4014247002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Chloride	mg/L	<1.1	5.0	03/03/09 18:36	
Sulfate	mg/L	<0.51	4.0	03/03/09 18:36	

LABORATORY CONTROL SAMPLE: 131509

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	20	19.3	97	90-110	
Sulfate	mg/L	20	18.9	95	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 131510 131511

Parameter	Units	1088653001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L		20	20	27.1	27.2	97	98	90-110	.5	20	
Sulfate	mg/L		20	20	28.2	28.3	92	93	90-110	.5	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 131512 131513

Parameter	Units	4014209001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	940	400	400	1360	1360	105	105	90-110	.2	20	
Sulfate	mg/L	51.3			73.1	73.3				.2	20	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch:	MERP/1452	Analysis Method:	EPA 7470
QC Batch Method:	EPA 7470	Analysis Description:	7470 Mercury ASTM

Associated Lab Samples: 4014247003

METHOD BLANK: 131948 Matrix: Water

Associated Lab Samples: 4014247003

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Mercury	ug/L	<0.10	0.20	03/05/09 11:22	

LABORATORY CONTROL SAMPLE: 131949

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Mercury	ug/L	5	4.9	98	85-115	

MATRIX SPIKE SAMPLE: 131950

Parameter	Units	4014247003 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Mercury	ug/L	<0.10	5	4.8	97	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 131951 131952

Parameter	Units	4014288001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Mercury	ug/L	<0.10	5	5	4.9	4.8	98	97	85-115	1	20	

QUALITY CONTROL DATA

Project: 3081.93 DAIRYLAND POWER COOP
Pace Project No.: 4014247

QC Batch: WETA/3344
QC Batch Method: EPA 300.0
Analysis Method: EPA 300.0
Analysis Description: 300.0 IC Anions ASTM
Associated Lab Samples: 4014247003

METHOD BLANK: 132275
Matrix: Water
Associated Lab Samples: 4014247003

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Sulfate	mg/L	<0.36	4.0	03/05/09 18:06	

LABORATORY CONTROL SAMPLE: 132276

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	20	18.8	94	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 132277 132278

Parameter	Units	4014247003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Sulfate	mg/L	784	1000	1000	1720	1720	94	93	80-120	.09	20	

QUALIFIERS

Project:	3081.93 DAIRYLAND POWER COOP
Pace Project No.:	4014247

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

Pace Analytical is NELAP accredited. Contact your Pace PM for the current list of accredited analytes.

U - Indicates the compound was analyzed for, but not detected.

ANALYTE QUALIFIERS

1j	Analyte was detected in the associated ASTM blank at 1.51umho/cm.
2j	Analyte was detected in the associated extraction blank at 0.0026 mg/L.
3j	Analyte was detected in the associated extraction blank at 0.21 mg/L.
D3	Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.
H6	Analysis initiated more than 15 minutes after sample collection.
M0	Matrix spike recovery was outside laboratory control limits.
P6	Matrix spike recovery was outside laboratory control limits due to a parent sample concentration notably higher than the spike level.
R1	RPD value was outside control limits.

RMT

CHAIN OF CUSTODY RECORD

✓ ↙

№ 063214

744 Heartland Trail, P.O. Box 8923 • Madison, WI 53708-8923 • Phone (608) 831-4444 • FAX (608) 831-3334

Project No.: 3081.93

Project/Client: Dairyland Power Coop

Project Manager/Contact Person: Curt Madsen

Filtered (Yes/No): Y / Y / Y

Preserved (Code): B / A / A

PRESERVED CODES
A - NONE
B - HNO_3
C - H_2SO_4
D - NaOH
E - HCl
F - METHANOL
G - ______

Lab No.	Yr. 09 Date	Time	Sample Station ID	Total Number Of Containers	MATRIX	B, Ca, Cr, K, Na	Chloride, Specific cond.	Sulfate, TSS	Al, Sb, As, Ba, Be, B, Cd	Ca, Cr, Co, Cu, Fe, Pb	Mg, Mn, Mo, Ni, Se, Ag	Na, Sr, Tl, V, Zn	ASTM D3987-85, pH, Hg and TDS, Sulfate, Specific Cond.	Comments:
001	2/18	4:00PM	Conc. Leachate - Preserved 500ml	1	Aq	X								Preserved to pH <2 w/ HNO_3
002	2/18	4:00PM	Conc. Leachate ↓	1	Aq		X	X						
003	2/18	4:00PM	Sherco #3 Scrubber Mat. 32oz	1	S				X	X	X	X	X	Use this sample for both
														total metals and Water leach
														test. Plenty of solid is
														provided. Comp Metals use
														this list.
														ASTM Water leach, use same metals
														list, but omit Co, Mo, Sr
														and V. Please measure pH

SPECIAL INSTRUCTIONS The analyte list for these may be confusing. See attached Memo.

After Water leach and also analyze Hg and TDS, Sulfate and Specific Conductivity

SAMPLER Relinquished by (Sig.)	Date/Time 2/19/09 7:00 AM	Received by ~~(Sig.)~~ D. Fenier	Date/Time 2/19/9 0850	HAZARDS ASSOCIATED WITH SAMPLES	Turn Around (circle one) [✓ Normal] Rush Report Due ______
Relinquished by ~~(Sig.)~~ D-Fenier	Date/Time 2/19/9 1700	Received by (Sig.) Walto	Date/Time	☐ Flammable ☐ Corrosive ☐ Highly Toxic ☐ Other (list) ______	(For Lab Use Only) #4014247 Receipt Temp: Temp Blank Y N ROI Receipt pH (Wet/Metals) OK
Relinquished by (Sig.) Walto	Date/Time 2/20/09 8:30	Received by (Sig.) L. Mann	Date/Time 2/20/09 8:30		

Custody Seal: Present/Absent Intact/Not Intact Seal #'s

F-268 (R6/95)

WHITE - LABORATORY COPY YELLOW - REPORT APPENDIX PINK - SAMPLER/SUBMITTER

Sample Condition Upon Receipt

Pace Analytical

Client Name: UMT

Project # 4014247

Optional
Proj. Due Date:
Proj. Name:

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☐ Client ☒ Commercial ☐ Pace Other ________

Tracking #: ________

Custody Seal on Cooler/Box Present: ☐ yes ☒ no Seals intact: ☐ yes ☐ no

Packing Material: ☐ Bubble Wrap ☐ Bubble Bags ☒ None ☐ Other ________

Thermometer Used NA

Type of Ice: [✓ Wet] Blue None

☐ Samples on ice, cooling process has begun

Cooler Temperature ROI

Temp should be above freezing to 6°C

Biological Tissue is Frozen: Yes No

Comments:

Date and Initials of person examining contents: U 2/20/09

Chain of Custody Present:	☒Yes	☐No	☐N/A	1.
Chain of Custody Filled Out:	☒Yes	☐No	☐N/A	2.
Chain of Custody Relinquished:	☒Yes	☐No	☐N/A	3.
Sampler Name & Signature on COC:	☒Yes	☐No	☐N/A	4.
Samples Arrived within Hold Time:	☒Yes	☐No	☐N/A	5.
Short Hold Time Analysis (<72hr):	☐Yes	☒No	☐N/A	6.
Rush Turn Around Time Requested:	☐Yes	☒No	☐N/A	7.
Sufficient Volume:	☒Yes	☐No	☐N/A	8.
Correct Containers Used:	☒Yes	☐No	☐N/A	9.
-Pace Containers Used:	U 2/2 ~~☒Yes~~	☒No	☐N/A	
Containers Intact:	☒Yes	☐No	☐N/A	10.
Filtered volume received for Dissolved tests	☐Yes	☐No	☒N/A	11.
Sample Labels match COC:	☒Yes	☐No	☐N/A	12.
-Includes date/time/ID/Analysis Matrix: W/S				
All containers needing preservation have been checked.	☒Yes	☐No	☐N/A	13.
All containers needing preservation are found to be in compliance with EPA recommendation.	☒Yes	☐No	☐N/A	
exceptions: VOA, coliform, TOC, O&G, WI-DRO (water)	☐Yes	☐No		Initial when completed U Lot # of added preservative
Samples checked for dechlorination:	☐Yes	☐No	☒N/A	14.
Headspace in VOA Vials (>6mm):	☐Yes	☐No	☒N/A	15.
Trip Blank Present:	☐Yes	☐No	☒N/A	16.
Trip Blank Custody Seals Present	☐Yes	☐No	☒N/A	
Pace Trip Blank Lot # (if purchased):________				

Client Notification/ Resolution:

Field Data Required? Y / N

Person Contacted: ________ Date/Time: ________

Comments/ Resolution: ________

Project Manager Review: DA **Date:** 2/26/09

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e out of hold, incorrect preservative, out of temp, incorrect containers)

F-ALLC003rev.3, 11September2006

DAVY LABORATORIES
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FAX (608) 784-6611

DAVY LABORATORIES
Division of Davy Engineering Co.

TABLE 1
BULK CHEMICAL ANALYSIS RESULTS FOR GENOA FLY ASH

Sample No. # 44641
Sample Site DPC Genoa Fly Ash

PARAMETER:	METHOD:	MDL:	RESULT:
Chloride as Cl(1:2)	EPA 325.2	0.6 ppm	22.1 mg/kg
Fluoride as F	EPA 340.2	0.002 ppm	1.48 mg/kg
Nitrate+Nitrite as NO3+NO2-N	EPA 353.1	0.01 ppm	0.24 mg/kg
Total Phosphorus as P	EPA 365.4	50 ppm	1,880 ppm
Moisture, %	EPA 160.3	---	0.0 %
Loss on Ignition	---	---	0.26 %
Total Organic Carbon	EPA 9060	0.01	2.0 %
Aluminum-Total	EPA 7020	200 ppm	32,600 mg/kg *
Antimony-Total	EPA 7041	0.015 ppm	0.157 mg/kg *
Arsenic-Total	EPA 7060	3.2 ppm	109 mg/kg *
Barium-Total	EPA 7080	0.6 ppm	73.1 mg/kg *
Beryllium-Total	EPA 7091	0.280 ppm	5.07 mg/kg *
Boron-Total	Jackson	6 ppm	127 mg/kg *
Cadmium-Total	EPA 7130	0.03 ppm	1.80 mg/kg *
Calcium -Total	EPA 7140	190 ppm	26,900 mg/kg *
Chromium-Total	EPA 7190	0.12 ppm	60.7 mg/kg *
Cobalt-Total	EPA 7201	0.1 ppm	9.0 mg/kg *
Copper-Total	EPA 7210	0.35 ppm	73.8 mg/kg *
Iron-Total	EPA 7380	540 ppm	41,300 mg/kg *
Lead-Total	EPA 7420	0.3 ppm	95.3 mg/kg *
Magnesium-Total	EPA 7450	20 ppm	6,080 mg/kg *
Manganese-Total	EPA 7460	0.6 ppm	87.0 mg/kg *
Mercury-Total	EPA 7471	0.018 ppm	0.305 mg/kg *
Molybdenum-Total	EPA 7481	0.260 ppm	12.1 mg/kg *
Nickel-Total	EPA 7520	0.38 ppm	47.3 mg/kg *
Potassium-Total	EPA 7610	105 ppm	3,070 mg/kg *
Selenium-Total	EPA 7740	0.248 ppm	1.82 mg/kg *
Silica-Total	SM 3111D	4.2 ppm	102 mg/kg *
Silver-Total	EPA 272.2	0.003 ppm	0.234 mg/kg *
Sodium-Total	EPA 7770	22 ppm	2,060 mg/kg *
Thallium-Total	EPA 7841	0.047 ppm	2.07 mg/kg *
Zinc-Total	EPA 7950	1.6 ppm	101 mg/kg *
Vanadium-Total	EPA 7910	.2 ppm	155 mg/kg *
Strontium-Total	SM 3113	15.5 ppm	558 mg/kg *
Tin-Total	EPA 282.2	0.273 ppm	3.40 mg/kg *

MDL = Minimum Detection Level
* Calculated on a 'dry weight' basis

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DAVY LABORATORIES
Division of Davy Engineering Co.

TABLE 1
BULK CHEMICAL ANALYSIS
RESULTS FOR ALMA FLY ASH

PARAMETER:	METHOD:	MDL:	RESULT:
Sample No.			# 44638
Sample Site			DPC Alma Fly Ash
Chloride as Cl(1:2)	EPA 325.2	0.6 ppm	47.4 mg/kg
Fluoride as F	EPA 340.2	0.002 ppm	2.75 mg/kg
Nitrate+Nitrite as NO3+NO2-N	EPA 353.1	0.01 ppm	0.24 mg/kg
Total Phosphorus as P	EPA 365.4	20 ppm	1,850 ppm
Moisture, %	EPA 160.3	---	0.0 %
Loss on Ignition	---	---	6.04 %
Total Organic Carbon	EPA 9060	0.01	6.1 %
Aluminum-Total	EPA 7020	200 ppm	37,000 mg/kg *
Antimony-Total	EPA 7041	0.146 ppm	<0.146 mg/kg *
✓Arsenic-Total	EPA 7060	1.28 ppm	76.2 mg/kg *
✓Barium-Total	EPA 7080	6 ppm	11 mg/kg *
Beryllium-Total	EPA 7091	0.280 ppm	5.00 mg/kg *
Boron-Total	Jackson	6 ppm	110 mg/kg *
✓Cadmium-Total	EPA 7130	0.03 ppm	2.09 mg/kg *
Calcium -Total	EPA 7140	380 ppm	69,200 mg/kg *
✓Chromium-Total	EPA 7190	0.12 ppm	49.5 mg/kg *
Cobalt-Total	EPA 7201	0.1 ppm	10.1 mg/kg *
Copper-Total	EPA 7210	0.14 ppm	88.3 mg/kg *
Iron-Total	EPA 7380	270 ppm	18,500 mg/kg *
✓Lead-Total	EPA 7420	0.3 ppm	53.8 mg/kg *
Magnesium-Total	EPA 7450	60 ppm	10,700 mg/kg *
Manganese-Total	EPA 7460	0.6 ppm	148 mg/kg *
✓Mercury-Total	EPA 7471	0.018 ppm	0.390 mg/kg *
Molybdenum-Total	EPA 7481	260 ppm	15.0 mg/kg *
Nickel-Total	EPA 7520	0.19 ppm	52.6 mg/kg *
Potassium-Total	EPA 7610	105 ppm	3,680 mg/kg *
✓Selenium-Total	EPA 7740	0.248 ppm	5.55 mg/kg *
Silica-Total	SM 3111D	4.2 ppm	36.4 mg/kg *
✓Silver-Total	EPA 272.2	0.001 ppm	0.062 mg/kg *
Sodium-Total	EPA 7770	110 ppm	5,300 mg/kg *
Thallium-Total	EPA 7841	0.047 ppm	1.65 mg/kg *
Zinc-Total	EPA 7950	1.6 ppm	156 mg/kg *
Vanadium-Total	EPA 7910	10 ppm	206 mg/kg *
Strontium-Total	SM 3113	78 ppm	1,500 mg/kg *
Tin-Total	EPA 282.2	0.273 ppm	6.06 mg/kg *

MDL = Minimum Detection Level
* Calculated on a 'dry weight' basis

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TABLE 1
BULK CHEMICAL ANALYSIS
RESULTS FOR JPM FLY ASH

Sample No.	# 44640
Sample Site	DPC JPM Fly Ash

PARAMETER:	METHOD:	MDL:	RESULT:
Chloride as Cl(1:2)	EPA 325.2	0.6 ppm	3.0 mg/kg
Fluoride as F	EPA 340.2	0.002 ppm	7.88 mg/kg
Nitrate+Nitrite as NO3+NO2-N	EPA 353.1	0.01 ppm	0.24 mg/kg
Total Phosphorus as P	EPA 365.4	20 ppm	3,490 ppm
Moisture, %	EPA 160.3	---	0.0 %
Loss on Ignition	---	---	0.41 %
Total Organic Carbon	EPA 9060	0.01	0.41 %
Aluminum-Total	EPA 7020	400 ppm	59,200 mg/kg
Antimony-Total	EPA 7041	0.015 ppm	0.078 mg/kg *
✓Arsenic-Total	EPA 7060	3.2 ppm	56.0 mg/kg *
✓Barium-Total	EPA 7080	6 ppm	113 mg/kg *
Beryllium-Total	EPA 7091	0.066 ppm	1.60 mg/kg *
Boron-Total	Jackson	6 ppm	63 mg/kg *
✓Cadmium-Total	EPA 7130	0.03 ppm	2.29 mg/kg *
Calcium -Total	EPA 7140	380 ppm	98,800 mg/kg *
✓Chromium-Total	EPA 7190	0.12 ppm	69.2 mg/kg *
Cobalt-Total	EPA 7201	0.1 ppm	7.9 mg/kg *
Copper-Total	EPA 7210	0.35 ppm	156 mg/kg *
Iron-Total	EPA 7380	540 ppm	22,700 mg/kg *
✓Lead-Total	EPA 7420	0.3 ppm	31.4 mg/kg *
Magnesium-Total	EPA 7450	100 ppm	23,900 mg/kg *
Manganese-Total	EPA 7460	1.2 ppm	311 mg/kg *
✓Mercury-Total	EPA 7471	0.018 ppm	<0.018 mg/kg *
Molybdenum-Total	EPA 7481	0.065 ppm	1.46 mg/kg *
Nickel-Total	EPA 7520	0.19 ppm	33.3 mg/kg *
Potassium-Total	EPA 7610	21 ppm	942 mg/kg *
✓Selenium-Total	EPA 7740	0.248 ppm	1.02 mg/kg *
Silica-Total	SM 3111D	21 ppm	355 mg/kg *
✓Silver-Total	EPA 272.2	0.003 ppm	0.251 mg/kg *
Sodium-Total	EPA 7770	110 ppm	5,710 mg/kg *
Thallium-Total	EPA 7841	0.005 ppm	0.086 mg/kg *
Zinc-Total	EPA 7950	0.4 ppm	30.7 mg/kg *
Vanadium-Total	EPA 7910	2 ppm	24 mg/kg *
Strontium-Total	SM 3113	155 ppm	1,960 mg/kg *
Tin-Total	EPA 282.2	0.273 ppm	<0.273 mg/kg *

MDL = Minimum Detection Level
* Calculated on a 'dry weight' basis

APPENDIX B

DPC Leachate Generation Procedure
(Revised August 4, 2008)

DPC Leachate Generation Procedure (revised 8/04/08)

This procedure is intended to simulate a high solid to liquid ratio leaching scenario. Use a ratio of 150 percent moisture to fly ash for leachate generation (e.g., 1000 grams fly ash/1500 mL H_2O) and concentrate the leachate through 5 iterations. Quarterly fly ash samples will be homogenized together to create one fly ash composite sample for leachate generation and testing.

1. Homogenize the quarterly samples in their individual buckets.
2. Create a fly ash composite using equal amounts of each quarterly sample and homogenize together.
3. Place 1,000 grams fly ash composite in a 2-liter bottle.
4. Add 1.5 liters deionized water to the bottle, and seal using an air/water-tight lid.
5. Perform the extraction by placing the bottle in a TCLP tumbler. Agitate the sample for a period of 14 – 18 hours in the tumbler end-over-end at a rate of 30 rotations per minute.
6. After the tumbling period, let the mixture settle for at least four hours and decant the supernatant by carefully pouring or using a peristaltic pump if available. Do not allow any solid material in the supernatant (leachate).
7. Measure and record the volume of the leachate.
8. Bring the volume of the leachate up to 1.5 liters with deionized water and place in a 2-liter bottle.
9. Add 1,000 grams of new fly ash composite (created in step 2) to the bottle with the re-used leachate (from step 8).
10. Repeat steps above as appropriate (i.e., reusing the leachate each time) until five iterations have been completed.
11. After the fifth iteration is complete, let the mixture sit for >24 hours to allow for maximum settling. After settling, decant the supernatant and measure volume. Pass leachate through a 0.45 µm filter using a vacuum filtration apparatus. Split the final leachate into two bottles appropriate for shipment. One bottle will remained unpreserved. Preserve the other sample according to method specifications (e.g., acidify to pH <2 for metals). Refrigerate samples and ship to laboratory for analysis.

Date	Volume of Leachate (mL)	Notes
	Final Volume:	

APPENDIX C

Hydraulic Conductivity and Swell of Nonprehydrated Geosyntehtic Clay Liners Permeated with Multispecies Inorganic Solutions

Dale C. Kolstad; et. al.

Hydraulic Conductivity and Swell of Nonprehydrated Geosynthetic Clay Liners Permeated with Multispecies Inorganic Solutions

Dale C. Kolstad, M.ASCE[1]; Craig H. Benson, M.ASCE[2]; and Tuncer B. Edil, M.ASCE[3]

Abstract: The influence of multispecies inorganic solutions on swelling and hydraulic conductivity of non-prehydrated geosynthetic clay liners (GCLs) containing sodium bentonite was examined. Ionic strength and the relative abundance of monovalent and divalent cations (RMD) in the permeant solution were found to influence swell of the bentonite, and the hydraulic conductivity of GCLs. Swell is directly related to RMD and inversely related to ionic strength, whereas hydraulic conductivity is directly related to ionic strength and inversely related to RMD. RMD has a greater influence for solutions with low ionic strength (e.g., 0.05 M), whereas concentration effects dominate at high ionic strength (e.g., 0.5 M). No discernable effect of cation species of similar valence was observed in the swell or hydraulic conductivity data for test solutions with similar ionic strength and RMD. A strong relationship between hydraulic conductivity and free swell was found, but the relationship must be defined empirically for a particular bentonite. A regression model relating hydraulic conductivity of the GCL to ionic strength and RMD of the permeant solution was developed. Predictions made with the model indicate that high hydraulic conductivities (i.e., $>10^{-7}$ cm/s) are not likely for GCLs in base liners in many solid waste containment facilities. However, for wastes with stronger leachates or leachates dominated by polyvalent cations, high hydraulic conductivities may occur.

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CE Database subject headings: Hydraulic conductivity; Swelling; Inorganic chemicals; Clay liners; Bentonite.

Introduction

Geosynthetic clay liners (GCLs) are factory-manufactured clay liners consisting of a layer of bentonite clay encased by geotextiles or glued to a geomembrane. GCLs have become a popular alternative to compacted clay liners in waste containment applications because of their relatively low cost, ease of installation, perceived resistance to environmental distress (e.g. freeze–thaw and wet–dry cycling), smaller air–space requirements, and low hydraulic conductivity to water ($<10^{-8}$ cm/s). For GCLs that do not contain a geomembrane, bentonite is responsible for the low hydraulic conductivity. Sodium (Na) montmorillonite mineral is the primary component of bentonite, and largely controls the hydraulic conductivity of GCLs (Shackelford et al. 2000).

A variety of studies have shown that the hydraulic conductivity and swelling of bentonite can be affected by inorganic permeant solutions (Alther et al. 1985; Shan and Daniel 1991; Egloffstein 1997, 2001; Quaranta et al. 1997; Ruhl and Daniel 1997; Petrov and Rowe 1997; Shackelford et al. 2000; Jo et al. 2001; Vasko et al. 2001; Ashmawy et al. 2002; Katsumi et al. 2002, 2003; Shan and Lai 2002). The general conclusion of these studies is that the hydraulic conductivity and swelling of GCLs is sensitive to the concentration of the permeant solution and the cation valence. In general, higher hydraulic conductivity and lower swell are obtained in more concentrated solutions or solutions with a preponderance of divalent cations. However, no systematic study has been made regarding how the concentration and relative proportions of monovalent and polyvalent cations in a multispecies (i.e., more than one cation species) solution affect swelling and hydraulic conductivity of bentonite and GCLs.

Several studies have been conducted in soil science regarding the effect of multispecies solutions on the hydraulic conductivity of montmorillonitic soils (Reeve and Bower 1960; McNeal and Coleman 1966; McNeal et al. 1966; Mustafa and Hamid 1975; Malik et al. 1992). However, these studies have focused on increasing the hydraulic conductivity of montmorillonitic soils for land drainage and agricultural applications rather than maintaining low hydraulic conductivity for containment applications. Moreover, none of these studies has focused on clay soils very rich in montmorillonite, such as the Na-bentonites used for GCLs.

This paper discusses how the ionic strength and relative amounts of monovalent and divalent cations in multispecies solutions affect swelling and hydraulic conductivity of nonprehydrated GCLs containing Na-bentonite. The focus is on applications where inorganic solutes are the primary factor affecting hydraulic conductivity (e.g., conventional solid waste containment facilities for municipal, hazardous, or mining wastes) and where complete prehydration (i.e., prehydration by permeation with distilled, deionized, or potable water) is unlikely. The effects of complete prehydration and organic compounds are discussed

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by others (e.g., Shan and Daniel 1991; Petrov and Rowe 1997; Ruhl and Daniel 1997; Shackelford et al. 2000).

Background

Exchangeable Cations, Mobility of Water, and Hydration of Bentonite

A weak interlayer bond allows the montmorillonite crystal layers to separate during hydration as water molecules enter the interlayer space (Grim 1968; van Olphen 1977). Consequently, cations on the interlayer surfaces become exchangeable, which renders the physical properties of Na-montmorillonite susceptible to interactions with the permeant liquid. The degree of exchange depends on the valence, relative abundance, and size of the cations. Generally, cations of greater valence and smaller size replace cations of lower valence and larger size. The preference for replacement is the lyotropic series, which is $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+ < Mg^{2+} < Ca^{2+} < Ba^{2+} < Cu^{2+} < Al^{3+} < Fe^{3+}$ (Sposito 1981; 1989; McBride 1994). Because Na^+ is at the lower end of the lyotropic series, Na-bentonites are prone to cation exchange when permeated with solutions containing divalent or trivalent ions (Sposito 1981).

Water in the pores of bentonite can be considered mobile or immobile. Mobile water is bulk pore water that is free to move under a hydraulic gradient. Immobile water is bound to the external and internal (i.e., interlayer) mineral surfaces by strong electrical forces, and is believed to act as an extension of the solid surface. When the amount of immobile water in the system increases, the hydraulic conductivity of bentonite decreases because the interparticle flow paths for mobile water become more constricted and tortuous. This is especially true in bentonites where swell is constrained (e.g., needle-punched GCLs or GCLs under confining pressure) (Reeve and Ramaddoni 1965; McNeal and Coleman 1966; McNeal et al. 1966; Lagerwerff et al. 1969; Mesri and Olson 1971; Petrov and Rowe 1997; Shackelford et al. 2000; Jo et al. 2001). Changes in the volume of immobile water also cause volume changes in the bentonite (swell occurs as the volume of immobile water increases). Thus swell and hydraulic conductivity are generally inversely related for bentonites (Shackelford et al. 2000; Jo et al. 2001; Ashmawy et al. 2002; Katsumi et al. 2002).

The fraction of the pore water that is immobile is proportional to the number of layers of water molecules hydrating the interlayer surfaces of the montmorillonite particles (McBride 1994). Hydration of montmorillonite in electrolyte solutions occurs in two phases: the crystalline phase and the osmotic phase (Norrish and Quirk 1954; McBride 1994, Zhang et al. 1995; Prost et al. 1998). The crystalline phase occurs first as several molecular layers of water hydrate the interlayer and outer surfaces from the completely dry state. Osmotic hydration occurs when additional water molecules hydrate the interlayer surfaces, resulting in large interlayer distances (McBride 1994). Crystalline hydration generally results in a small expansion of the interlayer space and a limited amount of immobile water, which is manifested at the macroscale as a small amount of swelling (referred to as "crystalline swell") and higher hydraulic conductivity. Osmotic hydration can result in appreciable expansion of the interlayer space, a large fraction of the pore water being bound, and is responsible for the large amount of swelling (referred to as "osmotic swell") and low hydraulic conductivity often associated with Na-bentonites.

When the interlayer cations are monovalent, both crystalline and osmotic hydration occur, allowing the interlayer spacings to become large. However, only crystalline swelling occurs when the interlayer cations are divalent or trivalent, limiting expansion of the interlayer region to approximately 1.96 nm (four layers of water molecules). Strong electrostatic attraction between the montmorillonite sheets and the interlayer cations prevent osmotic swelling when the cations are polyvalent, despite the larger hydration energy associated with polyvalent cations (McBride 1994; 1997; Quirk and Marčelja 1997). Thus, appreciable swelling and lower hydraulic conductivity occur when the interlayer cations are monovalent, whereas very little swelling and higher hydraulic conductivity occur when the cations are divalent or trivalent (Norrish and Quirk 1954; McBride 1994; Wu et al. 1994; Egloffstein 1997, 2001; Onikata et al. 1999; Jo et al. 2001; Ashmawy et al. 2002). In monovalent solutions, the volume of swelling and spacing of the interlayer region is inversely proportional to the square root of the concentration of the solution (Norrish and Quirk 1954; McBride 1994; Zhang et al. 1995; Onikata et al. 1999).

Hydraulic Conductivity to Single-Species Inorganic Solutions

Mesri and Olson (1971) studied the mechanisms controlling the hydraulic conductivity of bentonite when the interlayer cation was sodium or calcium. At similar void ratios, the hydraulic conductivity of Na-bentonite was approximately five times lower than that of the Ca-bentonite. Mesri and Olson (1971) attributed the lower hydraulic conductivity of the Na-bentonite to the presence of immobile water, which resulted in smaller and more tortuous flow paths for mobile water.

Petrov and Rowe (1997) investigated how NaCl solutions of varying concentration affected the hydraulic conductivity of a GCL containing Na-bentonite. Tests were conducted with distilled (DI) water and NaCl solutions having concentrations between 0.1–2.0 M. Hydraulic conductivity of the GCL generally increased as the NaCl concentration increased. At 2.0 M, the hydraulic conductivity was as much as 800 times higher than that with distilled water. For concentrations less than 0.1 M, the hydraulic conductivity was comparable to that obtained with distilled water. Prehydration with at least one pore volume of distilled water tempered the sensitivity of hydraulic conductivity to salt concentration. For 2.0 M NaCl, prehydration with distilled water resulted in a hydraulic conductivity 25 times lower than that obtained by direct permeation with 2.0 M NaCl. Tests conducted over a range of confining stresses (3 to 118 kPa) showed that, at a given concentration, the hydraulic conductivity can vary by a factor of 10 to 50 depending on the effective stress.

Jo et al. (2001) investigated how cation valence and concentration of single-species salt solutions affect free swell and hydraulic conductivity of nonprehydrated GCLs containing Na-bentonite. Salt solutions with cation valences of 1, 2, and 3 and concentrations between 0.005 and 1.0 M were used. All tests were conducted until the physical and chemical termination criteria in ASTM D 6766 were achieved. Permeation with salt solutions having concentrations less than 0.1 M (monovalent) or 0.01 M (divalent or trivalent) yielded hydraulic conductivities similar to those with DI water ($\approx 10^{-9}$ cm/s), regardless of cation valence. For higher concentrations, swell decreased and hydraulic conductivity increased as the concentration or valence increased. Swelling in the presence of monovalent cations followed the order of the hydrated radius (r_h) and the lyotropic series, with Li ($r_h \approx 0.6$ nm) solutions yielding the greatest swell and K (r_h

≈ 0.3 nm) solutions yielding the lowest swell at a given concentration. In contrast, hydraulic conductivity to the monovalent solutions was insensitive to cation species. No dependence on species was observed for swell or hydraulic conductivity when the solutions contained divalent or trivalent cations. In addition, solutions with trivalent cations resulted in swell and hydraulic conductivity essentially identical to those obtained with solutions having divalent cations at the same concentration.

Jo et al. (2001) conclude that swell and hydraulic conductivity depend more on valence at intermediate concentrations (0.025 M to 0.1 M), whereas concentration dominates at low (0.005 M) and high (1 M) concentrations. They also conclude that hydraulic conductivity and swelling have a strong inverse relationship, and suggest that swell tests can be used as an indicator of adverse chemical interactions that affect the hydraulic conductivity of GCLs.

Hydraulic Conductivity to Multispecies Inorganic Solutions

Reeve and Bower (1960) investigated how sodium adsorption ratio (SAR) of the permeant solution and electrolyte concentration affected the hydraulic conductivity of a sodic (sodium rich) soil with a montmorillonitic clay fraction. SAR is a ratio describing the relative amounts of sodium, calcium, and magnesium in the pore water equilibrated with the soil, and can be written as (McBride 1994):

$$\mathrm{SAR} = \left[\frac{\mathrm{Na}^{+}}{[(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})/2]^{1/2}} \right]_{e} \qquad (1)$$

where the cation (Na^+, Ca^{2+}, Mg^{2+}) concentrations are expressed in meq/L (note: 1 meq/L = 1 mN). The soil had a cation exchange capacity (CEC) = 8.9 meq/100 g. The permeant solutions were Salton sea water (SAR = 57) and diluted Salton sea water with SAR = 40, 27.2, 18.2, and 2.2. Reeve and Bower (1960) found that the rate of monovalent for divalent exchange is a function of the divalent cation concentration and SAR of the permeant solution. At a given SAR, solutions with higher ionic strength resulted in more rapid exchange and higher hydraulic conductivity.

McNeal and Coleman (1966) and McNeal et al. (1966) used Na–Ca solutions to investigate how concentration and SAR affect swelling and hydraulic conductivity of Gila clay from New Mexico, USA, which has CEC = 41.2 meq/100 g and consists of 29% montmorillonite. Swelling was quantified as the mass of "bound" solution per mass of clay. Test solutions were prepared with NaCl and $\mathrm{CaCl_2}$ salts at concentrations of 0.8, 0.2, 0.05, 0.012, and 0.003 mN with SAR = 0, 15, 25, 50, 100, and ∞. Specimens for hydraulic conductivity testing were initially equilibrated by permeation with 10 pore volumes of a 0.8 N solution having the same SAR as the test solution, and then were sequentially permeated with test solutions of decreasing concentration.

McNeal et al. (1966) found no appreciable swell in solutions with SAR = 0 (all divalent) regardless of concentration, which is consistent with the lack of an osmotic swelling phase when the interlayer contains polyvalent cations (Norrish and Quirk 1954). Measurable swelling began at 0.012 N and SAR = 25, and increased as the SAR of the solution increased. Decreases in hydraulic conductivity occurred with decreasing concentration and increasing SAR of the permeant solution. For example, the hydraulic conductivity was 1.5×10^{-5} cm/s for a 0.8 N solution with SAR = 0, 5.9×10^{-6} cm/s for a 0.050 N solution with SAR = 100, and 1.5×10^{-7} cm/s for a 0.012 N solution with SAR = ∞ (all sodium).

McNeal et al. (1966) concluded that salt concentration and SAR affect swelling and hydraulic conductivity of Gila clay in an inverse manner, which was also reported by Jo et al. (2001) for GCLs permeated with single-species solutions. Increasing the concentration or relative abundance of divalent cations (lower SAR) results in less swell and higher hydraulic conductivity. McNeal et al. (1966) postulate that swelling of montmorillonite is the dominant mechanism affecting its hydraulic conductivity because it affects the opening and closing of pores.

Mustafa and Hamid (1975) investigated how electrolyte concentration and SAR of the permeant solution affected the hydraulic conductivity of two montmorillonitic soils, one containing 32% montmorillonite and the other 14% montmorillonite. The hydraulic conductivity of both soils exhibited the same trends with concentration and SAR as reported by McNeal et al. (1966). However, Mustafa and Hamid (1975) indicate that the relationships between swell, hydraulic conductivity, and characteristics of the permeant solution are unique for each soil.

Malik et al. (1992) investigated how mixed Na–Ca solutions of various concentrations affect swelling, dispersion, and flow in two unsaturated clays reported to be montmorillonitic (the montmorillonite content was not reported). NaCl and $\mathrm{CaCl_2}$ solutions with SAR = 0, 5, 15, 25, and 50 and concentrations of 3.1, 12.5, 50, 200, and 500 mM were used. Their results were also similar to those reported by McNeal et al. (1966); swell of both soils increased and the hydraulic conductivity decreased as the concentration decreased or the SAR increased.

Materials and Methods

Geosynthetic Clay Liner

The GCL used in this study contains granular sodium bentonite encapsulated between a 170 g/m^2 slit-film monofilament woven geotextile and a 206 g/m^2 staple-fiber nonwoven geotextile. The geotextiles are bonded by needle-punching fibers that are thermally fused to the geotextiles. The specific gravity of the bentonite is 2.65, and the average mass of bentonite per area is 4.3 kg/m^2. The initial thickness of the GCL ranges from 5.5 to 6.5 mm, and the average initial gravimetric water content of the bentonite was 9%.

X-ray diffraction showed that the bentonite contains 86% montmorillonite, 3% quartz, 5% tridymite, 3% plagioclase feldspar, 1% K-feldspar, 1% aragonite, 1% illite/mica, and trace amounts of calcite, siderite, clinoptilolite, rutile, and gypsum. The granule size distribution for the GCL (determined by mechanical sieve analysis on the air-dry bentonite) is shown in Fig. 1 along with the granule size distribution for the GCL used by Jo et al. (2001). Both GCLs contain sand-size bentonite granules, but the GCL used in this study has smaller granules.

The CEC and composition of the exchange complex (Ca, Mg, Na, and K) were measured on two samples of bentonite from the GCL using the procedures in *Methods of Soil Analysis* (Spark 1996). Soluble salts were extracted with DI water and exchangeable metals were extracted with ammonium acetate. These replicate measurements yielded CECs of 65.2 and 73.5 meq/100 g and the following exchange complex: Na—56.1 and 40.0 meq/100 g, K—0.6 and 0.8 meq/100 g, Ca—12.0 and 15.7 meq/100 g, Mg—4.0 and 4.8 meq/100 g. Thus, the bentonite used in this study is predominantly Na-montmorillonite.

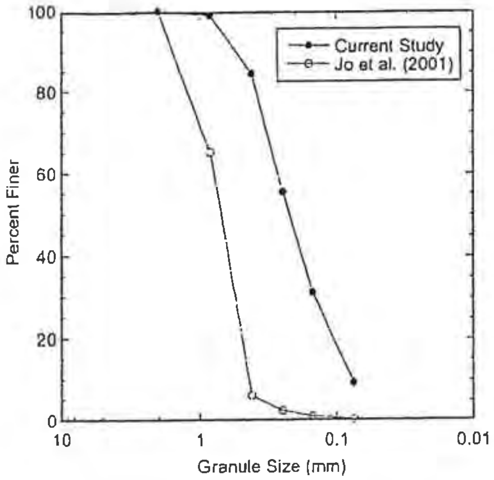

Fig. 1. Granule size distributions for geosynthetic clay liner used in this study and by Jo et al. (2001)

Permeant Liquids

The multispecies salt solutions were prepared with anhydrous inorganic salts (>96% purity) dissociated in DI water. LiCl and NaCl salts were used to investigate the effects of monovalent cations, and $CaCl_2$ and $MgCl_2$ salts were used to investigate the effects of divalent cations. The anionic background (Cl^-) was held constant for all permeant solutions. Type II DI water was used to prepare the solutions and as the reference solution.

A summary of the solutions used in this study is in Table 1. All of the solutions have near neutral pH (6.6 to 8.5). The parameter RMD in Table 1 represents a ratio of the concentrations of monovalent and divalent cations in the permeant solution. RMD is defined as

$$\mathrm{RMD} = \frac{M_M}{\sqrt{M_D}} \tag{2}$$

where M_M=total molarity of monovalent cations; and M_D=total total molarity of divalent cations in the solution. RMD is slightly different from SAR in that RMD characterizes the permeant solution introduced to the soil, whereas SAR generally describes pore water equilibrated with the soil (although SAR has been used to describe solutions by some investigators). RMD also is in terms of molar concentrations (rather than normality), includes all monovalent and divalent cations (SAR is limited to Na, Mg, and Ca) in solution, and does not include a factor of 2 in the denominator (because more than two cations can contribute to M_D).

Solutions having ionic strength (I) ranging from 0.05 to 0.5 M and RMD from 0 to ∞ (all divalent to all monovalent) were used as permeant liquids. These solutions were selected to represent the range of ionic strengths and RMDs expected in leachate from modern disposal facilities for municipal solid waste, hazardous wastes, construction and demolition wastes, fly ash, paper sludge, and mine waste. A review of literature pertaining to the composition of leachates from these wastes is included in Kolstad (2000), and is summarized later in this paper. Most of the solutions were Li–Ca mixtures. However, tests were also conducted with Na–Mg and Li–Na–Ca–Mg mixtures to investigate how cation species affected swell and hydraulic conductivity of the GCL.

Free Swell Tests

Free swell tests were conducted in accordance with ASTM D 5890. Bentonite from the GCL was ground to a fine powder using a mortar and pestle and dry sieved through a No. 200 U.S. standard sieve. The sieved bentonite was air dried for 24 h, and then stored in an airtight container prior to testing. A 100 mL graduated cylinder, accurate to ±0.5 mL, was filled to the 90 mL mark with the test solution. Two grams of sieved bentonite were added to the graduated cylinder in 0.1 g increments. Test solution was then added to the cylinder to reach a final volume of 100 mL by flowing the solution along the cylinder wall so that any particles adhered to the wall would be washed into solution. Swell volume (mL/2 g) was recorded after 24 h, which Jo et al. (2001) report is adequate to establish equilibrium.

Hydraulic Conductivity Tests

Falling head hydraulic conductivity tests with constant tailwater elevation were conducted on the GCL specimens using flexible-wall permeameters in general accordance with ASTM D 5084 and D 6766. An average hydraulic gradient of 100 and effective stress of 20 kPa were applied. Hydraulic gradients this large are uncommon when testing clay soils, but are common when testing GCLs. Large gradients are acceptable when testing GCLs because the differential in effective stress across a thin specimen is not very sensitive to the hydraulic gradient (Shackelford et al. 2000). Aqueous solutions of the inorganic salts (Table 1) were used as the permeant solutions. Backpressure was not used to permit convenient collection of effluent samples for pH and electrical conductivity (EC) testing.

GCL test specimens were prepared by cutting a sample from a GCL panel using a steel cutting ring (105 mm in diameter) and a sharp utility knife following the method described in Daniel et al. (1997). A small amount of test solution was applied along the inner circumference of the ring using a squirt bottle to prevent bentonite loss when removing the specimen from the trimming ring. Excess geotextile fibers were removed from the edge of the specimen with sharp scissors to eliminate potential preferential flow paths between the GCL and flexible membrane (Petrov et al. 1997). Paste prepared with the test solution and bentonite trimmings was delicately placed along the perimeter of the specimen with a small spatula to minimize the potential for sidewall leakage during permeation.

The initial thickness of the GCL specimen was measured to the nearest 0.1 mm with a caliper. Four measurements were made and the average thickness was recorded. The initial weight of the specimen was measured to the nearest 0.01 g. On completion of the hydraulic conductivity test, the specimen was removed from the permeameter and the final thickness and weight were measured in the same manner.

Sidewall leakage and preferential flow paths along the needle-punched fibers are of concern when permeating GCLs with solutions that alter the hydraulic conductivity of bentonite. When relatively high hydraulic conductivities ($>10^{-6}$ cm/s) were obtained, the influent solution was spiked with Rhodamine WT dye (5 mg/L) to stain the flow paths bright red. For all tests that were conducted, the dye tests showed that preferential flow along the needle-punching fibers and the sidewalls did not occur. Jo et al. (2001) report similar findings in their single-species tests on GCLs.

Table 1. Summary of Permeant Solutions

Type of solution	Ionic strength (M)	Monovalent concentration 10^{-2} (M)	Divalent concentration 10^{-2} (M)	RMD ($mM^{1/2}$)	pH	EC (S/m)
Li–Ca	0.05	5.00	0.00	∞	7.4	0.50
		4.35	0.22	0.93	7.6	0.48
		3.33	0.56	0.45	7.7	0.43
		2.00	1.00	0.20	7.2	0.42
		0.00	1.67	0.00	7.8	0.36
Na–Mg		3.33	0.56	0.45	7.4	0.43
Li–Na		3.33	0.56	0.45	7.2	0.43
Ca–Mg		Li(1):Na(3)[a]	Ca(1):Mg(3)[b]			
Li–Ca	0.1	10.0	0.00	∞	6.8	0.88
		8.70	0.44	1.32	7.9	0.87
		8.33	0.56	1.12	8.5	0.88
		7.77	0.77	0.88	8.1	0.87
		6.67	1.11	0.64	7.7	0.86
		5.00	1.67	0.38	7.3	0.80
		2.50	2.50	0.16	7.5	0.77
		1.00	3.00	0.06	7.4	0.72
		0.00	3.33	0.00	7.9	0.70
Na–Mg		8.70	4.35	1.32	6.8	0.87
		6.67	1.11	0.64	6.6	0.86
		1.00	3.00	0.06	7.2	0.73
Li–Na		8.33	0.56	1.12	7.1	0.88
Ca–Mg		Li(3):Na(1)[a]	Ca(3):Mg(1)[b]			
Li–Na		2.50	2.50	0.16	6.5	0.77
Ca–Mg		Li(1):Na(1)[a]	Ca(1):Mg(1)[b]			
Li–Ca	0.2	20.0	0.00	∞	8.1	1.86
		16.7	1.11	1.58	7.2	1.72
		13.3	2.22	0.89	7.1	1.62
		8.00	4.00	0.40	7.2	1.50
		0.00	6.67	0.00	7.2	1.29
Na–Mg		13.3	2.22	0.89	6.7	1.61
Li–Na		8.00	4.00	0.40	7.2	1.50
Ca–Mg		Li(1):Na(3)[a]	Ca(3):Mg(1)[b]			
Li–Ca	0.5	50.0	0.00	∞	8.1	3.45
		38.5	3.85	1.97	7.3	3.46
		31.3	6.25	1.24	8.2	3.29
		20.0	10.0	0.64	8.1	3.03
		0.0	16.7	0.00	7.6	2.74
Na–Mg		31.3	6.25	1.24	7.2	3.30
Li–Na		38.5	3.85	1.97	6.6	3.46
Ca–Mg		Li(3):Na(1)[a]	Ca(1):Mg(3)[b]			
Li–Na		20.0	10.0	0.64	6.9	3.02
Ca–Mg		Li(2):Na(1)[a]	Ca(1):Mg(2)[b]			

Note: RMD=Relative abundance of monovalent and divalent cations; EC=Exchange capacity.

[a] Molar ratio of monovalent cations when two species are present.

[b] Molar ratio of divalent cations when two species are present

The hydraulic conductivity tests were terminated when the termination criteria in ASTM D 5084 and D 6766 were satisfied. The hydraulic conductivity was required to be steady (±25% of the mean with no statistically significant trend for at least four values), the ratio of outflow to inflow was between 0.75 and 1.25 for four consecutive values, and the pH and EC of the influent and effluent deviated less than 10%. A minimum of 2 pore volumes of flow (PVF) was also stipulated, although all tests required more than 2 PVF to satisfy all of the termination criteria (some tests required more than 150 PVF). A pH meter and a portable electrical conductivity probe were used to measure the pH and EC.

Table 2. Summary of Free Swell Data

Ionic strength (M)	RMD $mM^{1/2}$	Free swell (mL/2 g) Li–Ca solutions	Na–Mg solutions	Li–Na–Ca–Mg solutions
0.05	0.93	30.5	—	—
	0.45	24.5	24.5	—
	0.20	22.0	—	—
	0.00	19.0	—	—
0.1	1.32	21.5	21.0	—
	1.12	21.0	—	21.0
	0.88	19.0	—	—
	0.64	17.5	17.5	—
	0.38	14.0	—	—
	0.16	13.5	—	13.0
	0.06	11.5	12.0	—
	0.00	11.0	—	—
0.2	1.67	19.0	—	—
	0.89	15.0	15.5	—
	0.40	12.0	—	12.5
	0.00	9.5	—	—
0.5	1.97	11.5	—	12.0
	1.24	10.5	10.0	—
	0.64	8.5	—	8.5
	0.00	6.5	—	—

Note: Free Swell in distilled water=36.5 mL/2 g; RMD=Relative abundance of monovalent and divalent cations.

Results of Free Swell Tests

Effect of Concentration and Relative Abundance of Monovalent and Divalent Cations

Free swell tests were conducted using solutions with ionic strengths ranging from 0.05 M to 0.5 M and RMD ranging from 0 to 1.97 $mM^{1/2}$. The multispecies solutions were prepared with Li and Ca, Na, and Mg, or Li, Na, Ca, and Mg. Results of the tests are summarized in Table 2.

Free swell is shown as a function of ionic strength in Fig. 2 for the Li–Ca solutions. The data are segregated by solutions that are predominantly divalent ($RMD < 0.35\ mM^{1/2}$), solutions with comparable fractions of monovalent and divalent cations ($0.35\ mM^{1/2} < RMD < 0.90\ mM^{1/2}$), and solutions that are predominantly monovalent ($RMD > 0.90\ mM^{1/2}$). Free swell of the bentonite decreases with increasing concentration for each range of RMD. Lower free swell also occurs as the RMD decreases because the presence of more divalent cations suppresses the osmotic component of swelling. RMD also affects the sensitivity to concentration. For the predominantly monovalent solutions ($RMD > 0.90\ mM^{1/2}$), the free swell decreases 19 mL/2 g, on average, as the ionic strength is varied between 0.05 to 0.5 M. For the predominantly divalent solutions ($RMD < 0.35\ mM^{1/2}$), the free swell decreases 14 mL/2 g, on average, over the same range of ionic strengths.

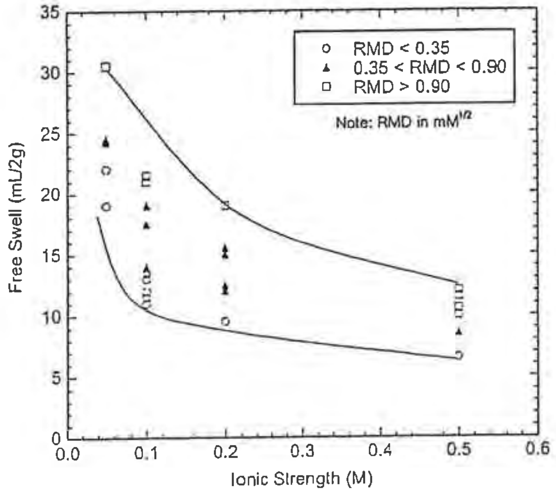

Fig. 2. Free swell of geosynthetic clay liner bentonite as a function of ionic strength for low, intermediate, and high relative abundance of monovalent and divalent cation

The influence of RMD on swell at constant ionic strength is shown in Fig. 3. The relationships are approximately linear, with trend lines fitted to the data using least-squares linear regression. The slope of each trend line reflects the sensitivity of swell to RMD; the intercept is the free swell when the solution only contains divalent cations. When the ionic strength is lower, the trend lines have a larger slope (e.g., slope=12.1 for $I=0.05$ M and 2.6 for $I=0.5$ M), which indicates that RMD has a stronger influence on swelling at low ionic strength and less effect at high ionic strength.

The trends in the free swell tests are consistent with those reported by McNeal et al. (1966) for swelling of Gila clay in mixed Na–Ca solutions. They found a unique relationship between swell and SAR when the concentration was fixed, and that the sensitivity to SAR diminished as the concentration increased. Jo et al. (2001) report similar findings for single species solutions. They found that concentration has a greater effect on free swell for monovalent solutions than divalent solutions.

The sensitivity of free swell to concentration and RMD is

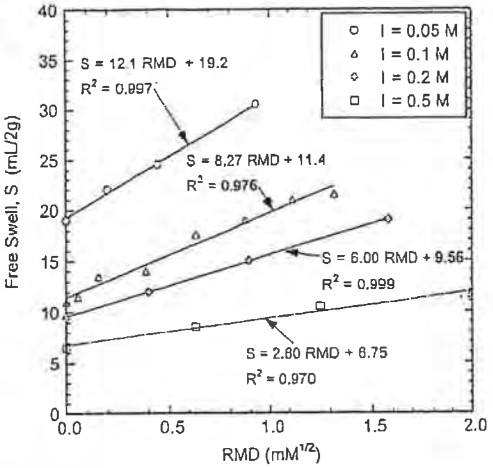

Fig. 3. Free swell of GCL bentonite as a function of RMD for ionic strengths of 0.05, 0.1, 0.2 and 0.5 M

caused by expansion and contraction of the interlayer space as a result of crystalline and osmotic swelling. This effect is illustrated in Fig. 4, which shows basal spacing (i.e., sum of interlayer separation distance and thickness of one montmorillonite layer, also referred to as d_{001}) as a function of ionic strength. The basal spacing was computed using the method in Smalley (1994), which is based on particle geometry, free swell of the bentonite, the thickness of a montmorillonite layer (≈ 0.9 nm), the basal spacing of Ca-montmorillonite in water (≈ 1.96 nm), and the free swell of Ca-montmorillonite in water (≈ 8.0 mL/2 g). The symbol size in Fig. 4 is proportional to RMD (larger symbols for larger RMD). At high ionic strength (0.5 M), the basal spacing (d_{001}) ranges between 1.5 and 2.9 nm, indicating that the swelling is in the crystalline phase ($d_{001} \leqslant 1.96$ nm) or the low end of the osmotic phase ($d_{001} > 1.96$ nm). In contrast, the basal spacing ranges between 4.5 and 8.6 nm at lower concentration ($I \leqslant 0.05$ M), which corresponds to crystalline and osmotic swelling ($d_{001} > 1.96$ nm). Moreover, the smallest symbols (lowest RMD) often correspond to the lowest d_{001} for each ionic strength, reflecting suppression of osmotic swelling due to the preponderance of divalent cations.

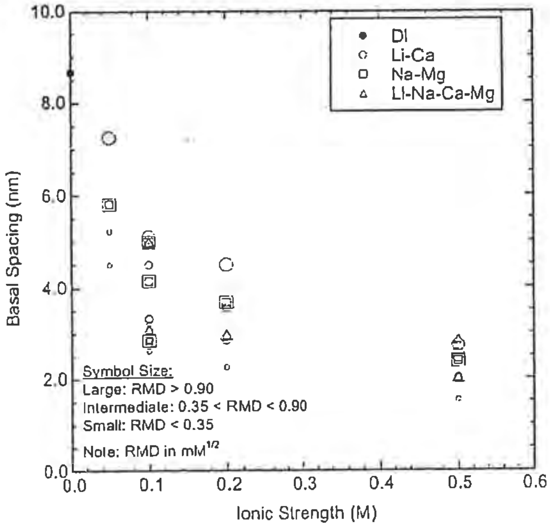

Fig. 4. Free swell of GCL bentonite as a function of computed basal spacing of montmorillonite

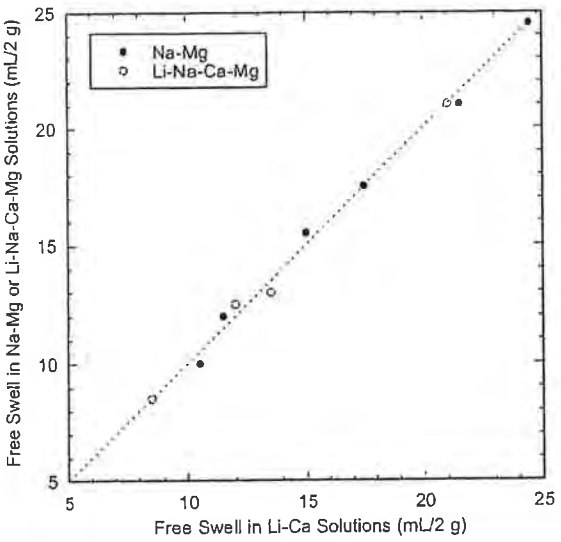

Fig. 5. Comparison of free swell of bentonite in Na–Mg and Li–Na–Ca–Mg solutions to free swell in Li–Ca solutions for solutions prepared with the same ionic strength and RMD

Effect of Cation Species

The influence of cation species on free swell is illustrated in Fig. 5 using data from the Li–Ca, Na–Mg, and Li–Na–Ca–Mg solutions. Swell in the Na–Mg and Li–Na–Ca–Mg solutions is essentially equal to the swell in the Li–Ca solutions at the same ionic strength and RMD. No discernable effect of cation species is evident. The tendency of divalent cations to suppress osmotic swelling, combined with the insensitivity of free swell to type of divalent cation species (i.e., as in Jo et al. 2001), probably muted any sensitivity to species for the monovalent cations. The single-species tests by Jo et al. (2001) also show that free swell in monovalent solutions is only slightly sensitive to cations species. Thus, free swell is likely to be insensitive to cation species for most monovalent–divalent cation mixtures.

Results of Hydraulic Conductivity Tests

Effect of Concentration and Relative Abundance of Monovalent and Divalent Cations

Hydraulic conductivity tests were conducted using multispecies aqueous solutions listed in Table 1. The ionic strength of the test solutions ranged from 0.05 M to 0.5 M, and the RMD ranged from 0 to 1.97 mM$^{1/2}$. Hydraulic conductivities obtained from these tests are summarized in Table 3.

Hydraulic conductivity is shown in Fig. 6 as a function of ionic strength (I). As in Fig. 2, the solutions have been characterized as primarily divalent (RMD $<$ 0.35 mM$^{1/2}$), comparable mixtures (0.35 mM$^{1/2}$ $<$ RMD $<$ 0.90 mM$^{1/2}$), and primarily monovalent (RMD $>$ 0.90 mM$^{1/2}$). The hydraulic conductivity is sensitive to the composition of the permeant solution, ranging from 5.6×10^{-10} cm/s ($I = 0.05$ M and RMD $= 0.66$ mM$^{1/2}$) to 1.0×10^{-5} cm/s ($I = 0.5$ M and RMD $= 0$), and varies exponentially

Table 3. Summary of Hydraulic Conductivities

Ionic strength (M)	RMD ($mM^{1/2}$)	Hydraulic conductivity (cm/s) Li–Ca solutions	Na–Mg solutions	Li–Na–Ca–Mg solutions
0.05	0.93	5.6×10^{-10}	—	—
	0.45	1.1×10^{-9}	2.1×10^{-9}	—
	0.20	3.0×10^{-9}	—	—
	0.00	9.2×10^{-9}	—	—
0.1	1.32	2.4×10^{-9}	8.9×10^{-10}	—
	1.12	2.3×10^{-9}	—	4.8×10^{-9}
	0.88	3.3×10^{-9}	—	—
	0.64	5.2×10^{-9}	6.5×10^{-9}	—
	0.38	9.3×10^{-9}	—	—
	0.16	9.5×10^{-9}	—	2.1×10^{-8}
	0.06	1.1×10^{-8}	8.5×10^{-9}	—
	0.00	1.3×10^{-8}	—	—
0.2	1.67	2.8×10^{-9}	—	—
	0.89	2.5×10^{-8}	3.4×10^{-8}	—
	0.40	4.9×10^{-8}	—	5.2×10^{-8}
	0.00	1.0×10^{-7}	—	—
0.5	1.97	2.4×10^{-7}	—	9.1×10^{-8}
1.24		8.5×10^{-7}	4.2×10^{-7}	—
0.64		5.0×10^{-6}	—	8.5×10^{-6}
0.00		1.0×10^{-5}	—	—

Note: Hydraulic conductivity to distilled water=9.0×10^{-10} cm/s; RMD=Relative abundance of monovalent and divalent cations.

with ionic strength (linearly on a semilogarithmic graph). The highest hydraulic conductivities at any ionic strength were obtained using the primarily divalent (RMD$<$0.35 $mM^{1/2}$) solutions, and the lowest for the primarily monovalent (RMD$>$0.90 $mM^{1/2}$) solutions.

The effect of RMD at constant ionic strength is shown in Fig. 7. The base-10 logarithm of hydraulic conductivity ($\log_{10}K$) is approximately linearly related to RMD. The trend lines relating $\log_{10}K$ and RMD in Fig. 7 were fit using least-squares linear regression. Their slope describes the sensitivity of hydraulic conductivity to RMD, and the intercept is the hydraulic conductivity to the divalent solution. The hydraulic conductivity exhibits greater sensitivity to RMD at lower ionic strength (i.e., slope =1.25 at I=0.05 M and 0.86 at I=0.5 M). The data for the tests conducted at an ionic strength of 0.1 M are an exception to the trend. The reason for this deviation is unknown.

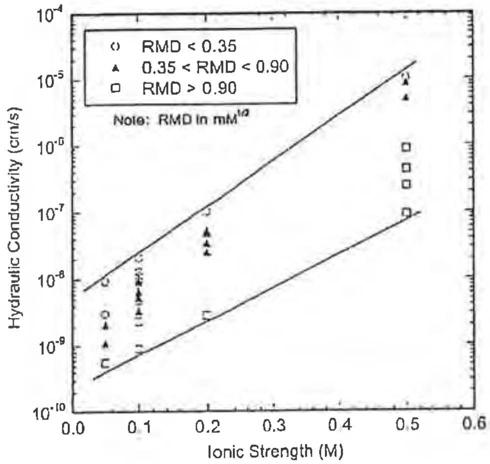

Fig. 6. Hydraulic conductivity of GCL as a function of solution ionic strength for low, intermediate, and high RMD

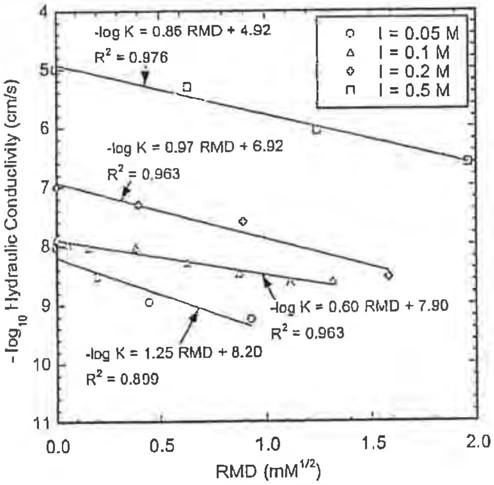

Fig. 7. Hydraulic conductivity of GCL as a function of RMD for ionic strengths of 0.05, 0.1, 0.2, and 0.5 M

The trends in Figs. 6 and 7 are comparable to the trends reported by McNeal and Coleman (1966) for Gila clay. They found that the hydraulic conductivity increases with increasing concentration and decreasing SAR, and distinct curves relating hydraulic conductivity to SAR exists when the concentration is fixed. McNeal and Coleman (1966) report that SAR has a stronger influence on hydraulic conductivity at low concentrations, and that the effect of SAR diminishes at high concentrations. Jo et al. (2001) also report similar sensitivity to ionic strength and cation valence for single species solutions. At a given ionic strength, the highest hydraulic conductivities were obtained with divalent or trivalent solutions, and the lowest with monovalent solutions.

A diminished effect of ionic strength and RMD probably would have been observed had much lower or much higher ionic strengths been used. For example, DI water is the limiting case for dilute solutions (in this study, the hydraulic conductivity of the GCL to DI water was 9.0×10^{-10} cm/s). In addition, Jo et al. (2001) report that the hydraulic conductivity of the GCL they tested leveled off between 10^{-5} to 10^{-4} cm/s for ionic strengths greater than 1 M. When the ionic strength is high, osmotic swelling becomes negligible, and the basal spacing is reduced to its smallest value in the hydrated state ($\approx$2 nm). Once this compressed condition is reached, no further increase in hydraulic conductivity can occur. In fact, a decrease in hydraulic conductivity is possible due to the higher viscosity of concentrated solutions (Fernandez and Quigley 1988).

Effect of Cation Species

Li–Ca, Na–Mg, and Li–Na–Ca–Mg solutions having various RMD and ionic strengths were used to investigate how differences in cation species affect the hydraulic conductivity of GCLs

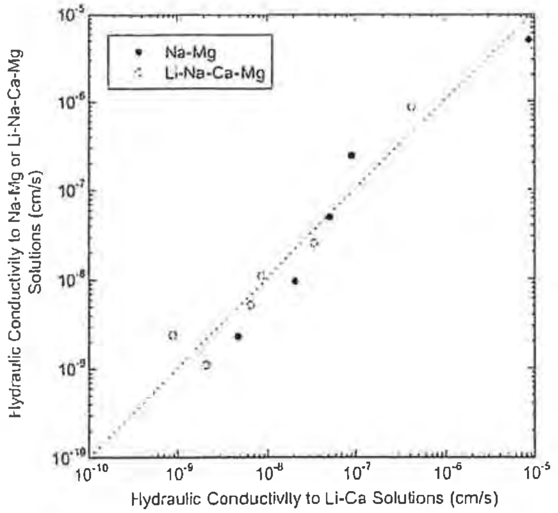

Fig. 8. Comparison of hydraulic conductivities of GCL obtained with Na–Mg and Li–Na–Ca–Mg solutions to hydraulic conductivities obtained with Li–Ca solutions for solutions prepared with the same ionic strength and RMD

permeated with mixed solutions. Composition of each solution is summarized in Table 1 and the hydraulic conductivities are in Table 3.

Hydraulic conductivities obtained using the Li–Ca solutions are compared with those obtained from the Na–Mg and Li–Na–Ca–Mg solutions in Fig. 8. At comparable ionic strengths and RMD, essentially the same hydraulic conductivities were obtained with the Na–Mg and Li–Na–Ca–Mg solutions as with the Li–Ca solutions. No discernable effect of cation species is apparent. The insensitivity of hydraulic conductivity to cation species is analogous to the insensitivity of free swell to cation species. Differences in preference of the montmorillonite for Ca over Mg and Na over Li appear to have a small effect compared to the effects of RMD and concentration. In addition, Jo et al. (2001) found that the hydraulic conductivity was insensitive to cation species for a given valence.

The insensitivity to cation species evident in Fig. 8, combined with the insensitivity to cation species observed by Jo et al. (2001) for single-species solutions, suggests that the hydraulic conductivity at fixed RMD is likely to be insensitive to cation species in most monovalent–divalent mixtures. Moreover, Jo et al. (2001) found that permeation with single-species solutions containing divalent and trivalent cations yielded essentially the same hydraulic conductivity at a given concentration. Thus, the insensitivity to cation species may extend to multispecies solutions in general, with ionic strength and RMD being the dominant variables controlling hydraulic conductivity. In this case, the denominator of RMD would include the total normality of the polyvalent (valence$\geqslant +2$) cations in the solution. While this hypothesis is plausible, more testing is needed to confirm its validity.

Practical Implications

Free Swell and Hydraulic Conductivity

Jo et al. (2001) show that a strong relationship exists between free swell of bentonite and the hydraulic conductivity of GCLs exposed to single-species solutions. A similar relationship could be expected for multispecies solutions as well because Figs. 2, 3, 6, and 7 show that ionic strength and RMD affect swell and hydraulic conductivity in a consistent and similar manner. McNeal et al. (1966) also report a strong correlation between swelling and hydraulic conductivity for Gila clay permeated with solutions having different ionic strengths and SAR.

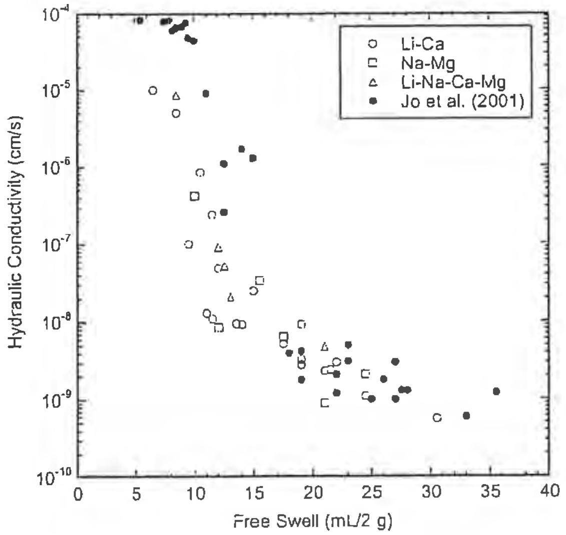

Fig. 9. Hydraulic conductivity of GCL as a function of free swell of bentonite. Test data are from this study and from Jo et al. (2001)

Hydraulic conductivity of the GCL specimens permeated with the multispecies solutions is shown in Fig. 9 as a function of free swell along with the single-species data from Jo et al. (2001). A strong relationship exists between hydraulic conductivity and free swell for both data sets. The slight offset in the two data sets at lower swell volumes (and higher hydraulic conductivities) is most likely due to differences in the granule size distributions of the bentonites and not the use of multispecies versus single species solutions. The GCLs used in both studies were essentially identical, except the bentonite in the GCL used in this study has smaller granules than the bentonite in the GCL used by Jo et al. (2001) (Fig. 1). Mesri and Olson (1971) and McNeal et al. (1966) indicate that bentonites with larger "domains" (quasi-crystals) permit larger flow paths and higher hydraulic conductivity. In addition, Katsumi et al. (2002) show that nonprehydrated GCLs containing bentonite with larger granules are more permeable than GCLs with smaller granules when permeated using stronger ($\geqslant$0.2 M) salt solutions. Because the granules do not swell appreciably in strong solutions, bentonites with larger granules have larger intergranular pores, and higher hydraulic conductivity. That is, the hydraulic conductivity of granular bentonite permeated with strong solutions follows a similar relationship with particle size as do granular soils; i.e., the hydraulic conductivity increases as the particle size increases, all factors being equal (e.g., Lambe and Whitman 1969; Terzaghi et al. 1996). In contrast, granule size has no effect on free swell, because the bentonite is crushed to pass the No. 200 sieve prior to free swell testing.

McNeal et al. (1966) conclude that swelling of expansive minerals such as montmorillonite is the dominant mechanism affecting the hydraulic conductivity. The results of this study, as well as those in Jo et al. (2001), support this conclusion. The trends shown in Fig. 9 also indicate that free swell tests can be a relatively simple and quick screening method to evaluate the compatibility of GCLs permeated with inorganic salt solutions containing mixtures of cations. Although not a surrogate for chemical compatibility testing (direct testing is needed to demonstrate that a GCL is compatible with a liquid), free swell testing can be used to identify liquids that are incompatible with GCLs. The data in Fig. 9 also illustrate that the relationship between hydraulic conductivity and free swell is bentonite specific, and needs to be identified empirically.

Estimating Hydraulic Conductivity

The approximately linear trends shown in Figs. 6 and 7 suggest that a relatively simple empirical model can be used to estimate hydraulic conductivity of GCLs as a function of ionic strength and RMD. A model relating these parameters was developed using stepwise regression (Draper and Smith 1998) using a significance level of 0.05:

$$\frac{\log K_c}{\log K_{\mathrm{DI}}} = 1.085 - 1.097I + 0.0398I^2\,\mathrm{RMD} \qquad (3)$$

In Eq. 3, K_c=hydraulic conductivity to the inorganic chemical solution and K_{DI}=hydraulic conductivity to deionized water. The R^2 for Eq. (3) is 0.967 and the p statistic is less than 0.0001. Eq. (3) is linear in both I and RMD, and the product $I^2 \times \mathrm{RMD}$ reflects that the sensitivity to RMD varies nonlinearly with ionic strength (e.g., as in Fig. 7). Eq. (3) is valid for $I = 0.05-0.5$ M and $\mathrm{RMD} < 2.0\ \mathrm{mM}^{1/2}$.

Eq. (3) is based on data from the GCL tested in this study under the state of stress that was employed (effective stress =20 kPa). However, Eq. (3) can be used to *estimate* how inorganic solutions may affect the hydraulic conductivity of other GCLs provided they employ granular Na-bentonite consisting of approximately 80% montmorillonite. Many of the GCLs used in North America today fit this description. Even if the granule size or montmorillonite content differs from those in this study, the relative effects of ionic strength and RMD should be approximately correct. In addition, Petrov and Rowe (1997) show that the hydraulic conductivity of GCLs exhibits similar sensitivity to effective stress regardless of whether DI water or a salt solution is used as the permeant liquid. Thus, Eq. (3) can be used to *estimate* the hydraulic conductivity at different effective stresses if the hydraulic conductivity to DI water at these stresses is known.

A comparison of K_c predicted with Eq. (3) and the measured hydraulic conductivity is shown in Fig. 10(a). The contour lines in Fig. 10 correspond to Eq. (3), whereas the data points correspond to the I and RMD for the tests conducted in this study. Eq. (3) captures the data reasonably well. Hydraulic conductivities predicted with Eq. (3) are also shown as contours in Fig. 10(b) along with points corresponding to I and RMD for actual leachates from a variety of wastes and solid waste disposal facilities reviewed by Kolstad (2000). The ionic strength and RMD of each leachate is summarized in Table 4, along with the data source (literature and regulatory agency reports) and the type of containment facility. The points and contour lines in Fig. 10(b) illustrate what hydraulic conductivity likely would have been had the GCL used in this study been tested with these leachates.

Of the 50 points shown in Fig. 10(b), 37 fall below 10^{-7} cm/s (74%) and 24 fall below 10^{-8} cm/s (48%). Thus, GCLs with high hydraulic conductivities ($>10^{-7}$ cm/s) should not be common in bottom liners where leachates similar to those in Table 4 are likely to be found. Moreover, many of the points in Fig. 10(b) associated with high hydraulic conductivities correspond to "young" (landfill age<5 yr) municipal solid waste (MSW) leachates (Table 4). The composition of MSW leachate changes over time, and thus high hydraulic conductivities may not be realized because of the relatively long time required for a GCL and leachate to reach equilibrium under field conditions (Jo 2003). However, some of the points for mine waste, paper sludge, and fly ash disposal facilities are associated with high hydraulic conductivities, and the composition of leachates from these wastes can be persistent.

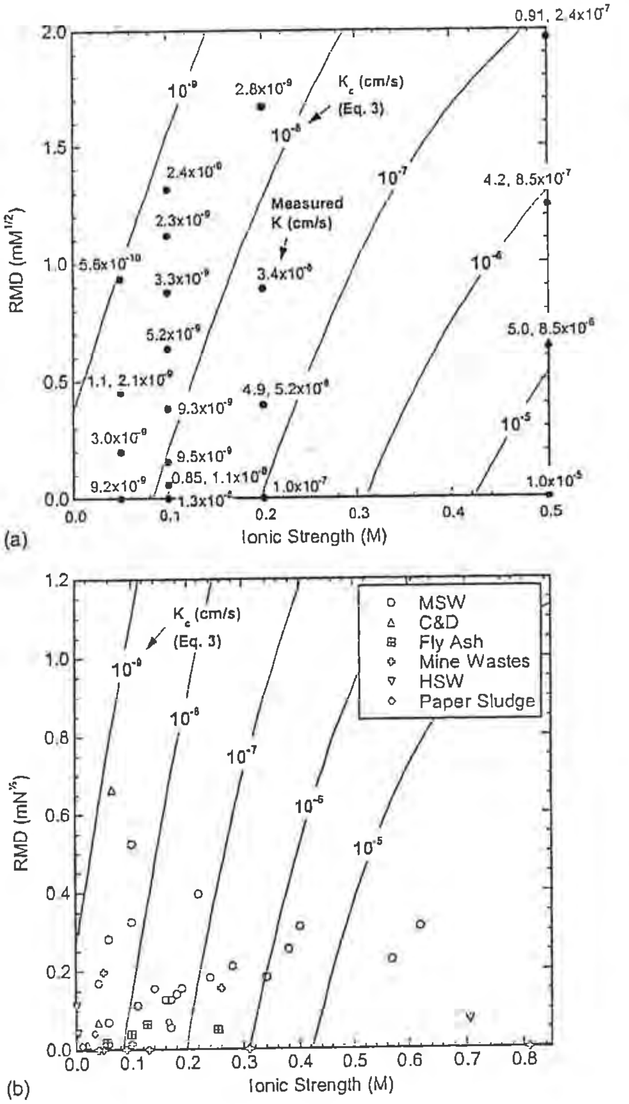

Fig. 10. Contours of hydraulic conductivity as a function of RMD and ionic strength predicted with Eq. (3) along with (a) measured hydraulic conductivities as solid circles and (b) points corresponding to ionic strength and RMD of various leachates. Data from Williams (1975) (I=1.87 M and RMD=0) and Kolstad (2000) (I=1.37 M and RMD=2.52 mM$^{1/2}$) are off the scale in (b).

Effect of Prehydration

The results of this study pertain specifically to nonprehydrated GCLs. Different results may have been obtained had the GCLs been completely prehydrated by permeation with DI or potable water for several pore volumes of flow. Comparisons between hydraulic conductivities of nonprehydrated and completely prehy-

Table 4. Summary of Ionic Strength and RMD of Various Leachates

Source	Leachate type	Ionic strength (M)	RMD ($mM^{1/2}$)
Ehrig (1983)	Young MSW leachate (<5 yr)	0.28	0.21
Pohland (1980)		0.38	0.25
Tchbanoglous et al. (1993)		0.14	0.16
Chian and DeWalle (1976)		0.17	0.13
Cheremisinoff (1983)		0.22	0.40
Alker et al. (1995)		0.16	0.13
Chian and DeWalle (1975)		0.57	0.23
Chian and DeWalle (1975)		0.62	0.31
Chian and DeWalle (1975)		0.34	0.18
Farquhar (1989)		0.40	0.31
Shams et al. (1994)		0.24	0.18
Ehrig (1983)	Intermediate MSW leachate (5–10 yr)	0.10	0.52
Pohland (1980)		0.10	0.33
Chian and DeWalle (1975)		0.17	0.06
Chian and DeWalle (1975)		0.11	0.11
Farquhar (1989)		0.18	0.14
Chian and DeWalle (1975)	Old MSW leachate (>10 yr)	0.06	0.01
Chian and DeWalle (1975)		0.06	0.28
Farquhar (1989)		0.06	0.07
Alker et al. (1995)		0.04	0.17
Kmet and McGinley (1982)	MSW leachate	0.19	0.16
Ruhl and Daniel (1997)	C and D leachate	0.04	0.17
Kolstad (2000)		0.05	0.01
Kolstad (2000)		0.02	0.01
WMNA (1993)		0.04	0.07
Weber et al. (2002)		0.066	0.66
Kolstad (2000)	Fly ash leachate	0.03	0.25
Kolstad (2000)		0.03	0.06
Kolstad (2000)		0.02	0.10
Kolstad (2000)		0.05	0.23
Kolstad (2000)		0.06	0.13
Kolstad (2000)		0.07	0.20
Kolstad (2000)		0.37	2.52
Kolstad (2000)		0.76	0.71
Al et al. (1994)	Mine process water	0.05	0.00
Shackelford (1998)		0.04	0.00
Jordan et al. (1998)		0.05	0.20

Table 4. (*Continued.*)

Source	Leachate type	Ionic strength (M)	RMD ($mM^{1/2}$)
Williams (1975)	Acidic mine waste drainage	1.87	0.00
Christensen and Laake (1996)		0.13	0.00
Christensen and Laake (1996)		0.09	0.00
Al et al. (1994)		0.81	0.00
Shackelford (1998)		0.31	0.00
Williams (1975)	Pyritic tailings leachate	0.26	0.16
Pettit and Scharer (1999)	Ur rock drainage	0.10	0.01
Kolstad (2000)	Hazardous waste leachate	0.001	0.11
		0.70	0.07
		0.003	0.04
Kolstad (2000)	Paper mill landfill leachate	0.17	0.07
		0.01	0.01
		0.03	0.04

Note: RMD=Relative abundance of monovalent and divalent cations; MSW=Municipal solid waste.

drated GCLs that have been permeated long enough to establish chemical equilibrium between the bentonite solid and the solution show that prehydration by permeation with DI water results in hydraulic conductivities an order of magnitude lower than those obtained without prehydration, even if cation exchange between the mineral surface and the permeant liquid is complete (Petrov and Rowe 1997; Jo et al. 2004).

Although the effect of complete prehydration is significant, complete prehydration is unlikely to occur in the field. Most GCLs in field applications hydrate as water is drawn to the bentonite from an underlying subgrade via vapor diffusion or gradients in matric potential (Daniel et al. 1993, 1998; Katsumi et al. 2003). The prehydration afforded by these processes does not appear to have the same effect as complete prehydration by direct permeation. Vasko et al. (2001) found that the hydraulic conductivity of GCLs prehydrated with DI water via capillary wetting and vapor diffusion and permeated with $CaCl_2$ solutions had essentially the same hydraulic conductivity as nonprehydrated GCLs unless the solution was very strong (concentration >0.1 M). Comparable findings are reported by Katsumi et al. (2003). These observations suggest that hydraulic conductivities reported in this study are likely to be more representative of most field conditions than hydraulic conductivities of completely prehydrated GCLs.

Summary and Conclusions

This study dealt with the influence of multispecies inorganic salt solutions on swelling and hydraulic conductivity of nonprehydrated GCLs. Free swell and hydraulic conductivity tests were conducted on nonprehydrated specimens of a commercially available GCL using DI water and aqueous solutions of LiCl, NaCl, $CaCl_2$, and $MgCl_2$ salts. The relative amounts of monovalent and divalent cations in solution were quantified with the parameter RMD, which is the ratio of the total molarity of monovalent cations to the square root of the total molarity of divalent cations.

Results of the free swell tests show that swell is directly related to RMD and inversely related to ionic strength. RMD has a strong effect on swell in weaker solutions, and a modest effect in strong solutions. Similar findings were obtained from the hydraulic conductivity tests. Hydraulic conductivity was found to be directly related to ionic strength and inversely related to RMD, with RMD having a greater effect on hydraulic conductivity in weaker solutions. Tests were also conducted to determine if cation species affects swell or hydraulic conductivity. No discernable effect of cation species was evident in the free swell or hydraulic conductivity for tests conducted at a given ionic strength and RMD.

A strong relationship between hydraulic conductivity and free swell was found that is analogous to the relationship reported by Jo et al. (2001) for tests conducted using single-species salt solutions. However, the hydraulic conductivity-free swell relationship is not unique, and must be defined empirically for a particular bentonite if free swell tests are to be used for chemical compatibility screening.

The hydraulic conductivity data were also used to develop a regression model relating hydraulic conductivity of the GCL to ionic strength and RMD of the permeant solution. Predictions made with the model indicate that high hydraulic conductivities (i.e., $>10^{-7}$ cm/s) are unlikely for nonprehydrated GCLs in base liners in many solid waste containment facilities. However, for some wastes that transmit stronger leachates or leachates that are dominated by polyvalent cations (e.g., fly ash, paper sludge, and mine wastes), high hydraulic conductivities may be realized provided adequate time exists for the bentonite and leachate to reach chemical equilibrium.

Acknowledgments

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Erratum note for

Hydraulic Conductivity and Swell of Nonprehydrated Geosynthetic Clay Liners Permeated with Multispecies Inorganic Solutions, by Kolstad, Benson, and Edil.

Journal of Geotechnical and Geoenvironmental Engineering, Vol. 130, No. 12, 1236–1249.

By Craig H. Benson[1]

The units for RMD in the text and graphs in this paper should be $M^{1/2}$ rather than the units of $mM^{1/2}$ shown in the published version. In addition, the plotting positions for the fly ash leachates were reversed in Fig. 10b (i.e., the fly ash leachate data were plotted as RMD vs. I instead of I vs. RMD). A correct version of Fig. 10b is presented here. This error does not affect any of the conclusions or inferences in the paper.

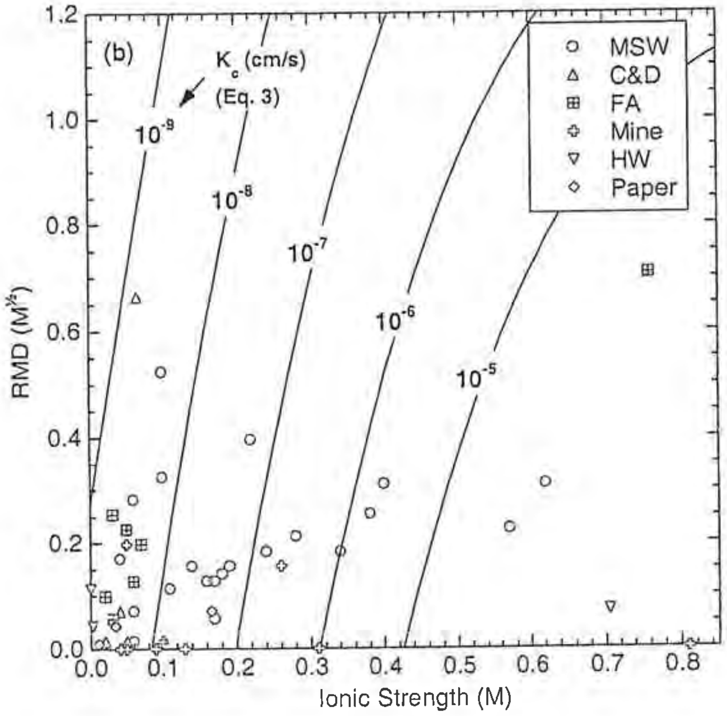

Fig. 10b. Contours of hydraulic conductivity as a function of RMD and ionic strength predicted with Eq. 3 along points corresponding to ionic strength and RMD of various leachates. Data from Williams (1975) (I = 1.87 M and RMD = 0) and Kolstad (2000) (I = 1.37 M and RMD = 2.52 $mM^{½}$) are off the scale in (b).

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[1] Professor and Kellet Fellow, Dept. of Civil and Environmental Engineering, 1415 Engineering Drive, Madison, WI 53706, USA, benson@engr.wisc.edu

H.2.2
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November 4, 2013

Mr. Martin Herrick, P.E.
Wisconsin Department of Natural Resources
3500 Mormon Coulee Road
La Crosse, WI 54601

Subject: Plan Modification
Phase IV Disposal Area, License #4126
Dairyland Power Cooperative

Dear Mr. Herrick:

On behalf of Dairyland Power Cooperative (DPC) TRC Environmental Corporation (TRC) is submitting two copies of a Plan Modification to accept new waste streams that will be generated at the J. P. Madgett Power Plant in Alma, WI (JPM) and at the Genoa Unit 3 Power Plant in Genoa, WI (G-3) and disposed of in the Alma Off-Site Ash Disposal Facility, Phase IV Disposal Area in Alma, WI (AOS Phase IV Disposal Area), License #4126. We request that the Wisconsin Department of Natural Resources (WDNR) review and approve this plan modification request in accordance with NR 514.09. To support this request detailed information on the waste types, characteristics and quantities; anticipated schedule of when the waste types will begin to be generated; and how it will be managed within the landfill is presented in the following text and accompanying attachments.

Background

New waste streams will be generated at JPM and at G-3 and disposed in the AOS Phase IV Disposal Area. The wastes generated are in response to federal regulations on the control of sulfur dioxide (SO_2) and mercury in the plant air emissions. The wastes are from dry sorbent injection (DSI) for the control of SO_2 at JPM and activated carbon injection (ACI) at both JPM and G-3 for the removal of mercury. The modifications presented in this request will pose low potential risk of adverse impacts on public health or the environment.

Schedule

The schedule for start-up and testing of the various processes to be implemented at the two plants is as follows:

■ JPM – dry sorbent injection and activated carbon injection	December 2013
■ G-3 – activated carbon injection	August 2014

In addition, NO_x control systems using selective catalytic reduction (at JPM) and selective non-catalytic reduction (at G-3) are planned to be implemented in the near future (late 2014 to early 2015). Although these are gas–phase reactions that consume the ammonia or urea that is injected, there will be some minor ammonia carry-over into the fly ash requiring landfill disposal.

Rather than submit multiple plan modification requests to the WDNR as the different processes are brought on-line at different dates, DPC is requesting a plan modification to incorporate the three waste streams.

Waste Characterization

In accordance with NR 506.09 the WDNR requests the following information for wastes proposed for disposal.

(a) Detailed physical and chemical characteristics including percent solids, material safety data sheets where appropriate and the results of the paint filter test.

(b) The volume of waste to be disposed of on a daily and yearly basis.

(c) The source of the waste and a description of the processes which generated the waste.

(d) The duration of disposal.

(e) Special handling and disposal procedures.

(f) Based on a preliminary review of the above information, the department may require additional information to determine the compatibility of the waste with the existing design and operation of the landfill.

Information for above items (a), (b) and (d) is summarized in Table 1. More detailed information is provided below.

Schematics for the air pollution control systems at both plants are provided in Figures 1 and 2. The systems are slightly different at the two plants.

- At JPM, the gas stream passes through an electrostatic precipitator to remove fly ash, which is followed by ammonia injection to convert NO_x to N_2 gas and water. Activated carbon is then injected for mercury removal, followed by sodium bicarbonate injection for SO_2 removal. The activated carbon, DSI residual material, and fly ash are collected in a baghouse prior to exhaust gas emission from the stack. See Figure 1 (attached).

- At G-3, urea is injected into the boiler for NO_x removal. Activated carbon is then injected into the exhaust gas from the boiler, followed by an electrostatic precipitator to remove fly ash. Lime (CaO) is then injected for SO_2 removal, and the residual activated carbon (referred to as flue gas desulfurization material or FGD) and fly ash are collected in a baghouse. Disposal of the FGD residual material that is removed from the baghouse in the AOS Phase IV Disposal Area was the subject of a previous WDNR approval associated with a plan modification dated May 4, 2009. See Figure 2.

Dry Scrubber Injection for Sulfur Dioxide Removal

Sodium bicarbonate can be injected into the gas stream from a coal-fired power plant to remove sulfur dioxide (SO_2), and in the process generate a residual material containing sodium sulfite, sodium sulfate, and residual injected material. DPC evaluated sodium bicarbonate injection (DSI) in field trials conducted in July and August 2011. The DSI residual material is similar to the FGD residual material generated at G-3, except that there is a higher sodium and lower calcium content.

One of the characteristics of both the DSI and FGD residual materials (removed with the fly ash from the baghouses) noted in the testing was the ability to absorb water and over time to harden into a monolithic material. This ability was evaluated by adding different amounts of water to the DSI material, allowing the wet material to sit for several days and then running a paint filter test on the material. The results, shown in Table 2 and Figure 3, indicate that the DSI material can absorb approximately its own weight in water before releasing any free water. The annual precipitation in the area is approximately 30 inches per year. Thus, a layer of DSI residual and fly ash material, approximately 3-feet thick, would be sufficient to absorb all the annual precipitation. The combined annual production of DSI and FGD residual material and fly ash from both the G-3 and JPM baghouse facilities will be in excess of 200,000 cubic yards, which correlates to an area of approximately 40-acres covered with a layer of DSI/FGD/fly ash material 3-feet thick per year. Since the total area of the landfill open at any time will likely range from 10 to 15-acres, it is clear that the depth of DSI/FGD/fly ash material will be much greater than 3-feet per year. Therefore, the apparent absorption capacity of the DSI/FGD/fly ash material placed in the landfill is greater than the annual precipitation. This does not mean that there will be no leachate generated from the landfill, but rather that the leachate comes predominantly from surface runoff and flow through fractures in the solidified material rather than uniform percolation through the DSI/FGD/fly ash material.

Activated Carbon for Mercury Control

Activated carbon can be used for mercury removal from coal-fired power plant exhaust gases. The carbon is amended with sulfur species to enhance mercury removal. No test runs have been done using the activated carbon, so no samples from the facility are available for testing. Some formulations of the mercury-removal carbon contain bromine to assist in the removal process. The decision as to whether to use the bromine spiked carbon or not has not been made, nor has a selection been made as to which supplier of activated carbon to use. Typical MSDS publications for both activated carbons – one bromine containing, one not – are provided in Attachment 1. The activated carbon will remove mercury and perhaps trace amounts of other contaminants from the gas stream, but the bulk physical and chemical characteristics of the carbon are not anticipated to change during the scrubbing process. The characteristics of the waste will be more thoroughly evaluated once the system is on-line, and the information will be provided to the WDNR.

Handling

The DSI and ACI residual material collected in the baghouse at JPM will increase the annual tonnage of ash waste residual material to be landfilled by approximately 15,000 tons and 1,230 tons, respectively. The ACI residual material collected in the baghouse at G-3 will increase the annual tonnage of ash waste residual material to be landfilled by approximately 1,610 tons. Since the DSI and/or ACI is injected into the flue gas stream it will be uniformly mixed with the fly ash material removed from the baghouses. Thus, it will present and behave in a similar manner to the material currently removed from the baghouses (i.e., dry, powdery material). Residual material removed from the baghouses will continue to be managed using current practices. The current practice at G-3 is to remove the material from the baghouse using a pneumatic tanker truck, which then transports the material to the AOS Phase IV Disposal Area, where it is pneumatically off-loaded into a temporary storage silo prior to moisture conditioning to approximately 10 to 15 percent (for dust control), and hauled and placed in the landfill (followed by grading and compaction). The baghouse material at JPM can be managed in a similar manner as at G-3. The JPM facility also has the ability to transfer the baghouse material directly into an adjacent pin-mixer to moisture condition, and then direct haul by dump truck to the active face of the AOS Phase IV Disposal Area for placement, grading and compaction.

Regulatory Considerations

Condition 29 of the Conditional Plan of Operation Approval for the Dairyland Power Cooperative Phase IV Disposal Area, dated May 15, 2001, requires that DPC analyze the ash for compatibility with the Geosynthetic Clay Liner (GCL) in the event of a major process change or coal source change. The purpose of the compatibility testing is to assess the impact of the ash leachate on the bentonite minerals of the GCL, particularly concerning geochemical changes and subsequent permeability changes. In consideration of the results from previous compatibility testing performed annually (from 2003 through 2007); the more recent laboratory testing performed on the sodium bicarbonate residual samples from the JPM baghouse; and the type of product and limited quantity that will be used for ACI, we do not anticipate any significant increase in permeability of the GCL based on the similarity in leaching characteristics between the lime-based and sodium bicarbonate-based material.

Please invoice DPC directly (to the attention of Bill Kowalski) for the applicable review fee. If you have any questions regarding this information, please contact Curt Madsen, at (608) 826-3640.

Sincerely,

TRC Environmental Corporation

Robert Stanforth
Robert Stanforth, Ph.D.
Senior Applied Chemist

Curt Madsen
Curtis D. Madsen, P.E.
Senior Project Manager

Attachments: Table 1 – Summary of Required Information of Three Coal Combustion Residuals
Table 2 – Moisture Holding Capacity of Sodium Bicarbonate-treated (JPM) and Lime-treated (Genoa) FGD Residual Material
Figure 1 – Schematic of the Air Pollution Control System for the JPM Facility
Figure 2 – Schematic of the Air Pollution Control System for the G-3 Facility
Figure 3 – Moisture Holding Capacity of JPM (sodium bicarbonate treated) and G-3 (lime treated) Material
Attachment 1 – Material Safety Data Sheets

cc: Bill Kowalski – DPC

Report Certification

I, ________, hereby certify that I am a registered professional engineer in the State of Wisconsin, registered in accordance with the requirements of Chapter A-E4, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in Chapter A-E8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document was prepared in compliance with all applicable requirements in Chapters NR 500 to 538, Wis. Adm. Code.

CURTIS D.
MADSEN
E-22619
MADISON,
WI

11-4-2013

Curtis D. Madsen, P.E.
Senior Project Manager

Table 1
Summary of Required Information of Three Coal Combustion Residuals

INFORMATION	DRY SCRUBBER WASTE JPM	ACTIVATED CARBON	
		JPM	GENOA
Physical and Chemical Characteristics			
Solids Content	100%	100%	100%
MSDS	NA	See attached	
Paint Filter Test	No free liquid – waste generated from a high temperature combustion process		
Volume and Duration of Waste Disposed			
Monthly	1,250 tons/mo	103 tons/mo	134 tons/mo
Yearly	15,000 tons/yr	1,231 tons/yr	1,607 tons/yr
Duration	Through lifespan of landfill		
Source of Wastes and Special Handling – in text			

Table 2
Moisture Holding Capacity of Sodium Bicarbonate-treated (JPM) and Lime-treated (G-3) FGD Residual Material

ADDITIVE/WASTE	WATER (mL/kg)		
	ADDED	RECOVERED	ABSORBED
Sodium Bicarbonate/ JPM	250	0	250
	500	0	500
	1,000	167	833
	1,500	325	1,175
	2,000	760	1,240
	3,000	1,680	1,320
Lime/ G-3	500	0	500
	1,000	0	1,000
	1,500	0	1,500
	2,000	665	1,335
	3,000	1,670	1,330
	4,000	2,250	1,750

Figure 1
Schematic of the Air Pollution Control System for the JPM Facility

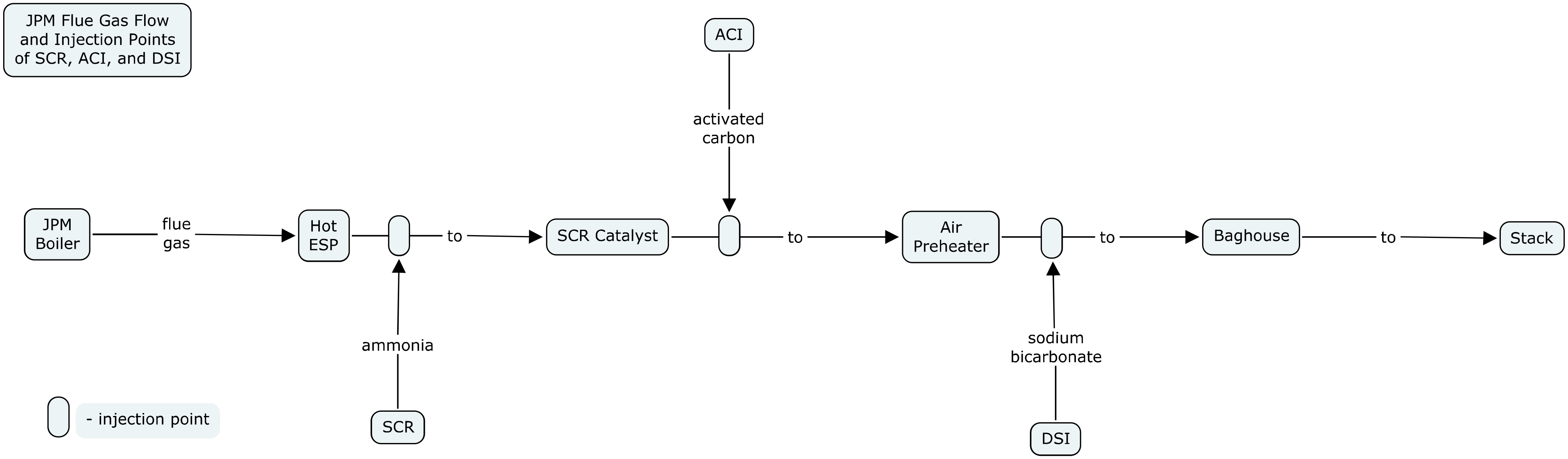


Figure 2
Schematic of the Air Pollution Control
System for the G-3 Facility

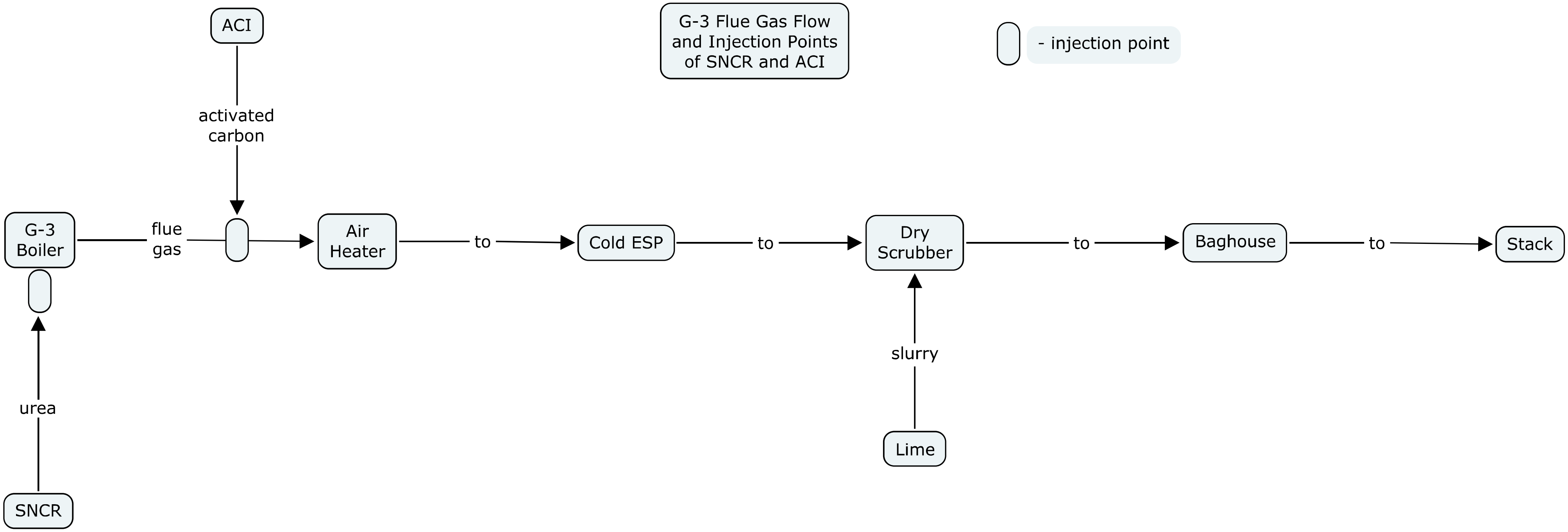
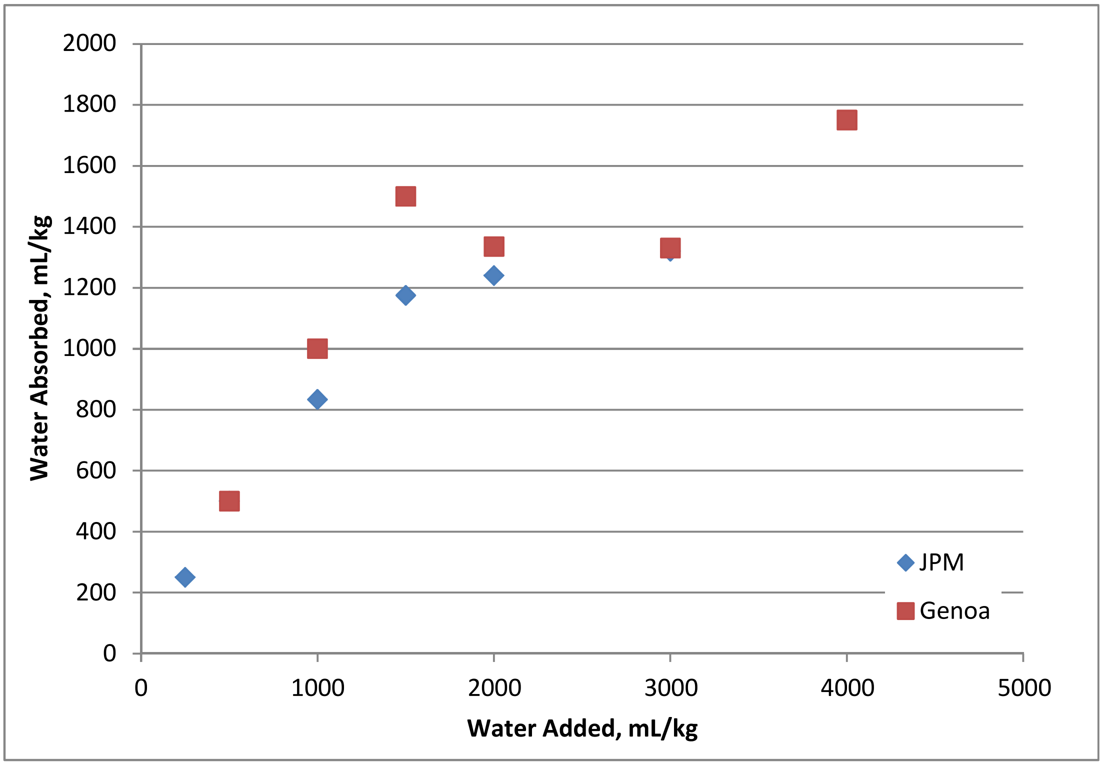


Figure 3
Moisture Holding Capacity of JPM (sodium bicarbonate treated) and G-3 (lime treated) Material



Attachment 1

Material Data Safety Sheets

- Material Safety Data Sheets for Activated Carbon from ADA Carbon Solutions, LLC
- Material Safety Data Sheets for Activated Carbon from Albemarle Corp.

MATERIAL SAFETY DATA SHEET

PowerPAC™ Emission Control Treatment Series

1. Product and Company Identification

Supplier **ADA Carbon Solutions, LLC** **8100 SouthPark Way, Unit A-2** **Littleton, CO 80120-4527** **Telephone Number:** 888-843-8416 **FAX Number:** 303-962-1970	**Manufacturer** **ADA Carbon Solutions, LLC** **8100 SouthPark Way, Unit A-2** **Littleton, CO 80120-4527** **Telephone Number:** 888-843-8416 **FAX Number:** 303-962-1970
Supplier Emergency Contacts & Phone Number **CHEMTREC: 800-424-9300**	**Manufacturer Emergency Contacts & Phone Number** **CHEMTREC: 800-424-9300**

Issue Date: 06/2011

Product Name: Power PAC™, Power PAC LF™
CAS Number: N/A

Product/Material Uses
Powdered carbon sorbent of vapor-phase mercury in flue gas, primarily in coal-fired power plants.

2. Composition/Information On Ingredients

Ingredient Name	CAS Number		Percent of Total Weight
Carbon, activated	7440-44-0		0–100

This product contains no hazardous ingredients when evaluated by criteria established in the OSHA Hazard Communication Standard (29 CFR 1910.1200).

EMERGENCY OVERVIEW

Wet activated carbon removes oxygen from air and can lower the concentration of oxygen inside vessels and other confined spaces. During combustion, toxic and irritating gases including high levels of carbon monoxide may be produced.

3. Hazards Identification

Primary Routes of Entry
Inhalation, skin contact, eye contact

Eye Hazards
Dust may cause mild mechanical irritation.

Skin Hazards
Prolonged or repeated skin contact may cause irritation, drying, and redness.

Ingestion Hazards
May cause mild gastrointestinal tract irritation.

Inhalation Hazards
High airborne concentrations of low-toxicity dusts may cause coughing, sneezing, and mild temporary irritation.

Avoid use in confined spaces. Wet activated carbon can absorb and deplete oxygen from the air, causing a severe hazard to workers.

Chronic/Carcinogenicity Effects
Activated carbons may contain crystalline silica, which is classified as a potential human carcinogen. Prolonged

inhalation of excessive dust may cause pulmonary disorders.

4. First Aid Measures

Eye

Hold eyelids apart and flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation develops.

Skin

Wash affect areas with soap and water. Get medical attention immediately if irritation develops.

Ingestion

If person is fully conscious, give one or two cups of water or milk to drink. Get medical attention immediately if large quantities are ingested.

Inhalation

Remove person from source of exposure and into fresh air. Get medical attention if irritation or breathing difficulties develop.

5. Fire-Fighting Measures

Lower Explosive Limit: N/A
Upper Explosive Limit: N/A

Fire and Explosion Hazards

High dust concentrations may form explosive mixtures with air, which can be ignited by spark or flame. Dusts may accumulate a static discharge. Keep dust concentrations low.

Fire is possible at elevated temperatures or by self-heating when exposed to strong oxidizers. Activated carbon tends to burn slowly without producing smoke or flame. Material allowed to smolder for long periods in enclosed spaces may produce carbon monoxide, which may reach a lower explosive limit for carbon monoxide (12.5%) in air. Wet activated carbon depletes oxygen from the air.

Warning: Electrostatic precipitator and baghouse hoppers containing powdered activated carbon or fly ash with activated carbon can autoignite and present a smoldering fire hazard when exposed to elevated temperature and other sources of heat, such as heaters. If activated carbon is present, hoppers should be emptied frequently and particular care should be exercised when hopper heaters are in use. Cutting or welding operations should not be used near this material due to potential for smoldering combustion. This material is not a self-heating material as classified for transportation.

Extinguishing Media

In case of fire, use water spray, dry chemical, or CO_2. Use water to cool fire-exposed containers.

Fire-Fighting Instructions

Firefighters should wear self-contained breathing apparatus and full protective gear. Remove product from building to a non-hazardous area, preferably outdoors, if safe to do so.

6. Accidental Release Measures

Provide maximum dilution or explosion-proof exhaust ventilation. Avoid generating dust. Pick up released product with appropriate implements and return to original container if reusable, or dispose.

7. Handling and Storage

Handling Precautions

Follow good handling and housekeeping practices. Avoid spills and accumulations of dust, or generation of airborne dust. Do not enter places where bulk material is used or stored until adequately ventilated to prevent asphyxiation.

As with all finely divided materials, precautions should be taken to avoid inhalation and eye contact. Ground all transfer, blending, and dust collecting equipment to prevent static discharge in accordance with NFPA 70, National Electric Code," NFPA 499, "Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas," NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids," and OSHA Combustible Dust standards. Remove all ignition sources from material handling, transfer, and processing areas where dust may be present.

Storage Precautions

Store in sealed containers in a clean cool, dry, well-ventilated area away from strong oxidizers, ignition sources, combustible materials, and heat. Do not store near, or allow contact with, moisture or strong oxidizers.

Warning: Wet activated carbon depletes oxygen, creating oxygen-deficient atmospheres in confined spaces.

Work/Hygienic Practices

Wash thoroughly with soap and water after handling.

8. Exposure Controls/Personal Protection

Engineering Controls

Use with adequate general and local exhaust ventilation to prevent excessive airborne dust concentrations. Local exhaust ventilation should be provided, to maintain exposures below recommended occupational exposure limits. Confined spaces where activated carbon is present should be well ventilated and monitored for oxygen content.

Eye/Face Protection

Safety glasses with side shields are recommended as minimum industrial eye protection when handling bulk product or performing spill cleanup.

Skin Protection

Protective gloves are recommended to minimize skin contact. Use a lab coat or disposable coveralls to prevent excessive contamination to personal clothing.

Respiratory Protection

In case of inadequate ventilation to control dust, use NOISH-approved respirator for particulates (e.g., N95). Supplied air respirators may be needed for entering confined spaces where product is stored or handled to protect against oxygen deficiency.

Ingredients – Exposure Limits

Carbon, activated.
OSHA PEL-TWA: 15 mg/m^3, total dust, as particulates not otherwise specified
OSHA PEL-TWA: 5 mg/m^3, respirable dust, as particulates not otherwise specified

9. Physical and Chemical Properties

Appearance

Grey to black, free-flowing powder

Odor

Odorless

Chemical Type: Mixture
Physical State: Solid
Specific Gravity: > 1*
Packing Density: 0.5 to 0.65
Vapor Pressure: N/A
Solubility: Slightly soluble
Evaporation Rate: N/A

* - Skeletal density (true density without pores)

10. Stability and Reactivity

Stability: Stable under ordinary conditions of shipment, storage, and use.
Hazardous Polymerization: Will not occur.

Incompatible Materials

Avoid contact with strong oxidizing agents such as ozone, liquid oxygen, chlorine, permanganate, sulfuric acid, and nitric acid.

Hazardous Decomposition Products

Thermal decomposition (“burning”) may produce irritating and toxic fumes of carbon (carbon dioxide, carbon monoxide), formaldehyde, ethylene, and acrylic acid. The exact chemicals formed depend on many factors including temperature and heating rate.

11. Toxicological Information

Chronic/Carcinogenicity

The product is not listed as potentially carcinogenic by NTP, IARC, OSHA, or ACGIH.

May contain trace concentrations of bound silica. Crystalline silica is considered to be a probable human carcinogen.

Ingredients – Toxicological Data

Carbon, activated.

LC50 (inhal, rat): > 64,400 mg/m^3
LD50 (oral, rat): > 10,000 mg/kg

12. Ecological Information

Ecotoxicological Information

No information available for the product. However, ecotoxicity is expected to be minimal.

This material will increase the conductivity of water by increasing dissolved solids. Used activated carbon may exhibit characteristics of the absorbed material.

Environmental Fate Information

No information available.

13. Disposal Considerations

Activated carbon in pure form is not a hazardous material but spent carbon could potentially be a hazardous waste depending on the application. Dispose in accordance with applicable federal, state, and local government regulations.

14. Transport Information

Additional Shipping Paper Description

Shipping name: Activated Carbon.

This product is NOT considered spontaneously combustible under the “Self-Heating Test for Carbon” protocol listed in the United Nations Manual of Tests and Criteria [33.3.1].

15. Regulatory Information

U.S. Regulatory Information

Toxic Substance Control Act (TSCA): All ingredients of the product are listed on the TSCA 8(b) Chemical Substance Inventory or are exempt.

Product is not classifiable under any of the five SARA Title III hazard ratings.

Product does not have a CERCLA RQ.

SARA Section 313 Notification

This product does not contain any ingredients regulated under Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 or 40 CFR 372.

Canadian Regulatory Information

Product is not regulated or controlled under WHMIS (Canada). This product is not classifiable as hazardous under the Canadian Hazardous Products Act (HPA).

DSL: 6798

16. Other Information

NFPA Rating
Health: 1
Fire: 1
Reactivity: 0

HMIS Rating
Health: 0
Fire: 0
Reactivity: 0
Personal Protection: B

Disclaimer

This information relates to the product designated herein and does not relate to its use in combination with any other material or in any other process. To the best of ADA Carbon Solutions' knowledge, the information contained herein is reliable and accurate as of this date; however, accuracy, suitability, and completeness are not guaranteed. Users are responsible to verify this data for their own particular use and they assume all risks of their reliance upon information contained herein. ADA Carbon Solutions, LLC, shall under no circumstances be liable for incidental or consequential damages as a result of reliance upon information contained herein.

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LIMIT OF LIABILITY: ADA Carbon Solutions shall not be liable for, and Buyer assumes responsibility for, personal injury and property damage resulting from the handling, possession, use, storage, or resale of the product, whether used or in combination.

ADA Carbon Solutions, LLC

B-PAC™

Material Safety Data Sheet

Revision Date: 23-Dec-2009
Supersedes New

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name	B-PAC™
Chemical Name	Mixture.
CAS-No	Mixture
Recommended use	Not available
Emergency Telephone Numbers	225-344-7147
For Non-Emergency	800-535-3030

	NFPA	**HMIS**
Health	1	1
Flammability	1	1
Physical Hazards	0	0

2. HAZARDS IDENTIFICATION

Caution

Emergency Overview

Product dust may be irritating to the eyes and respiratory system.

Potential Health Effects

Eyes	Irritating to eyes.
Skin	Not expected to be an irritant.
Inhalation	Irritating to respiratory system.
Ingestion	Not expected to be acutely toxic.

See Section 11 for additional Toxicological information.

Occupational Exposure Limit See Section 8

3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No	Weight %
Carbon	7440-44-0	90-95
Bromine	7726-95-6	5-10

4. FIRST AID MEASURES

Eye contact	In the case of contact with eyes, rinse immediately with plenty of water and seek medical advice
Skin Contact	Wash off immediately with soap and plenty of water removing all contaminated clothes and shoes.
Inhalation	Move to fresh air If not breathing, give artificial respiration, preferably mouth to mouth. If breathing is difficult, give oxygen. Seek immediate medical attention/advice.
Ingestion	Drink plenty of water.

5. FIRE-FIGHTING MEASURES

Combustion/explosion hazards	Contact with combustible material may cause fire.
Suitable Extinguishing Media	Carbon dioxide, dry chemicals, foam, water spray (mist).
Hazardous Combustion Products	Carbon monoxide.
Protective Equipment and Precautions for Firefighters	Wear self contained breathing apparatus for fire fighting if necessary.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions	Evacuate unnecessary personnel. Do not breathe dust..
Environmental precautions	Sweep up and shovel into suitable containers for disposal.
Methods for Clean-up	Avoid dust formation. Sweep up and shovel into suitable containers for disposal..

7. HANDLING AND STORAGE

Handling	Avoid dust formation. Avoid breathing dust. Wash thoroughly after handling. Wet activated carbon removes oxygen from air causing a severe hazard to workers inside carbon vessels and enclosed or confined spaces. Before entering such an area, sampling and work procedures for low oxygen levels should be taken to ensure ample oxygen availability, observing all local, state, federal or national regulations.
Storage	Keep containers tightly closed in a dry, cool and well-ventilated place.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Component	CAS-No	Weight %	ACGIH TLV (TWA)	ACGIH (STEL or Ceiling)	OSHA PEL (TWA)	OSHA (STEL or Ceiling)
Carbon	7440-44-0	90-95	spirable fraction.		15MPPCF 5mg/m^3 Respirable fraction. 15mg/m^3 Total dust. 2.5mg/m^3 Respirable dust. 10mg/m^3 Total dust.	
Bromine	7726-95-6	5-10	0.1PPM	0.2PPM (STEL)	0.7mg/m^3; 0.1PPM 0.1PPM	2mg/m^3; 0.3PPM (STEL)

Engineering Controls	Ensure adequate ventilation, especially in confined areas.

Personal Protective Equipment

Eye/face Protection	Safety glasses or goggles recommended.
Skin Protection	Wear protective gloves/clothing.
Hand protection	Gloves resistant to chemical permeation.
Respiratory protection	NIOSH approved particulate filter respirator is recommended if excessive dust is generated.

9. PHYSICAL AND CHEMICAL PROPERTIES

Flash point	Not applicable.	**Flammable limits (LEL, UEL)**	No data available
Form	Powder/Particulate	**Vapour pressure**	No data available
Color	Black.	**Density**	0.4-0.7g/cc
Odor	Unknown.	**Vapor density**	No data available
Water Solubility	Negligible.	**Boiling Point**	Not applicable
Melting/freezing point	Not applicable	**Viscosity, dynamic**	No data available
Viscosity, kinematic	No data available		

10. STABILITY AND REACTIVITY

Stability	Stable.
Materials to avoid	Avoid strong oxidizing agents. Avoid strong reducing agents.
Hazardous decomposition products	Carbon monoxide.
Hazardous Polymerization	None under normal processing.

11. TOXICOLOGICAL INFORMATION

Acute Effects

Eye contact	Irritant.
Skin contact	Not irritating
Ingestion	Not expected to be acutely toxic.
Inhalation	May irritate the nose, throat, and lungs.
LD50 Oral:	>2000 mg/kg (rat)

12. ECOLOGICAL INFORMATION

Ecotoxicity

Ecotoxicity effects	No information available.

13. DISPOSAL CONSIDERATIONS

Waste Disposal Method	Dispose in a safe manner in accordance with local/national regulations.

14. TRANSPORT INFORMATION

DOT

Proper Shipping Name	NOT REGULATED FOR TRANSPORTATION
Hazard Class	Not regulated
UN No.	Not regulated
Packing Group	Not regulated
Description	Not regulated

IMDG/IMO

IMO Class	Not regulated
Packing Group	Not regulated
UN-No	Not regulated
IMO Labelling and Marking	Not regulated
Proper Shipping Name	Not regulated
EmS	Not regulated
Marpol - Annex II	Not regulated
Marpol - Annex III	Not regulated
Transport Description	Not regulated

IATA/ICAO

IATA/ICAO Class	Not regulated
Packing Group	Not regulated
UN-No	Not regulated
IATA/ICAO Labelling	Not regulated
Passenger Aircraft	Not regulated
Cargo aircraft only	Not regulated
Proper shipping name	Not regulated
Transport Description	Not regulated

15. REGULATORY INFORMATION

International Inventories	TSCA	DSL	NDSL	AICS	EINECS	ELINCS	ENCS	KECL	PICCS	CHINA	NZIoC
B-PAC™	X	X	-	X	X	-	X	X	X	X	X

(X) Complies (-) Does not Comply

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product contains a chemical or chemicals which are subject to the reporting requirements of the Act and and Title 40 of the Code of Federal Regulations, Part 372:

Component	CAS-No	Weight %
Bromine	7726-95-6	5-10

SARA 311/312 Hazardous Categorization

Chronic Health Hazard	No
Acute Health Hazard	Yes
Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

Reportable and Threshold Planning Quantities

The following components have RQs and/or TPQs under SARA and/or CERCLA

Component	CAS-No	Weight %	SARA 302 RQ, lbs	CERCLA RQ, lbs	SARA 302 TPQ, lbs
Bromine	7726-95-6	5-10	500		500

State Regulations
This product contains the following chemicals regulated in the states listed below.

Component	CAS-No	California Prop. 65	Massachusetts	New Jersey	Pennsylvania
Carbon	7440-44-0		Listed.		Listed.
Bromine	7726-95-6		Listed.	Listed.	Listed.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazards
D2B Toxic materials

16. OTHER INFORMATION

Prepared By

Health & Environment Department
Albemarle Corporation

FOR ADDITIONAL NONEMERGENCY PRODUCT INFORMATION, CONTACT:

HEALTH AND ENVIRONMENT DEPARTMENT
ALBEMARLE CORPORATION
451 FLORIDA ST.
BATON ROUGE, LA. 70801
(800) 535-3030

The information contained herein is accurate to the best of our knowledge. The Company makes no warranty of any kind, express or implied, concerning the safe use of this material in your process or in combination with other substances.

Appendix I: Supplemental Leachate Collection System Design Demonstrations

- I.1: Cell 3A Liner Construction Documentation Report – Piping and Permeability Calculation
- I.2: Cell 3B Liner Construction Documentation Report – Piping and Permeability Calculation
- I.3: Ineos's Chemical Resistance Guide

I.1
Cell 3A Liner Construction Documentation Report Piping and Permeability Calculation

Results you can rely on

Phase IV, Cell 3A Liner Construction Documentation Report

Dairyland Power Cooperative
Alma Off-Site Ash Disposal Facility

January 2013

WISCONSIN
1/17/13
KIM D.
PAWLISCH
E-28175
Madison,
WI
PROFESSIONAL ENGINEER

Kim D. Pawlisch, P.E.
Senior Project Engineer

Todd W. Martin

Todd W. Martin
Project Manager

Nicholas D. Bower
Resident Project Representative

Appendix Q
Piping and Permeability Calculations

708 Heartland Trail, Suite 3000, Madison, WI 53717 • www.TRCsolutions.com

SHEET 1 OF 1

PROJECT/LOCATION: Dairyland Power Phase IV, Cell 3A Liner Construction		PROJECT / PROPOSAL NO. 187576.0000.0000
SUBJECT: Piping and Perm Calcs (SP1)		
PREPARED BY: K. Pawlisch	DATE: 8/23/2012	FINAL X
CHECKED BY: T. Martin	DATE: 8/23/2012	REVISION

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base (Select Granular Fill pt. 697)

$D15_B$	0.46	mm	=	0.02	inches
$D50_B$	0.85	mm	=	0.03	inches
$D85_B$	1.80	mm	=	0.07	inches
$Cu^{2,3}$	2.57	mm	=	0.10	inches

Filter (3/4" River Rock SP1)

$D15_F$	6.35	mm	=	0.25	inches
$D50_F$	9.90	mm	=	0.39	inches
$D85_F$	15.51	mm	=	0.61	inches

Collection Pipe

Pipe Hole Diameter 0.50 inches or Slot Width n/a inch

Results

Head Loss (Permeability Criteria)

	Actual		Required	Results
$D15_F / D15_B$	13.9	>	4.0	OK

Perforation Size Results (Piping Criteria)

	Actual		Required	Results
$D85_F /_{HOLE}$	1.2	>	1.2	OK
or				
$D85_F /_{SLOT}$	n/a	>	1.4	n/a

Particle Migration (Piping Criteria)

	Actual		Required	Results
$D15_F / D85_B$	3.5	<	5.0	OK
$D50_F / D50_B$	11.7	<	25.0	OK
$D15_F / D15_B$	13.9	<	20.0	OK

Notes:

1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve (NAVFAC, 1986).

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SHEET 1 OF 1

PROJECT/LOCATION: Dairyland Power Phase IV, Cell 3A Liner Construction		PROJECT / PROPOSAL NO.
SUBJECT: Piping and Perm Calcs (SP2)		187576.0000.0000
PREPARED BY: K. Pawlisch	DATE: 8/23/2012	FINAL X
CHECKED BY: T. Martin	DATE: 8/23/2012	REVISION

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base (Select Granular Fill pt. 697)

$D15_B$	0.46	mm	=	0.02	inches
$D50_B$	0.85	mm	=	0.03	inches
$D85_B$	1.80	mm	=	0.07	inches
$Cu^{2,3}$	2.57	mm	=	0.10	inches

Filter (3/4" River Rock SP2)

$D15_F$	6.71	mm	=	0.26	inches
$D50_F$	10.88	mm	=	0.43	inches
$D85_F$	16.03	mm	=	0.63	inches

Collection Pipe

Pipe Hole Diameter 0.50 inches or Slot Width n/a inch

Results

Head Loss (Permeability Criteria)

	Actual		Required	Results
$D15_F / D15_B$	14.7	>	4.0	OK

Perforation Size Results (Piping Criteria)

	Actual		Required	Results
$D85_F / _{HOLE}$	1.3	>	1.2	OK
or				
$D85_F / _{SLOT}$	n/a	>	1.4	n/a

Particle Migration (Piping Criteria)

	Actual		Required	Results
$D15_F / D85_B$	3.7	<	5.0	OK
$D50_F / D50_B$	12.8	<	25.0	OK
$D15_F / D15_B$	14.7	<	20.0	OK

Notes:

1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve (NAVFAC, 1986).

RMT

COMPUTATION SHEET

SHEET 1 OF 1

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
DPC	By: *MJD*	Date: 6/18/01	By: BJK	Date: 6/18/01	3081.44

Piping and Permeability Calculation

Input

Fly Ash

$D15_B$	0.02
$D50_B$	0.03
$D85_B$	0.05

Drainage Layer

$D15_F$	0.21
$D50_F$	0.29

Results

Permeability Results

	Actual	Required
$D15_F/D15_B$	8.2	NA

Piping Results

	Actual	Required
$D15_F/D85_B$	4.6	< 6
$D50_F/D50_B$	9.5	< 25
$D15_F/D15_B$	8.2	< 20

NOTES

1. All units are in millimeters unless specified.
2. For very uniform base material (Cu<1.5): $D15_F/D85_B$ may be increased to 6.
3. For broadly graded base material (Cu>4): $D15_F/D15_B$ may be increased to 40 (Piping equation only).
4. To avoid segregation, filter material should contain no sizes larger than 3 inches.
5. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve.
   (NAVFAC, 1986)
6. NA = Not Applicable

RMT

COMPUTATION SHEET

SHEET 1 OF 1

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
DPC	By: *MJD*	Date: 6/18/01	By: BJK	Date: 8/18/01	3081.44

Piping and Permeability Calculation

Input

Bottom Ash

$D15_B$	0.09
$D50_B$	0.25
$D85_B$	3.00

Drainage Layer

$D15_F$	0.21
$D50_F$	0.29

Results

Permeability Results

	Actual	Required
$D15_F/D15_B$	2.3	NA

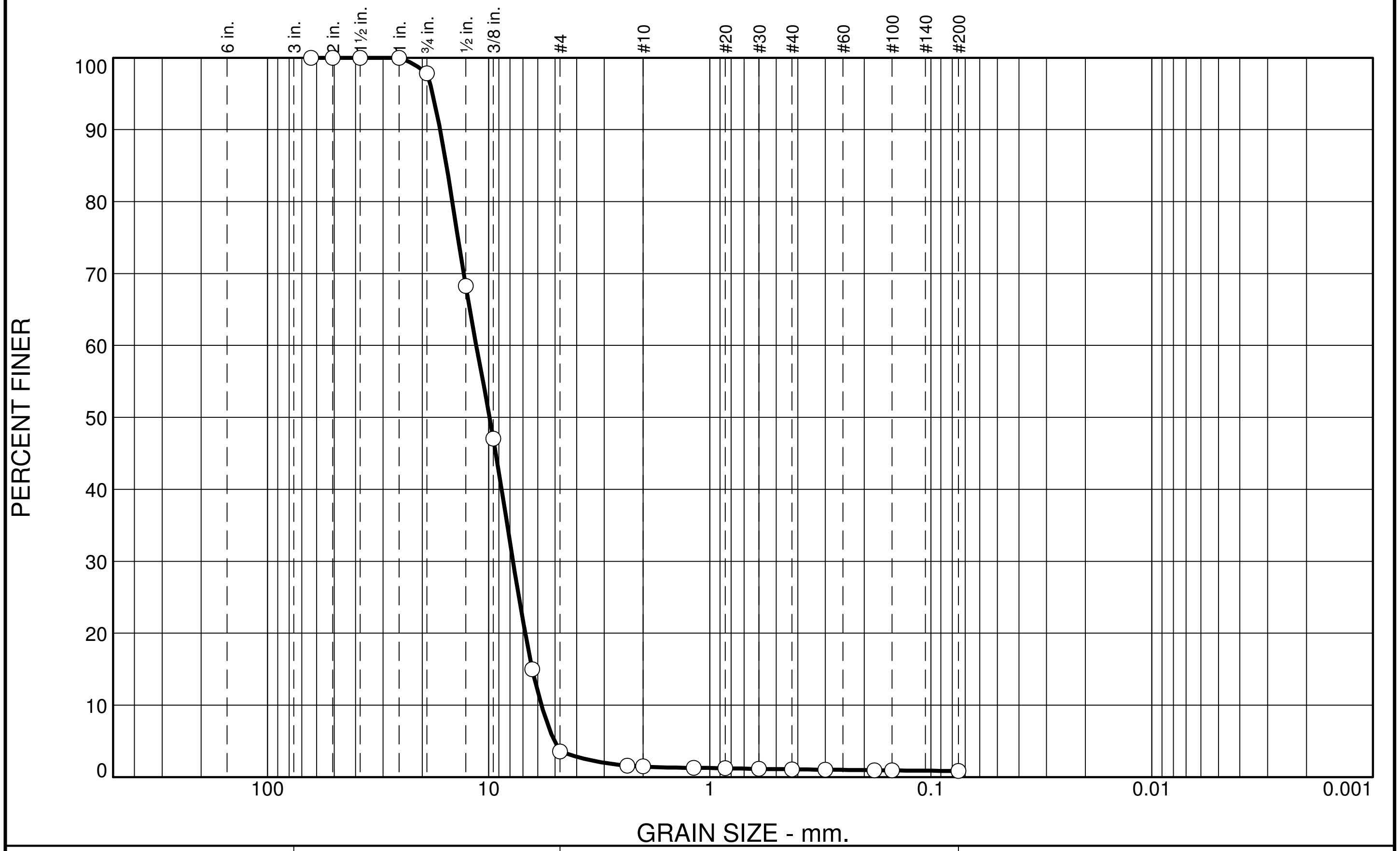
Piping Results

	Actual	Required
$D15_F/D85_B$	0.1	< 6
$D50_F/D50_B$	1.2	< 25
$D15_F/D15_B$	2.3	< 20

NOTES

1. All units are in millimeters unless specified.
2. For very uniform base material (Cu<1.5): $D15_F/D85_B$ may be increased to 6.
3. For broadly graded base material (Cu>4): $D15_F/D15_B$ may be increased to 40 (Piping equation only).
4. To avoid segregation, filter material should contain no sizes larger than 3 inches.
5. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve.
   (NAVFAC, 1986)
6. NA = Not Applicable

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.2	94.3	2.0	0.4	0.3	0.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2.5	100.0		
2.0	100.0		
1.5	100.0		
1.0	100.0		
.75	97.8		
.5	68.3		
.375	47.0		
.25	15.0		
#4	3.5		
#8	1.6		
#10	1.5		
#16	1.3		
#20	1.2		
#30	1.1		
#40	1.1		
#50	1.0		
#80	1.0		
#100	0.9		
#200	0.8		

* (no specification provided)

Material Description

Poorly graded gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 16.5583 D_{85}= 15.5103 D_{60}= 11.3782
D_{50}= 9.9041 D_{30}= 7.7598 D_{15}= 6.3497
D_{10}= 5.7831 C_u= 1.97 C_c= 0.92

Classification

USCS= GP AASHTO=

Remarks

Source of Sample: Select Aggregate Fill
Sample Number: River Run SP-1

Date: 08-23-12

TRC Environmental Corp.

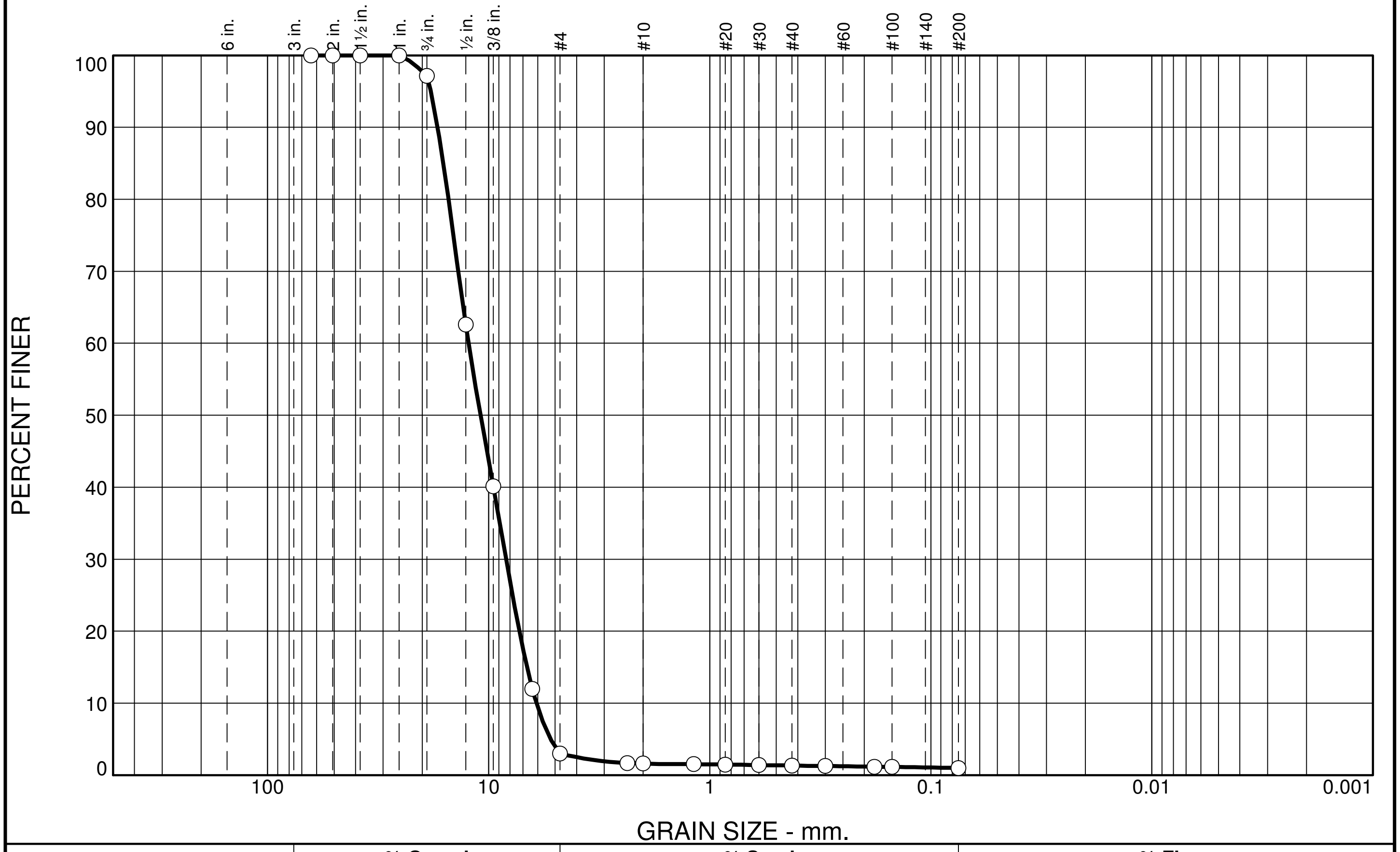
Madison, Wisconsin

Client: DPC
Project: DPC - PH4 Cell 3A

Project No: 187576.0000 **Figure**

Tested By: JPH **Checked By:** JPH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.8	94.2	1.4	0.3	0.3	1.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2.5	100.0		
2.0	100.0		
1.5	100.0		
1.0	100.0		
.75	97.2		
.5	62.6		
.375	40.1		
.25	12.0		
#4	3.0		
#8	1.7		
#10	1.6		
#16	1.5		
#20	1.5		
#30	1.4		
#40	1.3		
#50	1.3		
#80	1.2		
#100	1.1		
#200	1.0		

* (no specification provided)

Material Description

Poorly graded gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 17.0003 D_{85}= 16.0276 D_{60}= 12.3298
D_{50}= 10.8803 D_{30}= 8.3374 D_{15}= 6.7126
D_{10}= 6.0888 C_u= 2.03 C_c= 0.93

Classification

USCS= GP AASHTO=

Remarks

Source of Sample: Select Aggregate Fill
Sample Number: River Run SP-2

Date: 08-23-12

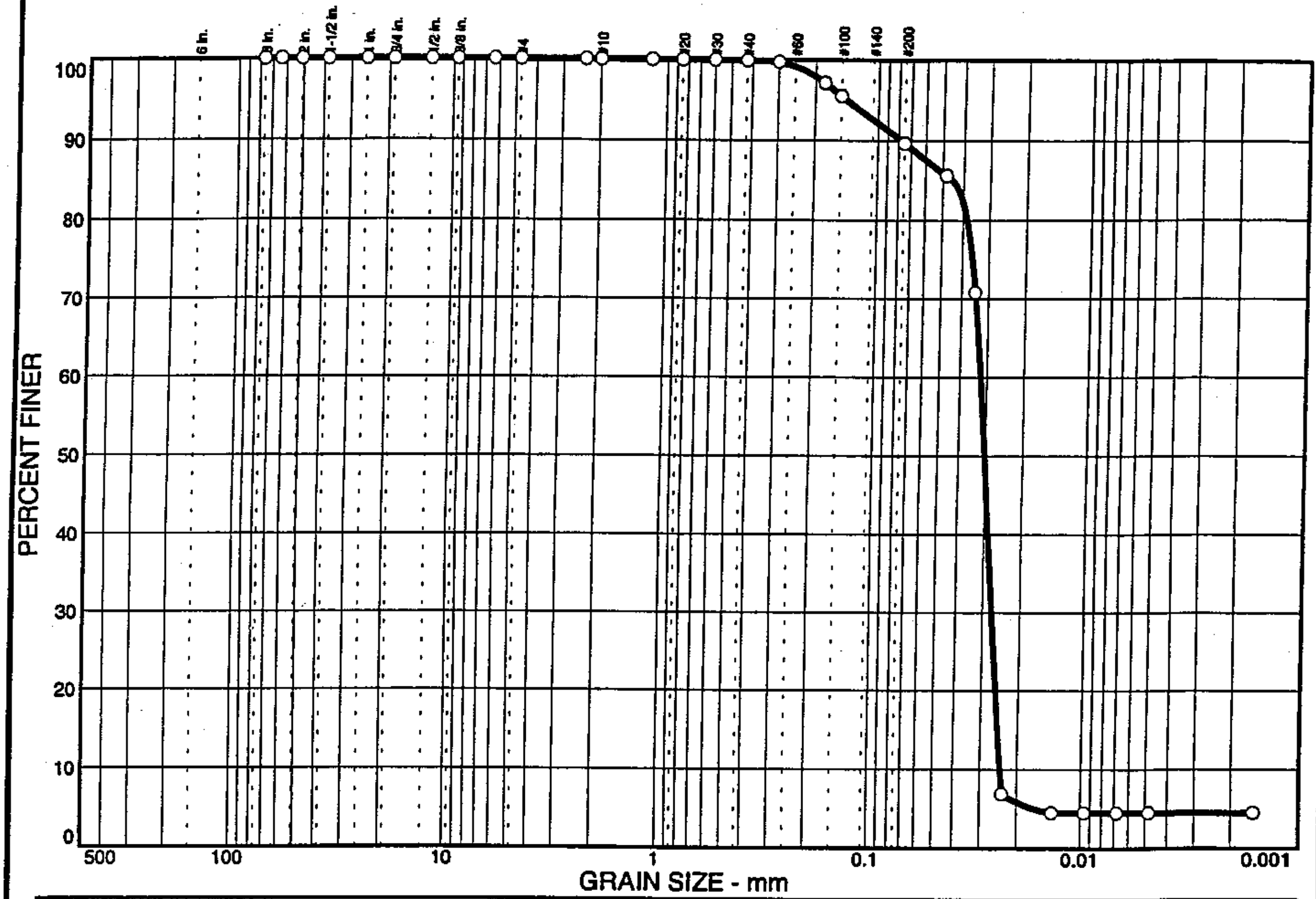
TRC Environmental Corp.

Madison, Wisconsin

Client: DPC
Project: DPC - PH4 Cell 3A
Project No: 187576.0000 **Figure**

Tested By: JPH **Checked By:** JPH

GRAIN SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	10.3	85.2	4.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3.0 in.	100.0		
2.5 in.	100.0		
2.0 in.	100.0		
1.5 in.	100.0		
1.0 in.	100.0		
.75 in.	100.0		
.5 in.	100.0		
.375 in.	100.0		
.25 in.	100.0		
#4	100.0		
#8	100.0		
#10	100.0		
#16	100.0		
#20	100.0		
#30	100.0		
#40	99.9		
#50	99.7		
#80	97.1		
#100	95.5		
#200	89.7		

* (no specification provided)

Soil Description

(Fly Ash)

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.0450 D_{60}= 0.0321 D_{50}= 0.0303
D_{30}= 0.0272 D_{15}= 0.0249 D_{10}= 0.0241
C_u= 1.33 C_c= 0.96

Classification

USCS= AASHTO=

Remarks

Sample No.: Alma-1 **Source of Sample:** DPC-Alma **Date:** 6-6-01
Location: FLY ASH **Elev./Depth:**

RMT, Inc.

Client:
Project: DAIRYLAND POWER COOPERATIVE
Project No: 3081.49 **Figure:**

DAVY LABORATORIES
115 South 6th Street
P.O. Box 2076
La Crosse, WI 54602-2076
(608) 782-3130
FAX (608) 784-6611

DAVY LABORATORIES
Division of Davy Engineering Co.

TABLE 3
PHYSICAL ANALYSIS RESULTS FOR ALMA BOTTOM ASH

I. Particle Size Distribution

Sample Number: 44639 Sample Size: 50 grams

Sieve No.	Grams Retained	Total Retained	% Retained	% Total Retained	% Finer
3/8	0.00	0.00	0.00	0.00	100
4	5.16	5.16	10.33	10.33	89.67
8	3.53	8.69	7.07	17.40	82.60
16	4.50	13.19	9.01	36.41	73.59
30	5.75	18.94	11.51	37.92	62.07
50	9.00	37.94	18.02	55.94	44.06
100	9.73	37.67	19.48	75.42	24.58
200	6.81	44.48	13.64	89.06	10.94
Pan	5.46	---	---	---	---

Total Weight Recovered 49.94 grams

II. Bulk Dry Density, pcf (ASTM:C29) 51.8

I.2
Cell 3B Liner Construction Documentation Report
Piping and Permeability Calculation

TRC
Results you can rely on

Phase IV, Cell 3B Liner Construction Documentation Report

Dairyland Power Cooperative
Alma Off-Site Ash Disposal Facility

License No. 4126

October 2015

WISCONSIN
Douglas R.
Genthe
E-27604
Madison,
WI
PROFESSIONAL ENGINEER

Douglas R. Genthe
10.23.2015

Douglas R. Genthe, P.E.
Managing Principal

Todd W. Martin

Todd W. Martin
Project Manager

Madsen for Spencer Sellner

Spencer Sellner
Resident Project Representative

Appendix N
Piping and Permeability Calculations

708 Heartland Trail, Suite 3000, Madison, WI 53717 • www.TRCsolutions.com

PROJECT/PROPOSAL NAME/LOCATION: DPC Phase IV Cell 3B Liner Construction		PROJECT / PROPOSAL NO. 216851.0004
SUBJECT: Piping and Permeability Calculation		
PREPARED BY: T. Halena	DATE: 6/22/2015	FINAL X
CHECKED BY: R. Wienkes	DATE: 10/19/2015	REVISION ☐

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base, Soil Being Retained (Graded Filter)

$D15_B$	2.89 mm	=	0.11	inches
$D50_B$	3.90 mm	=	0.15	inches
$D85_B$	5.22 mm	=	0.21	inches
Cu[2,3]	1.55 mm	=	0.06	

Filter (Pipe Bedding)

$D15_F$	6.96 mm	=	0.27	inches
$D50_F$	11.32 mm	=	0.45	inches
$D85_F$	17.04 mm	=	0.67	inches

Collection Pipe

Pipe Hole Diameter N/A inches or Slot Width N/A inch

Results

Permeability Results

	Actual		Required	Results
$D15_F / D15_B$	2.4	>	N/A	N/A

Perforation Size Results

	Actual		Required	Results
$D85_F / _{HOLE}$	N/A	>	1.2	N/A
or				
$D85_F / _{SLOT}$	N/A	>	1.4	N/A

Piping Results

	Actual		Required	Results
$D15_F / D85_B$	1.3	<	5.0	OK
$D50_F / D50_B$	2.9	<	25.0	OK
$D15_F / D15_B$	2.4	<	20.0	OK

Notes:

1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve. (NAVFAC, 1986)
3. For a uniform base (Cu<1.5), $D15_F/D85_B$ may be increased to 6 (piping equation only).
4. For a broadly graded base material (Cu>4), $D15_F/D15_B$ may be increased to 40 (piping equation only).

TRC

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PROJECT/PROPOSAL NAME/LOCATION: DPC Phase IV Cell 3B Liner Construction		PROJECT / PROPOSAL NO.
SUBJECT: Piping and Permeability Calculation		216851.0004
PREPARED BY: T. Halena	DATE: 6/22/2015	FINAL X
CHECKED BY: R. Wienkes	DATE: 10/19/2015	REVISION ☐

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base, Soil Being Retained (Select Granular Fill)

$D15_B$	0.29 mm	=	0.01 inches	
$D50_B$	0.50 mm	=	0.02 inches	
$D85_B$	1.02 mm	=	0.04 inches	
Cu[2,3]	2.32 mm	=	0.09	

Filter (Select Graded Fill)

$D15_F$	3.09 mm	=	0.12 inches
$D50_F$	4.30 mm	=	0.17 inches
$D85_F$	5.65 mm	=	0.22 inches

Collection Pipe

Pipe Hole Diameter N/A inches or Slot Width N/A inch

Results

Permeability Results

	Actual		Required	Results
$D15_F / D15_B$	10.7	>	N/A	N/A

Perforation Size Results

	Actual		Required	Results
$D85_F /_{HOLE}$	N/A	>	1.2	N/A
or				
$D85_F /_{SLOT}$	N/A	>	1.4	N/A

Piping Results

	Actual		Required	Results
$D15_F / D85_B$	3.0	<	5.0	OK
$D50_F / D50_B$	8.6	<	25.0	OK
$D15_F / D15_B$	10.7	<	20.0	OK

Notes:

1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve. (NAVFAC, 1986)
3. For a uniform base (Cu<1.5), $D15_F/D85_B$ may be increased to 6 (piping equation only).
4. For a broadly graded base material (Cu>4), $D15_F/D15_B$ may be increased to 40 (piping equation only).

TRC

708 Heartland Trail, Suite 3000, Madison, WI 53717 • www.TRCsolutions.com

PROJECT/PROPOSAL NAME/LOCATION: DPC Phase IV Cell 3B Liner Construction		PROJECT / PROPOSAL NO. 216851.0004
SUBJECT: Piping and Permeability Calculation		
PREPARED BY: T. Halena	DATE: 6/22/2015	FINAL X
CHECKED BY: R. Wienkes	DATE: 10/19/2015	REVISION ☐

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base, Material Being Retained (Fly Ash)

$D15_B$	0.02 mm	=	0.00	inches
$D50_B$	0.03 mm	=	0.00	inches
$D85_B$	0.05 mm	=	0.00	inches
$Cu^{2,3}$	1.33 mm	=	0.05	

Filter (Select Granular Fill)

$D15_F$	0.29 mm	=	0.01	inches
$D50_F$	0.56 mm	=	0.02	inches
$D85_F$	3.36 mm	=	0.13	inches

Collection Pipe

Pipe Hole Diameter N/A inches or Slot Width N/A inch

Results

Permeability Results

	Actual		Required	Results
$D15_F$ / $D15_B$	14.5	>	N/A	N/A

Perforation Size Results

	Actual		Required	Results
$D85_F$ / $_{HOLE}$	N/A	>	1.2	N/A
or				
$D85_F$ / $_{SLOT}$	N/A	>	1.4	N/A

Piping Results

	Actual		Required	Results
$D15_F$ / $D85_B$	5.8	<	6.0	OK
$D50_F$/$D50_B$	18.7	<	25.0	OK
$D15_F$ / $D15_B$	14.5	<	20.0	OK

Notes:

1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve. (NAVFAC, 1986)
3. For a uniform base (Cu<1.5), $D15_F/D85_B$ may be increased to 6 (piping equation only).
4. For a broadly graded base material (Cu>4), $D15_F/D15_B$ may be increased to 40 (piping equation only).

PROJECT/PROPOSAL NAME/LOCATION: DPC Phase IV Cell 3B Liner Construction		PROJECT / PROPOSAL NO.
SUBJECT: Piping and Permeability Calculation		216851.0004
PREPARED BY: T. Halena	DATE: 6/22/2015	FINAL X
CHECKED BY: R. Wienkes	DATE: 10/19/2015	REVISION ☐

Piping and Permeability Calculation

Base Material / Filter Material / Collection Pipe

Input

Base, Material Being Retained (Bottom Ash)

$D15_B$ 0.09 mm = 0.0035 inches
$D50_B$ 0.25 mm = 0.0098 inches
$D85_B$ 3.00 mm = 0.1181 inches
$Cu^{2,3}$ mm = 0.0000

Filter (Select Granular Fill)

$D15_F$ 0.29 mm = 0.01 inches
$D50_F$ 0.56 mm = 0.02 inches
$D85_F$ 3.36 mm = 0.13 inches

Collection Pipe

Pipe Hole Diameter N/A inches or Slot Width N/A inch

Results

Permeability Results

	Actual		Required	Results
$D15_F / D15_B$	3.2	>	N/A	N/A

Perforation Size Results

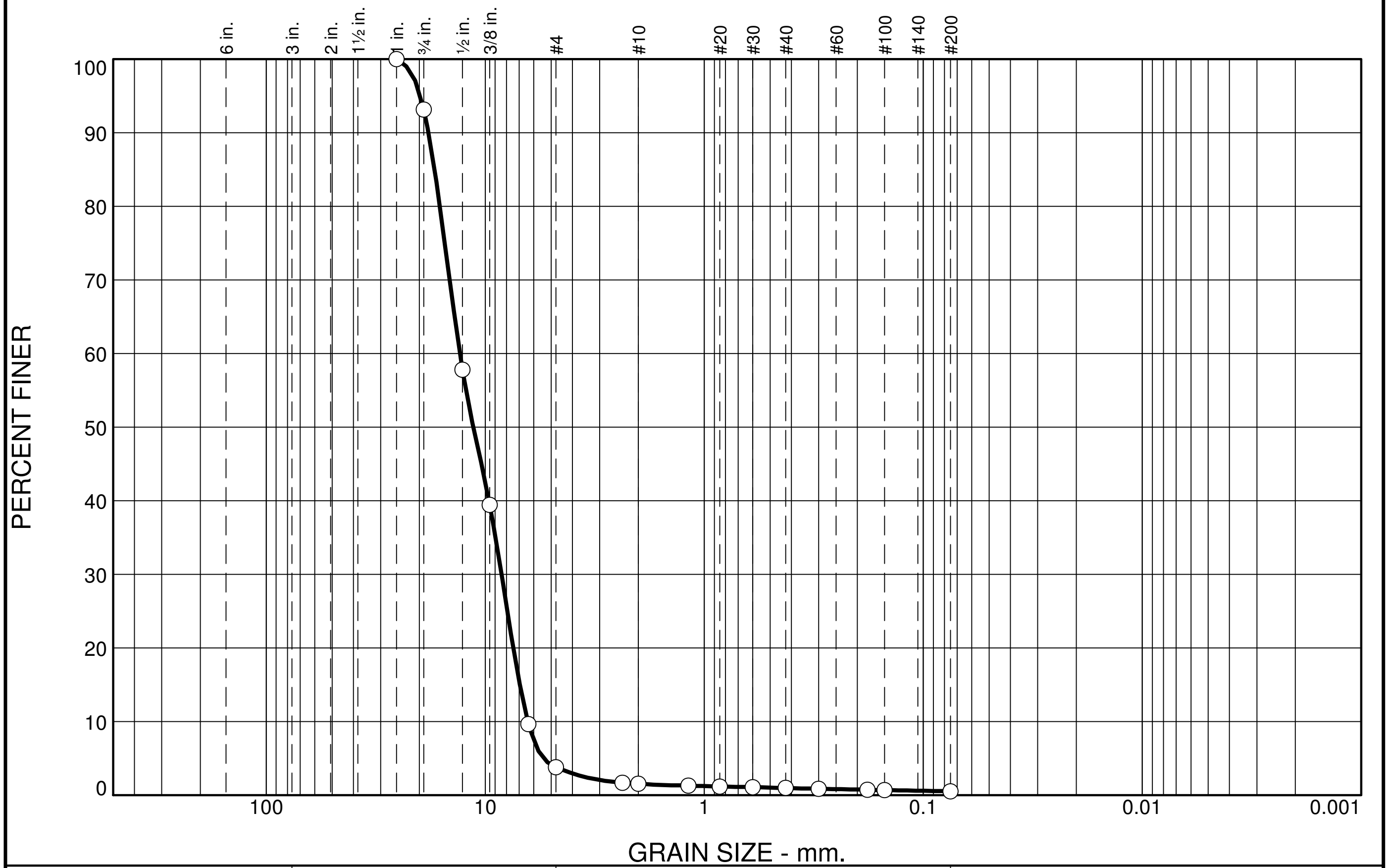
	Actual		Required	Results
$D85_F / _{HOLE}$	N/A	>	1.2	N/A
or				
$D85_F / _{SLOT}$	N/A	>	1.4	N/A

Piping Results

	Actual		Required	Results
$D15_F / D85_B$	0.1	<	6.0	OK
$D50_F / D50_B$	2.2	<	25.0	OK
$D15_F / D15_B$	3.2	<	20.0	OK

Notes:
1. To avoid segregation, filter material should contain no sizes larger than 3 inches.
2. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve. (NAVFAC, 1986)
3. For a uniform base (Cu<1.5), $D15_F/D85_B$ may be increased to 6 (piping equation only).
4. For a broadly graded base material (Cu>4), $D15_F/D15_B$ may be increased to 40 (piping equation only).

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	6.8	89.4	2.3	0.5	0.5	0.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.0	100.0		
.75	93.2		
.5	57.8		
.375	39.4		
.25	9.7		
#4	3.8		
#8	1.7		
#10	1.5		
#16	1.3		
#20	1.2		
#30	1.1		
#40	1.0		
#50	0.9		
#80	0.7		
#100	0.7		
#200	0.5		

* (no specification provided)

Material Description

Poorly graded gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 18.1422 D_{85}= 17.0358 D_{60}= 13.0457
D_{50}= 11.3188 D_{30}= 8.4236 D_{15}= 6.9563
D_{10}= 6.3957 C_u= 2.04 C_c= 0.85

Classification

USCS= GP AASHTO=

Remarks

Most conservative (largest) grain size distribution

Source of Sample: Select Aggregate Fill
Sample Number: Pt. 793

Date: 08-20-15

TRC Environmental Corp.

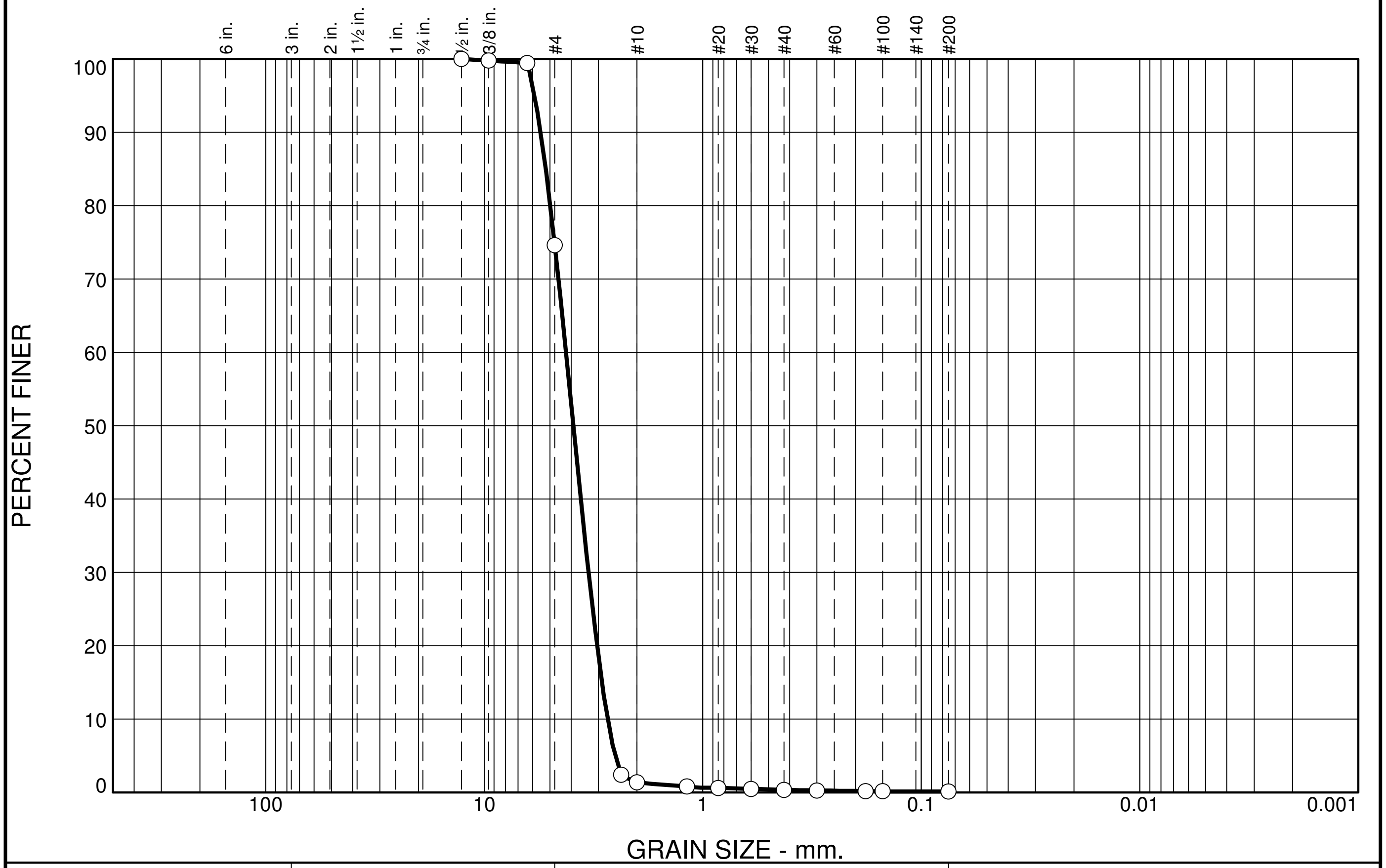
Madison, Wisconsin

Client: DPC
Project: DPC - Phase IV, Cell 3B

Project No: 216851.0004 **Figure**

Tested By: MBW **Checked By:** MBW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	25.4	73.2	1.1	0.2	0.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.5	100.0		
.375	99.8		
.25	99.4		
#4	74.6		
#8	2.4		
#10	1.4		
#16	0.8		
#20	0.6		
#30	0.5		
#40	0.3		
#50	0.3		
#80	0.2		
#100	0.1		
#200	0.1		

* (no specification provided)

Material Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 5.5110	D_{85}= 5.2248	D_{60}= 4.2186
D_{50}= 3.9042	D_{30}= 3.3288	D_{15}= 2.8904
D_{10}= 2.7237	C_u= 1.55	C_c= 0.96

Classification

USCS= SP AASHTO=

Remarks

Most conservative (smallest) grain size distribution

Source of Sample: Select Graded Fill
Sample Number: Pt. 782

Date: 08-20-15

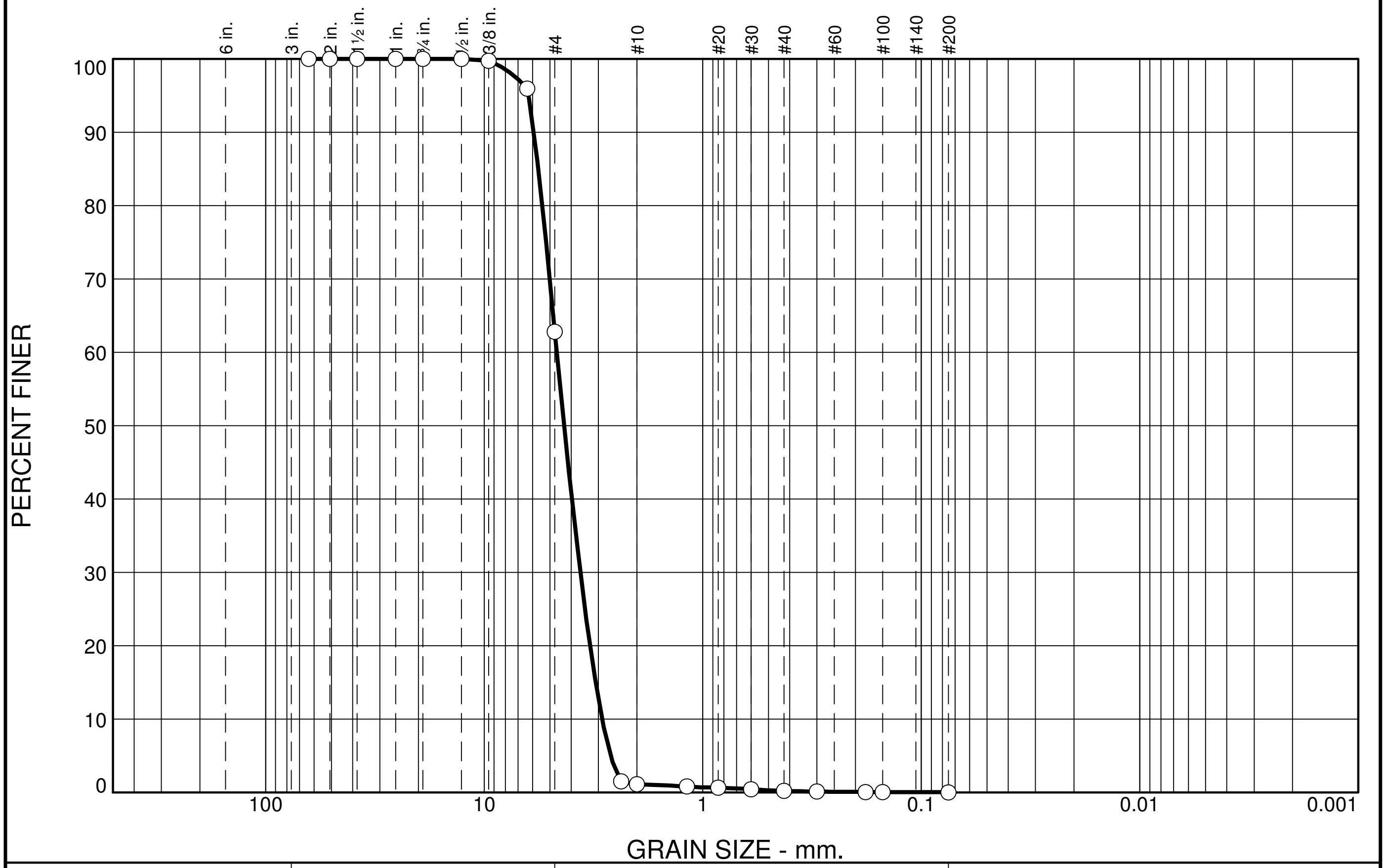
TRC Environmental Corp.

Madison, Wisconsin

Client: DPC
Project: DPC - Phase IV, Cell 3B
Project No: 216851.0004 **Figure**

Tested By: MBW **Checked By:** MBW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	37.2	61.7	0.9	0.2	0.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2.5	100.0		
2.0	100.0		
1.5	100.0		
1.0	100.0		
.75	100.0		
.5	100.0		
.375	99.7		
.25	95.9		
#4	62.8		
#8	1.5		
#10	1.1		
#16	0.8		
#20	0.6		
#30	0.4		
#40	0.2		
#50	0.1		
#80	0.1		
#100	0.0		
#200	0.0		

* (no specification provided)

Material Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 5.9193 D_{85}= 5.6487 D_{60}= 4.6510
D_{50}= 4.3038 D_{30}= 3.6268 D_{15}= 3.0902
D_{10}= 2.8854 C_u= 1.61 C_c= 0.98

Classification

USCS= SP AASHTO=

Remarks

Most conservative (largest) grain size distribution

Source of Sample: Select Graded Fill
Sample Number: Sample #1

Date: 07-02-15

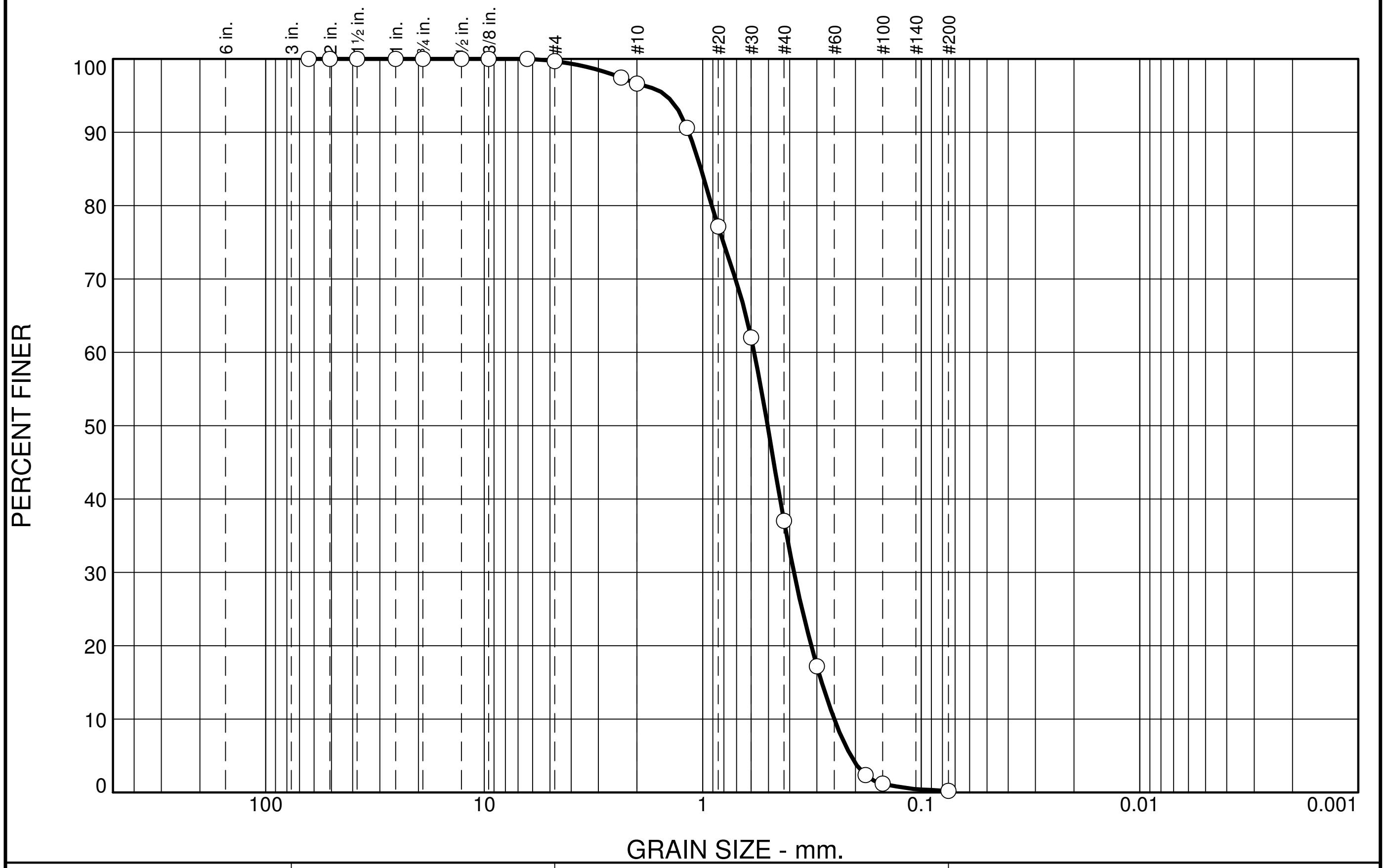
TRC Environmental Corp.

Madison, Wisconsin

Client: DPC
Project: DPC - Phase IV, Cell 3B
Project No: 216851.0004 **Figure**

Tested By: MBW **Checked By:** MBW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.3	3.1	59.6	36.8	0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2.5	100.0		
2.0	100.0		
1.5	100.0		
1.0	100.0		
.75	100.0		
.5	100.0		
.375	100.0		
.25	100.0		
#4	99.7		
#8	97.4		
#10	96.6		
#16	90.6		
#20	77.1		
#30	62.0		
#40	37.0		
#50	17.2		
#80	2.4		
#100	1.2		
#200	0.2		

* (no specification provided)

Material Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.1574 D_{85}= 1.0181 D_{60}= 0.5806
D_{50}= 0.5048 D_{30}= 0.3824 D_{15}= 0.2852
D_{10}= 0.2503 C_u= 2.32 C_c= 1.01

Classification

USCS= SP AASHTO=

Remarks

Most conservative (smallest) grain size distribution

Source of Sample: Select Granular Fill
Sample Number: Sample #2

Date: 07-29-15

TRC Environmental Corp.

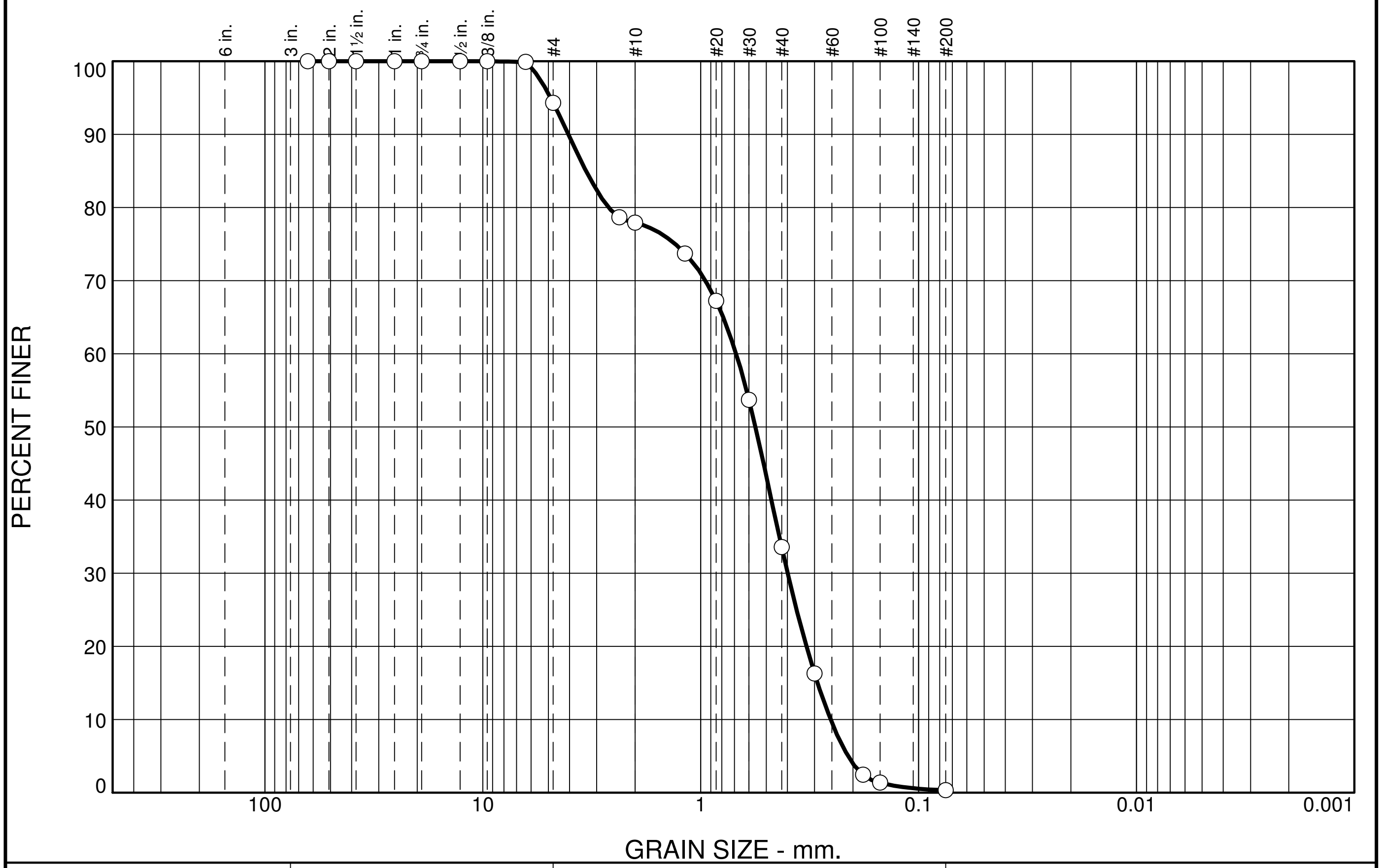
Madison, Wisconsin

Client: DPC
Project: DPC - Phase IV, Cell 3B

Project No: 216851.0004 **Figure**

Tested By: JPH **Checked By:** JPH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	5.7	16.4	44.3	33.3	0.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2.5	100.0		
2.0	100.0		
1.5	100.0		
1.0	100.0		
.75	100.0		
.5	100.0		
.375	100.0		
.25	99.9		
#4	94.3		
#8	78.6		
#10	77.9		
#16	73.7		
#20	67.2		
#30	53.7		
#40	33.6		
#50	16.3		
#80	2.4		
#100	1.4		
#200	0.3		

* (no specification provided)

Material Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 4.0446 D_{85}= 3.3555 D_{60}= 0.6875
D_{50}= 0.5605 D_{30}= 0.3988 D_{15}= 0.2907
D_{10}= 0.2534 C_u= 2.71 C_c= 0.91

Classification

USCS= SP AASHTO=

Remarks

Most conservative (largest) grain size distribution

Source of Sample: Select Granular Fill
Sample Number: Sample #1

Date: 07-02-15

TRC Environmental Corp.

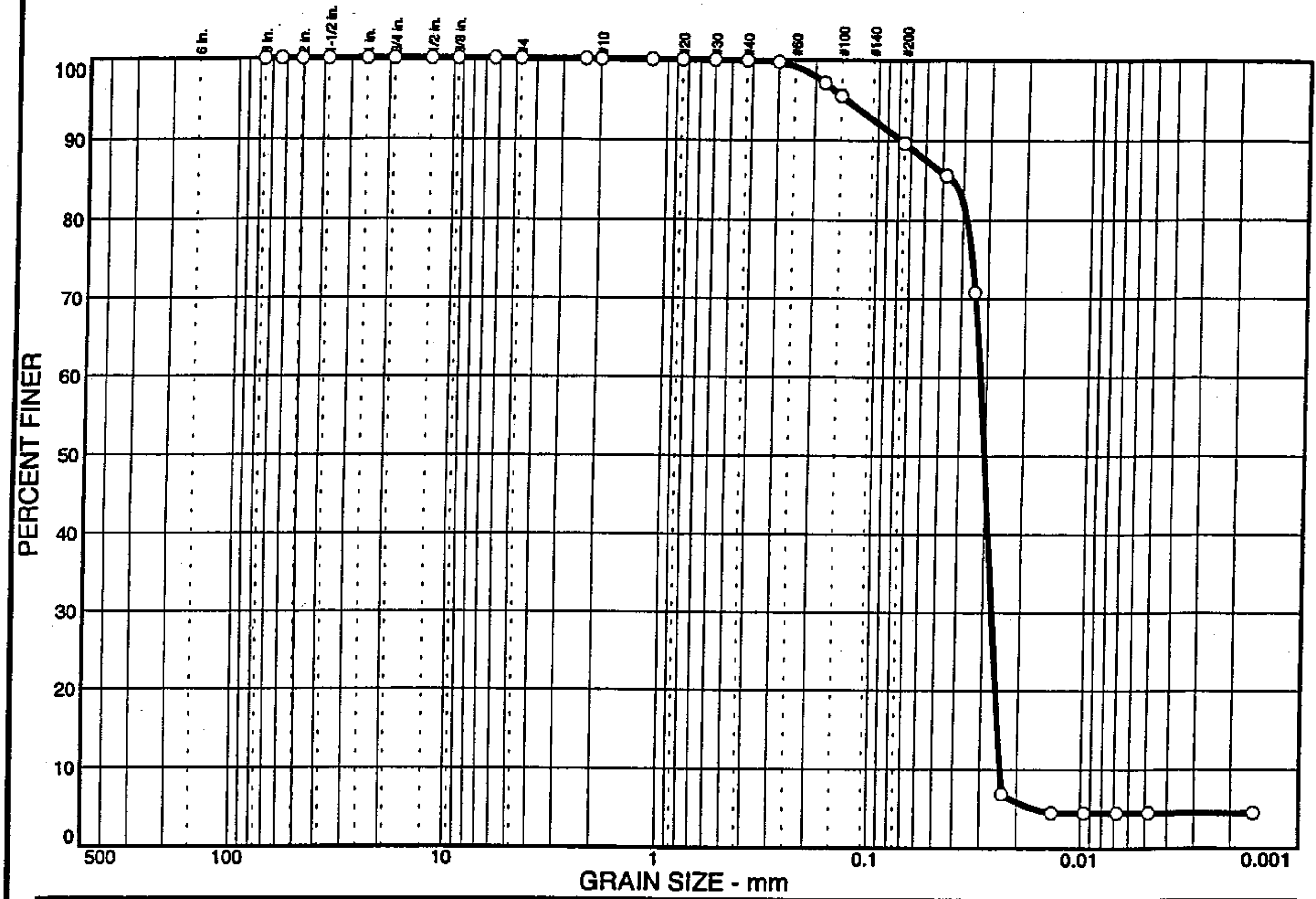
Madison, Wisconsin

Client: DPC
Project: DPC - Phase IV, Cell 3B

Project No: 216851.0004 **Figure**

Tested By: MBW **Checked By:** MBW

GRAIN SIZE DISTRIBUTION TEST REPORT



% + 3"	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	10.3	85.2	4.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3.0 in.	100.0		
2.5 in.	100.0		
2.0 in.	100.0		
1.5 in.	100.0		
1.0 in.	100.0		
.75 in.	100.0		
.5 in.	100.0		
.375 in.	100.0		
.25 in.	100.0		
#4	100.0		
#8	100.0		
#10	100.0		
#16	100.0		
#20	100.0		
#30	100.0		
#40	99.9		
#50	99.7		
#80	97.1		
#100	95.5		
#200	89.7		

* (no specification provided)

Soil Description

(Fly Ash)

Atterberg Limits

PL=

LL=

PI=

Coefficients

D_{85}= 0.0450
D_{60}= 0.0321
D_{50}= 0.0303
D_{30}= 0.0272
D_{15}= 0.0249
D_{10}= 0.0241
C_u= 1.33
C_c= 0.96

Classification

USCS=

AASHTO=

Remarks

Sample No.: Alma-1
Source of Sample: DPC-Alma
Date: 6-6-01
Location:
FLY ASH
Elev./Depth:

RMT, Inc.

Client:
Project: DAIRYLAND POWER COOPERATIVE
Project No: 3081.49
Figure:

DAVY LABORATORIES
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Division of Davy Engineering Co.

TABLE 3
PHYSICAL ANALYSIS RESULTS FOR ALMA BOTTOM ASH

I. Particle Size Distribution

Sample Number: 44639 Sample Size: 50 grams

Sieve No.	Grams Retained	Total Retained	% Retained	% Total Retained	% Finer
3/8	0.00	0.00	0.00	0.00	100
4	5.16	5.16	10.33	10.33	89.67
8	3.53	8.69	7.07	17.40	82.60
16	4.50	13.19	9.01	36.41	73.59
30	5.75	18.94	11.51	37.92	62.07
50	9.00	37.94	18.02	55.94	44.06
100	9.73	37.67	19.48	75.42	24.58
200	6.81	44.48	13.64	89.06	10.94
Pan	5.46	---	---	---	---

Total Weight Recovered 49.94 grams

II. Bulk Dry Density, pcf (ASTM:C29) 51.8

I.3
Ineos's Chemical Resistance Guide

HDPE Chemical Resistance Guide

Reagent	70º F (21º C)	140º F (60º C)
A		
Acetaldehyde	S	O
Acetic acid (1-10%)	S	S
Acetic acid (10-60%)	S	O
Acetic acid (80-100%)	S	O
Acetic anhydride	S	S
Acetone	S	S
Acids (aromatic)	S	S
Acrylic emulsions	S	S
Adipic acid	S	S
Aluminum chloride concentrated	S	S
Aluminum chloride dilute	S	S
Aluminum fluoride concentrated	S	S
Aluminum sulfate concentrated	S	S
Alums (all types) concentrated	S	S
Amino acetic acid	S	S
Ammonia (100% dry gas)	S	S
Ammonium acetate	S	S
Ammonium bromide	S	S
Ammonium carbonate	S	S
Ammonium chloride saturated	S	S
Ammonium fluoride (20%)	S	S
Ammonium hydroxide	S	S
Ammonium metaphosphate (sat.)	S	S
Ammonium nitrate saturated	S	S
Ammonium persulfate saturated	S	S
Ammonium phosphate	S	S
Ammonium sulfate saturated	S	S
Ammonium sulfide saturated	S	S
Ammonium thiocyanate saturated	S	S
Amyl acetate (100%)	O	U
Amyl alcohol (100%)	S	S
Amyl Chloride (100%)	O	U
Aniline (100%)	S	U
Anise seed oil	O	U
Antimony chloride	S	S
Aqua Regia	O	U
Aromatic hydrocarbons	U	U
Arsenic	S	S
Aspirin	S	S

Reagent	70º F (21º C)	140º F (60º C)
B		
Barium carbonate saturated	S	S
Barium carbonate saturated	S	S
Barium hydroxide	S	S
Barium sulfate saturated	S	S
Barium sulfite saturated	S	S
Beer	S	S
Benzaldehyde	S	O
Benzene	O	U
Benzene sulfonic acid	S	S
Benzoic acid crystals	S	S
Benzoic acid saturated	S	S
Bismuth carbonate saturated	S	S
Black liquor	S	S
Bleach lye (10%)	S	S
Borax cold saturated	S	S
Boric acid concentrated	S	S
Boric acid dilute	S	S
Brine	S	S
Bromic acid (10%)	S	S
Bromine liquid (100%)	O	U
Bromochloromethane	U	U
Butadiene	U	U
Butanediol (10%)	S	S
Butanediol (60%)	S	S
Butanediol (100%)	S	S
Butter	S	S
Butyl acetate (100%)	O	U
Butyl alcohol (100%)	S	S
Butylene glycol	S	S
Butyric acid (100%)	S	S
C		
Caffeine citrate saturated	S	S
Calcium bisulfide	S	S
Calcium bromide	S	S
Calcium carbonate saturated	S	S
Calcium Chlorate saturated	S	S
Calcium hydroxide	S	S
Calcium hypochlorite bleach solution	S	S
Calcium nitrate (50%)	S	S
Calcium sulfate	S	S

Legend: S = Satisfactory O = Some attack U = Unsatisfactory

HDPE Chemical Resistance Guide

Reagent	70º F (21º C)	140º F (60º C)
Camphor crystals	S	S
Camphor oil	U	U
Carbon dioxide (100% dry)	S	S
Carbon dioxide (100% wet)	S	S
Carbon dioxide cold saturated	S	S
Carbon disulphide	O	U
Carbon monoxide	S	S
Carbon tetrachloride	U	U
Carbonic acid	S	S
Carnauba wax	S	S
Carrot juice	S	S
Castor oil concentrated	S	S
Catsup	S	S
Caustic soda	S	O
Cedar leaf oil	U	U
Cedar wood oil	U	U
Chlorine liquid	O	U
Chlorobenzene	O	U
Chloroform	U	U
Chlorosulfonic acid (100%)	U	U
Chrome alum saturated	S	S
Chromic acid (10-20%)	S	O
Chromic acid (50%)	S	O
Cider	S	S
Cinnamon	S	S
Cinnamon oil	U	U
Citric acid saturated	S	S
Citronella oil	O	U
Cloves (ground)	S	S
Coconut oil alcohols	S	S
Cod liver oil	S	S
Coffee	S	S
Copper chloride saturated	S	S
Cooper cyanide saturated	S	S
Copper fluoride (2%)	S	S
Copper nitrate saturated	S	S
Copper sulfate dilute	S	S
Copper sulfate saturated	S	S
Corn oil	S	S
Cottonseed oil	S	S
Cranberry sauce	S	S
Cresols	S	O
Cuprous chloride saturated	S	S
Cuprous oxide	S	S
Cyclohexane	U	U
Cyclohexanone	U	U
D		
Decalin	S	S
Detergents (synthetic)	S	S
Developers (photogenic)	S	S
Dextrin saturated	S	S
Dextrose saturated	S	S
Dibutyl ether	O	U
Dichlorobenzene (ortho and para)	U	U
Diethylene glycol	S	S
Dioxane	S	S
Disodium phosphate	S	S
E		
Emulsions (photographic)	S	S
Ether	O	O
Ethyl acetate (100%)	O	O
Ethyl alcohol (35%)	S	S
Ethyl alcohol (100%)	S	S
Ethylbenzene	O	U
Ethylene glycol	S	S
F		
Ferric chloride saturated	S	S
Ferric nitrate saturated	S	S
Ferrous ammonium citrate	S	S
Ferrous chloride saturated	S	S
Ferrous sulfate	S	S
Fluoboric acid	S	S
Fluorine	S	U
Fluosilicic acid (32%)	S	S
Fluosilicic acid concentrated	S	S
Formaldehyde (10-30%)	S	S
Formaldehyde (30-40%)	S	O
Formic acid (20%)	S	S
Formic acid (50%)	S	S
Formic acid (100%)	S	S
Fructose saturated	S	S
Fuel oil	S	U
Furfural (100%)	O	U
Furfuryl alcohol	S	O
G		
Gallic acid saturated	S	S
Gasoline	S	U
Glucose	S	S
Glycerine	S	S
Glycol	S	S
Glycolic acid (30%)	S	S
Grape juice	S	S
Grapefruit juice	S	S
H		
Heptane	O	U
Hexachlorobenzene	S	S
Hexane	U	U
Hydrobromic acid (50%)	S	S

Legend: S = Satisfactory O = Some attack U = Unsatisfactory

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Reagent	70º F (21º C)	140º F (60º C)
Hydrochloric acid (10%)	S	S
Hydrochloric acid (30%)	S	S
Hydrochloric acid (35%)	S	S
Hydrocyanic acid	S	S
Hydrocyanic acid saturated	S	S
Hydrofluoric acid (40%)	S	S
Hydrofluoric acid (60%)	S	S
Hydrofluoric acid (75%)	S	S
Hydrogen (100%)	S	S
Hydrogen bromide (10%)	S	S
Hydrogen chloride dry gas	S	S
Hydrogen peroxide (30%)	S	O
Hydrogen sulfide	S	S
Hydroquinone	S	S
Hypochlorous acid concentrated	S	S
I		
Inks	S	S
Iodine crystals	O	O
Isobutyl alcohol	S	S
Isopropyl alcohol	S	S
Isopropyl ether	O	U
K		
Kerosene	O	O
L		
Lactic acid (10%)	S	S
Lactic acid (90%)	S	S
Lanolin	S	S
Lard	S	S
Lead acetate saturated	S	S
Lead nitrate	S	S
Lemon juice	S	S
Lemon oil	O	U
Lime juice	S	S
Linseed oil	S	S
M		
Magnesium carbonate saturated	S	S
Magnesium chloride saturated	S	S
Magnesium hydroxide saturated	S	S
Magnesium nitrate saturated	S	S
Magnesium sulfate saturated	S	S
Margarine	S	S
Mercuric chloride	S	S
Mercuric cyanide saturated	S	S
Mercurous nitrate saturated	S	S
Mercury	S	S
Methyl alcohol (100%)	S	S
Methyl ethyl ketone (100%)	U	U

Reagent	70º F (21º C)	140º F (60º C)
Methylene chloride (100%)	U	U
Methylsulfuric acid	S	S
Milk	S	S
Mineral oils	S	U
Molasses	S	S
Mustard (prepared)	S	S
N		
Naphtha	O	U
Naphthalene	S	U
Natural gas (wet)	S	S
Nickel chloride saturated	S	S
Nickel nitrate concentrated	S	S
Nickel sulfate	S	S
Nicotinic acid	S	S
Nitric acid (0-30%)	S	S
Nitric acid (30-50%)	S	O
Nitric acid (70%)	S	O
Nitric acid (95-98%)	U	U
Nitrobenzene (100%)	U	U
Nitroglycerine	O	U
O		
Octane	S	S
Oleum concentrated	U	U
Olive oil	S	S
Orange juice	S	S
Oxalic acid dilute	S	S
Oxalic acid saturated	S	S
Ozone	O	O
P		
Palm oil	S	S
Paraffin oil	S	O
Peanut butter	S	S
Pepper (fresh ground)	S	S
Peppermint oil	O	U
Perchloric acid (50%)	S	O
Perchloroethylene	U	U
Petroleum ether	U	U
Petroleum jelly	S	S
Phenol	S	S
Phosphoric acid (0-30%)	S	S
Phosphoric acid (30-90%)	S	S
Phosphoric acid (over 90%)	S	S
Photographic solutions	S	S
Phthalic anhydride	S	S
Pickling baths	S	S
Hydrochloric acid	S	S
Sulfuric acid	S	S
Sulfuric-nitric	S	U

Legend: S = Satisfactory O = Some attack U = Unsatisfactory

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Reagent	70º F (21º C)	140º F (60º C)
Pine oil	O	U
Plating solutions		
Brass	S	S
Cadmium	S	S
Chromium	S	S
Copper	S	S
Gold	S	S
Indium	S	S
Lead	S	S
Nickel	S	S
Rhodium	S	S
Silver	S	S
Tin	S	S
Zinc	S	S
Potassium bicarbonate saturated	S	S
Potassium borate (1%)	S	S
Potassium bromate (10%)	S	S
Potassium bromide saturated	S	S
Potassium carbonate	S	S
Potassium chlorate saturated	S	S
Potassium chloride saturated	S	S
Potassium chromate (40%)	S	S
Potassium cyanide saturated	S	S
Potassium dichromate (40%)	S	S
Potassium ferri / ferro cyanide	S	S
Potassium nitrate saturated	S	S
Potassium perborate saturated	S	S
Potassium perchlorate (10%)	S	S
Potassium permanganate (20%)	S	S
Potassium persulfate saturated	S	S
Potassium sulfate concentrated	S	S
Potassium sulfide concentrated	S	S
Potassium sulfite concentrated	S	S
Propane gas	S	S
Propargyl alcohol	S	S
Propyl alcohol	S	S
Propylene glycol	S	S
Pyridine	S	O
R		
Rayon coagulating bath	S	S
Resorcinol	S	S
S		
Salicylic acid	S	S
Seawater	S	S
Shortening	S	S
Silicic acid	S	S
Silver nitrate solution	S	S
Soap solution concentrated	S	S
Sodium acetate saturated	S	S
Sodium benzoate (35%)	S	S
Sodium bicarbonate saturated	S	S
Sodium bisulfate saturated	S	S
Sodium bisulfite saturated	S	S
Sodium borate	S	S
Sodium carbonate concentrated	S	S
Sodium chlorate saturated	S	S
Sodium chloride saturated	S	S
Sodium cyanide	S	S
Sodium dichromate saturated	S	S
Sodium ferricyanide	S	S
Sodium ferricyanide concentrated	S	S
Sodium fluoride saturated	S	S
Sodium hydroxide concentrated	S	S
Sodium hypochlorite	S	S
Sodium nitrate	S	S
Sodium nitrite	S	S
Sodium perborate	S	S
Sodium phosphate	S	S
Sodium sulfide (25% to saturated)	S	S
Sodium sulfite saturated	S	S
Sodium thiosulphate	S	S
Soybean oil	S	S
Stannic chloride saturated	S	S
Stannous chloride saturated	S	S
Starch solution saturated	S	S
Stearic acid (100%)	S	S
Styrene	U	U
Sulfuric acid (0-50%)	S	S
Sulfuric acid (70%)	S	O
Sulfuric acid (80%)	S	U
Sulfuric acid (96%)	O	U
Sulfuric acid (98% concentrated)	O	U
Sulfuric acid (fuming)	U	U
Sulfurous acid	S	S
T		
Tannic acid (10%)	S	S
Tartaric acid	S	S
Tea	S	S
Tetrahydrofuran	O	O
Toluene	U	U
Tomato juice	S	S
Transformer oil	S	O
Trichloroethylene	U	U
Trisodium phosphate saturated	S	S
Turpentine	O	U
U		
Urea	S	S
Urine	S	S

Legend: S = Satisfactory O = Some attack U = Unsatisfactory

Reagent	70º F (21º C)	140º F (60º C)
V		
Vanilla extract	S	S
Vaseline	S	S
Vinegar (commercial)	S	S
W		
Wetting agents	S	S
Whiskey	S	S
Wines	S	S
X		
Xylene	U	U
Y		
Yeast	S	S
Z		
Zinc chloride saturated	S	S
Zinc oxide	S	S
Zinc sulfate saturated	S	S

Note: The proceeding information concerns general chemical resistance only. Since other factors such as permeation, ESCR and container design are involved, full compatibility testing is recommended.

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Appendix J: Supplemental Final Cover Design Demonstrations

- J.1: 2004 Final Cover Plan of Operation Modification
- J.2: Saturated Head on the Final Cover Liner
- J.3: Final Cover Event 2A Interface Stability Evaluation

J.1
2004 Final Cover Plan of Operation Modification

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Plan of Operation Modification

Dairyland Power Cooperative
Phase IV Disposal Area – License #4126
Alma Off-Site Ash Disposal Facility
Town of Belvedere
Buffalo County, Wisconsin

January 2004

Prepared For
Dairyland Power Cooperative

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Project Manager

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Section 1
Introduction

1.1 Background

Dairyland Power Cooperative (DPC) owns and operates a coal ash disposal facility (Alma off-site disposal facility) located in the Town of Belvedere, Buffalo County, Wisconsin. Phase I of the facility was closed in 1993, Phase II was closed in 1997, and Phase III is expected to be closed in 2004 (License # 2927). A conditional Plan of Operation approval for the Phase IV disposal area (License #4126) was granted on May 15, 2001 (see Appendix A), by the Wisconsin Department of Natural Resources (WDNR). DPC is currently filling Cell 1 of the Phase IV disposal area.

In the Feasibility Report for the Phase IV Ash Disposal Facility, two final cover options were presented for the WDNR's consideration. A "standard" NR 504.07 cover design for a high volume industrial waste landfill, and an alternative final cover system design in accordance with NR 504.10(3). The alternative cover system consisted of a 6-inch–thick soil grading layer over the waste followed by a GCL, a 40-mil geomembrane, a 1-foot–thick sand drainage layer, a 1-foot–thick general soil cover layer, and a 6-inch–thick topsoil layer. The WDNR conditionally approved the alternative cover design in the September 10, 1999, Feasibility Determination, provided that the WDNR's "Guidance for the Use of Geosynthetic Clay Liners (GCLs) at Solid Waste Facilities" and manufacturers recommendations are followed.

DPC and RMT proceeded in preparing the Plan of Operation in late 1999 utilizing the alternative final cover design presented in the Feasibility Report. The Plan of Operation was submitted in October 2000, with the alternative cover design conditionally approved in the Feasibility Determination, with the understanding that the final lift of ash and the grading layer met the intent of the GCL subbase requirements, and with the assumption that concurrence with the WDNR on the final cover design had previously been obtained during the preparation of the Feasibility Study.

In the conditional Plan of Operation approval, the WDNR revised and approved a different final cover than was proposed in both the Feasibility Report and the Plan of Operation. The approved final cover design consisted of a minimum 3 feet of drain layer, rooting zone soil, and topsoil above the geomembrane, and a minimum of 2 feet of barrier layer between the ash and the GCL. The result of this revised final cover design was that the final cover thickness was increased from 3 feet to 5 feet.

The approved final cover design presents several design and construction challenges for this site. First, the quantity of suitable low-permeability soil in the vicinity of the site is limited (refer to Appendix C of Plan of Operation). Second, the increased final cover thickness (3 feet to 5 feet) will require significant design modifications to tie the cover into the sidewall berm and to maintain the site's design capacity, which is critical to DPC. This Plan of Operation Modification is being submitted to modify the approved final cover design to provide an effective final cover that addresses these design and construction challenges.

1.2 Purpose and Scope

DPC is proposing to modify the Plan of Operation for Phase IV of the Alma off-site disposal facility to include a final cover system design in accordance with NR 504.10(3) that utilizes beneficially reused fly ash as the low-permeability barrier layer in a composite final cover system. The characteristics of the fly ash, as well as several special design and construction features for the Phase IV disposal facility, are presented in support of this proposed modification.

This text and its accompanying appendices present modifications to the Plan of Operation necessary for the remaining construction, operation, and closure of the facility.

This document is divided into three major sections—Proposed Engineering Modifications (as influenced by the proposed final cover), Site Operations (a description of the select ash placement procedures), and Site Closure (final cover placement and revised cost estimates for financial responsibility). Design calculations, correspondence, plan sheets, and other pertinent data to document the design and operational procedures for this facility are included in the appendices.

Section 2
Proposed Engineering Modifications

2.1 General

This plan modification for the DPC Phase IV Ash Disposal Facility been prepared in accordance with applicable sections of the Wisconsin Administrative Code s. NR 500 Series, State Statute s. 289 and all prior WDNR plan modification approval documents and accompanying conditions as appropriate. Supporting test data and/or calculations for the design modifications are referenced as appropriate, and are included in the appendices. Details and drawings illustrating design specifications are referenced as applicable and are presented on the attached drawings.

The modifications proposed include the beneficial reuse of select fly ash in a composite final cover system. In addition, several special design and construction features for Phase IV are presented that support the approval of the proposed design. The proposed design will reduce the facility's dependency on on-site or off-site borrow soil and its accompanying costs and degree of environmental impact. The following discussion presents the proposed final cover design.

2.2 Final Cover Design

This Plan Modification proposes an alternative cover system in accordance with NR 504.10 (3), consisting of the following components (from bottom to top):

- Two feet of moisture-conditioned and compacted "select" fly ash (i.e., a mixture containing a minimum of 40 percent of the more reactive J.P. Madgett [JPM] fly ash)
- A 40-mil geomembrane with enhanced construction quality assurance
- A 1-foot–thick sand drainage layer
- A 1.5-foot–thick general soil cover layer
- A 6-inch–thick topsoil layer

This design provides the desired 3-foot thickness of soil over the geomembrane, as required in the Plan of Operation conditional approval. The moisture-conditioned and compacted ash layer will be constructed as waste filling progresses within each cell as further described in Section 3. The anticipated properties of the ash layer, once it has cured, are based on extensive previous studies conducted by DPC as described in Subsection 2.3. The specifications and documentation proposed for the ash layer are described in Subsection 4.2.

The final grades at the site and the design capacity remain consistent with the WDNR 2001 Plan of Operation approval. The 2 feet of fly ash to be used in the final cover are included in the 3,011,000 cubic yards of approved design capacity for the site. DPC will not gain additional disposal capacity as a result of this modification.

The proposed alternative final cover design adequately protects public health, welfare, and the environment and meets or exceeds the performance standards of NR 504.04, as demonstrated in the following sections. In addition, the site provides several special design and construction features that support the approval of the proposed design. These include the following:

- The landfill design includes composite liner and final cover systems that provide upgraded performance as compared to the "standard" NR 504 liner and final systems required for a high-volume industrial waste landfill.
- The integrity of the geomembrane component of the composite liner and composite final cover will be verified using electrical resistivity testing during each phase of construction. As demonstrated during Cell 1 construction, this additional construction quality assurance step was extremely effective in identifying and allowing the repair of liner defects that would have otherwise gone undetected, had "standard" NR 516 construction documentation procedures been followed. The resulting integrity and environmental protection provided by the composite liner and cover systems are considered to be extremely high.
- On-site sand borrow areas will be used to obtain material for construction of the final cover drainage layer. Laboratory testing performed on this material indicates that the sand is over five times more permeable than the minimum acceptable hydraulic conductivity of 1×10^{-3} cm/s required for final cover drainage layers. The use of this material will enhance the performance of the final cover system.
- Collection pipes are incorporated in the final cover drainage layer at each of the surface water diversion berms as shown on Detail 2 on Plan Sheet 19 of the Plan of Operation. This provides improved water removal efficiency from the cover as compared to "typical" landfill designs in Wisconsin.
- DPC ash has been extensively employed in various beneficial use applications. Annual testing of the ash has been conducted on the various ash sources in accordance with the requirements of NR 538 (see Appendix B). The fly ash proposed for use in the final cover is classified as a Category 4 ash, and meets all of the Category 3 standards, with the exception of chromium. The fly ash is suitable for use in confined geotechnical fills and in landfill uses as defined in NR 538.

- The ash disposed in the landfill is placed in a low-moisture state (refer to DPC's Fly Ash Characterization Studies contained in Appendix C) and has been shown to have a very high affinity for water, making the overall water balance efficiency of the site very high.

2.3 DPC Ash Studies and Performance Data

Fly ash contains primarily oxides of silicon, aluminum iron, and calcium. Magnesium, potassium, sodium, titanium, and sulfur are also present to a lesser degree (ACAA, 2003). The types of coal burned affect the properties of the fly ash. High-calcium fly ash, or Class C fly ash, typically contains more than 20 percent calcium oxide (CaO) or free lime. High-calcium fly ash, when mixed with water, undergoes a hydration reaction that solidifies the ash into a concrete-like mass. Class C fly ash is generally derived from sub-bituminous or western coal. DPC's Madget Station burns a Powder River Basin coal, which is a western coal with a high–calcium oxide content. Low-calcium fly ash, or Class F ash, typically contain less than 10 percent CaO. Class F ash is generally derived from bituminous and anthracite coals or eastern coals. DPC's Alma Units 1-5 and Genoa Stations burn a mixture of eastern (Illinois) and western (Powder River Basin) coals. The proposed final cover barrier layer will consist of 2 feet of moisture-conditioned and compacted fly ash containing at least 40 percent of the more reactive JPM fly ash.

The properties of the JPM fly ash are well suited for use as a barrier layer as demonstrated in DPC's previous landfill phases and in previous ash characterization studies. DPC has invested significant resources into the study of the ash for purposes of controlled landfill placement. The following Subsections provide additional information on the findings of these studies.

2.3.1 Fly Ash Characterization Reports

DPC retained Warzyn Engineering, Inc., to complete a series of studies designed to investigate the physical and chemical properties of fly ashes generated from the Alma Generating Station, Units 1 through 5, and the Madgett Generating Station, Unit 6 (Warzyn, 1979, 1980a, 1980b, 1980c, 1980d, and 1980e). These studies investigated the properties of DPC's fly ash as they relate to disposal, site operations, and licensing. Information on the ash's chemical composition, compaction properties, setting properties, specific gravity, permeability, strength, grain size, erosion resistance, and dusting was presented in the reports summarizing these studies.

In the report titled "Supplemental Fly Ash Characterization Report, Fly Ash Conditioning with Low Moisture Content, Alma Madgett Generating Station Units 1–6" (Warzyn 1980e), information was presented on the conclusions of the general fly ash conditioning program. This program looked at the physical characteristics of various mixtures of JPM ash and Alma Units 1-5 ash in the low-moisture condition (i.e., 5 percent to 15 percent added moisture). A copy of this report, along with the initial fly ash characterization report, is included in Appendix C.

The ash tested in these studies included ash from DPC's Alma and JPM generating stations, as well as ash from similar facilities. The ash used in these studies is similar in composition and physical properties to the ash currently generated by DPC. In fact, the Alma Units 1-5 are currently burning a coal mixture that consists of a greater percentage of Powder River Basin coal, which will result in an even more reactive ash. Based on these studies, it was found that a mixture containing at least 40 percent JPM ash resulted in a compacted hydraulic conductivity ranging from 8×10^{-7} cm/s to 1×10^{-9} cm/s. The testing, using ash comparable to the JPM ash, had similar results. A summary of these results is included in Table 1.

On the basis of these studies, DPC has used ash mixtures containing at least 40 percent JPM ash as an initial waste lift and in constructing low-permeability ash and ash-slurry containment berms within Phases I through III of their landfill (DPC, 1993). The ash mixtures containing the JPM ash have been found to be extremely dense, durable, and to have a low permeability once compacted and cured. This field experience has supported the findings of the previous ash studies.

Table 1
Fly Ash Hydraulic Conductivity Test Results
DPC Off-Site Disposal Facility

MIX RATIO(1)	HYDRAULIC CONDUCTIVITY (CM/S)			ASH SOURCE(2)
	MOISTURE CONTENT 5%	MOISTURE CONTENT 10%	MOISTURE CONTENT 15%	
10/90	$1x10^{-5}$	$3x10^{-6}$ to $4x10^{-6}$	$5x10^{-6}$ to $7x10^{-6}$	Neal #4
10/90	$5x10^{-6}$	$4x10^{-6}$ to $5x10^{-6}$	--	JPM #1
20/80	$1x10^{-5}$	$6x10^{-7}$ to $9x10^{-7}$	$3x10^{-6}$ to $4x10^{-6}$	Neal #4
40/60	$5x10^{-7}$	$7x10^{-7}$ to $8x10^{-7}$	$4x10^{-7}$	JPM #1
40/60	$5x10^{-7}$ to 7 $x10^{-7}$	$1x10^{-7}$ to $2x10^{-7}$	$2x10^{-7}$ to $3x10^{-7}$	Neal #4
60/40	$1x10^{-6}$ to $4x10^{-7}$	$1x10^{-7}$ to $8x10^{-8}$	$1x10^{-7}$	Neal #4
80/20	$1x10^{-7}$	$2x10^{-7}$ to $5x10^{-8}$	$1x10^{-7}$ to $5x10^{-8}$	Neal #4
100/0	$2x10^{-9}$	$1x10^{-9}$	$2x10^{-9}$	JPM #1
100/0	$2x10^{-7}$	$5x10^{-8}$ to $8x10^{-8}$	$5x10^{-8}$ to $6x10^{-8}$	Neal #4

Notes:
Samples cured 7 days prior to testing.
Test results from Warzyn Engineering, Inc., report (Warzyn, 1980e).

Footnotes:

(1) Mix Ratio represents percentage of reactive fly ash/Alma fly ash.

(2) JPM #1 is fly ash obtained from the DPC JPM ash source. Neal #4 is a similar fly ash to the JPM ash obtained from the Neal Unit #4 Iowa Public Service facility.

2.3.2 Final Cover Performance Evaluation

The proposed final composite cover will provide significantly better performance, in terms of controlling infiltration, than a standard NR 504 high-volume industrial waste landfill final cover. The proposed cover will also perform equivalently to the composite cover approved in the Plan of Operation. To demonstrate this, HELP Model calculations have been performed comparing the proposed final cover with the approved final cover and a standard NR 504 final cover (Appendix D). For the proposed final cover, the conditioned and compacted fly ash was assumed to have a hydraulic conductivity of 1.0×10^{-6} cm/s, which can be achieved with a minimum of 40 percent JPM ash, as has been demonstrated through previous studies. On the basis of these calculations the approved final cover and the proposed final cover are over 99.99 percent efficient as compared to the standard NR 504 cover, which is 96.6 percent efficient. These results compare well to previous studies and published data that show that a composite cover with a geomembrane will increase a final cover efficiency to over 99.9 percent as compared to a standard clay cover, which is in the 96 to 97 percent efficiency range. These calculations support the use of the proposed final cover.

Section 3
Site Operations

Daily operations at the Phase IV landfill are not expected to change substantially as a result of the proposed plan modification. The placement of low-permeability ash layers and the filling of ash will continue within the approved limits of waste as is currently being performed in order to achieve the final waste grades. Access roads will be constructed as necessary to facilitate access within the cell.

The conditioned and compacted ash layer that will comprise the lower portion of the final cover will be placed in stages as the landfill filling progresses. As in previous phases, a mixture of fly ash containing a minimum of 40 percent JPM ash will be conditioned with 5 to 15 percent moisture and transported to the landfill in dump trucks. The ash will be dumped, and a containment berm will be constructed with the ash mixture around the perimeter of the phase. The ash will be spread and compacted in maximum 12-inch lifts using a dozer. The containment berm will be constructed approximately 10 feet wide at the top. The exterior sideslope will be constructed at a 4:1 (horizontal to vertical) slope to match the final cover grades. The interior sideslope will be constructed at an approximate 2:1 slope. Subsequent truck traffic over the lift will provide additional compaction as the berm is constructed. The berm will typically be constructed to a final height of approximately 10 feet. However, as long as the minimum berm width is 10 feet, the resulting minimum ash layer thickness will be 2.5 feet, given the 4:1 final cover slope.

Construction of the berms in this manner will result in a conditioned and compacted ash layer greater than 2.5 feet in thickness. Periodic surveys will be conducted to set the berm locations, and verification survey shots will be taken by DPC personnel or their designee as the berm construction progresses. Construction of the berm in this manner will ensure that the minimum conditioned and compacted ash layer thickness of 2 feet is achieved.

Given the marketability of the JPM ash during the summer for other beneficial use applications, construction of the ash berms will typically occur during the late fall or early spring. Ash will be placed within the berms when JPM ash is not available. When necessary, DPC will divert the JPM ash from other beneficial use applications when the JPM ash is needed to build the containment berms at the landfill.

Based on current ash disposal records, DPC is projected to generate approximately 51,200 tons of JPM fly ash in 2003. This quantity of ash is sufficient to construct the cover as proposed.

DPC will divert JPM Fly ash from other beneficial use applications as necessary to construct the final cover.

Section 4
Site Closure

4.1 General

Revised closure activities and cost estimates have been prepared in accordance with the requirements of NR 514.06(9) and (10). The design details for the revised final cover system are discussed in Section 2.

4.2 Final Cover Placement and Certification

The conditioned and compacted ash component of the final cover will be constructed incrementally as waste filling progresses as described in Section 3. Once a cell has been brought up to final grades, the remainder of the final cover will be constructed as shown on the phasing plans contained in the Plan of Operation.

Prior to geomembrane placement, the surface of the conditioned and compacted ash layer will be fine-graded and/or additional JPM ash or on-site loess material will be brought in as necessary to fill in uneven areas. The entire geomembrane subgrade will then be smooth drum–rolled and inspected/certified prior to geomembrane placement. The construction of the geomembrane layer, and the subsequent layers of the final cover, will then proceed as described in the Plan of Operation.

Since the ash component of the final cover would be constructed incrementally, certification of this layer will require a different approach than would be applied to a traditional clay barrier layer. Once placed and cured, the conditioned and compacted ash component of the final cover will harden to a low-permeability concrete-like mass as demonstrated on previous landfill phases. Density testing would provide little useful information since the properties of the cured ash are affected by both the ash density and the hydration reactions, and since additional compaction would not be possible. Hydraulic conductivity testing is not practicable owing to the hardness of the cured ash. RMT's experience with the coring of ash to retrieve samples for hydraulic conductivity testing is that the samples develop cracks and are otherwise disturbed, making the laboratory testing results unrepresentative of the field conditions.

Given this, DPC is proposing an approach that utilizes up-front technical studies and field data (i.e., DPC's historical ash studies and subsequent 20 years of operational experience) to determine the properties of the conditioned and compacted ash that can be achieved with a relatively high degree of certainty. Since the proposed cover specifications are based on these properties (i.e., a minimum 2-foot–thick layer with a maximum hydraulic conductivity of 1×10^{-6} cm/s), the operational procedures historically used to achieve these properties will continue to be followed. DPC proposes to monitor that the minimum ash mix proportions and moisture contents are achieved, the approved means of placement are followed, and the minimum thicknesses are achieved. DPC will also commit to an annual audit of the operating procedures to verify that these operating procedures are followed.

Records from the ash processing facility will be used to document the mix proportions and moisture content of the select ash mix. Operating records will be utilized to document the ash placement procedures. Survey data will be utilized to document the ash layer thickness. Density testing, hydraulic conductivity testing, or other ash physical testing is not proposed at this time.

4.3 Closure Cost Estimate

The cost of closure for the facility is representative of "the total cost of closure for the point in time during operation of the facility when the extent and manner of its operation make closure most expensive." This cost estimate satisfies NR 520.07, which requires that the premature phased closure be identified. This point in time would occur when Cell 3 is active and final cover would be required over the entire Cell 3 area and over portions of Cells 1, 2A, and 2B.

The premature closure cost estimate assumes that the active Cell 3 area has not yet received the conditioned and compacted ash layer, and that, to close this area, soil needs to be imported, placed, and tested to certify that an equivalent layer to the ash is achieved.

The cost estimate to perform closure activities includes installing a final cover system and a surface water drainage structure, vegetating the final cover, and preparing a closure documentation report. A 25 percent contingency is also included. Final cover construction includes hauling, placing, and compacting the soil components of the final cover; placing the geomembrane; seeding and mulching the topsoil; and constructing drainage controls. The documentation report includes soil testing results and verification that closure activities were performed in accordance with the requirements of the Plan of Operation. The updated closure cost estimate is included in Appendix E. The updated cost of approximately $1.35 million is slightly less than the closure cost of $1.41 million included in the Plan of Operation conditional approval

4.4 Financial Responsibility

The net worth method is used by DPC to provide proof of financial responsibility for the closure and long-term care of the landfill site. The necessary amounts of proof of financial responsibility have been calculated in accordance with NR 520.08(1) and (2).

Section 5
References

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Warzyn Engineering, Inc. (Warzyn). 1979. Executive summary and report, fly ash characterization study. Alma-Madgett Generating Station Units 1-6. October 12, 1979.

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Warzyn Engineering, Inc. (Warzyn). 1980d. Supplemental fly ash characterization report, fly ash slurry setting retarder effects. Alma-Madgett Generating Station Units 1–6. September 3, 1980.

Warzyn Engineering, Inc. (Warzyn). 1980e. Supplemental fly ash characterization report, fly ash conditioning with low moisture content. Alma-Madgett Generating Station Units 1 through 6. November 26, 1980.

Appendix A
Conditional Plan of Operation Approval for Dairyland Power Cooperative Phase IV Disposal Area. License #4126

WISCONSIN
DEPT. OF NATURAL RESOURCES

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Scott McCallum, Governor
Darrell Bazzell, Secretary
Scott A. Humrickhouse, Regional Director

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May 15, 2001

FID # 606009360
Buffalo Co.
SW/LIC. File

Mr. Robert Carothers
Dairyland Power Cooperative
JPM Station
500 Old State Highway 35
Alma, WI. 54610

Subject: Conditional Plan of Operation Approval for Dairyland Power Cooperative Phase IV Disposal Area, Alma Off-Site Ash Disposal Facility, Town of Belvidere, Buffalo County, License #4126.

Dear: Mr. Carothers:

We have completed our review of your plan of operation for the proposed Phase IV Disposal Area Landfill and determined that it is consistent with Wisconsin's solid waste regulations. Therefore, the plan of operation is approved, subject to compliance with chs. NR 500-590, Wis. Adm. Code, and the conditions of the attached approval.

This approval contains conditions that require certain changes to the proposed design, construction, and monitoring of this facility. They include revisions to the final cover design, leachate extraction system, and several minor aspects of construction documentation, and leachate monitoring.

You are reminded that this approval does not relieve you of obligations to meet all other applicable federal, state and local permits, as well as zoning and regulatory requirements.

If you have any questions regarding this approval please call Marty Herrick at (608) 789-5518 or Barb Hennings at (608) 264-6021.

Sincerely,

David R. Lundberg

David R. Lundberg
Waste Management Team Leader
West Central Region

Attachments: Project Summary, Conditional Plan of Operation Approval, Table 1 (PALs), Table 2 (ACLs), Monitoring Summary

cc:
Dennis Mack/Paul Huebner/Bureau Files-WA/3
Jack Tritt-WCR
Barb Hennings-WA/3
Marty Herrick-LAX
Tony McKimmy-DPC
Bernie Krantz-RMT
Colleen Hellenbrand-WA/3
Bob Grefe-WA/3
Steve Karklins – DG/3

PROJECT SUMMARY
DAIRYLAND POWER COOPERATIVE
PHASE IV DISPOSAL AREA
ALMA OFF-SITE ASH DISPOAL FACILITY

GENERAL INFORMATION

AUTHORIZED CONTACT:

Mr. Robert Carothers
Dairyland Power Cooperative
JPM Station
500 Old State Highway 35
Alma, WI. 54610

LICENSEE AND PROPERTY OWNER: Dairyland Power Cooperative

SITE LOCATION: Dairyland Power Cooperative (DPC) is proposing to construct an industrial ash landfill located in the NE ¼ of the NE ¼ of Section 19 and portions of Sections 18 and 20, Township 21N, Range 12 W, Town of Belvidere, Buffalo County, Wisconsin. The site is located approximately 4,000 ft. east of State Trunk Highway (STH) "35" and 3200 ft. south of County Road "E".

One water supply well is located within 1,200 feet of the proposed limits of fill and will be abandoned prior to waste placement in the Phase IV disposal facility. A new water supply well will be installed south of the existing landfills at a distance greater than 1200 feet from any limits of filling.

ACREAGE AND ACCESS: The licensed disposal area will be 32.1 acres of a 1,113 acre parcel of land owned by DPC. Access to the facility is from U.S. Highway 35 onto the landfill's private haul road.

PROPOSED CAPACITY AND SITE LIFE: The facility will provide 3,011,000 cubic yards of capacity for the disposal of ash from DPC's Alma and Genoa power generating facilities. The Phase IV disposal area has a projected site life of 13.9 years. The estimated annual quantity of ash to be placed is 217,000 cubic yards. Filling rates will be influenced by power demands and the ability of DPC to use the ash for beneficial reuse purposes.

WASTE TYPES AND GENERATORS SERVED: The site is owned and operated as a private industrial solid waste disposal facility. The facility will accept primarily fly ash and bottom ash from the burning of coal at DPC's Alma and Genoa power generating stations. The facility will also accept sludge from the wastewater treatment plants for the Alma and Genoa facilities and asbestos generated from renovations at the respective facilities as well. An asbestos disposal plan is being approved as part of this plan of operation. The chemical characteristics of the leachate are expected to be similar to the existing Phase III disposal site.

PRESENT LAND USE AND ZONING: Land use in the area of the landfill is restricted by the local vertical relief which is approximately 500 feet between the southern end of the valley floor and the bluff top. Some of the land located above the facility on the bluff tops is used for agricultural purposes. The Phase IV disposal facility is located in the valley below the bluffs and the Phases I though III disposal facilities are located on the adjacent side hills. The bluffs and valley are forested and bedrock crops out at the top of the bluffs.

The proposed landfill is not located within a floodplain or a wetland but is located at the confluence of the surface waterways for the surrounding bluffs. Sediment and retention ponds and diversion channels will reroute the surface discharges from the surrounding bluffs around the perimeter of the landfill, which will occupy the center of the drainage confluences. Ultimately the surface water drains into the Mississippi River.

DPC is currently using a portion of the property for coal ash disposal operations in Phases I through III. Phases I, II and III are located 1000 feet, 100 feet and 1400 feet respectively to the south/southwest of the proposed landfill's footprint. Phase I was closed in 1993 and Phase II was closed in October 1997. Phase III is approximately 7 acres in size and is expected to reach its final approved capacity in the near future. The 1113 acre parcel is zoned as an agricultural district. As part of this approval DPC has modified the conditional use permit from Buffalo County to include the Phase IV disposal facility. There are no designated recreational areas within a mile of the site and the facility is not visible from U.S. HWY 35. No historical, archaeological or environmentally unique areas are known to be present within one mile of the proposed landfill or borrow sites.

PERIOD OF LONG TERM CARE RESPONSIBILITY: DPC has, by law, a 40 year proof of financial responsibility period for long term care following landfill closure. However, DPC will be responsible for the long term care of the facility in perpetuity.

SITE CHARACTERISTICS

The site is located within the Mississippi River drainage basin in a valley at the confluence of four ephemeral surface water drainage-ways.

The surficial soil at the proposed site generally consists of sand and silty sand with lenses of gravel. Lenses of finer grained soil, including silt and clay, range from a few feet to forty feet in thickness. The sandy soils typically extend to bedrock with depths of 15 to 60 feet below the existing ground surface. The soils are from fluvial deposition and weathering of the sandstone bedrock.

Generally the bedrock in the area is composed of the Prairie du Chien Group Dolomite underlain by Cambrian Sandstone. However in the area of the Phase IV landfill the dolomite has been eroded and the bedrock is composed of the Cambrian Sandstone. The bedrock is fine grained with interbedded lenses of dark brown sandstone and calcareous, shaley constituents. The Prairie du Chien group crops out at upper elevations of the valley. The bedrock surface varies between 24 to 64 feet below the existing ground surface. The subbase of the landfill liner will be a minimum of 12 feet above the bedrock surface and no bedrock removal is anticipated as part of the landfill development.

The groundwater table beneath the site is present both within the unconsolidated sandy sediment and within the sandstone bedrock. The overlying sand and gravel aquifer is hydraulically connected to the sandstone bedrock. The depth to groundwater varies from 27.5 feet to 110 feet below ground surface. The minimum separation between the proposed subbase grades and the high water table is approximately 30 feet. Groundwater flows into the central portion of the valley and then toward the Mississippi River approximately one mile south /southwest of the site.

The *in situ* hydraulic conductivity of the fluvial sand and gravel across the site ranges from 5.3 X 10^{-3} to 2.8 X 10^{-4} cm/sec. The geometric mean horizontal hydraulic conductivity for this unit is approximately 1.4 X10^{-3} cm/sec. The in situ hydraulic conductivity in the Cambrian sandstone is varied with the permeability ranging from 2.5 X 10^{-5} to 1.0 X 10^{-2} cm/sec. The geometric mean horizontal hydraulic conductivity within the geologic unit is 1.1 X 10^{-3} cm/sec.

For the proposed site, baseline groundwater quality results for indicator parameters and for public health and welfare parameters were provided as part of the feasibility report. In one or more wells installed at the site the concentrations of lead, manganese, nitrogen (nitrate + nitrite), selenium and sulfate attained or exceeded the preventive action limit (PAL) or enforcement standard (ES) established in ch. NR 140, Wis. Adm. Code. The Department granted exemptions to groundwater standards in the feasibility determination. As part of the plan of operation, DPC has requested both alternative concentration limits (ACLs) for the parameters listed above and additional exemptions to the groundwater standards for selenium and lead. The plan of operation approval grants the exemptions for selenium but rescinds both a previously granted exemption for lead at well MW-101 because 6 of the 8 results are "no detect" and all exemptions at Station 6 because the well will not be part of the monitoring program for Phase IV. The requested exemptions for lead were not granted.

FACILITY DESIGN

The Phase IV ash disposal facility will be developed in four phases with filling beginning in a six acre tract along the east central portion of the site and generally progressing westward. The area of the Phase IV ash disposal is approximately 32 acres with a design capacity of 3, 011,000 cubic yards.

The surface water control system was designed for a 100 year, 24 hour storm event. Surface water control measures will be phased to match the construction of the landfill. Temporary sedimentation basins will be constructed and abandoned during various phases of construction and operation.

The landfill liner design includes the following components from top to bottom: a one foot thick granular drainage layer, a 60 mil High Density Polyethylene (HDPE) geomembrane, a geosynthetic clay liner (GCL) and a 2 foot thick low permeability subbase soil layer. The subbase will be compacted prior to placement of the low permeability soil barrier layer. The subbase is a fluvial sand deposit that will have loess material placed in various locations to bring it to the final grade. The low permeability soil barrier layer is a loess material obtained on site. It will be placed to achieve a density or compaction of at least 90% of the Modified Proctor and a hydraulic conductivity no greater than 1.0×10^{-5} cm/s. The loess barrier soils will be obtained as part of the excavation for the respective cells and will be characterized prior to placement.

Leachate from the landfill will be captured in a granular drainage layer and directed to the sump area of the leachate collection system. Because the volume of leachate generated is anticipated to be low a sidewall penetration of the liner is being allowed. This allows leachate to flow by gravity to the leachate collection tank. The leachate collection tank is a 30,000-gallon double walled steel tank located near the existing processing facility. The leachate would then be pumped into the processing facility where it is mixed with a retarding agent and then applied to the incoming ash prior to placement in the landfill. The retarding agent is used to slow the cementing nature of the ash. Excess leachate will be trucked to either DPC's wastewater treatment plant at the Alma generating station or to the City of LaCrosse, Wisconsin wastewater treatment plant.

Final cover for the landfill includes, from the bottom up: a 2 foot soil barrier above the ash, a GCL, a 40 mil very flexible polyethylene (VFPE) geomembrane, a 1 foot sand drainage layer, an 18 inch general cover layer and a 6 inch topsoil layer. Final grades are designed at a maximum of 4H: 1V slope. Because of the lack of organic matter in the ash a gas extraction system is not required. The two foot soil barrier layer below the GCL will consist of a one foot layer of coarse grained material placed on top of the ash and an upper one foot layer having properties similar to the material used for the soil barrier in the liner.

The final use for the landfill is green space.

ENVIRONMENTAL MONITORING

Environmental and performance monitoring will extend through the period of active site operation and perpetual long-term care. Monitoring data will be reported to the Department on diskettes in a format supplied by the Department, as specified in s. NR 507.26(3), Wis. Adm. Code. To determine exceedances of groundwater standards, analytical results will be compared to the indicator PALs in Table 1 and the ACLs in Table 2 of the attached approval, or the standards in ch. NR 140, Wis. Adm. Code.

Environmental monitoring will be conducted semi-annually at groundwater monitoring wells, the water supply well, and sedimentation ponds. Monthly monitoring will be performed at the leachate collection tank and leachate head wells. Environmental monitoring requirements are provided in the Environmental Monitoring Summary Report attached to the plan of operation approval.

Annual testing of the coal ash will be performed for three years following completion of the first phase of the landfill. The results will be compared to the existing data and at the end of the third year a brief report will be submitted. The purpose of the analysis is to account for the variability of the coal sources and demonstrate the compatibility of the ash with the GCL components of the liner and cap for the landfill. Four discrete samples will be collected on a quarterly basis and then blended to form a composite sample from which a synthetic leachate will be generated. The leachate will be analyzed for the following properties: boron, calcium, chromium, potassium, sodium, chloride, specific conductance, total suspended solids and sulfate.

CLOSURE AND LONG TERM CARE COSTS

Although DPC will be perpetually responsible for the long term care of the landfill, proof of owner financial responsibility for a long term care period of 40 years is required by law. Actions to be taken during closure and the 40 year owner financial responsibility period, along with the associated cost estimates, are summarized below. Closure costs for the Phase IV facility are based on a worst case scenario where cell 3 is open and final cover would be required for cells 1, 2A, 2B and 3. The premature closure cost estimate includes installing the final cover system, seeding and vegetating the final cover system and preparing a closure documentation report. The final cover system is composed of the barrier soils, the GCL, the geomembrane and the surface water management features.

CLOSURE COSTS:

Item	Quantity	Unit Cost	Estimated Cost
Barrier Layer (24 in.)			
12 in. Silty Soil	20,000 cy	$1.5/cy	$30,000
12 in. Coarse Material	20,000 cy	$1.5/cy	$30,000
GCL	542,300 sf	$0.4/sf	$217,000
40 Mil VFPE Geomembrane	542,300 sf	$0.36/sf	$195,200
Granular Drainage Layer (12in.)	60,260 sy	$5.57/sy	$335,700
Vegetative Layer (18 in)	90,390 sy	$1.26/sy	$113,900
Topsoil (6 in)	10,000 cy	$1.50/cy	$15,000
Surface Water Control System			$50,000
Seed, Fertilize, Mulch	12.4 Acre	$1350/Acre	$16,700
Construction Plans			$20,000
Construction Observation	16 Weeks	$5500/Week	$88,000
Documentation Report			$ 20,000
Contingencies (25%)			$282,875
Total Cost			$1,414,375

LONG TERM CARE COSTS:

Long term care costs are itemized below and are based on estimated yearly expenses for:

Item	Quantity	Unit Cost	Estimated Cost/Year
Cover Vegetation			
Reseed/Erosion Damage	32 Acre	$ 500/Acre	$16,000
Mowing	Event	$3200	$3200
O &M			
Storm Water Control Structures	Event	$5000	$5000
Settlement/Siltation			
Repair Cover	32 Acre	$200/Acre	$6400
Sedimentation Basin Cleaning	Event	$500	$500
Leachate Control Features			
Leachate Collection Line Cleaning	Event	$2000	$2000
Operation & Maintenance	Event	$3000	$3000
Leachate Disposal	876,000 Gallons	$.025	$21,900
Environmental Monitoring	Event	$6500	$6500
Compatibility Testing	Event	$10,000	$10,000 (one time)
Inspections		$2000	$2000
Reporting		$3000	$3000
Contingencies (25%)		$17,375	$17,375
40 Year Total			$3,485,000

DPC will use the Net Worth test for demonstrating compliance the long term care account in s. NR 520.06(6), Wis. Adm. Code.

BEFORE THE
STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

CONDITIONAL PLAN OF OPERATION APPROVAL
FOR
DAIRYLAND POWER COOPERATIVE
PHASE IV DISPOAL AREA
ALMA OFFSITE ASH DISPOAL FACILITY
TOWN OF BELVIDERE, WISCONSIN
WDNR LICENSE # 4126

FINDINGS OF FACT

The Department finds that:

1. Dairyland Power Cooperative (DPC) has proposed to construct an ash disposal landfill in the NE ¼ of the NE ¼ of Section 19 and portions of Sections 18 and 20, T21N, R12W, Town of Belvidere, Buffalo, County, Wisconsin.

2. The proposed ash disposal facility is intended to serve the needs of DPC as a private industrial solid waste disposal facility. Waste disposed at this site will consist of fly and bottom ash, which is produced at Units 1-5 at the John P. Madgett (JPM) and the Genoa Station No. 3 (G-3) power generating facilities owned and operated by DPC. The facility will also accept sludge from the wastewater treatment plants for the JPM and Genoa facilities and asbestos generated from renovations at the respective facilities as well.

3. The proposed ash disposal landfill would have a design capacity of 3,011,000 cubic yards with an approximate operational life of 13.9 years.

4. On September 10, 1999, the Department issued a favorable feasibility determination for the proposed Dairyland Power Cooperative Phase IV Ash Disposal Facility.

5. On October 23, 2000, the Bureau of Waste Management received a report entitled " Plan of Operation, Phase IV Disposal Area, Alma Off-Site Ash Disposal Facility, Town of Belvidere, Buffalo County Wisconsin." The report, which included 23 plan sheets, was dated October 2000 and was prepared by RMT of Madison, Wisconsin. The Plan of Operation review fee, invoice SWK-0159, for $7000 was received by the Department on November 22, 2000.

6. The information submitted in connection with the plan of operation includes the following:

   a. On September 19, 2000, DPC received a ruling from the Department's Air Management program noting that a construction permit was not required,

   b. On November 21, 2000, additional information on the compatibility testing of the GCL and the associated synthetic leachate generation analysis was submitted to the Department by RMT for DPC,

   c. On February 8, 2001, DPC submitted to the Department an asbestos disposal plan,

d. On March 15, 2001, DPC submitted to the Department additional information including a revised plan sheet number 13. The information was in response to a January 22, 2001 e-mail to DPC and RMT from Martin Herrick of the Department,

e. In response to a telephone conversation with Barb Hennings of the Department, on April 2, 2001, DPC submitted revised monitoring plan sheets because well "Station 6" was removed from the monitoring program.

7. Additional Documents considered in the review of the plan of operation include the following:

   a. The Department's guidance on GCL's and sample conditions,

   b. The DPC Feasibility Report, accompanying plan sheets, and the Department's Feasibility determination,

   c. March 21, 2001 memo from Barb Hennings to the DPC file explaining how PALs and ACLs were reviewed and approved,

   d. March 21, 2001 memo from Barb Hennings to Steve Karklins of the Department requesting review of exemptions to groundwater standards,

   f. March 27,2001 memo from Steve Karklins to Dave Lundberg concurring with the proposed exemptions to the groundwater standards for selenium at wells P-42A, P-42B, Station 1, W-42, W-101, W-101A, W-102, W-104, W-105, and W-106.

8. Additional facts relevant to the review of the engineering aspects of the plan of operation include the following:

   a. Geosynthethic Clay Liners (GCLs) have been proposed, in conjunction with a soil a barrier layer, as a technical substitute for the clay component of composite liners and final covers for this project,

   b. The Department has issued guidance on the use of GCL's, which has been combined with technical literature, soil barrier layers, and other project experience to develop conditions that are intended to maximize the longevity and integrity of the GCL's.

9. Additional facts relevant to the review of the groundwater quality and monitoring aspects of the plan of operation include the following:

   a. The proposed location of the replacement water supply well is outside the border of plan sheet 3 at station 168470N, 1476700E. This location is 1200 feet from the limits of filling of the Phase 3 landfill.

   b. The Plan of Operation included indicator Preventive Action Limit (PAL) and Alternative Concentration Limit (ACL) calculations and requests for approval.

   c. The Plan of Operation included a request for additional exemptions to groundwater standards.

   d. At least eight values were used in the calculations of PALs. The calculated PALs and ACLs were rounded up to two significant figures.

e. PALs and ACLs were granted largely as proposed except that actual result values were used in the calculation of specific conductance rather than the rounded values used in the calculations by the facility. Several PALs were not calculated due to insufficient information or likely impacts due to well construction.

f. The baseline monitoring results for chemical oxygen demand at wells W-42, W-100, W-101A, and W-105 indicate likely impacts due to well construction. The more recent results show no detect whereas the initial results vary considerably, in the range of 5 to 60 mg/L.

g. Of the eight analytical results submitted for chemical oxygen demand at well W-100A, one is ten times higher than the others. Excluding this outlier leaves seven values to be used for the calculation of a preventive action limit where s. NR 140.20(1), Wis. Adm. Code, requires 8 values.

h. The Department considered the following information while reviewing the need for exemptions to groundwater standards at this facility:

i. Baseline groundwater monitoring data provided in the Plan of Operation, the Addendum and electronic submittal dated 3/05/2001,

ii. Well construction details and boring logs provided in the Feasibility Report,

iii. Well location plan sheets provided with the Plan of Operation and the Addendum,

iv. Water table maps provided in the Feasibility Report and Addenda to the Feasibility Report,

v. Reports from the Department's GEMS electronic database including time vs. concentration plots for various parameters at Station 1 and Station 6,

vi. The landfill design specifications provided in the Plan of Operation as conditioned herein.

10. Based on an examination of site conditions, the Department finds the following:

a. Groundwater concentrations of lead, and selenium are found at concentrations exceeding the ch. NR 140, Wis. Adm. Code, groundwater standards. These exceedances are due to baseline groundwater quality associated with natural hydrogeologic conditions or substances released by other human activities on, or near, the proposed facility,

b. The elevated concentrations of boron at Station 6 reflect groundwater quality related to the Phase II ash disposal area,

c. Station 6 will not be used as a monitoring point for the Phase IV facility.

11. Based on an examination of the groundwater quality data for the proposed facility for substances of public health concern, and the information listed in Findings of Fact 9 and 10, the Department finds the following:

a. Mean baseline concentrations of samples analyzed for selenium in wells P42A, P42B, Station 1, W42, W101, W101A, W102, W104, W105, and W106 are less than the PAL but the results vary widely,

b. Mean baseline concentrations for lead at wells W104 and W105 approach but are not greater than the PAL. Six of the eight results are no detect. Therefore, an exemption to the groundwater standard for lead at these wells is not necessary,

c. An exemption for the groundwater standard for lead was granted at well W 101 in the 9/10/00 Feasibility Determination. The mean baseline concentration is greater than the PAL for lead. However, 6 of the 8 results are "no detect". Therefore, the exemption to the groundwater standard for lead at well W 101 is not necessary.

d. The proposed facility will not cause the concentration of selenium to exceed the ES for these substances at a point of standards application because of the landfill design,

e. The proposed facility is designed to achieve the lowest possible concentrations for selenium, which are technically and economically feasible.

12. The indicator PALs and special conditions set forth below are needed to assure that an increase in the concentration of selenium does not cause an increased threat to public health or welfare or inhibit compliance with chs. NR 500-590, Wis. Adm. Code.

13. Neither the applicant, nor any person owning a 10% or greater legal or equitable interest in the applicant or in the assets of the applicant:

    a. Is in noncompliance with a plan approval or order issued by the Department for a solid or hazardous waste facility in Wisconsin,

    b. Owns or previously owned a 10% or greater legal or equitable interest in a person, or in the assets of a person, who is not in compliance with a plan approval or order issued by the Department for a solid or hazardous waste facility in Wisconsin.

14. Granting the exemptions that are set forth below will not inhibit compliance with the Wisconsin solid waste management standards in chs. NR 500 through 590, Wis. Adm. Code

15. The Department has complied with the requirements of NR 150, Wis. Adm. Code, and s.1.11, Stats., and has adopted all practical means to avoid or minimize environmental harm consistent with social, economic and other essential considerations.

The special conditions set forth below are needed to assure that the facility will not pose a substantial hazard to public health or welfare.

CONCLUSIONS OF LAW

1. The Department has authority under s. 289.30, Stats. to approve a plan of operation with special conditions if the conditions are needed to ensure compliance with chs. NR 500 to 590, Wis. Adm. Code.

2. The Department has authority s. NR 500.08(4), Wis. Adm. Code, to approve exemptions to the requirements of chs. NR 500 to 590 in special cases except as otherwise provided.

3. The Department has the authority under s. NR 140.28, Wis. Adm. Code, and ss. 160.19 (8) and (9), Stats., to grant exemptions to groundwater standards and to specify terms and conditions under which the Department may seek remedial action relating to standards for which an exemption has been granted. This may include establishing alternative concentration limits.

4. The Department has the authority under s. 160.15(3), Stats., and s. NR 140.20, Wis. Adm. Code, to establish preventive action limits for indicator parameters.

5. The conditions of approval set forth below are needed to ensure compliance with chs. NR 500 to 590, Wis. Adm. Code.

6. In accordance with foregoing, the Department has the authority under ch. 289, Stats., to issue the following conditional approval.

GRANT OF EXEMPTIONS

1. DPC has demonstrated circumstances, which warrant an exemption from s. NR 504.05(5), Wis. Adm. Code requirement, whereby leachate flowing across the base of a liner is required to encounter a perforated leachate collection line within 130 feet. The following areas are exempted from the 130 foot flow length requirement:

Location	Area (acres)	Average Exceedance	Base Slope
NE Corner of Cell 2, Module A	0.165	27	6%
SW Corner of Cell 3	0.025	9	6%
SW Corner of Cell 4, Module A	0.070	19	6%
Small Area along East Wall of Cell 4, Module B	0.035	12	10%

2. DPC has demonstrated circumstances, which warrant an exemption from s. NR 504.06(5)(j), Wis. Adm. Code, whereby a penetration through the sideslope of the liner is being allowed and a sump and sideslope riser will not be installed. But instead the leachate is able to gravity drain to the leachate collection tank located near the ash processing facility.

3. DPC has demonstrated circumstances, which warrant an exemption to the groundwater standards for selenium in ch. NR 140, Wis. Adm. Code as specified in s. NR 140.28, Wis. Adm. Code. Therefore, the Department grants an exemption to allow the landfill to be developed in an area where a preventive action limit or enforcement standard has been attained or exceeded. Exemptions are, therefore, granted for these parameters and the wells listed in Findings of Facts 9 and 10. The Alternative Concentration Limits established for these exemptions and those granted in the Feasibility determination can be found in Table 2 of this approval. Based on additional information the Department may modify this approval.

RESCINDED EXEMPTIONS

1. With the initial four sampling results DPC demonstrated that an exemption to the groundwater standard for lead at well W101 was warranted. However, of the last four sampling results, three were no detect for a total of 6 results that showed no detect. Therefore, an exemption to the groundwater standard for lead at well W101 is not necessary and the grant of exemption is rescinded.

2. DPC demonstrated that an exemption to the groundwater standards for selenium and sulfate at well Station 6 was warranted. However, DPC has removed well Station 6 from the groundwater monitoring plan for this facility. Therefore, an exemption to the groundwater standards for sulfate and selenium at well Station 6 is not necessary and the grant of exemption is rescinded.

CONDITIONAL PLAN OF OPERATION APPROVAL

The Department hereby approves the Plan of Operation for the DPC Phase IV Ash Disposal Area, subject to compliance with chs. NR 500 to 590 Wis. Adm. Code, and the following conditions:

General

1. The capacity of this facility may not exceed its design volume of 3,011,000 cubic yards.

2. DPC shall perform all aspects of construction and operation of the landfill in accordance with the plan of operation, the requirements of chs. NR 500 to 590, Wis. Adm. Code, and the conditions of the approval. In the case of any discrepancies between the approval conditions and the plan of operation and its associated plan sheets, the approval conditions shall take precedence.

3. DPC shall present any proposed changes to the plan or this approval to the Department. If the changes are compatible with the desired performance of this landfill, as determined by the Department, an addendum will be added to this approval indicating acceptance of those modifications to this approval. Written Department approval is necessary prior to implementing any changes with the exception of minor field modifications that are documented in accordance with s. NR 516.04(3)(d), Wis. Adm. Code. All field modifications shall be discussed with the Department prior to implementation. Other changes may be handled as expedited plan modifications under s. NR 514.09, Wis. Adm. Code, as appropriate.

Design, Construction and Construction Documentation

4. A preconstruction report shall be submitted to the Department for review at least 2 weeks prior to the installation of the GCL component of the liner and final cover. One copy shall be submitted to the Bureau of Waste Management Technical Support Section and one copy shall be submitted to the regional environmental engineer. The report shall:

   a. Identify any proposed revisions to the approved design, construction or documentation requirements including detailed diagrams incorporating all changes.

   b. Identify the manufacturer of the GCL and the manufacturer's qualifications, and provide technical specifications of the bentonite and geosynthetics used for the GCL (e.g., thickness, bentonite mass, powdered or granules, bonding method, printed overlap lines on both sides).

   a. Identify the installation contractor for the GCL, indicating specific on-site supervisory staff and a summary of their qualifications and experience, and quality control plans that the installation contractors will follow in the installation of the GCL.

   b. Identify the quality assurance consultant indicating specific on-site staff and summarizing their qualifications and experience, and include a copy of the construction quality assurance plan to be used during documentation of the construction.

   c. Describe contractor-specific storage and material handling procedures, deployment methods, attachment methods, panel overlaps, patching, procedures for minimizing bentonite loss in the GCL, and acceptable limits on sub-grade including maximum rut depth, maximum stone size and weather conditions.

d. Provide results of all chemical compatibility and slope stability testing. Describe any measures intended to assure that an adequate slope stability safety factor will be present during construction and after hydration of the GCL.

e. Describe the method to be used to assure a smooth and firm surface prior to GCL placement including a method of removing gravel, cobbles and other debris in the surface of the soil layer.

f. Describe the method to be used to assure the GCL does not become saturated prior to covering with soil and the procedure that will be followed if the GCL does become saturated. Describe the methods and equipment to be used to place the geomembrane over the GCL, and the maximum time between deployment of the GCL and placement of soil cover layers to limit free swell of bentonite.

g. Provide the planned panel layout pattern for GCL placement.

5. Conformance sampling and testing shall be conducted on the GCL delivered on site and used in construction. Sampling shall be conducted by the quality assurance engineer or qualified technician. Laboratory testing shall be performed by the quality assurance engineer or at another laboratory not affiliated with the quality control testing.

   a. Clay mass per unit area (dried) shall be tested at a rate of one test per 40,000 ft^2 of GCL installed; results shall be reported at 0% moisture content.

   b. Grab and peel tensile strength (MD and CD) shall be tested at a rate of one test per 100,000 ft^2 of GCL installed (ASTM D-4632).

   c. Index flux shall be tested at a rate of one test per 100,000 ft^2 of GCL installed (ASTM D-5887).

   d. Bentonite recovered from GCL sample shall be tested for free swell at a rate of one test per 100,000 ft^2 of GCL installed.

   e. GCL shall be certified needle-free through magnetic and metal detection tests.

6. The placement of the GCL component of the final cover shall comply with the following:

   a. The GCL shall consist of a layer of pure sodium bentonite clay encapsulated between two geotextiles.

   b. The GCL shall be installed in a relaxed condition and shall be free of tension or stress upon completion of the installation. Stretching of the GCL to fit shall not be allowed.

   c. Adjoining panels of GCL shall be laid with a minimum of six inches of overlap on the longitudinal seams and a minimum 20 inches of overlap on the panel end seams.

   d. Irregular-shapes, cuts, or tears in the installed GCL shall be covered with a GCL patch that provides a twelve-inch overlap onto adjacent GCL surfaces.

   e. Loose bentonite or bentonite amended soil shall be placed at all penetrations.

   f. The GCL shall be covered with a geomembrane the same day that it is unpacked and placed in position. The GCL shall not be installed in standing water or during rain. The GCL shall be dry when installed and covered. GCL exhibiting unconfined swelling shall be removed and replaced.

   g. A rub sheet shall be placed over the GCL during installation of a geomembrane if a textured geomembrane will be in contact with the GCL.

7. Placement and testing of the two-foot soil barrier layer below the GCL shall meet the following minimum requirements:

   a. The upper one-foot of the barrier layer shall be composed of either a fine-grained soil or a well graded sandy soil with fines, with a maximum particle diameter less than one inch and meeting the criteria for USCS soil types ML, CL, CH, SM or SC with at least 80% by weight passing the No. 60 screen and a P200 content of 40% or greater.

   b. Compacted in maximum one-foot lifts to at least 90% modified Proctor density.

   c. One sample grain size distribution through the .005-millimeter particle size for each 1,500 cubic yards of soil placed.

   d. Dry density and moisture testing in accordance with s. NR 516.07(1)(a), Wis. Adm. Code.

8. Quality assurance personnel shall be on site and performing their assigned duties at all times that the GCL is being deployed and covered. Daily inspector's summary reports shall be prepared by the quality assurance personnel for each day that installation of the GCL is either attempted or accomplished. The reports shall describe practices employed during the low-permeability soil layer placement and acceptance before GCL installation. Outline drawings on 8-1/2" X 11" paper shall be prepared as necessary to record the construction events. These reports shall be appended to the construction documentation reports and shall include the following information:

   a. Amount and location of the GCL placed, with changes from the design plan noted.

   b. Methods and procedures used during placement of the GCL, minimum overlap of the panels, placement of additional bentonite, any problems due to precipitation events, and any loss of bentonite from the GCL.

   c. Methods and equipment used to place the geomembrane over the GCL. The amount of time elapsed between placement of the GCL and placement of the geomembrane over the GCL.

   d. Dates, locations and panel numbers where GCL samples are taken.

9. DPC shall notify the Department's environmental engineer assigned to this site a minimum of one week prior to beginning each of the construction events, listed below, for the purpose of allowing the Department to inspect the work. A construction documentation report shall be submitted in accordance with the requirements in ch. NR 516, Wis. Adm. Code, for the liner and final cover construction in the respective cells as noted below. Fees shall be paid to the Department in accordance with s. NR 520.04(5), Wis. Adm. Code, for each of the inspections and associated construction documentation reports as noted below.

	Liner Construction	Final Construction
Cells	1, 2A, 2B, 3, 4A, 4B	1, 2A& 2B, 3, 4A, 4B
Inspections	Subase & barrier soils	Barrier Layer Soils
	Place GCL & geomembrane	GCL & Geomembrane installation
	Leachate collections system components	Drainage Layer
	Drainage blanket	Rooting Zone & Topsoil Placement

10. The construction documentation reports for the final cover shall include the following additional items listed below:

    a. Written certifications from the GCL installer's quality control representative, and the quality assurance consultant, that the construction was completed in accordance with approved plans with any deviations noted.

    b. Identification of all contractors and subcontractors involved with construction.

    c. Identification of the GCL supplier/manufacturer, material specifications of the installed GCL, and attachment methods used on the project. The report shall include the names of the on-site GCL installer and quality assurance personnel. A sample of the GCL used in the construction shall be included with the report.

    d. A narrative chronologically describing the construction including placement and compaction of the soil barrier layer, installation of the GCL, orientation, repairs and penetrations of the GCL, and placement of the geomembrane. If a textured geomembrane is used, the discussion of the method of placing the geomembrane shall include the type of slip sheet used. The narrative shall describe in detail the method used to connect the GCL to the previously constructed area and protection of edges for future connections.

    e. Identification of the source of the soil used to construct the low-permeability soil layer below the GCL.

    f. Documentation of the soil barrier layer thickness below the GCL on a 100-foot grid pattern, and results of all testing completed on the soil barrier layer.

    g. Photos/details documenting the following construction activities:

        i. Equipment compacting the soil barrier layer in preparation for GCL placement.

        ii. Equipment deploying the GCL and overlying materials.

        iii. Tie-in of GCL to previously placed barrier (i.e., clay or GCL) layers.

        iv. Protection of the edge of the GCL at end of day and for future connections.

11. The final cover structure shall be revised to include the following:

    a. A minimum of three feet of drain layer, rooting zone soil, and topsoil above the geomembrane component of the composite capping layer.

    b. A minimum of two feet of soil barrier layer between the top of the ash waste and the bottom of the GCL component of the capping layer. The soil barrier component of the composite capping layer shall include a minimum one foot of compacted soil meeting the construction and material specifications of the soil barrier layer component of the composite liner. A minimum of one foot of coarse-grained soil shall underlay the fine-grained upper layer. The coarse-grained lower layer shall be selected based on grain size and permeability properties such that this layer acts as a capillary break between the ash waste and the fine grained component.

12. Soil borrow sources for the fine-grained and coarse–grained components of the soil barrier component of the capping layer shall be identified, investigated, sampled, and proposed to the Department for review and approval no later than the date of submittal of the preconstruction report for the liner construction of cell 2A. The soil properties of the fine-grained and coarse-grained soils shall be compared and analyzed to demonstrate that the proposed soils are compactable, self-filtering, and capable of establishing a capillary break.

13. The construction documentation requirements proposed in the plan of operation and required by ch. NR 516, Wis. Adm. Code, shall be amended to include the following items and submitted within 90 days from the date of this approval:

    a. The fine-grained components of the soil barrier layer components of the composite liner and cap shall be sampled and tested for liquid limit and plasticity index at a minimum rate of 1 per 5,000 yd^3 of soil placed. Testing of the coarse grained component of the soil barrier layer of the cap shall be conducted as proposed in the plan of operation.

    b. Piping/permeability calculations for the ash waste and leachate collection sand, based upon the grain size characteristics of the ash waste and the soil used for the collection layer.

    c. Summary of the electrical resistivity testing to be conducted on the geomembrane component of the liner and capping layer for each cell. The summary shall include identification of the contractor that performed the inspection, and identification of all defects detected and remedial measures taken to correct such defects. A plan sheet with locations and identifications of all defects and repairs, and actions taken to replace and repair other soil and geosynthetic layers that were disturbed as a part of the remedial actions.

    d. Summary of quality assurance measures taken to detect and remove broken needles in the geotextile and GCL products used in the liner or final cover construction, both in fabricating plants and during installation of geosynthetics.

14. The leachate removal system shall be revised to include details for the anti-seep collar and use of factory-fabricated pipe boots and liner penetrations.

15. The final cover drainage system shall be revised to include a downslope flume on the Northeast side of the final covered area. The downslope flume shall intercept drainage sufficiently to eliminate routing water around the eastern exterior corner of the final cover.

16. The collection tank design shall be revised to eliminate the direct connection of the piping from manhole 5. The drain piping from manhole 5 shall be revised to connect directly to the manway of the tank, with provisions for inspecting, cleaning and pressure testing the pipe as the need arises.

17. Sedimentation basin details 2/22 and 3/22 shall be revised to include shutoff valves to control flow from the sedimentation basins.

18. Geotechnical stability analyses shall be conducted on each cell of liner construction, using the site specific testing data from ash waste, soils, and geosynthetics to be used in each cell. The stability analyses shall include a sliding block analysis. The sliding block analysis for cell 1 shall be submitted no later than the construction documentation for cell 1. For all subsequent liner cells, the analysis shall be included in the preconstruction report for each cell. The report for the analysis shall assess each interface of ash waste, soils, and geosynthetics for its effect on the stability analysis.

Environmental Monitoring

19. DPC shall perform environmental monitoring during both the active and post closure perpetual care periods in accordance with the attached Environmental Monitoring Summary report.

20. DPC shall provide all environmental monitoring data required in the Department's electronic format. Semi–annual environmental monitoring shall be performed in the months of March and September and the annual monitoring shall be performed in September. Monthly monitoring results shall be submitted with the semi-annual monitoring results.

21. Based on Finding of Fact 11c, the exemption to the groundwater standard for lead at well W-101 is no longer necessary. The exemption for lead at well W-101 is withdrawn.

22. DPC shall electronically submit the results for alkalinity, parameter number 39036, at wells W-102 on 12/15/1997 and W-107 on 9/8/1998 with in 30 days from the date of this approval.

23. Results from at least four additional rounds at wells W-42, W-100, W-101A and W105 shall be submitted to the Department electronically, in order to calculate PALs for chemical oxygen demand.

24. Indicator PALs and ACLs are established as presented in Tables 1 and 2. PALs and ESs for all other substances shall be as specified in ch. NR 140, Wis. Adm. Code, Tables 1 and 2. When submitting data to the Department, DPC shall compare the groundwater sampling results with these standards to determine whether exceedances have occurred.

Replacement Wells

25. The replacement water supply well shall be located no closer than 1200 feet from any limits of filling. The proposed location is approximately station 168470N, 1476700E.

26. In addition to any other Department requirements, DPC shall submit both the assigned Wisconsin Unique Well Number and copies of the well construction and well development forms to the Department's waste management hydrogeologist located in the LaCrosse Service Center.

27. The location of well nest W-100R, as proposed in the March 9, 2001 revised plan sheet 13, is approved. In the event that the W-100R well nest is submerged, DPC shall notify the Department within 30 days.

28. At any new or replacement wells, DPC shall collect the eight baseline monitoring samples no more than 90 days apart during the first two years following installation

Compatibility Testing and Report

29. In the event of a major process change or change of a coal source, DPC shall analyze the ash for compatibility with the GCL. The compatibility test protocol shall be proposed to the Department for review and approval prior to starting the compatibility testing. Compatibility testing shall assess the impact of the ash leachate on the bentonite minerals of the GCL, particularly concerning geochemical changes and subsequent permeability changes.

30. Beginning during the first year of filling, DPC shall perform testing of the coal ash for compatibility with the GCL by taking a representative sample of the ash quarterly and then blending it to make one composite sample. The composite sample shall be tested annually using the synthetic leachate analysis procedures in Appendix J of the feasibility submittal. At a minimum the compatibility test protocol shall include the following constituents be analyzed annually according to the referenced test methods:

Analyte	Units	Prep Method	Analysis Method
Boron	Ug/l	SW 846 3015	SW 846 6010B
Calcium	Ug/l	SW 846 3015	SW 846 6010B
Chromium	Ug/l	SW 846 3015	SW 846 6010B
Potassium	Ug/l	SW 846 3015	SW 846 6010B
Sodium	Ug/l	SW846 3015	SW 846 6010B
Chloride	Ug/l	EPA 300.0	EPA 300.0
Conductance, specific	Umhos/cm		EPA 120.1
Solids, total suspended	Mg/l	EPA 160.2	EPA 160.2
Sulfate	Mg/l	EPA 300.0	EPA 300.0

a. The sample results shall be submitted electronically within 90 days of testing and can be included with another data submittal.

b. After the third year, DPC shall analyze the trends and provide the Department with a recommendation whether additional testing or other modifications are warranted. The recommendation shall be submitted to the department within 90 days of the completion of testing.

The Department reserves the right to require the submittal of additional information and to modify this approval at any time, if in the Department's opinion, modifications are necessary. Unless specifically noted, the conditions of this approval do not supersede or replace any previous conditions of approval for this facility.

NOTICE OF APPEAL RIGHTS

If you believe that you have a right to challenge this decision, you should know that Wisconsin statutes and administrative rules establish time periods within which requests to review Department decisions must be filed.

For judicial review of a decision pursuant to ss. 227.52 and 227.53, Stats., you have 30 days after the decision is mailed, or otherwise served by the Department, to file your petition with the appropriate circuit court and serve the petition on the Department. Such a petition for judicial review shall name the Department of Natural Resources as the respondent.

This notice is provided pursuant to s. 227.48(2), Stats.

Dated: May 15, 2001

DEPARTMENT OF NATURAL RESOURCES
For the Secretary

David Lundberg
David R. Lundberg
Waste Management Team leader
West Central Region

Martin Herrick
Martin Herrick, P.E.
Environmental Engineer
West Central Region

Barbara Hennings
Barbara Hennings, P.G.
Hydrogeologist
West Central Region

TABLE 1
Summary of Indicator Preventive Action Limits

Well Name	**Specific Conductance** (umho/cm)	**Chemical Oxygen Demand,** Filtered (mg/l)	**Hardness,** Total Filtered (mg/l as $CaCO_3$)	**Alkalinity,** Total Filtered (mg/l as $CaCO_3$)
Station 1	700	30	410	390
W-42	680	--	410	390
P-42A	680	36	410	390
P-42B	660	31	410	390
W-100	1300	--	660	710
W-100A	870	--	490	650
W-101	670	39	400	380
W-101A	660	--	390	380
W-102	660	49	400	--
W-102A	640	33	390	370
W-104	660	36	390	380
W-104A	660	41	400	370
W-105	670	--	390	370
W-106	670	32	400	380
W-107	740	38	420	--

Note: Empty cells indicate insufficient data available to calculate PALs.

TABLE 2
Summary of Approved Alternative Concentration Limits

Well Name	**Selenium,** Filtered (ug/L) PAL = 10, ES = 50	**Nitrate plus Nitrate,** Filtered (mg/L as N) PAL = 2, ES = 10	**Lead,** Filtered (ug.L) PAL = 1.5, ES = 15
Station 1	23	--	--
P-42	23	--	--
P-42A	25	--	--
P-42B	24	--	--
W-100	56	4.4	--
W-100A	31	3.4	12
W-101	22	--	exemption rescinded
W-101A	20	--	--
W-102	20	--	--
W-102A	25	--	--
W-104	24	--	--
W-104A	26	--	--
W-105	24	--	--
W-106	25	--	--
W-107	--	2.8	--

Note: Empty cells denote no groundwater standard exemption.

Points Listing by DNR Point ID

License: 4126 Facility: DAIRYLAND POWER COOP PHASE IV-BELVIDERE

FID: 606043900 County: Buffalo City: BELVIDERE TN, WI

DNR Point ID	Point Name	Point Type	Point Status	WUWN	Linked	Gradient
1	STATION 1	12 Piezometer-Non Sub D Well	A	BX385	Y	Up
2	STATION 2	12 Piezometer-Non Sub D Well	A	BX386	Y	Up
17	W-42	11 WT Obs Well-Non Sub D	A	LO914		Side
18	P-42A	12 Piezometer-Non Sub D Well	A	LO915		Side
19	P-42B	12 Piezometer-Non Sub D Well	A	LO916		Side
20	W-43	11 WT Obs Well-Non Sub D	A	LO917		Down
21	W-100	11 WT Obs Well-Non Sub D	A	LO918		Down
22	W-100A	12 Piezometer-Non Sub D Well	A	LO919		Down
23	W-101	11 WT Obs Well-Non Sub D	A	LO920		Up
24	W-101A	12 Piezometer-Non Sub D Well	A	LO921		Up
25	W-102	11 WT Obs Well-Non Sub D	A	LO922		Side
26	W-102A	12 Piezometer-Non Sub D Well	A	LO923		Side
27	W-104	11 WT Obs Well-Non Sub D	A	LO924		Side
28	W-104A	12 Piezometer-Non Sub D Well	A	LO925		Side
29	W-105	11 WT Obs Well-Non Sub D	A	LO926		Side
30	W-106	11 WT Obs Well-Non Sub D	A	LO927		Side
31	W-107	11 WT Obs Well-Non Sub D	A	LO928		Up
32	PW-01	13 Private Well - Potable	A	LO929		Down
33	PW-02	99 Other	I			
40	W-100R	99 Other	I			

License: 4126 Facility: DAIRYLAND POWER COOP PHASE IV-BELVIDERE

FID: 606043900 County: Buffalo City: BELVIDERE TN, WI

DNR Point ID	Point Name	Point Type	Point Status	WUWN	Linked	Gradient
42	MW-100AR	99 Other	I			
44	W-102R	99 Other	I			
46	W-102AR	99 Other	I			
401	LEACHATE TANK	23 Leachate Collection Sys	I			
601	LH-1	24 Leachate Head Well	I			
604	LH-2	24 Leachate Head Well	I			
607	LH-3	24 Leachate Head Well	I			
610	LH-4	24 Leachate Head Well	I			
613	LH-5	24 Leachate Head Well	I			
616	LH-6	24 Leachate Head Well	I			
619	LH-7	24 Leachate Head Well	I			
622	LH-8	24 Leachate Head Well	I			
851	SG-1	36 Staff Gauge	I			
852	SG-2	36 Staff Gauge	I			
871	OUTFALL 001	34 Run-Off	I			
872	OUTFALL 002	34 Run-Off	I			
997	FIELD BLANK	99 Other	A			

```
R592R17C      04/06/2001                Environmental Monitoring Summary                                           Page:  1
                                      By Group Category Report Order Number

 License Number:        4126     Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                                 FID: 606043900      DNR Region:  West Central Region          County:  Buffalo

 PLAN OF OPERATION APPROVAL

Group Category:  Groundwater Monitoring Well        Group Description:   routine monitoring wells

Group Number:   1     Group Name:   GROUNDWATER MONITORING WELLS

   Common Name           DNR ID #
   -----------           --------   Sample Frequency:    Semi-Annual          Schedule Number:    1
   MW-101AR                 42      Sample Months:   J      F       M-Yes  A     M     J     J     A     S-Yes  O     N     D
   P-42A                    18                          Parameter
   STATION 1                 1                          ---------
   W-100                    21                                  1   COMMENT, SAMPLE ODOR
   W-100A                   22                                  2   COMMENT, SAMPLE COLOR
   W-100R                   40                                  3   COMMENT, SAMPLE TURBIDITY
   W-101                    23                                 10   TEMPERATURE, WATER (DEGREES CENTIGRADE)
   W-101A                   24                                 94   SPECIFIC CONDUCTANCE, FIELD (UMHO/CM @ 25C)
   W-102                    25                                341   CHEMICAL OXYGEN DEMAND, FILTERED (MG/L)
   W-102A                   26                                400   PH, FIELD (STANDARD UNITS)
   W-102AR                  46                                946   SULFATE, DISSOLVED (MG/L SO4)
   W-102R                   44                               1020   BORON, DISSOLVED (MG/L B)
   W-104                    27                               1145   SELENIUM, DISSOLVED (UG/L SE)
   W-104A                   28                              22413   HARDNESS, TOTAL, FILTERED (MG/L AS CACO3)
   W-105                    29                              39036   ALKALINITY, TOTAL FILTERED (MG/L AS CACO3)
   W-106                    30                              72020   ELEVATION, GROUNDWATER (FEET ABOVE MSL)
   W-107                    31
   W-42                     17
```

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R592R17C     04/06/2001            Environmental Mon   ring Summary                              Page:
                                  By Group Category Re   t Order Number

License Number:      4126   Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                            FID: 606043900     DNR Region:  West Central Region       County: Buffalo

PLAN OF OPERATION APPROVAL
Group Category:  Groundwater Monitoring Well       Group Description:  Elevation only
Group Number:  2     Group Name:  WELLS TO BE ABANDONED

  Common Name          DNR ID #   Sample Frequency:   Semi-Annual      Schedule Number:  2
  -----------          --------   Sample Months:  J     F     M-Yes  A    M    J    J    A    S-Yes  O    N    D
  STATION 2                 2
  W-43                     20                  Parameter
                                               ---------
                                                72020  ELEVATION, GROUNDWATER (FEET ABOVE MSL)
```

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License Number:      4126     Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                              FID: 606043900      DNR Region:  West Central Region        County: Buffalo
PLAN OF OPERATION APPROVAL

Group Category:  Groundwater Monitoring Well        Group Description:   wells for background monitoring
Group Number:   8      Group Name:  REPLACEMENT GROUNDWATER WELLS

   Common Name            DNR ID #
   -----------            --------     Sample Frequency:   Quarterly           Schedule Number:   10
   MW-101AR                  42        Sample Months:   J     F     M-Yes  A     M     J-Yes  J     A     S-Yes  O     N     D-Yes
   W-100R                    40                             Parameter
   W-102AR                   46                             ---------
   W-102R                    44                                 1   COMMENT, SAMPLE ODOR
                                                                2   COMMENT, SAMPLE COLOR
                                                                3   COMMENT, SAMPLE TURBIDITY
                                                               10   TEMPERATURE, WATER (DEGREES CENTIGRADE)
                                                               94   SPECIFIC CONDUCTANCE, FIELD (UMHO/CM @ 25C)
                                                              341   CHEMICAL OXYGEN DEMAND, FILTERED (MG/L)
                                                              400   PH, FIELD (STANDARD UNITS)
                                                              631   NITRITE PLUS NITRATE, DIS. 1 DET. (MG/L AS N)
                                                              946   SULFATE, DISSOLVED (MG/L SO4)
                                                              950   FLUORIDE, DISSOLVED (MG/L F)
                                                             1000   ARSENIC, DISSOLVED (UG/L AS)
                                                             1005   BARIUM, DISSOLVED (UG/L BA)
                                                             1020   BORON, DISSOLVED (MG/L B)
                                                             1025   CADMIUM, DISSOLVED (UG/L CD)
                                                             1030   CHROMIUM, DISSOLVED (UG/L CR)
                                                             1040   COPPER, DISSOLVED (UG/L CU)
                                                             1049   LEAD, DISSOLVED (UG/L PB)
                                                             1056   MANGANESE, DISSOLVED (UG/L MN)
                                                             1075   SILVER, DISSOLVED (UG/L AG)
                                                             1090   ZINC, DISSOLVED (UG/L ZN)
                                                             1145   SELENIUM, DISSOLVED (UG/L SE)
                                                            22413   HARDNESS, TOTAL, FILTERED (MG/L AS CACO3)
                                                            39036   ALKALINITY, TOTAL FILTERED (MG/L AS CACO3)
                                                            71890   MERCURY, DISSOLVED (UG/L HG)
                                                            72020   ELEVATION, GROUNDWATER (FEET ABOVE MSL)
```

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R592R17C    04/06/2001              Environmental Mon    ring Summary                              Page:
                                  By Group Category Re   t Order Number

License Number:     4126    Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                            FID: 606043900     DNR Region:  West Central Region         County:  Buffalo

PLAN OF OPERATION APPROVAL

Group Category:  Private Well                        Group Description:   water supply
Group Number:  3     Group Name:  WATER SUPPLY WELL

   Common Name          DNR ID #                                      Schedule Number:   3
   -----------          --------   Sample Frequency:   Semi-Annual
   PW-01                      32   Sample Months:   J     F     M-Yes  A     M     J     J     A     S-Yes  O     N     D
   PW-02                      33                              Parameter
                                                              ---------
                                                                   1   COMMENT, SAMPLE ODOR
                                                                   2   COMMENT, SAMPLE COLOR
                                                                   3   COMMENT, SAMPLE TURBIDITY
                                                                  10   TEMPERATURE, WATER (DEGREES CENTIGRADE)
                                                                  94   SPECIFIC CONDUCTANCE, FIELD (UMHO/CM @ 25C)
                                                                 340   CHEMICAL OXYGEN DEMAND, UNFILTERED (MG/L)
                                                                 400   PH, FIELD (STANDARD UNITS)
                                                                 410   ALKALINITY, TOTAL (MG/L AS CACO3)
                                                                 900   HARDNESS, TOTAL (MG/L AS CACO3)
                                                                 945   SULFATE, TOTAL (MG/L SO4)
                                                                1022   BORON, TOTAL (MG/L B)
                                                                1147   SELENIUM, TOTAL (UG/L SE)
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License Number:     4126    Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                            FID: 606043900     DNR Region:  West Central Region        County: Buffalo

PLAN OF OPERATION APPROVAL

Group Category:  Leachate                     Group Description:   collection tank

Group Number:  4     Group Name:  LEACHATE COLLECTION TANK

  Common Name          DNR ID #
  -----------          --------    Sample Frequency:   Semi-Annual          Schedule Number:   4
  LEACHATE TANK          401       Sample Months:   J     F    M-Yes  A    M     J     J     A     S-Yes  O     N     D
                                                  Parameter
                                                  ---------
                                                       1   COMMENT, SAMPLE ODOR
                                                       2   COMMENT, SAMPLE COLOR
                                                       3   COMMENT, SAMPLE TURBIDITY
                                                      94   SPECIFIC CONDUCTANCE, FIELD (UMHO/CM @ 25C)
                                                     150   SOLIDS, TOTAL SUSPENDED (MG/L)
                                                     310   BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20DEG C)
                                                     340   CHEMICAL OXYGEN DEMAND, UNFILTERED (MG/L)
                                                     400   PH, FIELD (STANDARD UNITS)
                                                     410   ALKALINITY, TOTAL (MG/L AS CACO3)
                                                     900   HARDNESS, TOTAL (MG/L AS CACO3)
                                                     940   CHLORIDE, TOTAL OR DISSOLVED IN WTR SMPL (MG/L CL)
                                                     945   SULFATE, TOTAL (MG/L SO4)
                                                    1022   BORON, TOTAL (MG/L B)
                                                    1027   CADMIUM, TOTAL (UG/L CD)
                                                    1051   LEAD, TOTAL (UG/L PB)
                                                    1055   MANGANESE, TOTAL (UG/L MN)
                                                    1147   SELENIUM, TOTAL (UG/L SE)
                                                   71900   MERCURY, TOTAL (UG/L HG)
                                                   74010   IRON, TOTAL (MG/L FE)

                                   Sample Frequency:   Annual               Schedule Number:   5     ***** ACID / BASE Neutral Extractable *****
                                   Sample Months:   J     F     M     A     M     J     J     A     S-Yes  O     N     D
                                                  Parameter
                                                  ---------
```

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R592R17C     04/06/2001            Environmental Mon    ring Summary                                        Page:
                                  By Group Category R    rt Order Number

 License Number:      4126    Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                              FID: 606043900     DNR Region:  West Central Region        County: Buffalo

 PLAN OF OPERATION APPROVAL
                                              Group Description:   collection tank
Group Category:  Leachate
Group Number:  4     Group Name:  LEACHATE COLLECTION TANK               ***** GROUP CONTINUED FROM PREVIOUS PAGE *****

   Common Name          DNR ID #     Sample Frequency:    Monthly             Schedule Number:    6
   -----------          --------     Sample Months:    J-Yes  F-Yes  M-Yes  A-Yes  M-Yes  J-Yes  J-Yes  A-Yes  S-Yes  O-Yes  N-Yes  D-Yes
                                                   Parameter
                                                   ---------
                                                      32   LEACHATE, VOLUME PUMPED (1000 GALLONS)
```

Environmental Monitoring Summary
By Group Category Report Order Number

License Number: 4126 Facility: DAIRYLAND POWER COOP PHASE IV-BELVIDERE

FID: 606043900 DNR Region: West Central Region County: Buffalo

PLAN OF OPERATION APPROVAL

Group Category: Leachate Group Description: leachate head wells

Group Number: 5 Group Name: LEACHATE HEAD WELLS

Common Name	DNR ID #
LH-1	601
LH-2	604
LH-3	607
LH-4	610
LH-5	613
LH-6	616
LH-7	619
LH-8	622

Sample Frequency: Monthly Schedule Number: 7

Sample Months: J-Yes F-Yes M-Yes A-Yes M-Yes J-Yes J-Yes A-Yes S-Yes O-Yes N-Yes D-Yes

Parameter	
31	LEACHATE, DEPTH IN FEET
99423	ELEVATION, LEACHATE (FEET ABOVE MEAN SEA LEVEL)

Environmental Mon[illegible]ring Summary
By Group Category R[illegible]t Order Number

License Number: 4126 Facility: DAIRYLAND POWER COOP PHASE IV-BELVIDERE

FID: 606043900 DNR Region: West Central Region County: Buffalo

PLAN OF OPERATION APPROVAL

Group Category: Surface Water Group Description: sed pond outfalls

Group Number: 7 Group Name: OUTFALLS

Common Name	DNR ID #
OUTFALL 001	871
OUTFALL 002	872

Sample Frequency: Semi-Annual Schedule Number: 9

Sample Months: J F M-Yes A M J J A S-Yes O N D

Parameter	
3	COMMENT, SAMPLE TURBIDITY
10	TEMPERATURE, WATER (DEGREES CENTIGRADE)
94	SPECIFIC CONDUCTANCE, FIELD (UMHO/CM @ 25C)
340	CHEMICAL OXYGEN DEMAND, UNFILTERED (MG/L)
400	PH, FIELD (STANDARD UNITS)
410	ALKALINITY, TOTAL (MG/L AS CACO3)
900	HARDNESS, TOTAL (MG/L AS CACO3)
945	SULFATE, TOTAL (MG/L SO4)
1022	BORON, TOTAL (MG/L B)
1147	SELENIUM, TOTAL (UG/L SE)

```
License Number:      4126     Facility:  DAIRYLAND POWER COOP PHASE IV-BELVIDERE
                              FID: 606043900     DNR Region:  West Central Region        County: Buffalo
 PLAN OF OPERATION APPROVAL

Group Category:  Surface Water                    Group Description:   sed ponds
Group Number:   6     Group Name:   STAFF GAGES

   Common Name          DNR ID #
   -----------          --------    Sample Frequency:   Semi-Annual         Schedule Number:   8
   SG-1                    851      Sample Months:  J     F      M-Yes  A     M     J     J     A     S-Yes  O     N     D
   SG-2                    852                   Parameter
                                                 ---------
                                                  72020   ELEVATION, GROUNDWATER (FEET ABOVE MSL)
```

Appendix B
Beneficial Use Ash Characterization Data

2003 Dairyland Power Ash Products
- Coal Sources and Classifications

Ash	Sample Date	Composition	Wisconsin NR 538 Classification
Genoa Bottom Ash	2/26/03	Composite Mix	Category 3
Alma Bottom Ash	2/24/03	Composite Mix	Category 3
Genoa-3 Fly Ash	2/26/03	50% Rend Lake, IL 50% Antelope - Kenicot	Category 4
JPM Fly Ash	2/18/03	East Pit (Peabody) - Powder River Basin	Category 4
Alma 1-5 Fly Ash	2/18/03	High BTU - Prosperity (Indiana) Low BTU - Antelope	Category 4

2003 Total Elemental Analysis

Alma and Genoa Ash Products

Parameter	WI DNR Category 1 Limits (mg/kg)	WI DNR Category 2 Limits (mg/kg)	G-3 Bottom Ash (mg/kg)	Alma Bottom Ash (mg/kg)	G-3 Fly Ash (mg/kg)	JPM Fly Ash (mg/kg)	Alma 1-5 Fly Ash (mg/kg)	Analysis Date
Aluminum			39,800	47,500	54,800	80,300	33,500	4/14/03
Antimony	6.3		<2.3	<2.3	<2.5	<2.5	<2.5	4/29/03
Arsenic	0.042	21	32	38	230	60	110	4/30/03
Barium	1100		1,200	2,300	900	610	900	4/15/03
Beryllium		7	2.6	2.3	7.5	2.6	11	4/29/03
Boron	1400		200	220	1,200	580	1,200	4/29/03
Cadmium	7.8		1.3	1.2	2.8	2.5	2.1	4/15/03
Calcium			47,200	89,700	61,400	170,000	43,100	4/14/03
Chromium			26	21	76	47	52	4/15/03
Cobalt			15	14	28	22	23	4/29/03
Copper			27	53	80	130	52	4/15/03
Iron			27,700	30,700	58,300	39,700	51,400	4/14/03
Lead	50		21	9.1	170	30	50	4/15/03
Magnesium			9,400	15,500	12,400	33,200	8,500	4/14/03
Manganese			43	61	50	100	79	4/15/03
Mercury	4.7		<0.040	<0.040	0.35	<0.040	0.38	5/2/03
Molybdenum			<4.6	<4.6	11	<5.0	7.5	4/29/03
Nickel	310		28	21	68	29	73	4/15/03
Selenium			<0.14	0.13	1.2	3.7	1.8	4/30/03
Silver			<1.0	<1.0	<1.0	<1.0	<1.0	4/15/03
Sodium			3,500	5,300	4,000	10,700	2,700	4/14/03
Thallium	1.3		<0.14	<0.14	2.4	<0.15	2.3	5/1/03
Zinc	4700		46	35	170	81	96	4/15/03
% Solids			71.9%	76.6%	100.0%	100.0%	100.0%	4/3/03

*** Note** Values are reported on a dry weight basis

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Genoa Bottom Ash Composite**	Report Date:	5/7/03
Sampling Location:	Genoa, WI	Sample Type:	Bottom Ash
Collected By:	Tad Schwartzhoff	Date Collected:	2/26/03
Delivered By:	Tad Schwartzhoff	Date Received:	2/26/03

Parameter	Method	LOD	LOQ	Result	Units	Notes
Aluminum, Total	6010B	4.6	15	39,800	mg/kg, dry wt.	
Antimony, Total	6010B	2.3	7.7	<2.3	mg/kg, dry wt.	
Arsenic, Total	7060A	0.093	0.31	32	mg/kg, dry wt.	
Barium, Total	6010B	0.46	1.5	1,200	mg/kg, dry wt.	A
Beryllium, Total	6010B	0.046	0.15	2.6	mg/kg, dry wt.	
Boron, Total	6010B	1.2	4.0	200	mg/kg, dry wt.	
Cadmium, Total	6010B	0.23	0.77	1.3	mg/kg, dry wt.	A
Calcium, Total	6010B	46	153	47,200	mg/kg, dry wt.	
Chromium, Total	6010B	0.46	1.5	26	mg/kg, dry wt.	
Cobalt, Total	6010B	2.3	7.7	15	mg/kg, dry wt.	A
Copper, Total	6010B	0.93	3.1	27	mg/kg, dry wt.	
Iron, Total	6010B	1.2	4.0	27,700	mg/kg, dry wt.	
Lead, Total	6010B	2.3	7.7	21	mg/kg, dry wt.	A
Magnesium, Total	6010B	46	153	9,400	mg/kg, dry wt.	
Manganese, Total	6010B	0.46	1.5	43	mg/kg, dry wt.	
* Mercury, Total	7471A	0.040	0.13	<0.040	mg/kg, dry wt.	B
Molybdenum, Total	6010B	4.6	15	<4.6	mg/kg, dry wt.	A
Nickel, Total	6010B	0.93	3.1	28	mg/kg, dry wt.	A
Selenium, Total	7740	0.14	0.47	<0.14	mg/kg, dry wt.	A
Silver, Total	6010B	0.93	3.1	<1.0	mg/kg, dry wt.	
Sodium, Total	6010B	46	153	3,500	mg/kg, dry wt.	
Thallium, Total	7841	0.14	0.47	<0.14	mg/kg, dry wt.	
Zinc, Total	6010B	0.46	1.5	46	mg/kg, dry wt.	
% Solids		N/A	N/A	71.9	%	

= Results between LOD and LOQ

LOD = Limit of Detection

LOQ = Limit of Quantitation

A = Matrix Spike Recovery was outside of control limits

B = Matrix Duplicate recovery was outside of control limits

The laboratory analyses reported above were determined in accordance with approved EPA Methodology and the latest edition of STANDARD METHODS.

Dairyland Power Cooperative Chemical Services Laboratory is a Wisconsin Registered Testing Laboratory. Our Wisconsin Registration ID Number is 632023810.

* Mercury analysis was performed by Great Lakes Analytical of Buffalo Grove, IL.

Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND
Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Alma Bottom Ash Composite**	Report Date:	5/7/03
Sampling Location:	Alma, WI	Sample Type:	Bottom Ash
Collected By:	Ron Franz	Date Collected:	2/24/03
Delivered By:	Dave Lesky	Date Received:	2/25/03

Parameter	Method	LOD	LOQ	Result	Units	Notes
Aluminum, Total	6010B	4.6	15	47,500	mg/kg, dry wt.	
Antimony, Total	6010B	2.3	7.7	<2.3	mg/kg, dry wt.	
Arsenic, Total	7060A	0.093	0.31	38	mg/kg, dry wt.	
Barium, Total	6010B	0.46	1.5	2,300	mg/kg, dry wt.	A
Beryllium, Total	6010B	0.046	0.15	2.3	mg/kg, dry wt.	
Boron, Total	6010B	1.2	4.0	220	mg/kg, dry wt.	
Cadmium, Total	6010B	0.23	0.77	1.2	mg/kg, dry wt.	A
Calcium, Total	6010B	46	153	89,700	mg/kg, dry wt.	
Chromium, Total	6010B	0.46	1.5	21	mg/kg, dry wt.	
Cobalt, Total	6010B	2.3	7.7	14	mg/kg, dry wt.	A
Copper, Total	6010B	0.93	3.1	53	mg/kg, dry wt.	
Iron, Total	6010B	1.2	4.0	30,700	mg/kg, dry wt.	
Lead, Total	6010B	2.3	7.7	9.1	mg/kg, dry wt.	A
Magnesium, Total	6010B	46	153	15,500	mg/kg, dry wt.	
Manganese, Total	6010B	0.46	1.5	61	mg/kg, dry wt.	
* Mercury, Total	7471A	0.040	0.13	<0.040	mg/kg, dry wt.	B
Molybdenum, Total	6010B	4.6	15	<4.6	mg/kg, dry wt.	A
Nickel, Total	6010B	0.93	3.1	21	mg/kg, dry wt.	A
Selenium, Total	7740	0.14	0.5	0.13	mg/kg, dry wt.	A
Silver, Total	6010B	0.93	3.1	<1.0	mg/kg, dry wt.	
Sodium, Total	6010B	46	153	5,300	mg/kg, dry wt.	
Thallium, Total	7841	0.14	0.47	<0.14	mg/kg, dry wt.	
Zinc, Total	6010B	0.46	1.5	35	mg/kg, dry wt.	
% Solids		N/A	N/A	76.6	%	

= Results between LOD and LOQ

LOD = Limit of Detection

LOQ = Limit of Quantitation

A = Matrix Spike Recovery was outside of control limits

B = Matrix Duplicate recovery was outside of control limits

The laboratory analyses reported above were determined in accordance with approved EPA Methodology and the latest edition of STANDARD METHODS.

Dairyland Power Cooperative Chemical Services Laboratory is a Wisconsin Registered Testing Laboratory. Our Wisconsin Registration ID Number is 632023810.

* Mercury analysis was performed by Great Lakes Analytical of Buffalo Grove, IL.

Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Genoa- 3 Fly Ash**	Report Date:	5/7/03
Sampling Location:	Genoa, WI	Sample Type:	Fly Ash
Collected By:	Tad Schwartzhoff	Date Collected:	2/26/03
Delivered By:	Tad Schwartzhoff	Date Received:	2/26/03

Parameter	Method	LOD	LOQ	Result	Units	Notes
Aluminum, Total	6010B	5.0	17	54,800	mg/kg, dry wt.	
Antimony, Total	6010B	2.5	8.3	<2.5	mg/kg, dry wt.	
Arsenic, Total	7060A	0.10	0.33	230	mg/kg, dry wt.	
Barium, Total	6010B	0.50	1.7	900	mg/kg, dry wt.	A
Beryllium, Total	6010B	0.050	0.17	7.5	mg/kg, dry wt.	
Boron, Total	6010B	1.3	4.2	1,200	mg/kg, dry wt.	
Cadmium, Total	6010B	0.25	0.83	2.8	mg/kg, dry wt.	A
Calcium, Total	6010B	50	167	61,400	mg/kg, dry wt.	
Chromium, Total	6010B	0.50	1.7	76	mg/kg, dry wt.	
Cobalt, Total	6010B	2.5	8.3	28	mg/kg, dry wt.	A
Copper, Total	6010B	1.0	3.3	80	mg/kg, dry wt.	
Iron, Total	6010B	1.3	4.2	58,300	mg/kg, dry wt.	
Lead, Total	6010B	2.5	8.3	170	mg/kg, dry wt.	A
Magnesium, Total	6010B	50	167	12,400	mg/kg, dry wt.	
Manganese, Total	6010B	0.50	1.7	50	mg/kg, dry wt.	
* Mercury, Total	7471A	0.040	0.13	0.35	mg/kg, dry wt.	B
Molybdenum, Total	6010B	5.0	17	11	mg/kg, dry wt.	#, A
Nickel, Total	6010B	1.0	3.3	68	mg/kg, dry wt.	A
Selenium, Total	7740	0.15	0.5	1.2	mg/kg, dry wt.	A
Silver, Total	6010B	1.0	3.3	<1.0	mg/kg, dry wt.	
Sodium, Total	6010B	50	167	4,000	mg/kg, dry wt.	
Thallium, Total	7841	0.15	0.50	2.4	mg/kg, dry wt.	
Zinc, Total	6010B	0.50	1.7	170	mg/kg, dry wt.	
% Solids		N/A	N/A	100	%	

LOD = Limit of Detection

LOQ = Limit of Quantitation

= Results between LOD and LOQ

A = Matrix Spike Recovery was outside of control limits

B = Matrix Duplicate recovery was outside of control limits

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Dairyland Power Cooperative Chemical Services Laboratory is a Wisconsin Registered Testing Laboratory.
Our Wisconsin Registration ID Number is 632023810.
* Mercury analysis was performed by Great Lakes Analytical of Buffalo Grove, IL.

Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**JPM Fly Ash**	Report Date:	5/7/03
Sampling Location:	Alma, WI	Sample Type:	Fly Ash
Collected By:	Ron Franz	Date Collected:	2/18/03
Delivered By:	Dave Lesky	Date Received:	2/25/03

Parameter	Method	LOD	LOQ	Result	Units	Notes
Aluminum, Total	6010B	5.0	17	80,300	mg/kg, dry wt.	
Antimony, Total	6010B	2.5	8.3	<2.5	mg/kg, dry wt.	
Arsenic, Total	7060A	0.10	0.33	60	mg/kg, dry wt.	
Barium, Total	6010B	0.50	1.7	610	mg/kg, dry wt.	A
Beryllium, Total	6010B	0.050	0.17	2.6	mg/kg, dry wt.	
Boron, Total	6010B	1.3	4.2	580	mg/kg, dry wt.	
Cadmium, Total	6010B	0.25	0.83	2.5	mg/kg, dry wt.	A
Calcium, Total	6010B	50	167	170,000	mg/kg, dry wt.	
Chromium, Total	6010B	0.50	1.7	47	mg/kg, dry wt.	
Cobalt, Total	6010B	2.5	8.3	22	mg/kg, dry wt.	A
Copper, Total	6010B	1.0	3.3	130	mg/kg, dry wt.	
Iron, Total	6010B	1.3	4.2	39,700	mg/kg, dry wt.	
Lead, Total	6010B	2.5	8.3	30	mg/kg, dry wt.	A
Magnesium, Total	6010B	50	167	33,200	mg/kg, dry wt.	
Manganese, Total	6010B	0.50	1.7	100	mg/kg, dry wt.	
* Mercury, Total	7471A	0.040	0.13	<0.040	mg/kg, dry wt.	B
Molybdenum, Total	6010B	5.0	17	<5.0	mg/kg, dry wt.	A
Nickel, Total	6010B	1.0	3.3	29	mg/kg, dry wt.	A
Selenium, Total	7740	0.15	0.5	3.7	mg/kg, dry wt.	A
Silver, Total	6010B	1.0	3.3	<1.0	mg/kg, dry wt.	
Sodium, Total	6010B	50	167	10,700	mg/kg, dry wt.	
Thallium, Total	7841	0.15	0.50	<0.15	mg/kg, dry wt.	
Zinc, Total	6010B	0.50	1.7	81	mg/kg, dry wt.	
% Solids		N/A	N/A	100	%	

= Results between LOD and LOQ

LOD = Limit of Detection

LOQ = Limit of Quantitation

A = Matrix Spike Recovery was outside of control limits

B = Matrix Duplicate recovery was outside of control limits

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND
Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Alma 1-5 Fly Ash**	Report Date:	5/7/03
Sampling Location:	Alma, WI	Sample Type:	Fly Ash
Collected By:	Ron Franz	Date Collected:	2/18/03
Delivered By:	Dave Lesky	Date Received:	2/25/03

Parameter	Method	LOD	LOQ	Result	Units	Notes
Aluminum, Total	6010B	5.0	17	33,500	mg/kg, dry wt.	
Antimony, Total	6010B	2.5	8.3	<2.5	mg/kg, dry wt.	
Arsenic, Total	7060A	0.10	0.33	110	mg/kg, dry wt.	
Barium, Total	6010B	0.50	1.7	900	mg/kg, dry wt.	A
Beryllium, Total	6010B	0.050	0.17	11	mg/kg, dry wt.	
Boron, Total	6010B	1.3	4.2	1,200	mg/kg, dry wt.	
Cadmium, Total	6010B	0.25	0.83	2.1	mg/kg, dry wt.	A
Calcium, Total	6010B	50	167	43,100	mg/kg, dry wt.	
Chromium, Total	6010B	0.50	1.7	52	mg/kg, dry wt.	
Cobalt, Total	6010B	2.5	8.3	23	mg/kg, dry wt.	A
Copper, Total	6010B	1.0	3.3	52	mg/kg, dry wt.	
Iron, Total	6010B	1.3	4.2	51,400	mg/kg, dry wt.	
Lead, Total	6010B	2.5	8.3	50	mg/kg, dry wt.	A
Magnesium, Total	6010B	50	167	8,500	mg/kg, dry wt.	
Manganese, Total	6010B	0.50	1.7	79	mg/kg, dry wt.	
* Mercury, Total	7471A	0.040	0.13	0.38	mg/kg, dry wt.	B
Molybdenum, Total	6010B	5.0	17	8	mg/kg, dry wt.	A
Nickel, Total	6010B	1.0	3.3	73	mg/kg, dry wt.	A
Selenium, Total	7740	0.15	0.5	1.8	mg/kg, dry wt.	A
Silver, Total	6010B	1.0	3.3	<1.0	mg/kg, dry wt.	
Sodium, Total	6010B	50	167	2,700	mg/kg, dry wt.	
Thallium, Total	7841	0.15	0.50	2.3	mg/kg, dry wt.	
Zinc, Total	6010B	0.50	1.7	96	mg/kg, dry wt.	
% Solids		N/A	N/A	100	%	

LOD = Limit of Detection

LOQ = Limit of Quantitation

# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

2003 ASTM Water Leachate Analyses

Alma and Genoa Ash Products

Parameter	WI DNR Cat. 2 & 3 Limits (mg/L)	WI DNR Category 4 Limits (mg/L)	G-3 Bottom Ash ASTM (mg/L)	Alma Bottom Ash ASTM (mg/L)	G-3 Fly Ash ASTM (mg/L)	JPM Fly Ash ASTM (mg/L)	Alma 1-5 Fly Ash ASTM (mg/L)	Duplicate Alma 1-5 Fly Ash ASTM (mg/L)	Analysis Date	Analysis Method
Aluminum	15		3.7	8.5	51	56	33	32	4/28/03	6010B
Antimony	0.012		<0.005	<0.005	0.012	<0.005	<0.005	0.005	4/30/03	7041
Arsenic	0.050		0.0045	0.0056	0.095	0.044	0.047	0.037	4/30/03	7060A
Barium	4.0		0.20	0.30	1.7	33	1.2	1.4	4/28/03	6010B
Beryllium	0.004		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	4/28/03	6010B
Cadmium	0.005	0.025	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	4/28/03	6010B
Chromium	0.10	0.50	<0.010	<0.010	0.16	<0.010	0.23	0.25	4/28/03	6010B
Copper			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	4/28/03	6010B
Iron			<0.025	<0.025	0.048	0.066	<0.025	<0.025	4/28/03	6010B
Lead	0.015		<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	4/28/03	6010B
Manganese	0.25		0.010	<0.005	<0.005	<0.005	<0.005	<0.005	4/28/03	6010B
Mercury	0.002		<0.002	<0.002	<0.0002	<0.002	<0.0002	N/A	5/9/03	7470A
Nickel			<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	4/28/03	6010B
Selenium	0.10	0.25	<0.003	<0.003	0.067	<0.003	0.034	0.037	4/30/03	7740
Silver	0.10	0.25	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	4/28/03	6010B
Thallium	0.004		<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	5/1/03	7841
Zinc			<0.010	<0.010	<0.010	<0.010	<0.010	0.012	4/28/03	6010B
Sulfate (mg/L)	1250	2500	240	85	790	<1.0	410	330	5/1/03	375.4
pH			9.15	9.85	10.80	11.80	11.14	11.13	4/23/03	Hydrolab
Conductivity (uS)			540	300	1730	3730	1520	1360	4/23/03	Hydrolab
Total Dissolved Solids (mg/L)			0.35	0.19	1.11	2.39	0.97	0.87	4/23/03	Hydrolab
Sulfate (mg/L)	1250	2500								
Total Hardness (mg/L as CaCO3)			180	120	900	800	550	450	4/28/03	6010B

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Genoa Bottom Ash Composite**	Report Date:	5/6/03
Sampling Location:	Genoa, WI	Sample Type:	ASTM D3987-85 Leachate
Collected By:	Tad Schwartzhoff	Leach Date	4/23/03
Delivered By:	Tad Schwartzhoff	Date Collected:	2/26/03
		Date Received:	2/26/03

Parameter	Method	LOD	LOQ	Result	Category 2 Limit	Units	Notes
Aluminum	6010B	0.10	0.33	3.7	15	mg/L	
Antimony	7041	0.005	0.017	<0.005	0.012	mg/L	
Arsenic	7060A	0.002	0.007	0.0045	0.050	mg/L	#
Barium	6010B	0.010	0.033	0.20	4.0	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.004	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.005	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.10	mg/L	
Copper	6010B	0.010	0.033	<0.010	1.3	mg/L	
Iron	6010B	0.025	0.083	<0.025	1.5	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.015	mg/L	
Manganese	6010B	0.005	0.017	0.010	0.25	mg/L	#
*Mercury	7470A	0.002	0.0067	<0.002	0.002	mg/L	
Nickel	6010B	0.020	0.067	<0.020	0.20	mg/L	
Selenium	7740	0.003	0.010	<0.003	0.10	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.10	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.004	mg/L	
Zinc	6010B	0.010	0.033	<0.010	25	mg/L	
Sulfate	375.4	1.0	3.3	240	1250	mg/L	

LOD = Limit of Detection

LOQ = Limit of Quantitation

# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

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* Mercury analysis was performed by Great Lakes Analytical of Buffalo Grove, IL.

Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID: **Alma Bottom Ash Composite**
Report Date: 5/6/03

Sampling Location: Alma, WI
Collected By: Ron Franz
Delivered By: Dave Lesky

Sample Type: ASTM D3987-85 Leachate
Leach Date 4/23/03
Date Collected: 2/24/03
Date Received: 2/25/03

Parameter	Method	LOD	LOQ	Result	Category 2 Limit	Units	Notes
Aluminum	6010B	0.10	0.33	8.5	15	mg/L	
Antimony	7041	0.005	0.017	<0.005	0.012	mg/L	
Arsenic	7060A	0.002	0.007	0.0056	0.050	mg/L	#
Barium	6010B	0.010	0.033	0.30	4.0	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.004	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.005	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.10	mg/L	
Copper	6010B	0.010	0.033	<0.010	1.3	mg/L	
Iron	6010B	0.025	0.083	<0.025	1.5	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.015	mg/L	
Manganese	6010B	0.005	0.017	<0.005	0.25	mg/L	
*Mercury	7470A	0.002	0.0067	<0.002	0.002	mg/L	
Nickel	6010B	0.020	0.067	<0.020	0.20	mg/L	
Selenium	7740	0.003	0.010	<0.003	0.10	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.10	mg/L	
Thallium	7841	0.003	0.010	<0.003	1250	mg/L	
Zinc	6010B	0.010	0.033	<0.010	0.004	mg/L	
Sulfate	375.4	1.0	3.3	85	1250	mg/L	

LOD = Limit of Detection
LOQ = Limit of Quantitation
# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Genoa- 3 Fly Ash**	Report Date:	5/14/03
Sampling Location:	Genoa, WI	Sample Type:	ASTM D3987-85 Leachate
Collected By:	Tad Schwartzhoff	Leach Date	4/23/03
Delivered By:	Tad Schwartzhoff	Date Collected:	2/18/03
		Date Received:	2/25/03

Parameter	Method	LOD	LOQ	Result	Category 2 Limit	Units	Notes
Aluminum	6010B	0.10	0.33	51	15	mg/L	
Antimony	7041	0.005	0.017	0.012	0.012	mg/L	#
Arsenic	7060A	0.002	0.007	0.095	0.050	mg/L	
Barium	6010B	0.010	0.033	1.7	4.0	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.004	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.005	mg/L	
Chromium	6010B	0.010	0.033	0.16	0.10	mg/L	
Copper	6010B	0.010	0.033	<0.010	1.3	mg/L	
Iron	6010B	0.025	0.083	0.048	1.5	mg/L	#
Lead	6010B	0.015	0.050	<0.015	0.015	mg/L	
Manganese	6010B	0.005	0.017	<0.005	0.25	mg/L	
*Mercury	7470A	0.0002	0.0007	<0.0002	0.002	mg/L	
Nickel	6010B	0.020	0.067	<0.020	0.20	mg/L	
Selenium	7740	0.003	0.010	0.067	0.10	mg/L	#
Silver	6010B	0.010	0.033	<0.010	0.10	mg/L	
Thallium	7841	0.003	0.010	<0.003	1250	mg/L	
Zinc	6010B	0.010	0.033	<0.010	0.004	mg/L	
Sulfate	375.4	1.0	3.3	790	1250	mg/L	

LOD = Limit of Detection
LOQ = Limit of Quantitation
# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

DAIRYLAND Power
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID: **JPM Fly Ash**
Report Date: 5/6/03

Sampling Location: Alma, WI
Collected By: Ron Franz
Delivered By: Dave Lesky

Sample Type: ASTM D3987-85 Leachate
Leach Date 4/23/03
Date Collected: 2/18/03
Date Received: 2/25/03

Parameter	Method	LOD	LOQ	Result	Category 2 Limit	Units	Notes
Aluminum	6010B	0.10	0.33	56	15	mg/L	
Antimony	7041	0.005	0.017	<0.005	0.012	mg/L	
Arsenic	7060A	0.002	0.007	0.044	0.050	mg/L	
Barium	6010B	0.010	0.033	33	4.0	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.004	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.005	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.10	mg/L	
Copper	6010B	0.010	0.033	<0.010	1.3	mg/L	
Iron	6010B	0.025	0.083	0.066	1.5	mg/L	#
Lead	6010B	0.015	0.050	<0.015	0.015	mg/L	
Manganese	6010B	0.005	0.017	<0.005	0.25	mg/L	
*Mercury	7470A	0.002	0.0067	<0.002	0.002	mg/L	
Nickel	6010B	0.020	0.067	<0.020	0.20	mg/L	
Selenium	7740	0.003	0.010	<0.003	0.10	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.10	mg/L	
Thallium	7841	0.003	0.010	<0.003	1250	mg/L	
Zinc	6010B	0.010	0.033	<0.010	0.004	mg/L	
Sulfate	375.4	1.0	3.3	<1.0	1250	mg/L	

LOD = Limit of Detection
LOQ = Limit of Quantitation
# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
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Submitted by:

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DAIRYLAND POWER
COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Alma 1-5 Fly Ash**	Report Date:	5/14/03
Sampling Location:	Alma, WI	Sample Type:	ASTM D3987-85 Leachate
Collected By:	Ron Franz	Leach Date	4/23/03
Delivered By:	Dave Lesky	Date Collected:	2/18/03
		Date Received:	2/25/03

Parameter	Method	LOD	LOQ	Result	Category 2 Limit	Units	Notes
Aluminum	6010B	0.10	0.33	33	15	mg/L	
Antimony	7041	0.005	0.017	<0.005	0.012	mg/L	
Arsenic	7060A	0.002	0.007	0.047	0.050	mg/L	
Barium	6010B	0.010	0.033	1.2	4.0	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.004	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.005	mg/L	
Chromium	6010B	0.010	0.033	0.23	0.10	mg/L	
Copper	6010B	0.010	0.033	<0.010	1.3	mg/L	
Iron	6010B	0.025	0.083	<0.025	1.5	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.015	mg/L	
Manganese	6010B	0.005	0.017	<0.005	0.25	mg/L	
*Mercury	7470A	0.0002	0.0007	<0.0002	0.002	mg/L	
Nickel	6010B	0.020	0.067	<0.020	0.20	mg/L	
Selenium	7740	0.003	0.010	0.034	0.10	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.10	mg/L	
Thallium	7841	0.003	0.010	<0.003	1250	mg/L	
Zinc	6010B	0.010	0.033	<0.010	0.004	mg/L	
Sulfate	375.4	1.0	3.3	410	1250	mg/L	

LOD = Limit of Detection

LOQ = Limit of Quantitation

# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

2003 EPA Method 1312 (Synthetic) Leachate Analyses

Alma and Genoa Ash Products

Parameter	MPCA Regulatory Limit (mg/L)	G-3 Bottom Ash 1312 (mg/L)	Alma Bottom Ash 1312 (mg/L)	G-3 Fly Ash 1312 (mg/L)	JPM Fly Ash 1312 (mg/L)	JPM Fly Ash Dup. 1312 (mg/L)	Alma 1-5 Fly Ash 1312 (mg/L)	Analysis Date
Antimony	0.060	<0.005	<0.005	0.013	<0.005	<0.005	<0.005	4/30/03
Arsenic	0.50	0.0045	0.0046	0.065	0.038	0.042	0.045	4/30/03
Barium	7.6	0.21	0.29	1.8	40	40	1.3	4/28/03
Beryllium	0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	4/28/03
Boron	6.0	0.60	1.0	14	3.3	3.1	19	4/28/03
Cadmium	0.040	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	4/28/03
Chromium	0.33	<0.010	<0.010	0.17	<0.010	<0.010	0.24	4/28/03
Copper	10	<0.010	<0.010	0.024	<0.010	<0.010	<0.010	4/28/03
Iron	3.0	<0.025	<0.025	<0.025	0.027	0.031	<0.025	4/28/03
Lead	0.15	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	4/28/03
Manganese	1.0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	4/28/03
Nickel	1.0	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	4/28/03
Selenium	0.16	0.003	<0.003	0.066	<0.003	<0.003	0.036	4/30/03
Silver	0.30	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	4/28/03
Thallium	0.006	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	5/1/03
Zinc	20	0.012	0.011	0.024	0.028	0.012	<0.010	4/28/03
Sulfate	2,500	240	85	790	<1.0	N/A	410	5/1/03
Mercury	0.009	<0.002	<0.002	<0.002	<0.002	N/A	<0.002	5/2/03
pH	N/A	9.20	9.85	10.97	11.90	11.92	11.2	4/22/03
Conductivity (uS)	N/A	525	280	1750	4080	4060	1510	4/22/03
Total Dissolved Solids (mg/L)	N/A	0.34	0.18	1.1	2.6	2.6	1.0	4/22/03
Total Hardness (mg/L as CaCO3)	N/A	180	120	850	900	870	550	4/28/03
Calcium	N/A	67	48	340	360	350	220	4/28/03
Magnesium	N/A	3.8	<1.0	<1.0	<1.0	<1.0	<1.0	4/28/03

DAIRYLAND Power
COOPERATIVE - LACROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID: **Genoa Bottom Ash Composite** Report Date: 5/6/03

Sampling Location: Genoa, WI
Collected By: Tad Schwartzhoff
Delivered By: Tad Schwartzhoff

Sample Type: EPA 1312 SPLP Leachate
Leach Date 4/22/03
Date Collected: 2/26/03
Date Received: 2/26/03

Parameter	**Method**	**LOD**	**LOQ**	**Result**	**MPCA Limit**	**Units**	**Notes**
Antimony	7041	0.005	0.017	<0.005	0.060	mg/L	
Arsenic	7060A	0.002	0.007	0.0045	0.50	mg/L	#
Barium	6010B	0.010	0.033	0.21	7.6	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.0008	mg/L	
Boron	6010B	0.025	0.083	0.6	6.0	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.040	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.33	mg/L	
Copper	6010B	0.010	0.033	<0.010	10	mg/L	
Iron	6010B	0.025	0.083	<0.025	3.0	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.15	mg/L	
Manganese	6010B	0.005	0.017	<0.005	1.0	mg/L	
Nickel	6010B	0.020	0.067	<0.020	1.0	mg/L	
Selenium	7740	0.003	0.010	0.003	0.16	mg/L	#
Silver	6010B	0.010	0.033	<0.010	0.30	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.006	mg/L	
Zinc	6010B	0.010	0.033	0.012	20	mg/L	#
Sulfate	375.4	1.0	3.3	240	2,500	mg/L	
* Mercury	7470A	0.002	0.007	<0.002	0.009	mg/L	

LOD = Limit of Detection

LOQ = Limit of Quantitation

# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

The laboratory analyses reported above were determined in accordance with approved EPA Methodology and the latest edition of STANDARD METHODS.

Dairyland Power Cooperative Chemical Services Laboratory is a Wisconsin Registered Testing Laboratory.
Our Wisconsin Registration ID Number is 632023810.
* Mercury analysis was performed by Great Lakes Analytical of Buffalo Grove, IL.

Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

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3251 East Ave. South
La Crosse, WI 54601
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Chemical Analysis Report Form

Sample ID: **Alma Bottom Ash Composite** Report Date: 5/6/03

Sampling Location: Alma, WI
Collected By: Ron Franz
Delivered By: Dave Lesky

Sample Type: EPA 1312 SPLP Leachate
Leach Date 4/22/03
Date Collected: 2/24/03
Date Received: 2/25/03

Parameter	Method	LOD	LOQ	Result	MPCA Limit	Units	Notes
Antimony	7041	0.005	0.017	<0.005	0.060	mg/L	
Arsenic	7060A	0.002	0.007	0.0046	0.50	mg/L	#
Barium	6010B	0.010	0.033	0.29	7.6	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.0008	mg/L	
Boron	6010B	0.025	0.083	1.0	6.0	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.040	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.33	mg/L	
Copper	6010B	0.010	0.033	<0.010	10	mg/L	
Iron	6010B	0.025	0.083	<0.025	3.0	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.15	mg/L	
Manganese	6010B	0.005	0.017	<0.005	1.0	mg/L	
Nickel	6010B	0.020	0.067	<0.020	1.0	mg/L	
Selenium	7740	0.003	0.010	<0.003	0.16	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.30	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.006	mg/L	
Zinc	6010B	0.010	0.033	0.011	20	mg/L	#
Sulfate	375.4	1.0	3.3	85	2,500	mg/L	
* Mercury	7470A	0.002	0.007	<0.002	0.009	mg/L	

LOD = Limit of Detection
LOQ = Limit of Quantitation
# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
B = Matrix Duplicate recovery was outside of control limits

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

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COOPERATIVE - LA CROSSE, WISCONSIN

Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID:	**Genoa- 3 Fly Ash**	Report Date:	5/6/03
Sampling Location:	Genoa, WI	Sample Type:	EPA 1312 SPLP Leachate
Collected By:	Tad Schwartzhoff	Leach Date	4/22/03
Delivered By:	Tad Schwartzhoff	Date Collected:	2/26/03
		Date Received:	2/26/03

Parameter	**Method**	**LOD**	**LOQ**	**Result**	**MPCA Limit**	**Units**	**Notes**
Antimony	7041	0.005	0.017	0.013	0.060	mg/L	#
Arsenic	7060A	0.002	0.007	0.065	0.50	mg/L	
Barium	6010B	0.010	0.033	1.8	7.6	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.0008	mg/L	
Boron	6010B	0.025	0.083	14	6.0	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.040	mg/L	
Chromium	6010B	0.010	0.033	0.17	0.33	mg/L	
Copper	6010B	0.010	0.033	0.024	10	mg/L	#
Iron	6010B	0.025	0.083	<0.025	3.0	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.15	mg/L	
Manganese	6010B	0.005	0.017	<0.005	1.0	mg/L	
Nickel	6010B	0.020	0.067	<0.020	1.0	mg/L	
Selenium	7740	0.003	0.010	0.066	0.16	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.30	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.006	mg/L	
Zinc	6010B	0.010	0.033	0.024	20	mg/L	#
Sulfate	375.4	1.0	3.3	790	2,500	mg/L	
* Mercury	7470A	0.002	0.007	<0.002	0.009	mg/L	

LOD = Limit of Detection
LOQ = Limit of Quantitation
# = Results between LOD and LOQ
A = Matrix Spike Recovery was outside of control limits
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Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
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Chemical Analysis Report Form

Sample ID: **JPM Fly Ash**
Report Date: 5/6/03

Sampling Location: Alma, WI
Collected By: Ron Franz
Delivered By: Dave Lesky

Sample Type: EPA 1312 SPLP Leachate
Leach Date 4/22/03
Date Collected: 2/18/03
Date Received: 2/25/03

Parameter	Method	LOD	LOQ	Result	MPCA Limit	Units	Notes
Antimony	7041	0.005	0.017	<0.005	0.060	mg/L	
Arsenic	7060A	0.002	0.007	0.038	0.50	mg/L	
Barium	6010B	0.010	0.033	40	7.6	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.0008	mg/L	
Boron	6010B	0.025	0.083	3.3	6.0	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.040	mg/L	
Chromium	6010B	0.010	0.033	<0.010	0.33	mg/L	
Copper	6010B	0.010	0.033	<0.010	10	mg/L	
Iron	6010B	0.025	0.083	0.027	3.0	mg/L	#
Lead	6010B	0.015	0.050	<0.015	0.15	mg/L	
Manganese	6010B	0.005	0.017	<0.005	1.0	mg/L	
Nickel	6010B	0.020	0.067	<0.020	1.0	mg/L	
Selenium	7740	0.003	0.010	<0.003	0.16	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.30	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.006	mg/L	
Zinc	6010B	0.010	0.033	0.028	20	mg/L	#
Sulfate	375.4	1.0	3.3	<1.0	2,500	mg/L	
* Mercury	7470A	0.002	0.007	<0.002	0.009	mg/L	

LOD = Limit of Detection

LOQ = Limit of Quantitation

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Chemical Services Laboratory
3251 East Ave. South
La Crosse, WI 54601
(608)788-4000

Chemical Analysis Report Form

Sample ID: **Alma 1-5 Fly Ash**
Report Date: 5/6/03

Sampling Location: Alma, WI
Collected By: Ron Franz
Delivered By: Dave Lesky

Sample Type: EPA 1312 SPLP Leachate
Leach Date 4/22/03
Date Collected: 2/18/03
Date Received: 2/25/03

Parameter	**Method**	**LOD**	**LOQ**	**Result**	**MPCA Limit**	**Units**	**Notes**
Antimony	7041	0.005	0.017	<0.005	0.060	mg/L	
Arsenic	7060A	0.002	0.007	0.045	0.50	mg/L	
Barium	6010B	0.010	0.033	1.3	7.6	mg/L	
Beryllium	6010B	0.0005	0.002	<0.0005	0.0008	mg/L	
Boron	6010B	0.025	0.083	19	6.0	mg/L	
Cadmium	6010B	0.005	0.017	<0.005	0.040	mg/L	
Chromium	6010B	0.010	0.033	0.24	0.33	mg/L	
Copper	6010B	0.010	0.033	<0.010	10	mg/L	
Iron	6010B	0.025	0.083	<0.025	3.0	mg/L	
Lead	6010B	0.015	0.050	<0.015	0.15	mg/L	
Manganese	6010B	0.005	0.017	<0.005	1.0	mg/L	
Nickel	6010B	0.020	0.067	<0.020	1.0	mg/L	
Selenium	7740	0.003	0.010	0.036	0.16	mg/L	
Silver	6010B	0.010	0.033	<0.010	0.30	mg/L	
Thallium	7841	0.003	0.010	<0.003	0.006	mg/L	
Zinc	6010B	0.010	0.033	<0.010	20	mg/L	
Sulfate	375.4	1.0	3.3	410	2,500	mg/L	
* Mercury	7470A	0.002	0.007	<0.002	0.009	mg/L	

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Submitted by:

Dairyland Power Cooperative Chemical Services Laboratory

Tad Schwartzhoff, Analytical Chemist II.

Appendix C
Select Previous DPC Ash Studies

Table of Contents

Executive Summary and Report. Fly Ash Characterization Study Alma Madgett Generating Station Units 1-6. Dairyland Power Cooperative Alma, Wisconsin. October 1979. Prepared by Warzyn Engineering, Inc.

EXECUTIVE SUMMARY

FLY ASH CHARACTERIZATION STUDY
ALMA MADGETT GENERATING STATION UNITS 1-6
DAIRYLAND POWER COOPERATIVE
ALMA, WISCONSIN

C 8181

EXECUTIVE SUMMARY

FLY ASH CHARACTERIZATION STUDY
ALMA/MADGETT GENERATING STATION
UNITS 1-6
DAIRYLAND POWER COOPERATIVE
ALMA, WISCONSIN

INTRODUCTION AND SCOPE

The purpose of this study was to investigate the physical and chemical properties of the Dairyland Power Cooperative Alma/Madgett Generating Station Units 1 through 6 fly ashes as they relate to disposal site operations and licensing. The electrical generating capacity of existing Alma Units 1-5 (209 megawatts) is being supplemented with the construction of Unit No. 6 (350 megawatts) for a total generating capacity of 559 megawatts. The ash disposal requirement for the Alma Units 1-6 between the years 1979 and 2015 is projected to range from 60,000 tons to 147,000 tons per year.

Since the Alma Unit No. 6 is not yet operational, samples representative of Unit 6 were obtained from the Lansing Generating Station Unit #4, Lansing, Iowa which burns the same coal type (Wyoming sub-bituminous Belle Ayr-AMAX Coal Company) in the same boiler type (dry bottom pulverized fuel fired) as that proposed at Alma No. 6. Alma Units 1-5 burn a mixture of Illinois-Kentucky bituminous and Montana sub-bituminous coals in dry bottom pulverized fuel fired furnaces. Samples representative of existing Alma Units 1-5 were collected over an extended period from the fly ash precipitator hoppers. Fly ash from Alma Units 1-5 were collectively evaluated as a single ash source.

This study also included physical and chemical tests on a mixture of the Lansing Unit 4 and Alma Units 1-5 fly ashes in a 60/40 percent ratio, the anticipated respective ash production ratio, to examine the characteristics of the waste material if blending and co-disposal of the fly ashes is deemed necessary.

FLY ASH COMPOSITION

Analyses of the Alma Units 1-5 and Lansing Unit 4 fly ashes indicate the following bulk composition:

Parameter	Alma #1-5	Lansing #4
Silica, SiO_2	46.20%	30.91%
Alumina, Al_2O_3	19.89	17.36
Titania, TiO_2	0.81	1.52
Ferric Oxide, Fe_2O_3	18.65	6.41
Calcium Oxide, CaO	6.93	30.09
Magnesium Oxide, MgO	1.54	5.11
Potassium Oxide, K_2O	1.95	0.36
Sodium Oxide, Na_2O	1.12	2.22
Sulfur Trioxide, SO_3	2.08	4.27
Phos. Pentoxide, P_2O_5	0.28	0.69
Strontium Oxide, SrO	0.00	0.23
Barium Oxide, BaO	0.15	0.72
Undetermined	0.40	0.11

Values reported as %, ignited basis.

A major distinction between the two fly ashes is the high calcium content in the Lansing Unit 4 ash. When water is added to the fly ash, calcium combines with silica, alumina and sulfate to form stable minerals having cementitious qualities. Calcium is a key ingredient contributing to the Lansing Unit 4 pozzolanic activity and resulting hardening properties. The lower calcium content of the Alma Units 1-5 ash is responsible for the lower overall strengths.

Since coal is generally a heterogeneous material containing a wide variety of minerals, elements become concentrated in the fly ash residue after combustion of the organic material. Trace metals in the coal will also be present in the fly ash. Inorganic mass spectrophotometric analysis for trace metal distribution indicates there are generally few elements absent in the Alma Nos. 1-5 and Lansing No. 4 fly ashes. Moreover, the concentrations of trace elements present were very similar among fly ashes tested. Although the coal sources for the different units are quite different, few trace elements show significant concentration differences between the fly ashes.

The discussion to follow summarizes the physical characteristics and the chemical leaching properties of the Alma Units 1-5 and Lansing Unit 4 fly ashes as received by Warzyn Engineering Inc. For brevity the term 60/40 is used to describe a mix of 60 percent Lansing No. 4 and 40 percent Alma Nos. 1-5 fly ashes. Also the terms Alma No. 6 and Lansing No. 4 are used interchangeably.

PHYSICAL PROPERTIES

Proctor Compaction

The moistened fly ash can be compacted by Modified Proctor methods. The maximum densities that may be attained are as follows: The Alma Units 1-5 fly ash has a maximum density of 93 lbs./cu.ft. at a moisture content of 21 percent. A density of 119.7 lbs./cu.ft. at 11 percent moisture was determined for the Lansing Unit 4 fly ash. The 60/40 mixture has a maximum density of 109 lbs./cu.ft. at 15 percent moisture.

Dry, uncompacted weights were also obtained. The Alma Unit 1-5 fly ash has an approximate weight of 59 lbs./cu.ft., the Lansing Unit 4 fly ash has an approximate weight of 69 lbs./cu.ft., and the 60/40 mixture is 63 lbs./cu.ft.

Tests were also performed on fly ash that had been allowed to set after the addition of optimum moisture. It was found that Lansing Unit 4 had a maximum density of 102 lbs./cu.ft. at 18 percent moisture and the 60/40 mixture had a 98 lb./cu.ft. maximum density at 23 percent moisture.

Setting Properties

Setting tests were performed on the Alma Unit 1-5 and Lansing Unit 4 fly ashes and on the 60/40 mixture. Two approaches to the test for setting were used. In the first approach 2 inch compression test cubes were broken and in the second approach pocket penetrometer readings were taken on slurry mixes.

The Alma Unit 1-5 fly ash in both procedures failed to produce setting. The cubes did not hold their shape and the slurries did not set. The addition of lime caused a very slow setting, not noticeable within six hours of test.

The Lansing Unit 4 fly ash cube strengths increased rapidly to 2300 PSI at 3 hours with further increases to 3200 PSI after 36 hours. The time and rate at which the various slurries obtained a 4.5 TSF reading on the penetrometer varied considerably. At 20 percent moisture the reading increased rapidly from the initial addition of water to a 4.5 TSF reading in 6 minutes. At 50 percent moisture, the 4.5 TSF reading was not reached until 18 minutes after the water addition. At 30 and 40 percent moistures, the set was zero for approximately 6 minutes, then it quickly increased to 4.5 TSF at approximately 10 minutes. Temperature readings were taken on the compacted and slurry mixes. Ten minutes after the addition of water to the fly ash the highest temperature measured was 57° C at 14 percent moisture.

The 60/40 mixture of fly ash cubes had rapid strength increases to 1100 PSI at 3 hours and further increases to 1350 PSI after 36 hours. The 4.5 TSF penetrometer reading was variable as in the Lansing Unit 4 slurry. The 20 percent moisture slurry attained the 4.5 TSF reading in 7 minutes. At 50 percent moisture, the 4.5 TSF reading was not reached until 32 minutes after the water addition.

Pocket penetrometer readings were taken on uncompacted Lansing Unit 4 and the 60/40 mixture fly ash and they were found not to set up without the compaction. The fly ashes were prepared at the optimum moisture contents and observed for several hours.

Specific Gravity

The specific gravities, by a modified soil test procedure, are 2.47 for Alma Units 1-5 fly ash, 2.54 for Lansing Unit 4 fly ash, and 2.63 for the 60/40 mixture.

Permeability

A permeability test was performed on a compacted Lansing Unit #4 fly ash sample at 94 percent of the Modified Proctor density. This is typical for compacted soils. The hydraulic conductivity, as determined in the falling head permeameter, is 4 to 5 x 10^{-9} cm./sec. Permeability tests were also performed on the Alma 1-5 fly ash. One test was at 97 percent and one at 100 percent of the maximum density. The results verified that the Unit 1-5 fly ash is more permeable; the 97 percent compaction test having a hydraulic conductivity of 6 to 7 x 10^{-6} cm./sec. and the 100 percent compaction permeability of 3 to 4 x 10^{-6} cm./sec. The results of the permeability test for the 60/40 mixture of fly ash are 3 to 5 x 10^{-9} cm./sec. at 100 percent compaction and 1 to 3 x 10^{-8} cm./sec. at 92 percent compaction.

Strength Characteristics

Unconfined compressive strength tests were performed under two conditions. One method was on compacted samples and the other on fly ash and water mixtures of slurry consistency, which then set up.

Only one test was performed on the Alma Units 1-5 fly ash. This was a compacted sample at maximum density which yielded a seven day strength of 175 PSI. Other test samples of this fly ash were not stable enough to test. A sample prepared with 5 percent lime and compacted at 21 percent moisture had a seven day strength of 550 PSI.

The Lansing Unit 4 results varied from 1500 PSI to 5000 PSI for seven day compacted material. The highest strength was at the same moisture content that produced the maximum density. The 5000 PSI strength is comparable to a high-early strength concrete. The 28 day strength tests on compacted material had a maximum of 1900 PSI at a moisture content of near that which produced the maximum density. A slurry was obtained at a moisture content greater than 20 percent by weight of dry fly ash. At seven days a cylinder of each moisture content (25, 30, 40, 50 and 60 percent) was broken in compression. The range of strengths was from 1120 PSI to 3210 PSI, with the maximum strength at a moisture content of 30 percent. The maximum 28 day unconfined strength tests on the Lansing Unit 4 fly ash slurry was 3100 PSI at 40 percent moisture.

The 60/40 mixture of fly ash also had the strength tests performed. The maximum for the compacted material was 1150 PSI at 19 percent moisture at seven days and 1290 PSI at 15 percent moisture at 28 days. The results on the slurry samples had a maximum of 1340 PSI for seven days and 1918 PSI for 28 days with both having 30 percent moisture.

Grain Size

The grain size of the Lansing Unit 4 fly ash is very uniform at a grain size diameter of 0.02 millimeter. This is in the silt category according to ASTM D2487. The grain size of the fly ash from Alma Units 1-5 is predominantly silt with some clay and a trace of sand size particles.

Erosion Resistance Tests

A series of tests were performed to determine the physical durability of the fly ash materials to erosion and to gather data on the quality of the resulting runoff. The erosion tests were conducted in several stages of increasing water velocities and volumes ranging from a light water misting to simulation of high impact rainfall using an inverted lawn sprinkler.

The erosion tests indicate that the Alma 1-5, Lansing 4 and the 60/40 ash mixture of Lansing 4/Alma 1-5 were similar under relatively mild water application velocities using fertilizer sprayers and an open 3/4" diameter hose. Typical erosion rates were on the order of 10^{-3} to 10^{-4} tons per acre per inch of water applied.

Differences between the fly ashes became apparent under more rigorous testing using an inverted lawn sprinkler at maximum pressure. The Alma 1-5 ash showed significant erosion in the areas impacted by the water stream producing depressions of 1/4" to 3/4" deep. The durability of the Lansing 4 ash was considerably better due to its superior hardening characteristics compared to the Alma 1-5 fly ash. Some horizontal cracking and separation of the Lansing #4 ash was noted between layers of the compacted ash and erosion occurred where the force of the water broke up these thinner horizontal layers. The 60/40 ash mixture of Lansing #4/Alma #1-5 was considered the most durable to erosion and exhibited minimal breakdown under water applications substantially more severe than that subjected to the individual ashes. All of the fly ashes and ash mixtures tested appeared to be substantially more resistant to erosion than would be anticipated from a natural soil of comparable grain distribution.

Miscellaneous Tests

Dust control tests were performed to obtain an idea of the moisture required to control problems with vehicle loading and surface winds. A 3 percent moisture content appears to be satisfactory for control of dust during vehicle loading and a 15 percent moisture content appears necessary to keep a 22 miles per hour wind from blowing dust from the surface of a landfill site.

A standard grout consistency funnel was used to determine fluidity period of slurry consistency mixes.

Setting of slurries is practically non-existent for periods needed for pumping transport of approximately 30 minutes. After 30 minutes, setting takes place quite rapidly. The minimum moisture condition necessary for this condition is: 60 percent for Lansing No. 4 and also for Alma Nos. 1-5, and 70 percent for the 60/40 mix.

The workability of all the fly ashes varies with the moisture content. Up to 15 percent moisture the fly ash should be satisfactory for working with standard earth-moving equipment. A moisture condition between 20 and 60 percent may be more difficult to handle due to a paste consistency which develops. Above 60 percent the fly ash appears to be in the pumpable category.

Upon observing all phases of testing, there appears to be a slight condition of efflorescence at all moisture contents for all fly ashes tested.

Freezing temperatures following the addition of 10-20 percent water to the 60/40 mixture does not appear to preclude setting.

CHEMICAL TESTS

Various tests were performed for the purpose of assessing the characteristics of leachates derived from the Alma Generating Station waste materials. Leachates were generated from the fly ash samples by both the shake-flask and column leaching methods.

Shake Flask Tests

The shake flask test procedure involved the rigorous stirring of 100 grams of fly ash with 1 liter of distilled water for a period of 48 hours. Following filtration, the leachates were analyzed for 33 parameters.

Principal cationic species in the Lansing Unit 4 fly ash leachate were calcium, sodium, and strontium in concentrations up to 500 mg/l. Curing of the fly ash for one week at optimum moisture prior to testing appeared to shift the major anionic forms from carbonate and bicarbonate to hydroxide and carbonate ions. The involvement of calcium in the hardening reactions also appears to reduce the leaching of this element from the cured fly ash which in turn also reduces the leachate pH.

The shake flask leachate characteristics of Alma 1-5 fly ash are somewhat different from the Lansing Unit 4. Total dissolved solids, indicated by specific conductance, were about 1/3 of that observed in the Lansing Unit 4 fly ash. Sulfate, which was virtually absent in the Lansing Unit 4 ash leachate, is a major anionic species in the Alma 1-5 leachate at concentrations up to 620 mg/l. The Alma Units 1-5 leachate also shows significantly lower strontium concentrations than were observed in the Lansing Unit 4 leachate.

The shake flask tests performed on a 60/40 mixture of Lansing No. 4/Alma No. 1-5 fly ashes results in a leachate which is more similar to the Lansing No. 4 than the Alma No. 1-5. Relatively few parameters were "well-behaved", leaching from the mixed ash sample in the same proportions as those observed in the individual unmixed ash leachates. A significant effect of mixing the fly ashes is the reduction of sulfate leaching from the Alma No. 1-5 fly ash.

Trace metals were generally absent in the shake flask leachates at the detection limits utilized. Barium, mercury and selenium were trace metals typically detected and at concentrations exceeding the drinking water standards.

Column Tests

Column leaching tests were performed on 1' to 4' thicknesses of Lansing No. 4, Alma Nos. 1-5 and a 60/40 fly ash mixture (Lansing #4/Alma Nos. 1-5) in 5 1/2" diameter plexiglass columns. The fly ash was compacted in the columns in 2" to 3" lifts at slightly above optimum moisture and allowed to cure for one week before testing began. A total of 6 columns were constructed in which a head of deionized water was maintained over the waste material and the column effluents analyzed for up to 33 parameters.

Due to the extremely low permeability of the Lansing Unit 4 fly ash (10^{-9} cm./sec.) no leaching data is available from the columns containing 1' and 2' thicknesses of this ash. Visual observations indicate that moisture had percolated through the Lansing Unit 4 fly ash to a depth of approximately 4" to 6" below the surface. No leachate has been produced from these columns since testing began in late May and early June, 1979.

Alma Units 1-5 Fly Ash

Three columns containing Alma Units 1-5 fly ash in thicknesses ranging from 1' to 4' were tested. Leachate samples were collected representing a maximum of 41 pore volume displacements to evaluate long term leaching characteristics of Alma Units 1-5 ash.

Major constituents of the Alma Units 1-5 column leachates include sodium and potassium sulfates, hydroxides, and carbonates. In general, order of magnitude concentration decreases are typical within the first five pore volume displacements with gradual decreases thereafter. As high sodium and potassium concentrations decline, increases in calcium and strontium occur and contribute to a significant percentage of the cations present. The availability of sulfate and, to a lesser extent, chloride anions appear to be controlling factors in the leaching process.

The maximum concentrations of each element observed in the leachate from the three Alma Units 1-5 columns do not increase with increasing fly ash thickness. An equilibrium appears to be developed in the fly ash leachate after infiltrating relatively short thicknesses through the waste material. Although the equilibrium developed appears to limit the maximum concentrations of each element observed in the leachate, the thickness of the waste material governs the duration for which these maximum concentrations are found.

Leaching of elements from the Alma Units 1-5 fly ash does not occur in proportion to their availability. Those parameters which comprise the bulk of the ash composition leach in the greatest concentrations but at the smallest percentages compared to the total amounts of these elements available in the column. Trace metal leaching is generally discouraged due to the high pH of the leachates except for those elements which form soluble hydroxides. Arsenic, chromium, nitrate, selenium and sulfate typically exceeded drinking water standards within the first several pore volume displacements.

Runoff Quality

Surface water runoff samples were collected at regular intervals in conjunction with the physical testing for erodability of the various fly ashes. The runoff water was recirculated over a 3 square foot surface area of fly ash to evaluate the quality of the resulting runoff water after lengthy exposure to the fly ash.

The analysis of the runoff leachates for the Lansing Unit 4, Alma Units 1-5 and the 60/40 ash mixture indicate that sodium and potassium sulfates, carbonates and bicarbonates were major constituents of the leachate for all three fly ashes tested. Compared to the shake flask leaching tests, major cations remained the same while anions shifted from predominantly hydroxide and carbonates in the shake flask tests to carbonates and bicarbonates in the runoff water.

While sulfate anions were insignificant in the shake flask tests for the Lansing No. 4 ash and the 60/40 ash mixture, sulfate was a major constituent of all runoff leachates. The migration (efflorescence) of sodium sulfate to the fly ash surface after exposure to the atmosphere for several days is a major factor in the leaching of these ions.

In general, trace metals were below detection limits or drinking water standards after lengthy recirculation simulating more than 300 ft. of exposure to the fly ash surface. Parameters which exceeded the EPA drinking water standards were chromium for Alma Units 1-5, arsenic, fluoride, selenium and sulfate for the Lansing Unit 4 ash and chromium and selenium for the 60/40 ash mixture.

DISCUSSION AND RECOMMENDATIONS

The investigation of the waste materials to be produced at the Alma Generating Station has indicated that these fly ashes can be disposed of in an environmentally safe manner. The additon of water to the Alma Unit 6 fly ash initiates pozzolanic reactions similar to Portland cement concrete to form a hardened mass. Calcium reacts with the water to form lime which reacts with the silica and alumina to form stable minerals having cementitious qualities.

It is recommended that the fly ash materials be dry pumped to the disposal area or hauled in covered trucks at 3% moisture to minimize dusting. At the disposal site, the material may be stored in protected areas or immediately placed in its final position with additional spreading and compaction. If hauled to the disposal site in open trucks, the fly ash should be uniformly moistened to a 3% moisture content prior to loading to minimize dusting during transport.

At the disposal site, it is recommended that the Alma Units 1-5 not be disposed of routinely by itself. It should be mixed with the fly ash produced from Alma Unit 6 at some minimum percentage to improve its overall stability. It appears that the addition of lime to the Alma Units 1-5 fly ash results in very slow setting, but a hard stable end product.

Because of the favorable physical properties encountered at both low and high moisture contents, either of two disposal methods are possible for the Alma Unit 6 and the 60/40 ash mixture. The methods are: 1. Compaction at low moisture contents with the fly ash at an earth-like consistency and/or 2. The ponding of a fly ash slurry.

The low moisture content disposal method involves end dumping the fly ash from trucks, leveling the ash piles, wetting the fly ash and compacting with additional wetting as necessary. The leveled thickness of each lift of fly ash may be 3'. After leveling the ash, a sufficient quantity of water is sprayed on the surface to bring the fly ash to optimum moisture. This moisture content should be 10 to 13% for the Alma Unit 6 fly ash and 16 to 19% for the 60/40 ash mixture, although it is not critical. Moisture contents above 15 and 20%, respectively, may cause more difficult handling conditions until setting is underway.

Because of the low support capability of the moistened fly ash, a crust should be allowed to form before using the compaction equipment. This compaction and possibly final leveling should be done with large rubber-tired dozers.

If the fly ash is to be used as a lining material, it is recommended that the ash be placed and compacted in a 3' thickness. This layer should then be quickly covered with a 5 to 10' lift of fly ash by standard disposal procedures. This will provide the best conditions for low permeability in prevention of shrinkage cracks. It is also recommended that this work be performed with the air temperatures in the range of 35 to 50° F.

The slurry method of disposal, in general, involves the preparation of retaining structures at the site, mixing water with the fly ash at the site and pumping to the location of final placement. The location where water is mixed with the fly ash should be as close as possible to the area where final end placement will occur. Minimizing the transportation distance and time between the addition of water and final placement will allow disposal of the slurry at minimum moisture contents and eliminate the necessity for collection and handling of excess water. A wide range of moisture contents (30-60%, dry weight basis) appear to exist whereby the fly ash exhibits a slurry consistency and absorbs all moisture in the hydration reactions. Because of the lack of significant hardening of the Alma Units 1-5 fly ash, it is recommended that this ash not be disposed of by itself in a slurry consistency.

At the disposal site, the fly ash should be thoroughly blended with 60% water to form a slurry suitable for pumping. At the 60% moisture content, the Lansing Unit 4 of the 60/40 ash mixture should allow for 10 to 15 minutes of placement time before difficulties are encountered in pumping. Beyond this time, the fly ash becomes increasingly viscous and hardening occurs within about 20 minutes. At 60% moisture, no excess water is anticipated. In the event that excess water should appear within the disposal area, it is recommended that this water be retained within the structure and used for subsequent disposal operations.

Due to the hardening characteristics of the Alma Unit 6 fly ash and the 60/40 mixture, disposal of the Alma 6 ash individually or blending with Alma Nos. 1-5 would be the preferred disposal method from the standpoint of minimizing chemical leaching. The extremely low permeability of this ash (10^{-9} cm./sec.) is such that the generation of leachate from infiltrating surface water is not anticipated with maintenance of proper slopes to promote runoff. Moreover, the durability of this ash to erosion appears to be substantially greater than natural soils of comparable grain size distribution. Should it become necessary to dispose of Alma Units 1-5 ash individually for short periods, we recommend that the Alma Units 1-5 ash be contained within berms of the Alma Unit 6 or 60/40 ash mixture, followed by a layer of 60/40 on top.

The recommended procedure for disposal of runoff wastewater from the site would be re-use of this water for either dust control or raising the moisture content of the fly ash to initiate its pozzolanic activity and hardening reactions. Due to the appearance of several trace metals in significant concentrations, the discharge of runoff to surface and groundwaters is discouraged.

Groundwater quality monitoring of the disposal site should be concentrated in areas under and down gradient of the ash fill area to establish the immediate impact of the site on local water quality. Suction lysimeters would be useful to obtain samples in the unsaturated zone above the groundwater table. Parameters which should be monitored routinely at all well locations would include calcium, sodium, potassium, sulfate, total and phenolphthalein alkalinity, chloride, aluminum and silica. Trace elemental analyses should include boron, strontium, and those parameters which are listed as drinking water standards.

Supplemental Fly Ash Characterization Report. Fly Ash Conditioning with Low Moisture Content. Alma Madgett Generating Station Units 1-6. Dairyland Power Cooperative Alma, Wisconsin. November 1980. Prepared by Warzyn Engineering, Inc.

SUPPLEMENTAL FLY ASH CHARACTERIZATION REPORT
FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

ALMA MADGETT GENERATING STATION
UNITS 1 THROUGH 6
DAIRYLAND POWER COOPERATIVE
ALMA, WISCONSIN
C 8181

WARZYN
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November 26, 1980
C 8181

Dairyland Power Cooperative
2615 East Avenue South
LaCrosse, WI 54601

Attention: Mr. Dan Crady

Re: Supplemental Fly Ash Characterization Report
Fly Ash Conditioning with Low Moisture Content
Alma Madgett Generating Station
Units 1 through 6
Dairyland Power Cooperative
Alma, Wisconsin

Gentlemen:

As requested, we have performed physical tests to determine general characteristics for handling and disposal purposes on samples of low moisture conditioned fly ash representing mixtures of JPM No. 1 fly ash and Alma No. 1 through No. 5 fly ash. This report supplements earlier reports dated October 12, 1979 and September 3, 1980.

This work completes the requested physical and chemical testing. We recommend that larger scale tests be performed to establish the most suitable equipment types for use in the full-scale ash conditioning operation.

Thank you for your cooperation in this investigation. If you have any questions, please do not hesitate to contact us.

Very truly yours,

WARZYN ENGINEERING INC.

Clifton E. R. Lawson / ww

Clifton E.R. Lawson, P.E.
Principal/Chief Materials Engineer

CERL/dkp
[WEI-4-1]
(6 copies)
cc: Stanley Consultants (3 copies)
Mr. Pat Mullin

SUPPLEMENTAL FLY ASH CHARACTERIZATION REPORT
FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT
ALMA MADGETT GENERATING STATION
UNITS 1 THROUGH 6
DAIRYLAND POWER COOPERATIVE
ALMA, WISCONSIN

INTRODUCTION AND SYNOPSIS

The basic report in this series dated October 12, 1979, entitled "Fly Ash Characterization Study" described the general physical characteristics of a specific mix of fly ash to be produced at the Alma Station. In that report, 60% of Alma Unit No. 6 (JPM No. 1) fly ash was mixed with 40% of fly ash from Units No. 1 through No. 5. Both the low moisture physical properties and some of the high moisture physical properties were described in the earlier report.

Later, it was apparent that other percentage mixtures of fly ash might be produced and disposed of at this plant, either as a high moisture slurry or as a slightly moisture conditioned material.

The original request for determining physical characteristics of fly ash mixes in the slightly moistened condition, that is, the "conditioned" state, was given to our firm in the spring of 1980. The work in the laboratory commenced shortly thereafter, but soon was interrupted by a change in priorities, requiring that the slurry states be given immediate investigation, including determining retarder effects.

It was found that the rapid setting of the mixes, due to high calcium content, required the use of retarders. Therefore, the report dated September 3, 1980, specifically addressed itself to determining the amount and type of retarder most suitable for facilitating the handling and disposal of fly ash in a slurry state.

After the slurry work was completed, Dairyland Power Cooperative decided to continue the physical tests on the conditioning treatment, and it is this work that is reported herein.

Different fly ash sample sources were used from time to time, due to no JPM fly ash being available in the early stage of the investigation and difficulty in obtaining adequate sample amounts from one source. This apparently did not affect the results, but did require some check tests to verify sample similarity.

The general fly ash conditioning program was directed towards determining the mixing and handling characteristics of broadly different percentages of JPM No. 1 mixed with Alma No. 1-5 fly ash. The main observation emphases were on the basic physical characteristics dealing with: resulting dust produced, density, compressive strength and permeability characteristics of the mixes. Various delay times between conditioning and physical testing were incorporated into the testing program to simulate interim storage in a conditioned stock pile, followed by subsequent transportation and compaction in a landfill.

In summary, it was found that low moisture (5 - 15%) conditioning of fly ash will reduce the potential for dust at least tenfold, but it will not eliminate it (with the conditioning methods used in this study).

The resulting compacted densities, strengths and permeabilities of the compacted mixes appear to be very suitable for landfill disposal. The permeability information shows that it is necessary to have a large fraction of the final mix composed of high calcium fly ash, such as JPM No. 1, in order to keep permeability at a low level generally suitable for landfill liner purposes.

It would appear from this study that it is necesary to experiment with bench scale mixer models, at least 1/10 of full scale, to determine the machinery type most suitable for blending of low moisture with the fly ash, both to minimize the dust potential, and to minimize problems in the handling of the material.

MATERIALS TESTED

A. High Calcium Fly Ash

Initial physical tests were performed using on-hand stocks of Lansing Unit No. 4 high calcium fly ash, as was used in the basic report dated October 12, 1979. These stocks soon ran out and another high calcium fly ash from Neal Unit No. 4 (Iowa Public Service) was utilized for the bulk of the study. It was necessary to add 8%, by weight, of a dolimitic quick lime to this fly ash to duplicate the rapid setting characteristics of the Lansing No. 4 fly ash in slurry form. Both the Lansing No. 4 and Neal No. 4 fly ash samples were considered "not fresh".

In June of 1980, the first samples of JPM No. 1 fly ash became available. Initial setting tests were performed on this fly ash, indicating it would set considerably more rapidly than earlier materials tested. Larger stocks became available after July 10, 1980. Noting the considerably more rapid setting characteristic of the fresh JPM No. 1 fly ash, Dairyland Power Cooperative decided to duplicate some of the already completed conditioning tests, using JPM No. 1 fly ash including set retarder in the mix water. The purpose of these check tests was to verify that the earlier work fully represents JPM No. 1 properties. Fortunately, the check tests show that most of the earlier test work is valid, probably because the fly ash types are from the same coal source (Belle Ayre) and similar boiler types. The variation in setting rates between old and fresh fly ash is believed to be due to the effects of atmospheric carbon dioxide combining with the free calcium in the older fly ash, somewhat slowing the rate of setting that otherwise occurs in fresh fly ash.

B. Retarder

The fresh high calcium JPM No. 1 fly ash was found to set and harden so rapidly after conditioning, that a set retarder was considered necessary for this method of disposal. Therefore, a set retarder was utilized for all physical tests with this material. Based upon the earlier report, dated September 3, 1980, it was decided to use 1%, by weight, of sulfite liquor, based upon the total dry weight of fly ash. Since the sulfite liquor was furnished at 57% concentration, approximately 2% of this liquid was added to the conditioning water. Please note, the percentage of retarder added was based upon the total weight of combined fly ash types, not the amount of high calcium fly ash in the mix.

C. Low Calcium Fly Ash

The first part of the test work utilized a mix containing low calcium fly ash from Alma Units No. 1-5, as furnished for the basic study reported on October 12, 1979. This supply ran out quickly.

Most of the study then utilized an Illinois coal fly ash obtained from commercial sources of concrete admixture suppliers, since the Alma No. 1-5 fly ash was not available. After July 10, 1980, low calcium fly ash was again available from the Alma plant, but it consisted of only an approximate mix, compared to ultimate production ratios of Units 1 through 4. There was no fly ash available from Unit 5. Results of tests do not appear to be affected by these changes in sources for low calcium fly ash.

D. Mix Ratios

In accordance with the instructions of Stanley Consultants, the design engineers for the project, mix ratios of the high calcium fly ash to the low calcium fly ash, expressed as a ratio, were varied between 10/90 and 100/0, respectively. The ratios initially considered were 10/90, 20/80, 40/60, 60/40, 80/20, and 100/0. Later in the program, it became apparent that 30/70 is a more probable final mix ratio that would be in the disposal site. Thus, some of the final tests were performed using this mix ratio also.

LABORATORY PROCEDURES FOR PHYSICAL TESTS

A. Moisture Conditioning Procedure

In the spring of 1980, under the general direction of Stanley Consultants, various types of laboratory mixers were experimented with on a laboratory scale to determine which method would be most suitable for thoroughly blending low moisture percentages with high calcium fly ash. The method of water application was found to be very important in properly distributing it with the fly ash sample. It was found that bulk-placing water in the fly ash, by pouring it directly into the fly ash, was not satisfactory due to the rapid uptake of the moisture in local zones of fly ash only. It was very difficult to then distribute this moisture to the rest of the dry fly ash. Apparently, hydration (chemical reaction of the water with the calcium oxide) occurs rapidly and, for all practical purposes, takes a considerable portion of the moisture into chemical combination so that it is not available for moistening purposes. Also, the rapid development of adhesive characteristics in the moist fly ash causes great difficulties in blending the zones of high moisture fly ash in with the dry fly ash. The high moisture portions of the fly ash adhere tenaciously to the tools and the container. Considerable mechanical effort is required to keep tools clean and distribute this pasty, moist section of fly ash.

Conventional blenders (food blenders) were found to be inadequate, since the slightly moistened material clung to on the side of the container and no longer was in contact with the propeller blades. Hand mixing with spoons was found to be quite time consuming, not uniform, and generally not suitable for test reproducibility.

It has been our observation that the moisture conditioning of high calcium fly ash, into a state similar to moist earth, not so wet as to cause a slurry, requires dynamic break-up of the fly ash clumps and wiping of the mixing parts against each other. Therefore, we developed a small laboratory ball-mill using a small power concrete mixer. A five-gallon plastic pail was inserted into the throat of the concrete mixer to serve as the container for the mixing operation. One inch by one inch angle irons were bolted to the inside of the plastic pail (3) on a diagonal to the axis. Three steel ball bearings, 1 1/4" diameter, were also placed in the container. The angle of the axis upon which the container rotated was adjusted so that the steel ball bearings would be carried up the sides of the container on the angles and dropped partway along the sides, so as to provide maximum pulverization of moist fly ash clumps and dynamic cleaning of the mixer interior. Speed of rotation was approximately 40 rpm.

A plastic cover was snapped on the top of the container, after fly ash was placed therein. A 1" diameter hole in the center of the cover permitted the injection of water. The water was added using a conventional paint sprayer, providing a fine mist, as the mixer was rotating. All of the water generally could be added within the first minute of operation. Ten pounds of fly ash was used with each batch and mixing time was five minutes, except for certain mixes, as noted, that ran somewhat longer, due to apparent non-uniform blending in five minutes.

The general observations of dust coming from the moisture injection hole, stickiness of the mix within the mixer and general difficulty or ease of sample removal has been recorded in the laboratory notes. These notes are summarized in the figures, provided with this report.

B. Dust Potential Test

Using the basic recommendations of ASTM Test Designation D 2009-65, a drop-test procedure was developed to provide a consistent handling scheme to intentionally develop air-borne dust within a container. This air-borne dust was then drawn off by vacuum and collected on filter paper, which was subsequently weighed to determine the dust amount. The general configuration of the test apparatus and procedures are shown on Figure C 8181-A44.

C. Setting and Hardening

The low moisture conditioned fly ash was generally in an earth-like consistency after the mixing. A portion of this was placed in a plastic container and observed for general hardening action, utilizing the pocket penetrometer device fitted with a 16 square centimeter base attachment. Readings were taken with this penetrometer periodically after mixing, as was temperature (where a temperature rise appeared obvious). This setting test is not a precise measure of set, since there is a certain amount of natural shear strength available within the low moisture conditioned fly ash that affects readings. In particular, after moisture is added, a capillary attraction takes place between particles, somewhat masking the hardening that is also occurring. A general increase of penetrometer reading with time was noted in most tests.

The approximate set time and then one or two near final readings are recorded in the figures attached hereto, showing something of the general rate of hardening that occurs. No attempt is made to document exact rate of setting.

D. Densities

Densities of the freshly-mixed low moisture fly ash were obtained approximately 10 minutes after removal from the mixer. Compacted density was obtained by compacting the freshly conditioned fly ash into a Proctor mold according to Modified Proctor procedure (ASTM D 1557) with no additional moisture added. Loose density was measured by lightly tamping the mix into a container by hand to duplicate approximate density that would occur in a truck.

One series of tests permitted the moisture conditioned fly ash to remain in a loose (covered to prevent moisture loss) condition for four hours prior to compaction. In this case, no additional moisture was added. This was intended to duplicate storage in stock pile prior to compaction.

However, one of the early tests at the start of the basic program in 1979, as well as tests for delayed compaction for permeability, permitted longer delays in the stock pile, followed by compaction to achieve maximum density. In this case there was so much loss of moisture due to hydration action that more moisture was required prior to compaction, as one would do for many soil types.

E. Permeability

Permeability testing was performed by first compacting freshly conditioned fly ash, at the available moisture condition in the Proctor mold, followed by a seven day moist curing. Thereafter, conventional falling head permeability tests were performed. The length of time for these tests varied from two weeks to six weeks, depending upon results observed. In some cases, swelling of the test mixes occurred for the first few weeks, followed thereafter by a drop in the falling head readings. These special conditions are noted on the lab test summary figures attached hereto.

F. Compressive Strength

It was not possible to use any of the permeability samples for compressive strength, as had been planned when the work program was established, due to the damage that occurred to samples in removing them from the molds. Therefore, separate 4" diameter samples were compacted in the Proctor molds, immediately ejected and then cured in a moist condition for seven days. Compressive strengths were determined in a compression test machine, without use of leveling caps.

G. Miscellaneous Tests

When JPM No. 1 fly ash was being tested, 1% of the total fly ash weight of sulfite liquor retarder was used. To determine the general effect of lesser retarder percentages, one series of mixing ease, setting and hardening tests was performed at varying retarder percentages on three different ratios of high calcium to low calcium fly ash. The time for initial setting was recorded for this test program.

Loose and maximum densities of the Neal No. 4 fly ash were also performed with no lime added to the fly ash, to determine if the lime addition affected densities.

Varying of blending time, as originally described in our proposed program letter of February 8, 1980, was not generally performed. It was found that blending time short of that required to produce a uniform blend resulted in obviously unsatisfactory conditioning of the fly ash. Excessive dust, lumping, sticking of the wet fly ash to the mixer, etc. were such obvious problems that it was decided not to investigate variation of blending time in this investigation. It was concluded that excessive dust would occur if there is non-uniform blending of the moisture with the fly ash.

DUSTING POTENTIAL TEST RESULTS

See the attached Figures C 8181-A45 through A48. The results of the dust potential tests, according to the procedure described earlier in this report, are summarized on these sheets. Two tests were performed without any moisture addition, one on the Alma No. 1-5 fly ash and the other on the Neal No. 4 with 8% quick lime, as shown on C 8181-A45. These results also should be compared to the 5% moisture conditioning results on Figure C 8181-A47, which show the dust potential test for JPM No. 1 with 1% retarder after 24 hours of delay in performing the test. Moisture absorbed by hydration, for all practical purposes, dried the 5% moisture mixes so that considerable dusting occurred. The general range of dust collected for the zero moisture content fly ash and the 5%, 24 hour delay test should be considered as a base reference when comparing the dust potential tests for other moisture contents and mixes of fly ash.

In summary, the Neal No. 4 fly ash with 8% quick lime at various mixtures with Alma No. 1-5, as well as the JPM No. 1 with 1% retarder in various mix ratios, show approximately the same degree of dust reduction when conditioned. These tests also show at least a tenfold reduction in air-borne dust with low moisture conditioning. The wide scatter of test results cannot be explained. It is felt that the test is very crude, and only a general order of magnitude for accuracy of results is expected. Even with this general order of magnitude of results, it is apparent that dust reduction by the addition of 5, 10 or 15% moisture is roughly the same for any of the mixes or moisture contents.

It is apparent that 5% moisture conditioning is not adequate if the JPM No. 1 with 1% retarder fly ash mixes are held in a stockpile for 24 hours. However, the 10 and 15% moisture conditioning appears to be reasonably effective, 24 hours after conditioning. This slight difference is explained by the loss of free moisture to hydration of the calcium oxide in the reactive fly ash. It is interesting to note the changing percentage of high calcium fly ash in the mixes did not seem to have a noticeable effect on the outcome of the dust potential test, immediately or after 24 hours of delay.

In summation, this test series indicates air-borne dust (when dropped) can be considerably reduced, but not eliminated, if the fly ash and moisture are blended in a manner similar to the laboratory mixing. Our experience indicates the success of blending the moisture with the fly ash is very sensitive to many factors. Therefore, it is considered feasible to construct a blender that will reduce the air-borne dust potential considerably more than the reduction achieved by the method utilized in the laboratory investigation. Whether a practical, economical full-scale mixer can be built is another matter.

It is evident from this test work that JPM No. 1 fly ash does require a retarder in the conditioning water to prevent rapid set.

HANDLING OBSERVATIONS

During the blending of low moisture with the fly ash mixes and thereafter, in the setting and hardening tests, as well as other tests requiring conditioned fly ash, observations were made regarding general handling characteristics of the conditioned fly ash. As hardening, or setting took place, generally measured with the pocket penetrometer, notations were made, and then summarized on Figure C 8181-A49 through A52. These sheets include measurements of temperature rise above room temperature. The temperature readings shown indicate the maximum measured temperature rise, which generally was measured somewhat after the first indication of setting. Arbitrarily, a pocket penetrometer reading of 0.05 tons per square foot (plus or minus) was utilized to determine the time for inital set. This is not necessarily related to any standard setting test, but indicates the early obvious beginning of hardening.

A. Mixing

Observations during mixing indicate no significant relationship between moisture content and mixing problems other than 5% moisture appears to have somewhat more dust problems than the 15% moisture content. Also, more sticky conditions, lumpy conditions, etc. were observed at the higher moisture content mixes.

The mixes containing highest calcium, that is the 80/20 or the 100/0 mixes, tended to show more temperature rise (and more rapid setting and hardening, although not universally so) than the mixes with lower calcium content. Apparently, the added lime in Neal No. 4 fly ash is required to speed up set (in lab tests) of slurries, but the added lime has little effect in conditioning laboratory tests in the low moisture (5-15%) range.

Observations of the mixing show that the full scale mixer operation should provide moisture to the fly ash in a fine spray, with the ability to contact each fly ash particle, without the need for significant mechanical blending to transfer the moisture from particle to particle. If the moisture is applied too rapidly, resulting in excessive moisture in small zones, clumps develop. These clumps will stay this way, unless mechanically broken up. It appears that the fly ash, of its own weight and impact in a rotary mixer, will not adequately break up clumps. This is why a ball mill or other positive blending device with impact appears to be required.

The mixer must be totally enclosed so that free dust is not likely to escape before it contacts the moisture.

A moisture content somewhat higher than 15% could be considered for conditioning provided a running slurry does not develop. In some cases (in previous test work) 20% moisture was too low to create a slurry, yet may be adequate for creating a soil-like conditioned situation.

B. Hardening Characteristics

Whether the high calcium fly ash is Neal No. 4 with 8% lime, Neal No. 4 with no lime added, or JPM No. 1, hardening takes place gradually after conditioning. The exception is the high moisture JPM No. 1 blends, which require set retarder to prevent immediate set accompanied by rapid temperature increase and what is considered to be excessive hardening after one hour or thereabouts. The retarded JPM No. 1, and other high calcium fly ash mixes, apparently tend to remain sufficiently uncemented that they can be handled with earth-moving equipment within approximately one day of the conditioning, provided the mixes are not compacted.

Figure C 8181-A52 shows an experiment with JPM No. 1 fly ash and three different mix ratios with a variation in the percentage of retarder used. It is apparent that approximately 0.10% of retarder is suitable for the 10/90 mixes, whereas approximately 0.5 to 1% retarder is needed for the 100/0 mix (100% JPM No. 1 fly ash). In effect, the percentage of retarder required for properly conditioned mixes is similar to the percentage retarder required for slurries. From the previous tests with slurries, it is also probable that high temperature fly ash conditioning requires even greater percentage retarder to avoid the rapid set and hardening that is characteristic of the higher temperature fly ash.

Data available from Figure C 8181-A55, for the Lansing No. 4 fly ash without a retarder, in a large sample (30 pounds), shows significant temperature rise can occur inside this conditioned material, taking approximately 4.2% of the moisture by hydration in the first hour. Fresh JPM No. 1 fly ash is expected to be even more active than the Lansing No. 4 shown on this Figure. Thus, a retarder is considered necessary to slow the hydration rate and thus slow the rate of set.

C. Summary of Handling Observations

Successful conditioning of fly ash requires a special mixer, possibly of a design not yet available on the market. However, when adequately blended, the conditioned fly ash, at any ratio of high calcium to low calcium, can be conveniently handled within a period of 24 hours after conditioning, perhaps more, depending upon retarder percentage used.

A general interpretation of the test data indicates that approximately 1% sulfite liquor is required for conditioning, as measured against the proportion of JPM No. 1 fly ash in the mix. Again, this is a room temperature requirement. Use more retarder at high temperatures (and less at low temperatures) to reduce the hardening rate and thus permit convenient handling.

DENSITY TEST RESULTS

Both loose densities and compacted densities were determined, as described earlier herein. The test data is summarized on Figures C 8181-53 through 55. Modified Proctor Compaction Method (ASTM D 1557) is used for determining maximum density, except as noted.

By reviewing the data in the referenced sheets, it is apparent that by increasing percentages of high calcium fly ash, both the loose densities and the compacted densities increase. Moisture content does not seem to have a significant effect in either the loose or compacted densities. There are some variations in maximum densities achieved, probably due to hydration effects removing the available water that otherwise would be usable for lubrication during compaction. Thus, the maximum densities shown should be considered the general range only.

Neal No. 4 fly ash appears to develop roughly the same loose or compacted densities whether or not quick lime is added.

The 48 hour delayed compaction work, Figure C 8181-A55, shows slightly lower compacted densities, than would be achieved without delay, but not significantly so. However, the permeability test performed on a conditioned (15% moisture content) fly ash mix of 60/40 ratio shows roughly the same results as for materials compacted immediately. (See the next section.)

In summary, consider the dry unit weight of fly ash in a conditioned form, when loaded in the truck to be about 30 to 60 pounds per cubic foot, probably averaging 50 pounds per cubic foot. Compacted densities vary from 75 to 125 pounds per cubic foot, probably averaging 105 pounds per cubic foot. Add to these figures the weight of water included.

PERMEABILITY TEST RESULTS

The results of permeability tests are shown on Figures C 8181-A56 and A57. These tests are on compacted specimens using mixes of Neal No. 4 with 8% lime (as the high calcium fly ash) and Illinois fly ash (as the low calcium fly ash). Check tests using mixes of JPM No. 1 with 1% retarder also are shown.

The data sheets show the densities to which the specimens were compacted prior to the permeability test, followed by the densities measured after the permeability test is complete. In some cases, swelling occurred during the testing. However, most of the changes in density were increases, especially when high calcium percentages are included in the mix. These density increases appear to be the result of the chemical combination of water with the calcium (hydration).

It is evident from the test information that permeability of the various mixes decreases with increasing density. This may be an incidental relationship since the test data also show that the permeability decreases with increasing percentage of high calcium fly ash. Related data, for density test results, show that the mixes with a higher percentage of calcium oxide develop higher densities when compacted.

There is no significant difference in permeability resulting from the use of Neal No. 4 fly ash, versus JPM No. 1 fly ash with retarder. Densities using JPM No. 1 fly ash apparently are significanly higher for unexplained reasons.

In order to obtain approximately 1 x 10^{-7} cm/sec permeability, one should have a mix of at least 60/40 of JPM No. 1 fly ash to Illinois fly ash compacted to Modified Proctor Density.

If a delay in compaction occurs after conditioning, as shown on Figure A55, apparently the resulting permeability of the compacted mix is not significantly different than for samples compacted immediately after conditioning.

COMPRESSIVE STRENGTH TEST RESULTS

Figure C 8181-A55 summarizes compressive strength tests performed on various mixes and conditioning moisture contents using JPM No. 1 fly ash with 1% retarder as the high calcium fly ash. Compaction was according to Modified Proctor Method, ASTM D 1557.

The compressive strengths after seven days of curing are considerably stronger than those obtained using slurries mixed at higher moisture contents (see Report dated September 3, 1980).

Compression test results compare roughly with earlier compression tests using Lansing No. 4 fly ash and Alma No. 1-5 fly ash mixes at 21% moisture content. However, earlier, Lansing No. 4 fly ash, when compacted, yielded somewhat higher compressive strengths than those obtained with 100% JPM No. 1 fly ash.

General order of magnitude of compressive strengths developed with compacted conditioned fly ash mixes increase with increasing percentage of high calcium fly ash in the mix. Moisture content differences do not appear to be important.

EFFLORESCENCE OBSERVATIONS

Efflorescence, on samples that have been exposed to the atmosphere for a considerable period of time after conditioning, but not exposed to any additional water, was generally non-existent in the series of tests reported in this study. The low availability of free water in these mixes is believed to be the major reason for the lack of efflorescence.

CONCLUSIONS AND RECOMMENDATIONS

In summation, low moisture conditioning produces an earth-like fly ash mix which has reduced potential for dust by an order of magnitude (i.e., a ten-fold reduction). The moisture conditioning, by the methods utilized in the laboratory, does not fully eliminate the dust potential. It is considered probable that better blending methods can be developed which would further reduce the air-borne dust by more thorough blending of moisture with the fly ash. Partial blending of moisture with fly ash results in a dust potential almost as severe as if no conditioning whatsoever were attempted. Thus, emphasis on thorough blending of the moisture with the fly ash is a prime finding of this investigation.

From our observations, it would appear that the blending equipment requires complete enclosure, with moisture application in fine mist form impinging directly upon the individual fly ash particles and further moisture distribution by mechanical mixing being kept to a minimum, since it is difficult. The moisture apparently adheres tenaciously to the particles it initially contacts. Transferring this moisture to other fly ash particles is very difficult. The mixer definitely requires impact or mechanical scraping to accomplish this blending. Merely dumping the fly ash around and around in a drum mixing device, such as a concrete mixer, is not considered suitable for low moisture content ash conditioning. The machinery required should have a blending capability similar to a rod or ball mill.

The completely conditioned fly ash produces slight dust if it is not dropped free-fall. Therefore, the handling equipment should be designed with a minimum of free-fall of the fly ash in transfer. Belt conveyors, both up and down, might be considered, as well as vibrating chutes, or augers encased in split housings.

Little hardening is expected of consequence if the conditioned fly ash is not compacted. It is always possible that conditioned fly ash may receive an excessive (accidental) amount of moisture during the mixing or transfer operation resulting in severe hardening, similar to weak concrete. Therefore, all equipment must be capable of ready disassembly and jack hammer removal of hardened fly ash. Redundancy is recommended.

Significant amounts of energy are required for adequate laboratory blending. We recommend that model mixers, roughly 1/10 full-scale, be tested for suitability, with energy measurements scaled upward to the full-scale design size. It appears that the difficulty of combining moisture with dry fly ash from the dampened zone of fly ash will take much more energy than for a conventional concrete mix of the same weight.

The end product after low moisture conditioning, an earth-like material, is readily handled in conventional earth-moving equipment and probably requires only a minimum of dust protection, such as canvas covers over dump trucks. When compacted to near maximum density, very low permeabilities can be created with the freshly conditioned fly ash. If a delay of one day or more is involved between the mixing and the compaction, it will be necessary to add some moisture at the disposal site to facilitate compaction. Resulting density, strength and permeability will be similar to the freshly compacted conditioned fly ash.

Long delays between the ash conditioning mixing and compaction also will require addition of moisture to the fly ash to minimize dust problems, due to the loss of moisture by hydration combining of water with calcium oxide. It is recommended that a water distribution truck, or hose, be available at the disposal site to wet down loose fly ash areas to minimize the air borne dust picked up by wind.

In summary, low moisture conditioning of fly ash, if accomplished with adequate blending equipment, appears to have merit for creating a material that can be handled in a manner similar to damp earth. The high calcium fly ash does not set significantly within 24-48 hours (uncompacted) provided adequate percentages of retarder are used with JPM No. 1 fly ash.

Respectfully submitted,

WARZYN ENGINEERING INC.

Clifton E.R. Lawson /ww

Clifton E.R. Lawson, P.E.
Principal/Chief Materials Engineer

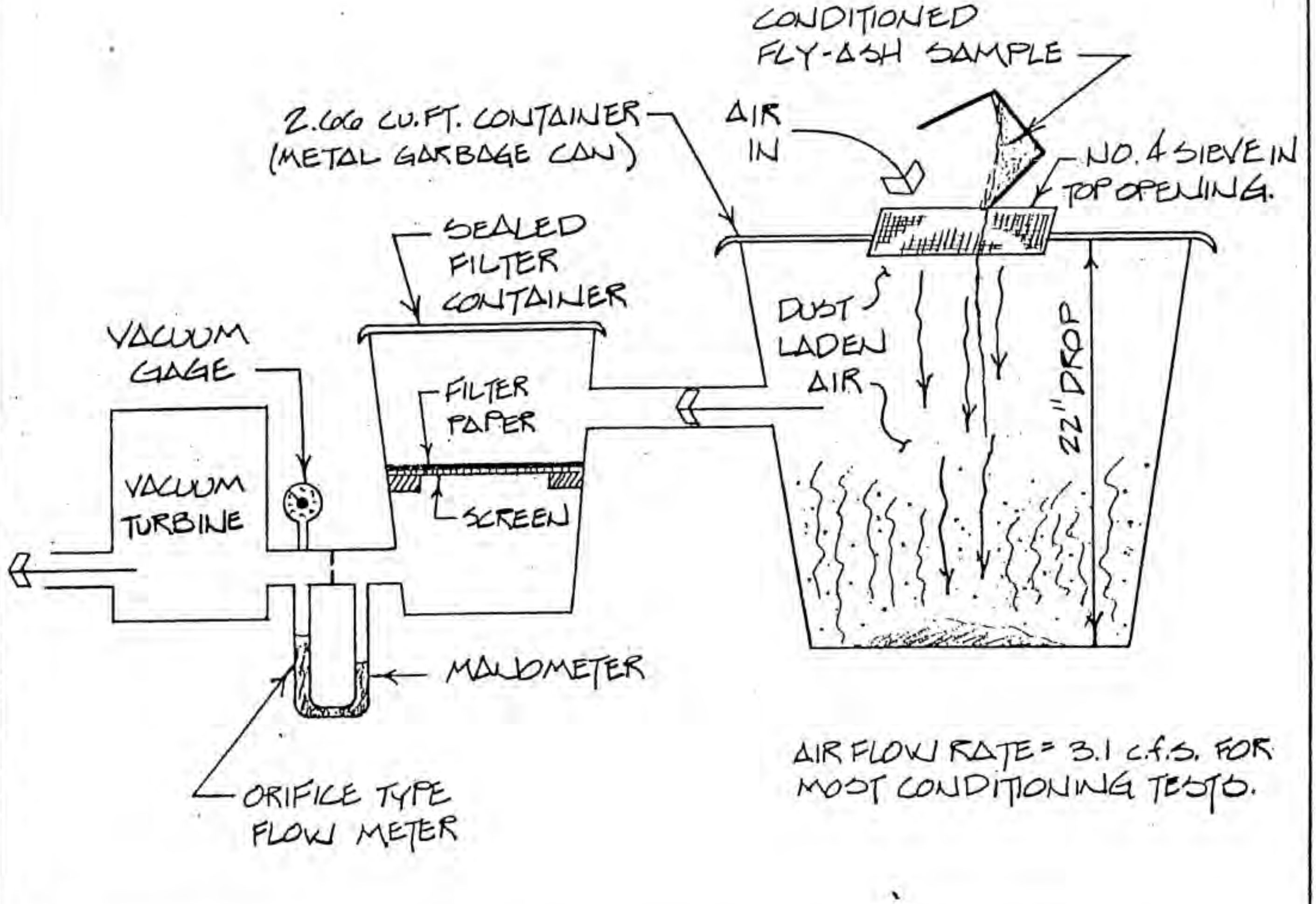
CERL/dkp
[WEI-4-1]

FLY ASH

DUST POTENTIAL TEST APPARATUS

(AFTER ASTM METHOD D 2009-65)

- 1/30 CU.FT. OF MOISTURE CONDITIONED FLY ASH IS POURED INTO CONTAINER THROUGH SIEVE.
- AIR DRAWN OFF FOR 10 SECONDS.
- FILTER PAPER COLLECTS ALL AIRBORN FLY ASH.



AIR FLOW RATE = 3.1 c.f.s. FOR MOST CONDITIONING TESTS.

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DUST POTENTIAL TEST APPARATUS
JPM #1/ALMA #1-5 LOW MOISTURE CONDITIONING
ALMA MADGETT STATION
DAIRYLAND POWER COOPERATIVE

DWN JDP
CHK'D CL
APP'D Wm. W. Wuellr
DATE 11-6-80
CB181-A44

FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

IMMEDIATE DUST POTENTIAL

WESTERN ASH TYPE

Neal #4 w/8% Lime

MIX RATIO	MOISTURE CONTENT (%) 5	10	15
	Weight of Dust Collected From Dropping 1/30 Cu.Ft. Freshly Conditioned Fly Ash Mix, Grams. Drop Height = 22 inches.		
0/100 (Alma #1-5)	6.1911 Grams at Zero Moisture Content		
100/0 (Neal #4 w/8% Lime)	1.1969 Grams at Zero Moisture Content		
10/90	0.3132	0.06910,0.3523 *0.2452	0.1721
20/80	0.0891	0.5980	0.2413
40/60	0.1216	0.0861	0.3875
60/40	0.2347	0.111 *0.3316	0.1797
80/70	0.4719	0.0328	0.2028
100/0	0.1597	0.0488 *0.3718	0.2034

REMARKS:

For Neal #4 Without Lime, See C 8181-A48

See Figure C 8181-A44 For Diagram For Test Set-Up.

* For JPM #1 Fly Ash Without Retarder.

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Figure C 8181-A45

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

IMMEDIATE DUST POTENTIAL

WESTERN ASH TYPE

JPM #1 w/8% Retarder

Weight of Dust Collected from Dropping 1/30 Cu.Ft. Freshly Conditioned Fly Ash Mix, Grams. Drop Height = 22 inches.

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90	0.1386	*0.2452	0.3021
30/70		No Reading but Minor Dust Observed	
40/60	0.0699	*0.3516	0.0829
100/0	0.7436	0.5885 *0.3718	0.0140

REMARKS:

* For JPM #1 Fly Ash Without Retarder.

See Figure C 8181-A44 for Diagram for Test Set-Up.

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Figure C 8181-A46

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

WESTERN ASH TYPE

DUST POTENTIAL 24 HRS. AFTER CONDITIONING

JPM #1, w/1% Retarder

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
	Weight of Dust Collected From Dropping 1/30 Cu.Ft. 24 Hr. Old Conditioned Fly Ash Mix, Grams. Drop Height = 22 inches.		
10/90	4.8257	0.3121	0.2362
20/80	5.0137	0.4243	0.4866
40/60	5.4359	1.5309	0.5034
60/40	2.9999	1.2261	0.2668
80/20	6.9787	0.4905	0.2166
100/0	4.8750	0.6492	0.1951

See Figure C 8181-A44 for Diagram for Test Set-Up.

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Figure C 8181-A47

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

WESTERN ASH TYPE

Neal #4, No Lime Added

TEST SERIES

IMMEDIATE DUST POTENTIAL

Weight of Dust Collected From Dropping 1/30 Cu.Ft. Freshly Conditioned Fly Ash Mix, Grams. Drop Height = 22 inches.

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90		0.3523	
20/80		0.0777	
40/60		0.1541	
60/40		0.1884	
80/20		0.000 (7 Minute Mix)	
90/10		0.2870	
100/0		0.0863	

See Figure C 8181-A44 for Diagram for Test Set-Up.

Figure C 8181-A48

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

WESTERN ASH TYPE

MIXING EASE, SETTING AND HARDENING

Neal #4 w/8% Lime

MIX RATIO	MOISTURE CONTENT (%) 5	 10	 15
10/90	Very Dusty, Poor Mixing Set @ 35 Min.(5°C) 24 Hrs. to 0.1 TSF	Dusty, OK Mix 35 Min. (2° C) 24 Hrs. to 0.5 TSF	Mix OK, Slight Sticky 45 Min. 4 Hrs. to 0.2 TSF
20/80	Little Dust, Mix OK, Set @ 25 Min. (10°C) 24 Hrs. to 1.25 TSF	Sticky, Poor Mix rate 30 Min. 24 Hrs. to 1.8 TSF	Mix OK, Slight Sticky 15 Min. 2 1/2 Hrs. to 0.22 TSF
40/60	Little Dust Mix OK, Set @ 30 Min. No Reading Final	Good Mixing 20 Min. (19°C) 24 Hrs. to 2.2 TSF	Mix Ok, Lumpy, Sticky 15 Min. 24 Hrs. to 0.28 TSF
60/40	Dusty, Mix OK, Set @ 45 Min. (12°C) 5 Hrs. to 1.25 TSF	Good Mixing 20 Min. (10°C) 24 Hrs. to 3.5 TSF	Mix OK, Lumps, Sticky 15 Min. (9°C) 1 Hr. to 0.28 TSF
80/20	Minor Dust, Mixed Well Set @ 45 Min. (18°C) No Final Reading	Good Mixing 30 Min. (10°C) 2 Hrs. to 0.2 TSF	Good Mix, Slight Sticky 5 Min. (18°C) 1 Hr.-15 Min. to 0.28
100/0	Mixed OK Set @ 30 Min. (16°C) 4 Hrs. to 3.0 TSF	Mix OK, But Warm 5 Min. (28°C) 45 Min. to 1.75 TSF 5 Hrs. to 4.5 TSF	OK Mix, But Lumpy 5 Min. (16°C) 20 Min. to 0.28

These mixes for 5 minutes.

KEY: Mixing Conditions
Set Time, (Temp. Rise)
Rate of Hardening

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Figure C 8181-A49

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

MIXING EASE, SETTING AND HARDENING

WESTERN ASH TYPE

Neal #4 No Lime Added

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90		Mixed Poorly, Some Dry Zones 2 Hrs. Set (1°C) 19 Hrs. to 0.05 TSF	
20/80		Good Mix 10 Min. Set (2°C) 18 Hrs. to 0.20	
40/60		Good Mix 5 Min. Set (6°C) 2 Hrs. to 1.7 TSF 17 Hrs. to 4.5 + TSF	
60/40		Mix OK, Sticks to Mixer 5 Min. Set (16°C) 1 Hr. to 0.12 TSF 16 Hrs. to 4.5 + TSF	
80/20		Mix OK, Sticks in Mixer Immediate Set (20°C) 15 Min. to 1.5 TSF 1 Hr. to 4.5 TSF	
90/10		Not Well Mixed, Clumps 5 Min. Set (20°C) 1 Hr. to 1.0 TSF 2 Hrs. to 4.5 TSF	
100/0		Lumpy Mix, Sticks In Mixer Immediate Set (25°C) 15 Min. to 1.75 TSF 40 Min. to 4.5 + TSF	

These Mixes for 7 Minutes,
Except 90/10 for 5 Minutes.

KEY: Mixing Comments
Set Time (Temp. Rise)
Rate of Hardening

Figure C 8181-A50

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

MIXING EASE, SETTING AND HARDENING

WESTERN ASH TYPE

JPM No. 1 w/1% Retarder
(Except as Noted)

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90	Mixes Poorly, Sticky 1 Hr. Set 2 Hrs. to 0.05 TSF	* Mixes Poorly, Dusty 45 Min. Set (5°C) 2 Hrs. to 0.16 Little Change	Mixed OK, Dusty First Min. 2 Hr. Set No Final Reading
30/70		Mixes Good Set @ 50 Min. 4 Hrs. to 0.18 TSF	
40/60	Dusty While Mixing 2 Hrs. Set No Final Reading	* Poor Mixing, Dusty 10 Min. Set (20°C) 45 Min. to 0.28	Mix OK, Dusty First Min. 30 Min. Set 1 Hr. to 0.60 TSF
100/0	Minor Mixing Prob. 5 Min. Set (6°C) 1 Hr. 15 Min. to 0.28 TSF	Mixes OK 3 Min. Set (6°C) No Final Reading	Poor Mix, Sticky 5 Min. Set (3°C) 2 Hrs. to 1.0 TSF
100/0		* Hard Lumps in Mix, Warm 3 Min. Set (34°C) 15 Min. to 0.28	

These mixes for 5 minutes.

KEY: See C 8181-A50

REMARKS:

*[For JPM #1 Without Retarder]

Figure C 8181-A51

FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

MIXING EASE, SETTING AND HARDENING

WESTERN ASH TYPE

Variable Retarder, JPM #1 Fly Ash Mix

AT 10% MOISTURE CONTENT (%)
RETARDER, PERCENT OF DRY FLY ASH

MIX RATIO	0.05	0.1	0.5
10/90	10 Min. Set 2 Hrs. to 0.15 TSF 17 Hrs. to 2.45 TSF	20 Min. Set 2 Hrs. to 0.16 TSF 17 Hrs. to 0.13 TSF	10 Min. Set 1 1/2 Hrs. to 0.18 TSF 17 Hrs. to 0.27 TSF
40/60	Immediate Set 1 Hr. to 1.6 TSF 16 Hr. to 5.0 TSF	Immediate Set 1 Hr. to 1.0 TSF 16 Hrs. to 2.4 TSF	15 Min. Set 1 1/2 Hr. to 0.20 TSF 6 1/2 Hr.s to 2.4 TSF
100/0	Immediate Set 15 Min. to 2.5 TSF 45 Min. to 4.5 TSF 1 Hr. to > 4.5 TSF	5 Min. Set 20 Min. to 1.6 TSF 30 Min. to > 4.5 TSF	1 to 2 Hr. Set 4 1/2 Hr. to 1.0 TSF 6 Hr. to 1.2 TSF

These mixes for 5 minutes.

KEY: Set Time
Rate of Hardening

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Figure C 8181-A52

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

DENSITY SUMMARY

(lbs./cu.ft.)

WESTERN ASH TYPE

JPM #1 w/1% Retarder
Neal #4 w/8% Lime

	MOISTURE CONTENT (%)					
MIX RATIO	5		10		15	
10/90	34.5 50.0	92.9	33.9 47.0	[76.4] 76.1 98.8 (104)	30.5 49.6	96.8
20/80	51.1	94.0	54.1	[76.9] 103.6	52.4	99.9
30/70		JPM #1	48.3	95.5		
40/60	40.0 48.2	[78.8] 100.3	*39.5 51.7	[86.5] 86.5 103.1	37.2 57.2	[89.0] 104.6
60/40	49.7	101.7	53.9	102.3	59.5	106.1
80/20	50.8	100.3	52.6	106.6	60.8	110.6
100/0	65.4,63.5 53.8	[122.5] 104.6	*56.2 60.2 64.0	[125.2] 110.0 107.7	76.7 62.7	[124.7] 111.4

* JPM #1 - No Retarder

KEY:		[Note 1]
	Loose, Note 2	Modified Proctor, Note 2
	Loose, Note 3	Modified Proctor, Note 3
		(Note 4)

Note 1, JPM #1 w/1% Retarder, Standard Proctor, After 4 Hour Delay
Note 2, JPM #1 w/1% Retarder
Note 3, Neal No. 4 w/8% Lime
Note 4, Neal No. 4, w/8% Lime After 4 Hr. Delay

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Figure C 8181-A53

FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

DENSITY SUMMARY

(lbs./cu.ft.)

WESTERN ASH TYPE

Neal #4 - No Lime Added

	MOISTURE CONTENT (%)			
MIX RATIO	5	10		15
10/90		46.1	100.4	
20/80		54.1	98.5	
40/60		58.0	106.4	
60/40		58.9	112.9	
80/20		63.4	107.5	
90/10		54.4	108.8	
100/0		62.9	101.2	

KEY: Loose Immediate Modified Proctor

Figure C 8181-A54

LONG DELAYED COMPACTION AND PERMEABILITY
SUMMARY OF TEST DATA

15% Moisture Conditioning (August 1979)
Fly Ash 60/40 Mix (Lansing #4/Alma #1-5)

First Day

30 lb. sample mixed with 15% water, temperature rise 20°C to 57°C. Appeared granular soil-like condition.

One hour later, oven dry moisture determined to be 10.8%, (4.2% hydrated).

Cover sample, allow to sit for two days; still soil-like.

Third Day

Performed Standard Proctor compaction test, by adding % moisture shown.

Moisture (%)	9	12	15	18
Dry Density (lb./cu.ft.)	91.9	95.2	97.8	95.6

Permeability test run at 15% moisture compacted at 91.6 lb/cu.ft., or 98% compaction. $K = 3 \text{ to } 7 \times 10^{-7}$ cm/sec.

Summary

15% conditioning moisture did not cause serious setting problems (provided mix was not compacted) with storage for two days prior to final compaction.

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Figure C 8181-A55

FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

PERMEABILITY, COMPACTED

(cm./sec.)

WESTERN ASH TYPE

Neal #4 w/8% Lime

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90	1×10^{-5} @ 95.7 to 95.7	3 to 4×10^{-6} @ 97.9 to 91.8	5 to 7×10^{-6} @ 96.7 to 97.2
20/80	1×10^{-5} @ 93.7 to 93.7	6 to 9×10^{-7} @ 103.6 to 101.8	3 to 4×10^{-6} @ 99.9 to 99.9
40/60	5 to 7×10^{-7} @ 100.3 to 102.6	1 to 2×10^{-7} @ 102.8 to 102.3	2 to 3×10^{-7} @ 104.6 to 104.6
60/40	1×10^{-6} to 4×10^{-7} (Reducing with Time) @ 101.7 to 107.2	1×10^{-7} to 8×10^{-8} @ 102.3 to 104.0	1×10^{-7} @ 106.2 to 106.2
80/20	1×10^{-7} @ 100.3 to 107.0	2×10^{-7} to 5×10^{-8} @ 106.6 to 105.8	1×10^{-7} to 5×10^{-8} @ 110.6 to 110.6
100/0	2×10^{-7} @ 104.6 to 114.9	5 to 8×10^{-8} @ 107.7 to 111.5	5 to 6×10^{-8} @ 111.8 to 111.4

KEY: $\dfrac{\text{Permeability}}{\text{@ Initial density to final density (P.C.F.)}}$

NOTE: Samples compacted 10 minutes after mixing with water, then cured 7 days and tested.

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Figure C 8181-A56

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

PERMEABILITY, COMPACTED

(cm./sec.)

WESTERN ASH TYPE

JPM #1 w/1% Retarder

MIX RATIO	MOISTURE CONTENT (%)		
	5	10	15
10/90	5×10^{-6} @ 89.7 to 96.9 Final	4 to 5×10^{-6} @ 76.1 to 78.7	
40/60	5×10^{-7} @ 96.6 to 115.8	7 to 8×10^{-7} @86.5 to 91.1	4×10^{-7} @87.4 to 95.6
100/0	*2×10^{-9} @114.9 to 140.6	*1×10^{-9} @112.4 to 122.1	2×10^{-9} @101.0 **

KEY: Permeability
@ Compacted Density and Final Density Shown (#/Cu. Ft.)

Samples Compacted 10 Minutes After Mixing in Water.

7 Day Cure Prior to Test

* Considerable Swell Noted for 3 Weeks Prior to Obtaining a Reading in Correct Direction.

** A slurry sample at 30% moisture obtained 6×10^{-9} @ 104.9 lbs./cu.ft.

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pag

Figure C 8181-A57

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FLY ASH CONDITIONING WITH LOW MOISTURE CONTENT

TEST SERIES

COMPRESSIVE STRENGTH

(P.S.I.)

WESTERN ASH TYPE

JPM #1 w/1% Retarder

	MOISTURE CONTENT (%)		
MIX RATIO	5	10	15
10/90		Crumbled @ 87.3	22 @ 89.7
20/80		Crumbled @ 88.9	136 @ 90.8
40/60		361 @ 90.0	631 @ 95.5
60/40		641 @ 94.9	1894 @ 104.9
80/20		1122 @ 118.2	996 @ 104.6
100/0	517 @ 113.1	1321 @ 114.5	891 @ 119.7

KEY: Compressive Strength After 7 Days @ Density Noted, PCF.

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Figure C 8181-A58