ANNEXE « QC-83 »

PRODUCTION DE BIOGAZ

Tableau QC-83 : Production de biogaz - LES, Cellule 2009 et LET en m^3 / an

Année	Production LES (1988-2008)	Production Cellule 2009	Production LET (2010-2046)	Total	Émissions surfaciques LES	Production biogaz LET	% de captage	Émissions surfaciques LET	Émissions surfaciques totales	Année
2008	6 559 369	0	0	6 559 369	6 559 369	0	0%	0	6 559 369	2008
2009	6 762 741	0	0	6 762 741	6 762 741	0	0%	0	6 762 741	2009
2010	6 407 238	548 184	0	6 955 421	6 407 238	548 184	0%	548 184	6 955 421	2010
2011	6 070 423	519 367	1 027 844	7 617 634	6 070 423	1 547 211	0%	1 547 211	7 617 634	2011
2012	5 751 313	492 065	2 001 657	8 245 035	5 751 313	2 493 721	0%	2 493 721	8 245 035	2012
2013	5 448 979	466 198	2 924 278	8 839 455	5 448 979	3 390 476	0%	3 390 476	8 839 455	2013
2014	5 162 538	441 691	3 798 399	9 402 627	5 162 538	4 240 090	0%	4 240 090	9 402 627	2014
2015	4 891 154	418 472	4 626 569	9 936 195	4 891 154	5 045 041	70%	1 513 512	6 404 666	2015
2016	4 634 036	396 474	5 411 204	10 441 714	4 634 036	5 807 678	70%	1 742 303	6 376 340	2016
2017	4 390 435	375 632	6 154 593	10 920 660	4 390 435	6 530 225	70%	1 959 067	6 349 502	2017
2018	4 159 639	355 886	6 858 903	11 374 428	4 159 639	7 214 789	70%	2 164 437	6 324 075	2018
2019	3 940 975	337 178	7 526 189	11 804 342	3 940 975	7 863 367	70%	2 359 010	6 299 985	2019
2020	3 733 807	319 453	8 158 397	12 211 657	3 733 807	8 477 850	70%	2 543 355	6 277 162	2020
2021	3 537 528	302 660	8 757 372	12 597 560	3 537 528	9 060 032	70%	2 718 009	6 255 538	2021
2022	3 351 568	286 750	9 324 859	12 963 177	3 351 568	9 611 609	70%	2 883 483	6 235 051	2022
2023	3 175 383	271 676	9 862 515	13 309 574	3 175 383	10 134 191	70%	3 040 257	6 215 640	2023
2024	3 008 460	257 395	10 371 907	13 637 762	3 008 460	10 629 302	70%	3 188 791	6 197 250	2024
2025	2 850 311	243 864	10 854 522	13 948 697	2 850 311	11 098 386	70%	3 329 516	6 179 827	2025
2026	2 700 477	231 044	11 311 767	14 243 288	2 700 477	11 542 811	70%	3 462 843	6 163 320	2026
2027	2 558 518	218 899	11 744 975	14 522 392	2 558 518	11 963 874	70%	3 589 162	6 147 680	2027
2028	2 424 022	207 392	12 155 411	14 786 825	2 424 022	12 362 803	70%	3 708 841	6 132 863	2028
2029	2 296 597	196 490	12 544 271	15 037 357	2 296 597	12 740 760	70%	3 822 228	6 118 825	2029
2030	2 175 869	186 161	12 912 689	15 274 719	2 175 869	13 098 850	70%	3 929 655	6 105 524	2030
2031	2 061 488	176 375	13 261 740	15 499 603	2 061 488	13 438 115	70%	4 031 434	6 092 923	2031
2032	1 953 120	167 103	13 592 442	15 712 666	1 953 120	13 759 545	70%	4 127 864	6 080 984	2032
2033	1 850 449	158 319	13 905 761	15 914 528	1 850 449	14 064 079	70%	4 219 224	6 069 673	2033
2034	1 753 175	149 996	14 202 608	16 105 779	1 753 175	14 352 604	70%	4 305 781	6 058 956	2034
2035	1 661 014	142 111	14 483 851	16 286 976	1 661 014	14 625 962	70%	4 387 789	6 048 803	2035
2036	1 573 698	134 641	14 750 310	16 458 648	1 573 698	14 884 950	70%	4 465 485	6 039 183	2036
2037	1 490 972	127 563	15 002 761	16 621 296	1 490 972	15 130 324	70%	4 539 097	6 030 069	2037
2038	1 412 595	120 857	15 241 942	16 775 394	1 412 595	15 362 799	70%	4 608 840	6 021 434	2038
2039	1 338 338	114 504	15 468 549	16 921 391	1 338 338	15 583 053	70%	4 674 916	6 013 253	2039
2040	1 267 984	108 485	15 683 244	17 059 713	1 267 984	15 791 729	70%	4 737 519	6 005 503	2040
2041	1 201 329	102 782	15 886 653	17 190 764	1 201 329	15 989 435	70%	4 796 831	5 998 159	2041
2042	1 138 177	97 379	16 079 369	17 314 926	1 138 177	16 176 748	70%	4 853 024	5 991 202	2042
2043	1 078 346	92 260	16 261 955	17 432 561	1 078 346	16 354 215	70%	4 906 264	5 984 610	2043
2044	1 021 659	87 410	16 434 942	17 544 012	1 021 659	16 522 352	70%	4 956 706	5 978 365	2044
2045	967 953	82 815	16 598 836	17 649 604	967 953	16 681 651	70%	5 004 495	5 972 448	2045
2046	917 070	78 462	16 754 114	17 749 646	917 070	16 832 576	70%	5 049 773	5 966 843	2046
2047	868 861	74 337	16 901 230	17 844 428	868 861	16 975 567	70%	5 092 670	5 961 531	2047

A N N E X E « QC-84 »

CRITÈRES DE QUALITÉ DE L'AIR POUR CERTAINS CONTAMINANTS

CRITÈRES DE QUALITÉ DE L'AIR POUR CERTAINS CONTAMINANTS

MINISTÈTE DU DÉVELOPPEMENT DURABLE, DE L'ENVIRONNEMENT ET DES PARCS DU QUÉBEC

16 juillet 2008

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite ($\mu g/m^3$)	Colonne 2 Concentration initiale ($\mu g/m^3$)	Période
Acétone	67-64-1	8 600	170	4 minutes
Acétone	67-64-1	900	4	1 an
Acétophénone	98-86-2	100	0	1 an
Acide acrylique	79-10-7	270	0	4 minutes
Acide acrylique	79-10-7	1	0	1 an
Acrylonitrile	107-13-1	12	0	1 an
Ammoniac	7664-41-7	350	20	4 minutes
n-Amyle, acétate d'	628-63-7	25	0	4 minutes
Aniline	62-53-3	0,5	0	1 an
Antimoine métal et composés (exprimée en Sb)	7440-36-0	0,17	0,007	1 an
Argent (composés solubles, exprimé en Ag)	7440-22-4	0,23	0,005	1 an
Arsenic, élémentaire et composés inorganiques (sauf l'arsine),	7440-38-2	0,003	0,002	1 an

[1] Les numéros inscrits au regard des contaminants mentionnés à la présente annexe correspondent au code d'identification attribué par la division *Chemical Abstract Services* de l'*American Chemical Society*.

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite (µg/m^3)	Colonne 2 Concentration initiale (µg/m^3)	Période
(exprimée en As)				
Azote, dioxyde d’	10102-44-0	414	150	1 heure
Azote, dioxyde d’	10102-44-0	207	100	24 heures
Azote, dioxyde d’	10102-44-0	103	30	1 an
Baryum, métal et composés solubles (exprimée en Ba)	7440-39-3	0,05	0,025	1 an
Benzaldéhyde	100-52-7	100	0	1 an
Benzène	71-43-2	10	3	24 heures
Benzo(a)pyrène	50-32-8	0,0009	0,0003	1 an
Béryllium, métal et composés (exprimée en Be)	7440-41-7	0,0004	0	1 an
2-Butoxyéthanol	111-76-2	640	0	4 minutes
n-Butyle, acétate de	123-86-4	30	0	4 minutes
Bromoforme	75-25-2	0,9	0,01	1 an
Bromométhane	74-83-9	0,5	0,4	1 an
Cadmium, composés de (exprimée en Cd)	7440-43-9	0,0036	0,003	1 an
Carbone, disulfure de	75-15-0	50	0	4 minutes
Carbone, monoxyde de	630-08-0	34 000	2 650	1 heure
Carbone, monoxyde de	630-08-0	12 700	1 750	8 heures
Chlore, dioxyde de	10049-04-4	0,2	0	1 an
Chlorobenzène	108-90-7	2,1	0,3	1 an
Chloroéthane	75-00-3	10 900	0	4 minutes

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite (µg/m³)	Colonne 2 Concentration initiale (µg/m³)	Période
Chloroéthane	75-00-3	500	0	1 an
-Chloropropène	107-05-1	0,05	0	1 an
Chrome	7440-47-3	0,004	0,0037	1 an
Cuivre	7440-50-8	2,5	0,2	24 heures
Cumène	98-82-8	40	0	4 minutes
Cumène	98-82-8	20	0	1 an
Dibromo-1, chloro-3 propane	96-12-8	0,01	0	1 an
Dibromo-1,2 éthane	106-93-4	0,022	0,02	1 an
o-Dichlorobenzène	95-50-1	4 200	0	4 minutes
o-Dichlorobenzène	95-50-1	200	0	1 an
p-Dichlorobenzène	106-46-7	730	0	4 minutes
p-Dichlorobenzène	106-46-7	95	0	1 an
Dichlorométhane	75-09-2	14 000	6	1 heure
Dichlorométhane	75-09-2	2	1	1 an
Dichloro-1,2 propane	78-87-5	4	0	1 an
Dichloropropène	542-75-6	0,2	0	1 an
Diisobutylcétone	108-83-8	3 000	0	4 minutes
N,N-Diméthylformamide	68-12-2	6	0	1 an
Dioxines et furannes (en équivalent toxique de 2,3,7,8-T_4CDD)	1746-01-6	0,00000006	0,00000004	1 an
Épichlorohydrine	106-89-8	0,8	0	1 an
Époxy-1,2 butane	106-88-7	20	0	1 an

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite (µg/m³)	Colonne 2 Concentration initiale (µg/m³)	Période
Éthanol	64-17-5	340	0	4 minutes
Éther de bis (chlorométhyle)	542-88-1	0,000016	0	1 an
Éther de dichloroéthyle	111-44-4	0,003	0	1 an
Éther de méthyle et de butyle tertiaire	1634-04-4	150	0	1 an
Éthylbenzène	100-41-4	200	3	1 an
Éthyle, acétate d'	141-78-6	20	0	4 minutes
Éthyle-3-éthoxy, propionate d'	763-69-9	300	0	4 minutes
Éthylène, oxyde d'	75-21-8	0,01	0	1 an
Formaldéhyde	50-00-0	37	3	15 minutes
Hexachloroéthane	67-72-1	0,15	0	1 an
n-Hexane	110-54-3	35	3	1 an
Hydrogène, chlorure d'	7647-01-1	2 100	0	1 heure
Hydrogène, chlorure d'	7647-01-1	20	0	1 an
Hydrogène, sulfure d'	7783-06-4	6	0	4 minutes
Hydrogène, sulfure d'	7783-06-4	2	0	1 an
Isobutyle, acétate d'	110-19-0	35	0	4 minutes
Isobutyle, isobutyrate d'	97-85-8	440	0	4 minutes
Isopropanol	67-63-0	7 800	0	4 minutes
Mercure	7439-97-6	0,15	0,01	1 an
Méthanol	67-56-1	5 500	120	4 minutes
Méthanol	67-56-1	50	10	1 an

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite ($\mu g/m^3$)	Colonne 2 Concentration initiale ($\mu g/m^3$)	Période
Méthyl éthyl cétone	78-93-3	740	1,5	4 minutes
Méthylisobutylcétone	108-10-1	400	0	4 minutes
Méthyle, méthacrylate de	80-62-6	200	0	4 minutes
N,N-Diméthylaniline	121-69-7	2	0	1 an
Naphtalène	91-20-3	200	5	4 minutes
Naphtalène	91-20-3	3	0	1 an
Nickel, composés de	7440-02-0	6	0,25	1 heure
Nickel, composés de	7440-02-0	0,012	0,01	1 an
Nitrobenzène	98-95-3	0,55	0,05	1 an
Nitro-2 propane	79-46-9	1	0	1 an
Ozone	10028-15-6	160	130	1 heure
Ozone	10028-15-6	125	120	8 heures
Particules fines ($PM_{2,5}$)	-	30	20	24 heures
Particules totales	-	120	90	24 heures
Pentachlorophénol	87-86-5	0,8	0,5	1 an
Phénol	108-95-2	230	0	4 minutes
Phosphine	7803-51-2	0,15	0	1 an
Phosphorique, acide	7664-38-2	10	0	1 an
Plomb	7439-92-1	0,1	0,025	1 an
Propylène, oxyde de	75-56-9	3 100	0	1 heure
Propylène, oxyde de	75-56-9	0,3	0	1 an

Nature des contaminants	CAS[1]	Colonne 1 Valeur limite (µg/m³)	Colonne 2 Concentration initiale (µg/m³)	Période
Soufre, dioxyde de[2]	7446-09-5	1 050	150	4 minutes
Soufre, dioxyde de	7446-09-5	288	50	24 heures
Soufre, dioxyde de	7446-09-5	52	20	1 an
Styrène, monomère	100-42-5	150	0	1 heure
Tétrachloro-1,1,2,2 éthane	79-34-5	0,05	0,03	1 an
Trichloro-1,1,2 éthane	79-00-5	0,06	0,04	1 an
Tétrachloroéthylène	127-18-4	2	1	1 an
Tétrachlorométhane	56-23-5	1	0,07	1 an
Thallium	7440-28-0	0,25	0,05	1 an
Toluène	108-88-3	600	260	4 minutes
Trichloroéthylène	79-01-6	0,4	0,3	1 an
Triéthylamine	121-44-8	2 700	0	4 minutes
Triéthylamine	121-44-8	7	0	1 an
Vanadium	7440-62-2	1	0,01	1 an
Vinyle, acétate de	108-05-4	400	0	4 minutes
Vinyle, acétate de	108-05-4	100	0	1 an
Vinyle, chlorure de	75-01-4	0,1	0,03	1 an
Xylène (o,m,p)	1330-20-7	1 500	150	4 minutes
Xylène (o,m,p)	1330-20-7	100	8	1 an
Zinc	7440-66-6	2,5	0,1	24 heures

[2] Cette valeur limite peut être excédée jusqu'à 0,5 % du temps sur une basse annuelle, sans toutefois dépasser 1310µg/m³.

ANNEXE « QC-95 »

RAPPORT DE FORAGE DU PUITS 07P01-S

A N N E X E « QC-98 »

MONTANTS ANNUELS DE CAPITALISATION ET DE DÉCAISSEMENT AU FONDS DE GESTION POST-FERMETURE

Calcul d'une fiducie de lieu municipal (LET de Neuville)

Coût annuel de post-fermeture(CA):	271 520.00 $		
Taux d'inflation moyen en %(ti):	0.023	Contribution unitaire	1.804615362 /m3
Taux de rendement brut	0.06		
Taux de frais de gestion	0.01		
Taux de rendement net	0.05		
Marge pour écart défavorable	0.005		
Capacité totale du LET en m3:	2940000		
Durée de vie utile totale du LET(n):	37		
Volume annuel utilisé en m3(U):	79459.45946		

CT1	9 526 916.23 $	***Contribution totale pour les 30 premières années***
CT2	12 964 816.66 $	***Valeur de la contribution totale des 30 premières années***
CT3	1 149 896.34 $	***Contribution totale des 7 dernières années***
Ctotal	14 114 713.00 $	***Contribution totale après 37 années***

Coût de gestion post-fermeture (CA1) 629 796.54 $

Tableau 1 Capitalisation des fonds

Année d'exploitation	Paiement au fonds	Intérêts	Valeur du fonds
1	143 393.76 $	- $	143 393.76 $
2	143 393.76 $	7 169.69 $	293 957.21 $
3	143 393.76 $	14 697.86 $	452 048.83 $
4	143 393.76 $	22 602.44 $	618 045.03 $
5	143 393.76 $	30 902.25 $	792 341.05 $
6	143 393.76 $	39 617.05 $	975 351.86 $
7	143 393.76 $	48 767.59 $	1 167 513.22 $
8	143 393.76 $	58 375.66 $	1 369 282.64 $
9	143 393.76 $	68 464.13 $	1 581 140.53 $
10	143 393.76 $	79 057.03 $	1 803 591.32 $
11	143 393.76 $	90 179.57 $	2 037 164.65 $
12	143 393.76 $	101 858.23 $	2 282 416.64 $
13	143 393.76 $	114 120.83 $	2 539 931.23 $
14	143 393.76 $	126 996.56 $	2 810 321.56 $
15	143 393.76 $	140 516.08 $	3 094 231.39 $
16	143 393.76 $	154 711.57 $	3 392 336.73 $
17	143 393.76 $	169 616.84 $	3 705 347.32 $
18	143 393.76 $	185 267.37 $	4 034 008.45 $
19	143 393.76 $	201 700.42 $	4 379 102.63 $
20	143 393.76 $	218 955.13 $	4 741 451.53 $
21	143 393.76 $	237 072.58 $	5 121 917.86 $
22	143 393.76 $	256 095.89 $	5 521 407.52 $
23	143 393.76 $	276 070.38 $	5 940 871.66 $
24	143 393.76 $	297 043.58 $	6 381 309.00 $
25	143 393.76 $	319 065.45 $	6 843 768.21 $
26	143 393.76 $	342 188.41 $	7 329 350.38 $
27	143 393.76 $	366 467.52 $	7 839 211.66 $
28	143 393.76 $	391 960.58 $	8 374 566.01 $
29	143 393.76 $	418 728.30 $	8 936 688.07 $
30	143 393.76 $	446 834.40 $	9 526 916.23 $
31	143 393.76 $	428 711.23 $	10 099 021.22 $
32	143 393.76 $	454 455.96 $	10 696 870.94 $
33	143 393.76 $	481 359.19 $	11 321 623.89 $
34	143 393.76 $	509 473.08 $	11 974 490.73 $
35	143 393.76 $	538 852.08 $	12 656 736.58 $
36	143 393.76 $	569 553.15 $	13 369 683.48 $
37	143 393.76 $	601 635.76 $	14 114 713.00 $

Tableau 2 Détermination du montant à accumuler

Année GPF	RET-$ COU	Intérêts		
1	629 796.54 $	- $	13 484 917.37 $	
2	644 281.86 $	606 821.28 $	13 447 456.79 $	
3	659 100.35 $	605 135.56 $	13 393 492.00 $	
4	674 259.65 $	602 707.14 $	13 321 939.49 $	
5	689 767.63 $	599 487.28 $	13 231 659.14 $	
6	705 632.28 $	595 424.66 $	13 121 451.52 $	
7	721 861.82 $	590 465.32 $	12 990 055.01 $	
8	738 464.65 $	584 552.48 $	12 836 142.84 $	
9	755 449.33 $	577 626.43 $	12 658 319.94 $	
10	772 824.67 $	569 624.40 $	12 455 119.67 $	
11	790 599.63 $	560 480.39 $	12 225 000.42 $	
12	808 783.43 $	550 125.02 $	11 966 342.01 $	
13	827 385.45 $	538 485.39 $	11 677 441.95 $	
14	846 415.31 $	525 484.89 $	11 356 511.53 $	
15	865 882.86 $	511 043.02 $	11 001 671.69 $	
16	885 798.17 $	495 075.23 $	10 610 948.75 $	
17	906 171.53 $	477 492.69 $	10 182 269.91 $	
18	927 013.47 $	458 202.15 $	9 713 458.59 $	
19	948 334.78 $	437 105.64 $	9 202 229.44 $	
20	970 146.48 $	414 100.32 $	8 646 183.29 $	
21	992 459.85 $	389 078.25 $	8 042 801.68 $	
22	1 015 286.43 $	361 926.08 $	7 389 441.33 $	
23	1 038 638.01 $	332 524.86 $	6 683 328.18 $	
24	1 062 526.69 $	300 749.77 $	5 921 551.26 $	
25	1 086 964.80 $	266 469.81 $	5 101 056.26 $	
26	1 111 964.99 $	229 547.53 $	4 218 638.80 $	
27	1 137 540.19 $	189 838.75 $	3 270 937.36 $	
28	1 163 703.61 $	147 192.18 $	2 254 425.92 $	
29	1 190 468.80 $	101 449.17 $	1 165 406.29 $	
30	1 217 849.58 $	52 443.28 $	0.00 $	**Intérêts à 4.5% à partir de cette année**
			14 114 713.92 $	

A N N E X E « QC-101 »

FIGURE 1.7 CORRIGÉE

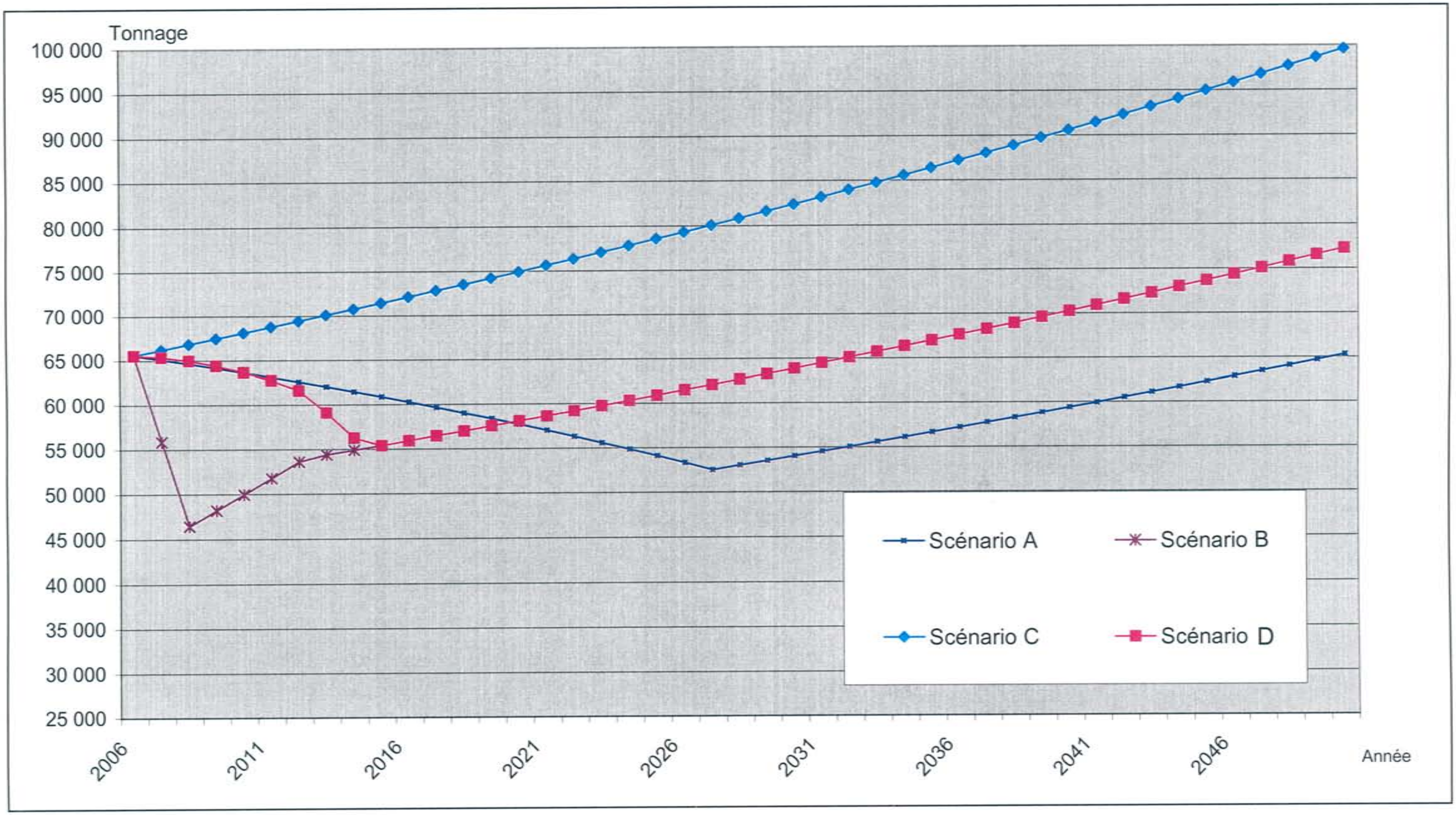


Figure 1.7. Estimation des besoins futurs en élimination pour les municipalités membres de la RRGMRP.

ANNEXE « QC-102 »

FIGURES 2.2 ET 2.3 CORRIGÉES

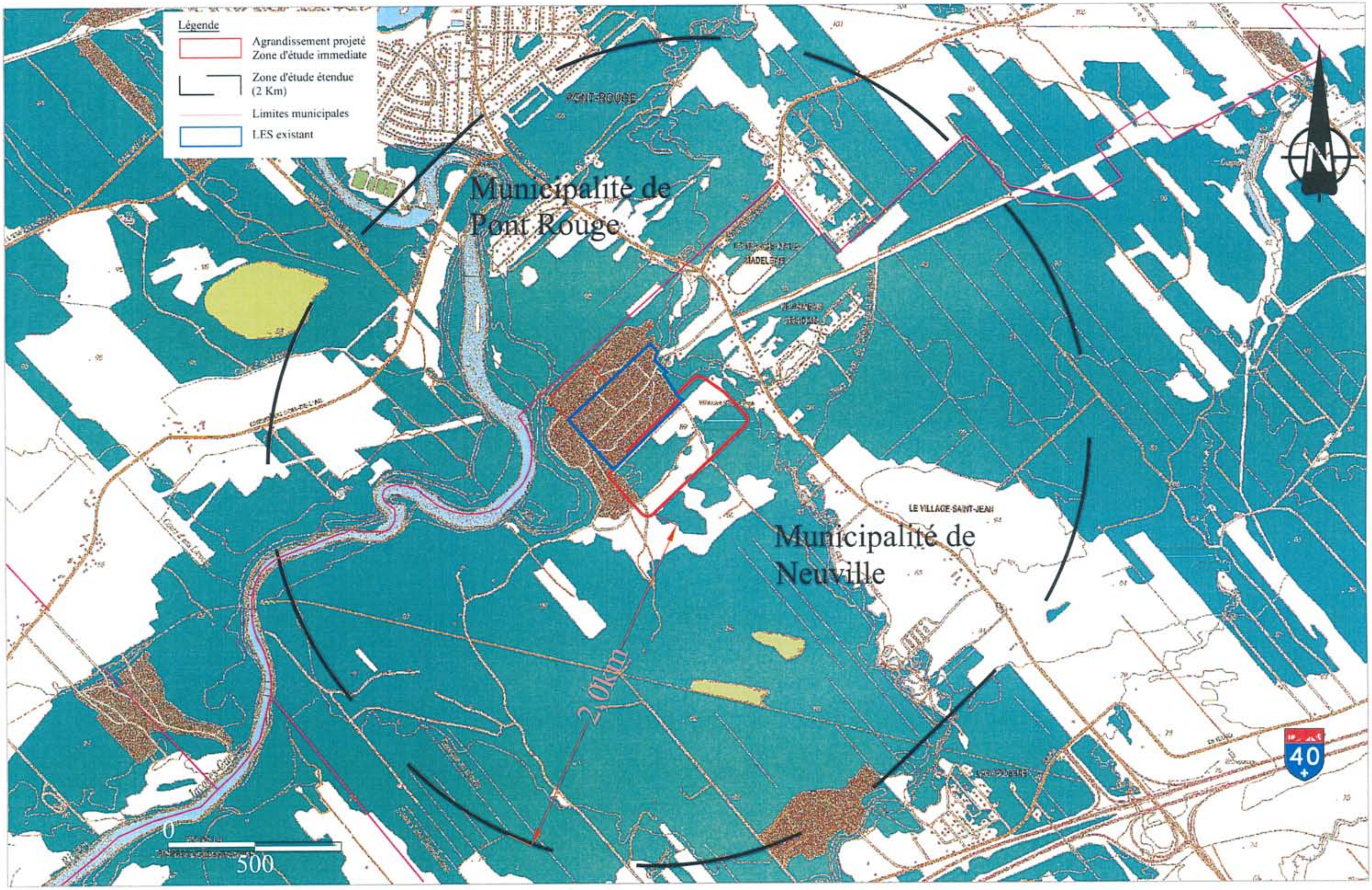


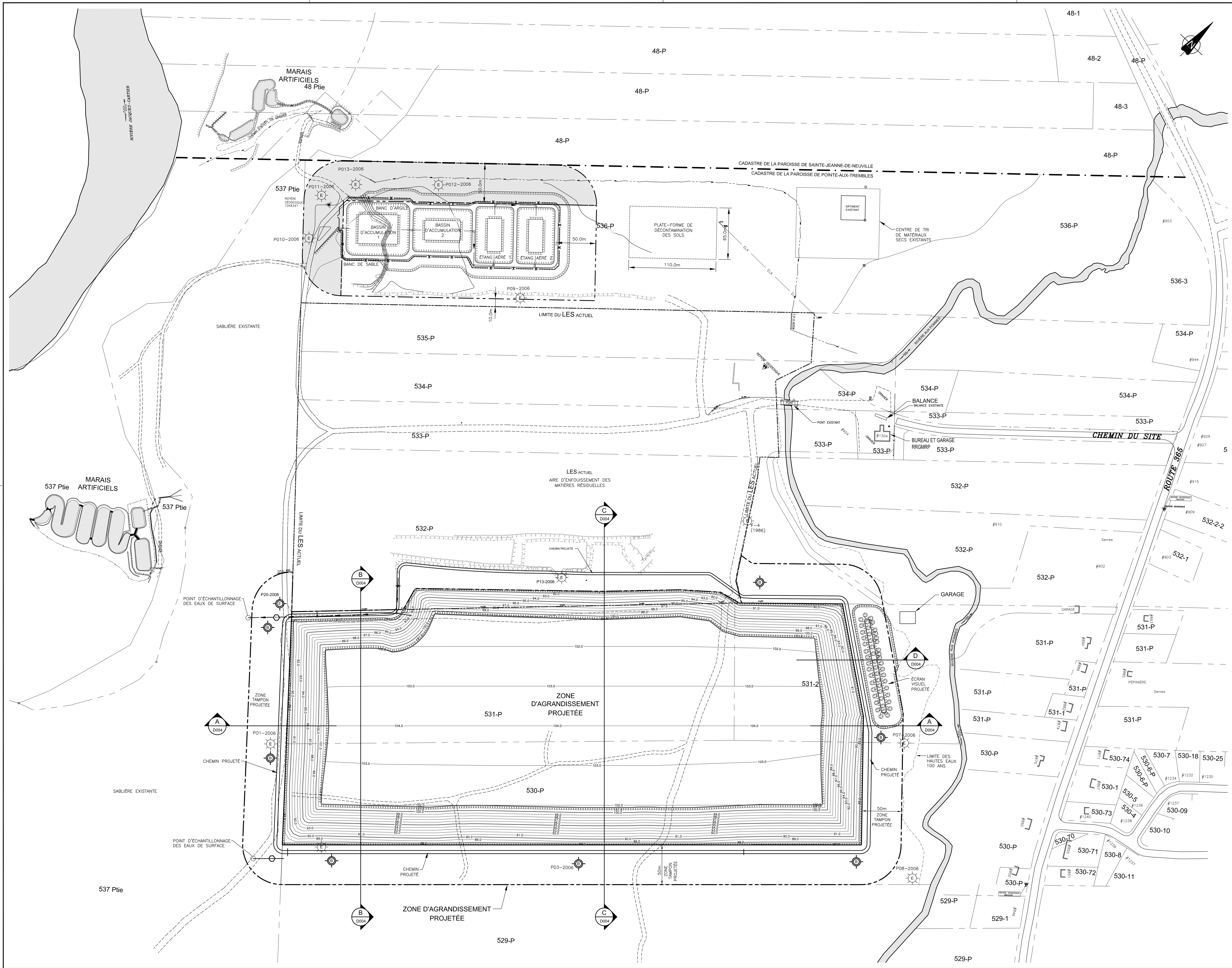
FIGURE 2.2: Carte topographique de la zone d'étude

Figure 2.3: Réseau hydrographique du secteur environnant

Source de la photo: Ministère des Ressources naturelles et de la faune, octophotographie 2000

A N N E X E « QC-103 »

PLAN 58465M137-C-D003 RÉVISÉ



FORMAT A0 metrique 1189x841

LÉGENDE

- LIMITE DU L.E.S. ACTUEL
- LIMITE DE LA ZONE D'AGRANDISSEMENT PROJETÉE
- LIGNE DE LOT
- LIMITE MUNICIPALE
- CHEMIN EN GRAVIER
- CHEMIN OU ROUTE PAVÉ
- BAS TALUS
- HAUT TALUS
- CENTRE DU FOSSÉ
- CLÔTURE
- COURBE DE NIVEAU
- ZONE TAMPON PROJETÉE
- PUITS DE SURVEILLANCE DES BIOGAZ PROJETÉ
- PUITS DE SUIVI DES EAUX SOUTERRAINES PROJETÉ
- PUITS DE SUIVI DES EAUX SOUTERRAINES EXISTANT

RÉV. / DATE D'ÉMISSION	TECH.	DESCRIPTION RÉVISIONS ET ÉMISSIONS
1 2008/07/28	D.L.	ÉMIS POUR RÉPONSE M.D.D.E.P.
0 2008/01/17	D.L.	ÉMIS POUR RAPPORT D'ÉTUDE D'IMPACT
A 2007/12/21	D.L.	ÉMIS POUR COORDINATION

SCEAUX

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PROJET
ÉTUDE D'IMPACT SUR L'ENVIRONNEMENT AGRANDISSEMENT DU LES NEUVILLE

TITRE
GÉOMÉTRIE DU RECOUVREMENT FINAL ET PUITS DE SURVEILLANCE DES EAUX SOUTERRAINES ET DES BIOGAZ

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A N N E X E « QC-107 »

FIGURE 2.27 MODIFIÉE

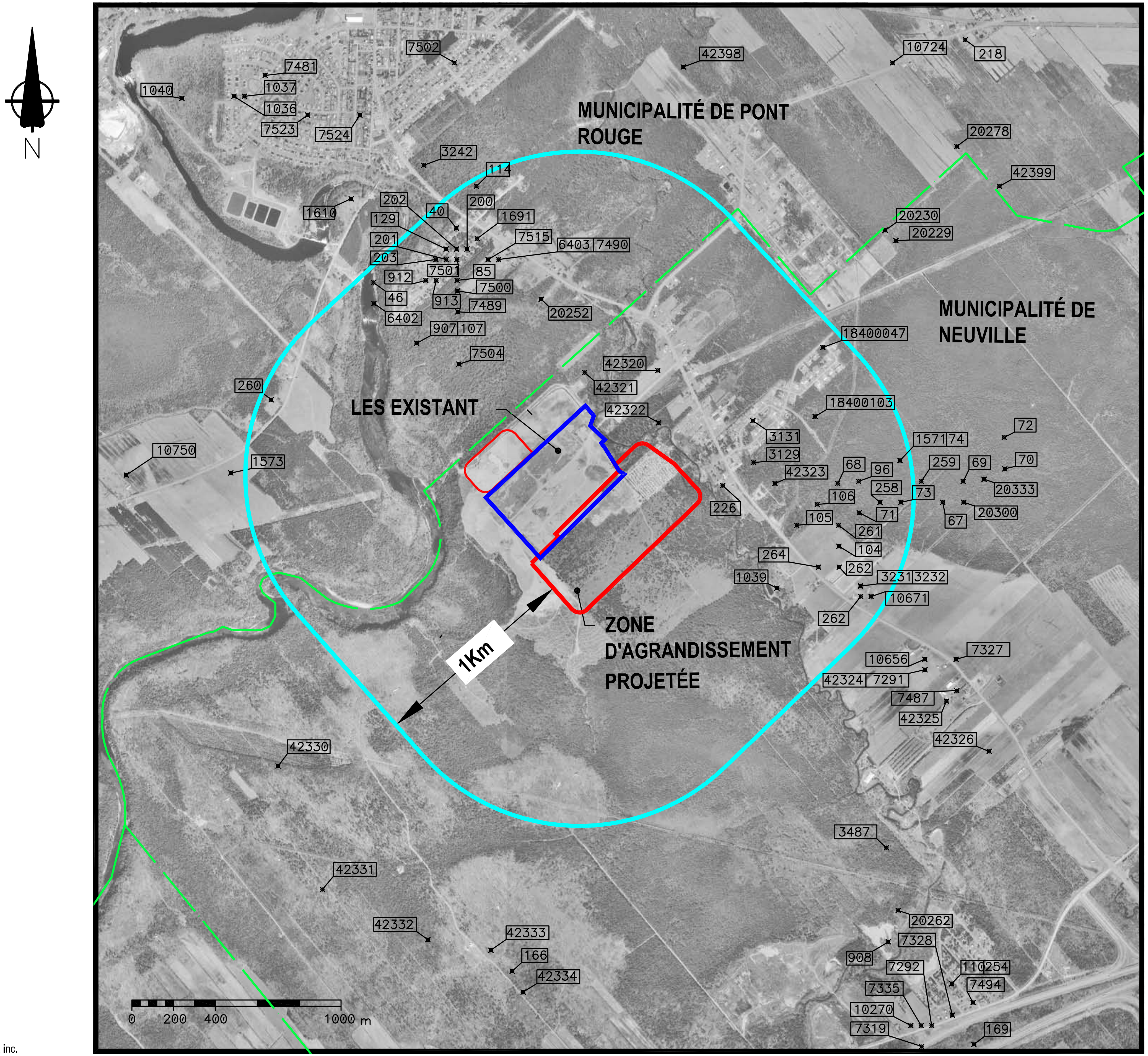

FIGURE 2.27: Localisation des puits individuels d'eau potable dans la zone d'étude étendue

LÉGENDE

- Limite du LES existant
- Limite des municipalités
- Agrandissement projeté zone d'étude immédiate
- Zone d'étude étendue
- 7327 Numéro puits

Source d'information puits: système hydrogéologique MDDEP

Source de la photo: Ministère des ressources naturelles et de la faune, ortophotographie, 2000

A N N E X E « QC-117 »

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FACT SHEET

Leachate Recirculation in Municipal Solid Waste LandfillsWith Alternative Liners Incorporating GCLs

INTRODUCTION

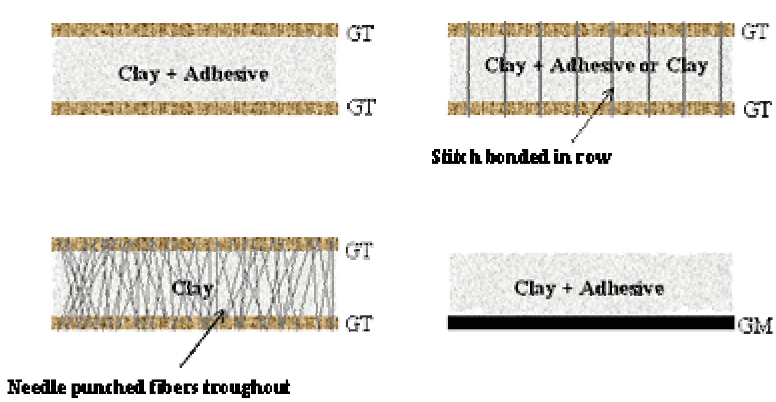
This Fact Sheet describes the manufacturing, installation, testing, design and performance of geosynthetic clay liners, or GCLs. It focuses specifically on GCLs used as the lower component of a composite liner with a flexible membrane liner (or FML) placed above. [This Fact Sheet will refer to FMLs as geomembranes (i.e., GMs)]. The GCL component of the composite liner is considered to be an alternate to the regulated low permeability compacted soil (or compacted clay liner, i.e., CCL) per 40 CFR 25.8.28(a)(2). This regulation calls for the CCL to be at least 50cm(2-ft) thick with a permeability of 1 x 10^{-7} cm/sec, or less. The alternate, in this case GCL, must be equivalent, or superior, in its performance to the CCL. The geomembrane above the GCL or CCL is not at issue and remains as being up to 2.5mm(100 mils) thick. While GCLs are equally as appropriate in final cover systems, the complete focus of this fact sheet is GCL usage in base liner systems.

MANUFACTURING

GCLs are factory manufactured barrier materials using dry bentonite in powder or granular form. Bentonite is a geologically occurring clay mineral and is well recognized for its excellent sealing effects (Madsen and Nuesch, 1995). In the U. S., the bentonite used for GCLs is sodium based and is known to be the lowest permeability of any naturally occurring mineral. Its permeability ranges from 5 x 10^{-9} cm/sec to 5 x 10^{-10} cm/sec, which is 20 to 200 times lower than the soil used for a regulatory prescribed compacted clay liner (Daniel, et al., 1997).

The bentonite is placed at approximately 4500 to 5000 g/m^2 which results in a 7 to 10 mm thick layer between geotextiles, or on a geomembrane. For the geotextile-related GCLs, the composite can be needled together or stitch bonded. For the geomembrane-related GCLs, both thick and thin geomembranes have been used. The resulting cross-sections are shown in Figure 1 where GT refers to geotextile and GM to geomembrane. As manufactured, GCLs are typically 3.5 to 5.0 m (10 to 16 feet) wide and approximately 30 m (100 ft) in length. The currently available types are given in Figure 1.

Figure 1 - Typical GCL Cross-Sections



INSTALLATION

A major advantage of GCLs over CCLs is their rapid installation. The photograph of Figure 2 illustrates the ease of placement. Adjacent GCLs rolls are installed with an overlap of approximately 220 mm (9 in.). The overlap is generally self-sealing, but can be augmented with additional bentonite in dry or paste form, see Figure 4. Due to the great attraction of water to bentonite (with subsequent swelling), the covering geomembrane must be placed before precipitation occurs, see Figure 3. Of course, this is the exact situation of an alternate base liner to which this Fact Sheet is directed, i.e., a GM/GCL composite liner.

Figure 2 - A GCL Being placed on a Side Slope

Figure 3 - Covering of a GCL by a Geomembrane thereby Forming a Composite iner, i.e., a GM/GCL Composite

TESTING

The manufacturing quality control (MQC) testing of GCLs is very well positioned insofar as ASTM test methods and standards are concerned. Table 1 illustrates that all components (bentonite, geotextiles and geomembranes) are addressed, as well as the finished product. Not only are properties and test methods covered in this standard, but also frequency of testing.

Figure 4 - Different Overlap seam Methods

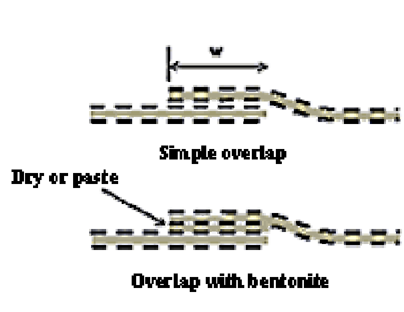


Figure 5 - Simple GCL overlap

Table 1 - Various Tests and Testing Frequencies for the Manufacturing Quality Control of GCLs, per ASTM D5889

Test Designation	Test Method	Frequency of Testing	Report Value
Clay[A]			
Free swell	D5890	One per truck or railcar but min, every 50 tonnes	Minimum Average
Fluid loss	D5891	One per truck or railcar but min, every 50 tonnes	Minimum Average
Geosynthetic Materials:			
Geotextile			
Mass per unit area	D5261	20,000 m^2 (200,000 ft^2)	Typical and MARV
Grab tensile strength (MD and CD)	D4632	20,000 m^2 (200,000 ft^2)	MARV
Geomembrane			
Mass per unit	D5261	20,000 m^2 (200,000 ft^2)	Typical and MARV
Thickness	D5199	20,000 m^2 (200,000 ft^2)	MARV
Tensile strength at break and yield (MD and CD)	D638	20,000 m^2 (200,000 ft^2)	MARV
Finished GCL[B]			
Clay mass per unit area (dried)[C]	D5993	4,000 m^2 (40,000 ft^2)	MARV
Clay Moisture Content	D4643	4,000 m^2 (40,000 ft^2)	Average Value[F]
Grab tensile strength (MD and CD)[D]	D4632	20,000 m^2 (200,000 ft^2)	MARV
Index Flux[E]	D5887	Once weekly with the last 20 values reported[G]	Minimum value

[A] The tests on the betonite are to be peformed on the as-received material before fabrication into the GCL product.
[B] Components from finished GCL product should not be seperated and tested, because the production process may alter the properties of the components.
[C] Dried betonite should be defined as 0% moisture content.
[D] This test may not be applicable for geomembrane-based GCLs.
[E] Certification letter from component manufacturer or QA from GCL manufacturer, or both. Certification letters must arrive and be checked before the components are used for the GCL production.
[F] Only for information.
[G] The last 20 values to be reported should end at the production date of supplied GCL. If the manufacturer has more production facilities or production lines, or both, the tests must be performed and reported for each line.

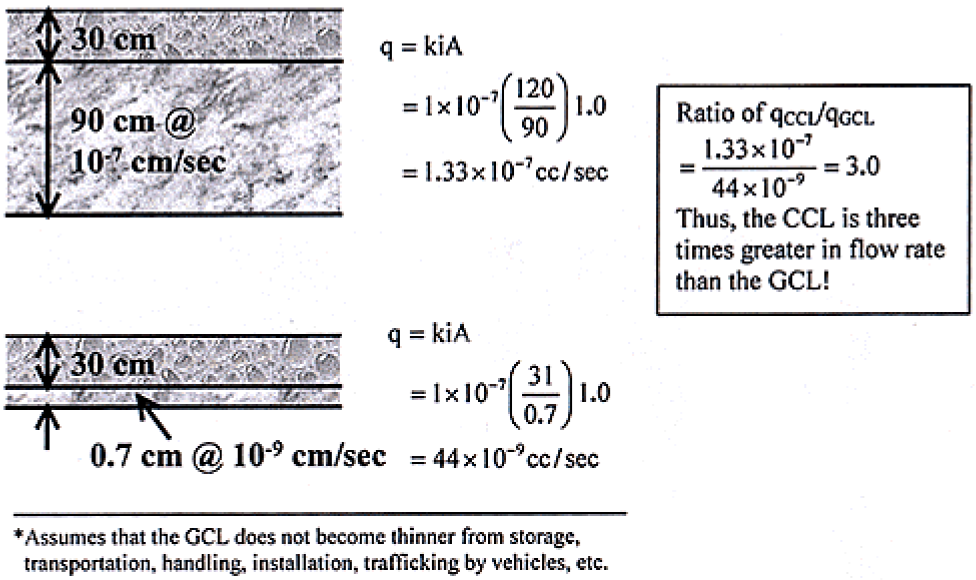
In addition to the previous MQC tests, which are often considered to be index tests, there are numerous performance tests which have been standardized by ASTM. These are presented in Table 2. Depending on the site-specific design process, some or all of these tests may be necessary.

Table 2 - Selected Design (Performance) Tests for GCLs

Property	Test Method	General Comments
Flux	ASTM D5887	• always important • should use site-specific stress and pressure conditions • should have thickness measured at end of the test so as to calculate hydraulic conductivity (permeability coefficient)
Direct Shear	ASTM D6243	• necessary for side slope designs • generally the upper interface is of main concern • sometimes internal strength is of concern • sometimes the lower interface is of concern
Creep Shear	ASTM D6243-mod.	• difficult and costly test • sometimes necessary with low factor-of-safety designs • generally the upper interface is of concern • sometimes internal strength is of concern • rarely is the lower interface required
Wide Width Tensile Strength and Elongation	ASTM D4595	• only necessary when tensile stresses are to be resisted (which is rare) • possibly necessary when shear stresses are to be resisted
Multi-Axial Tensile	ASTM D5617-mod.	• only necessary for anticipated yielding subgrade situations
Soil Compatibility, or Indentation	ASTM D5818-mod.	• for subgrades with soil particles ≥ 12 mm (0.5 in.)
Chemical Resistance	ASTM D6141	• for aggressive or reaction liquid permeants

DESIGN

Having standardized test methods (both index and performance types) available, GCL design has proceeded in an organized manner as with all other engineering materials. In this regard, one counterpoints the alternative materials (GCLs) with the traditional materials (CCLs). Critical in this regard is to compare the flux that passes through the two materials under identical conditions. The example selected is to calculate the flow rate, or flux, through the two competing materials under 30 cm (12 in.) of hydraulic head. This value of head was selected because it is the maximum leachate head allowed on the base liner system beneath a municipal solid waste landfill.



While this flux comparison speaks well for GCLs over CCLs, there are additional issues to consider. They are presented in Table 3. It will be noted that all of these issues confirm the appropriateness of using GCLs as alternate barrier materials to CCLs. In addition to the contents of the table, see Note 1 with respect to freeze-thaw behavior, and Note 2 with respect to attenuation considerations.

Table 3 - Technical Equivalency Issues of GCLs versus CCLs

Characteristic	GCLs	CCLs
Materials	Bentonite, adhesives, GTs and GMs	• Native soils, bentonite admixes
Thickness	7 to 10 mm	Typically 300 to 900 mm
Hydraulic conductivity	5×10^{-9} to 5×10^{-10} cm/sec	1×10^{-7} cm/sec
Construction deployment	Rapid and simple installation	Slow complicated construction
Regarding manufacturing quality control (MQC)	Factory manufacturing requires continuous MQC	Naturally located clay mineral materials
Regarding construction quality assurance (CQA)	Relatively simple, straightforward, common-sense procedures	Complex CQA procedures requiring detailed knowledge of clay soils and moisture/compaction relations
Vulnerability to damage due to desiccation	When dry, no concern; when wet, desiccation can occur but upon rewetting bentonite self heals	CCLs are nearly saturated and can desiccate during construction, upon rewetting little self-healing occurs
Availability of materials	Materials easily shipped to any site	Suitable materials not always available; may require expensive transportation
Typical installed cost	Approx. up to $ 10.00 per square meter for a large site	Highly variable - estimated range: up to $50.00 per square meter
Experience	Began in 1986 and use is rapidly expanding	Used successfully and unsuccessfully for many years

Note 1: Freeze-thaw cycling clearly favors GCLs over CCLs insofar as its potential susceptibility to damage is concerned. However, for base liner systems freeze-thaw issues are not of concern except during the installation period prior to covering to a frost-free depth.
Note 2: Attenuation of pollutants passing through the covering geomembrane are better adsorbed by a thick CCL than by a thin GCL. If this is a major concern, the GCL can be augmented by an underlying layer of low permeability local soil, e.g., 1×10^{-4} to 1×10^{-5} cm/sec.

This will provide attenuation and at a far more reasonable cost than a 1 x 10^{-7} cm/sec CCL.

PERFORMANCE

Since their inception in 1986, GCLs have been used in the upper base liner system of double liners with leak detection in a number of landfills. [There are 12 states requiring double liner systems for MSWLFs, Koerner, et al., 1998]. Having the underlying leak detection system as a witness drain allows for an assessment of the upper liner's performance. Fortunately, a major study has just been completed for the U. S. EPA which includes 91 landfills containing 287 single or multiple cells, Bonaparte, et al., 1999. Three different types of primary liners were involved (GM alone, GM/CCL and GM/GCL) and two types of leak detection materials (sand and geonet). Thus six combinations are available, see Table 4. Even further, data is available for three different stages during the life of the respective landfill cells (initial, active and post closure).

The above data set has been plotted in Figure 6 (for the average flow rates) so as to give a graphic representation as to the effectiveness of the GM/GCL alternate barrier system. Note that the plotted data represents the average flow rates of 287 single or multiple cells monitored for up to 10-years. Readily seen is that the alternate GM/GCL outperforms the standard GM/CCL in all cases and at every life cycle stage. Clearly, the strong absorptive capability of the bentonite in the GCLs is having a significant influence in attenuating leakage through the covering geomembranes.

Figure 6 - Leakage rates for 287 landfill cells from CR 821448/01/0 final report to US. EPA, Bonaparte, et al. 1999

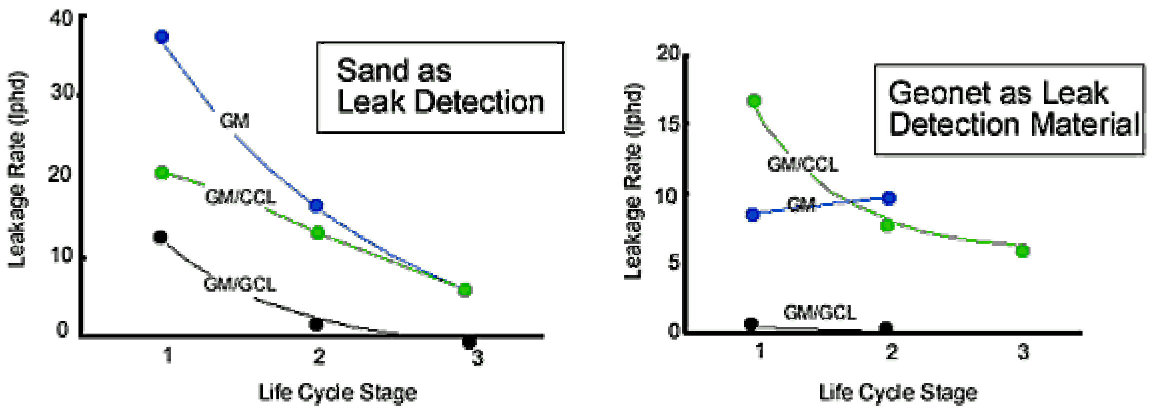


Table 4 - Leakage Rates from Leak Detection Systems of Double-Lined Landfillsfrom EPA Study CR-821448, by Bonaparte, et al., 1999
[All Flow Rates are in Gal/Acre-day (gpad)]

Liner/LDS Type	Type I (GM-Sand)			Type II (GM-GN)			Type III (GM/CCL-Sand)		
Life of Cycle Stage	1	2	3	1	2	3	1	2	3
Average Flow Minimum Flow Maximum Flow	41 0.81 229	18 0.0 158	6.8 0.02 26	10 0.51 40	11 0.15 38	ND ND ND	12 0.13 126	15 2.4 71	6.8 0.0 29
No. of "points" No. of landfills	30 11	32 11	8 4	7 4	11 6	ND ND	31 11	41 11	15 4
Liner/LDS Type	Type IV (GM/CCL-GN)			Type V (GM/GCL-Sand)			Type VI (GM/GCL-GN)		
Life of Cycle Stage	1	2	3	1	2	3	1	2	3
Average Flow Minimum Flow Maximum Flow	18 0.0 74	8.9 0.0 54	7.0 0.0 14	14 0.0 104	2.38 0.0 30	0.03 0.0 0.10	0.70 0.0 3.6	0.28 0.0 1.0	ND ND ND
No. of "points" No. of landfills	21 6	27 9	12 3	19 3	19 3	4 1	6 2	4 2	ND ND

CONCLUSION

This fact sheet has presented data and information indicating that geosynthetic clay liners (GCLs) are bona fide alternates to compacted clay liners (CCLs) used as the lower component of a composite base liner of a MSWLF. GCLs are factory manufactured materials challenged by an entire set of established ASTM standards, which also allows for a rational design methodology. By virtue of their ability to be rolled out directly upon a prepared soil subgrade or leak detection layer, their ease of installation is outstanding. All of these issues taken together lead to a very low installed cost in comparison to traditional CCLs.

In 1991 when the original EPA regulation on MSWLF liners [i.e., 40 CFR 258.28 (a)(2)] was promulgated, GCLs were in their infancy. Today, GCLs have been shown to be superior in their barrier function to CCLs. The data of Figure 5 clearly attests to this situation.

It is felt that if the technical background for Subtitle "D" regulations were developed today, the regulated cross section for MSWLF's would be a GM/GCL and not a GM/CCL! The alternate GM/GCL is clearly superior to the standard GM/CCL insofar as its barrier performance is concerned.

In conclusion, it is recommended that GM/GCL liner composites be allowed as alternates to GM/GCL liner composites in the base liner system of MSWLFs that practice leachate recycling, i.e., bioreactor landfills.

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