ISL Engineering and Land Services

Inspiring sustainable thinking

2013 CCE AWARDS SUBMISSION

Exshaw Municipal Water System

Category: Water Resources

Client/Owner: Municipal District of Bighorn

Consultants : Oasis Filter International Ltd.
Levelton Consultants Ltd.
Colleaux Engineering Inc.

Contractors: Tritech Group Ltd.
Slimdor Contracting Ltd.

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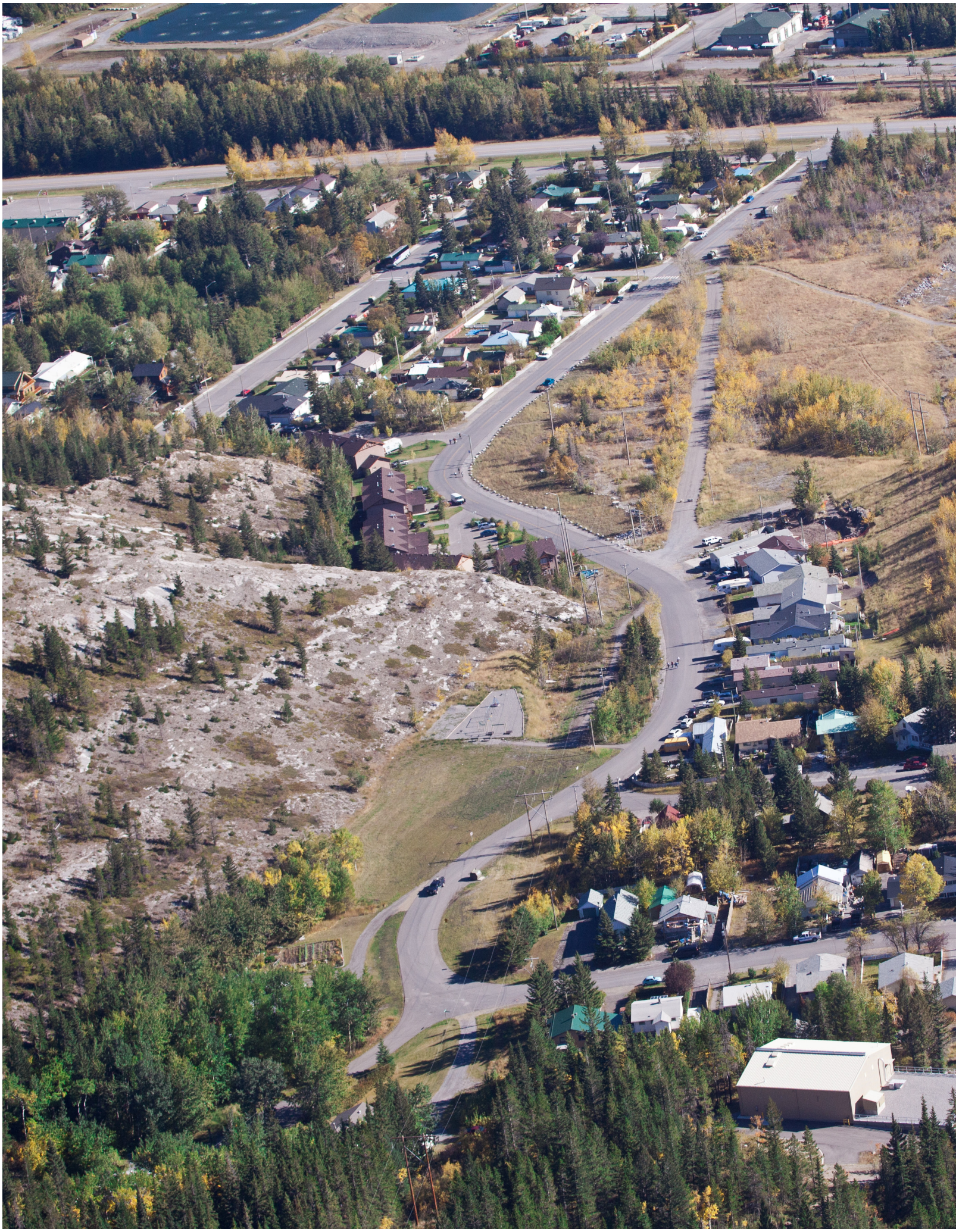

Exshaw Municipal Water System

A sustainable retrofit with a low tech, low life-cycle cost solution

Replacing private water wells as a source of untreated potable water, ISL Engineering and Land Services designed and facilitated a complete municipal water system for the community of Exshaw in the Municipal District of Bighorn (M.D.). Besides allowing the M.D. to provide a safe, secure potable water supply for this community, the solution was exemplary of sustainability considerations.

At its heart is a sustainable water treatment system that effectively treats the complex source water drawn from the new Exshaw municipal well, located in the Calgary Deep Aquifer. ISL's selected water treatment process is low tech, low maintenance and has a low lifecycle cost; it requires little energy to run, and does not require highly trained operators. It also produces minimal wastewater: a fraction of the volume expected from using other treatment technologies.

In addition, the complete municipal water system was retrofitted within the existing community, involving the relocation of existing utilities, the total reinstatement of the roads, and the complexities of watermains crossing a provincial highway, Canadian Pacific (CP) rail track and creeks; all occuring in environmentally sensitive areas.

The solution required careful design and hydraulic modelling, making use of topography to minimize pumping, and using leading edge technology and innovative thinking to construct the water system within the constraints (e.g. environmental sensitive areas) and advantages of the location (e.g. undulating topography). It also required extensive liaison with other stakeholders, ranging from utility companies to local, provincial and federal government departments for permitting.

The result for the community is high quality potable water at their taps and a readily available supply of water for fire protection.

BACKGROUND

Just 45 minutes' drive west from Calgary, and on the eastern slopes of the Canadian Rockies, lies the small community of Exshaw (current population 362, ultimate 1,600). It is the largest of the hamlets within the M.D. of Bighorn, and its municipal seat.

Situated in the popular Bow Valley Corridor, Exshaw is in an area that has experienced a high demand for development over the past 10 years. For the M.D., this has meant a growing demand for fully-serviced residential and industrial lots.

The Bow Valley towards Canmore, showing the Hamlet of Exshaw with Highway 1A and CP Rail next to the Bow River

Before the project, there was no municipal water system to treat, distribute, and provide potable water. Households and industries had to draw their water from private water wells in shallow aquifers prone to surface contamination and use it untreated.

"Some of us have excellent water quality and some of us have poor quality water and some of us have no water whatsoever," Reeve Dene Cooper said at the project start in 2008 (Canmore Leader, 2008, *Exshaw water woes*). Alberta Environment was particularly concerned that the residents were drawing water from shallow wells, which were susceptible to surface contaminants and other ground-level influences. In southwest Exshaw, also known as "Little Italy," there are areas where both iron and sulphur have been found in the drinking water. In the Knowlerville neighbourhood in northwest Exshaw, residents can't get water by drilling wells due to shallow rock and were using surface water from Exshaw Creek instead. In the words of Reeve Dene Cooper: *"This is both important and urgent. It goes to duty of care, which is providing a high quality of water, safely, to every resident."*

Without a water system, there were also no water reserves for firefighting in the community and surrounding areas. Everything had to be trucked in from the Lafarge cement plant some distance away using the municipal fire department's 3,000-gallon tanker, delaying firefighting efforts to the neighbouring communities of Harvey Heights and Morley by a good 15 minutes.

The new water system would not only provide assured, quality drinking water for Exshaw, but also fire hydrants in its streets. This means that while the tanker won't become obsolete, refilling it from Exshaw's hyrants for runs to the neighbouring communities will see a 10 to 15 minute decrease in turn-around time—time that could be vital in saving property or lives. *"It will bring a new level of personal and property safety,"* Cooper had added.

"It's about what brings this community collectively into its future—and one of those things is a water system."

- Reeve Dene Cooper

FINDING THE RIGHT SOLUTION FOR THE COMMUNITY

In July 2008, the M.D. of Bighorn engaged ISL to resolve these water issues by designing and implementing a complete municipal water system for Exshaw. ISL's involvement covered the full spectrum: securing a raw water source, water treatment, treated water storage, disinfection and distribution. The $14M project was funded in large part by the Province of Alberta via the Municipal Sustainability Initiative (MSI) grant and The Alberta Municipal Water/Wastewater Partnership (AMWWP), with the remaining share contributed by the M.D. and other funding sources.

Hamlet of Exshaw, showing the raw water well at the bottom centre and the WTP/reservoir at the upper left, with the Hamlet of Exshaw on both sides of Exshaw Creek flowing into the Bow River

ISL worked closely with the M.D. to ensure successful completion of the project by May 2011, providing the full range of services: conceptual, preliminary and detailed design; cost estimates; regulatory approvals; bidding and award; contract management, close-out, and maintenance. ISL's hands-on and solution-oriented approach included assisting the client in obtaining the funding.

The complex project required a range of expertise and ISL's team included sub-consultants Levelton Engineering (for geotechnical issues), Oasis Filters (water treatment), and Colleaux Engineering (for Electrical/Controls, ranging from power supply to SCADA controls of all the components).

Securing a Raw Water Source

For the new municipal water source, a well was drilled into the Calgary Deep Aquifer near Exshaw. This satisfied both regulatory requirements (regarding surface water under the influence) and a moratorium on surface water withdrawal. However, although considered high quality groundwater, there were significant treatment challenges…

Treating the Water: ISL's Design Philosophy

While obliged to meet regulatory requirements, such as the Guidelines for Canadian Drinking Water Quality, other factors also come into play when selecting a treatment system. For many, the capital cost (initial capital outlay to construct) is often the deciding factor and there is less emphasis on the owner's need to minimize the cost of running the facility over its expected lifetime. For the owner, the M.D., the operating budget and staffing were vital considerations. Therefore, ISL's focus was on designing a water treatment system that would also achieve the following:

- Have the lowest possible life-cycle cost
- Be as operator-friendly as possible
- Address sustainability considerations
- Require the least amount of chemicals possible
- Be as energy efficient as possible
- Have the least effect on existing infrastructure within Exshaw
- Achieve the optimal integration of all process equipment for an efficient system

Treating the Complex Source Water

Although water from the Calgary Deep Aquifer is considered high quality groundwater, treatment challenges were encountered. In addition to elevated levels of iron and manganese, toxic hydrogen sulphide (H_2S), was also present. The aquifer was also infected with SRB (sulphate reducing bacteria) and IRB (iron reducing bacteria). Special considerations were required to effectively treat and remove all these contaminants.

ISL considered a number of evaluation procedures to identify the best solution for both treating the complex source water and meeting the owner's operational needs. This included conducting thorough analyses and bench testing of the raw source water. The team also provided expertise to optimize the water treatment process.

Possible treatment options were identified and a thorough evaluation of the potential treatment processes was conducted before deciding on two processes for pilot testing.

The pilot testing results' both qualified and quantified the two treatment options and led to the selection of the preferred treatment process. The comparison of the treatment options is summarized in the table below.

Table 1: Summary Comparison of Potential Water Treatment Systems

Criteria	Greensand Filters	Manganese Filters	Biological treatment	Low Head Polishing Filter (Selected)
Treatment				
Manganese	Yes	Yes	Yes	Yes
Iron	Yes	Yes	Yes	Yes
H_2S	Partial	Partial	Yes	Yes
SRB/IRB	Partial	Partial	Yes	Yes
Impact of Source Water Quality Variations	High	High	Medium	Low
Ease of Operations	Moderate	Moderate	Very difficult	Low
Ease of Maintenance	Difficult	Difficult	Difficult	Low
Estimated Capital Cost	$$	$$	$$$	$$
Estimated Operating Cost	$$	$$	$$	$
Wastewater Production	High	High	High	Minimal

View of treated water outlet from the filters (blue pipes) and water for filter maintenance (green pipes). Distribution pumping in the foreground.

A TREATMENT SYSTEM IS SELECTED!

A variation of traditional slow-sand filtration, a Low Head Polishing Filter (LHPF), was selected as the best available treatment system to meet the M.D.'s needs and ISL's design philosophy.

Demonstrating an advancement of technology, this project shows how the conventional slow-sand filtration system can be enhanced to eliminate most of this system's typical constraints while maintaining its natural effectiveness. ISL worked with the supplier to customize this water treatment system: simplifying filter maintenance by reducing the need replace the filter media as frequently; enabling it to accommodate higher loadings; reducing filter maintenance (backwash) to monthly; and enabling on-demand operation.

The Treatment Process

The treatment process allows for the oxidation of the iron, manganese and H_2S; the destruction of the SRB and IRB prior to filtration; and the removal of all residual particulate matter and biomass through filtration. It involves the following steps:

1. Raw source water is pumped directly from the well into the contact tanks, and chlorine (in the form of sodium hypochlorite), is injected into the source water just before it enters the tanks.
2. The contact tanks provide opportunity for the chlorine to oxidize the iron and manganese in the source water and form pinflocs (very small clusters of matter). The chlorine also removes the H_2S and destroys the SRB and IRB.
3. After the contact tanks, the pre-treated source water is transferred to the LHPF (which consist of four equal cells operated in parallel). This layered media removes the oxidized pinflocs, as well as and the biomass coming from the H_2S, SRB and IRB. The filtered water is collected at the bottom of the LHPF and drains under gravity into the treated water storage reservoir.

Filter maintenance can be conducted monthly and takes less than 30 minutes to complete. It merely involves isolating the LHPF from the inlet flow and feeding (backflowing) its four filter cells, one at a time, from the distribution system. The upward flow fluidizes the media and the residue (collected on top of the media) is re-suspended. The backflow is stopped, the media allowed to settle, and the resulting wastewater and suspended matter are siphoned to the wastewater collection system. Treatment of the source water can then resume immediately.

ISL met the treatment design challenges with an innovative and low-tech solution. The selected technology uses a process that requires very little energy to operate it, largely relying on gravity. This greatly increases effectiveness, enables easy filter maintenance, and increases the lifespan of the filter media. The technology is also set up to allow integration with newer approaches or future upgrades, such as SCADA.

Simple, lasting equipment and system

The design of the treatment plant uses basic equipment that requires uncomplicated procedures, and enables low-cost plant operation and maintenance. The media used in the LHPF consists of various layers of carefully graded and selected sand—a natural material. The filtration system and media are expected to last for the lifetime of the project (a minimum of 25 years). The other equipment consists of standard, and readily available off-the-shelve items—also expected to last the project's lifetime, except for normal wear-and-tear of electro/mechanical components such as pumps.

Showing the inlets to filters (green pipes) and the outlet of wastewater from the filters (brown pipes)

Very low energy footprint

The real savings come from the operation of the system, which uses far less energy and produces a lot less wastewater than the other systems considered. The energy footprint of the system is small: it is estimated that the lights inside the building probably uses more power than the pumps required for the treatment process. Once the raw source water is pumped from the well to the water treatment plant, the process runs under gravity through the treatment system and into the storage reservoir. Apart from chemical feed pumps, the only other process pumping required is to transfer the unfiltered water from the contact tanks to the filters. In contrast, the other treatment system considered in the pilot testing would have required high pressure pumps to force the water through the treatment components (i.e. more energy and more operational costs).

Optimizes a limited resource

In conventional systems, the media typically requires periodic replacement. Daily backwash is the norm, resulting in huge amounts of wastewater (and therefore more loading on the wastewater treatment system), as well as more operator time, and a higher level of operator.

In contrast, very little maintenance of the LHPF filters is required. Filter maintenance uses treated water off the pressurized distribution system and is typically done once a month, discharging minimal volumes of wastewater into Exshaw's wastewater system (a fraction of the volume of wastewater than the other systems). This solution optimizes the use of a precious resource: the source water (as less than 1% of the total water production). By reducing the volume of wastewater requiring treatment, the treatment technology is saving downstream energy, costs, and resources for the M.D.

Minimal chemical requirement

Only one chemical is used, sodium hypochlorite, which is required by the regulators as a minimum for disinfection. This chemical is generic, readily available, and does not require any special modes of transport and storage.

Modular for ease of expansion

The filter units are modular and the treatment capacity can be expanded with ease, allowing the treatment capacity to be doubled with relative ease and low cost. As a result, the treatment system can not only accommodate the future demands of Exshaw at full development but could support further expansion to service other new developments in the municipal area.

Simple to operate and maintain

Not only is the operational cost extremely low but the treatment system can be run by the M.D.'s existing Level 1 operators. The operators can easily and effectively control the treatment system using the controls designed by electrical sub-consultant Colleaux Engineering. The use of standard plastic piping and valves also allows the operators to complete repairs with minimal equipment and time.

To complement its ease of operation, ISL worked with the staff to prepare Standard Operating Procedures. An allowance was also built into the budget for the plant to start-up fully equipped.

View of the Water Treatment Plant/Pumphouse building on top of the reservoir structure

Energy Efficient Building

Considering energy efficiency in the building design and features was a clear way to enable a reduction in the lifecycle cost associated with running the facility. The effective use of special insulation and glazing also helped reduce the energy footprint for heating and lighting.

The Sustainability Benefits

In summary, the selected water treatment process has the following sustainability benefits:

- Uses very little energy and has a small energy footprint.
- Provides far better water quality than the water obtained from the shallow aquifers.
- Uses standard off-the-shelve equipment that does not require any replacement over the life of the plant.
- Uses natural material as the filter media.
- Uses only one chemical (similar to the one required by regulators for disinfection).
- Requires infrequent maintenance.
- Can be operated by existing Level 1 operators already employed by the M.D.
- Uses locally available resources.
- Reduces the storage volume usually required for contact time by providing additional storage through the contact tanks and filters.
- Produces minimal wastewater, saving downstream costs and optimizing the use of a limited resource and existing infrastructure.

Installing watermains in an existing road

The effective and sustainable treatment of the complex source water demonstrates the technical excellence achieved. One could say that the resulting water treatment process is low-tech, low maintenance and low life-cycle cost, while providing safe treated water to the community. Since the system is designed to be robust and low maintenance, the M.D. will not have to spend as much to operate and maintain it over its expected lifespan of 25 plus years.

In addition, ISL's structural team provided a cost-effective design for the treatment plant building and the treated water reservoir.

RETROFITTING A COMPLETE WATER SYSTEM INTO THE COMMUNITY

Apart from the excellence achieved in the treatment process, this project included retrofitting the complete water distribution system within the existing community. While Exshaw lacked a water system, the community was otherwise well-served with underground utilities including sanitary sewer, gas, power (low and high voltage), cable, high speed internet; and above ground utilities including overhead power cables, paved streets, stormwater management, a provincial highway, and multiple CP rail tracks. Therefore, one of the main challenges of a retrofit of this size was addressing conflicts with these existing utilities. For example, the retrofit resulted in the total reinstatement of Exshaw's roads, which required careful planning and execution to minimize the impacts of this work on the community.

For frost protection, the water lines were installed at a minimum of three metres deep within the existing road right-of-ways. Alberta Transportation and CP had very specific procedures for crossing their properties. In response, the ISL team took extra care to liaise well in advance with all utility owners, holding timely discussions early on in the design process to determine the preferred location and method of installing the water pipeline crossings. Agreements and procedures with the utility owners were established prior to inviting tenders for construction. As a result, the bidders had accurate information by which to determine construction costs; this helped control costs and mitigate potential delays.

The project was also located in an environmentally sensitive area: Exshaw Creek runs through the community and the community's eastern portion is located on the Jura Creek flood plain. Special considerations were also given to related factors, such as seasonal high groundwater. For example, the ISL team scheduled underground construction for late summer and fall to take advantage of a lower water table.

The ISL team also addressed other geotechnical concerns, such as deep gravels. Levelton Engineering provided guidance regarding the expected underground conditions and methods to address these concerns, and advised on material selection and installation.

The complex range of work varied from underground pipe installation and road/site reinstatement to structural concrete, electromechanical, process equipment installation, control systems, and buildings. Since it is unusual to find all this expertise in one contractor and the M.D. wanted to give local contractors the opportunity to partake in this project, ISL divided the project on a discipline basis into two separate contracts: one more civil (pipeline, site works, road reinstatement) and the other more building/mechanical/electrical orientated. This enabled contractors with different skill sets to bid. To ease the contract administration during construction, there was also a clear physical/geographical divide between the two contracts.

BENEFITING THE SOCIETY AND THE ENVIRONMENT: A PERFECT OUTCOME

By May 2011, the first houses and business were connected to Exshaw's new municipal water system. The environmentally-friendly system brings the community into the future. Exshaw residents and businesses no longer need to use untreated water from shallow wells but can access safe, treated water at the turn of a tap.

The new water distribution system and fire hydrants mean that water is also readily available for fire protection in the community, bringing a "new level of personal and property safety"; just as Reeve Dene Cooper had hoped. This was tested when, two months later, "the biggest fire in MD of Bighorn history" broke out at the Francis Cooke Landfill site just five minutes east of Exshaw. Firefighting "crews relied on tanker trucks filling up at new fire hydrants in Exshaw [to dump] over 2,000 cubic metres of municipal water" (Rocky Mountain Outlook, *Massive blaze consumes landfill woodpile*, July 21, 2011). Without that water supply, the outcome could have been very different.

Completed within the budget, the project also directly benefits the M.D. of Bighorn through extensive sustainability solutions. The M.D. now has a low tech and low life-cycle cost treatment system that effectively treats the complex source water issues and uses local staff resources to maintain it. Minimal effort is required by their operational staff to operate and maintain the relatively simple system, which also operates at low energy and produces minimal wastewater. The new municipal water system will provide municipal water to the community of Exshaw for at least the next 25 years, while the modular treatment system means it can easily be expanded to meet future development and servicing needs in the municipal district.

"This project represents exemplary engineering by providing the simplest sustainable solution at the lowest cost for the benefit of all."

"The team demonstrated outstanding innovative and collaborative engineering skills in successfully overcoming the multiple technical, economic, environmental, and social challenges for the creation of a safe, secure and sustainable municipal potable water supply."

- Judges' comments
2013 Showcase Awards Consulting Engineers of Alberta
(Award of Excellence: Water Resources)

"The water we are using has been isolated from surface water for 10,000 years. [As required by Alberta Environment,] it's not surface water. It's not turbid water and they designed a system for efficiency. I'm very pleased. I think the project has some really significant successes."

M.D. Reeve Dene Cooper
(February 14, 2013, Rocky Mountain Outlook)

"It really was (is) a great project and was the result of the efforts of a super group of people. Congratulations, ISL et al."

- Greg Birch, RPP, MCIP
Former M.D. Assistant Manager/Project Manager
(pers. comm., February 22, 2013)

EXSHAW MUNICIPAL WATER SYSTEM - AT A GLANCE!

Innovation	• Customization, testing and implementation of a variation of traditional slow-sand filtration • Project demonstrated how traditional slow-sand filtration could be enhanced to maintain its natural effectiveness while removing most of this treatment system's usual constraints • Treatment system is robust enough to handle variations in source water quality • Filters provide additional contact time during treatment, reducing the storage volume that would otherwise be required • Equipment layout was used to minimize process pumping • Topography was used to minimize distribution pumping
Complexity	• Treatment of complex source water including H_2S, iron reducing bacteria and sulphate reducing bacteria • Retrofit of a complete municipal water system within an existing community • Worked around major existing utilities, plus rail tracks and highway • Project located within an environmentally sensitive area
Social and Economic Benefits	• Safe, secure potable water supply for community and firefighting needs • State of the art, environmentally friendly municipal water system that will provide municipal water to the community for at least the next 25 years • Excellent treated water quality compared to the water previously obtained from the shallow private wells • Locally available staff resources can be used to operate and maintain the system • Work was divided into separate contracts to use local skillsets and typical areas of contracting expertise
Environmental Impact	• Less than a tenth the volume of wastewater is produced compared to other treatment processes, saving downstream costs and optimizing use of a limited resource, i.e., source water • A whole variety of potential treatment chemicals was reduced to just the one required by the regulators for disinfection • Annual energy consumption of treatment technology is <6,000kWh compared to 40,000 kWh estimated for more traditional technologies • Natural materials used for treatment (sand media)
Meeting the Client's Needs	• As well as the usual project management responsibilities, ISL assisted the client in obtaining funding and worked closely with them throughout to meet all needs • Effective and sustainable treatment of complex raw water issues • All equipment can be operated by existing Level 1 operators already employed by the client • Infrequent filter maintenance means less workload for the operators • Lower life-cycle costs as the treatment technology requires very little energy to operate it, largely relying on gravity. • Simplicity of the treatment system reduced the level of operational input required • Modular filter units allow the client to double treatment capacity with relative ease and low cost to meet future servicing needs for other developments