CLOVER BAR BIOSOLIDS LAGOONS RISK AND OPERATION STUDY

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Introduction

The Clover Bar biosolids lagoons at the Edmonton Waste Management Centre serve the Edmonton Capital Region—1,100,000 people and growing. These five lagoons receive biosolids—the residue remaining after treatment—from two local wastewater treatment plants. The lagoons currently house enough biosolids to cover 300 CFL football fields one metre deep; about every two months, they receive enough to cover another ten. To put it plainly, the lagoons are full.

Over the last ten years, Edmonton's population growth and the expansion of its wastewater and stormwater management systems have resulted in significant increases to the inflow of solids. During this time, Edmonton has expanded select operations—including land application and composting programs—to keep pace with the growing influx of biosolids. The City, EPCOR, and the Alberta Capital Region Wastewater Commission have worked together to develop a long-term biosolids management strategy, but the excess from the past remains.

LAGOON DESIGN AND CONSTRUCTION

In the 1970s, the City of Edmonton completed construction of the Clover Bar lagoons. This facility comprises four working lagoons and one large storage lagoon on a 65-hectare plot at the Edmonton Waste Management Centre. Situated in the northwest near the North Saskatchewan River, the lagoons were built with an initial capacity of over 2,000,000 cubic metres.

A network of pipe carries the biosolids from Gold Bar Wastewater Treatment Plant in east Edmonton to the lagoons, crosses under the North Saskatchewan River twice, and returns the supernatant via a pump house at the lagoon site. The lagoons also take biosolids from the Alberta Capital Region Wastewater Commission. Three lagoons are "working," used for settlement and thickening of biosolids. One is a supernatant lagoon, where the liquid is drawn off and pumped back to Gold Bar. The final and largest by far, Lagoon 5, holds more than 60% of the total capacity and can function as both a working and a storage lagoon.

OVERFLOW: A MOUNTING CONCERN

Since the implementation of the city's forward-looking Combined Sewer Overflow (CSO) Control Strategy in 2001, more sediment-heavy storm water is being captured and directed to Gold Bar. This, coupled with area population growth, has led to continual increases in solids entering the wastewater stream.

As a result, in the spring of 2013, Clover Bar's largest lagoon, Lagoon 5, reached its highest level in history, with contents rising to near the top of the berm.

Given the lagoons' heights above ground and their proximity to the North Saskatchewan River—just 300 metres away—overflow or breach would be environmentally disastrous. The high concentration of phosphorous and nitrogen in these biosolids, though beneficial resources when used in land application and composting, could cause deep damage to the delicate river ecosystem. It was clear that a solution was needed.

EPCOR AND EDMONTON LAY THE GROUNDWORK

For over twenty years, the City of Edmonton and EPCOR have been working together to identify solutions for the lagoons. While the city's focus has been on managing on the solids, EPCOR—which operates Gold Bar and the Clover Bar lagoons—centred its efforts on the liquids.

Between 2009 to 2014, these teams brought about many successes. They worked together to significantly improve composter operations and upgraded the pump house and piping system at the lagoons. EPCOR increased operations presence at the lagoons, the city cleaned

Project Highlights

- Evaluated and tested operations at Clover Bar Lagoons: 68 million pieces of data, 75,000 lines of code, and a customized, automated data visualization report
- Model calculated solids, liquids, and nitrogen and phosphorus loads in the supernatant every day for more than 10 years, 2011-2024
- Study integrated simulation with Failure Mode and Effects Analysis and risk analysis with pre- and post-mitigation quantification to fully understand the lagoon operations
- Developed a full mitigation plan, including operational and equipment upgrades, to help safeguard the environment and keep Clover Bar running smoothly

Technical Excellence

- Statistical data analysis of four years of Gold Bar and Clover Bar operational data required to identify trends and significant correlations prior to fitting 28 distributions
- State of the art visualization techniques to calculate and represent key information
- Modeled chemical constituents as well as solids and liquids
- Custom database created for the failure and risk analysis

Project Complexity

- First study to fully answer these questions
- 68 million data points, 75,000 lines of code, 700 graphs
- Entire simulation completed in a month; the study took only three months total

EDMONTON'S BIOSOLIDS MANAGEMENT

There are five active above-ground lagoons at the Clover Bar Site, numbered 2, 3E, 3W, 4, and 5. Lagoon 4 is the smallest and Lagoon 5 is by far the largest and deepest; it is about 20 meters deep and 104,000 m^2 in area, about ten times as large as the next largest lagoon. A network of berms forms the lagoons, with fairly narrow service roads running on top of the berms. Various pipes, valves, access points, and decant culverts run within the berms to carry biosolids and supernatant, and temporary piping and pumps may also be set up if operationally desirable. One temporary pump is almost continuously used at Cell 5, and one is used for the NutriGold operations (see below).

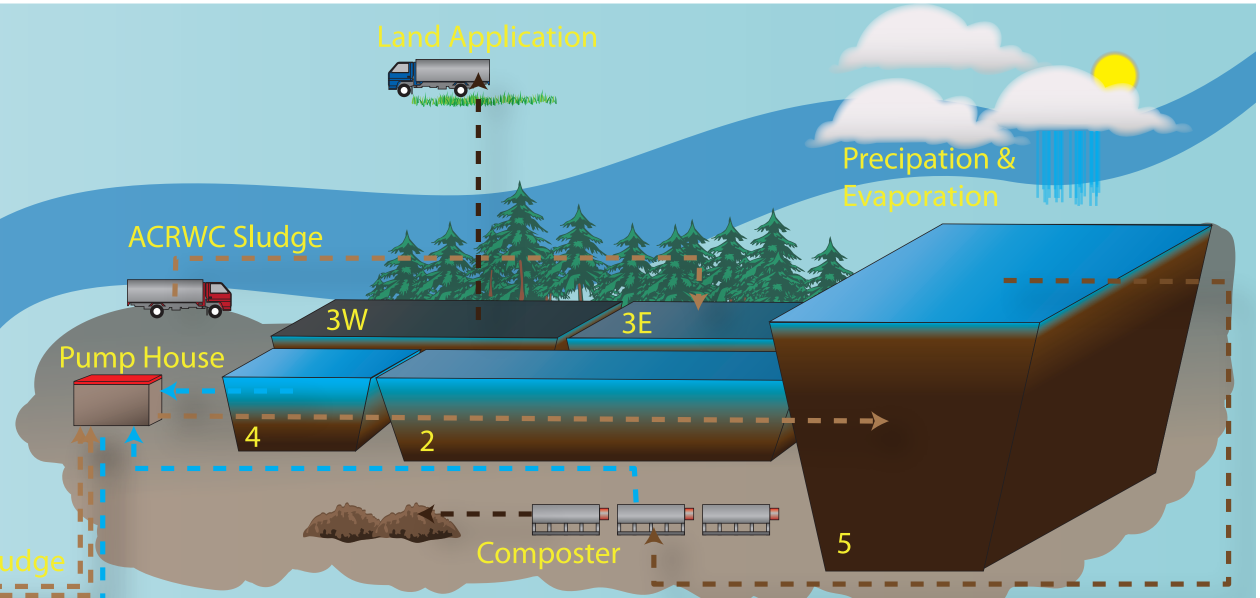
Biosolids are pumped to the lagoons from Gold Bar through 11 km of pipes. Once at Clover Bar, the biosolids are decanted through a series of settlement lagoons and the supernatant is ultimately returned to Gold Bar. The pipes which span the distance from Gold Bar to Clover Bar can be used for either supernatant return or pumping biosolids, and a series of chambers with valving found along their alignment allow for operation to be adjusted, as well as enabling acid cleaning of the system when necessary. The pipes cross under the North Saskatchewan River in two places.

In order to enter or leave Clover Bar, piped biosolids must pass through the Pump House, which is located on the west side of the Clover Bar lagoon site. Biosolids enter the lagoons from two major sources, Gold Bar and the Alberta Capital Region Wastewater Commission (ACRWC) Plant. The Gold Bar biosolids are piped into Cell 5. ACRWC biosolids are trucked in and dumped into either Cell 3E (in summer) or Cell 3W (in winter).

There are two major sources for biosolids removal: NutriGold and the composter. Once a year, before summer operations begin, about half the biosolids in Cell 3E are pumped into Cell 3W to ensure there is enough for the NutriGold program, and more biosolids may be pumped into Cell 3W during the summer if necessary. The NutriGold program requires a higher biosolids concentration (8-10% is desirable). The NutriGold loading operations are handled from a facility on the west side of Cell 3E with a weigh scale and a pump.

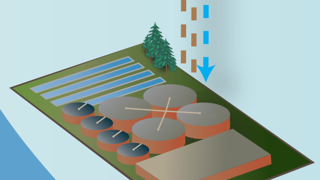
Biosolids in Cell 5 are removed exclusively by the composter operations using a barge and pump, and are then centrifuged to remove solids; supernatant from the composters is returned through an off-site connection to the Clover Bar inflow line. There is slightly more volume of supernatant returned than biosolids removed (about 6% more), because a polymer must be added during centrifuging.

Supernatant from Cell 3E and Cell 5 decants into Cell 2, and from there to Cell 4. Cell 4 is the final and cleanest lagoon at Clover Bar; it is typically pumped down and cleaned out about once every two years. It holds the final supernatant, ready to be returned to Gold Bar and the ACRWC Plant. Supernatant is pumped back via three pumps in the Pump House. A flowmeter in one of the chambers monitors the return of supernatant to ACRWC. The return of supernatant to Gold Bar is constrained by the nutrient loading to the plant, and occasionally may have to be reduced or suspended. At some points of the year, the supernatant from Clover Bar may make up about 30% of the phosphorus loading to the plant. The nutrient loading is a concern for another reason; struvite is formed when high nutrient levels spontaneously crystallize in the system and can cause clogs and other maintenance issues. Acid cleaning of the lines will remove the struvite scaling, but must be done every one to two years. Between cleanings, the pipe capacity decreases over time because of the struvite buildup. This is the reason for EPCOR's plan to install nutrient removal equipment, made by Ostara, which turns the nutrients into fertilizer.



Clover Bar Lagoon Facility

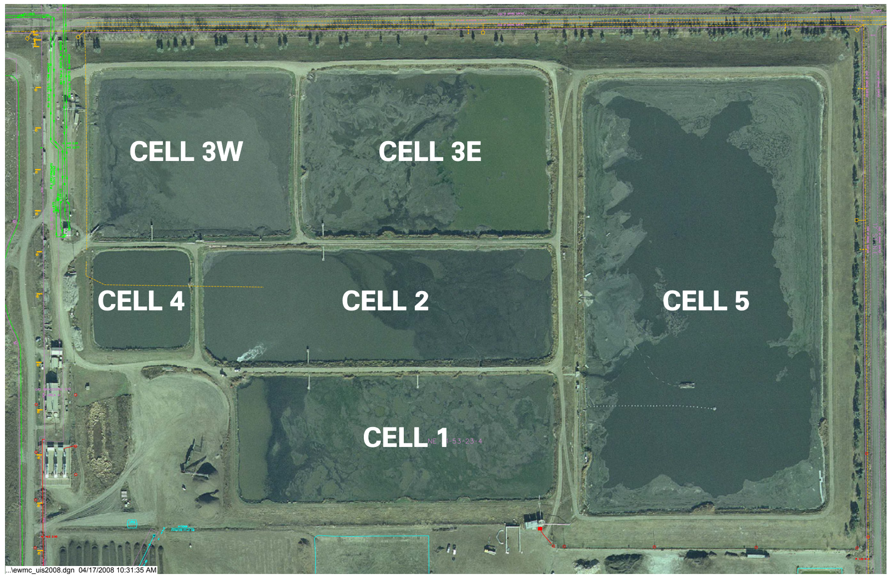
North Saskatchewan River



Gold Bar Wastewater Treatment Plant

out Lagoon 1 almost completely, and Clover Bar's facilities became the first in Western Canada to pilot test Ostara nutrient removal technology.

In addition, major improvements in solids handling at the Gold Bar plant meant that the biosolids being pumped out to Clover Bar were much thicker and occupied less volume in the lagoons. As of 2014, these changes had already begun to ease operations at Clover Bar. Plans were also in place for larger upgrades: construction of new biosolids removal technology in Lagoon 1, further composter upgrades, new equipment, and the full-fledged installation of Ostara nutrient technology.



View of Clover Bar lagoons from above. Photo courtesy of EPCOR.

Major steps have been initiated to improve the facility; however, the crucial task of assessing the risk of overflow at Clover Bar, particularly in light of these proposed upgrades, had yet to be undertaken.

SMA TAKES ACTION

In 2014, EPCOR and Stantec—the prime consultant on the project—brought in SMA Consulting to assess the risks, improve operations, and evaluate future maintenance and improvement needs. SMA quickly determined that the complex effects of weather, nutrient loading, multiple sources, population increases, operation strategies, and other variables made spreadsheet models unworkable.

Working closely with EPCOR and Stantec personnel, the prime consultant on the project—SMA developed a custom simulation model of the lagoons. This model brought together five years of operational data, current and future operation strategies, projected future trends, and proposed facility upgrades. Given the situation's complexity, SMA integrated multiple techniques—continuous/discrete event simulation, failure mode and effects analysis (FMEA), and SMA's proprietary Structured Risk Analysis Process—to develop a comprehensive understanding of Clover Bar's risks and needs.

Putting Innovation to Work

PHASE 1: AN AWARD-WINNING SIMULATION PROCESS

Managing Solids, Liquids, and Chemical Constituents

One of SMA's key innovations in the simulation effort for this project was its ability to model and track nitrogen and phosphorus concentration in the supernatant, as well as the liquids and solids in the system. Ostara sizes its units based on the specific weight of phosphorus and ammonia removed per day. However, the corresponding amount of supernatant required varies based on its concentration. Therefore, managing the lagoons requires pumping the appropriate amount of supernatant to Gold Bar on a given day; if the

Simulation Variables Tested

Ostara Units

How many Ostara units and of what size were in service.

Values Tested: None, 2 Pearl 2000s, 3 Pearl 2000s, 1 Pearl 5000, 1 Pearl 10000

Ostara Limits

Whether the Ostara units were limited to a certain percentage of their capacity; over-capacity operation can lead to potential quality control issues with the fertilizer

Values Tested: None, 150% Capacity, 150% Capacity but allow blending with the non-processed supernatant, 300% Capacity

Operating Strategy

How the model calculates how much supernatant to try to pump back to Gold Bar (affected by constraints)

Values Tested: "Greedy" (pump as much back as possible), "Smooth" (pump as much back as comes in), 1 MLD Lower Limit (smooth but at least 1 MLD), 2 MLD Lower Limit (smooth but at least 2 MLD), 3 MLD Lower Limit (smooth but at least 3 MLD)

Phosphorus & Nitrogen Levels

The concentration of Total Ammonia Nitrogen (TAN) and Total Phosphorus (TP) in the supernatant; may vary by time of year

Values Tested: Low (Static), Low Seasonal (Sampled), Moderate (Sampled), Moderate Seasonal (Sampled), High (Sampled), High Seasonal (Sampled)

Phosphorus & Nitrogen Limits

The amount of TAN and TP that Gold Bar is capable of processing; may vary by time of year

Values Tested: No Limit, TP 500 & TAN 2000, TP 700 & TAN 2000, TP 846 & TAN 4400, TP 846 & TAN 5400, TP 846 & TAN 5400 & TAN Fall 5500

Solids Removal Rates

Rate at which solids are removed from the lagoons

Values Tested: 2013 levels, City targets for solids removal amount pumped is too much or not enough for the Ostara unit, it can cause problems. The simulation model result showed that for maximum flexibility and risk management, the Ostara 10000 unit was needed.

Combined Modelling: Discrete and Continuous

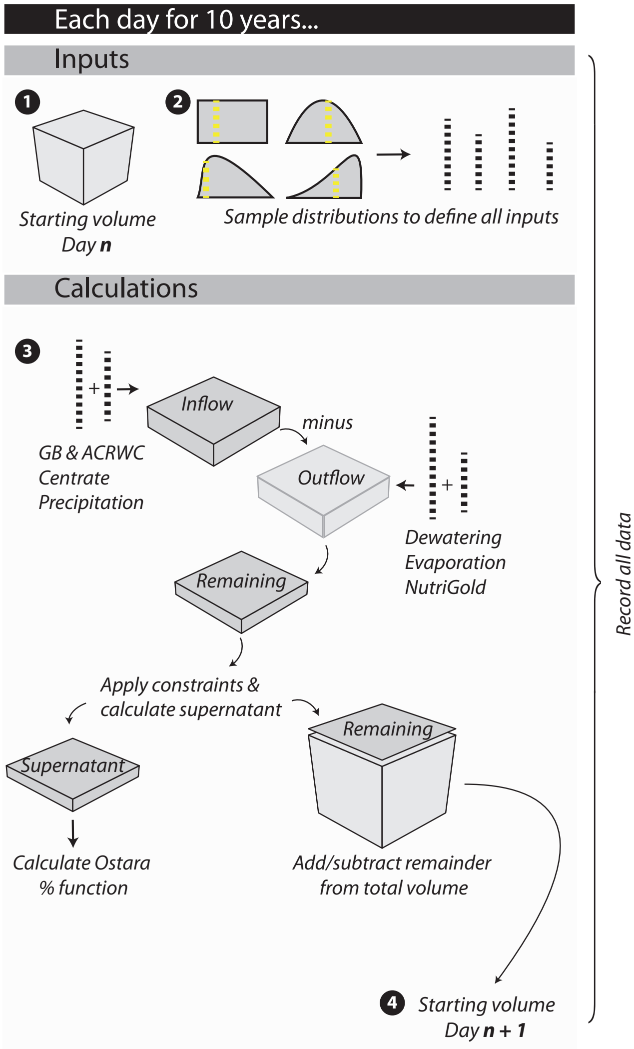
SMA created its model using the powerful simulation software *Simphony.NET*. This process simulated interactions within the given environment using a combination of discrete events and continuous simulation modelling. Discrete event simulation models a system using a sequence of events. The effects of each event are recorded and the simulation moves to the next event in the sequence. This process assumes that there are no changes to the system between events. Continuous event simulation, conversely, divides the simulation time span into small slices and records the effects of activities occurring in each slice. In this model, changes to the system are assumed to be continuous.

Integrating Hard and Soft Data

SMA drew the data behind the simulation from numerous types of sources. One strength of discrete event simulation is the ability to combine "hard" data—including four years of daily records on the amounts pumped to Clover Bar—with "soft" data—projected population increases, predicted outcomes of the city's CSO Control Strategy, planned change to operational procedures, and the possibility that Gold Bar might be receive more phosphorus than expected. If it can be modelled mathematically, it can be incorporated into a simulation.

A Scenario-Based Approach

This type of simulation empowers engineers to actually answer the important "what if" questions in a demonstrable, quantifiable way. Once the model was producing consistent results, SMA ran 50 scenarios. These explored the effects of combining 29 different settings of 6 variables: Ostara sizing, Ostara operating strategies, limits on nitrogen concentration in the supernatant pumped back to Gold Bar, limits on phosphorus concentration, rates of solids removal, and expected nutrient concentrations.



Explanation of simulation model function

Struvite and Ostara: From Blocked Pipes to Fertilizer

The high concentrations of nitrogen and phosphorus in wastewater and even higher concentrations in biosolids is part of what makes biosolids such a valuable soil amendment. However, they are also found in high concentrations in the liquid, or supernatant, which is drained off of settling biosolids. The concentrations can be so high that crystals of magnesium ammonium phosphate hexahydrate — the same crystals which can cause kidney stones — will spontaneously form in equipment, causing maintenance issues. In addition, most wastewater treatment plants are not set up to remove these levels of phosphorus and nitrogen, and can be damaged by them. In the worst cases, the result can be a closed loop, where phosphorus- and nitrogen-rich supernatant is pumped back to the wastewater treatment plant, only to pass through and return to the biosolids facility, only to be returned to the wastewater treatment plant. The key benefit of the Ostara Pearl process is that it opens this loop: before being pumped back to the wastewater treatment plant, most of the phosphorus and a significant portion of the nitrogen is removed from the supernatant and turned into high-quality fertilizer. This protects Gold Bar from the harmful effects of too-high nutrient levels, and allows much more freedom in managing the lagoons. In addition, the new less-saturated supernatant will not only *not* contribute to future struvite buildup, it will actually begin to slowly dissolve existing buildup.

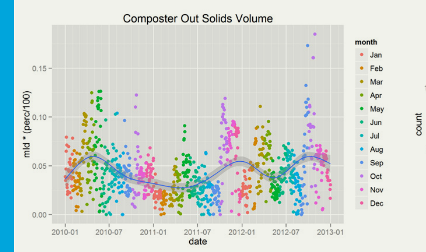
Results of the Ostara Pearl process: Crystal Green fertilizer. Photo courtesy Ostara Nutrient Recovery Technologies

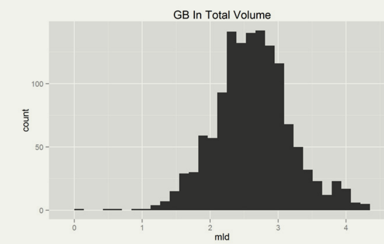
Model Inputs

A model is only as good as its data. The 25 model inputs were drawn from statistical analysis of Clover Bar's daily operations from 2010-2013, Alberta Agriculture daily precipitation for the same time period, a 100+-year temperature dataset from Environment Canada, engineering reports and technical memos, City of Edmonton projected population trends, and consultation with plant personnel. The model was extensively discussed and the results validated against operations personnel experience.

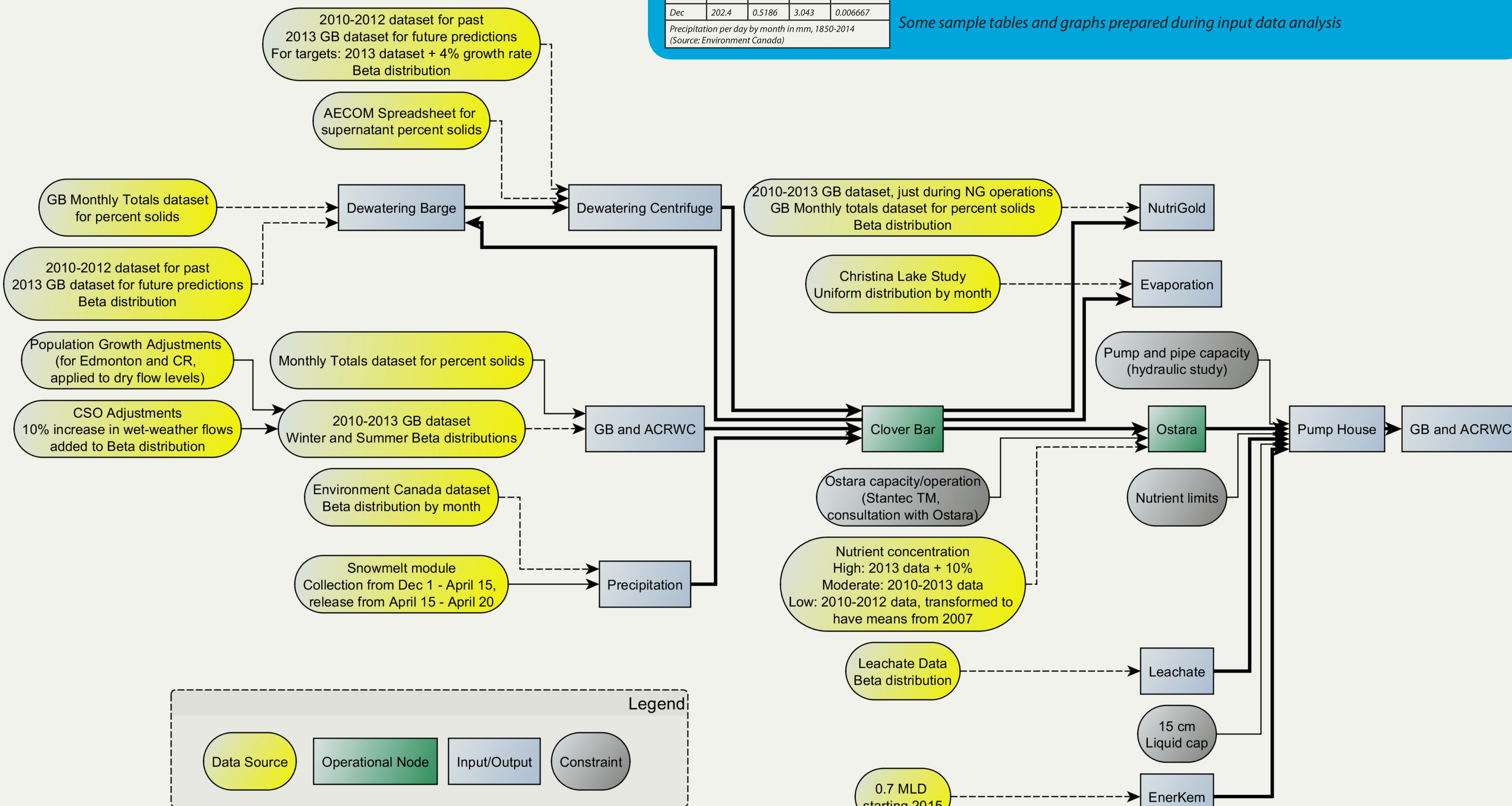
month	mean	sd	max	min
Jan	229.1	0.6302	3.077	0.006667
Feb	170.3	0.4726	2.253	0.006667
Mar	187.9	0.5151	3.113	0.03
Apr	230.5	0.6168	3.387	0.03333
May	408.7	0.9986	6.903	0.2367
Jun	682.7	1.361	7.67	0.5267
Jul	764.7	1.424	9.937	0.14
Aug	545	1.252	6.757	0.09333
Sep	332.4	0.9205	4.947	0
Oct	188.4	0.5299	2.71	0
Nov	189.5	0.5886	3.417	0
Dec	202.4	0.5186	3.043	0.006667

Precipitation per day by month in mm, 1850-2014 (Source: Environment Canada)





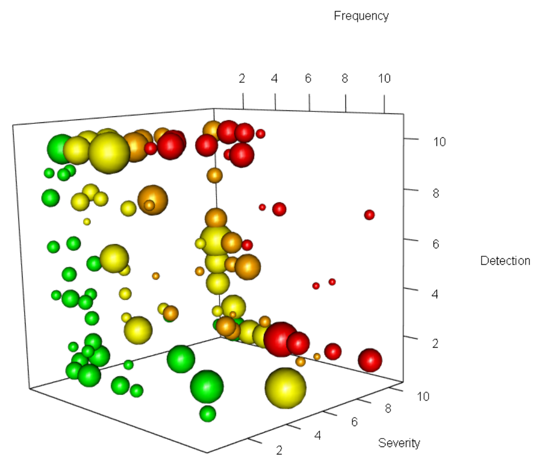
Some sample tables and graphs prepared during input data analysis



The simulation model logic diagram, showing all inputs and outputs

In total, SMA analyzed more than 68,000,000 pieces of data and used advanced visualization techniques to transform the information into understandable graphs. For each scenario, SMA created two custom, scripted visualization reports: a full ten-graph report and an executive summary of the four most useful graphs. Such reports enabled the project team to quickly understand and analyze the day-by-day operations of the lagoons and easily compare scenarios. Because reports were run for each scenario, this initiative generated more than 700 graphs total.

Ultimately, results showed that the lagoons could be manageable in the short term without expensive solids removal. The reports highlighted operational and capital improvements and helped EPCOR and Stantec plan for installation of the Ostara Pearl® system. Specifically, the simulation demonstrated that the Ostara 10000 was the ideal unit for the site, providing maximum flexibility and risk management.



Failure Mode and Effects Analysis "results space." Size indicates number of failure modes at each point.

Lingering Questions

Despite the first phase's success, questions remained. Would these changes be enough to bring the Lagoon 5 levels down? Which upgrades should happen first? Would the Ostara nutrient removal equipment allow EPCOR to fully manage the lagoon levels, or would constraints remain? Could the city build new technology in Lagoon 1, or was it needed for emergency storage?

The new improvements would take time to construct and the benefit of the previous improvements would take time to measure. But these issues were immediate. Answers were needed quickly.

PHASE 2: ANALYZING RISK AND FAILURE

The simulation was next integrated with a comprehensive failure modes and effect analysis (FMEA) to identify necessary changes and upgrades. Both the FMEA and the simulation model require a comprehensive understanding of the facility's equipment and operations, so the information from the FMEA was then fed into the simulation model. This step served to identify the "problem areas" in the proposed system and capture suggestions for improving reliability. The combination of these engineering principles ultimately led to a more robust process and eliminated the duplication of effort that would have arisen were the studies conducted separately.

What is FMEA?

Failure Mode and Effects Analysis is a step-by-step approach used in safety engineering for identifying possible failure modes of the system components, evaluating their influences on system behavior and proposing proper countermeasures to suppress these effects. Failures are any errors or defects and are prioritized according to how serious their consequences are, how frequently they occur, and how easily they can be detected.

The subsequent results were used during risk analysis and quantification. Using a context-based risk identification process, SMA identified 269 failure modes, 79 of which were considered critical. The aggregated results of the FMEA were fed into SMA's Structured Risk Analysis Process alongside other information: lagoon operations data, related risk literature, past projects, details gathered from SMA's risk database, interviews with maintenance personnel and the project team, and a detailed overview of the project.

SMA also created a custom central database to house all risk and failure analysis data, from interviews to the workshop to report generation.

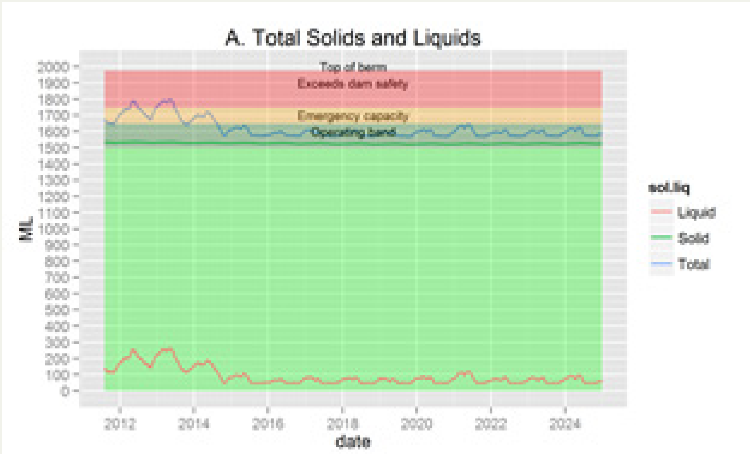
Project Complexity

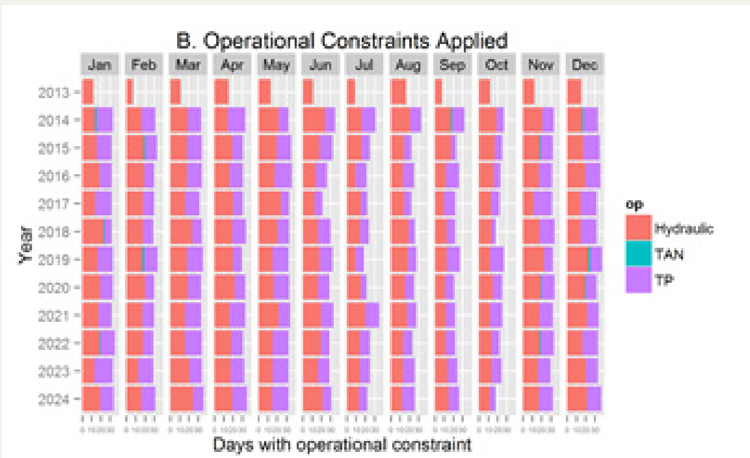
INCORPORATING CUTTING-EDGE TECHNOLOGY

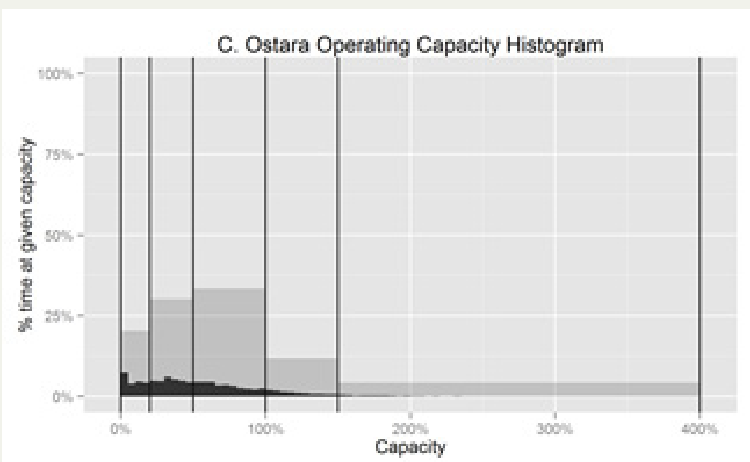
It is difficult to be an early adopter. EPCOR was the first to adopt the Ostara technology in Western Canada with a pilot project at the Clover Bar facility in 2007. However, a full-scale implementation of this scope was uncharted territory. Fortunately, SMA's simulation model allowed the team to virtually test the Ostara units prior to committing to a final design.

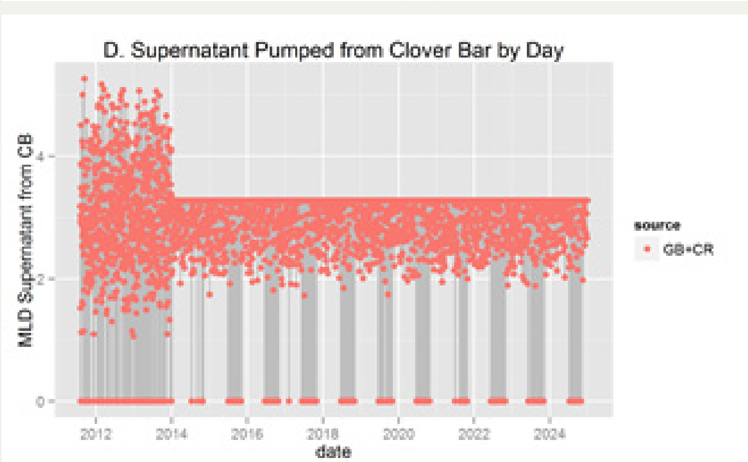
STRUVITE BUILDUP

Although the simulation predicted that biosolids levels would remain stable, certain maintenance issues related to nutrient buildup would remain. Furthermore, it is likely that nutrient levels would continue to increase without Ostara, because there would be no channel for removing phosphorus from the system.









The Visualizations

The visualizations were created using *R*, an open-source statistical modeling environment. The output from each scenario was run through a custom script which performed additional analysis, generated graphs, and produced a Word-formatted report for ease of distribution. The four graphs shown here were the most useful for comparing the scenarios and were chosen as the "executive summary" graph report.

Graph A shows the total solids (green), liquids (red), and overall volume (blue) in the lagoons over the modeling period (10 years). The shading indicates the desired operating levels (green), emergency capacity (yellow), and the levels which exceed dam safety design levels (red).

Graph B shows the types and number of operational constraints which were applied during modeling, grouped by month (at the top) and year (at the left side). More than one constraint may be applied during a day. The constraints which are recorded are: Hydraulic, which indicates that there was more supernatant to pump back than could be accommodated by the piping; TAN, which indicates that there was too much nitrogen in the supernatant for Gold Bar to accept all of it; TP, which indicates that there was too much phosphorus in the supernatant for Gold Bar to accept all of it; Liquid Cap, which indicates that no pumping could occur because a certain liquid level must be maintained to prevent odor; Blend, which indicates that blended supernatant was pumped back to Gold Bar; and Ostara Cap, which indicates that Ostara was operating at above capacity. This graph only shows Hydraulic, TAN, and TP, indicating that those constraints were the only ones applied during this simulation.

Graph C shows the time the Ostara units spend operating at a given capacity. The black bars show the time spent at each capacity; the gray background bars are a summation of the time spent within each range. Ostara units can be operated above or below their normal, desired operating range, but quality may become an issue.

Finally, Graph D shows the megalitres (millions of litres) of supernatant pumped from Clover Bar per day. Prior to 2014 no constraints were applied and the amount of supernatant pumped back was sampled from a distribution of the 2010-2012 data. After 2014, the operating strategy being tested and all operational constraints go into effect; this is why there is such a drastic reduction in pumping starting in 2014.

Biosolids being pumped into Clover Bar Lagoon 5

The high concentration of nitrogen and phosphates in the biosolids causes a buildup of struvite—magnesium ammonium phosphate hexahydrate—in the pipes, valves, and pumps that return liquid to Gold Bar. This can reduce pumping capacity by up to 50% and greatly increase maintenance requirements: the pipes must be cleaned with a strong solution of hydrochloric acid, which is messy, expensive, and hazardous.

OPERATIONAL CHALLENGES

Because the lagoons are so full, there is little operational buffer. As of 2013, the largest lagoon had about 1 metre of storage available from a total depth of almost 20 metres. Every month, Gold Bar produces on average about 71 million litres of biosolids, which are pumped directly into Lagoon 5 and fill an additional 0.7 metres of depth. Lagoon 5 has no permanent connection to the other lagoons, so the only exit is via the composting facility, which can't keep pace with the input. In case of emergency, excess biosolids can be moved to the other lagoons using a temporary system of pumps and piping.

UNITING ALL STAKEHOLDERS

There are also numerous stakeholders involved. The lagoons are owned by the City of Edmonton but operated by EPCOR. As part of the agreement, Edmonton is responsible for the solids in the lagoons, while EPCOR is responsible for the liquids. In practice, this means that EPCOR employees, city personnel, and subcontractors are all on site, so their activities must be coordinated. The city and EPCOR have made great strides in identifying the best solution for reducing solids levels in the lagoons, but until that long-term plan is implanted, all parties must cooperate to ensure that lagoon levels are carefully managed

COORDINATION WITH GOLD BAR

After Clover Bar receives biosolids from Gold Bar Wastewater Treatment Plant, the liquid from the supernatant lagoon is drawn off and pumped back to Gold Bar. Because the nutrient concentration in the supernatant is extremely high, pumping too much back to Gold Bar can upset the plant's delicate biological processes. The restrictions on nutrients also vary seasonally. Unfortunately, in early spring, when rainfall and snowmelt mean the desire to pump is greatest, the plant can accept the least supernatant. The simulation needed to account for this challenge as well.

Community-Wide Benefits

SOCIAL BENEFITS

This project resulted in numerous benefits for EPCOR, the Clover Bar Lagoons, the Gold Bar Wastewater Treatment Plant, the City of Edmonton, the North Saskatchewan River, and residents of the region. First, the study identified critical maintenance requirements in hard-to-reach locations. By proactively identifying these locations, EPCOR will be able to prevent future pipe failure in residential and River Valley areas, protecting residents and the North Saskatchewan River itself.

Second, the study established that 15 centimetres of supernatant liquid is necessary at the lagoons; if this level is not maintained, the smell negatively affects nearby residents.

Third, the simulation allowed the implementation of a range of "soft" data. By incorporating details about Edmonton's CSO Control Strategy, Clover Bar was able to align its capabilities with the city's goals for sustainability. Similarly, given the Edmonton metropolitan area's rapid population growth—3.3% in the past year alone—this simulation allowed the city to plan its response to the growing wastewater stream.

Finally, the fertilizer produced by the Ostara technology will be available across North America, effectively transforming a costly problem into an eco-friendly product.

ECONOMIC BENEFITS

The study also had numerous economic benefits. By producing recommendations to ensure safe lagoon levels, the city saved Edmonton taxpayers millions in potential removal costs. In addition, the risk and failure analysis results will empower the city and EPCOR to efficiently direct millions of dollars in operations, maintenance, and upgrade activities at the lagoons for years to come.

Clover Bar Lagoons 2 (far) and 3E (near), with Edmonton Waste Management Centre in the distance

Environmental Impacts

Environmental and sustainability issues were inherent in SMA's Clover Bar Biosolids Risk and Operation Study. One of the major goals of the project was to ensure that the lagoons do not overflow and subsequently drain into the watershed and North Saskatchewan River just 300 metres away. If biosolids were to reach the river, their nutrient content would spur the growth of algae and other aquatic plants. This, in turn, would reduce sunlight and oxygen levels and make it difficult for aquatic wildlife to survive.

To alleviate the threat of overflow, the City of Edmonton would have to spend millions of dollars to haul tonnes of biosolids to a landfill—an action completely contradictory to its goals for sustainability.

SMA's simulation models allowed EPCOR and the City of Edmonton to move forward with new, environmentally friendly biosolids technology that successfully eliminates phosphorus, nitrogen, and other harmful byproducts. As a result, the lagoons will contain less supernatant liquid and therefore increase their capacity for biosolids from Edmonton and surrounding areas.

In addition, the simulation ensured that Clover Bar's lagoons would have enough capacity to support the Enerkem Alberta Biofuels facility. In collaboration with the city, this facility converts solid waste into clean fuels and green chemicals, such as ethanol and methanol, and therefore helps divert waste from landfills.

Supporting Client Needs

ALLEVIATING A GROWING CONCERN

The capacity of the lagoons had been an increasingly pressing concern for the City of Edmonton and EPCOR for nearly two decades. In just three months, SMA rigorously quantified the lagoon operations, gave EPCOR the evidence to show that the lagoons could be managed, and identified a clear course of action.

Among SMA's most important finding was the prediction that solids levels will remain effectively constant; maintaining 2013 removal rates will keep pace with the expected increase in population and CSO flow. The simulation showed that aggressively operating lagoons and maintaining moderate nutrient levels would allow Clover Bar to function without Ostara for some time.

Innovation

- Used discrete-event and continuous simulation modelling to fully quantify the risk of overflow
- Integration of failure analysis, simulation, and formal risk analysis to provide the most comprehensive picture
- Quantification both pre- and post-mitigation to demonstrate reduction in risk profile
- Creation of a custom database aligned with EPCOR's risk framework to centralize and store all risk and failure data
- Synergy of simulation, risk analysis, and failure analysis eliminated rework and yielded more benefit than if the studies were performed separately

Benefit to Society

- Saves Edmonton taxpayers millions in potential solids removal costs
- Facilitates cooperation between EPCOR and the City of Edmonton

Environmental Protection

- Helped EPCOR and the City plan measures to ensure the lagoons do not overflow, protecting the North Saskatchewan River and watershed
- Prevented tonnes of biosolids being trucked to landfills
- Helped EPCOR choose the right technology and move forward with the innovative Ostara Pearl process
- Allowed EPCOR and the City of Edmonton move forward with new, environmentally friendly biosolids technology by showing Lagoon 1 was not needed for storage

DEFINING A NEW MANAGEMENT STRATEGY

SMA's risk analysis and simulation also helped clearly define a new management strategy for Clover Bar. Having identified 43 risks and nearly 90 mitigation actions, SMA quantified these risks for both pre- and post-mitigation scenarios. The simulation phase itself was completed within just one month, providing the critical answers EPCOR and Stantec needed for the Ostara project.

SMA's specific recommendations for decreasing risk included:

- Revising appropriate operating levels.
- Developing a plan to bring lagoons to appropriate operating levels.
- Modifying the biosolids strategy when appropriate.
- Working closely with the City of Edmonton and other stakeholders to implement the updated strategy
- Retaining Lagoon 1 for lagoon maintenance and emergency use until lagoons reach the defined operational levels
- Including inventory and input/output among key performance indicators.
- Developing a clear emergency response plan.
- Including reaching lagoon maximum capacity as an emergency scenario in the operations plan.
- Optimizing Ostara operations to aid in liquid management.
- Revisiting wet-weather solids handling protocol to include a lagoon capacity limit.

FOSTERING COLLABORATION

Facilitating cooperation between EPCOR and the City of Edmonton was a vital component of the project. Although the city owns the lagoons, both parties share operation responsibilities. The results of SMA's simulation and risk analysis provided a basis for EPCOR's collaborations with the city on this crucial problem and brought together reams of data and technical memos into one easily discussed, easily understood visual report.

Conclusion

The Clover Bar lagoons are nearly full. The City of Edmonton and EPCOR have taken important steps toward alleviating their burden, but needed help from SMA Consulting to clarify the risk of overflow.

SMA's advanced discrete event/continuous simulation modelled the lagoons' operations both with and without the proposed solutions, analyzed key equipment failures, developed a complete risk profile, and calculated suggested operating levels.

SMA proved that the City of Edmonton could continue to pursue its sustainable solids management program, rather than spend millions on an environmentally damaging solids removal operation. The simulation showed that it would be possible to keep the levels within safe boundaries, even without Ostara technology, for the short-term future.

SMA's model also underscored construction of the proposed full-size Ostara equipment as an ideal long-term solution for easily managing biosolids levels. Ultimately, this collaboration successfully provided EPCOR and the City of Edmonton with scores of data to direct future discussions, maintenance, and upgrades at the Clover Bar Lagoons and keep the facility operating smoothly well into the coming years.

Clover Bar Lagoon 5, northwest corner