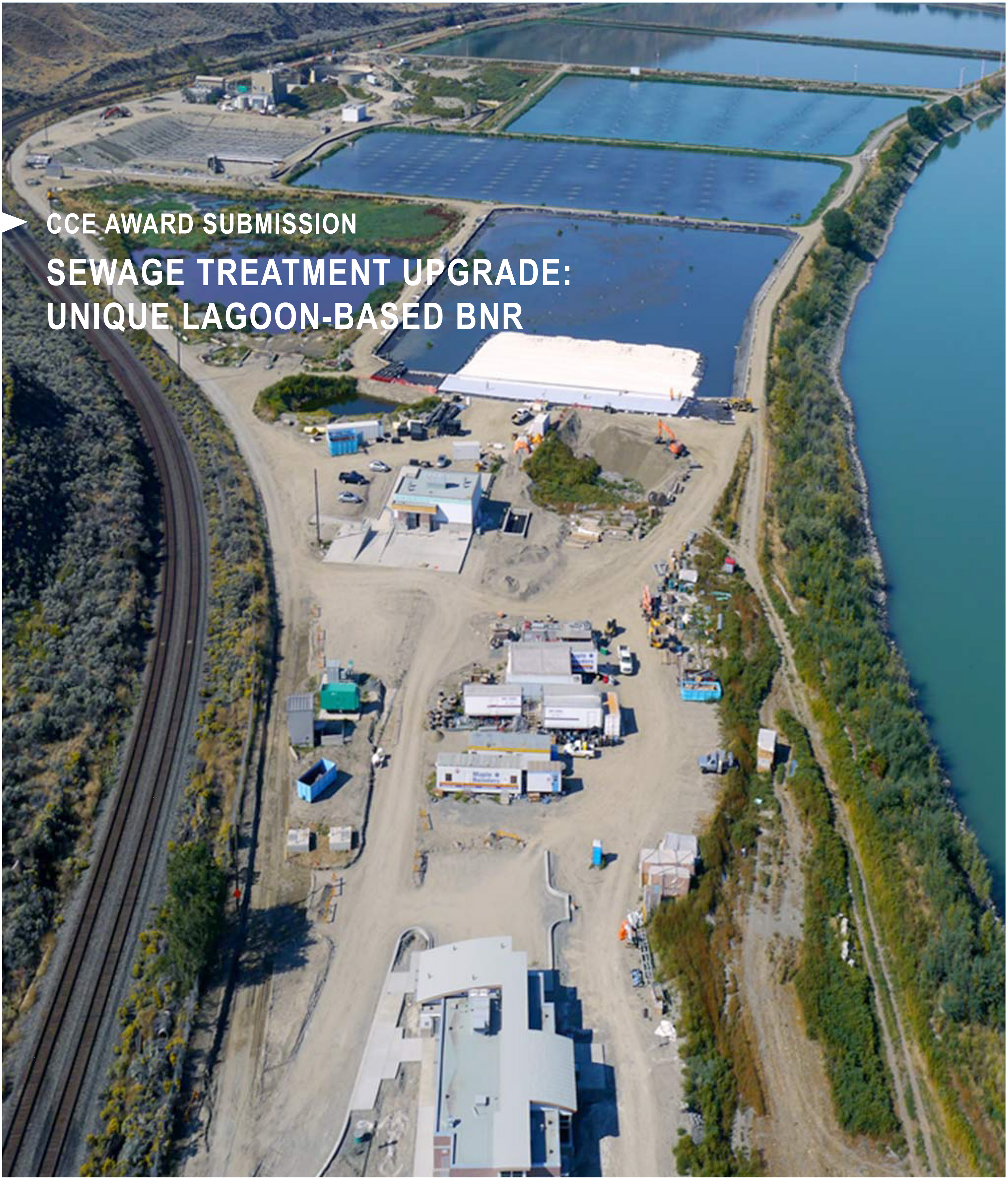
CCE AWARD SUBMISSION

SEWAGE TREATMENT UPGRADE: UNIQUE LAGOON-BASED BNR



URBAN systems

Golder Associates

PART 1: PROJECT SUMMARY

INTRODUCTION

The new City of Kamloops' (the City) biological nutrient removal facility is a unique and sustainable advanced wastewater treatment process that is based on the most basic treatment element – the lagoon – arguably the most common form of wastewater treatment for rural areas all around North America. The design is highly sustainable in that it is the lowest-cost solution that meets regulatory requirements, protects the aquatic environment, incorporates existing wastewater treatment infrastructure and operator skills, reduces greenhouse gasses and odors, and improves the agronomic value of the residual waste biosolids by increasing the phosphorus content.

The City has carried out wastewater treatment for many decades using secondary treatment lagoons with chemical treatment to reduce phosphorus levels. The City discharges 80% of their treated effluent into the Thompson River and reuses 20% for agricultural and golf course irrigation. Alum-based solids are removed annually from one of the lagoons and then are trucked over to the north shore of the Thompson River where they are composted.

When it came time for the City to expand the capacity of the treatment facilities, they needed to comply with the registration requirements under the British Columbia Municipal Sewage Regulation (MSR). A Liquid Waste Management Plan (LWMP) was initiated involving extensive public consultation. Additionally an Environmental Impact Study (EIS) and biological response risk assessment were completed that verified an effluent total phosphorus concentration of 1.0 mg/L would protect the ecological balance in the Thompson River and have little to no effect on the benthic algal and invertebrate communities and fish populations of the Thompson River. The LWMP also determined that a biological phosphorus reduction treatment process was desirable to add agricultural value to the residual waste biosolids and, based on a 20 year present worth analysis, the phosphorus concentration established by the LWMP process saved the City an estimated $42.5M over the lifecycle of the facility in comparison to removing phosphorus to the lowest level achievable by the existing best technology available.

Although the City had identified a preference for incorporating membranes into the treatment process (similar to equipment used in their water treatment plant) soaring construction costs necessitated reconsideration and an assessment of alternative lower cost technologies. While a membrane technology process was estimated at $73Min 2009, an alternative lagoon-based option was identified that could reduce that cost to $40M.

THE SOLUTION

The adopted solution is technically innovative as it involves applying the principles of biological nutrient removal to upgrade the existing lagoon wastewater treatment system and meet the effluent phosphorus water quality. The solution uses an existing anaerobic lagoon for pre-treatment, removing grit, total suspended solids (TSS) and biochemical oxygen demand (BOD), as well as generating volatile fatty acids that are essential to biological nutrient removal, without the input of any mechanical energy. The anaerobic lagoon was also modified to include a cover to capture methane and prevent the greenhouse gas from being released to the atmosphere. A cost analysis demonstrated the anaerobic lagoon reduces the overall life-cycle costs by $19 M, primarily because of the energy and chemical savings resulting from the treatment occurring in this anaerobic lagoon. To mitigate the release of methane and eliminate the odor that has been offending residents on the north side of the river, the anaerobic lagoon (Cell 1A) was covered and the captured gas is flared – converting the methane to carbon dioxide and significantly lowering the greenhouse gas emission to the atmosphere by an estimated (Carbon Dioxide Equivalent or CO2E) 8,900 tonnes per year. The intent is to measure the amount of methane that is generated and investigate the economics of converting the methane to reusable heat or energy.

The engineering design principles taken into consideration in converting a secondary treatment process to achieve biological nutrient removal are illustrated in Figures 1 and 2.

Figure 1 is a conventional activated sludge process that provides bacteria with wastewater (food) and oxygen (aeration/mixing), and retains the bacteria in the system with a clarifier and return activated sludge line. The aerated secondary treatment lagoons used for decades by the City incorporate the same elements but use less energy (lower cost) though they require more land area than the conventional mechanical activated sludge plant.

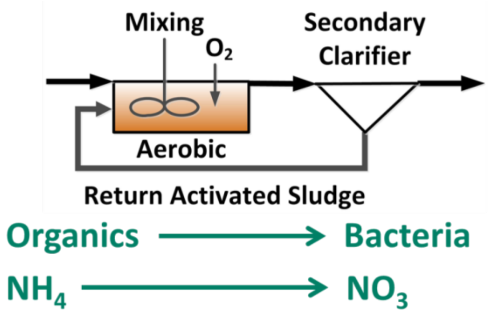


Figure 1: Illustrating conventional secondary treatment with the primary function of converting soluble organic contaminants into bacteria and converting ammonia to nitrate.

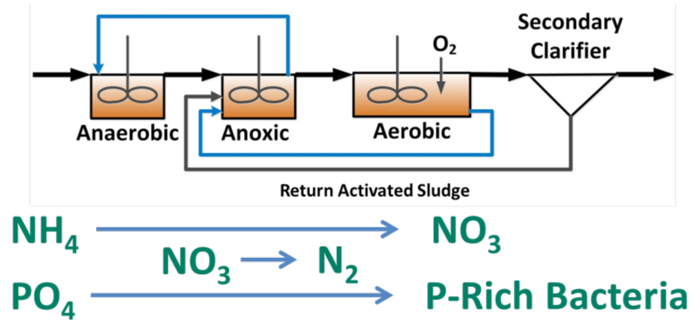


Figure 2: Illustrating the more complex mechanical tertiary biological nutrient removal (BNR) treatment process configuration with internal recirculation and added nitrogen (as N2 gas release) and phosphorus removal capabilities.

Figure 2 illustrates the modified activated sludge process with a multiple bioreactor configuration required to achieve biological nutrient removal (i.e. the removal of nitrogen and phosphorus), consisting of an anaerobic bioreactor, an anoxic bioreactor, and an aerobic bioreactor – along with the associated recirculation lines.

Figure 3 illustrates how these same bioreactor environments are created using baffle partitions within a lagoon structure.

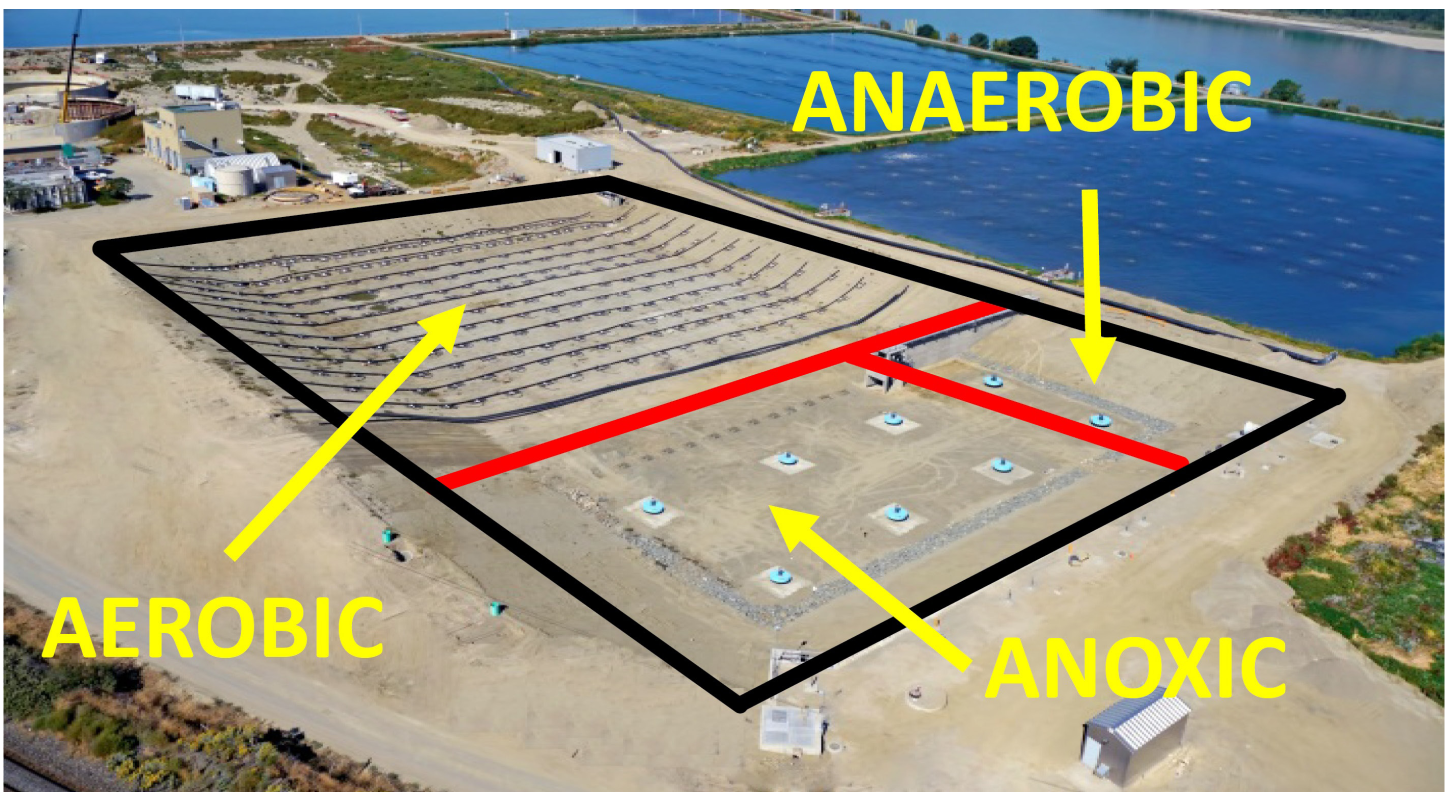


Figure 3: Modified and reduced size Cell with mixing and aeration equipment in place, prior to installing the baffles to partition the lagoon into the three separate environmental cells required for biological nutrient removal.

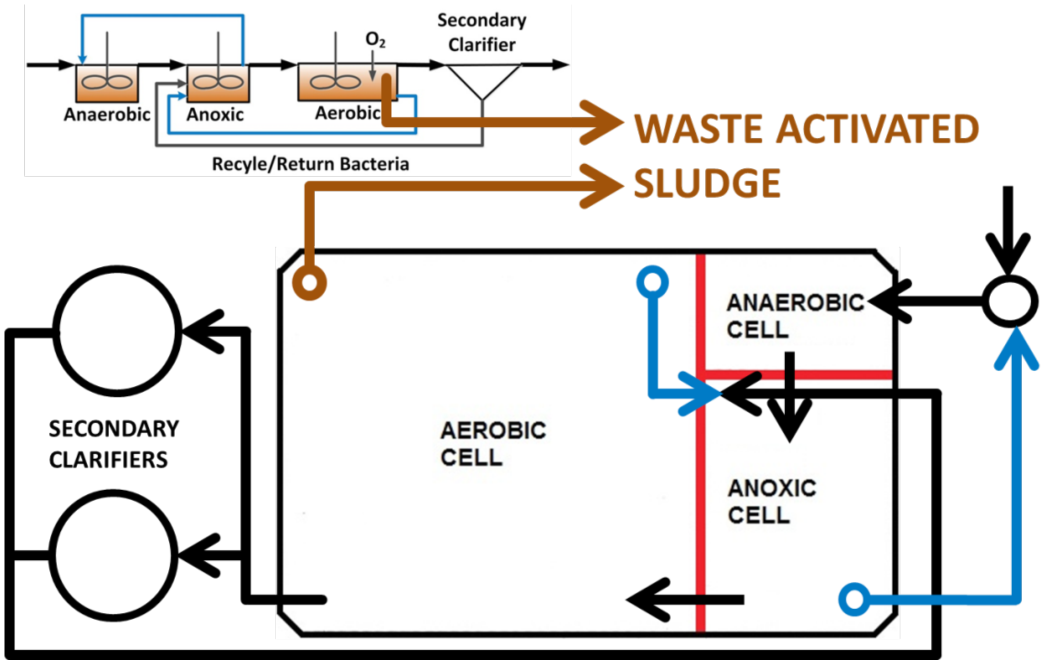


Figure 4: Illustrating the three cell BNR configuration and recirculation for a conventional mechanical process (upper left) and the parallel configuration and recirculation within the modified Kamloops lagoon process.

New clarifiers constructed downstream retain and recycle bacteria back to the front of the modified aerated lagoon. The treated effluent is then disinfected using ultraviolet light, eliminating the need for chlorine. This satisfies the Canadian Environmental Protection Act to ensure toxic chlorine residuals are eliminated from effluents.

While the modified lagoon system removes nutrients from the 54,500 m³/d of treated effluent for discharge to the river, several of the secondary aerated lagoons were retained to treat 5,500 m³/d of wastewater for reuse application for agricultural and golf course irrigation. The effluent used for irrigation did not need to have the nitrogen and phosphorus reduced because the nutrients will benefit the vegetation and less commercial fertilizer will be required. The reuse application reduces the demands on potable supplies for use in irrigation.

As three of the existing lagoons will no longer be required – the adopted solution frees up approximately 4.6 hectares (ha) of land and the conversion of one of the existing excess anaerobic lagoons into a wetland will also increase wildlife habitat.

By way of comparison, constructing a membrane biological process for a design horizon of approximately 25 years and a maximum daily flow of 60,000m³/d was estimated to have cost approximately $73M, whereas the modified lagoon-based biological nutrient removal process was $40M (all 2009 dollars). Further this novel solution maximizes the use of existing infrastructure and frees up a considerable area of land that can be used for other purposes, such as composting.

The proposed engineering alternative accepted by the City and the British Columbia Ministry of the Environment was environmentally sound, financially affordable and generationally sustainable. To our knowledge the conversion of an existing secondary lagoon process to achieve tertiary biological nutrient removal is unique for municipalities in North America.

SOCIAL AND ECONOMIC BENEFITS

The social and economic benefits of this project include:

1. The treatment capacity of the facility will be expanded to treat a maximum day flow of 60,000m³/d and accommodate population growth in the community from of 80,000 to 125,000 people.

2. The new administration building will be used to facilitate tours and school groups to improve education around sewage treatment and reuse of effluent.

3. The LWMP and EIS processes established the level of phosphorus removal required to protect aquatic life in the Thompson River and resulted in an estimated savings of $42.5 M, based on a 20 year present worth analysis, over the cost of implementing existing best available control technology to achieve the lowest possible phosphorus level.

4. The conversion of the existing secondary lagoon process into a lagoon-based biological nutrient removal process saved the City an estimated capital cost of $33M, compared to the membrane-based mechanical treatment process originally adopted by the City.

5. Greenhouse gases emitted to the atmosphere will be reduced by 8,900 tonnes per year and odors will be eliminated through flaring the anaerobic gases.

PART 2: TECHNICAL DESCRIPTION OF THE LAGOON PARTITIONING FOR BIOLOGICAL NUTRIENT REMOVAL

ANAEROBIC CELL

INLET FLOWS

Effluent from the primary anaerobic lagoon is combined with recycle flow from the anoxic cell, and the combined flow is directed through a 1200mm RC pipe to the anaerobic cell. A concrete pad is provided around the inlet to prevent clay bottom scour. The new inlet and the outlet of the anaerobic cell are located at opposite ends of the cell to minimize the potential for short circuiting.

CONCRETE PARTITION WALL

A concrete wall divides the anaerobic cell from the aerobic cell and allows access for sampling from the anaerobic, anoxic and aerobic cells, anchoring for the two dividing baffle and for the cell mixing system, support for the Return Activated Sludge (RAS) piping from the secondary clarifiers, support for the Aerobic Recycle Pump and associated piping, and an opening for the outlet of the anaerobic cell.

The Partition Wall extends approximately 37 m from the north shore of the cell. A 1.8 m walkway with guard rails is centred on top of the wall, terminating with a working platform on the end. From the working platform, a portable lifting davit permits lifting the Anoxic Reciculation Pump and it can be placed on a dolly that can be rolled out to shore for servicing if required. A short wall, perpendicular to the main partition wall underlies the northern edge of the working platform. A 1.9 m wide penetration of this end wall permits flow from the anaerobic cell to the anoxic cell. The RAS return line is installed underneath the walkway, passing over the wall under the working platform, before bending down to a submerged discharge in the anoxic cell. Electrical outlets are provided at several points along the walkway to permit the operation of small tools. Lighting also permits safe nighttime access.

Dock ladders allow access to boats, if required, for maintenance of equipment in the anaerobic and anoxic cells.

FLOATING BAFFLE

A floating baffle separates the anaerobic cell from the anoxic cell. The baffle is fixed to the concrete partition wall on one end and at the other end on the Cell Bank. A cable in a welded seam provides top and end tensile strength. Baffle weighting at the bottom is provided by a steel chain inserted into a seam thermally-welded to the bottom of the baffle and anchored at regular intervals with concrete blocks. The top of the blocks are set flush within the existing compacted clay liner of the cell. The excavated depression for the blocks is lined with a geosynthetic clay liner to maintain the low hydraulic capacity of the liner.

The connection of the baffle to the eastern shore of the cell is accomplished by passing the top cable through an High Density Polyethylene (HDPE) pipe sleeve that penetrates through a gap in the Mechanically Stabilized Earth (MSE) wall. This permits the cable to be anchored on shore, rather than into the MSE wall. On the western end, the baffle is anchored to the end of this short section of wall extending below the northern edge of the Partition Wall working platform.

MIXING

Two 20 horse power (hp) floating style radial flow pattern continuous operation mixers were selected for the anaerobic cell. The mixers are tethered in pairs from the concrete divider wall and anchor posts on the cell bank walls. Each mixer is provided with a concrete erosion control pad mounted directly below the mixer. The toe of the northern and eastern slopes of the cell are protected with 200 mm to 400 mm rip-rap underlain by a composite geotextile liner with embedded sodium bentonite clay to prevent loss of liquid to ground. The mixers are also provided with variable speed drives to enable some turndown for power savings if there appears to be excess mixing energy.

MIXER ACCESS FOR MAINTENANCE

The mixers require periodic (once every 3 years) motor greasing. To facilitate access to the mixers and for boat launching, a MSE wall comprised of three courses of concrete Lok-Bloks was added to the eastern side of the Cell. The wall extends far enough into the cell that a mixer can be floated up to the wall without grounding the impeller. The top of the wall is at the top of berm elevation, for safer access to the side of cell in the winter months. The MSE wall is designed for crane truck access for lifting and removing the mixers if necessary. Areas that are not suitable for crane truck access are protected with bollards.

Mixers are tethered with snap-on connections at the anchors located behind the wall, and with pulleys mounted on the wall on the eastern side of the anaerobic cell. To float a pair of mixers to the MSE wall, the mixers can be turned off to reduce the torque force on the anchor cable. On each of the two anchor posts behind the wall for a pair of mixers an extra length of cable that is kept in storage will be attached to the short strain relief cable at the anchor post. Then the main snap-on connection will be released, and the mixers pulled in to shore one by one and tethered for maintenance. At that point the mixer and float can be pulled from the water by a crane if needed, or the mixer and motor could be accessed by a temporary plank and drum float arrangement from the wall. If the motor or impeller must be removed for repair, the mixer float can be put back into the Cell to maintain the position of the second mixer of the pair so it can be put back into service while waiting for a replacement part, if necessary.

A boat can be launched at several points along the wall where there is sufficient clearance from cables, and can be pulled along to any location along the wall. Ladders are provided on the wall near every mooring point to allow exit from the Cell in case of an accidental fall. A guardrail is provided along the top of the wall to prevent personnel from accidentally backing into the Cell, with removable sections for mixer maintenance, and curbs offset back from the wall to prevent vehicles from backing into the Cell.

FLOATING SOLIDS MANAGEMENT

Surface transfer of generated floating solids is encouraged by providing flow of mixed liquor around the western end of the baffle separating the anaerobic and anoxic cells. However, prevailing winds may not be sufficient to permit full transfer. To manage any persistent floating solids accumulation, yard hydrants and a spray-down hose will be provided to manually disperse the floating solids buildup. Safe access to a portion of the cell is available via the walkway installed over the inlet pipe, and along the MSE wall. In addition, a portable, floating scum skimmer that sucks floating material into an impeller and forces it either downwards or into the anoxic cell can be used by the operators to help disperse the floating material. Electrical connections for the scum skimmer are provided at either ends of the floating baffle. It was expected that the skimmer would be initially be located near the outlet of the anaerobic cell.

ANOXIC CELL

INLET FLOWS

Flow enters the anoxic cell from three sources: first, from the anaerobic cell through the end of the concrete partition wall; second, from the aerobic cell via the Anoxic Recycle Pump; and third from the secondary clarifier underflow via the RAS piping supported on the concrete wall.

CONCRETE PARTITION WALL

The concrete partition wall working platform extends 3.75 m into the anoxic cell to provide support points for mixer anchorage, discharge area for the RAS piping, and discharge area and support for the Aerobic Recycle Pump Station and associated piping. A ladder allows access to the water level as required for boat access to mixers and sampling. A short concrete diversion wall directs flow from the aerobic cell into the centre of the anoxic cell to prevent short circuiting along the baffle.

FLOATING BAFFLE WALL

A floating baffle divides the anoxic cell from the aerobic cell. The baffle is fixed to the concrete partition wall on one end and at the other end on the Cell bank. A cable in a welded seam provides top and end tensile strength. Baffle weighting at the bottom is provided by a steel chain inserted into a seam thermally-welded to the bottom of the baffle and anchored at regular intervals with concrete blocks. The top of the blocks are set flush within the existing compacted clay liner of the Cell. The excavated depression for the blocks is lined with a geosynthetic clay liner to maintain the low hydraulic capacity of the liner.

The floating baffle components and final design will be the responsibility of the Contractor, who must issue sealed shop drawings for prior approval by the Engineer.

MIXING

Six- 15 hp floating style, radial flow pattern, continuous operation mixers, similar but smaller than the mixers in the anaerobic cell, were provided. The mixers are tethered in pairs from the concrete divider wall, anchor posts on the cell bank walls, and two anchor posts sunk into the floor of the cell. Each mixer is provided with a concrete erosion control pad mounted directly below the mixer. The toe of the cell walls are reinforced with 150 mm to 200 mm rip-rap.

ANAEROBIC RECIRCULATION

A single horizontal, propeller-type recirculation pump was installed in a chamber installed at the southeast corner of the Anoxic cell. Mixed liquor from the anoxic cell is drawn into the chamber through a 1800 x 1200 box culvert. The culvert has a single course of Lok Bloks installed along the southern side with earth backfill to provide personnel and boat access to the southern portion of the anoxic cell. Vehicular access in this area is prevented by bollards.

This type of pump operates at a very low head, and the total flow is therefore sensitive to slight variations in the static lift. In order to permit a competitive sourcing of the recycle pump, three pumps were pre-selected, each having different static head requirements to achieve the design flow rates. The appropriate static head differential is obtained by discharging to a Recirculation Pump Discharge Chamber with the outlet elevation set based upon the pump selection.

The Anaerobic Recirculation Pump is operated on a Variable Frequency Drive to permit adjustment of the flow rate between 0.5 and 1.2 times the daily inflow. Depending upon the selected pump, it should be possible to achieve nearly the full projected range of recirculation flows over the design life of the project. Since it is likely that equipment replacement will be required during the life of the project, the propeller and/or motor can be modified at the replacement interval to achieve the projected long term flow rates.

From the Recirculation Pump Discharge Chamber, the flow is conveyed through the existing 900mm RC pipe located in the eastern berm of the Cell to a new confluence manhole that directs the flow back to anaerobic cell inlet.

FLOATING SOLIDS MANAGEMENT

Surface transfer of accumulated floating solids is encouraged by providing flow of mixed liquor around the shore-end of the Anoxic/Aeration baffle. To manage any persistent floating solids accumulation, yard hydrants and spray-down hose are provided to manually disperse the floating solids buildup. Safe access to eastern side of the cell is available along the block wall. In addition, a floating scum skimmer, anchored near the southern end of the MSE wall, sucks floating material into an impeller and forces it either downwards or into the flow path to the aerobic cell (as directed by the operators) to help disperse the floating material.

OUTLET FLOWS

Transfer of mixed liquor from the anoxic cell to the aerobic cell is provided around the end of the baffle closest to the shore (SW corner of the cell) which allows accumulated floating solids to move downstream in the process. A concrete slab is installed at the transition between the cells to protect the bottom from scour.

AEROBIC CELL

CELL OUTLET AND ALUM DOSING

Mixed liquor overflows a sharp crested weir in the north-west corner of the aerobic cell, provided to maintain minimum cell depth for the aeration system. Alum for backup phosphorus removal can be dosed by headers at the upstream end of each weir to take advantage of the mixing action of the overflow as well as the retention time of the pipe to the clarifiers. Valves allow isolation of each alum header, and couplings allow removal of the alum headers from above the channel should they require cleaning. A valved vent allows both draining and/or cleaning of the alum piping with compressed air for long term shutdowns. The alum pipe is insulated below ground, and except for the valved portion, runs below water level. Grating over the weir structure and a peripheral handrail allows access for periodic weir cleaning and maintenance of the alum dosing piping. A local yard hydrant is provided for washdown. A safety grate, which can be pulled up for cleaning, is provided over the inlet to the Cell outlet pipe, to prevent personnel, birds or large objects from entering the pipe.

ANOXIC RECIRCULATION PUMPING

A single horizontal, propeller-type recirculation pump was installed in the partition wall between the Aeration Cell and the Anoxic cell.

As with the Anaerobic Recirculation Pump, this type of pump operates at a very low head, and the total flow is therefore sensitive to slight variations in the static lift. In order to permit a competitive sourcing of the recycle pump, three pumps were pre-selected, each having different static head requirements to achieve the design flow rates. The appropriate static head differential is obtained by discharging through an upturned pipe into the anoxic cell with the outlet elevation set based upon the pump selection.

The Anoxic Recirculation Pump will be operated on a Variable Frequency Drive to permit adjustment of the flow rate between 1.0 and 2.0 times the daily inflow. Depending upon the selected pump, it should be possible to achieve nearly the full projected range of recirculation flows over the design life of the project. Since it is likely that equipment replacement will be required during the life of the project, the propeller and/or motor can be modified at the replacement interval to achieve the projected long term flow rates.

SECONDARY CLARIFIERS

FLOW SPLITTING

From the aerobic cell, mixed liquor flows by gravity to weir splitter boxes located at each clarifier. An isolation gate is provided at the inlet to the weir boxes. The splitter weirs are mounted on downward opening gates to allow balancing of the flow split between the two clarifiers, allow level adjustment as flows increase at the plant, and maintain a balanced flow split after post construction settling. Pressure sensing level sensors upstream of the weirs provides inlet flow monitoring to each clarifier.

Grating over the downstream weir area allows visual inspection of clarifier inlet conditions, and a hatch in the concrete cover over the upstream weir area allows access to the tank below. The hatch has been sized to allow removal of the isolation gate on the inlet piping. A valve box cast into the concrete cover will allow access to the level sensor.

CLARIFIER MECHANISMS

There are two, 44 m diameter concrete clarifier stainless steel, each with 2% sloped bottom floors, a concrete inboard launder, and a coated steel and aluminum access bridge to the central drive mechanism.

After flowing over the inlet splitter weir, mixed liquor enters a 1067 mm diameter pipe running beneath the clarifier floor slab, and then flows upward through the central pier of the clarifier mechanism through an energy dissipating inlet (EDI), which provides mixing for flocculation as the flow exits to the central flocculation well of the clarifier. Clarified effluent flows around a perimeter Stamford baffle and beneath a peripheral scum baffle to the perimeter V-notch effluent weirs, which discharges to a perimeter launder. The launder is sized to allow personnel to walk around the launder as required. Clarified effluent enters a concrete outlet box that connects to a 900 mm diameter outlet pipe that allows flow to ultraviolet disinfection by gravity. A safety grate is provided over the outlet box to prevent personnel, birds or large objects from entering the clarifier outlet pipe.

Clarifier mechanisms are stainless, which dramatically reduces the servicing requirements. Effluent weirs and scum baffle are aluminum. The scum beach and scraper arm is 304 stainless steel. The sludge suction headers are hot dip galvanized steel, as manufacturers will not guarantee the quality of a paint coating on the inside of the headers.

Effluent reuse water is piped to the quarter points around the launder, including a standpipe at the top off the pump station, for washdown. A fifth standpipe is provided at the centre of the clarifier. The effluent reuse water pipe to the centre of the clarifier is self-draining to prevent freezing. A mounting post for a portable lifting davit is mounted at the centre of the clarifier. Ladders are provided at the quarter points around the launder for launder access. A ladder under the walkway allows access to one side of the scum beach.

The RAS pumps are able to dewater a clarifier to a liquid level just below the sludge suction header inlet holes. To dewater the remaining small volume, a sump is located in the bottom of the clarifier so that a trash pump can be lowered from the bridge deck into the sump, and the remaining liquid directed to either the RAS pump station or the inlet of the clarifier that remains in operation. The same trash pump can be used to draw down the liquid level in the inlet pipe so that it will be a maximum of half full. The RAS pipe orientation has been changed so that the RAS pipe is laid level, which will allow the RAS pumps to drain the pipe.

RETURN SLUDGE PUMPING

Settled sludge is removed by two suction header type sludge collectors which sweeps the bottom of the clarifier twice for every revolution of the clarifier drive mechanism.

The suction headers are connected to a central manifold, which in turn connects to the return activated sludge (RAS) suction pipe which discharges to the heated RAS pump station that is integral with the clarifier tank walls. The manifold has an elastomer seal that requires periodic inspection and replacement usually about every 5 years.

Two 30 hp Flygt submersible solids handling type pumps (RAS pumps) are mounted in the RAS pump station wetwells. Each has a capacity of 15,418 cubic meters per day (m3/d), and is equipped with variable frequency drives to allow a 50% turndown. The resulting RAS flow range is therefore 15,418 to 61,672 m3/d, or from 33 to 130 percent of design average day flow. At initial average day flow, the lower RAS flow range will be 60 % of initial average day flow. The RAS pumps operate 24 hours per day, and the double pumping system provides installed backup. When one clarifier is down for maintenance, two pumps provide a recycle rate of up to 65% of design average day flow, which is expected to be sufficient for the relatively short periods of time when one clarifier is down for inspection and/or maintenance.

The dual RAS pumps discharge to a heated, ventilated valve chamber that allows access to the 350 mm diameter check valves and isolation valves for each pump, without entering the wetwell. Access to the below grade valve chamber is by a central stairwell. Each pump discharge pipe connects to a common 450 mm diameter header, which is provided with an ultrasonic flow meter mounted in a downstream manhole. Downstream of the flow meters and isolation plug valves the two pump streams combine into a 750 mm diameter pipe which will direct RAS back to the anoxic cell. RAS flow is manually set by the operators using the flow meters to balance flows between the two clarifiers as needed. It is anticipated that changes in RAS flowrates would not be frequent once the commissioning phase is completed, with perhaps seasonal adjustments and to allow for increasing flow rates.

RAS sampling points are located in the valve chamber.

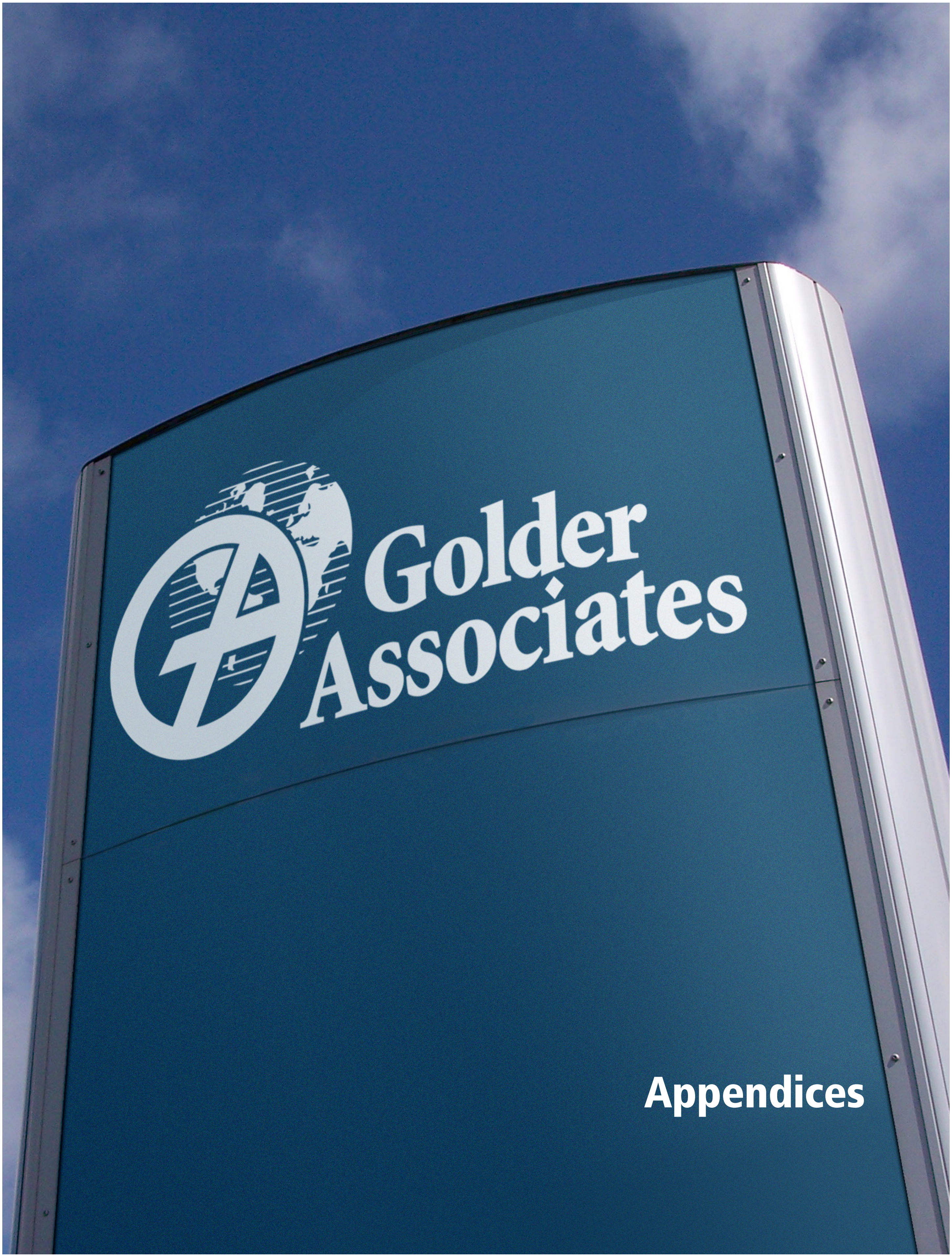
A connection on the RAS header from each clarifier will allow connection of 12 mm inside diameter hose for dosing of hypochlorite to the header if needed for filamentous control.

SCUM REMOVAL AND PUMPING

Scum is removed by two skimming arms that will discharge twice per revolution to the scum beach located next to the access bridge to the central pier. The scum beach has been provided with a radiant heater to prevent icing during cold winter temperatures. The beach will discharge to a heated scum wetwell containing a submersible 5 hp Flygt solids handling pump, which will operate on level (plus a timer option) to periodically discharge to the 450 mm RAS header from each clarifier.

Bars across the scum trough will prevent birds from getting caught in the scum piping.

A spray bar mounted below the bridge walkway above the centre flocculating well will be provided to break up scum and either cause it to sink or move it to the scum ports mounted around the centre flocculating well.



Appendices

OFFICIAL ENTRY FORM SUMMARY

The City of Kamloops used lagoons for secondary treatment for decades, but was faced with having to replace them with an expensive mechanical treatment plant to meet tertiary effluent requirements. Golder Associates Ltd. and Urban Systems collaborated to develop an innovative sustainable process design that modified the lagoons to achieve tertiary treatment at considerably lower cost, allowed for the use of existing operator skills and reduced greenhouse-gas emissions – creating a simple cost-effective sustainable state-of-the art solution.

OFFICIAL ENTRY FORM QUESTIONS

Q.1 Innovation (40%)

Biological phosphorus reduction is normally achieved in an activated sludge process with varying environmental conditions that stimulate some bacteria to store phosphorus in excess of biological growth requirements. The first biological nutrient removal (BNR) process in North America consisted of a complex configuration of twenty-one bioreactor cells. While simpler configurations have since been developed, BNR processes are generally considered to be among the most complex and expensive domestic wastewater treatment processes to build and operate.

In contrast, lagoon wastewater treatment processes are generally considered to be among the simplest and lowest cost treatment processes. The large land area requirements and the inability to significantly alter the degree of treatment are considered to be the primary disadvantages of lagoon systems. Typically lacking structural walls, compartmentalization and internal recirculation, lagoon-based wastewater treatment offers little to no ability for operators to improve or optimize treatment beyond what was designed and built. The lack of compartmentalization and the lack of operational flexibility and adaptability normally make lagoon systems inappropriate for consideration as a BNR process.

The City of Kamloops has operated and maintained lagoon wastewater treatment systems for decades, and their operations staff are highly familiar with the operations and maintenance requirements of lagoons. When the City's Liquid Waste Management Plan (LWMP) determined a BNR process was required so that the waste sludge could be beneficially used for agricultural purposes, rather than building a mechanical treatment process the City decided to modify their lagoons instead of replacing them with a more expensive mechanical process. The sustainability of the process was also enhanced by the ability of operations personnel to utilize and adapt their knowledge of lagoon system operations.

A "blue-collar" process, this modified lagoon system is designed to robustly and inexpensively achieve the required nitrogen and phosphorus effluent water quality. One of the lagoons was modified by adding a cover to enhance the generation of volatile fatty acids, an essential substrate for the special phosphorus-removing bacteria. A second lagoon was modified to incorporate aerators, mixers, recirculation pumps and low-cost baffles to create the three BNR environmental zones. Finally, two concrete clarifiers were constructed and ultraviolet disinfection was added. The combination of a lagoon-based BNR, and the retention of three other lagoons that sustainably treat 5500m3/d of secondary effluent for irrigation reuse, makes this upgrade unique in the world.

Q.2 Complexity (20%)

The design team developed an alternative BNR solution that involved modifying the existing lagoon infrastructure, rather than building a new compartmentalized mechanical treatment process with structural walls. This was estimated to save $33.6 M in capital, while meeting the effluent criteria established by the Canadian Council of Ministers of the Environment Canada-Wide Municipal Wastewater Strategy for discharge to surface waters under the Wastewater Systems Effluent Regulation.

A concept crystallization study and report confirmed that biological phosphorus removal could be achieved with a modified lagoon structure by:

1. Incorporating a covered anaerobic lagoon (Cell 1A) to ferment the sewage and generate the volatile fatty acids, in particular acetate, that are essential to the successful performance of the BNR process.

2. Modifying a second lagoon (Cell 2A) by reducing the overall size to minimize mixing energy; installing appropriate aerators, mixers and recirculating pumps; and compartmentalizing it using relatively inexpensive baffles into three separate environmental zones: anaerobic, anoxic, and aerobic.

3. Constructing two clarifiers instead of three.

The resulting lagoon-based BNR process achieves the same environmental conditions and similar nutrient removal levels as a much more expensive conventional mechanical BNR process.

Q.3 Social and/or Economic Benefits (15%)

The social and economic benefits are related to the increased treatment capacity of the facility to accommodate growth in the community from a population of 80,000 to 125,000, and to the cost-effective innovative and appropriate use of a low-technology wastewater treatment process (lagoons) to achieve tertiary treatment and reduce effluent phosphorus concentrations as required by the City of Kamloops Liquid Waste Management Plan (LWMP). The LWMP environmental impact study and associated risk assessment study established that an effluent phosphorus concentration of 1.0 mg/L would protect aquatic life and the ecological balance in the Thompson River, resulting in an estimated savings of $42.5 M, based on a 20 year present worth analysis, over the cost of implementing best available control technology to achieve the lowest possible phosphorus level. The low-cost lagoon wastewater treatment technology is well understood by existing operations staff without the need for extensive training or additional plant operators. The capital cost of the modified lagoon configuration is estimated to be $33.6M lower than a similarly configured mechanical treatment process. While training was required to help operators understand how the partitioning and recirculation results in enhanced biological phosphorus removal, the fundamentals of operating and maintaining pumps, mixers and aerators used in lagoon systems were maintained. Further, the reduction in chemical precipitates from the residual biosolids, and increased phosphorus content, improves the agronomic value of the biosolids. Greenhouse gasses were reduced, by comparison to current practices, by covering anaerobic lagoon (Cell A1) and capturing and flaring methane gas, preventing it from escaping into the atmosphere; helping the community to reduce its greenhouse gas emissions (CO2E) by 8900 tonnes per year and enabling future potential energy recovery. The social benefits also include the use of the new administration building to facilitate tours and school groups to improve education around sewage treatment and reuse of effluent, and the elimination of odors that residents of North Kamloops have endured for decades.

Q.4 Environmental Benefits (15%)

This innovative process achieves a number of environmental benefits including:

1. It eliminates the need to use chemicals to remove phosphorus from the wastewater, and produces a residual biosolids product that has an agronomic benefit, thereby reducing the need to apply chemical fertilizers.

2. It reduces the phosphorus loading to the Thompson River.

3. It achieves a more sustainable wastewater treatment solution in that:

   - The existing lagoon infrastructure continues to be used
   - The operator skill sets can be readily utilized with minimal additional training
   - The capital costs normally associated with a BNR process are significantly reduced
   - The amount of land required for wastewater treatment is reduced
   - The level of treatment matches the environmental discharge requirements.

Discharges to the Thompson River are tertiary treated using low-cost lagoon technology for phosphorus removal, while discharges for irrigation use continue to be secondary treated using lagoons so that the irrigated crops can benefit from the nutrients in the secondary effluent.

4. Covering the anaerobic lagoon improves the fermentation and generation of volatile fatty acids that are essential to biological phosphorus removal. The cover also allows for the capture of greenhouse gases, including methane, and prevents them from escaping into the atmosphere - reducing greenhouse gases (CO2E) by 8900 tonnes per year. While the methane generated is currently being flared, the intention is to implement energy recovery in the future.

Q.5 Meeting Client's Needs (10%)

The costs associated with constructing a new conventional mechanical BNR process were significantly reduced by about $33.6M by modifying the existing low-cost lagoon-based infrastructure to achieve the necessary compartmentalized environmental conditions.

The City of Kamloops has been spending approximately $200,000/year for chemicals to reduce the phosphorus levels. These costs will be eliminated with the implementation of this new BNR process.

The BNR treatment process will result in a waste residual biomass with up to five percent phosphorus content and high agricultural value.

The City covered the anaerobic lagoon (Cell 1A) and is extracting the malodourous gas to a flare (it is expected that once the quantity of methane is measured it will have a beneficial reuse in the future). This facet of the project will eliminate the odors that residents of North Kamloops have endured for decades and by traping greenhouse gases generated through wastewater treatment and preventing them from being released to the atmosphere – helping the community to reduce its greenhouse gas emissions by (Co2E) 8900 tonnes per year.

The resulting wastewater treatment process is considered to be a highly sustainable solution. It protects the environment by diverting nutrients from the Thompson River, making them available for beneficial agricultural application, and captures and prevents the release of greenhouse gases to the atmosphere. It utilizes existing low-capital cost lagoon wastewater treatment technology and operator skill sets, and eliminates the odors previously associated with the lagoon treatment operations.

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