SUPPLEMENTAL MATERIALS

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Assessment of Municipal Solid-Waste Landfill Liner Performance

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Tables (SI)

Table S1. Bottom liner and LCS drainage layer properties of the study sites for which the design data were available.

Site ID	State	Primary Liner Type	LCS Drainage Layer Type	Maximum LCS Leachate Collection Rate ($m^3\ ha^{-1}\ day^{-1}$)	Drainage Length (m)	Drainage Slope (%)	Hydraulic Conductivity of LCS Drainage Layer ($cm\ sec^{-1}$)	Estimated Maximum Head Over the Liner[a] (cm)
FL1	FL	HDPE	Geocomposite	55.1	42.9	2.0	10.8	0.13
FL3		HDPE	Geocomposite	30.6	18.3	2.0	10	0.033
PA1	PA	HDPE	Soil Media	20.4	45.7	2.0	0.01	33.58
FL4	FL	HDPE	Geocomposite	83.1	61.0	4.0	33	0.05
FL5		HDPE	Geocomposite	9.2	15.2	2.0	16	0.01
FL6		HDPE	Geocomposite	138.3	9.1	3.0	1.00	0.49
FL7		HDPE	Geocomposite	32.0	30.5	2.0	10	0.06
FL8		HDPE	Geocomposite	62.0	76.2	2.0	7.40	0.37
FL9		HDPE	Geocomposite	15.0	39.6	2.0	33	0.01
FL11		HDPE	Geocomposite/soil	26.4	140.2	1.0	15.89	0.29
NY1	NY	HDPE and GCL	Soil Media	23.9	42.7	2.0	0.01	35.4
FL2	FL	HDPE and GCL	Geocomposite	38.6	67.4	2.0	10	0.15
NY15	NY	HDPE+GCL	Soil Media	17.5	45.7	5.0	0.10	1.81
AR1	AR	HDPE and GCL	Geocomposite	157.1	131.1	2.3	9.84	0.49
NH1	NH	HDPE and GCL	Geocomposite	60.8	43.3	2.0	7.87	0.20
NY29	NY	HDPE and GCL	Stone	27.4	74.7	2.0	0.3	3.67
CA1	CA	HDPE and GCL	Gravel	22.1	91.4	2.0	1	1.14

[a]In the case of sand, soil media, gravel, and stone LCS drainage layer, the head over the liner was estimated using equations suggested by McEnroe (1993) and for the geocomposite LCS drainage layer, the head on the liner was estimated using equations suggested by Giroud (2004).

Table S2. Data summary for the study sites. Data include the state, annual rainfall, timeframe of data, primary and secondary LCS flow rates and areas, and the estimated primary liner efficiency.

Site ID	State	Annual Rainfall (mm)	Waste Type	Combination of Cells Number	Years of Data Available	Area (hectare)		Total Leachate Collected Volume (m^3)		Leachate Collection Rate (L $ha^{-1}day^{-1}$)		Primary Liner Leachate Collection Efficiency (%)
						LCS	LDS	LCS	LDS	LCS	LDS	
AR1	AR	1156.5		1	13.1	2.1	2.1	19,697	661	1,961	66	96.8%
				2	13.0	1.9	1.9	25,016	298	2,833	34	98.8%
				3	12.7	2.5	2.5	41,863	302	3,586	26	99.3%
				4	12.5	3.1	3.1	35,442	230	2,527	16	99.4%
				5	10.3	1.5	1.5	17,374	216	3,078	38	98.8%
				6	10.2	1.5	1.5	17,039	110	2,987	19	99.4%
				7	9.3	2.8	2.8	50,603	272	5,246	28	99.5%
				8	7.6	3.2	3.2	22,573	254	2,552	29	98.9%
				9	6.2	4.2	4.2	33,622	432	3,538	46	98.7%
				10	4.9	4.2	4.2	53,749	1,278	7,188	171	97.7%
				11	4.8	4.2	4.2	63,994	2,087	8,703	284	96.8%
				12	3.6	4.2	4.2	15,831	675	2,906	124	95.9%
CA1	CA	495.6		1	6.0	3.9	3.9	8,928	55	1,049	6	99.4%
				2	6.0	3.0	3.0	4,879	71	744	11	98.6%
FL1	FL	1315.5	49% Class I/46% Other Waste/3% Class III/2% Ash	1	2.5	6.1	6.1	54,963	2,481	10,047	256	95.7%
				2	2.0	6.1	6.1	22,640	152	5,109	34	99.3%
FL2	FL	1322.8	MSW	1	4.5	14.4	14.4	78,115	462	6,593	26	99.4%
FL3	FL	1315.5	MSW	1	6.7	7.7	7.7	48,667	272	2,556	14	99.4%
				2	5.3	10.6	10.6	51,517	177	2,594	9	99.7%
				3	8.2	13.2	13.2	212,303	8,408	5,346	212	96.2%
FL4	FL	1338.6	MSW	1	16.5	6.5	6.5	57,014	591	1,463	15	99.0%
				2	7.5	10.4	10.4	186,662	6,175	7,630	253	96.8%
FL5	FL	1299.5		1	4.8	3.5	3.5	5,436	110	901	18	98.0%
				2	5.0	6.4	3.7	20,604	148	1,766	22	-
				3	5.0	4.1	4.1	11,795	235	1,558	31	98.0%
				4	5.0	4.1	4.1	7,659	443	1,012	59	94.5%
				5	2.2	3.4	3.4	2,378	14	879	5	99.4%
				6	2.0	3.4	3.4	2,059	5	825	2	99.8%
FL6	FL	1557.5	WTE Ash/MSW	1	1.9	4.4	4.4	137,618	314	44,837	102	99.8%
				2	1.0	8.1	8.1	37,197	573	12,597	194	98.5%
				3	2.1	39.4	39.4	404,935	2,288	13,520	76	99.4%
				4	8.3	33.8	33.8	799,944	7,152	7,788	70	99.1%
				5	0.4	29.8	29.8	26,579	758	5,903	168	97.2%
				6	3.7	27.0	27.0	594,302	4,365	16,450	121	99.3%
				7	7.8	23.0	23.0	1,489,654	9,792	22,924	151	99.3%
				8	4.5	19.0	19.0	406,130	1,684	12,990	54	99.6%
				9	1.7	15.8	15.8	97,265	562	10,171	59	99.4%
				10	1.1	12.0	12.0	81,941	454	17,227	95	99.4%

Site ID	State	Annual Rainfall (mm)	Waste Type	Combination of Cells Number	Years of Data Available	Area (hectare)		Total Leachate Collected Volume (m^3)		Leachate Collection Rate (L $ha^{-1}day^{-1}$)		Primary Liner Leachate Collection Efficiency (%)
						LCS	LDS	LCS	LDS	LCS	LDS	
				11	7.4	9.0	9.0	387,596	10,881	15,860	445	97.3%
				12	7.7	19.8	19.8	914,430	2,175	16,487	39	99.8%
				13	4.2	16.9	16.9	350,384	4,040	13,619	157	98.9%
				14	2.8	12.9	12.9	82,618	2,804	6,189	210	96.7%
FL7	FL	1325.1		1	2.0	17.4	17.4	52,977	3,531	4,187	279	93.8%
				2	7.1	4.8	4.8	52,187	319	4,238	26	99.4%
				3	8.2	4.8	4.8	28,089	631	2,079	50	97.8%
				4	7.2	4.8	4.8	46,292	792	4,106	66	98.3%
				5	7.2	4.8	4.8	45,970	882	4,030	78	98.1%
				6	4.5	24.3	24.3	31,657	1,932	796	49	94.2%
FL8	FL	1282.2	MSW	1	7.2	9.8	9.8	129,971	286	7,630	27	99.8%
FL9	FL	1326.9		1	6.7	5.5	2.2	13,168	16	1,100	3	-
				2	0.3	2.1	2.1	542	0	2,146	1	100.0%
FL10	FL	1299.5		1	4.5	59.9	59.9	108,676	2,207	1,104	22	98.0%
FL11	FL	1336.5	MSW	1	4.4	2.9	2.9	3,043	30	643	6	99.0%
				2	4.4	2.9	2.9	1,744	46	368	10	97.4%
				3	4.3	1.9	1.9	2,820	686	936	228	80.4%
				4	4.2	1.9	1.9	8,977	1,755	3,095	605	83.6%
NH1	NH	1218.4	MSW/CDD/ Industrial/Other	1	6.5	11.3	11.3	153,013	4,297	9,753	265	97.3%
				2	5.6	11.3	11.3	375,258	4,506	16,257	195	98.8%
				3	5.1	11.3	11.3	268,012	7,097	12,750	338	97.4%
				4	0.2	2.2	2.2	2,319	274	11,449	1,351	89.4%
NH2	NH	966.0	MSW/CDD/ Industrial/Other	1	10.2	8.2	8.2	149,441	5,178	4,891	169	96.7%
NH3	NH	1259.8	MSW/CDD/ Industrial/Other	1	2.5	4.8	4.8	46,103	118	10,508	27	99.7%
				2	1.0	2.0	2.0	2,404	199	3,255	269	92.4%
NH4	NH	1053.8	MSW/CDD/ Industrial/Other	1	21.0	27.3	27.3	3,636,126	371	22,359	2	100.0%
NH5	NH	1003.8	MSW/CDD/ Industrial/Other	1	4.3	2.7	2.7	21,377	569	4,928	131	97.4%
				2	4.3	8.4	8.4	51,149	2,533	4,248	223	95.3%
				3	4.3	9.0	9.0	47,869	861	3,354	60	98.2%
NH6	NH	1295.9	MSW/CDD/ Industrial/Other	1	8.8	56.7	56.7	689,636	12,989	3,811	72	98.2%
NH7	NH	1295.9	MSW/CDD/ Industrial/Other	1	8.2	20.6	20.6	23,636	1,019	380	16	95.9%
NJ1	NJ	1146.3		1	0.8	6.9	6.9	14,924	146	7,089	69	99.0%
				2	1.0	6.5	6.5	7,953	7,841	3,365	3,318	50.4%
				3	1.0	7.3	7.3	7,068	32	2,658	12	99.6%
				4	1.0	4.9	4.9	2,560	68	1,444	38	97.4%
				5	1.0	5.3	5.3	34,289	3	17,856	2	100.0%
				6	1.0	6.9	6.9	25,550	54	10,175	22	99.8%
NJ2	NJ	1242.8		1	1.0	89.2	89.2	66,655	5,916	2,047	182	91.8%
				2	2.7	17.6	17.6	82,715	10,931	4,685	619	88.3%
				3	2.8	20.0	20.0	41,194	14,358	1,999	697	74.2%
				4	3.1	4.8	4.8	29,665	3,012	5,522	561	90.8%
				5	3.5	46.9	46.9	77,232	35	1,292	1	100.0%
NJ3	NJ	1246.9		1	0.5	89.6	89.6	38,363	400	2,326	24	99.0%
NJ4	NJ	1192.5		1	1.0	9.8	9.8	30,669	135	8,544	38	99.6%

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						LCS	LDS	LCS	LDS	LCS	LDS	
				2	1.0	2.1	2.1	5,771	17	7,661	22	99.7%
				3	1.0	3.9	3.9	17,676	1	12,337	1	100.0%
NY1	NY	976.1	88% MSW/9% Contaminated Soil/2% CDD/<1% Asbestos/Sewage Sludge/Other	1	2.8	20.0	20.0	81,307	1,755	4,003	86	97.9%
				2	5.0	17.3	17.3	274,471	2,331	8,779	74	99.2%
				3	6.0	23.0	23.0	343,673	2,617	6,810	52	99.2%
				4	0.2	19.4	19.4	4,866	1,337	4,112	1,130	78.4%
NY2	NY	984.3	48-91% MSW/0-48% ASR/0-4% CDD/0-10% Industrial/0-1% Contaminated Soil/0-3% Sewage Sludge	1	3.2	7.4	7.4	39,197	1,142	4,491	131	-
				2	0.2	7.6	7.6	2,518	40	3,627	58	98.4%
				3	1.5	7.9	7.9	15,532	590	3,585	136	96.3%
				4	3.0	8.5	8.5	53,055	1,065	5,701	114	98.0%
				5	8.0	9.7	9.7	90,838	2,627	3,203	93	97.2%
NY3	NY	888.2	CCD/Industrial/ Some MSW	1	14.0	40.5	40.5	1,443,631	5,044	8,428	32	99.7%
				2	3.0	18.6	18.6	344,630	455	16,906	22	99.9%
				3	4.0	17.4	17.4	51,840	494	2,040	19	99.1%
				4	3.0	11.7	11.7	344,167	1,875	30,993	181	99.5%
				5	3.0	49.0	47.8	313,517	2,631	6,118	165	-
				6	3.0	17.4	17.4	66,646	318	3,498	18	-
NY4	NY	1073.4	MSW/CDD	1	4.0	11.9	11.9	160,992	303	11,467	20	99.8%
				2	4.0	11.9	11.9	190,726	917	11,009	53	-
				3	3.0	11.9	11.9	110,054	200	11,371	20	99.8%
				4	3.0	11.9	11.9	140,185	318	12,336	27	99.8%
				5	2.0	11.9	11.9	78,731	223	9,065	26	99.7%
NY5	NY	831.6	45-60% MSW/11-20% CDD/17-20% Industrial/0-25% Contaminated Soil	1	10.0	15.5	15.5	179,457	966	3,608	20	99.5%
				2	0.5	15.5	15.5	10,595	80	3,767	28	99.3%
				3	3.5	18.7	18.7	95,028	289	3,980	12	99.7%
				4	1.0	21.8	21.8	29,843	98	3,755	12	99.7%
NY6	NY	1174.5	CDD	1	1.0	12.3	12.3	75,489	452	16,756	100	99.4%
				2	1.0	5.3	5.3	34,113	179	17,765	93	99.5%
				3	1.0	6.9	6.9	45,576	864	18,150	344	98.1%
NY7	NY	1001.0	70% MSW/20% CDD/10% Paper Sludge	1	1.0	7.2	7.2	39,059	7	14,855	3	100.0%
				2	4.0	8.4	8.4	194,080	104	17,591	9	99.9%
NY8	NY	998.2	MSW/CDD	1	3.0	24.3	7.6	171,490	135	6,450	16	-
				2	7.0	4.9	4.9	66,185	87	5,334	7	99.9%
				3	7.0	3.0	3.0	38,152	119	4,920	15	99.7%
				4	8.0	58.7	8.1	236,234	606	3,021	43	-
				5	3.0	58.7	7.7	145,446	276	5,727	33	-
				6	1.0	58.7	7.7	59,760	143	2,790	51	-
				7	2.6	58.7	7.6	131,098	130	2,372	18	-
				8	0.4	63.5	12.4	19,191	32	1,974	17	-
NY9	NY	1260.1	60% MSW /30% CDD/10% Other	1	1.0	33.7	17.6	36,077	68	2,932	11	-
				2	1.0	20.4	20.4	57,867	140	7,788	19	99.8%
				3	1.0	20.4	20.4	50,286	111	6,768	15	99.8%
				4	10.0	20.4	20.4	359,743	1,753	4,842	24	99.5%
NY10	NY	880.9	MSW/Industrial	1	4.0	18.9	18.9	87,381	1,988	3,523	83	-

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						LCS	LDS	LCS	LDS	LCS	LDS	
				2	3.0	15.4	15.4	57,052	290	3,388	17	99.5%
				3	4.0	9.8	9.8	63,714	268	4,456	19	99.6%
				4	3.0	7.4	7.4	56,071	308	7,407	38	-
NY11	NY	1132.1	MSW	1	1.0	9.6	9.6	11,744	37	3,358	10	99.7%
				2	13.0	2.5	2.5	52,419	1,472	4,698	130	97.3%
				3	13.0	1.7	1.7	115,106	337	14,272	42	99.7%
				4	10.2	1.2	1.2	115,921	51	25,729	11	100.0%
				5	2.0	1.5	1.5	28,560	38	26,128	35	99.9%
				6	2.0	4.0	4.0	40,039	263	13,553	89	99.3%
NY12	NY	1055.9	86% MSW/13% CDD/2% Industrial/<1% Asbestos and Contaminated Soil	1	7.0	1.3	1.3	7,232	45	2,119	13	99.4%
				2	7.0	1.7	1.7	3,457	27	796	6	99.2%
				3	7.0	2.2	2.2	15,986	97	2,811	17	99.4%
				4	7.0	2.3	2.3	18,899	196	3,207	33	99.0%
				5	7.0	5.2	5.2	52,564	358	3,943	29	-
				6	6.0	2.5	2.5	31,899	413	5,900	76	98.7%
				7	2.9	15.1	15.1	49,960	418	3,414	28	99.2%
				8	6.0	24.8	24.8	170,699	1,705	3,365	33	99.0%
				9	2.8	4.4	4.4	55,626	609	12,664	139	98.9%
NY13	NY	1007.1	MSW	1	0.7	10.4	10.4	27,497	70	10,837	27	99.7%
				2	7.0	3.6	3.6	31,674	44	3,404	5	99.9%
				3	7.2	7.6	7.6	182,283	1,026	9,224	52	99.4%
				4	7.0	3.9	3.9	58,470	47	5,857	5	-
				5	7.0	2.8	2.8	136,016	198	19,037	28	99.9%
NY14	NY	1094.7	MSW/Industrial/Contaminated Soil/CDD	1	1.0	24.6	24.6	77,721	393	8,667	44	99.5%
				2	6.0	27.0	27.0	439,404	1,646	7,439	28	99.6%
				3	4.0	17.6	17.6	102,546	544	3,998	21	99.5%
				4	5.0	21.4	21.4	381,367	1,308	9,744	33	99.7%
NY15	NY	1162.6	Compost Residuals/Sludge/ MSW	1	1.0	2.9	2.9	1,193	34	1,138	33	97.2%
				2	1.0	3.2	3.2	1,652	6	1,416	5	99.6%
				3	1.0	3.9	3.9	818	28	571	20	96.7%
				4	1.0	1.4	1.4	5,989	18	11,585	34	99.7%
				5	1.0	11.9	10.0	11,589	39	2,678	11	-
				6	11.0	14.0	11.4	313,736	1,324	5,564	29	-
NY16	NY	1185.7	MSW	1	5.0	6.2	6.2	78,777	515	10,498	70	99.4%
				2	0.4	1.8	1.8	2,843	9	10,532	32	99.7%
				3	1.0	2.5	2.5	4,717	61	5,069	65	98.7%
				4	2.0	2.5	2.5	17,774	280	9,550	151	98.4%
NY17	NY	987.0	49% MSW/19% Ash/11% CDD/11% Contaminated Soil/9% Sewage Sludge/<1% Other	1	13.0	2.2	2.2	25,111	38	2,453	4	99.8%
				2	13.0	2.3	2.3	42,392	66	3,942	6	-
				3	13.0	2.0	2.0	179,385	308	18,498	32	99.8%
				4	9.0	2.0	2.0	91,607	120	13,837	18	99.9%
				5	4.0	3.1	3.1	68,071	356	15,740	81	99.5%
				6	1.0	4.0	4.0	18,974	197	12,845	133	99.0%
				7	1.0	6.1	6.1	18,999	115	8,575	52	99.4%

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						LCS	LDS	LCS	LDS	LCS	LDS	
NY18	NY	810.3	68% MSW/8% CDD/10% Ash/5% Sewage/6% Industrial/1% Asbestos/1% Contaminated Soil	1	13.0	2.7	2.7	14,823	223	1,154	17	98.5%
				2	12.0	9.9	9.9	204,760	772	4,740	18	99.6%
				3	6.0	5.3	5.3	256,201	4,986	22,237	433	98.1%
				4	2.0	10.5	10.5	71,731	4,027	16,040	1,268	94.7%
				5	13.0	2.9	2.9	15,487	29	1,115	2	99.8%
				6	13.0	3.1	3.1	19,851	301	1,341	20	98.5%
				7	13.0	2.8	2.8	36,150	9	2,764	1	100.0%
				8	13.0	3.0	3.0	32,855	425	2,284	30	98.7%
				9	13.0	6.6	6.6	98,912	540	3,160	17	99.5%
				10	13.0	4.4	4.4	30,439	74	1,464	4	99.8%
				11	13.0	10.9	10.9	112,893	585	2,186	11	99.5%
				12	2.0	35.9	35.9	79,435	1,228	3,034	47	98.5%
NY19	NY	984.3	MSW	1	1.0	7.1	7.1	5,369	122	2,077	47	97.8%
				2	1.0	4.6	4.6	2,524	28	1,512	17	98.9%
				3	2.0	11.2	11.2	23,977	359	2,927	44	98.5%
				4	4.0	16.2	16.2	123,870	374	5,386	16	99.7%
				5	6.0	19.8	19.8	246,808	1,327	5,839	31	99.5%
				6	1.0	23.2	23.2	58,360	197	6,883	23	99.7%
				7	1.0	25.1	25.1	46,993	254	5,140	28	99.5%
NY20	NY	1267.7	WTE ash/CDD	1	6.0	1.6	1.6	16,642	591	4,694	167	96.6%
				2	7.0	21.7	21.7	3,120	356	93	10	89.8%
				3	7.0	22.5	22.5	221,875	5,386	3,989	97	97.6%
				4	7.0	35.7	35.7	421,473	5,242	6,120	70	98.8%
NY21	NY	1081.3	67% MSW/13% Contaminated Soils/9% CDD/5% Ash/Sewage Sludge/<2% Other	1	1.0	5.9	5.9	16,858	28	7,887	13	99.8%
				2	4.0	3.1	3.1	16,163	51	3,599	11	99.7%
				3	1.0	6.1	6.1	12,368	10	5,582	5	99.9%
				4	4.0	3.0	3.0	30,741	137	7,347	34	-
				5	1.0	2.6	2.6	12,432	39	13,275	41	99.7%
NY22	NY	897.6	MSW/CDD/ Sludge	1	10.0	8.1	8.1	246,314	1,082	8,338	37	99.6%
				2	10.0	22.5	22.5	327,231	1,420	3,989	17	99.6%
				3	10.0	6.0	6.0	140,801	556	6,441	25	99.6%
				4	1.0	6.4	6.4	12,731	198	5,490	85	98.5%
				5	4.0	30.0	30.0	156,159	2,451	3,727	57	98.5%
NY23	NY	918.2	93% MSW/2% Sewage Sludge/2% Industrial/<1% Other	1	11.0	61.1	61.1	677,410	3,210	3,343	16	99.5%
NY24	NY	1481.6	MSW/CDD/ Sludge	1	1.0	16.7	16.8	63,935	194	10,463	32	-
				2	1.0	20.9	20.9	120,637	184	15,797	24	99.8%
				3	3.5	6.5	6.5	120,611	289	14,516	35	99.8%
				4	4.5	9.4	9.4	252,849	799	16,417	52	99.7%
				5	2.0	17.1	17.1	139,754	292	11,165	23	99.8%
				6	1.0	17.0	17.0	100,285	125	16,142	20	99.9%
NY25	NY	851.7	MSW/CDD/ Sludge	1	3.0	23.9	23.9	128,921	2,882	4,931	110	97.8%
				2	1.0	15.8	15.8	10,027	295	1,736	51	97.1%

Site ID	State	Annual Rainfall (mm)	Waste Type	Combination of Cells Number	Years of Data Available	Area (hectare)		Total Leachate Collected Volume (m^3)		Leachate Collection Rate (L $ha^{-1}day^{-1}$)		Primary Liner Leachate Collection Efficiency (%)
						LCS	LDS	LCS	LDS	LCS	LDS	
				3	5.0	51.6	51.6	308,098	3,699	3,498	49	-
				4	2.0	33.4	33.4	144,447	567	5,919	23	99.6%
				5	1.0	34.5	34.5	75,094	134	5,967	11	99.8%
				6	3.0	42.0	42.0	339,385	1,189	7,508	27	99.7%
NY26	NY	1112.3	CDD	1	6.4	7.7	7.7	49,945	174	2,772	10	99.7%
				2	2.8	8.5	8.5	111,606	678	13,067	79	99.4%
				3	1.0	5.2	5.2	24,137	25	12,667	13	99.9%
				4	5.8	12.5	12.5	381,365	547	14,447	21	99.9%
				5	6.9	19.8	19.8	351,410	4,819	7,021	96	98.6%
				6	1.0	7.2	7.2	21,955	61	8,397	24	99.7%
				7	3.8	7.3	7.3	120,635	407	11,821	40	99.7%
				8	2.0	28.2	22.3	128,200	1,189	6,217	73	-
NY27	NY	907.5	75% MSW/15% CDD/5% Contaminated Soil/2% Sludge/2% Industrial/1% Ash/<1% other	1	4.0	83.9	83.9	147,584	2,076	1,362	19	98.6%
				2	1.0	88.2	88.2	63,272	291	1,965	9	99.5%
				3	6.0	119.0	119.0	707,113	4,171	2,938	17	99.4%
				4	1.0	94.1	94.1	88,858	971	2,587	28	98.9%
NY28	NY	1112.3	Ash	1	15.0	4.6	4.3	242,405	878	10,204	37	-
				2	7.0	2.3	2.3	78,246	164	13,047	27	99.8%
NY29	NY	999.5	MSW/CDD	1	13.0	29.8	16.8	871,042	3,754	8,493	64	-
PA1	PA	1164.8		1	9.5	5.1	5.1	11,835	31	674	2	99.7%
				2	1.0	24.5	24.5	15,731	80	1,757	9	99.5%
				3	9.5	2.0	2.0	7,266	37	1,035	5	99.5%
				4	9.5	3.0	3.0	14,049	14	1,334	1	99.9%
				5	9.5	3.8	3.8	15,298	44	1,147	3	99.7%
				6	9.5	2.8	2.8	13,694	162	1,414	17	98.8%
				7	9.5	2.8	2.8	16,398	129	1,693	13	99.2%
				8	9.5	2.6	2.6	25,854	27	2,877	3	99.9%
				9	9.5	2.4	2.4	23,098	76	2,789	9	99.7%

Table S3. Leakage rate distribution comparison among cell areas at sites with a geomembrane liner (10 study landfills) versus a composite liner (7 study landfills).

Percentile	Time-Weighted-Average Leakage Rate			
	Geomembrane Primary Liner (48 Cell Areas at 10 Sites)		Composite Primary Liner (27 Cell Areas at 7 Sites)	
	L ha^{-1} day^{-1}	gal ac^{-1} day^{-1}	L ha^{-1} day^{-1}	gal ac^{-1} day^{-1}
Minimum	0.60	0.06	5.2	0.56
10th Percentile	3.0	0.32	10.7	1.1
25th Percentile	9.3	1.0	19.7	2.1
40th Percentile	26.5	2.8	28.5	3.0
Median	43.9	4.7	32.8	3.5
60th Percentile	61.6	6.6	41.2	4.4
75th Percentile	116	12.4	74.5	8.0
90th Percentile	230	24.6	239	25.5
Maximum	605	64.7	1,350	144

Figures (SI)

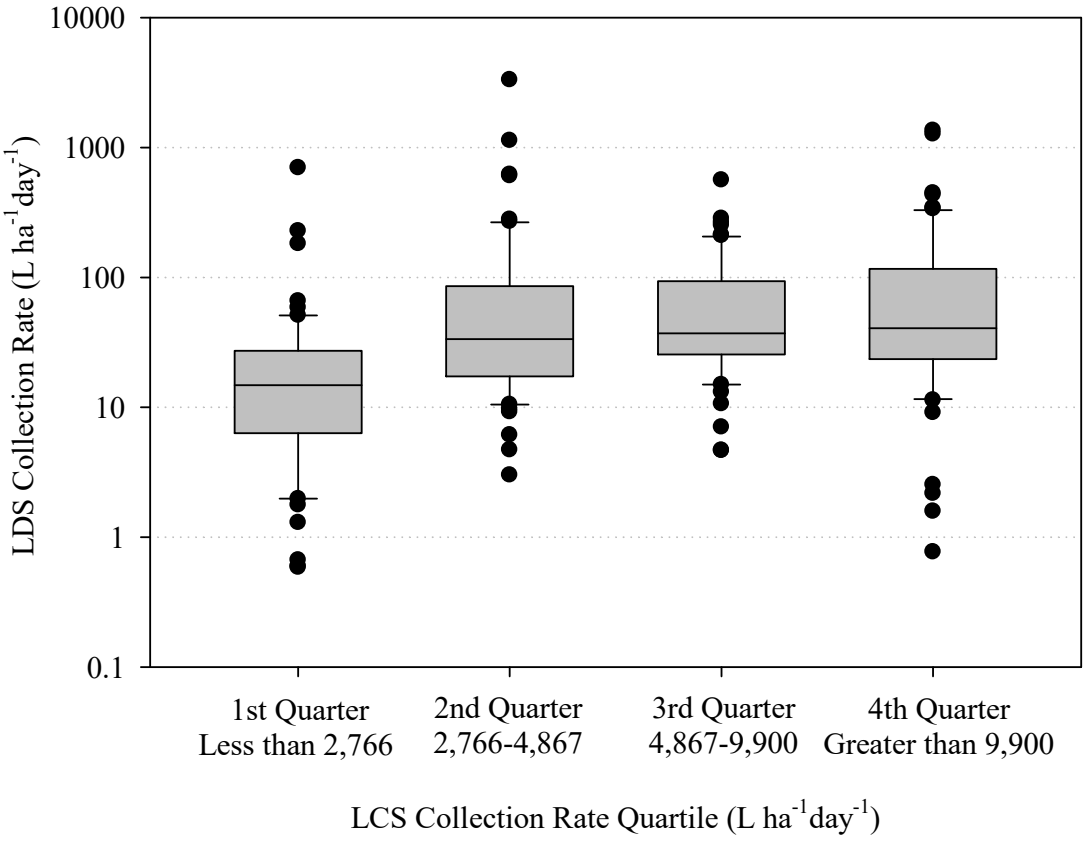

Figure S1. Distribution of the measured leakage rates from all cell areas arranged by LCS flow rate quartiles, from descending to ascending LCS flow rates.

Background on the Liner Leakage Rate Methodology used by the HELP model

The HELP model incorporates different hydrologic and landfill design-related parameters to predict the behavior of leachate within a landfill. In this case, the model was used to estimate the volume of leachate that could potentially leak into the LDS through the primary liner for each liner type in the analysis. Using equations presented in Schroeder et al. (1994), the HELP model considers three pathways to estimate the geomembrane liner leakage rate: liner vapor diffusion/transmissivity, leakage through installation defects (e.g., punctures, tears, seaming flaws), and leakage through pinholes (i.e., manufacturing defects) (US EPA 1997). In the HELP model, leakage through the geomembrane via vapor diffusion is a function of the hydraulic head on the liner, geomembrane thickness, and equivalent saturated hydraulic conductivity of the geomembrane (US EPA 1997). The model assumes that leakage from pinholes and installation defects (collectively referred to as flaws) is a function of the head over the liner, the number of flaws, flaws size, and characteristics (e.g., thickness, permeability) of the underlying layer. The equation used by the model to estimate leakage through flaws depends on whether the geomembrane is directly underlain by a high permeability layer (i.e., geomembrane liner, Figure 1A) or a low permeability layer (i.e., composite liner, Figure 1B).

For leakage through geomembrane primary liners, Giroud and Bonaparte (1989a) recommended that the HELP model use Poiseuille's equation (flow through a pipe) for leakage through pinholes and Bernoulli's equation (flow through an orifice) for leakage through defects. While liner leakage through a geomembrane primary liner underlain by a high permeability layer is simply a free-flow scenario, for composite liner conditions, a low permeability layer is in place to further impede the flow of leachate. Giroud and Bonaparte (1989b) determined that the geomembrane's contact quality with the underlying low permeability layer affected the liner's

leakage rate. As a result, Giroud and Bonaparte (1989b) developed a series of equations that accounted for the geomembrane's contact quality (perfect, excellent, good, or poor) with the underlying low-permeability layer. The HELP model assumes that good contact conditions represent about 80% of all real-world liner installations, whereas excellent and poor contact conditions represent the remaining 20% of real-world installations. All four conditions were considered in the present study. The equations used to predict the leakage rate through a geomembrane primary liner versus a composite liner suggest that a lower leakage rate would be observed in the composite liner scenario, as the geomembrane, in this case, is underlain by a low permeability layer that would further impede the flow of leachate to the LDS below. Giroud et al. (1989b) concluded that even if the contact conditions were far from perfect, this would still be the case.