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Secrets of Performing Successfully in both the Municipal and Oil & Gas Water/Wastewater Sectors

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Abstract

Traditionally, professionals and companies in the water & wastewater industry have focused on either the municipal or industrial sectors, and considered it difficult to be successful in both. This paper describes some of the key factors that can ensure success in both sectors, focusing on the oil & gas and municipal water/wastewater sectors.

There are common myths that have been reinforced in the industry, suggesting barriers to success in both sectors, and differences in engineering and project execution practices. We explore these with focus on technology applicability and project delivery, identifying key lessons from one sector useful in the other. Examples include:

- Technical myth – Biological treatment isn't effective for high strength wastewater in oil and gas;
- Strategic myth – The municipal sector is more competitive than oil and gas sector; and
- Execution myth – Modular equipment, favoured in the oil and gas sector, isn't as applicable for municipal applications.

Specific projects will be referenced, within a compare/contrast framework to highlight lessons from oil and gas that provide opportunities for success in municipal, and vice versa. Examples include:

- High-efficiency softening and membrane treatment used in oil and gas is providing opportunities in the municipal sector to exploit water sources that haven't traditionally been used;
- Design-build-operate and lease buy-back arrangements are gaining ground in the oil and gas market; and
- Water reuse strategies and frameworks that foster collaboration between oil and gas and municipal water users have been successfully implemented to improve water use and availability.

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[1] Integrated Sustainability Consultants Ltd., Canada

We also review the imperatives facing each sector and the importance of adopting a broad view to addressing the challenges. For example, oil and gas prices will continue to see downward supply-side pressure for the forseeable future, while, in municipal infrastructure, asset management is challenged by population growth and budget deficits. We conclude by explaining how both sectors can help one another to meet these challenges.

Introduction

Water and wastewater treatment are critical to the functioning of modern society, and are a truly multi-disciplinary pursuit, combining biological, civil, chemical, electrical and environmental engineering[2]. In general, engineering and design of water and wastewater treatment infrastructure is traditionally undertaken by multiple entities, with consulting engineers executing projects, equipment manufacturers providing equipment and contractors undertaking construction[3]. In the consulting engineering field, companies have traditionally focused on either municipal or industrial sector. Often engineers themselves have focused their careers on either municipal or industrial treatment, and generally a specialization in one sector is considered not readily transferrable to the other.

This paper identifies key lessons that are transferrable between sectors. The purpose of this paper is to identify successes and opportunities that arise from effectively using those lessons to perform well in both industries.

Water and Wastewater Treatment

Infrastructure development for municipal water and wastewater projects generally focuses on drinking water and sewage treatment. Infrastructure development for industrial water treatment depends on the various possibilities of the end use and its specific water quality requirements. End uses may include steam generation, irrigation, manufacturing, mineral processing, cooling, and inputs to countless refining and manufacturing processes. In this paper, we will focus on a comparison of municipal water and wastewater treatment and water treatment in the oil and gas industry.

In both sectors, source water (raw water) is typically treated before use to remove impurities by physical and chemical processes. For example, treatment of raw water for drinking generally focuses on suspended solids (and related turbidity), pathogens, and dissolved inorganic components that could cause health problems (e.g. nitrite, nitrate, toxic metals) or that must be removed for aesthetic reasons (e.g. iron, manganese,

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[2] Droste, 1997
[3] Metcalf and Eddy, 2003

hardness)[3]. In the oil and gas sector, different end uses may require additional treatment of raw water, including more advanced demineralization[4].

Municipal wastewater has a relatively consistent water chemistry (i.e. raw sewage)[3]; however significant advancements have been made in the technologies used to remove organic wastes, provide solid-liquid separation and eliminate pathogens. Wastewater streams in the oil and gas industry can be as variable as the locations where they are produced, based on local conditions. Key treatment parameters may include heavy metals, inorganic impurities, radioactive material, and a variety of toxic compounds. Common wastewater streams in oil and gas include produced water, blowdown from oil, gas and water treatment processes, cooling water wastewater, flue gas wastewater and oily waste[4].

The major differences between the oil and gas and municipal water treatment sectors are technical but also relate to accountability. In the municipal sector, projects invariably and visibly affect public spending and critical services, and so project development is a public process that is regulated and transparent. For example, most municipalities and other levels of government are mandated to award projects in a well-defined, competitive process that is transparent to the public. In private industry, including the oil and gas sector, project development decisions can be made according to the management and ownership of the company making the investment decision.

The technical and project development differences tend to create inertia for companies and individuals operating in each sector as they must become accustomed to the business development practices, project execution strategies, technical requirements and even the business culture particular to each sector. A perception may exist that engineering consultants skilled in the oil & gas sector don't have appropriate skill sets to apply to the municipal sector and vice versa.

Dispelling existing myths by identifying opportunities for extension of technology application and project execution can reduce this inertia and create valuable opportunities for companies and individuals to perform well in both sectors.

Identifying Myths and Opportunities

In this Section, we cover some examples of common misconceptions that have been persistent in the water and wastewater treatment industry and dispel them to illustrate opportunities that can be exploited to achieve success in both the municipal and oil and gas sectors.

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[4] Bahadori, 2013

Technical Myth: Biological treatment is not well suited for some high-strength wastewaters found in the oil and gas industry.

Biological wastewater treatment has a very long history in municipal wastewater treatment. In the oil and gas industry, the application of biological treatment is much less common; the waste streams tend to be highly variable, and often contain non biodegradable and/or recalcitrant components and high organic load.

However, advances in treatment technology from the municipal sector have expanded the applicability of biological treatment into the oil and gas market. In many cases, biological treatment is appropriate for industrial wastewater, although significant technical considerations must be made to ensure that a viable and stable biological community can be maintained to achieve treatment objectives, including reducing organics (COD, BOD) and nutrients (phosphorous, nitrogen compounds). Typically, biological treatment for organics removal is expected to be successful when COD to BOD ratio is 2 to 1[5].

The advancements in biological wastewater treatment presents an opportunity to expand the use of biological treatment into the oil and gas sector, but also provide an opportunity for municipal wastewater process specialists and microbiologists to add value in the oil and gas sector.

There are some critical factors to consider that will allow biological treatment to be effective for high-strength oil and gas wastewater streams. For high strength wastewaters (e.g. BOD values above 5,000 mg/L), it is often useful to stage biological treatment processes; for example using an initial process step to promote higher microorganism density (i.e. maintaining higher mixed liquor suspended solids concentration) using fixed film growth in an engineered biological aerated filter (BAF)[6]. Downstream biological processes using combination attached / suspended growth have also been used to create higher microorganism density. Technical advancements have contributed to opportunities to use biological treatment for oil and gas wastewater. The traditional sedimentation processes have been largely replaced with membrane filtration such as submerged hollow-fibre technology. This has helped improve effluent quality as biological density in activated sludge is increased. An important contributing factor that has made these advancements in higher microorganism density practical is the improvement in oxygen transfer as a result of microbubble aeration, which improves oxygen transfer to stimulate and maintain biological growth[5].

In some cases, biological treatment has been very useful and even critical in solving difficult challenges in oil and gas wastewater treatment. For example, in thermal heavy

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[5] Samudro and Mangkoedihardjo, 2010
[6] Qui *et al*, 2011

oil production, a significant amount of research has been devoted to developing reliable biological treatment to remove naphthenic acids for discharge to surface waters for treated tailings water release[7].

Strategic Myth: The municipal sector is more competitive than the oil and gas sector

It is a commonly held view that in comparison to the oil and gas sector, the municipal sector is a relatively mature market that is very competitive and has become primarily focused on project budgets with relatively less focus on the technical qualifications of project proponents and the technologies and project execution plans they propose. In the oil and gas sector, there has been a perception that projects tend to be driven primarily by technical considerations and budgets.

There is a natural difference in project execution in the municipal sector as compared to the oil and gas sector due to the ownership of infrastructure that is built. Municipal infrastructure is typically publicly owned, compared to privately owned infrastructure in much of the oil and gas sector. In the oil and gas sector, capital spending is often purely a business decision, and global economic forces can greatly affect spending dollars and the competition for the projects being funded at any given time, in contrast to the municipal market where infrastructure development is based on public funding, which can be decoupled from economic trends. In fact, municipal infrastructure spending is often promoted in periods of slow economic growth in order to increase productivity. The current landscape is instructive; crude oil prices fell sharply in the fourth quarter of 2014 as global oil demand was surpassed by increased production. The Brent crude benchmark reached a monthly peak of $112 per barrel in mid 2012, and fell to approximately $30 per barrel in 2016. Natural gas prices have fallen from approximately $5 per GJ in 2014 to lows below $2 in 2016 (Figure 1). The low price of oil and natural gas is restricting capital investment, which is driving more competitive bidding, a familiar concept for companies with experience in the municipal market.

The recent developments in market conditions have made a distinction in competitiveness between the two sectors less prominent. In the oil and gas market, low commodity prices since 2014 have shifted project drivers from delivery date and schedule milestone drivers towards budgets. Many projects in oil and gas now follow a strict competitive proposal process regardless of the business relationship that previously existed and the budget is often the most important aspect of the bid. For consulting engineers with experience in competitive bidding processes common in the municipal market, there is a significant opportunity to develop projects in the oil and gas

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[7] El-Din *et al.*, 2011

water treatment market, where increasing competition is changing the landscape and the ability to deliver projects at lower margin is a differentiator.

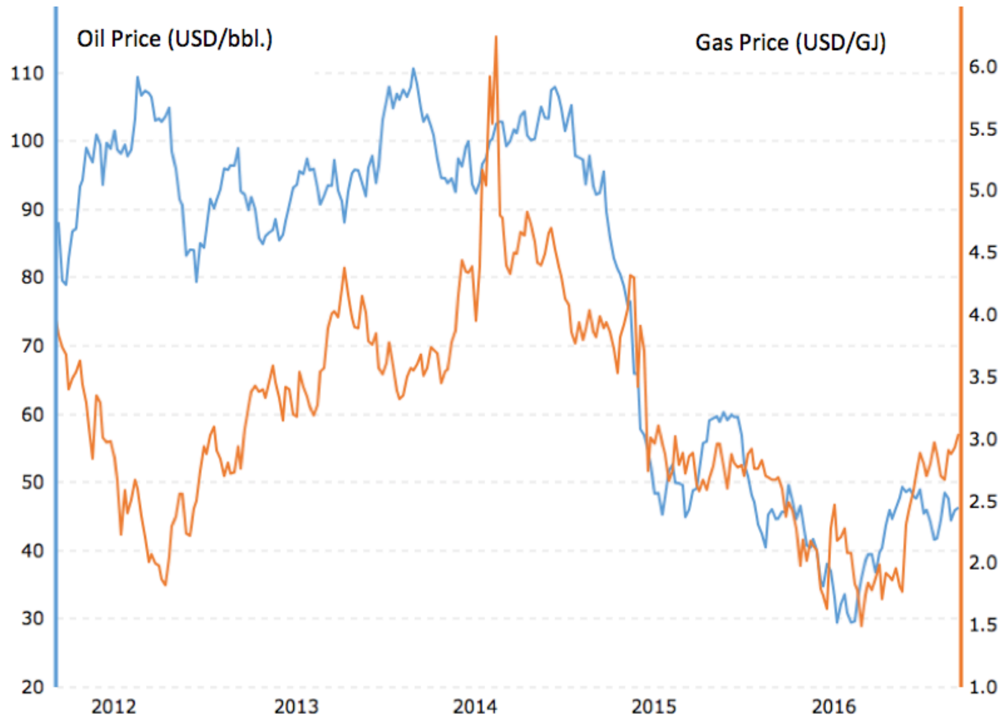

Figure 1: US Oil and Gas Prices, 2012-2016[8]

Competition in the oil and gas market in North America has also been stimulated by increased presence from multinational EPC and EPCM companies willing to execute projects with design-build, lump sum contracts, which puts pressure on existing engineering, equipment and construction companies to do more upfront work to ensure that costs and schedules are accurately forecasted even before projects begin. The future of the oil and gas water treatment industry can benefit greatly from looking to the municipal water and wastewater industry for successful project execution strategies that have been built in an intrinsically competitive environment.

One result of these trends is the emergence of non-traditional funding and project execution strategies. The variety of project models in the municipal water wastewater sector is very diverse, covering variations of scope, ownership and project risk. It is common to see design-build, design-build-operate, build-own-operate, build-own-operate-transfer projects and different of partnership between public and private entities to tailor a funding, revenue and risk framework that is best for a given project. More

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[8] US Energy Information Administration, 2016

recently, we have seen the oil and gas sector learn from this evolution and undertake non-traditional project execution strategies. A contributing factor is the complexity of advanced industrial water treatment technology, for which including an operations component to the infrastructure becomes high value. Good examples include the application of the familiar lease and buy-back structure to allow oil and gas facility owners to invest in key infrastructure, without overburdening tight capital budgets, and a greater prevalence of design-build projects where budgets are fixed at project outset.

Execution Myth: Modular equipment, favoured in the oil and gas sector, isn't as applicable for municipal applications

Municipal water and wastewater infrastructure has traditionally been built in place, which is effective for large treatment plants with long lifespans of 30 to 50 years plus. Conventional treatment for both municipal water and wastewater typically requires large facilities with significant in-ground infrastructure. For example, treated water reservoirs where chlorine is added to enable the appropriate amount of contact time to achieve disinfection; and large cast-in-place settling basins used for treating sewage are commonplace in cities in North America.

The use of modular equipment has been a driving force in reducing infrastructure development costs in oil and gas development in areas where higher-cost upstream production has been made more economical by driving down costs[9]. Modular equipment has had this impact in upstream production projects including heavy oil (e.g. oil sands) and shale and tight gas (e.g. the western Canada sedimentary basin) projects where construction schedules are shorter and infrastructure lifespans may only be 10 years. As a result, modular equipment advancements in oil and gas water treatment have added value by reducing site construction costs, which can be significantly higher than shop labour costs. The use of modular equipment has also extended to work camp applications, which are directly transferable to municipal applications, as work camps typically have decentralized potable and sewage treatment infrastructure.

This trend has been paralleled by an increased use of modular equipment in the municipal sector, and has had a similar positive effect on infrastructure installation costs. The drive to use modular equipment in municipal water and wastewater treatment has been partly supported by a trend to deliver water treatment infrastructure in the municipal market on a lump-sum basis. One key benefit of using modular equipment in the municipal market is the ability to select equipment that can be expanded to larger volumetric capacities and allows efficient replacement of major equipment (for example membrane systems).

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[9] Clark, 2016

A recent development is the emergence of more flexible, generic skid design that can accommodate several types and manufacturers of membrane modules as an open source racking system. The advantage of open source membrane racking is that the mechanical system is decoupled from the membrane elements themselves allowing engineers and owners to take advantage of product development from several manufacturers. The design features that make open source membrane selection possible are relatively simple piping and structural changes from traditional design that allow multiple permeate entry/exit points, module heights and diameters, and controls flexibility for differing manufacturers requirements for cleaning and backwash.[10]

The prospect of increased use of modular equipment in the municipal market has tremendous value for replacing and expanding aging infrastructure with increased project cost and schedule efficiency. The technology implementation and effectiveness has been well-demonstrated in the oil and gas water treatment market.

Lessons and Project Examples

This Section will identify some examples of lessons learned from one sector, which have been valuable in the other. A technical example invokes precedent from the oil and gas sector, which has great potential to add value to the municipal sector, and two examples show effective strategic collaboration on water reuse between oil and gas industry companies and municipalities that effectively bridge the gap between the two sectors.

High Efficiency Softening by Ion Exchange as Pretreatment for Membrane Filtration

In thermal oil and gas development water treatment, advanced softening is often used in steam generation water treatment plants to remove scale-forming ions, including divalent cations (e.g. Ca^{2+}, Mg^{2+}) that would otherwise cause scale and corrosion in the drum boilers. A similar practice of ion exchange pre-treatment has also been used for reverse osmosis membrane processes in the oil and gas, refining and mining industries. One of the primary values of pretreatment in membrane filtration is preventing precipitation and saturation of insoluble minerals (scale deposition) on membrane surfaces.

One example of a significant fouling mechanism is gypsum saturation, which can occur in treating groundwater and wastewater produced from oil and gas wells. Fouling occurs when the concentration of calcium and sulfate in the RO reject stream can result in the

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[10] H_2O Innovation, 2015

formation of gypsum solids. This results in the need for frequent clean in place cleaning and significantly reduces the membrane life[11].

In the municipal drinking water sector, fouling in membrane systems has traditionally been managed using the addition of antiscalants (chemical injection) to prevent fouling. This method is quite practical for good quality source waters, but becomes prohibitive for source waters with high mineral content due to the cost of chemicals, the increased operator attention required and the negative impacts to membrane life.

By adopting ion exchange as a pre-treatment for membrane systems in municipal drinking water treatment, chemical usage and membrane life may be improved, and better treated water recovery rates can be achieved, especially for source water types not well-suited for membrane treatment. In one project example[12], reverse osmosis (RO) treatment capital and operating costs were modeled with and without the use of ion-exchange pre-treatment. The bulk of modelling focused on water chemistry around a four-stage RO system to determine the required chemical injection and waste production for the system. The ability of modern ion exchange systems to target only the specific water constituents nearing their saturation point means that membrane efficiency can be increased without also increasing fouling and solids precipitation.

In a related recent project example[13], a reverse osmosis system was selected to treat source water for high levels of calcium (734 mg/L) and sulphate (1200 mg/L). A process review of pretreatment was considered, and the calcium and sulphate species were targeted for removal as they were predicted to reach 6 to 6.5 times gypsum saturation in the membranes before meeting the required throughput efficiency. The modelling showed that upstream removal of calcium and sulphate (down to 330 mg/L and 250 mg/L respectively) would allow the RO membranes to achieve 95% recovery without experiencing any significant fouling. For comparison, without this upstream pre-treatment, only 80% recovery in the membranes was projected before saturation and fouling occurred. The model showed that to manage the saturation points of calcium and sulphate and still achieve the design objectives without upstream ion-exchange, a clarifier would be required to remove these constituents downstream of the second stage of RO membranes. Additionally, in order to protect the third and fourth stages of the RO system, additional pre-treatment downstream of the clarifier would be required including an ultrafiltration (UF) system. The modelling of the system, shown in Figure 2, shows the system configuration and basic parameters in each line.

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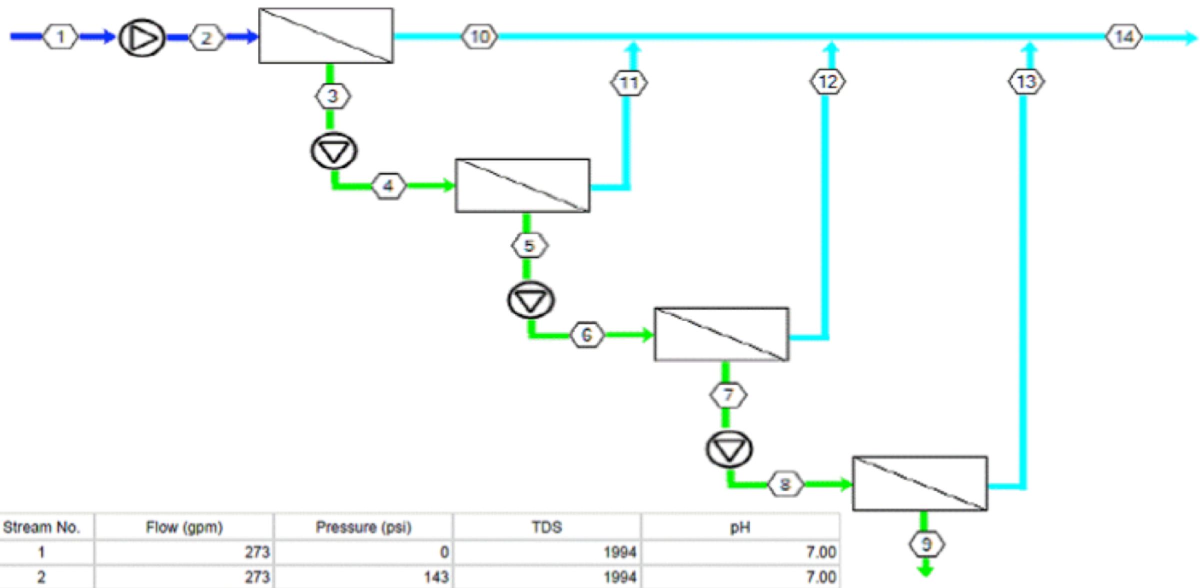
[11] Uchymiak *et al*, 2008
[12] Integrated Sustainability Consultants Ltd., 2016
[13] Integrated Sustainability Consultants Ltd., 2015



Stream No.	Flow (gpm)	Pressure (psi)	TDS	pH
1	273	0	1994	7.00
2	273	143	1994	7.00
3	169	86.3	3207	7.19
4	169	153	3207	7.19
5	90.2	113	5946	7.43
6	90.2	190	5946	7.43
7	39.4	164	13376	7.74
8	39.4	611	13376	7.74
9	13.4	592	39328	8.14
10	104	0	25.8	5.48
11	78.5	0	60.9	5.85
12	50.7	0	166	6.27
13	26.1	0	47.0	5.73
14	259	0	66.0	5.88

Figure 2: Simulation results of the RO membrane system using ion-exchange pre-treatment.

Use of Treated Municipal Wastewater Effluent for Industrial Cooling[14]

In the Canadian oil and gas sector, there have been a few recent examples of using municipal treated wastewater for make-up source water. The EPCOR and Suncor (formerly Petro-Canada) joint venture has shown how a collaborative water reuse application has provided economic benefits in terms of municipal costs and industry operations. This is an example of an eco-industrial relationship, which can open up potable water supply for other areas of development, while providing benefits to both partners.

Suncor Energy, The City of Edmonton, and Strathcona County worked together to develop a solution that would avoid withdrawing additional water from the North Saskatchewan River. The use of wastewater effluent from Edmonton's Gold Bar wastewater treatment plant for the Suncor refinery boiler feed water system was the first major industrial application of membrane treatment technology using municipal

[14] Alberta WaterSmart Solutions, 2013

wastewater in Canada (General Electric Company, 2006). Based on this new application of wastewater reuse, Suncor was able to change to a different type of cooling system. This system, reducing water requirements by half, coupled with the water received from the City meant that Suncor did not have to build their own treatment plant.

It also required wastewater conveyance from the EPCOR facility to the Suncor refinery. The Suncor refinery boiler feed water treatment system came online in October 2008. Since then, plans have been developed to implement a similar system with the Alberta Capital Region Waste Water Commission (ACRWWC) to supply reclaimed wastewater for process water at the proposed Fort Hills Sturgeon Upgrader. The effluent would then be sent back to the ACRWWC for further treatment and redistribution. This project is currently deferred, and the timeline has not been made public.

Depending on the laws and regulations in a region, municipal wastewater reuse may be the only option for new energy developments; for example where new water licenses cannot be issued by the government.

Municipal Wastewater Reuse for In-situ Oil Production[15]

In the heart of the Canadian oil sands industry, municipal water planning has been developed in an approach that integrates directly with the oil and gas industry. The Regional Municipality of Wood Buffalo (RMWB) has developed a regional water and wastewater strategy, shown in Figure 3. The key elements of the regional strategy include:

- northern and southern hubs for treatment of sewage, heat recovery and waste-to-energy;
- potable water for municipal rural and industrial domestic use (i.e. camps at thermal heavy oil facilities);
- wastewater reuse for industry and domestic use; and,
- industrial non-bitumen commodities movement for in situ reuse.

Reuse of existing municipal wastewater volumes for makeup sources in the thermal heavy oil industry have the potential to support up to 125,000 barrels per day (bpd) of production at a steam assisted gravity drainage (SAGD) facility, on an average daily basis, and assuming a makeup to bitumen production ratio of 0.6. Based on 2012 population projections in the RMWB, in approximately 30 years, if all available wastewater is reused on an average daily basis and assuming a makeup to bitumen production ratio of 0.6, it could enable 262,000 bpd of additional SAGD production.

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[15] Alberta WaterSmart Solutions, 2013

From a strategic execution perspective, this requires infrastructure for wastewater storage, conveyance, and treatment for both municipal wastewaters and in situ operation wastewater.

An opportunity for the RMWB, and for all municipalities interested in municipal wastewater reuse, is the development of large-scale wastewater user partnerships. This type of partnership offers the economies of scale and the funding capable of making reuse projects more cost effective. Particular opportunities include cost-sharing, providing significant industry capital contribution to municipal infrastructure, sharing of risk and liabilities, which further reduces insurance and unintended costs for the municipality long-term revenue source for the municipality (for the life of the project).

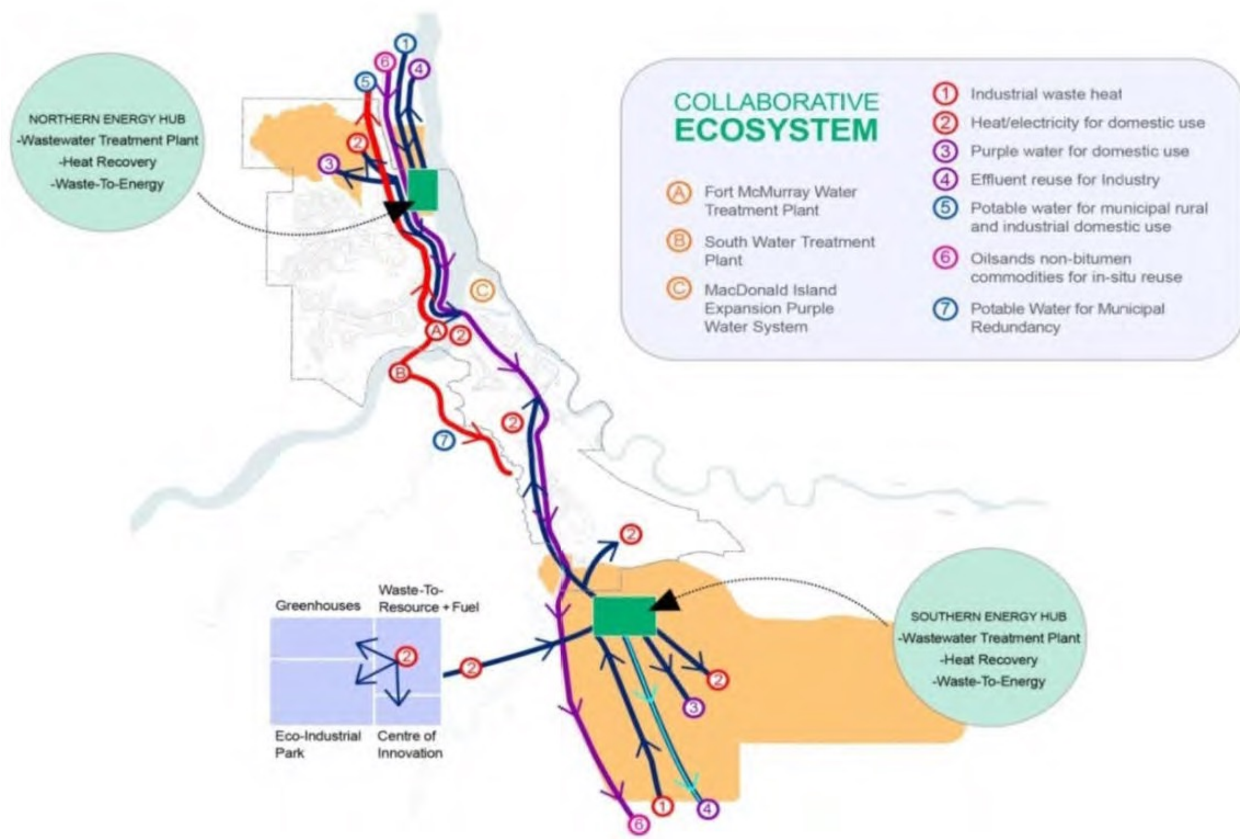

Figure 3. RMWB's Regional Water and Wastewater Strategy[16]

Conclusion

The challenges facing the water and wastewater industry are significant, and may be manifested similarly in the municipal and oil and gas industries, but the causes are

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[16] RMWB, 2012

diverse. In both sectors, regulatory drivers are limiting the availability of pristine water sources, while also presenting more stringent limits for treated wastewater effluent. On the municipal side, capital budgets are under very significant pressure from population growth, tighter public budgets and an infrastructure spending gap that results in aging infrastructure. In the oil and gas industry, there is persistent downward pressure on commodity pricing on the supply side, and capital spending is expected to grow slowly while oil and natural gas prices keep revenues low for the foreseeable future.

To meet these challenges, there is great potential to add value by looking past the traditional separation between the municipal and oil and gas water treatment industries. The competition and scrutiny familiar in the municipal market can help the oil and gas market operate more efficiently. The pace of technology development in the oil and gas sector needed to treat variable waste streams can provide valuable technical opportunities to municipal applications. The use of modular equipment that drives cost and schedule performance in the oil and gas sector can help alleviate the infrastructure gap in the municipal market. The innovation in contracting strategy development that has occurred in the municipal market can help encourage capital and risk efficiency for infrastructure development projects in the oil and gas sector. The collaborative environment between the oil and gas and municipal water treatment industries is already forming, with prominent success stories of water reuse and collaborative frameworks that achieve benefits for both industries.

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Speaker Biography

A.J. MacDonald is a versatile Environmental Engineer with specialties in water treatment, renewable energy and environmental management. AJ ‘s project experience includes both industrial and municipal sectors and has spanned all phases of project delivery including preliminary analysis, conceptual design, detailed design, construction QA/QC, commissioning and optimization. AJ has worked in municipal water & wastewater treatment, oil & gas, mining, petrochemical, refining, light industry and has focused on turn-key projects. AJ has a Master’s degree in Environmental Engineering from Carleton University in Canada. AJ is currently Director of Operations at Integrated Sustainability Consultants Limited in British Columbia Canada, an engineering company with offices in Alberta and British Columbia that specializes in water and wastewater treatment, water management, waste management and renewable energy solutions.

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