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CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN

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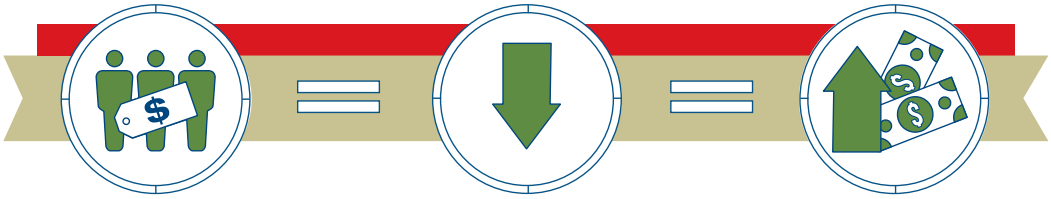

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CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN

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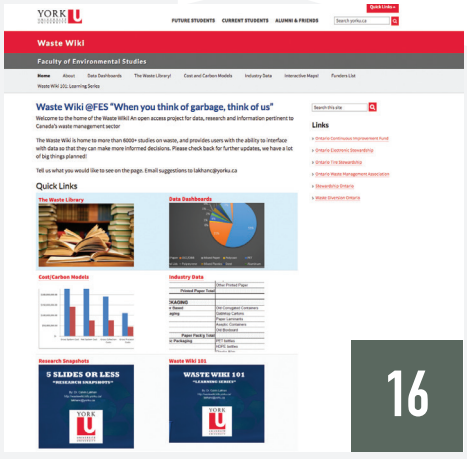

On the cover: (image, Getting Images)

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L'INGÉNIEUR CIVIL CANADIEN

CSCE/SCGC
521-300, rue St-Sacrement
Montreal, Québec H2Y 1X4
Tel.: 514-933-2634, Fax: 514-933-3504
E-mail: mahmoud.lardjane@csce.ca
www.csce.ca

PRESIDENT/PRÉSIDENTE
Glenn Hewus, P.Eng., FCSCE

MANAGING EDITOR/
DIRECTEUR DE LA RÉDACTION
Doug Picklyk
Tel.: 416-510-5119
dpicklyk@ccemag.com

ADVERTISING SALES/
PUBLICITÉ
Maureen Levy
Tel: 416-510-5111
mlevy@ccemag.com

ART DIRECTOR/
COMPOSITION ARTISTIQUE
Mark Ryan
Tel: 416-442-5600 x3541

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Annex Publishing & Printing Inc.,
111 Gordon Baker Road, Suite 400
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Tel.: 416-510-5111; Fax: 416-510-5140

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Glenn W. Hewus P.Eng., MBA, FCSCE, CGC
President, CSCE/Président de la SCGC
President@csce.ca

Stronger Through Communication

I would like to welcome Mrs. Lyanne St. Jacques to our National Office staff. Mrs. St. Jacques, director of marketing and communications, will complement the roles of Ms. Arkwright and Mr. Lardjane in our strategic initiatives. Mrs. St Jacques will provide guidance on our branding and marketing programs and assist with the launch of THE HUB. This innovative tool is expected to enhance our members' experience, provide a networking capability and provide the platform to discuss issues of the day, such as climate change, sustainability, CSCE's strategic initiatives, women in engineering and asset management to name but a few topics.

The recent Short and Medium Span Bridge conference (held every four years) and produced by CSCE was held in Quebec City. The program was a resounding success and brought together professionals from over thirty countries. Our sincere thanks to the conference organizers, volunteers, sponsors and participants in promoting civil engineering and the goals of sustainability, resiliency and innovation in the design and construction of new infrastructure.

I was truly impressed with our last issue of CIVIL wherein we were given a long overdue perspective on women in construction. It is incumbent upon all civil engineers in industry or academia to encourage, mentor, promote and engage women to succeed as practising engineers, whether it be in design, construction or even politics. The statistics of women practicing in engineering is less than 13 percent. Enrolment of women in university undergraduate programs is less than twenty percent. These statistics need to change, we must reverse the culture of education and bias in technical careers for women.

As I start the second quarter of my presidency there is much work to be done in CSCE's leadership role on issues such as promoting women in engineering, asset management, sustainability, infrastructure accessibility and promoting a Canadian infrastructure sustainability rating system. These will not be easy tasks nor can they be implemented in a single term by any one president. Communication on ideas and solutions related to the above topics will be critical and I am committed to working hard in advancing their strategic goals. To this end, I will solicit the help of CSCE's past president, president elect and senior vice president in expanding our tactical approach to CSCE's vision 2020.

As always, be seen, be heard, be relevant and be proud of our commitment to bettering the lives of others through Civil Engineering. ■

"...there is much work to be done in CSCE's leadership role on issues such as promoting women in engineering, asset management, sustainability, infrastructure accessibility and promoting a Canadian infrastructure sustainability rating system."

Plus forts par la communication

J'aimerais souhaiter la bienvenue à Mme Lyanne St. Jacques au sein de notre personnel du Bureau national. Directrice du marketing et des communications, Mme St. Jacques renforcera les rôles de Mme Arkwright et de M. Lardjane dans nos initiatives stratégiques. Mme St Jacques fournira des conseils sur nos programmes de marque et de marketing et participera au lancement du HUB. Cet outil novateur devrait améliorer l'expérience de nos membres, fournir une capacité de réseautage et servir de plateforme pour 'débattre de questions telles que le changement climatique, la durabilité, les initiatives stratégiques de la SCGC, les femmes dans l'ingénierie et la gestion d'actifs.

La Conférence sur les ponts de courte et moyen portée que la SCGC organise tous les quatre ans s'est tenue à Québec en août dernier. Le programme de la conférence a connu un succès retentissant et a réuni des professionnels de plus de trente pays. Je remercie sincèrement les organisateurs de la conférence, les bénévoles, les commanditaires, ainsi que les participants qui ont fait la promotion du génie civil et des objectifs de durabilité, de résilience et d'innovation dans la conception et la construction de nouvelles infrastructures.

J'ai été vraiment impressionné par le dernier numéro de notre revue CIVIL qui a présenté une perspective longtemps attendue sur les femmes dans la construction. Il incombe à tous les ingénieurs civils de l'industrie ou du monde universitaire d'encourager, d'encadrer, de promouvoir et d'engager les femmes afin qu'elles réussissent en tant que praticiennes, que ce soit dans la conception, la construction ou même les politiques. Les femmes constituent moins de 13% des personnes exerçant en ingénierie. Elles représentent moins de 20% des inscriptions dans les programmes universitaires de premier cycle. Ces statistiques doivent changer, nous devons inverser la culture existant dans l'enseignement et les préjugés dans les carrières techniques pour les femmes.

J'entame le deuxième trimestre de ma présidence et il y a encore beaucoup de travail à accomplir dans le leadership de la SCGC dans les domaines tels que la promotion de la présence des femmes dans l'ingénierie, la gestion d'actifs, la durabilité, l'accessibilité en infrastructures et la promotion d'un système d'évaluation de la durabilité des infrastructures. Ces tâches ne seront pas faciles et ne pourront être mises en œuvre durant un mandat de président. La communication sur les idées et les solutions liées à ces questions sera essentielle et je suis déterminé à travailler fort pour faire avancer leurs objectifs stratégiques. À cette fin, je solliciterai l'aide de la présidente sortante, du président élu et du premier vice-président de la SCGC afin d'élargir notre approche tactique de la vision 2020 de la Société.

<<… il y a encore beaucoup de travail à accomplir dans le leadership de la SCGC dans les domaines tels que la promotion de la présence des femmes dans l'ingénierie, la gestion d'actifs, la durabilité, l'accessibilité en infrastructures et la promotion d'un système d'évaluation de la durabilité des infrastructures.>>

Comme toujours, soyez vus, soyez entendus, soyez pertinents et soyez fiers de notre engagement pour l'amélioration de la vie par le génie civil. ■

Networking with Weak Links

Nicholas C. Kaminski, P. Eng., PMP, MCSCE
CSCE Young Professionals Committee Chair

Recently I was listening to a TED Talk where Tanya Menon, an organizational psychologist with Ohio State University, introduced the concept of "weak links" during her talk entitled "The secret to great opportunities? The person you haven't met yet."

Originally conceived by Mark Granovetter in "The Strength of Weak Ties," it is the idea that we typically find ourselves surrounded by like-minded people in narrow groups that may not offer new opportunities or ideas.

A weak link is an individual that at first may not seem like an ideal networking candidate because we are not familiar with them. However, over the course of time, if we remain in contact with these individuals they can provide us with vast future opportunities.

Menon's talk goes on to discuss that we need to be more intentional with expanding our networking and social circles in order to ensure that we have greater opportunities in the future.

Networking has been instrumental in my career; in fact, I obtained my current employment position entirely because of what I considered a "weak link."

I maintained contact with a senior engineer I had met through extended social circles working with a prospective firm for several years before getting invited to compete for an un-posted position.

I would not have had the opportunity to compete for the position, and ultimately obtain employment, if not for this "weak link."

Networking with people you do not know at industry events and conferences can be uncomfortable, and although networking may not produce immediate benefits, it is a powerful tool that can help your career prosper in the future.

As part of the Young Professionals Committee mandate, we seek to provide funding and support to local sections that are planning and hosting networking events for our members. The Young Professionals Committee is always happy to answer any questions you may have and to provide assistance whenever it can. Contact information for our members can be found on the CSCE's website.

kaminski.nick@icloud.com ■

Réseauter avec des maillons faibles

Nicholas C. Kaminski, P.Eng., PMP, MSCGC
Président, Comité des jeunes professionnels de la SCGC

Récemment, j'écoutais une présentation TED intitulée «Le secret des grandes opportunités? La personne que vous n'avez pas encore rencontrée». Tanya Menon, une psychologue organisationnelle de l'Ohio State University, présentait le concept des «maillons faibles».

Conçu à l'origine par Mark Granovetter dans «La force des liens faibles», il s'agit de l'idée que nous nous trouvons généralement entourés de personnes partageant les mêmes idées dans des groupes restreints qui n'offrent peut-être pas de nouvelles opportunités ou idées.

Un lien faible est une personne qui, au début, ne semble pas être un candidat idéal pour le réseautage parce que nous ne sommes pas familiers avec elle. Cependant, si nous restons en contact avec cette personne, avec le temps elle peut nous fournir de vastes opportunités d'avenir.

Tanya Menon poursuit en affirmant que nous devons élargir notre réseau et nos cercles sociaux afin de nous assurer d'avoir de meilleures opportunités.

Le réseautage a été déterminant dans ma carrière. En fait, j'ai obtenu mon emploi actuel grâce à une personne que je considérais comme un «maillon faible».

J'ai maintenu le contact avec un ingénieur expérimenté que j'avais rencontré dans des cercles sociaux élargis alors que je travaillais depuis plusieurs années aavant d'être invité à concourir pour un poste non affiché.

Je n'aurais pas eu l'occasion de postuler et d'obtenir cet emploi, si ce n'était pour ce «maillon faible».

Le réseautage avec des personnes que vous ne connaissez pas dans des événements de l'industrie et des conférences peut être inconfortable, et même si le réseautage ne produit pas d'avantages immédiats, il s'agit d'un outil puissant qui peut aider votre carrière à prospérer.

Dans le cadre du mandat du Comité des jeunes professionnels, nous cherchons à fournir du financement et du soutien aux sections locales qui planifient et organisent des activités de réseautage pour nos membres. Le comité est toujours heureux de répondre aux questions que vous pourriez avoir et de vous aider chaque fois que possible. Les coordonnées de nos membres sont disponibles sur le site Web de la SCGC.

kaminski.nick@icloud.com ■

New Academic Year, New Challenges, New Opportunities

Charles-Darwin Annan, Ph.D., P.Eng., MCSCE
Chair, CSCE Student Affairs Committee

A new academic year is here and on behalf of the CSCE Student Affairs Committee, I would like to extend a warm welcome to all civil engineering students across Canada.

Throughout the school year, you will be engrossed in your studies to acquire very important engineering skills to earn your degrees and diplomas. But let me remind you that equally important, and not typically covered in our classroom curricula, are personal development (e.g. leadership, goal setting, self reliance, can-do attitude, etc.) and professional development (e.g. teamwork, interpersonal relationship, project management, ethical behaviour, etc.). Many aspects of these personal and professional matters are the very reason why you will find joining a CSCE student chapter worth your while (membership is FREE).

If there is no student chapter in your school, START ONE; the Student Affairs Committee is here to assist you, and there are also useful resources available on our website (www.csce.ca/committees/student-affairs/) to help new and existing student chapters.

I can guarantee that your active participation in your student chapter will help you enrich yourself and begin making those lifelong professional contacts.

This year, we will focus on building and strengthening inter-chapter interactions using social media. Some student leaders who attended the chapter leaders' workshop in Fredericton, NB, in June have started working to build the required platform to launch this interesting initiative. Remember CSCE student chapters are for students to lead, set their own goals, plan and execute.

I would like to take this opportunity to express my profound gratitude to Professors Paul Thurston (BCIT), Yi Liu (Dalhousie University) and Tirupati Bolisetti (University of Windsor) for their contribution to Student Affairs in the last five years. And I would also like to welcome Professors Alan Lloyd (University of New Brunswick), John Adam Gales (York University), Saber Moradi (Ryerson University) and Ali Imanpour (University of Alberta) as new members.

Dr. Charles-Darwin Annan is an associate professor of civil engineering at Université Laval and can be reached at Charles-darwin.annan@gci.ulaval.ca. ■

Nouvelle année universitaire, nouveaux défis, nouvelles opportunités

Charles-Darwin Annan, Ph.D., P.Eng., MSCGC
Président du comité des affaires étudiantes de la SCGC

Une nouvelle année universitaire est ici. Au nom du Comité des affaires étudiantes de la SCGC, je souhaite la bienvenue à tous les étudiants en génie civil du Canada.

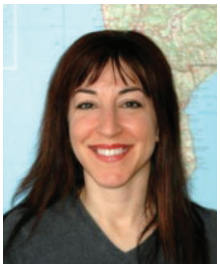
Tout au long de l'année universitaire, vos études vous permettront d'acquérir des compétences techniques très importantes pour l'obtention de vos diplômes. Mais permettez-moi de vous rappeler que le développement personnel (leadership, établissement d'objectifs, confiance en soi, attitude positive, etc.) et le développement professionnel (travail en équipe, relations interpersonnelles, gestion de projets, comportement éthique, etc.) sont tout aussi importants. De nombreux aspects de ces questions personnelles et professionnelles sont la raison même pour laquelle vous trouverez que vous joindre à un chapitre étudiant de la SCGC vous sera très bénéfique (l'adhésion est GRATUITE).

S'il n'y a pas de chapitre étudiant dans votre établissement, CRÉEZ-EN UN. Le comité des affaires étudiantes est là pour vous aider. De plus, des ressources utiles sont disponibles sur notre site Web (www.csce.ca/committees/student-affairs/) pour aider les chapitres étudiants nouveaux et existants.

Cette année, nous nous concentrerons sur la mise en place et le renforcement des interactions entre les chapitres par le biais des médias sociaux. Certains dirigeants étudiants qui ont participé à l'atelier des dirigeants des chapitres étudiants à Fredericton, au Nouveau-Brunswick, en juin, ont commencé à travailler à la création de la plateforme requise pour lancer cette initiative intéressante. Rappelez-vous que les chapitres étudiants de la SCGC sont là pour que les étudiants définissent, planifient et réalisent leurs propres objectifs.

J'aimerais profiter de cette occasion pour exprimer ma profonde gratitude aux professeurs Paul Thurston (BCIT), Yi Liu (Université Dalhousie) et Tirupati Bolisetti (Université de Windsor) pour leur contribution aux affaires étudiantes des cinq dernières années. Je voudrais également souhaiter la bienvenue aux nouveaux membres, les professeurs Alan Lloyd (Université du Nouveau-Brunswick), John Adam Gales (Université York), Saber Moradi (Université Ryerson) et Ali Imanpour (Université de l'Alberta).

Le Dr Charles-Darwin Annan est professeur agrégé en génie civil à l'Université Laval. Charles-Darwin.annan@gci.ulaval.ca. ■



Recent Highlights from the Vancouver Island Section

Caterina Valeo, Ph.D., P.Eng.
Vice President, Western Region

The Victoria Section of the Western Region is continuing to grow along with the very active Vancouver, Edmonton and Calgary sections. Victoria, and Vancouver Island in general, are gaining greater presence in the CSCE in part through the CSCE student chapter at the University of Victoria.

Only a few years old, this Chapter, and the Civil Engineering Undergraduate Degree program at the University of Victoria, have been hosting events to engage and connect with the Civil Engineering community on Vancouver Island. On June 20, 2018, the CSCE University of Victoria Student Chapter held an industry-student mixer with over 80 people attending and 30 different industry representatives.

The mixer theme was on the challenges and opportunities of partnering with Indigenous communities. Eli Enns who is the CEO of Cleantech Community Gateway (CTCG) shared his extensive experience in working with Indigenous Nations across Canada. CTCG is a non-profit organization that is dedicated to the development and deployment of clean technology solutions within remote communities in BC. Enns, from the Tla-o-qui-aht Nation on the West Coast of Vancouver Island, spoke on how he uses his western-style university education with his traditional Nuu-chah-nulth knowledge to develop effective solutions for these remote communities. For information please see, https://csce.engr.uvic.ca and https://m.facebook.com/UVicCSCEASCE/.

The 1st International Conference on New Horizons in Green Civil Engineering (NHICE-01) was held at the University of Victoria from April 25–27, 2018. The conference, which included several workshops, was organized by the University of Victoria and co-sponsored by BC Housing. NHICE-01 was attended by over a hundred academics, students, industry representatives and other stakeholders coming from Asia, Europe, the Middle East and North America.

Workshop sessions were based on three major themes: Passive House and Energy Systems; Resilient Infrastructure and Construction Technologies; and Building Envelopes. The technical papers, presentations and discussions held during the conference highlighted the impacts of climate change and mitigation strategies for Civil Engineering construction; future technologies, materials and methods for next-generation Civil Engineering construction that is sustainable and resilient; and recent developments in green buildings, wood engineering, smart buildings, intelligent structures, sustainable cities, environmental engineering and water resources.

Over 70 peer reviewed papers form the conference were published and are available online at https://nhice.engr.uvic.ca. The next conference (NHICE-02) is tentatively scheduled to be held in April 2020. More detailed information regarding the organization of NHICE-02 and the venue will be announced at the beginning of 2019. For further queries, please contact nhice@uvic.ca. ■

Récents faits marquants de la section de l'Île de Vancouver

Caterina Valeo, Ph.D., P.Eng.
Vice-présidente, Région de l'Ouest

La section de Victoria de la région de l'Ouest continue de croître avec les sections très actives de Vancouver, d'Edmonton et de Calgary. Victoria, et l'île de Vancouver en général, gagnent une plus grande présence au sein de la SCGC en partie grâce au chapitre étudiant de la SCGC de l'Université de Victoria. Datant d'à peine quelques années, ce chapitre a organisé en collaboration avec le programme de premier cycle en génie civil de l'Université de Victoria des événements pour engager la communauté du génie civil de l'île de Vancouver. Le 20 juin 2018, le chapitre étudiant de l'Université de Victoria a tenu une table ronde avec plus de 80 participants et 30 représentants de l'industrie. Le thème portait sur les défis et les opportunités de partenariat avec les communautés autochtones. Eli Enns, chef de la direction de Cleantech Community Gateway (CTCG), a partagé sa vaste expérience de travail avec les nations autochtones du Canada. CTCG est un organisme à but non lucratif qui se consacre à l'élaboration et la mise en œuvre de solutions de technologies propres dans les collectivités éloignées de la Colombie-Britannique. Eli Enns, de la nation Tla-o-qui-aht sur la côte ouest de l'île de Vancouver, a expliqué comment il utilise sa formation universitaire de style occidental avec ses connaissances traditionnelles des Nuu-chah-nulth pour élaborer des solutions efficaces pour ces communautés éloignées. Pour plus d'informations, consultez https://csce.engr.uvic.ca et https://m.facebook.com/UVicCSCEASCE/.

La première conférence internationale sur les nouveaux horizons en génie civil vert (NHICE-01) a eu lieu à l'Université de Victoria du 25 au 27 avril 2018. La conférence, qui comprenait plusieurs ateliers, a été or-

ganisée par l'Université de Victoria et coparrainée par BC Housing. Plus d'une centaine d'universitaires, d'étudiants, de représentants de l'industrie et d'autres parties prenantes provenant d'Asie, d'Europe, du Moyen-Orient et d'Amérique du Nord ont participé au salon NHICE-01. Les ateliers étaient basés sur trois thèmes principaux: Maison passive et systèmes énergétiques; Infrastructure résiliente et technologies de la construction; et Enveloppes de bâtiment. Les communications techniques, les présentations et les discussions ont mis en évidence les impacts du changement climatique et des stratégies d'atténuation pour la construction en génie civil; les technologies, les matériaux et les méthodes pour la prochaine génération de la construction durable et résiliente; et les développements récents dans les bâtiments écologiques, l'ingénierie du bois, les bâtiments et les structures intelligents, les villes durables, l'ingénierie environnementale et les ressources en eau. Plus de 70 communications examinées par des pairs ont été publiées et sont disponibles en ligne à https://nhice.engr.uvic.ca. La prochaine conférence (NHICE-02) est provisoirement prévue en avril 2020. Des informations plus détaillées concernant son organisation et le lieu seront annoncées début 2019. Pour toute autre question, veuillez contacter nhice @uvic.ca. ■

Meeting Seismic Design Requirements with the new Masonry Design Standard CSA 304-14

Mahmoud Lardjane,
Programs Director

Montreal, Quebec, Moncton – November 12-15, 2018

This course will provide a detailed overview of the new changes to the 2014 edition of the CSA S304. These changes are viewed as a substantial improvement to the 2004 standard. Design and detailing examples will be presented that illustrate how masonry seismic design has evolved to meet the requirements of the 2015 NBCC and how these changes will once again facilitate loadbearing masonry in post-disaster structures.

It is presented by Bennett Banting, Ph.D., P.Eng., the Masonry Research and Development Engineer at the Canada Masonry Design Centre (CMDC). Bennett's Ph.D. thesis contributed directly to several major changes to the new seismic design chapter of 2014 CSA S304. He is recipient of several awards and served as Chair of the Technical Committee for the 13th Canadian Masonry Symposium (2017).

Participants will obtain CEUs or PDHs for each presentation they attend.

Please visit www.csce.ca for full details and registration.

Continued on page 25

Satisfaire aux exigences de conception sismique avec la nouvelle norme de conception de maçonnerie CSA 304-14

Mahmoud Lardjane,
Directeur des programmes

Montréal, Québec, Moncton - du 12 au 15 novembre 2018

Formation offerte en anglais

Ce cours fournira un aperçu détaillé des nouveaux changements apportés à l'édition 2014 de la norme CSA S304, qui sont considérés comme une amélioration substantielle par rapport à la norme de 2004. Des exemples de conception et de détails illustrant comment la conception sismique de la maçonnerie a évolué pour répondre aux exigences du CCNB 2015 et comment ces changements faciliteront à nouveau la maçonnerie porteuse dans les structures post-catastrophe seront présentés.

Il est présenté par Bennett Banting, Ph.D., ing., Ingénieur en recherche et développement en maçonnerie du Centre canadien de la maçonnerie (CMDC). Sa thèse de doctorat a contribué directement à plusieurs changements majeurs apportés au nouveau chapitre sur la conception sismique de la norme CSA S304 de 2014. Il a reçu plusieurs prix et a présidé le comité technique du 13e symposium canadien sur la maçonnerie (2017).

Veuillez visiter www.csce.ca pour tous les détails et pour vous inscrire.

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LANDFILL OR WASTE-TO-ENERGY TECHNOLOGY? CVRD ASKS "WHAT IS BEST FOR OUR FUTURE?"

Morrison Hershfield

The cost of operating landfills and the environmental concern is causing municipalities and regional districts to evaluate their approach to waste management. With so many existing and emerging waste technologies, it's a big job deciding what is the most practical, cost-effective and environmentally friendly plan for the future.

Morrison Hershfield met with the Comox Valley Regional District (CVRD) Select Committee (BC, Canada) in April, 2018 to present the findings of a research study to determine the most cost-effective solution for the future management of residual waste in the Regional District.

Comox Lake, located near the Comox Valley Waste Management Centre.

The Options

The study involved a review of solutions available to CVRD to alleviate the rising costs of landfilling and environmental effects over the short and long term. The focus was on the residual waste stream that is currently landfilled. With recycling and composting already being optimized, the CVRD requested that Waste-to-Energy (WtE) options be considered. WtE has the potential to provide the most diversion from landfill. Our study evaluated several WtE technologies, including:

- Conventional combustion systems.
- Gasification and pyrolysis technologies.
- Refuse Derived Fuel (RDF).

Conventional combustion is the traditional form of WtE and involves the incineration of waste with the subsequent recovery of energy in the form of heat or steam for making electricity. Note: while this technology was carried through the evaluation process for comparative purposes, the CVRD decided early on in the process that conventional combustion should not be considered due to its relatively high costs and the potential for public concerns about a smoke stack in the community.

Gasification and pyrolysis technologies are advanced thermal recovery methods, first converting the waste into burnable gases or liquids, and then using these to generate electricity or as feedstock for chemical processes.

RDF technologies process various waste types to produce a homogeneous material that can be sold to third parties as fuel. An example of this is using RDF in cement kilns to offset the use of coal.

At the end of the analysis, three technologies were shortlisted for further analysis; a traditional combustion WtE, and two Mixed Waste Processing Facilities (MWPF) that produced RDF/fuel pellets for combustion by third parties. The MWPF also increased recycling, and one of the technologies included pyrolysis of plastics into diesel fuel.

Working closely with the CVRD, Morrison Hershfield established evaluation criteria specific to client needs and priorities. These technologies were then modeled in terms of costing and waste reduction based on their contribution to diversion. The analysis was conducted

Images courtesy Morrison Hershfield

TECHNIQUE D'ENFOUISSEMENT OU DE VALORISATION ÉNERGÉTIQUE? LE CVRD SE DEMANDE LAQUELLE EST LA MEILLEURE POUR NOTRE AVENIR?

Morrison Hershfield

Le coût d'exploitation des décharges et la préoccupation environnementale incitent les municipalités et les districts régionaux à évaluer leur approche en matière de gestion des déchets. Avec tant de technologies existantes et émergentes en matière de déchets, décider quel plan sera le plus pratique, le plus rentable et le plus écologique pour l'avenir constitue une grande tâche.

Morrison Hershfield a rencontré le Comité spécial du District régional de Comox Valley (CVRD) de Colombie-Britannique en avril 2018 pour lui présenter les résultats d'une étude visant à déterminer la solution la plus rentable pour la gestion future des déchets résiduels dans le District régional.

Les options

L'étude comportait un examen des solutions disponibles au CVRD afin d'atténuer les coûts croissants de la mise en décharge et des effets environnementaux à court et à long terme. L'accent était mis sur le flux de déchets résiduels actuellement mis en décharge. Le recyclage et le compostage étant déjà optimisés, le CVRD a demandé que les options de valorisation énergétique (VE) soient prises en compte. La VE a le potentiel d'éviter le plus le recours à la décharge. Notre étude a évalué plusieurs technologies VE, notamment:

- Systèmes de combustion conventionnels
- Technologies de gazéification et de pyrolyse
- Combustible dérivé des déchets (CDD)

La combustion conventionnelle est la forme traditionnelle de VE et implique l'incinération des déchets avec la récupération ultérieure d'énergie sous forme de chaleur ou de vapeur pour produire de l'électricité. Note: bien que cette technologie ait été utilisée dans le processus d'évaluation à des fins de comparaison, le CVRD a décidé très tôt que la combustion conventionnelle ne devrait pas être envisagée en raison de ses coûts relativement élevés et des préoccupations potentielles du public à propos des cheminées au sein de la communauté.

Les technologies de gazéification et de pyrolyse sont des méthodes avancées de récupération thermique, qui convertissent d'abord les déchets en gaz ou en liquides combustibles, puis les utilisent pour produire de l'électricité ou comme matière première pour les processus chimiques.

Les technologies CDD traitent différents types de déchets pour produire un matériau homogène pouvant être vendu à des tiers comme combustible. Un exemple est l'utilisation du CDD dans les fours à ciment pour compenser l'utilisation du charbon.

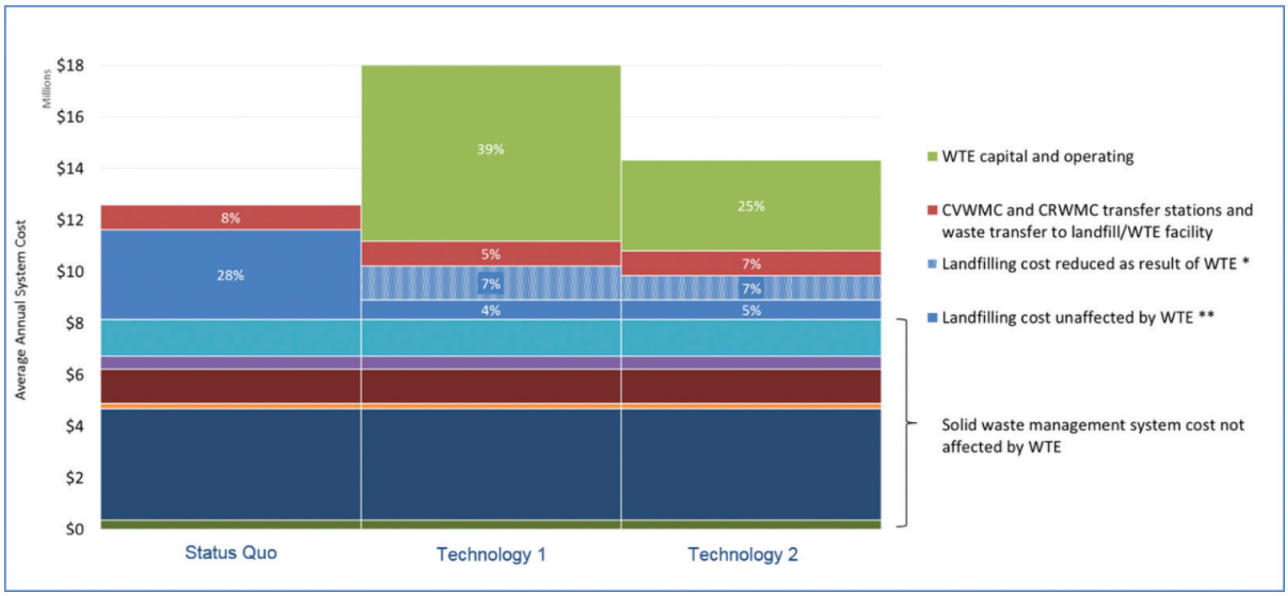
À la fin de l'analyse, trois technologies ont été retenues pour une analyse plus approfondie. Une combustion traditionnelle VE et deux installations de traitement des déchets mixtes (ITDM) produisant des pastilles CDD / combustibles pour utilisation par des tiers. Le MWPF a également augmenté le recyclage et l'une des technologies incluait la pyrolyse des plastiques en carburant diesel.

Travaillant en étroite collaboration avec le CVRD, Morrison Hershfield a établi des critères d'évaluation spécifiques aux besoins et aux priorités du client. Ces technologies ont ensuite été modélisées en termes de coût et de réduction des déchets en fonction de leur contribution au détournement. L'analyse a été menée dans le cadre d'une analyse des coûts complète et comparée au statu quo de la mise en décharge et du recyclage. La VE conventionnelle avec combustion n'a pas été modélisée, car elle n'était plus considérée.

Les résultats de la modélisation ont été présentés au comité des parties prenantes de CVRD en personne et les commentaires ont été intégrés dans une analyse élargie des coûts complets du système de gestion des déchets.

Les résultats

À l'heure actuelle, le statu quo est encore plus rentable pour le CVRD que l'utilisation de l'une des technologies de remplacement. Cependant, certaines technologies présentent un grand potentiel lorsque les coûts pourront être mieux définis et les marchés des produits confirmés. La présentation a donné aux directeurs du District région-



Average Annual System Cost Graph (CRWMC-Campbell River Waste Management Centre; CVWMC-Comox Valley Waste Management Centre)

in the context of a full cost analysis and compared to the status quo of landfilling and recycling. Conventional WtE with combustion was not modeled, since it was no longer being considered.

Modeling outcomes were presented to the CVRD stakeholder committee in person, and feedback incorporated into an expanded analysis of full waste management system costs.

The Results

At this time the status quo is still more cost effective for CVRD than going with one of the alternative technologies. However, some of the technologies show great potential for a time when costs can be more closely defined and markets for the products are confirmed. The presentation gave the Regional District directors a clear understanding of their current situation, the development path of various technologies and direction on which technologies to watch and how to implement them in the future to move away from landfills.

A Team Effort

Our thorough understanding of CVRD's needs and waste management system, experience with assessing traditional and emerging WtE technologies, and planning expertise helped to solidify the findings of the report. We also had full support from members of the Regional District Board's Select Committee, and assistance from the CVRD staff to execute the work.

"The success of this project was possible through close cooperation with our client. The Regional District was essentially part of the team working towards the common goal of identifying a cost-effective, future-oriented waste management system," said Konrad Fichtner, Waste Practice Lead for Morrison Hershfield.

What's Next?

CVRD will monitor the development of a technology that converts plastics into diesel fuel and organic components into fuel pellets, currently being implemented in Nova Scotia. Within the next year, they will have more data to re-evaluate the situation and potentially consider an alternative to landfilling.

Morrison Hershfield is looking forward to an opportunity to help the CVRD re-evaluate and run the financial model in the future with the new data.

In addition to the WtE study, Morrison Hershfield is currently helping CVRD find solutions on three other waste projects:

- Implementation of a composting facility.
- Review of the waste management planning process.
- Assessing landfill design.

Concluding Remarks from CVRD

"The WtE evaluation process undertaken with Morrison Hershfield provided the organization with important analysis that can be used to make service delivery decisions as we continue to look for cost effective, efficient and environmentally friendly alternatives to the traditional landfilling processes.

"The full system cost model developed will be an ongoing tool to assist analysis of service costs moving forward"

Andrew McGifford, CPA, CGA
Senior Manager Comox Strathcona Waste Management Services
Engineering Services Branch
Comox Valley Regional District

For more information, please contact Konrad Fichtner, Waste Practice Lead for Morrison Hershfield, at kfichtner@morrisonhershfield.com ■

Comox Valley Regional District, B.C.

al une compréhension claire de leur situation actuelle, de la voie de développement des diverses technologies et de l'orientation des technologies à surveiller et de la manière de les mettre en œuvre pour s'éloigner des décharges.

Un effort d'équipe

Notre compréhension approfondie des besoins du CVRD et de son système de gestion des déchets, notre expérience dans l'évaluation des technologies VE traditionnelles et émergentes, ainsi que notre expertise en matière de planification ont permis de consolider les conclusions du rapport. Nous avons également bénéficié du soutien total des membres du comité restreint du Conseil régional du district et de l'aide du personnel du CVRD pour accomplir le travail.

«Le succès de ce projet a été possible grâce à une coopération étroite avec notre client. Le District régional faisait essentiellement partie de l'équipe travaillant à l'objectif commun d'identification d'un système de gestion des déchets rentable et tourné vers l'avenir», a déclaré Konrad Fichtner, responsable de la gestion des déchets de Morrison Hershfield.

Prochaine étape

Le CVRD surveillera le développement d'une technologie qui convertit les plastiques en carburant diesel et les composants organiques en pastilles de combustible, actuellement mise en œuvre en Nouvelle-Écosse. Au cours de la prochaine année, ils disposeront de plus de données pour réévaluer la situation et envisageront éventuellement une alternative à la mise en décharge.

Morrison Hershfield a hâte de pouvoir aider le CVRD à réévaluer et à utiliser le modèle financier à l'avenir avec les nouvelles données.

En plus de l'étude VE, Morrison Hershfield aide actuellement le CVRD à trouver des solutions à trois autres projets de traitement des déchets:

- Mise en place d'une installation de compostage
- Examen du processus de planification de la gestion des déchets
- Évaluation de la conception des décharges

Remarques finales du CVRD

«Le processus d'évaluation de la VE entrepris avec Morrison Hershfield a fourni à l'organisation d'importantes analyses pouvant être utilisées pour prendre des décisions en matière de prestation de services pendant que nous continuons à chercher des solutions de rechange rentables, efficaces et respectueuses de l'environnement comme alternatives aux processus traditionnels d'enfouissement.»

«Le modèle de coût complet du système sera un outil continu pour faciliter l'analyse des coûts des services.»

Andrew McGifford, CPA, CGA

Gestionnaire principal, Services de gestion des déchets de Comox Strathcona

Direction des services d'ingénierie

District régional de Comox Valley

Pour plus d'informations, veuillez contacter Konrad Fichtner, responsable du traitement des déchets, Morrison Hershfield, à l'adresse kfichtner@morrisonhershfield.com. ■

How do we build knowledge into better waste management system in Canada?

Kelvin T. W. Ng, Ph.D., P.Eng., MCSCE, MASCE
Chair, Environmental Division, CSCE

Canadians generate more solid waste per capita than most of other industrial nations. According to Statistic Canada, we generated more than 24.9 million tonnes of waste in 2016, or about 1.94 kg/cap·-day. We diverted a fraction of our waste and sent most of the materials to landfills for permanent disposal. Methane gas and leachate generated from the decomposition of organics are some of the key concerns of the landfill technology. At current waste generation rates, many of our landfills and waste facilities are at risk of reaching their design capacities. Advanced waste treatment technology is vital to reduce Canada's greenhouse gas emissions by 30% by 2030.

The Conference Board of Canada ranked Canada 14th out of 16 peer countries and rated a "D" grade on our environmental performance in its 2016 report. Waste generation was used as one of the four environmental indicators by the Conference Board report. Our reliance on landfill technology as the primarily waste treatment method is not sustainable.

Canada needs an integrated plan for solid waste management that not only incorporates strategic replacement of old and unlined landfills but also a willingness to invest in cutting-edge waste management research.

The regulatory agencies should work closely with the industry and make sustainable waste management research a national environmental priority.

This edition of CIVIL features three interesting articles on the latest development of Canadian waste management projects. The first article describes the successes of an open access research system on waste management. The project highlights the importance of waste data in evidence-based policy development.

The second article discusses the continuing trend of regionalization of landfills in Canada. Fewer landfills may minimize pollution risk, however, the economic and environmental impacts of waste collection and transportation must be fully assessed.

The last paper reveals some of the common misconceptions in landfill design and provides valuable lessons and scientific insights on good landfill engineering.

Kelvin T. W. Ng is an Associate Professor and Graduate Coordinator of Environmental Systems Engineering at University of Regina, Saskatchewan. ■

Geography	Sources of waste for disposal	2008	2010	2012	2014	2016
	Tonnes					
Canada	All sources of waste for disposal	25,926,476	24,952,415	24,681,474	24,766,650	24,940,747
	Residential sources of waste for disposal	9,360,400	9,448,165	9,684,615	9,803,644	10,225,943
	Non-residential sources of waste for disposal	16,566,076	15,504,250	14,996,859	14,963,007	14,714,804

Statistics Canada

Comment intégrer nos connaissances dans un meilleur système de gestion des déchets au Canada?

Kelvin T. W. Ng, PhD, PEng, MSCGC, MASCE
Président, Division de l'environnement, SCGC

Les Canadiens génèrent plus de déchets solides par habitant que la plupart des autres pays industrialisés. Selon Statistique Canada, nous avons généré plus de 24,9 millions de tonnes de déchets en 2016, soit environ 1,94 kg / habitant par jour. Nous avons détourné

Géographie	Sources des déchets à des fins d'élimination	2008	2010	2012	2014	2016
	Tonnes					
Canada	Toutes les sources de déchets à des fins d'élimination	25,926,476	24,952,415	24,681,474	24,766,650	24,940,747
	Sources de déchets résidentielles à des fins d'élimination	9,360,400	9,448,165	9,684,615	9,803,644	10,225,943
	Sources de déchets non résidentielles à des fins d'élimination	16,566,076	15,504,250	14,996,859	14,963,007	14,714,804

Statistics Canada

une fraction de nos déchets et envoyé la plupart des matériaux aux décharges pour une élimination permanente. Le méthane et le lixiviat générés par la décomposition des matières organiques font partie des préoccupations majeures de la technologie des décharges. Au rythme actuel de production de déchets, nombre de nos décharges et de nos installations de gestion des déchets risquent d'atteindre leurs capacités de conception. Une technologie avancée de traitement des déchets est essentielle pour réduire les émissions de gaz à effet de serre du Canada de 30% d'ici 2030.

Dans son rapport de 2016, le Conference Board du Canada a classé le Canada au 14e rang parmi 16 pays semblables et a attribué une note «D» à notre performance environnementale. Le rapport du Conference Board a utilisé la génération de déchets comme l'un des quatre indicateurs environnementaux. Notre dépendance à l'égard de la technologie des décharges en tant que méthode de traitement des déchets principale n'est pas durable. Le Canada a besoin d'un plan intégré de gestion des déchets solides qui comprend non seulement le remplacement stratégique des sites d'enfouissement anciens et sans revêtement, mais également la volonté d'investir dans des recherches de pointe sur la gestion des déchets. Les organismes de réglementation devraient travailler en étroite collaboration avec l'industrie et faire de la recherche sur la gestion durable des déchets une priorité environnementale nationale.

Ce numéro de CIVIL présente trois articles intéressants sur le dernier développement de projets canadiens de gestion des déchets. Le premier article décrit les succès d'un système de recherche en libre accès sur la gestion des déchets. Le projet souligne l'importance des données sur les déchets dans l'élaboration de politiques fondées sur des données probantes. Le deuxième article traite de la tendance continue vers la régionalisation des décharges au Canada. Moins de décharges peuvent minimiser le risque de pollution. Cependant, les impacts économiques et environnementaux de la collecte et du transport des déchets doivent être pleinement évalués. Le dernier article révèle certaines des idées fausses les plus répandues dans la conception des décharges et fournit des enseignements précieux et des connaissances scientifiques sur une bonne ingénierie des décharges.

Kelvin T. W. Ng est professeur agrégé et coordonnateur des études supérieures en génie des systèmes environnementaux à l'Université de Regina, en Saskatchewan. ■

What is the Waste Wiki?

Calvin Lakhan, Ph.D.,
Postdoctoral Fellow
Mark Winfield, Ph.D., Professor
Faculty of Environmental Studies,
York University

The "Waste Wiki" is Canada's largest open access research project devoted to waste management that attempts to bridge the gap between academia, industry and government.

Hosted by York University's Faculty of Environmental Studies and launched in 2016, The Waste Wiki Project is partnered with more than 25 municipal, provincial and private sector stakeholders.

The four main areas of the Waste Wiki are:

(i) an online, open access resource that houses data, research and literature pertinent to Canada's Waste Management Sector. The website currently houses more than 6,000 academic studies on the waste management sector, as well as data dashboards, data visualization tools and cost/carbon models. These resources are provided free of charge to anyone who visits the site;

(ii) an opportunity to provide students with job skills training, employment opportunities, and the ability to co-author academic studies/grey literature. A key focus of the Waste Wiki is to cultivate new talent in the sector, and increase awareness among students that waste is a diverse subject that deserves more academic attention;

(iii) a research initiative designed to advance understanding surrounding diversion behavior and the impacts of waste management policy; and

(iv) a research service to stakeholders, regardless of their ability to financially contribute to the project.

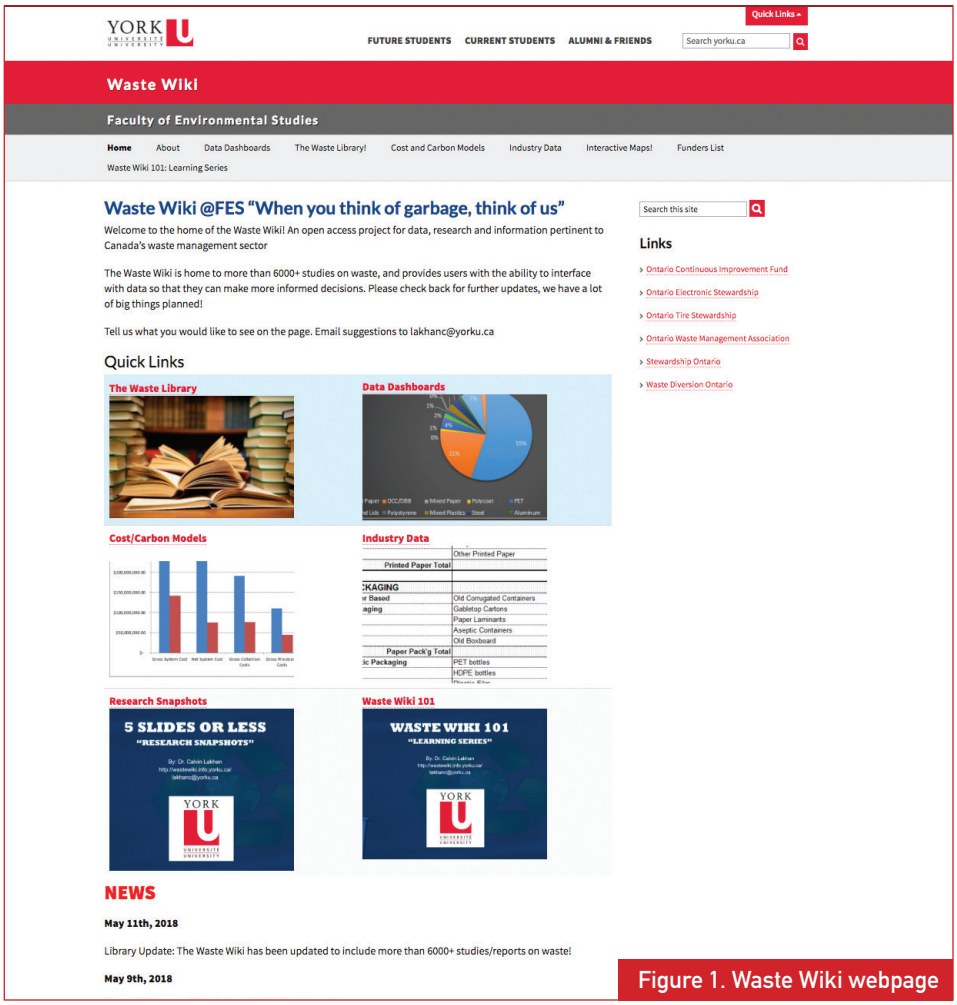


Figure 1. Waste Wiki webpage

The mission statement for the Waste Wiki is "democratization of research". Every stakeholder, big or small, should be able to have access to the same level of support and technical assistance. The ability to pay should never be the barrier to access research services. Often times, particularly in the waste management sector, a lack of access to data and information impedes evidence-based policy. While a wealth of data exists, particularly for programs in Ontario, Manitoba, British Columbia and Quebec, this information is not communicated in a way that is readily interpreted or analyzed. In most instances, users are provided with obscure Excel files that are difficult to navigate and interpret, particularly for organizations who may not have access to data scientists or statisticians.

The Waste Wiki is focused on "telling the story" of this data, helping stakeholders understand how the sector has changed over time, why it has changed, and what could potentially be on the horizon (Figure 1). In particular, the data dashboards created by the Waste Wiki team have created a visual interface for every single entry reported into the Resource Productivity and Recovery Authority (RPRA) Data Call. Users can download these dashboards for free from the university website, which are updated on quarterly basis.

Over the past two years, the Waste Wiki has formed research partnerships with more than 20 organizations (municipalities, provincial government, industry organizations and the private sector). Unlike most research initiatives, the Waste Wiki is financed exclusively from sector donations—the project is seen as playing a critical role in providing neutral methodologically-sound research that is not

biased by partisan issues. While the Waste Wiki project is still very much in its infancy, some key project highlights to date include:

• Diabetes Canada and York University National Textile Study

This project is Canada's first study designed to promote textile diversion at a municipal and provincial level. Waste Wiki staff work collaboratively with Diabetes Canada and other charitable actors to identify the economic, environmental and social impacts of textile diversion, while providing guidance on how best to develop local/provincial policy to promote alternative models of service delivery. From a research perspective, Diabetes Canada and York University have created partnerships with over 182 municipalities across Canada. To date, this program has diverted in excess of 50 millions pounds of textiles from landfill.

• Cost/Carbon Modeling:

Over the past two years, the Waste Wiki team has been involved in a number of projects that marry LCA modeling with economic analysis. In 2017, the university introduced a new metric for evaluating the efficacy of recycling programs ($/TCO2e) - How many dollars need to be spent on recycling activity in order to abate one tonne of carbon (calculated by material type). The results from this analysis resulted in the development of a Carbon Cost calculator, which assists stakeholders in prioritizing certain materials for recovery, and model various scenarios that reflect both legislative and market change. This analysis has proved critical in helping municipalities understand that the most effective recycling system is not necessarily the one that diverts the most material. The work the Waste Wiki has done is presently being used to inform Blue Box transition discussions and provide analytical support for optimizing printed paper and packaging recycling systems. Our models are presently hosted on the university web page:

http://wastewiki.info.yorku.ca/cost-and-carbon-models/

http://wastewiki.info.yorku.ca/cost-and-carbon-models/collection-and-mrf-models/

Helping stakeholders understand how to access, navigate and interpret research from across the world

Given the university's access to data and academic literature from across the world, we often engage in comprehensive reviews of issues pertinent to the waste management sector. To date, we have assisted both corporate and not-for-profit stakeholders in gathering best available literature/data, synthesizing and summarizing results, and engaging in comprehensive reviews of secondary research sources. This research is often used to develop policy papers and position pieces that help our stakeholders better understand the impact (both good and bad) of their operations. These tasks also allow the Waste Wiki to engage our graduate students, who are provided valuable opportunities to interact with institutions outside of academia, and better understand a wide range of issues for a diverse group of clients. Some of these projects include:

- Clorox Canada Bin vs. Bag study – experiences and learnings from across Canada
- AMERIPEN EPR Packaging Review of jurisdictions in Europe and the North America
- Clorox Canada review of plastic legislation in Latin America and Asia
- CIF Best Practices Review of funded projects – what have we learned to date?

Pioneers in original research:

The Waste Wiki takes great pride in undertaking and publishing original research, often in topics that have been neglected by academia. To date, the Waste Wiki has published over 26 academic papers in topics ranging from "Optimizing the mix of Blue Box Materials in the System" to "The role of race and ethnicity in influencing recycling behavior". Our work examining ethnic and cultural antecedents to recycling behavior is largely seen as the first of its kind in Canada, with findings from our studies informing how municipalities design, develop and deliver recycling promotion and education to its residents. Municipalities in the Greater Toronto Area have worked closely with the Waste Wiki in finding the most effective ways to engage ethnic minority groups to encourage participation in municipal waste diversion programs.

Key Learnings:

The main take away from having managed the Waste Wiki over the past two years is the instrumental role academia can play in helping to guide policy and decision making.

Historically, there has been a paucity of research devoted to waste in a Canadian context, and even less that has had an application to the public and private sector. The Waste Wiki strives to bridge the gap between sectors, encouraging collaboration and helping stakeholders better understand their data and research needs. We actively seek to identify new ways to interact with stakeholders, and encourage alternative models of waste service delivery and financing.

Historically, municipalities have been tasked with service delivery, while costs are born by tax payers, producers, or some combination thereof. The Waste Wiki works to expand this model, identifying alternative service solutions, while ensuring waste is diverted from landfill. Tangent to this line of inquiry, the Waste Wiki works closely with all levels of government to develop waste policy that facilitates alternative service models that encourages cross sector collaboration.

Of perhaps greatest importance is that the university is seen as a neutral party by the sector, with our research being deemed as credible and unbiased. Given the highly politicized and contentious nature of issues surrounding waste (who manages it, who pays for it etc.), the Waste Wiki has assumed a critical role in providing stakeholders with guidance. As the project evolves, the Waste Wiki will continue to work with the broader sector to shed light on neglected issues, or provide clarity regarding the potential impact of new policy and legislation. ■

Landfill Regionalization: A strategic move for all provinces?

Amy Richter, MASc, Doctoral Student
Kelvin T. W. Ng, Ph.D., P.Eng., Associate Professor
Environmental Systems Engineering, University of Regina

In 2014, the average Canadian produced an astounding 961 kg of waste (Statistics Canada, 2017a). Because of Canada's vast geographic extent and low population density, landfilling is a logical choice for many municipalities. As environmental concerns related to the disposal of waste in permanent landfills and other disposal sites become more important, many Canadian municipalities are working to improve their approach to solid waste management. However, the approaches taken vary greatly from municipality to municipality, and province to province (Wang et al., 2016; Bruce et al., 2016; Richter et al., 2017).

Most municipalities have aimed to reduce reliance on land disposal by promoting waste recycling. Recently, some municipalities have moved to adopt regionalized mega-landfills to minimize the number of waste facilities and the associated health and safety impacts.

Saskatchewan and Nova Scotia Waste Management Systems

Residents of Saskatchewan had one of the highest non-hazardous waste disposal rates in the country in 2014, sending an average of 839 kg/cap; second only to Alberta, with a waste disposal of 997 kg/cap (Statistics Canada, 2017a). On the other hand, residents of Nova Scotia disposed only 386 kg/cap in the same year, much less than the national average of 706 kg/cap (Statistics Canada, 2017a). The difference in waste diversion rate between Saskatchewan and Nova Scotia are also astounding. In 2014, the average Saskatchewan resident only diverted about 15.6% of their waste, the second lowest in the country, much less than the national average of 26.5%. Nova Scotia, on the other hand, had the highest diversion rate of all provinces in 2014 at 43.4%.

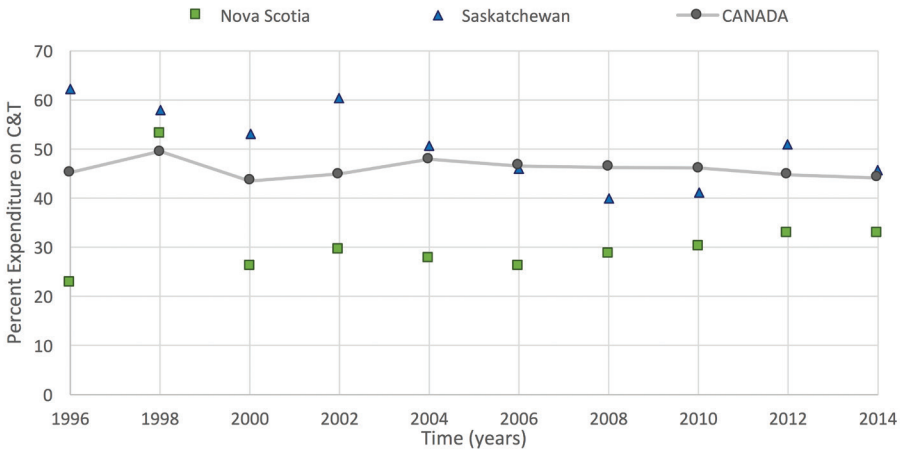


Figure 1: Percent expenditure on collection and transportation (C&T) in Nova Scotia and Saskatchewan over time.

Percentage expenditure on Waste Management systems

In Canada, waste collection and transportation costs typically contribute the most to total expenses for waste management (Richter et al., 2018). In fact, in 2014 Canadian municipalities spent about $1.3 billion transporting waste to landfills, recycling facilities, organics processing facilities, or other disposal sites (Statistics Canada, 2017b).

Direct comparisons between provinces are challenging given the differences in populations, as well as the size and scope of waste management systems among provinces. As such, percentage expenditure on waste management systems are used to investigate the trends in Saskatchewan and Nova Scotia. Figure 1 shows changes in average percent expenditure on Collection and Transportation between 1996 and 2014. The national average is quite consistent during the 18-year study period, with an average of 45.9%. With the exception of 1998, the cost of transportation in Nova Scotia was consistently below the national average. In Saskatchewan, the cost was generally higher than or close to the national average.

Considering the cost of treatment of waste (such as operation of disposal, incineration, and composting facilities), Nova Scotia generally spent a higher percentage of their total budget on treatment compared to collection and transportation, while the opposite is true in Saskatchewan. In fact, in 2012, Saskatchewan spent slightly over one-third of their budget (35.5%) on disposal and treatment of waste, whereas Nova Scotia spent close to half (47.2%) of the same category (Statistics Canada, 2017b).

Regionalized landfills

Studies on the spatial distribution of landfills, and a move towards regionalization of landfill sites are popular for regions with high collection and transportation costs. The Government of Saskatchewan is in the process of developing a strategy to deal with solid waste management in the province. The plan discusses a movement towards regionalized systems in the province (Government of Saskatchewan, 2017); which may seem like a logical move considering that Nova Scotia, among other provinces, have had success moving towards a regionalized system.

Figures 2A (right) and 2B (next page) show a comparison of the spatial density of landfills in Saskatchewan and Nova Scotia. These maps are created using ArcMap 10.5.1 Spatial Analyst Kernel Density tool (Esri, 2018). In Saskatchewan, there are an estimated 343 operational landfills (Government of Saskatchewan, 2018), while in Nova Scotia there are 82 waste management facilities (including landfills, recycling facilities, organics processing facilities, and other types of waste processing facilities).

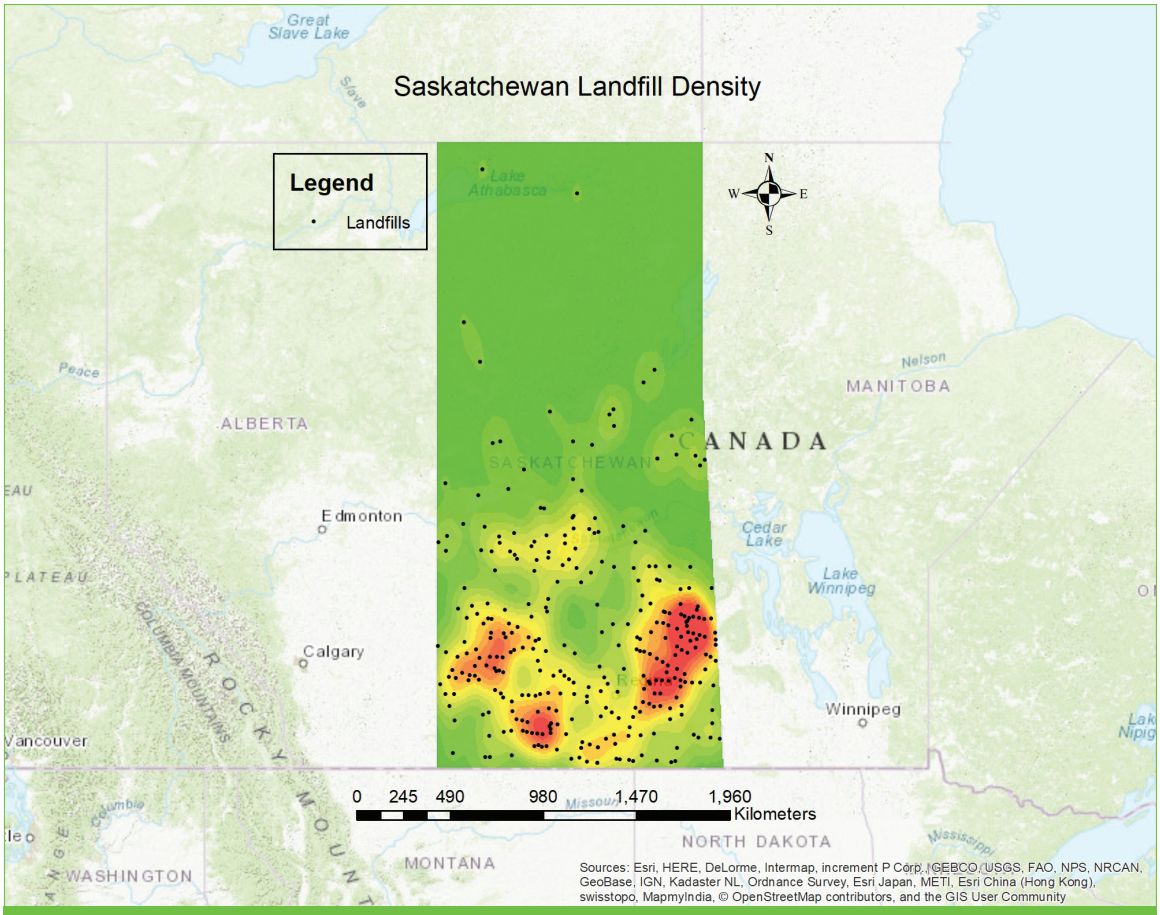


Figure 2A: Landfill Density in Saskatchewan (Data from Government of Saskatchewan, 2018)

In 2014, Nova Scotia had a population of about 0.94 million while Saskatchewan had a slightly higher population of 1.12 million (Statistics Canada, 2016). Most of Saskatchewan's population lies closer to the US border, and the province has a relatively low population density (1.7 cap/km2). The population of Nova Scotia is spread out more evenly, and the province has a higher population density.

One would expect that higher population density facilitates reductions in the cost of collection and transportation. However, data fails to support the hypothesis. Investigations into other spatial indicators such as population, primary sectors and industries, and other geographic features such as slope, soil type, and elevation may play a role in spatial location though data of this nature is often difficult to find at the appropriate scale.

Because population density is relatively low in each province (17 cap/km2 in Nova Scotia versus 1.7 cap/km2 in Saskatchewan), collection and transportation costs may be sensitive to the percentage of urban and rural population, and the array of sizes of census metropolitan areas in each province. Because of this, an index that encapsulates land area, population density, and population centres may be useful in helping to optimize provincial and regional waste transportation challenges.

Based on Figures 2A/2B, we might conclude that waste management facilities in Nova Scotia are more strategically placed. The high-density regions (shown in red) are well spread out over the province and appear to serve each region well; reflecting the move towards regionalized landfills and waste management facilities. On the other hand, there are less high-density areas in Saskatchewan (despite a larger population) and the high-density regions appear to be much closer to each other, possibly reflecting a lack of regionalization.

A major factor of consideration with respect to mega-landfills and regionalization movement is the impact that this will have on existing infrastructure. In Saskatchewan, many small communities have or share their landfills with close neighbors. Moving to a regional system means that the total num-

ber of landfills decreases, but the number of kilometers travelled to get to regionalized landfills increases, possibly stressing the provincial highway network. Furthermore, Saskatchewan winters pose an increased hazard during poor winter driving conditions, as well as the increase in larger sized vehicles on the road.

Aftercare costs for closed landfills presents another challenge, one which has been well reported in Nova Scotia. For example, the Cape Breton Regional Municipality has projected landfill aftercare costs of $41.2 million for 11 landfills; while Colchester County has a projected aftercare cost of $12.1 million for their Balefill site (Richter et al., 2017). If the development of waste management regions occurs, and the waste management regions need to take on the responsibility of aftercare costs for landfills within the region, equity in responsibility for closed landfills becomes another possible point of contention.

The move towards regionalized waste management in Saskatchewan appears to be complex, with many factors at play. Nova Scotia and Alberta have both moved in the direction of regionalized with relative success. Because of Saskatchewan's demographic and infrastructure demands, regionalization may be difficult. The next steps taken by the Saskatchewan government will be interesting, and perhaps will help other provinces to move in the same direction.

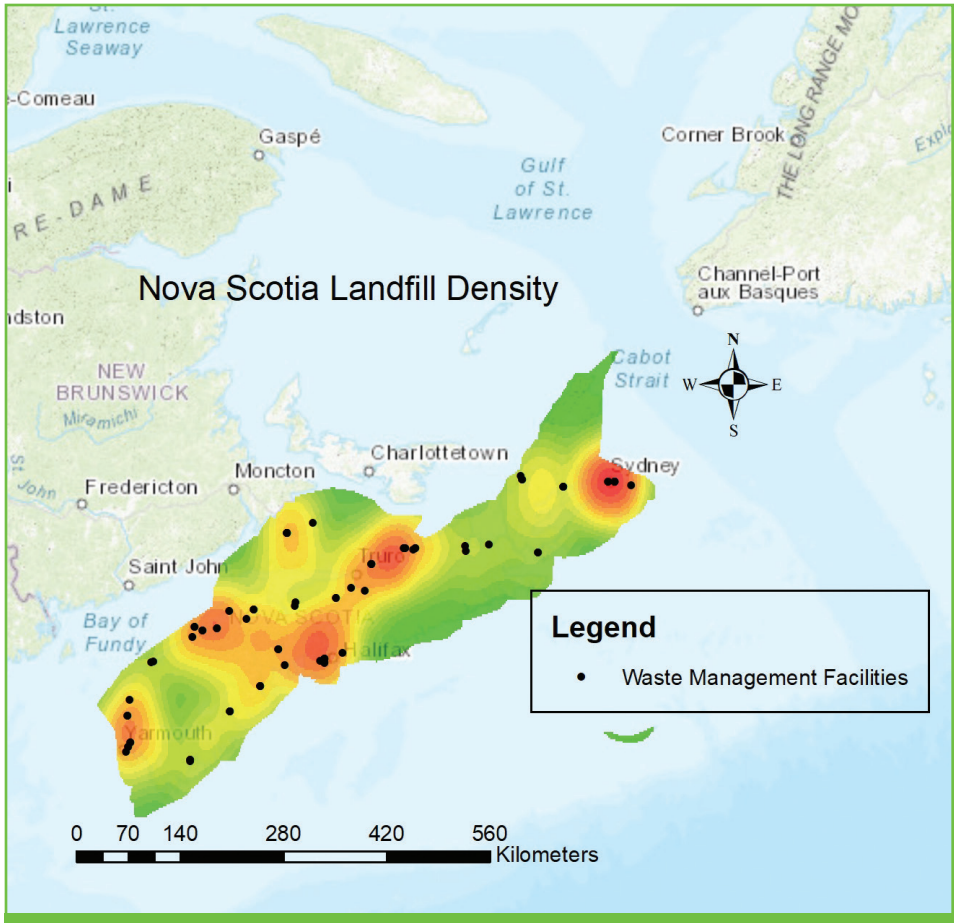


Figure 2B: Landfill Density in Nova Scotia (Data from Government of Nova Scotia, 2017)

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Figure 1A- A roof seems an extreme measure.

Elements of landfill engineering

Ian. R. Fleming, Ph.D., P.Eng., Professor of Geotechnical Engineering,
Department of Civil, Geological & Environmental Engineering, University of Saskatchewan

Except for the smallest rural communities, modern landfills are no longer just holes in the ground into which garbage is tossed with nary a care. Modern landfills require substantial expertise and engineering and there are a number of critical design elements—particularly those involving geotechnical and geosynthetics engineering—that are often misunderstood. When designing and constructing a landfill, we do not have the luxury of going back later to fix things: extreme measures may be required.

Figures 1A, 1B and 1C highlight three different problems that happened in three different (anonymous) landfills.

At site 1A (above), a roof (!) was actually placed to divert water away from the waste fill. At site 1B (right), the leachate collection system (LCS) clogged. The LCS is a pervious underdrain system placed below the waste and over the base barrier, and it is equipped with pipes and pumps/sump to remove leachate from the landfill.

Installing a geomembrane or clay seepage barrier without incorporating an overlying drain is just like building a bathtub with no drain. At site 1B, the clogged drain caused a buildup of hydraulic head forcing more leachate through the base barrier. The resulting leachate migration in the surficial aquifer has necessitated the installation of wells to extract the contaminated groundwater before it travels further.

This system has proven to be only partly effective and has led to substantial costs, perhaps including tens of millions of dollars for a geomembrane cover system covering dozens of hectares.

At site 1C (next page), millions of dollars were spent to excavate the waste and place a well-designed base barrier system (including LCS).

I could go on with dozens of other examples of expensive remedial activities that have been required for landfill sites around the world.

What do these three failures have in common? Leachate. One might think that collecting some garbage juice in a perforated drain and directing it to a sump or lagoon would be easy. Unfortunately, it's not just like a drainage tile around a house footing or a subdrain to lower

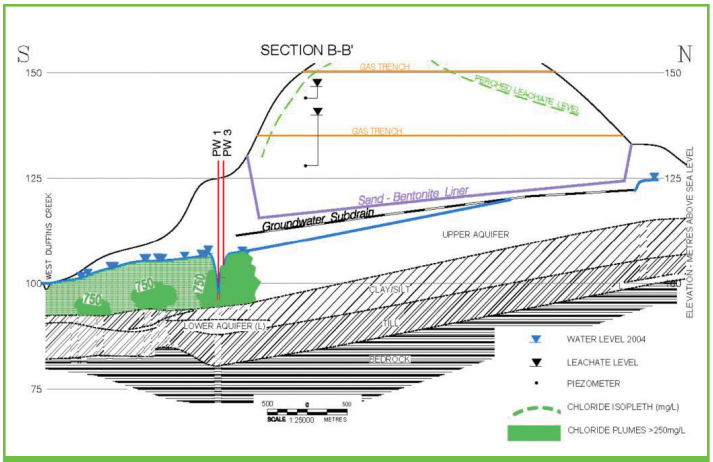

Figure 1B - What can go wrong when a leachate underdrain system fails (from Fleming, 2011)

the water table for a road underpass.

Leachate holds in solution a considerable amount of organic material and inorganic minerals. A complex biogeochemical reaction results in the drain clogging – see Fleming et al (1999) and Fleming & Rowe (2004). This may happen rather quickly as was observed at one Canadian site where a perimeter toe drain clogged in two years (Fleming et al, 2010).

So the key message of this article is that a barrier (geomembrane or low-permeability clay "liner") will only work if it has a good LCS. And a good LCS is expensive! And easy to get wrong.

Clogging of the drain isn't the only thing we have to worry about, but if we get the base barrier right, we're unlikely to have to spend millions later.

What are the key elements in designing and constructing a landfill? And who should be responsible?

A. Site selection (ground conditions, presence of aquifers, soft soils, settlement etc);

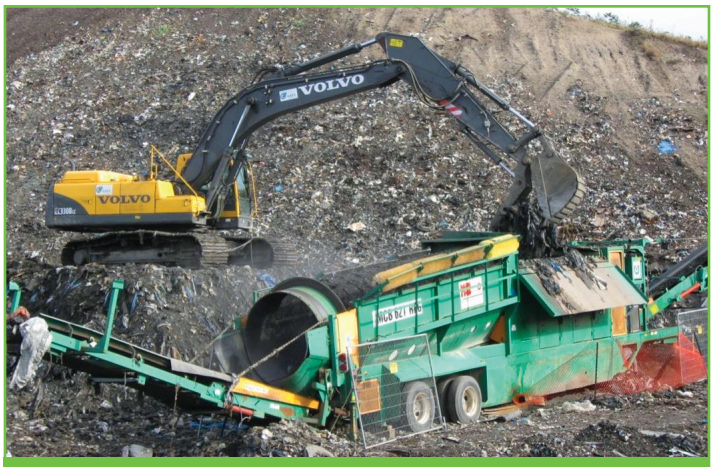

Figure 1C - Excavating most of a landfill to re-engineer the site with a proper base barrier system (Dewaele et al. 2011)

B. "Geometric design" i.e. size & shape of the footprint, slopes, crest area, overall capacity (volume and tonnage), sequence of staged cell construction and filling;

C. Base barrier system, which may be natural or imported clay, geosynthetics or a combination thereof (this includes the LCS);

D. Gas collection (if implemented);

E. Leachate management – now that we've collected all this "garbage juice", what shall we do with it? It may be pumped via forcemain to a nearby sewage treatment plant, or it may be pumped to an onsite (lined) lagoon from which it can be taken away by tanker truck for treatment, or may be recirculated into the waste mass to accelerate decomposition. Significant evaporation may be counted on in some parts of Canada (Sask., Alta.) whereas in wet coastal climates an open lagoon might not be the best choice.

F. Stormwater and runoff management (including erosion and sedimentation control);

G. Access and internal roads (the latter change periodically as each cell is built and as the waste fill grows and the tipping face moves), scales & scalehouse, equipment maintenance and storage facilities and other ancillary elements;

H. Leachate, groundwater, gas and settlement monitoring systems;

I. Final Cover design, post closure monitoring and aftercare.

Looking at the above list, it should be evident to all of us that A, C, H & I clearly require specialised geotechnical expertise. General municipal/environmental engineering practitioners are typically well-equipped for F & G, and the remaining critical aspects of design (B, D, E) require collaboration between the geotechnical and municipal/environmental practitioner and perhaps additional skills from a third designer.

So who should be designing our landfills? Clearly there is a substantial requirement for specialised geotechnical and geosynthetics engineering expertise. And clearly we also require some other skills that are part of everyday practice for municipal/environmental practitioners. Hopefully we can all consider this when writing proposals or assembling project teams. As a brief side-note, I did not include the term "hydrogeology" in the discussion above—mostly because I consider this to be an important aspect of geotechnical practice and thus may be understood to be included.

So what bits of landfill engineering are frequently misunderstood?

The remainder of this article will touch briefly on some issues which I frequently see designers get mixed up. I will focus largely (but not exclusively) on the geotechnical and geosynthetics aspects.

A. Site selection

Site selection has traditionally been a key part of landfill design/construction as geotechnical engineers and hydrogeologists bored holes to evaluate candidate sites regarding local aquifers, strength and compressibility of near surface soils and the depth to water table. A strong argument may be made that technology has progressed sufficiently that using modern engineering and geosynthetic materials, we could place a large landfill directly over an important aquifer with no adverse effects short or long term.Of course it wouldn't be cheap, but neither is land or road access. If selection of such a location were to mitigate some of the inevitable impacts (traffic, noise, dust) then it might be well worth considering.

B. Geometric Design

Sideslopes: One error I see over and over in raised landfill "hills' is sideslopes far shallower than they might be, thus wasting the available volume for a given footprint and increasing per tonne capital and maintenance cost considerably. Waste is strong, typically much stronger than soil (Eid et al, 2000; Singh et al, 2009) although waste fill typically exhibits significantly higher strain (Singh & Fleming, 2011). There is no good reason to build sideslopes flatter than 3H:1V and slopes considerably steeper than that may be built—the constraint becomes placement of final cover and prevention of erosion.

Overall capacity (tonnes vs volume): a concept known as apparent density may be used for planning purposes, basically the mass of waste across the scales during a given period divided by the corresponding increase in volume of compacted in place waste fill. Some operators track this weekly or even daily with frequent lidar scans by drone. Simply put, more compaction equals more revenue and (somewhat) less long-term settlement. This value should not be used to determine the stress at the bottom of a waste pile in order to calculate, for example, the load on buried pipes and geomembranes or the amount of consolidation settlement of a clayey foundation.

C. Base Barrier System

Geomembranes: Should be placed over a GCL or a low permeability clay soil that has been compacted and smooth-rolled to at least 95% std proctor compaction – passage of equipment and loaded trucks should not cause excessive rutting. A "protection layer" of nonwoven

geotextile should never be placed below a geomembrane.

Geomembranes on slopes represent a slip plane, NOT reinforcement. Interface shear strength of geomembranes has been extensively studied (Fleming et al 2006), so guidance is available! Geomembranes that are textured one side should always be placed textured side down.

Protection Layer: Geomembranes need a protection layer. Always. Full stop. Because the drainage aggregate must be of uniform large diameter, point loading to the geomembrane will result in localised strain concentrations exceeding 3-8% at which point the geomembrane is likely to experience stress cracking. The protection layer may be a (very) thick nonwoven geotextile or perhaps a layer of soil covered by a geotextile separator to prevent intrusion of the overlying coarse drainage material comprising the LCS. Brachman & Sabir (2013) suggest that even a thick multi-layer geotextile cushion may be inadequate to prevent excessive strain, however these tests were performed over a clay subgrade that was softer than what would usually be constructed in the field. In any event the protection layer will represent a significant cost and may exceed the cost of the membrane itself. For critical applications, testing with sit-specific materials may be carried out at the University of Saskatchewan using our purpose built equipment (Figure 2).

Drainage Layer: Much has been written about the clogging of leachate collection systems (e.g. Fleming et al, 1999, Rowe & Yu, 2013). The bottom line is that a leachate drainage layer serves two functions. Firstly it must transmit leachate with little loss of head thus minimising the average head on the low-permeability barrier, and to do so it requires high permeability. Perhaps even more importantly, a very large pore volume is required to store the mineral clog deposits that will inevitably precipitate in a MSW landfill. Large porosity requires uniform particles, and because the rate and severity of clogging are worse with increased surface area, large uniform particles are required. Not sand or pea gravel. Not well graded road base gravel. A landfill requires uniform, coarse, washed and screened particles of minimum size 38mm. This stuff is very expensive. Alternatives widely used in Canada include tire-derived aggregate (TDA) which has its own challenges. Extensive work is ongoing in this regard at U of S (see Adesokan et al 2018 and stay tuned).

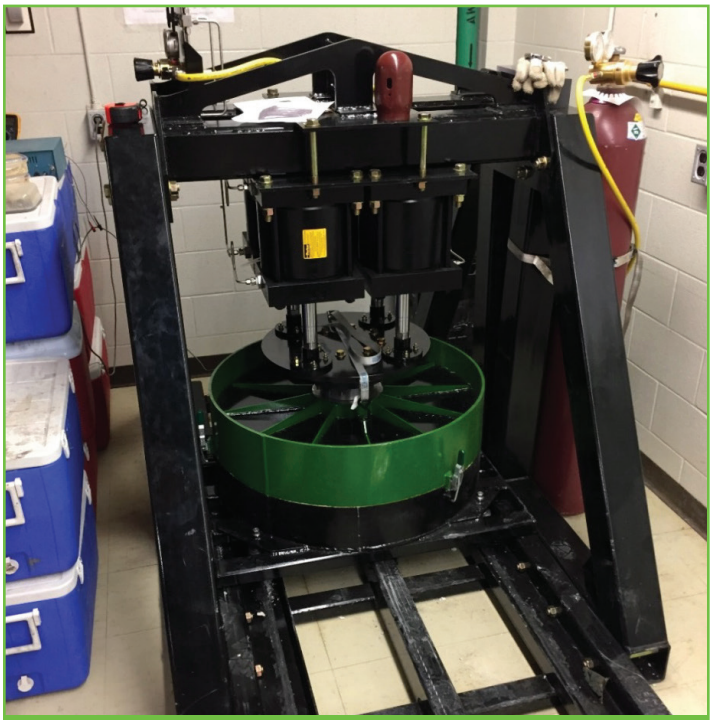

Figure 2 – Uof S large-scale testing device (0.9 m diam) for evaluating protection layers to avoid damage to geomembranes.

Required K_{SAT} of clogged geotextile for h=1m over geotextile			
	infiltration rate q_o in m/a		
	0.1	0.15	0.2
thickness of clogged GTX mm	Required clogged KSAT in m/s		
4	1.3E-11	1.9E-11	2.5E-11
8	2.5E-11	3.8E-11	5.0E-11
12	3.8E-11	5.6E-11	7.5E-11
20	6.2E-11	9.3E-11	1.2E-10
30	9.2E-11	1.4E-10	1.8E-10

Table 1 - For a geotextile placed between a LCS drainage blanket and the overlying waste, how clogged would it have to become to be a problem? Simple, Darcy's law: answer, more clogged than we have ever seen in the field or been able to achieve in the lab. So a geotextile filter must be placed.

Protecting the drainage layer: I am continually amazed when people ask me whether they should avoid putting a filter/separator over a leachate collection drainage blanket because it will clog. But given that coarse uniform gravel is just not filter-compatible with well graded heterogeneous waste, a filter is absolutely required to protect that expensive coarse aggregate from intrusion by fines and other materials from the overlying waste. Typically it would be a needle-punched nonwoven of at least 500 g/m2. Not cheap. But won't it clog? Yes, of course it will, but the resulting height of mounding is just not likely to be problematic (Table 1) and in any event, dealing with the problems that result from a clogged drain will almost certainly be a lot more expensive…

E. Leachate management

Operationally the LCS should be operated as a gravity drain reporting to a hydraulically-isolated sump, buried tank or lagoon. An insufficiently-deep internal sump with a pump operating on high/low level switches causes periodic flooding and high-velocity flushing of the drainage blanket and pipes, thus exacerbating the clogging problem. Fleming et al (1999) examined a clogged drain at a landfill operated this way and found that clog material had precipitated around

Figure 3 - An external lined leachate lagoon at a lower elevation allows leachate to continuously flow without periodic flooding and surging in the LCS which exacerbates clogging. Stage 1 was built first and the subsequent cells will connect and gravity drain through stage 1 to the lagoon.

large particles flushed in from the waste, made worse by the lack of a suitable filter-separator between the drainage gravel and the waste at this site. Figure 3 (above) shows a strategy employed at a newly-constructed facility in southern Saskatchewan.

I. Soil Final Cover

The role of final cover is not well understood. A cover soil plays a key role in the water balance as part of a complicated and dynamic interaction between the (unsaturated) soil and atmosphere. This has been long recognized in the case of covers for mining waste rock and tailings disposal sites, perhaps because these have more clearly been recognized to be geotechnical systems? Evaluating the performance of a cover soil requires specific expertise and usually help from the excellent software packages for unsaturated soils provided by, for example, Soilvision Systems (Saskatoon) or GeoSlope International (Calgary). Above all, it's a problem of unsaturated soils and hopefully we're all well aware that permeability isn't a number, but rather a function that depends on water content, and for clayey soils it increases considerably over the first few Canadian winters!

To wrap this up

One could go on at length about some of the challenges and common mistakes in designing landfills. I've tried to touch on some of the more common misconceptions that I have encountered in Canada and elsewhere over the past few decades. If it appears that these issues are skewed toward geotechnics, perhaps we might consider that a landfill is, after all, just a large and very expensive hill constructed from compacted fill.

There are some key elements that aren't geotechnical of course (stormwater management, roads), but these aren't so very different at a landfill than they are elsewhere. But we can do great things working together as a team, taking advantage of modern geosynthetics (and recognizing their weaknesses) and utilizing state-of-the-art tools for geotechnical analysis.

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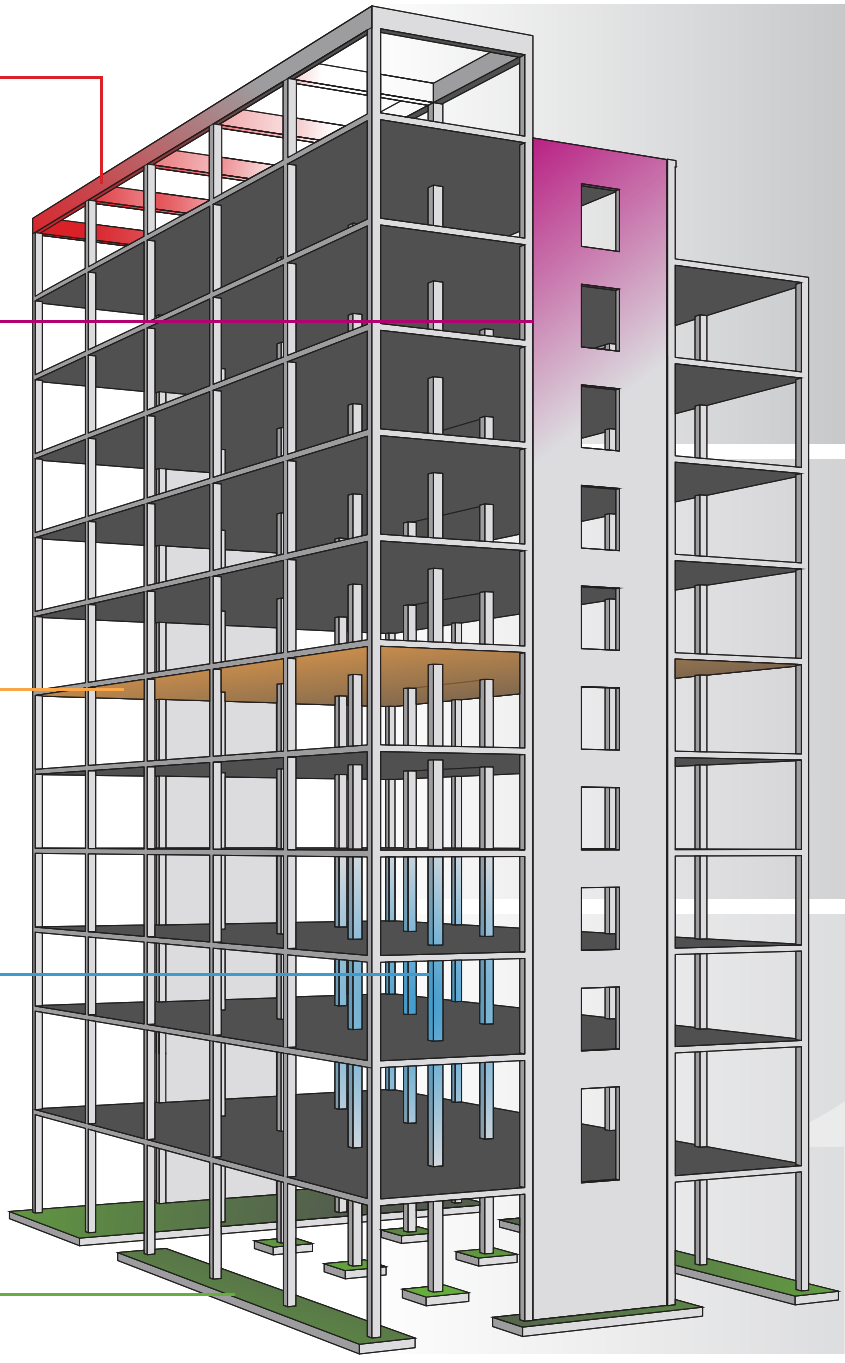

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