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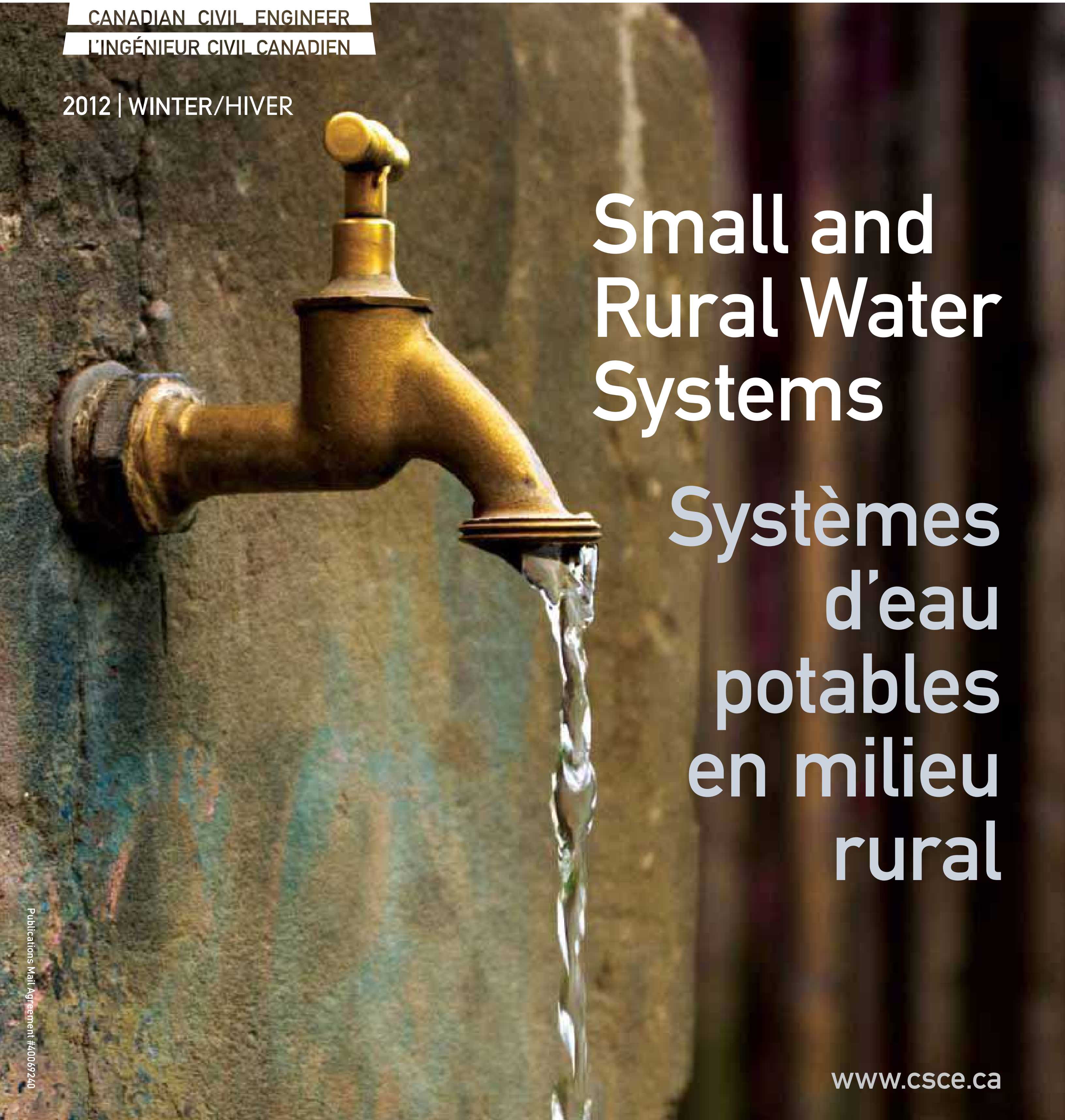
CANADIAN CIVIL ENGINEER

L'INGÉNIEUR CIVIL CANADIEN

- Cooperation: Northern Sunrise County, AB
- Decision support for small water systems
- River intake: Six Nations, ON
- Water pricing models

2012 | WINTER/HIVER



# Small and Rural Water Systems

# Systèmes d'eau potables en milieu rural

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L'INGÉNIEUR CIVIL CANADIEN

# contents

WINTER 2012/HIVER 2012 | VOLUME 29.5

## IN VIEW: PROJECTS



## TECHNICAL: SMALL AND RURAL WATER SYSTEMS/TECHNIQUE: SYSTÈMES D'EAU POTABLES EN MILIEU RURAL



## FORUM ON SUSTAINABLE INFRASTRUCTURE/ FORUM SUR LES INFRASTRUCTURES DURABLES



## NEWS, VIEWS & DEPARTMENTS / NOUVELLES, POINTS DE VUE ET DÉPARTEMENTS





CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN

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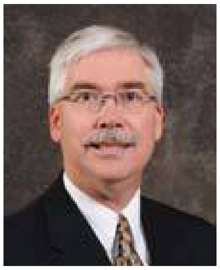


Jim Kells,
Ph.D., P.Eng., FCSCE, President CSCE/
Ph.D., ing., FSCGC, Président SCGC
PRESIDENT@CSCE.CA

# Sustainability: a little food for thought

One of the strategic directions of CSCE's Vision 2020 plan for the future is that we will become leaders in sustainable infrastructure. To achieve this leadership position, however, we must first have a good understanding of what is meant by sustainability in an engineering context. This is perhaps no surprise, but I suggest that achieving this understanding is immensely challenging.

As I was preparing my presentation for the joint Triennial Conference of CSCE, ASCE and ICE a few months ago, in which I spoke about aspects of sustainability in an educational context, I came across a video clip of Donella Meadows giving a keynote address nearly two decades earlier. Dr. Meadows was the lead author of the 1972 report for the Club of Rome entitled *The Limits to Growth*, which at the time stirred up considerable controversy in respect of human economic growth and the Earth's capacity to support such growth. In her address, Dr. Meadows spoke of the importance of having a clear vision for achieving a particular goal.

To illustrate, she used an example from a workshop that she had led previously in which the focus was on developing a vision for a world without hunger. What would a world without hunger look like? In this, Dr. Meadows was making the simple observation that, to arrive at a better place, one needs to have a good sense of what that place is like, what it is about.

Here, in the context of this discussion, could we not ask ourselves a similar question, namely: What would a truly sustainable world look like? What would be our concept of a world with truly sustainable infrastructure? Of course, realizing the vision is quite another thing, but the key point is that without a vision it isn't likely that we will achieve whatever may be our goal or dream.

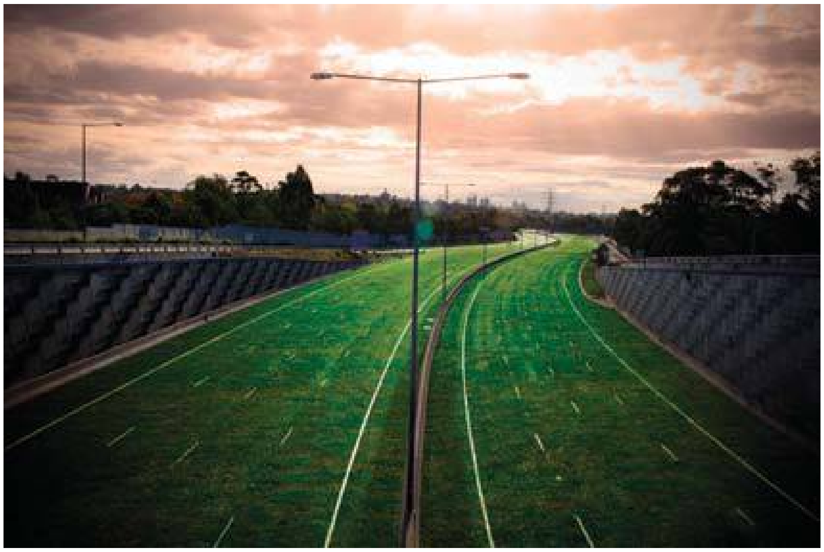
I got some insight into various aspects of what a sustainable world might look like in my reading of *Beyond Growth*, by ecological economist Herman Daly. Two points about sustainability as expressed by Daly stood out particularly strongly for me. The first point, which is apparently a Daly hallmark, is that the economic indicator of GDP is not an appropriate metric for success if one's objective is a sustainable world. Among other things, GDP calculations capture economic activity that may well be derived from the depletion of what Daly refers to as natural capital. In the case of non-renewable resources, for example, such diminution of natural capital is a one-time expenditure; it can never be done again. In the case of a renewable resource, such as the fisheries of the oceans, the depletion of natural capital occurs when we exceed the carrying capacity of the ecological system. Such depletion is tantamount to spending both the interest and some of the principal from an investment rather than just the interest generated therefrom. In both instances, our actions contribute to an unsustainable increase in GDP!

The other key point that I took from Daly's book is that growth and development are not the same and should not be treated as being synonymous. His contention is that it is quite possible in a sustainable world to have development, which he refers to as an improvement in human welfare or a "good living," without having growth in a conventional economic sense. Classical or traditional economic growth models, on the other hand, are simply unsustainable in a finite world.

The need for a clear vision, properly accounting for our expenditures of natural capital, and development without growth – perhaps these are food for thought for your sustainability journey? ■

# La durabilité, matière à réflexion

L'une des orientations stratégiques du programme « Vision 2020 » pour orienter l'avenir de la SCGC veut que nous devenions des chefs de file en matière d'infrastructures durables. Pour obtenir ce statut de chef de file, il nous faut cependant bien comprendre ce que signifie la durabilité dans le contexte du génie civil. Il n'y a peut-être là rien d'étonnant, mais j'estime qu'en arriver à cette compréhension est déjà un immense défi.



Au moment de préparer mon exposé pour le congrès triennal regroupant la SCGC, l'ASCE et l'ICE, il y a quelques mois, alors que je parlais de la durabilité dans un contexte de formation, j'ai découvert un vidé-clip de Donella Meadows, qui prononçait une allocution il y a presque 20 ans. Le professeur Meadows était l'auteure principale du rapport de 1972 du Club de Rome intitulé « Les limites de la croissance », exposé qui avait suscité beaucoup de controverse autour de la croissance économique des humains et de la capacité de la terre à supporter une telle croissance. Dans son allocution, le professeur Meadows mentionnait l'importance d'avoir une idée précise de ce que suppose l'atteinte d'un but précis.

En guise d'illustration, elle s'est servi de l'exemple tiré d'un atelier qu'elle avait animé et qui portait sur l'élaboration d'un monde sans faim. De quoi aurait l'air un monde sans faim ? À ce propos, le professeur Meadows observait tout simplement que, pour améliorer notre place au soleil, il fallait avant tout avoir une idée de ce qu'était cette place et de ce que cela comportait.

Ici, dans le cadre de cette discussion, on pourrait se poser la même question et se demander de quoi aurait l'air un monde vraiment durable. Quelle serait notre conception d'un monde doté d'infrastructures vraiment durables ? Évidemment, mettre en pratique une telle conception est une toute autre affaire, mais l'essentiel ici est de comprendre que sans une conception précise, il est peu probable que nous réussissions à mettre en œuvre notre but ou notre rêve.

J'ai trouvé quelques idées sur ce que pourrait être un monde durable en lisant l'ouvrage « Beyond Growth », écrit par l'économiste écologiste Herman Daly. Deux aspects de la durabilité soulignés par Daly m'ont particulièrement frappé. Le premier aspect, qui semble être le propre de Daly, est le fait que le PNB ne saurait être une bonne mesure de succès lorsque notre objectif est d'obtenir un univers durable. Entre autres choses, le calcul du PNB tient compte d'activités économiques reliées à l'épuisement de ce que Daly appelle le capital-nature. Dans le cas des ressources non-renouvelables, à titre d'exemple, un tel épuisement du capital-nature est une dépense non-répétitive, qui ne peut jamais être répétée. Dans le cas de ressources renouvelables, comme les pêcheries dans les océans, il y a épuisement du capital-nature lorsque nous dépassons les limites de la capacité de renouvellement du système écologique. Ce genre d'épuisement des ressources équivaut en gros au fait de dépenser l'intérêt et le principal d'un investissement, plutôt que de se limiter à n'utiliser que l'intérêt. Dans les deux cas, nos actions contribuent à un accroissement insoutenable du PNB !

L'autre aspect que j'ai retenu de l'ouvrage de Daly est que la croissance et le développement ne sont pas synonymes et ne devraient pas être traités comme tel. Il prétend qu'il est fort possible, dans un univers durable, d'avoir un développement, qu'il définit comme étant une amélioration du bien-être de l'humain, sans qu'il n'y ait de croissance au sens économique conventionnel. D'autre part, les modèles classiques ou traditionnels de croissance économique ne peuvent être soutenables dans un univers fini.

Il faut avoir une idée précise des choses, savoir comment nous dépensons notre capital-nature et savoir s'il y a développement sans croissance. Voilà matière à réflexion pour votre cheminement en matière de durabilité ! ■

Image: Thinkstock

Kelvin K. C. Cheung, Ph.D., MCSCE
VICE-CHAIRMAN, CSCE
HONG KONG BRANCH

## Hong Kong Branch hosts CSCE president

Welcome to the Canadian Society for Civil Engineering Hong Kong Branch (CSCEHKB), the first CSCE overseas branch in Hong Kong, China.

Back in 2004, the former CSCE President, Cathy Lynn Borbely, visited CSCE members in Hong Kong. During a BBQ dinner at the Hong Kong University of Science and Technology (HKUST), Borbely, some CSCE members and Prof. Moe Cheung (the founder and the first Chairman of CSCEHKB) discussed the formation/vision of the first CSCE overseas branch in Hong Kong, China. Since then, the CSCE made much effort until a cornerstone was laid.

In 2008, Prof. Ghani Razaqpur (former CSCE president), along with prominent professionals and some significant government officials, attended the inauguration ceremony of CSCEHKB at the HKUST campus.

This year, in early September, we were honored to have a third CSCE presidential visit by Dr. Jim Kells, and we warmly welcomed our president in Hong Kong for the following activities.

On September 6, the CSCEHKB and Dr. Kells visited the Hong Kong Institution of Engineers (HKIE). The HKIE president, Prof. KK Choy, along with representatives from the Civil Division and other key members, welcomed us with a presentation about the HKIE organization/operation and an open discussion on other collaboration opportunities.

After a great lunch with a beautiful view of Victoria Harbor, we went on a fascinating tour of the world's fourth tallest building, the International Commerce Centre (ICC). Completed in 2010, it is the tallest building in Hong Kong, at a height of about 484 m (1,588 ft.). It has 118 floors above ground and 4 floors below ground.

Then we attended the second annual general meeting and dinner. The events attracted more than 140 participants, among which were prominent professionals in the construction and engineering sectors. We were very honored to have Dr. Kells' presence and appreciated his inspiring speech.

On September 7, at HKUST, Dr. Kells visited several major facilities of the civil engineering department of HKUST. The department facilities are widely recognized internationally and rank among the very best in the world. These include the Geotechnical Centrifuge Centre, the Structural Engineering Laboratory, and the wind/wave tunnel facility. After that, Dr. Kells delivered an interesting speech about his experiences as a student, teacher and association president, which provided students and members with a broader view of the Canadian Society for Civil Engineering. Following the department visit, a relaxing lunch at the university restaurant was arranged by Prof. Chris Leung, head of the department of civil and environmental engineering at HKUST. Along with a group of students, we all enjoyed the opportunity to chat with Dr. Kells and appreciated the unique culture of CSCEHKB.

For more information about CSCEHKB, visit www1.ce.ust.hk/csce. ■

*Kelvin Cheung is project manager, Wan Chung Construction Co., Ltd.*

At HKIE (from left to right): Albert Chow (HKIE), Helen Kwan and George Cheng (CSCEHKB), Monica Yuen (HKIE), Paul Pang (CSCEHKB), Raymond Chan and KK Choy (HKIE), Jim Kells (CSCE), Moe Cheung (CSCEHKB), Jeanne Huang (CSCE), Kelvin Cheung (CSCEHKB) and Victor Cheung (HKIE)

À la HKIE (de gauche à droite ) : Albert Chow (HKIE), Helen Kwan et George Cheng (SCGC, SHK), Monica Yuen (HKIE), Paul Pang (SCGC, SHK), Raymond Chan et KK Choy (HKIE), Jim Kells (SCGC), Moe Cheung (SCGC, SHK), Jeanne Huang (SCGC), Kelvin Cheung (SCGC, SHK) et Victor Cheung (HKIE)

## La section de Hong Kong accueille le président de la SCGC

Bienvenue à la section de Hong Kong de la Société canadienne de génie civil, la première section outre-mer de la SCGC, située en Chine.

En 2004, l'ex-présidente de la SCGC, Cathy Lynn Borbely, a rendu visite aux membres de la SCGC à Hong Kong. À l'occasion d'un dîner-barbecue à l'Université des sciences et de la technologie de Ong Kong (HKUST), Mme Borbely, quelques membres de la SCGC, et le professeur Moe Cheung (fondateur et premier président de la section de Hong Kong de la SCGC), ont parlé de la création et des plans de la première section d'outre-mer de la SCGC, à Hong Kong, en Chine. Depuis, la SCGC a dépensé beaucoup d'énergie pour procéder à cette fondation.

En 2008, le professeur Ghani Razaqpur (ex président de la SCGC), en compagnie d'éminents professionnels et de certains dirigeants gouvernementaux, ont participé à la cérémonie d'inauguration de la section de Hong Kong de la SCGC, sur le campus de la HKUST.

Cette année, au début de septembre, nous avons eu l'honneur d'avoir une troisième visite présidentielle, puisque nous avons pu accueillir le professeur Jim Kells, qui a participé aux activités suivantes.

Le 6 septembre, la section de Hong Kong de la SCGC et le professeur Kells ont rendu visite à la « Hong Kong Institution of Engineers – HKIE ». Le président de la HKIE, le professeur KK Choy, ainsi que des représentants de la division de génie civil et d'autres membres importants, nous ont accueilli avec un exposé sur l'organisation et le fonctionnement de la HKIE, suivi d'une discussion sur diverses possibilités de collaboration.

Après un repas dans un lieu offrant une vue superbe du port de Victoria, nous avons visité le 4e édifice le plus élevé du monde, le « International Commerce Centre (ICC) ». Parachevé en 2010, c'est le plus haut édifice à Hong Kong, avec une hauteur de 484 m (1,588 pieds). L'édifice compte 118 étages hors terre et 4 étages sous terre.

Nous avons ensuite participé à la deuxième assemblée générale annuelle et au repas. Ces activités ont attiré plus de 140 participants, dont plusieurs éminents professionnels de la construction et du génie. Nous sommes honorés d'avoir pu recevoir le professeur Kells et d'avoir pu profiter de ses propos.

Le 7 septembre, à la HKUST, le professeur Kells a visité divers équipements importants du département de génie civil de l'établissement. Le département jouit d'une réputation internationale et compte parmi les meilleurs au monde. Le département compte notamment le Centre géotechnique centrifuge, le laboratoire de génie des charpentes, et le tunnel vent/vague. Le professeur a ensuite parlé de son expérience à titre d'étudiant, de professeur et de président d'association, ce qui lui a permis de donner aux étudiants et aux membres une idée de ce que fait la Société canadienne de génie civil. Après la visite du département, le professeur Chris Leung, directeur du département de génie civil et environnemental à HKUST, avait organisé un dîner au restaurant de l'université. En compagnie d'un groupe d'étudiants, tous ont apprécié l'occasion de causer avec le professeur Kells et de se familiariser avec la culture unique de la section de Hong Kong de la SCGC.

Pour obtenir plus de renseignements sur la section de Hong Kong de la SCGC, consultez le site http://www1.ce.ust.hk/csce. ■

*Kelvin Cheung est chef de projet, Wan Chung Construction Co., Ltd.*

# Laval University launches modeling contest

**By CSCE Student Chapter, Université Laval**

After visiting the Manic 2 and Manic 5 dams last year, the Student Section at Laval University has stepped up its activities once again. With the cooperation of the Quebec City Section, a modeling contest for a 100-year-old railway structure will take place from November 2012 to April 2013.

The teams of students (B.Sc. level) will use SAFI software to recreate a virtual representation of the steel structure of the railroad trestle bridge at Cap-Rouge, Que. Engineering students will have to produce a complete report of the modeling. In addition, a presentation of their procedure, methodology and results will take place in front of an audience made up of several seasoned engineers and teachers with relevant experience.

In addition, the team presentations will be open to the public, within the context of the various celebrations marking the 100th anniversary of the Cap-Rouge trestle bridge, which will provide grater visibility for civil engineering achievements.

Representatives of the Laval University Student Section./La section étudiante de l'Université Laval.

Members of the jury will have an array of parameters to assess in order to determine the winning teams. Professionalism, creative problem-solving methods and a cooperative spirit within each team will be added benefits in the training of all participants.

Along with this contest, the university's steering committee has organized a spaghetti bridge contest, a wooden crane contest, various conferences, a career forum and a trip to New York. CSCE members will have a lot to think about. ■

*For more information about the CSCE student chapter at Universite Laval contact Francis-Olivier Biron, president. He can be reached at francis-olivier.biron.1@ulaval.ca*

# Lancement d'un concours à l'Université Laval

**Chapitre étudiante de la SCGC, Université Laval**

Après avoir visité les barrages Manic 2 et Manic 5 l'an dernier, le Chapitre étudiant de l'Université Laval innove une fois de plus au niveau de ses activités. En fait, avec la collaboration de la Section de Québec, un concours de modélisation d'une structure ferroviaire centenaire se tiendra de novembre 2012 à avril 2013.

Les équipes d'étudiants au baccalauréat utiliseront le logiciel SAFI pour recréer virtuellement la structure d'acier du « Tracel »

Photos: Jean-Loup Robert

The 100-year-old trestle bridge at Cap-Rouge./Le « Tracel » du Cap-Rouge.

du Cap-Rouge. Les futurs ingénieurs devront produire un rapport de modélisation complet en plus de vulgariser leur démarche devant plusieurs ingénieurs et professeurs expérimentés dans ce domaine.

De plus, la présentation des projets de chaque équipe sera ouverte au public dans le cadre des festivités des 100 ans du « Tracel », ce qui permettra de rehausser la visibilité du génie civil.

Les membres du jury auront une panoplie de paramètres à évaluer afin de déterminer les équipes gagnantes. Le professionnalisme, les méthodes créatives de résolution de problèmes et l'entraide dans l'équipe seront des éléments ajoutés à la formation de chacun des étudiants.

Parallèlement à ce concours, le comité de l'Université ne chômera pas, car avec le concours de pont en spaghetti, le concours de grues, les multiples conférences, le forum carrière et le voyage à New York, les membres de la SCGC seront plus que sollicités. ■

*Pour plus d'informations sur le chapitre étudiant de l'Université Laval, veuillez contacter son président Francis-Olivier Biron. Vous pouvez le joindre à francis-olivier.biron.1@ulaval.ca*

# YP Committee seeks input on sessions, social networking

**Amie Therrien, P. Eng., M. Eng.**
CHAIR, CSCE YOUNG PROFESSIONALS COMMITTEE

The CSCE young professionals (YP) committee has been growing steadily since its creation more than a year ago. We now have a page on the revamped CSCE website (csce.ca/committees/young-professionals/), although it is still needs a lot of work. We plan to improve our communication network by creating a presence on LinkedIn, Twitter, Facebook, etc., so that we can connect and share information more easily. Which platform would be most useful for you? Get in touch and let us know.

We have also seen the YP activities at the annual conference grow over the last couple of years and plan to continue this for Montreal 2013 (www.csce2013.ca). The president's reception, which is a great event for networking with each other, as well as members of the CSCE executive, will still be a featured event. This year it will take place prior to the opening reception instead of during a breakfast. We are also working on a number of sessions that could include topics such as leadership, time management and career paths. Are there any topics on your wish list? Please send us an email with your suggestions.

There will be more YP social events this year, which are always fun and provide a great opportunity to interact in a less formal setting. New items that we are contemplating include the opportunity to participate in a service project that will help people in the Montreal community and a travel bursary to help offset your conference costs. Watch your inbox for upcoming conference details as well as other YP events and initiatives. ■

*Amie Therrien can be reached at yp@csce.ca*

# Le comité des jeunes professionnels cherche des idées en matière de réseautage, etc

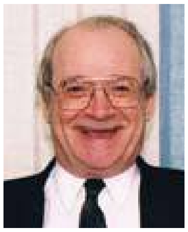
**Amie Therrien, ing., M. Ing.**
PRÉSIDENTE, COMITÉ DES JEUNES PROFESSIONNELS DE LA SCGC

Le comité des jeunes professionnels de la SCGC grandit constamment depuis sa création, il y a plus d'un an. Nous avons maintenant une page (csce.ca/committees/young-professionals/) sur le site web rénové, même s'il reste encore beaucoup à faire. Nous songeons à améliorer notre réseau de communication en assurant une présence sur LinkedIn, Twitter, Facebook, etc. afin que nous puissions faire circuler et partager l'information plus facilement. Pour vous, quelle serait la plate-forme la plus utile ? Faites-nous part de votre réponse.

Nous avons aussi été témoin des activités du comité des jeunes professionnels lors des congrès, au cours des dernières années, et nous comptons faire de même au congrès de Montréal, en 2013 (www.csce2013.ca). La réception du président, qui demeure un grand événement pour le réseautage entre nous comme avec les membres de la direction de la SCGC, demeure un événement important. Cette année, cet événement se déroulera avant la réception d'ouverture plutôt qu'à l'occasion d'un petit déjeuner. Nous préparons également diverses sessions qui pourraient comporter des sujets comme le leadership, la gestion du temps et le cheminement d'une carrière. Y a-t-il des sujets que vous aimeriez voir traiter ? Faites-nous part de vos suggestions.

Il y aura encore plus d'activités sociales pour les jeunes professionnels au cours de l'année, ce qui vous permettra d'interagir en vous amusant, dans un cadre détendu. Les nouveaux projets que nous aborderons comportent des occasions de participer à des projets susceptibles d'aider des gens au sein de la communauté montréalaise, ainsi qu'une aide financière permettant d'absorber une partie des frais de participation au congrès. Surveillez nos prochains courriels sur le prochain congrès ainsi que sur les autres activités pour les jeunes professionnels. ■

*Vous pouvez rejoindre Amie Therrien à l'adresse suivante : yp@csce.ca*



# D.J. Laurie Kennedy, CSCE President, 1975/76

By Mel Hosain, Hugh Krentz, and Peter Wright

The CSCE was saddened to learn of the passing of D. J. Laurie Kennedy on July 1, 2012, in Edmonton. Kennedy, who had been a most effective president in 1975-76, continued to serve the Society in many capacities, including being the chair of the Technical Activities Committee from 1986 to 1988, and chair of the Honours and Awards Committee from 1991 to 1994. His term as president marked the emergence of the Society as an organization with its own sense of place.

Kennedy received his B.A.Sc. from the University of Toronto, and his M.Sc. and Ph.D. from the University of Illinois. He joined the Department of Civil Engineering, University of Toronto in 1956 and was on the academic staff until 1970, when he became the chair of the Department of Civil Engineering at Carleton University. This was followed by a term as dean of engineering at the University of Windsor, after which he moved to Edmonton to pursue both an academic and consulting career. Over the years, in spite of his heavy research involvement, he was an excellent teacher, adored by his students.

Kennedy was internationally recognized as an accomplished researcher in structural engineering, having published extensively in refereed journals and supervised numerous graduate students. One early research example is his work on simple end plate beam connections, which are still included in the CISC Handbook of Steel Construction. Kennedy also served on the NSERC Grant Selection Committee, and undertook national lecture tours for the CSCE.

Kennedy excelled in many areas but his contributions to the development of limit states design requirements for steel building structures will likely be seen as his principal legacy. From 1968 to 2005 he was the chair of the Canadian Standards Association Technical Committee on Steel Structures for Buildings. Thus he has the distinction of chairing the committee that wrote the last version of the CSA S16 Standard based on allowable stress design procedures, published in 1969, and also the first version of the S16 standard based on limit states design procedures, published in 1974. The latter became the first steel design standard based on limit states design published outside of eastern Europe and was used as a model for standards in other countries.

Laurie Kennedy had a distinguished career as a practising civil engineer. His enthusiasm was infectious and his intellectual honesty ensured that whatever he undertook would be done with thoroughness, commitment and integrity. ■

The plant was designed with a small site footprint and features a solar wall.

# Northern Sunrise County Water Treatment Plant

**This project in Northern Alberta is a model example of how remote communities can come together to have a trustworthy water supply. Their new plant is also LEED-certified.**

By Nathan Miller, EIT
ASSOCIATED ENGINEERING

Located in Northern Alberta, Northern Sunrise County encompasses the village of Nampa, the communities of Three Creeks, St. Isidore, Marie Reine, Harmon Valley, Reno, Cadotte Lake, and Little Buffalo, as well as the Woodland Cree First Nation reserve. Together, these communities have a population of approximately 3,000 residents.

During the past decade communities in the county have faced the prospect of having to replace aging water treatment plants. Others such as the village of Nampa also found that their original water source had become unreliable. With increasingly stringent regulations, many communities determined that continuing with individual treatment plants was economically unfeasible, as well as impractical.

Responding to these challenges, Northern Sunrise County partnered with the village of Nampa and Woodland Cree First Nation to embark on a new regional water system. They established a vision to reduce the environmental footprint of the new facilities and to advance their communities' knowledge of water conservation and environmental awareness.

## Plant has small fooprint and efficient systems

The county engaged Associated Engineering to develop an economical and environmentally sustainable new water system. The $66-million project, delivered in two phases, resulted in 100 kilometres of new potable water pipeline and a new water treatment plant that achieved LEED Silver certification – a first for the region! The water treatment plant has a net design capacity of 1,490 m$^3$/day.

By adopting an integrated design process that focuses on sustainable practices, water conservation, and energy conservation, the LEED-

Photos courtesy: Associated Engineering

certified facility has stepped far beyond the current industry practices for the design and operation of water treatment plants.

The plant was designed to have a small site footprint, with storm water management and drought-tolerant landscaping. The building has water efficient plumbing fixtures, a solar wall pre-heat air ventilation system, and energy efficient lighting. A water-to-water heat pump provides a novel approach to the building's cooling system, sending reject heat to a process clarifier tank instead of using an air condensing unit. The design also incorporates daylighting, a high insulation R-value building envelope, recycled content in its materials, and low-VOC paints and sealants.

Micro filtration membrane equipment inside the plant.

## Desiltation and ultra-filtration membranes

The Peace River provides the raw water supply source for the plant. Water is drawn from the river via Shell Canada's existing river intake and transferred by two low-lift pumps to an adjacent desiltation pond. The desiltation pond is designed to allow silt and sand to settle from the water. Removing silt and sand reduces wear on the plant's mechanical components and reduces the amount of chemicals required to treat the water.

High pressure transmission pumps then transfer the raw water from the river valley to the water treatment plant's raw water reservoir. The reservoir is equipped with an aeration system that maintains and improves the stored water quality and inhibits algae growth. From the reservoir, raw water is fed to the water treatment plant by gravity, which reduces the pumping requirements.

The water treatment plant consists of a packaged clarifier system and ultra-filtration membranes. A total of 10 different chemicals are used to help in the pre-treatment, membrane maintenance and disinfection phases, helping to remove taste and odour and to settle particulates.

The packaged clarifier pre-treatment tank is equipped with mixers and a settling unit. Alum is used to coagulate and help settle out solids in the raw water. From here the water flows into a tank that supplies the membrane system.

Microfiltration membrane systems effectively remove very small particulate matter from the water, using 0.1 micron polyvinylidene-flouride (PVDF) hollow fiber membrane technology. The membranes remove the remaining suspended solids and pathogens, then the treated water flows to the clearwell where it is chlorinated for disinfection. At the end of the clearwell, ammonia is added to the water to form chloramines. Chloramine lasts much longer in the local water distribution systems than chlorine, meaning it provides them with greater protection against contamination from bacteria and viruses.

The treated water is delivered throughout the county via two regional water pipelines, one serving the communities to the east of the plant and the other serving those to the south.

## Project fosters relationships

The LEED Silver certified water treatment plant and regional water supply system is a model example of a community approach. The project fosters relationships between municipal governments, First Nations, federal agencies, the Government of Alberta, and private industry to develop a safe, reliable and sustainable source of drinking water. Northern Alberta farming communities, hamlets, towns, and First Nation communities that would normally rely on substandard local water sources, can now rely on a safe, robust source of drinking water that will sustain community growth and economic development in the region. ■

OWNER: Northern Sunrise County and NEW water Ltd. partners
PRIME CONSULTANT: Associated Engineering, Edmonton
(Blair Birch, P.Eng., Garry Drachenberg, P.Eng., Juliana Tang, P.Eng.)

# Water Treatment for The Six Nations

Water treatment plant under construction.

**A large First Nations community in southwest Ontario is building a water treatment plant to overcome problems with the Grand River water source.**

By Justin Gee, P.Eng.
VICE PRESIDENT, FIRST NATIONS ENGINEERING SERVICES LTD.

The Six Nations of the Grand River is the largest First Nation in Canada. It is located approximately 20 kilometres southeast of Brantford, Ontario, along the banks of the Grand River and has a population of 12,000 people.

The existing communal water supply, treatment and distribution system services approximately 14% of the community, primarily within the Village of Ohsweken. The rest of the population relies upon individual wells (53%), trucked water (20%) or other water supplies (2%), while approximately 11% has no water supply.

For decades the First Nation has been experiencing drinking water quality and supply issues with both individual residential groundwater supplies and the communal water system. In 2004, for example, a hydrogeological study found that 78% of the wells tested were contaminated and that a majority of the dug or bored wells had water shortages.

Photos courtesy: FNESL

The source of raw water for the existing communal water system is the Grand River. Treatment is by a full conventional treatment process and UV disinfection. The plant was originally commissioned in 1989 and over the years a number of water quality and operational issues have been reported. For example, persistent disinfection by-product issues could not be properly addressed due to the limitations of the technology in place, and Six Nations Council imposed a water consumption ban that lasted 55 weeks in 1992-1993 due to excess levels of N-Nitrosodimethylamine (NDMA).

As well, the quality of water in this section of the Grand River fluctuates dramatically depending upon the season. Turbidity, for instance, varies from 10-1,340 NTU. As a result, the vast majority of municipalities have abandoned the Grand River as their source of raw water.

## Decision to replace the existing plant

Six Nations retained First Nations Engineering Services Ltd. (FNESL) to review the existing communal water treatment and supply system in 2003. Based upon population, housing and non-domestic demand projections, we determined that the treatment and supply system was not able to meet the community's long term needs.

A decision was therefore made to build a new water treatment plant located 1.2 kilometres north of the existing plant along the Grand River. Now under construction by contractor Maple Reinders, the plant is scheduled for completion in spring 2013.

Construction of multi-port intake structure along the Grand River; there are also two twinned below-grade conduits to store raw water in case of contamination occurring upstream.

## Membrane pilot studies

Due to the problems associated with groundwater in the area, the Grand River remained the only viable source of supply for the community, so an analysis was conducted to determine an effective treatment system for this raw water source. The study examined various treatment technologies, including full conventional treatment, continuous contact upflow treatment, ozonation with slow sand filtration, the Actiflo process (used by the City of Brantford), and membrane filtration.

Two membrane systems were piloted head to head over a one year period. The pilot study demonstrated that membrane technology is robust and can handle the fluctuations of raw water from the Grand River with an appropriate dose of coagulant. It proved that membranes are an appropriate technology for difficult raw water. Due to funding constraints, however, the scope of the pilot study was limited and did not definitively address issues such as NDMA, taste and odour, disinfection by-products, or ammonia.

A design team led by First Nations Engineering Services with experts from across Canada, including Associated Engineering and AANDC, went through a rigorous process of assessing additional treatment technologies required to augment the proposed membrane filtration system. To meet the regulatory requirements that membranes alone could not address, a multi-barrier approach was deemed necessary. As a result, BAC contactors, UVAOP (ultra-violet advanced oxidation process), with hydrogen peroxide and chloramination were added to the treatment process.

## Fluctuating water levels

The historic high water level of the Grand River is almost 7 metres above the typical surface elevation in this location. A river bank intake structure that could accommodate the seasonal river level fluctuations was required, but the structure also had to deal with freezing in the winter, ice flows in the spring, and debris and sediment collection in the intake screens throughout the year.

The solution was a multiport intake structure along the bank of the river, with removable fish screens and backwash capabilities. The control building was located at an elevation above the river's historic high water level.

## Downstream from 37 municipalities

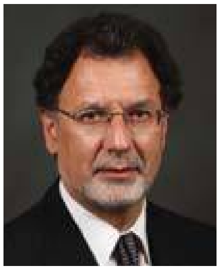
Because Six Nations is located in the lower end of the Grand River watershed, the water at the intake is susceptible to spills and contamination from any of 37 municipalities (Brantford, Cambridge, Kitchener, Waterloo and Guelph, total 1 million residents) that lie upstream.

To cope with such an event a system was required to allow the intake to be shut down on demand and allow spills to flow by the intake without interrupting the plant's water production. The solution was to have two twinned below-grade conduits that will store raw water to permit the plant's ongoing production. The twinned structures are also designed to encourage sedimentation of the raw water, which will attenuate turbidity spikes and make the plant operations easier.

The plant is designed to process 50 L/s but the capacity can be increased to 100 L/s without expanding the buildings. It will initially service 14% of the First Nation, but when the distribution system is expanded in the future, the plant will service an additional 1,000 homes ■

NAME OF PROJECT: The Six Nations of Grand River Water Treatment Plant
OWNER-CLIENT: The Six Nations of the Grand River
PRIME CONSULTANT, ENGINEERING DESIGN: First Nations Engineering Services Ltd., Ohsweken, Ont. (Justin Gee, P.Eng., Craig Baker, P.Eng., Kyle Gee)
SUBCONSULTANT, ENGINEERING DESIGN: Associated Engineering (Elia Edwards, P.Eng.)
CONTRACTOR: Maple Reinders

# The Infrastructure Deficit Defined – Is Asset Management the Solution?



**Carl Bodimeade, P.Eng.,**
CHAIR, ONTARIO COALITION FOR SUSTAINABLE INFRASTRUCTURE (OCSI)

**Darla D.W. Campbell, P.Eng.,**
EXECUTIVE DIRECTOR, OCSI

It has been said that we live in interesting times. That is especially true when it comes to the emerging challenge faced by municipalities in balancing their budgets while continuing to invest for the future. Talk about conflicting priorities. Elected officials are being pushed from all sides, hearing about the need for additional investment in social programs, increased protection with police services, enhanced funding to tackle potholes and more money for rehabilitating water and wastewater infrastructure to extend their useful life. And that is just the beginning.

## Crisis, what crisis?

This crisis has been creeping up on us over the past several decades. Thought leaders promoting the concept of managing infrastructure in a sustainable way were met with ignorance of the problem and delay. Although it made sense at the logical level, the renewal plans for existing infrastructure continued to take a back seat to what seemed to be more pressing issues at the time. Now the time has come.

The first Canadian Infrastructure Report Card was released in September 2012, a joint initiative by the Canadian Construction Association (CCA), Canadian Public Works Association (CPWA), Canadian Society of Civil Engineers (CSCE) and the Federation of Canadian Municipalities (FCM). The report card defines the municipal infrastructure deficit in 123 communities across the country. The results were then extrapolated across the country. In the four categories of municipal assets measured, municipal roads faired the lowest.

### CANADIAN INFRASTRUCTURE REPORT CARD - HIGHLIGHTS

**Physical condition assessment:**

- Drinking Water – Good, adequate for now (15.4% rank condition of pipes fair or below)
- Wastewater – Good, adequate for now (30.1% rank condition of pipes fair or below)
- Storm Water – Very Good, fit for the future (23.4% rank condition of pipes fair or below)
- Municipal Roads – Fair, requires attention (52.6% rank physical condition fair or below)

The infrastructure report card defined the replacement cost for municipal roads, i.e. to bring the infrastructure ranked fair and below up to good, as $91.1 billion or $7,325 per household in Canada. The total value of the four types of municipal infrastructure (their replacement cost) is estimated to be $538.1 billion.

## Ontario takes the lead in asset management plans

In August, Ontario Infrastructure Minister Bob Chiarelli announced the launch of the first phase of the province's Municipal Infrastructure Strategy. Asset management planning is a cornerstone of this strategy. This type of planning considers the long-term aspect of infrastructure and helps ensure communities get the greatest value from infrastructure investments.

The province included funding to assist smaller municipalities with asset management plans in the amount of $60 million over three years, under its long-term infrastructure plan, Building Together. More information is available at www.ontario.ca/municipalinfrastructure.

The Ontario Coalition for Sustainable Infrastructure (OCSI) publicly supported the new strategy. "Good asset management is one of the keys to ensuring infrastructure is safe and sustainable," remarked Carl Bodimeade, OCSI chair. "Well managed infrastructure is necessary to provide Ontarians with the level of service they require and expect."

## Three steps towards a solution

Through the collaborative work of the Coalition, OCSI suggests that the solution relies on a three-point approach.

**Awareness:** Increase awareness and recognize the extent of the problem. The recent adoption of the Public Servicing Accounting Board (PSAB) 3150 rules was a good first step, requiring municipalities to report the depreciated value of their assets in their financial reports, therefore quantifying the annual funds required to offset depreciation.

**Communication:** Communicate the problem to elected officials and the public. Articulate and demonstrate the value that the public receives through the various taxes they pay, how those are directly responsible for the infrastructure upon which our health, quality of life and economic competitiveness depend. And equally important, communicate the consequences if that infrastructure is not maintained.

**Planning:** With a better understanding of the problem, plan to address it. This will require integrated land use, engineering and fiscal planning. Take a longer range view of our communities and consider life cycle costing (as shown in Figure 1). Financial plans are required to provide the life cycle costs in a sustainable way.

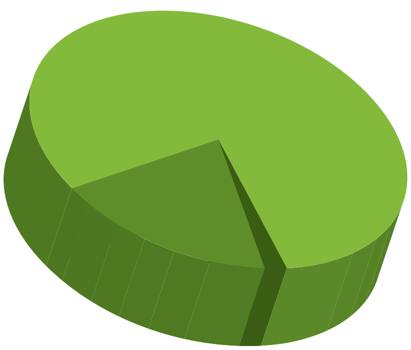



Figure 1: Asset life cycle costing
(Source: Infraguide, 2006)

## Get the right people at the table

Quoting from Albert Einstein, "Problems cannot be solved by the same level of thinking that created them." The infrastructure deficit problem will be solved by expanding the conversation to include input from new perspectives.

"We need new planning paradigms that entwine our cities and regions, we need clarity about what it will cost to make the public infrastructure investments that we require, and we need to embrace new, creative financing models," stated Jennifer Keesmaat, chief planner, City of Toronto, in an article in the *Globe and Mail* on September 10, 2012

OCSI recently expanded its membership beyond engineers and operation staff to include the voice of those making financial decisions. Municipal Finance Officers' Association of Ontario (MFOA) brings expertise related to the financing of municipal infrastructure, an essential component of the sustainability challenge faced by municipalities.

"When we learned about the mandate of OCSI, we recognized how important it would be to lend our voice, representing the financial aspects of infrastructure, to the experience of the well established organizations that build and operate the infrastructure," stated Calvin Barrett, treasurer and past president of MFOA.

## Contribute to the conversation

As the task of building infrastructure is expanded to include meeting the environmental sustainability challenge and incorporating operations and maintenance into the solution, the voice of the engineer is essential in the conversation. Engineers should seek opportunities to educate the public and municipal clients in the move towards achieving sustainability, as well as other levels of government.

Over the summer, the federal Minister of Infrastructure and Communities hosted roundtables to explore how future federal infrastructure programs could respond to specific challenges in various regions and sectors. OCSI's submission to Minister Denis Lebel included these key messages:

**Manage existing infrastructure:** The need for existing infrastructure to be maintained and funded. Sustainable infrastructure is not only about building new infrastructure, it's about managing existing infrastructure and getting good value. Effective management of existing infrastructure includes: operation and maintenance; repair, rehabilitation and replacement; and disposal.

**Determine life cycle costing:** Strive to minimize life cycle costing when building new capital projects. Identifying savings on the operations and maintenance are significant because over time the annual operating costs far exceed the initial capital cost by 5:1. Low bid options and pricing often run counter to long-term planning.

**Plan for asset management:** Develop and use asset management plans that integrate technical, operational/maintenance and financial perspectives, which provide municipalities with necessary information to make informed decisions, in particular, related to affordable service levels.

## Next steps

The sooner action is taken to make our infrastructure systems sustainable from environmental, societal (service level) and fiscal viewpoints, the less it will cost the citizens. The issue is on the table now that the infrastructure deficit is defined. Asset management planning is an essential aspect of the solution. The next step is to get the right people at the table, have a frank discussion and together seek sustainable solutions to adequately maintain municipal infrastructure and services in the long-term. ■

*Carl Bodimeade, P.Eng, has a strong interest in the sustainability of infrastructure systems. He is a senior vice-president with Hatch Mott MacDonald and Chair of OCSI.*

*Darla Campbell, P.Eng., is experienced in municipal and provincial infrastructure development. She is president, Amonavi Consulting Group Inc., and executive director of OCSI.*

*The OCSI coalition comprises: Municipal Engineers Association, Municipal Finance Officers' Association of Ontario, Ontario Good Roads Association, Ontario Public Works Association, Ontario Water Works Association and Water Environment Association of Ontario.*

# Small and Rural Water Systems Have Unique Needs

## Small water systems face both technological and financial constraints. The following technical papers explore some solutions.

**Gopal Achari, PhD, P.Eng**
CHAIR, CSCE, ENVIRONMENTAL DIVISION

Canada is a geographically diverse country with an estimated 20% of its population living in small and rural communities. Many of these communities have their own water treatment and distribution systems. With a few exceptions, the bulk of the water systems that exist in small and rural communities meet only a certain basic level of treatment. The source waters that feed these small water treatment plants are quite varied and the technologies in place to treat these source waters may not always match with the quality of the source waters.

The problems of small water systems are a combination of technological issues, financial constraints and operational oversight. Numerous small communities only have part-time operators who may or may not have the resources necessary to solve problems when the water quality changes. Limited financial resources become a major issue when the time comes for major repairs or the replacement of units.

Whereas some provinces provide support in the form of grants for capital enhancements, others have a dual system where high quality water is delivered for personal consumption only.

While such recognition of the lack of resources of small systems is welcome, more needs to be done. Support to small communities can be provided in a variety of ways, which include developing robust technologies that require minimal oversight, developing cost effective and reliable on-line water quality sensors, automated data collection and analysis, and sophisticated decision support systems. All of these will aid the operators to make timely decisions when the water quality changes. ■

*Gopal Achari is a professor with the Department of Civil Engineering, University of Calgary.*

# Les systèmes d'eau potables en milieu rural ont des besoins particuliers

**Gopal Achari, Ph.D., ing.**
PRÉSIDENT, LA DIVISION ENVIRONNEMENT DE LA SCGC

Le Canada est un pays dont la géographie varie et dont environ 20 % de la population vit dans de petites communautés rurales. Nombre de ces communautés ont leur propre réseau pour le traitement et la distribution de l'eau. À quelques exceptions près, la plupart des aqueducs en milieu rural ne font qu'un niveau élémentaire de traitement. Les eaux de source qui approvisionnent ces aqueducs présentent des caractéristiques très variées. Les technologies installées pour traiter ces eaux de source peuvent souvent ne pas correspondre à la qualité de ces eaux de source.

Les problèmes des petits aqueducs sont en fait un assortiment de problèmes technologiques, de contraintes financières et de négligence dans l'exploitation. Nombre de petites communautés n'ont que des opérateurs à temps partiel, qui n'ont pas toujours les ressources nécessaire pour régler les problèmes lorsque la qualité de l'eau évolue. La faiblesse des ressources financières devient un grave problème lorsque vient le temps de faire de grosses réparations ou des changements d'appareils.

Alors que certaines provinces fournissent de l'aide sous forme de subventions pour les investissements, d'autres ont un système à deux niveaux en vertu desquels l'eau de qualité n'est livrée que pour l'utilisation par les personnes.

Bien que le simple fait de reconnaître l'existence de ce manque de ressources est déjà un élément positif, il reste beaucoup à faire. L'aide aux petites communautés peut prendre diverses formes, comme l'élaboration de technologies simples et efficaces exigeant un minimum de surveillance, la création de senseurs pour vérifier directement la qualité de l'eau sur place, des systèmes automatisés de cueillette et d'analyse de données pour la prise de décisions. Tout ceci aide les exploitants à prendre des décisions en temps opportun lorsque la qualité de l'eau évolue. ■

*Gopal Achari est professeur au département de génie civil de l'Université de Calgary.*

# Water Pricing Models, Sustainability and Financial Viability of Small Water Systems in Canada

**Mohammed H. I. Dore,**
DEPARTMENT OF ECONOMICS,
BROCK UNIVERSITY

**Gopal Achari,**
DEPARTMENT OF CIVIL ENGINEERING,
UNIVERSITY OF CALGARY

This paper surveys the pricing of drinking water in Canada and the general inadequacy of revenues for the proper functioning and upgrading of water treatment plants. Some large water systems face the problem of deferred maintenance. The small water systems, due to either a lower tax base or political pressure in the local communities, also face inadequate funding, made worse in part by the downloading of financial responsibility from higher levels of government. Under these conditions the modernization of the water sector remains a challenge. Only the regulatory authorities with direct contact with public water utilities could encourage proper pricing and adequate planning for future upgrades of treatment plants.

## Introduction

Canadians use 1,600 cubic metres of water per person per year, which is more than twice as much as the average person in France, three times as much as the average German, almost four times as much as the average Swede and more than eight times as much as the average Dane. Canada's per capita water consumption is 65 per cent above the OECD average (The Conference Board of Canada 2012). Thus Canadian per capita consumption is ranked 28th among the 29 nations of the OECD. Only U.S. residents use more water than Canadians.

This level of usage is partly due to lifestyles of North Americans (large houses, expansive gardens, many with swimming pools, etc); and in Canada partly because Canadian households do not pay the full cost of producing and distributing water, even after the downloading of the financial responsibility to local communities. The pricing of water is not directly dependent on actual water used so that there is little incentive to economize in the use of water or to fix leaking pipes. Table 1 shows in summary form the pricing structure of water in Canada.

In 2009, 75 per cent of households were metered, mostly in the large urban areas (source: C.D. Howe Institute). Most small systems are on flat rate, are unmetered, and use 70 per cent more water compared to large water systems.

As shown in Table 2, Edmonton is one of the cities in Canada that prices water in such a way as to encourage conservation, as it has an increasing block rate by volume. But as Table 1 shows, increasing block rate locations account for only 9 per cent of the total population. Declining block rates encourage wasteful use of water.

Operating costs are also probably high as no industry benchmarks on optimal capital-labour ratios are given or are even known. In addition, labour union pressure may lead to over-employment; and, until the events of Walkerton, there was no serious oversight or monitoring of water quality and operations. One benefit of the tragedy of Walkerton in 2000 was that all provinces have implemented administrative structures that monitor drinking water quality. For example, Ontario has its Drinking Water Inspectorate; BC and Alberta have drinking water officers.

Some large older cities like Toronto and Halifax are suffering from the problem of "deferred maintenance," where large sums of money will be needed to fix and replace an aging water infrastructure. In the rural areas and in smaller communities, drinking water treatment is almost solely reliant on old rudimentary chlorine-based treatment systems with inadequate reservoirs, so that any sudden high demand leads to the water bypassing chlorine treatment, and consequently a boil water advisory is triggered.

Many communities have been living with more or less permanent boil water advisories. According to 5 B.C. health authorities, there were approximately 628 boil-water advisories in place in B.C. in May 2010. In Newfoundland and Labrador the number of boil water advisories remains high (201 in 2011), although the provincial government has a very progressive policy in supporting small water utilities. Typically, the smaller the population, the higher the price of water and the risk of contamination.

Of course, small water systems have additional problems, due in some cases to a lower tax base or simply because local political authorities have no interest in higher water quality in publicly owned water systems if that would mean higher water prices.

We found this to be the case in a number of island communities off the coast of B.C. In

**TABLE 1: THE STRUCTURE OF WATER PRICING IN CANADA**

| Type of pricing | % of population |
|---|---|
| Flat rate fee | 43 |
| Constant price per volume | 36 |
| Declining block rate per volume | 12 |
| Increasing block rate per volume | 9 |

Source: Brubaker (2011)

such communities water is underpriced except when it is managed by a private corporation; according to a C.D. Howe Report, B.C. has approximately 178 privately owned water utilities, charging much higher prices. But the publicly owned systems in general have either no treatment and are under boil water advisory or they use old and rudimentary chlorine injection treatments, where the amount of chlorine use can be excessive. Typically such systems charge a flat rate, which does not raise enough revenue for adequate maintenance or for upgrading of treatment plants.

Indeed, the revenue aspect is possibly the major constraint and so we next review two pricing models for water, one which would raise adequate revenue, if implemented properly, and one which would not. We focus on the full cost approach and the limited recovery approach.

## Two pricing models

Full cost includes the total capital, suitably amortized, as well as the total operating and maintenance costs. In this approach the amortization follows standard accounting procedures, as it would lead to the setting up of a fund for capital replacement. It should be emphasized that an appropriate amortization of the capital costs is essential, and is the major gap in many small water systems.

Limited cost recovery is used in a number of communities, especially in Alberta. Alberta Environment recommends that all water treatment plants should move towards full cost recovery, but the capital grant program is a disincentive. The limited cost recovery approach treats any capital paid for by a higher level of government as a free gift. The remaining costs are financed by raising a bond and only the debt service cost of this bond is covered in the pricing of water to the households.

## Some lessons from Alberta

In Alberta, small municipal systems receive up to 75 per cent of the capital cost as a grant. Most small systems do not price according to full cost recovery principles. In practice full cost pricing would mean a very steep increase in the price of water.

Comparing the estimated revenue per cubic meter with the estimated partial cost per cubic meter at several water plants in Alberta underscores the role that the grant program has played in providing small communities with a water treatment plant. Even with subsidization, most of the small communities in Alberta are currently not recovering their full cost, although some recognize the need to improve and adjust their water rates to recover full cost in the future.

## Motivating the production of higher water quality

In general, public water systems in Canada have no incentive to lower costs or upgrade water quality, as long as the utility is meeting the minimum requirements of disinfection, usually with dosages of chlorine, which is sometimes used excessively, exposing water users to potentially harmful long term health risks. Introducing newer treatment technology could reduce operating costs, but the low pricing policy ensures that they have no funds for that. Under these circumstances, it is very difficult to see how change towards higher water quality can be motivated. It seems that for this we will have to rely either on citizen pressure or on more stringent regulatory requirements. Newer cost-effective technologies exist, but with low water rates, water utilities cannot budget for improvements for plant upgrades.

In all the provinces of Canada, the main concern is disinfection: meeting the minimum regulatory requirements. Of course this is necessary, but in Ontario the Drinking Water Inspectorate reports more than 99 per cent compliance on pathogens. As a result the Inspectorate will be turning to more long-term contaminant issues. For example, NDMA is now controlled in Ontario. It would be good if more Canadian provincial authorities also expanded the scope of their oversight and monitoring to go beyond pathogens. Most water systems are unlikely

**TABLE 2: EXAMPLES OF WATER CHARGES IN CANADA**

| Location | Fixed water charge | Consumption charge per cubic meter | Annual cost to the household (in 2011 constant dollars) |
|---|---|---|---|
| Victoria/Esquimalt | $99.90 per annum | $1.0596 | $417.78 |
| Vancouver | Flat annual rate | Nil | $513.00 |
| Calgary | $163.68 per annum | $1.4876 | $609.96 |
| Regina | $208.05 per annum | $1.3500 | $613.05 |
| Winnipeg | $72.00 per annum | $1.3500 | $477.00 |
| Toronto | Nil | $2.4897 | $746.91 |
| Halifax | $206.36 per annum | $0.5090 | $359.06 |
| Edmonton | $78.60 per annum | $1.6435 (first 10m$^3$)<br>$1.7955 (10 - 35m$^3$)<br>$2.2691 (> 35m$^3$) | $736.50 |

Source: Capital Region District of Greater Victoria (2012).

to go beyond the minimum regulatory requirements unless compelled to do so.

Local public utilities lack incentives to think long term and improve water quality. There is no competitive pressure and no profit motive – the only driver is regulation. Many small communities want the lowest price of water that just meets the minimum regulatory requirements, and so either they claim that they really cannot afford to pay for upgrades, or their elected local politicians refuse to agree to upgrades.

> "Newer cost-effective technologies exist, but with low water rates, water utilities cannot budget for improvements for plant upgrades"

Unfortunately the downloading of financial responsibilities has further reduced the funding available to water systems, although for capital improvements there is still the federal-provincial-municipal program whereby each jurisdiction could contribute just one-third of the capital costs for new plants and upgrades. It does not seem that many take advantage of this program, except in Victoria, B.C., and communities in Newfoundland and Labrador. In fact, the Government of Newfoundland and Labrador adds further assistance, as shown in Table 3.

In addition to the fact that the Newfoundland and Labrador government offers assistance for the costs of the capital required for treatment plant based on the population size of the community, the following should be noted: (1) communities with a population of 10,000 or more are cities that can enjoy lower unit costs of producing water due to economies of scale, and so such cities receive no capital subsidy; (2) there has been no "downloading", so that the pricing policy followed by most communities in Newfoundland and Labrador is such that they pay water charges that cover operating costs only; (3) in addition, communities with populations less than 500 may apply for the establishment of a "Potable Water Dispensing Unit (PWDU)".

PWDUs are communal units that supply very high quality drinking water for $0.03 per litre on an honour system. These units are for very small communities which suffer from long-term boil water advisories or persistently high levels of disinfection byproducts; or which consistently exceed the maximum allowable contaminants (MCLs) specified in the Government of Canada Drinking Water Quality Guidelines. Some $21 million was budgeted for 2008-2011, specifically for PWDUs, by the Newfoundland and Labrador government. It would be good to see other provinces emulate Newfoundland and Labrador in following a very active water policy supportive of small communities.

## Concluding remarks

Publicly owned water utilities in Canada face the problem of inadequate funding. The larger, older cities have an old and unreliable infrastructure as a result of what is called "deferred maintenance" – due to either low revenue as a result of low and inadequate water charges, or lack of funding from higher levels of government (a phenomenon known

**TABLE 3: PROVINCIAL ASSISTANCE ON CAPITAL COSTS OF WATER SYSTEMS BY POPULATION IN NEWFOUNDLAND AND LABRADOR**

| Population | Provincial share of capital costs | May not exceed the following debt-service ratio |
|---|---|---|
| LSDs (non-municipal) | 100 per cent | 30 per cent |
| Less than 3000 | 90 per cent | 30 per cent |
| 3000 to 7000 | 80 per cent | 30 per cent |
| 7000 to 10,000 | 70 per cent | 30 per cent |

Dore and Lee (2012)

as "downloading"). The rural and small communities also face inadequate funding in addition to having a lower tax base. Under these conditions, the modernization of the public water sector remains problematic.

However, with the appropriate leadership from Drinking Water Inspectorates and drinking water officers, water utilities could be encouraged to set up long-term plans, perhaps in anticipation of tighter regulations in the future for higher water quality. For example, source waters that contain nitrosamines, pesticides and geosmin that are sometimes above the MCLs are the main reason why some municipalities will consider buying advanced oxidation treatment technologies, some of which are actually designed for small systems.

In a study by the US Geological Survey (USGS), published in September 2010, USGS researchers found that 91 per cent of algae blooms contained harmful algal toxins. In the U.S., the USEPA has listed freshwater cyanobacteria and their toxins on the Contaminant Candidate List. In addition, New Zealand, Germany, and the World Health Organization have established microcystin guidelines of 1.0 parts per billion (ppb), while Canada has established a 1.5 ppb guideline. Utilities should be encouraged to treat these current guidelines as possible future regulatory requirements, and therefore plan and budget for systematic plant upgrades. Only personnel from the regulatory authorities, like Inspectors and Drinking Water Officers, with actual direct contact with water system managers and operators can do that.

## Acknowledgement

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# A Decision Support Tool for Small Water Systems

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Water treatment plants (WTPs) rely on complex monitoring and control systems in order to ensure that drinking water meets the highest standards and poses no adverse health risk to the receiving population. WTPs in small communities often do not have the resources available to develop or maintain supervisory control and data acquisition (SCADA) systems and must rely on regional monitoring networks or on the abilities of their own operators. With the goal of providing a basis for consistent WTP operation, a decision support system (DSS) was developed as a tool for operators of small water treatment systems. The DSS contains a data management system, performance assessment, a checklist of preventative and corrective actions, and a screening-level quantitative microbial risk assessment (QMRA). The DSS process has been automated in the form of a Microsoft® Excel® spreadsheet that requires a minimal amount of operator input, and is intended to facilitate record keeping, regulatory reporting, and data analysis needs.

The DSS is intended to work with most small WTPs, and includes options for the operator to specify the source of raw water, which treatments units are present, and the filter type used. Assumptions made in developing the DSS generally reflect conditions and regulatory requirements currently present in Alberta.

## Operator inputs

The inputs required for the DSS to complete calculations are obtained directly from the operator or are default values based on conservative assumptions concerning source water quality and treatment system operations. Inputs are required in three separate fields: raw water chemistry, microbiology and WTP unit inputs. The operator must enter all required inputs to complete a record, which is saved in a database.

The raw water chemistry inputs are temperature, pH and turbidity, which are used to determine the required chlorine residual concentration for disinfection. Raw microbiology inputs are the expected colony forming unit (cfu) concentration for E. coli, Giardia, and Cryptosporidium, which are used in the QMRA calculations. It is expected that raw water concentrations will be based on values used in the WTP approval, with seasonal worst case concentrations applied. If these values are not available for a WTP, a default value is utilized to represent a worst case concentration for the specified raw water source. The WTP inputs are the output turbidity values from the sedimentation and filtration units, and the chlorine residual concentration and contact time (CT value) for the disinfection unit, which are used to complete the performance assessment. An additional option is provided for operators to enter a required CT value in directly, if it is available. Figures showing the system and record input pages of the DSS are included below.

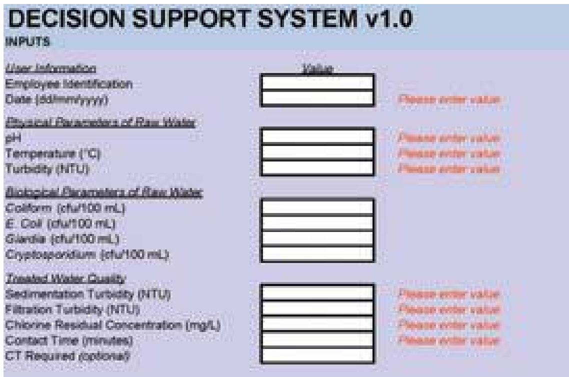
## Performance assessment

Currently, the DSS is configured for a WTP that includes some combination of a sedimentation unit, filtration unit, and/or disinfection unit. The performance of each unit is assessed individually using a performance function. The performance function includes consideration of any regulatory approval conditions, as well as a determination of system reliability and consistency over time. As this metric is intended for small WTPs, the performance functions are calculated using a minimal amount of data, all of which would be available as an operational requirement.


DECISION SUPPORT SYSTEM v1.0
SYSTEM DESCRIPTION

| | |
|---|---|
| Source Water Type | Surface Water |
| Treatment System | Filtration and Disinfection |
| Filter Type | Slow Sand or Diatomaceous Earth |

Figure 1. System level inputs.


DECISION SUPPORT SYSTEM v1.0
INPUTS

| User Information | Value | |
|---|---|---|
| Employee Identification | | |
| Date (dd/mm/yyyy) | | Please enter value |
| *Physical Parameters of Raw Water* | | |
| pH | | Please enter value |
| Temperature (°C) | | Please enter value |
| Turbidity (NTU) | | Please enter value |
| *Biological Parameters of Raw Water* | | |
| Coliform (cfu/100 mL) | | |
| E. Coli (cfu/100 mL) | | |
| Giardia (cfu/100 mL) | | |
| Cryptosporidium (cfu/100 mL) | | |
| *Treated Water Quality* | | |
| Sedimentation Turbidity (NTU) | | Please enter value |
| Filtration Turbidity (NTU) | | Please enter value |
| Chlorine Residual Concentration (mg/L) | | Please enter value |
| Contact Time (minutes) | | Please enter value |
| CT Required (optional) | | |

Figure 2. Record level inputs.

The performance functions provide a single value as output; a positive number indicates that treatment objectives are met and that the unit is operating properly, and a negative number indicates that the unit is performing poorly. The performance function output can be used as a direct assessment of how well the treatment unit is operating, whether regulatory requirements are being met, and if any action is required.

Performance in the sedimentation and filtration units is calculated using the turbidity outputs from that unit, calculated as follows (Zhang et al 2012):

$$PF = 1 - \frac{1}{2}\left(\frac{T_{95}}{T_{50}} + \frac{T_{50}}{T_{GOAL}}\right)$$

Where:
PF is the performance function,
$T_{95}$ is the 95$^{th}$ percentile turbidity,
$T_{50}$ is the media, or input turbidity, and
$T_{Goal}$ of the treatment objective for turbidity

The 95th percentile turbidity is calculated based on previous turbidity measurements, the number of which can be adjusted based on the variability of the source water. The treatment objective for turbidity is determined based on the filtration system used, based on guidance published by Alberta Environment and Sustainable Resource Development (ESRD). However, if a WTP has a more stringent treatment objective for turbidity as an operational approval condition, that value could also be applied.

Performance for the disinfection unit is determined using the CT value, the product of chlorine residual concentration, and the actual contact time. For the DSS, a generic CT requirement is used based on a 4-log reduction in Giardia for the input pH and temperature, as Giardia have the highest disinfection requirements. Required CT values are based on ESRD (2006) recommendations. The performance function for disinfection is calculated as follows:

$$PF = CT_{CALCULATED} - CT_{REQUIRED}$$

This functions identically to the CT ratio typically used by operators. The DSS output page is shown below as Figure 3.

## Unit checklists

Fault tree analysis is a method to identify interrelationships among critical events that can lead to system failure. For the DSS, reviews of expert knowledge and interviews conducted with operators were used to develop fault trees for each of the treatment units. In this case, fault tree analysis was used to identify the basic causes of poor treatment, as identified by a negative performance function value.

The four categories of basic causes identified were: poor raw water, mechanical failure, operator error, and failure of a preceding unit. For each category, several causes were identified for each individual unit. The DSS provides these basic causes in a checklist format, which can be used to identify the source of the problem. The results of the checklist are recorded, with the intention that it could be used as a maintenance record or to identify long-term issues with the treatment units. The checklists for each unit are shown below as Figure 4.

## Quantitative microbial risk assessment (QMRA)

Quantitative risk assessment is the process of calculating a value that represents the severity of a potential hazard and the probability of that hazard occurring. For QMRA, the hazard is illness related to improperly treated drinking water and the probability is expressed as disability-adjusted life years per person per year (DALY). QMRA is a methodology that has been adopted by Health Canada to assess the health risks of pathogens in drinking water and a basic form has been implemented into the DSS tool.

The QMRA involve a series of assumptions regarding the behaviour of both the receptor group drinking the water, and the behaviour of the pathogens. Pathogen concentrations are assumed to be unchanged from the raw water concentration except for a log-factor reduction based on successful treatment. The DSS assumes that if a treatment unit meets its performance goal, then it will reduce each pathogen concentration by a given factor, which differs for each unit and is based on ESRD publications (2006). The DSS does not allow for partial treatment credits. It is assumed that a typical individual ingests a

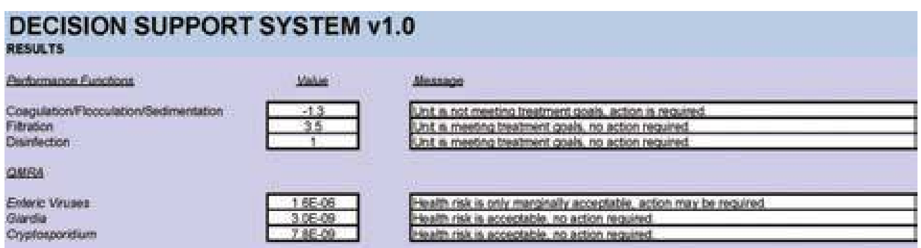



Figure 3. Performance and QMRA outputs.

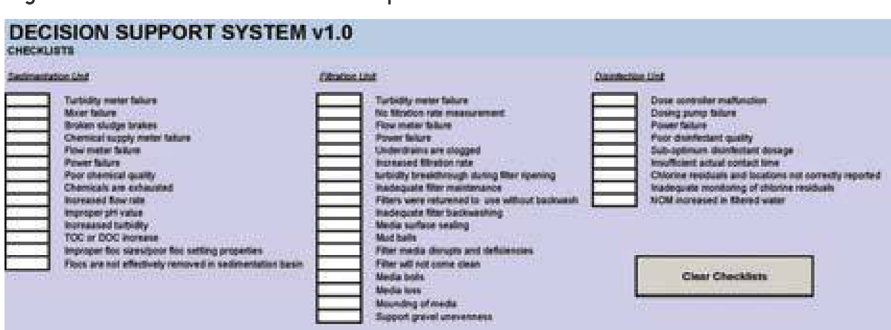



Figure 4. Treatment system checklists based on fault tree analysis.

known quantity of water per day, all of it obtained from the WTP, and the number of microbes ingested by the receptor can be predicted. At this point several assumptions regarding the behaviour of microbes within the human body are made, including the probability of causing infection, probability that the infection results in symptomatic illness, and the resulting disease burden of that illness. The values used by the DSS in these assumptions were all obtained from draft Health Canada guidance (2010). The value of DALY obtained at the end is a measure of time lost to illness by an individual in a year weighted by the expected illness severity. As expressed by Health Canada (2010), "10-6 DALY/person per year is approximately equivalent to an annual risk of illness for an individual of 1/1000 for a diarrhoea-causing pathogen with a low fatality rate."

A screening level QMRA is completed for each pathogen as an alternative means of assessing the WTP along with the use of performance functions. The purpose of the QMRA is to allow the operator to determine if treatment failure will result in unacceptable impacts to the receiving community and which pathogens and treatment units require attention. The way this is accomplished is by determining if an equivalent level of drinking water quality can be provided when a treatment unit fails. For example, if the turbidity performance function is not met, the results of the QMRA may indicate that the disinfection unit is sufficient to meet QMRA objectives. This would indicate that the drinking water meets a standard directly based on health outcomes, regardless of the turbidity standards.

As mentioned previously, if no raw water microbial inputs are entered by the operator, a default value will be applied. If the default microbial concentration is used, the QMRA calculation acts as an overall performance function that considers the entire system. While the output values have less individual meaning in this case, relative differences in QMRA DALY outputs can be compared and indicate how well the WTP is performing compared to previous records.

## DSS outputs

The performance function and QMRA values are displayed for the current record on a "results" page. A reporting option allows the operator to select multiple records which are displayed in a table, as well as charts of performance function values or QMRA calculations over time. An example output chart is shown below as Figure 5.

## Conclusions

A decision support tool to systematize the operations of a small water system has been developed. The DSS assesses the performance of different components of a small water system and alerts operators as the performance diminishes. The DSS provides operators with a checklist of actions to take and maintains a data base of the corrective actions taken. It also incorporates Health Canada's QMRA to provide operators with the risk posed upon failure of a particular unit.

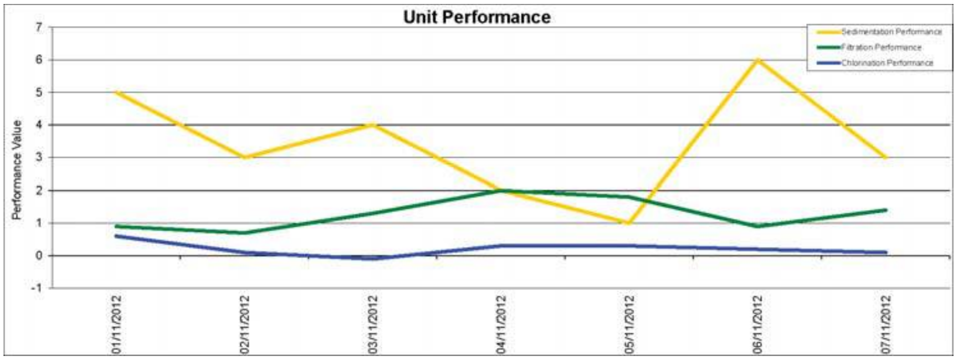



Figure 5. Example of performance output chart for 7 records.

## Acknowledgements

The authors wish to acknowledge the financial support received from Res'eau-WaterNet a NSERC-supported Strategic Network dedicated to find solutions for small water systems. ■

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# It Takes a Village to Raise Expectations

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The status of Canada's public infrastructure has been a hot topic of conversation for the past couple of years, tinged with every emotion from optimism to despair. Conservatively, hundreds of billions of dollars will be required in the coming decade to improve everything from the electrical grid to bridges and roads, while we work to build capacity in water and sewage treatment and transit expansions for a growing population.

Traditionally, this conversation tends to focus solely on the needs of larger municipalities and cities. What's missing from the dialogue is any acknowledgement of the crisis our small and rural communities (SRCs) are facing in terms of their access to reliable sources of clean drinking water – a crisis not born of aging infrastructure, but rather of perennial neglect, lack of funding and an historical failure to innovate on their behalf.

Millions of Canadians are exposed to untreated and potentially unsafe drinking water in SRCs and First Nations communities who have not seen the progress in water purification and protection that research, development and significant government funding have brought to areas with larger populations. Water contamination problems in these communities are under-reported and often undetected, but the statistics that do exist are sobering: almost 2,000 SRCs and more than 100 First Nations communities issue "boil water advisories" in any given year.

## Not wholly a technological problem

Solving SRCs' struggle for safe drinking water cannot be achieved by merely "miniaturizing" technologies developed for larger municipalities. Each SRC faces unique and complex socio-cultural, economic, political and technological challenges that prevent the implementation of one-size-fits-all technical solutions. Unique characteristics in terms of the quality and nature of the source water from which their drinking water is taken, the ability to secure appropriate financing for technological upgrades and the capacity to attract, train and retain operators and maintenance professionals are significant hurdles to overcome. Many other roadblocks to water purification – such as addressing micro-pollutants in the water supply – are beyond the capabilities of existing technologies designed for use in small systems.

And the problem is not wholly technological in nature. Varying degrees of public support for spending community resources on improvements to drinking water systems, particularly when contamination issues go unnoticed or seem to pale in comparison to other local health or economic issues, means that the human element will play as important a role in designing and implementing solutions as anything that can be done in a lab. There are also pervasive cultural sensitivities, particularly among First Nations and Aboriginal people, that must be taken into consideration.

## The Res'Eau-WaterNet network

At the intersection of this socio-scientific dilemma lies Res'Eau-WaterNet, a multi-disciplinary research network funded via a Natural Sciences and Engineering Research Council (NSERC) Strategic Network Grant and based at the University of British Columbia. Launched in 2009, Res'Eau-WaterNet is devoted to developing innovative and affordable solutions for SRCs.

Res'Eau-WaterNet seeks to understand the limitations and constraints that SRCs face, and to develop technologies in such a way that they can be readily diffused and adopted into this specialized market. The network's approach is therefore about much more than traditional R&D. It involves collaborative innovation and communication to create a bench-to-tap synergy between science, industry and end-users, working within the broader political, social and economic landscapes found in SRCs. Supporting these efforts are key industry partners that include technology providers and consultants, and more than 15 others from government organizations, municipalities, NGOs, NCEs, professional associations and related provincial and regional government agencies.

This expansive set of partnerships is a community in itself – one whose collective goal is to create affordable, manageable technologies and processes to provide clean water in SRCs, while fostering the political will at all levels to fund their installation and operation.

### SMALL WATER SYSTEMS IN CANADA

Res'Eau WaterNet focuses on the needs of systems that provide water for less than 2,000 residents, and/or fewer than 500 household connections. This definition encompasses many rural, isolated and cottage/fishing communities, First Nations reserves and outlying areas of urban centres where localized treatment approaches are utilized. While this may appear to be a fringe or niche target population, communities meeting these criteria account for 75% of all water systems in Canada. In all, more than six million Canadians get their drinking water within these settings.

## RES'EAU WATERNET RESEARCH PORTFOLIO

**Res'Eau-WaterNet is dedicated to maximizing benefits to small and rural communities by becoming the nation's premier solution provider for the drinking water treatment industry. The network's research program consists of several projects that collaborate across three broad themes of investigation. Here are just some of the key outcomes of the network's collaborations thus far:**

### THEME I: CHARACTERIZING SOURCE WATER QUALITY

**FOCUS:** Understanding and modeling the variability of source water quality in small rural communities (SRCs) and the impacts of source water on drinking water treatment.

**KEY OUTCOMES TO DATE:**

- A first-of-its-kind generation of comprehensive chemical and microbial data from source water ecosystems in conjunction with water quality data from distribution – an asset for Canadian communities for assessing risks from source water versus distribution systems.
- A water quality characterization, index development and validation model under changing climate and land-use scenarios: This will be an innovative tool for SRCs, and a new approach for Canada.
- Model predictions for establishing how climate and land-use changes can affect chemical and microbial water quality – another first for Canada that will inform the design of optimal treatment systems for use under variable conditions.
- A knowledge base about the impact of human factors on drinking water in SRCs.
- A state-of-the-art molecular microbiology lab that generates high-quality data on the types and concentrations of microbes in water has been established with the support of Res'Eau's partners.

### THEME II: DEVELOPMENT OF INNOVATIVE TREATMENT SOLUTIONS

**FOCUS:** Research projects within this grouping focus on the development of innovative, cost-effective water treatment technologies. UV-based advanced oxidation processes (AOPs), membrane filtration, ion exchange (IX), electrocoagulation (EC) and slow sand filtration (SSF) are among the technologies studied for surface water applications. Other efforts are being been made towards removing iron and manganese from groundwater.

**KEY OUTCOMES TO DATE:**

- UV-based AOP: A novel UV-based oxidation process, not requiring any chemical oxidants, has been developed for the removal of micro-pollutants, taste and odour compounds, and algal toxins. A pilot scale reactor has been built (through collaboration with partner BI Pure Water) for validation and proof-of-concept at a small community site in B.C.
- Ion exchange (IX) and Electro-coagulation (EC): IX and EC are two processes for the removal of natural organic matter (NOM) in surface water, thereby reducing the formation of harmful DBPs and enhancing the efficacy of downstream advanced treatment and disinfection processes. IX and EC were evaluated and novel reactor designs have been investigated for improving the efficacies of these processes. New inventions have results from this research.
- Removal of pharmaceuticals and endocrine-disrupting compounds (EDCs): Extensive pilot scale studies involving conventional treatments, slow sand filtration (SSF), ozone and UV oxidations were conducted in collaboration with partner Walkerton Clean Water Centre (WCWC). Such a comparative pilot scale study is unique and unparalleled, and the results are being received by stakeholders with great interest.

### THEME III: DIFFUSION OF INNOVATIVE SOLUTIONS

**FOCUS:** Integrating the knowledge produced through our research results within industry, the system operator community and the public and private sectors.

**KEY OUTCOMES TO DATE:**

- A four-step methodology has been developed, including source water classification, ranking of treatment train alternatives, costing and final evaluation. Also, a matrix was developed to compare treatment trains and alternatives.
- A framework for a decision support system to systematize the operation of small water treatment plants.
- An integrated framework for performance assessment of small water treatment systems based on reliability, robustness and risk analysis.
- Predictive models for determining coagulant dosage were developed for systems using this process.
- Statistical cost models of small water treatments have been developed based on manufacturers' cost data, plant level operational costs, and EPA and Environment Canada databases.

The network's current team consists of 12 faculty researchers and more than 80 graduate and undergraduate students (to date) who are working to tackle a number of the dilemmas SRCs face (see research portfolio, page 28). These include source water quality and its variation due to climate change and land-use patterns, the formation of disinfection by-products (DBPs) in distribution systems, robust treatment options to address a variety of contaminants, operational strategies for treatment systems, and the economics of water treatment alternatives.

Working closely with several community water operators and local governments, the Res'Eau team has looked at the impact of both water quality characteristics and operational parameters (with an emphasis on human factors) on water quality within small systems. A database allowing a better understanding of the variability of DBPs and the factors related to this occurrence in Canadian small systems has already been completed – a complex undertaking that represents a first for Canada's small systems. Res'Eau's researchers have been successful in bringing several treatment options to the piloting and proof-of-concept stages. In close collaboration with partners, community level pilot tests and demonstrations studies of systems and processes are underway that may lead the way towards the adoption and implementation of solutions developed within the network.

**"A database allowing a better understanding of the variability of DBPs and the factors related to this occurrence in Canadian small systems has already been completed – a complex undertaking that represents a first for Canada's small systems."**

Res'Eau's partnership-oriented, multidisciplinary approach to addressing all aspects of water quality management from source to tap is the only approach of its kind in Canada, and possibly the world. The benefits of the network's research successes have also attracted additional funding for important projects beyond its original research agenda, including work on addressing specific water quality issues in a select number of Aboriginal communities in B.C.

Finally, an emphasis on developing Canada's next generation of researchers with expertise in small systems permeates all of the network's activities, and will ensure the unique needs of these communities are met for years to come. By bridging the distance between the laboratory and the drinking glass and involving all stakeholders in the creation of real solutions for SRCs, it is the network's hope that their challenges can be overcome once and for all. ■

*Madjid Mohseni is scientific director for Res'Eau WaterNet, and a professor in chemical and biological engineering at the University of British Columbia. More information can be found at www.reseauwaternet.ca.*

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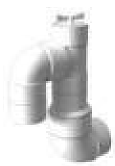

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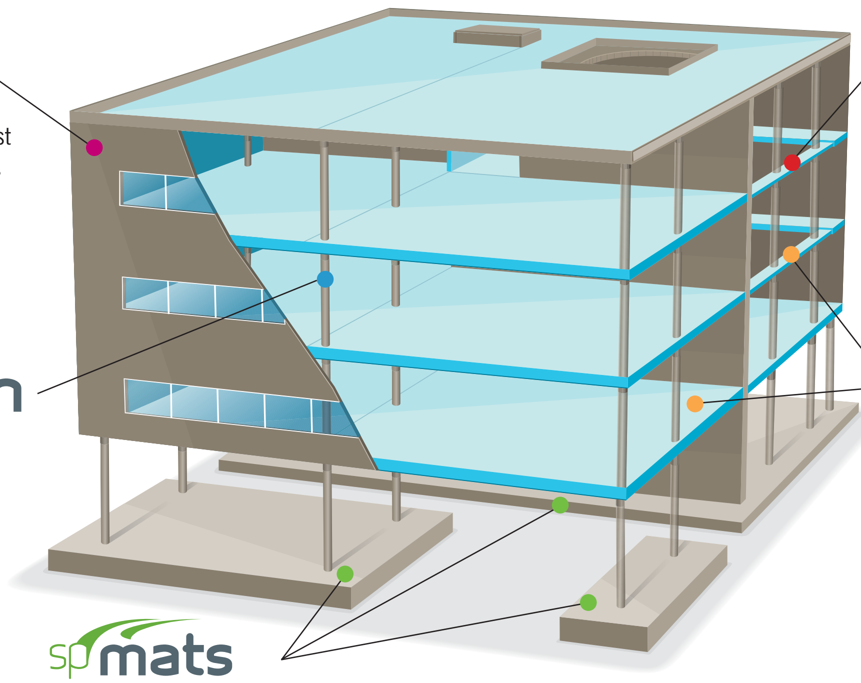

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