

Canadian Consulting Engineering Award 2012

East Calgary Landfill Stormwater Management Project



CWP129021/CCE
May 2012

Submitted to:
Canadian Consulting Engineer Magazine
80 Vallebrook Drive
Toronto, ON M3B 2S9

Submitted by:
AMEC Environment & Infrastructure
Calgary, Alberta

PROJECT HIGHLIGHTS

The East Calgary Landfill (ECL) is located in the southeast quadrant of the City of Calgary and has been in operation since 1968 as a Class II, or non-hazardous solid waste landfill. The landfill receives residential, commercial, and institutional wastes and construction and demolition waste in addition to having an active composting facility. Following changes by Alberta Environment to the landfill's Approval under the Environmental Protection and Enhancement Act, ECL needed a surface water management system that was capable of controlling surface water leaving (run-off) or entering (run-on) the site for storm events up to the 100-year return period. In addition, surface water generated by the 25-year return period rainfall event must be stored and tested before it is released offsite.

In 2004, AMEC Earth & Environmental (AMEC) was retained by the City of Calgary to complete the design of a new stormwater management system for the landfill that complied with the new requirements. The proposed ECL stormwater management system consisted of two stormwater wet ponds (north and south), drainage ditches that convey stormwater to the ponds and the re-alignment of Forest Lawn Creek. To improve the ponds' offsite release water quality, AMEC proposed that the design incorporate elements of a constructed wetland into the ponds as the water treatment component of the system so that the landfill can meet Alberta Environment's surface water quality limits stated in the landfill's Approval.

AMEC's strategy for the design of the ECL ponds was to utilize a combination of biochemical analysis and computational fluid dynamics (CFD) to design a system to effectively manage additional contaminants that are typically not found in stormwater generated by residential areas while minimizing sediment transport within the pond. Our design achieved this goal by maximizing flow contact with a densely vegetated section incorporated into each pond (constructed wetland system). This design allowed AMEC to create a long-term sustainable treatment process for managing stormwater at ECL. For the design of the re-aligned section of Forest Lawn Creek, AMEC used a meandering section and bio-engineered shorelines to create important ecological features.

To determine the contaminants to design for, AMEC analyzed water quality data from the ECL and other landfill sites in Calgary. The parameters that exceeded applicable regulatory criteria were identified. The parameters found to be in exceedance were examined in order to establish a design basis for the constructed wetland elements within each pond. AMEC concluded that the removal of total suspended solids (TSS) would provide adequate treatment for the discharges from the ponds to meet federal and provincial water quality criteria because the pollutants found to be in exceedance are known to strongly adsorb to suspended sediments. Removal of the suspended sediments would therefore equate to removal of the identified contaminants.

The goal of the CFD modelling exercise was to iteratively adjust the flow paths and depths within each pond to optimize the hydraulic condition for sedimentation and to minimize re-suspension and flushing zones. The CFD model, River2D, is a two-dimensional, depth averaged, finite element, hydrodynamic model. River2D was originally designed at the

University of Alberta for river and stream modelling but was applied to the pond modelling because of its capabilities for computing velocities and depths and its ability to indicate areas of high and low flows.

The combination of biochemical analyses and CFD modelling provides a total paradigm shift on how stormwater ponds can be designed to maximize their treatment capability. Pond designs can be evaluated through modelling to eliminate ineffective configurations that lead to short-circuiting and sediment re-suspension. All this can now be determined prior to detailed design and construction.

Traditionally, storm ponds are designed and constructed with a granular shoreline to minimize erosion. At ECL, the ponds and creek have a bio-engineered shoreline created from a combination of bio-degradable erosion control blankets, aquatic vegetation and shrub plantings. This design feature enhances the treatment capability of the pond while providing a more natural appearance to the facility. This landscape plan was also expected to complement and support the surrounding landscape long after the landfill is closed. For this reason, it was important that our design considers how the pond and creek will fit into a natural corridor that the City has planned to run north to south along the east boundary of the landfill. In addition, the pond was designed to reduce long-term maintenance efforts since frequent dredging and restoration of planted areas within each pond is considered neither sustainable nor cost effective, from an environmental management perspective.

AMEC also developed a 3-dimensional (3D) design of the ponds that included a layered point system that minimized construction effort. This approach reduced the number of construction control points by two-thirds, and correspondingly, lowered the project's survey costs. The 3D drawings were also converted into a Triangulated Irregular Network (3D surface) that were input directly to GPS-based construction equipment that increased construction accuracy and efficiency by minimizing layout errors and reducing costs.

Stormwater treatment using constructed wetlands is not an exact science but can produce predictable release water quality. Factors that could affect the release water quality include the inflow pollutant characteristics and loading rates. Prior to commencing this project, there was only limited data that could accurately define the water quality at ECL, and this data was available only for a limited period of time. There were only a few research papers that have estimated pollutant uptake rates of wetland plants. This lack of information, in addition to limited water quality data, made selecting the wetland plants even more difficult. However, AMEC was able to draw on its international and local experience in landfill leachate treatment and constructed wetland design to determine the treatment capacity of the wetlands.

Translating the hydraulic modelling results into a sustainable natural design was another challenge that AMEC faced in carrying out this project. The plantings in the wetland are required to provide not only aesthetic and treatment functions but also to minimize erosion of the pond shorelines. However, there are no set design guidelines that AMEC could follow. In this regard, the experience of our wetland specialists was valuable to the project team in identifying plants that could perform the necessary functions.



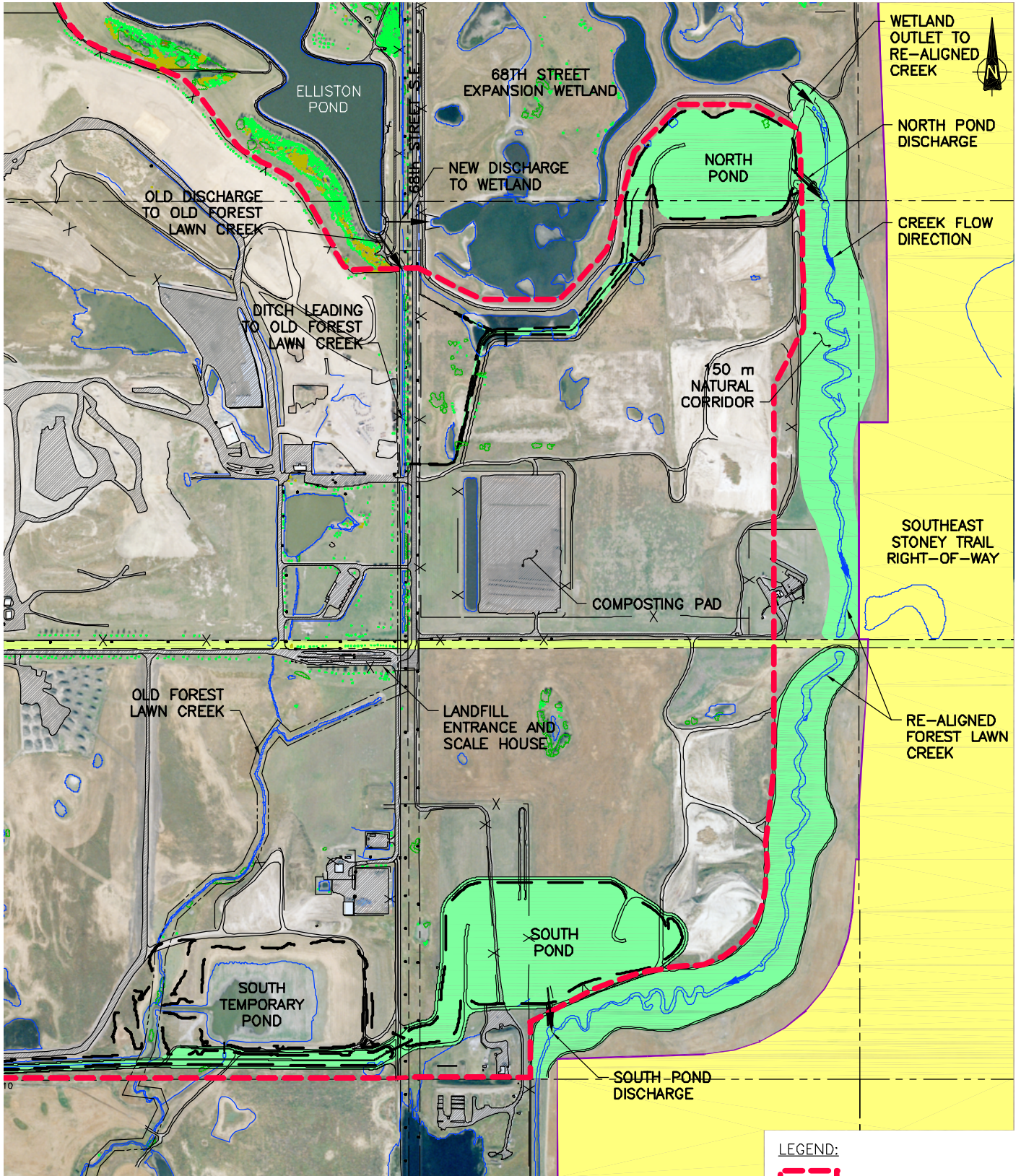
Project Summary

The East Calgary Landfill (ECL) is located in the southeast quadrant of the City of Calgary and has been in operation since 1968 as a Class II, or non-hazardous solid waste landfill. The landfill receives residential, commercial, and institutional wastes and construction and demolition waste in addition to having an active composting facility. Following changes by Alberta Environment to the landfill's Approval under the Environmental Protection and Enhancement Act, ECL needed a surface water management system that was capable of controlling surface water leaving (run-off) or entering (run-on) the site for storm events up to the 100-year return period. In addition, surface water generated by the 25-year return period rainfall event must be stored and tested before it is released offsite.

In 2004, AMEC Earth & Environmental (AMEC) was retained by the City of Calgary to complete the design of a new stormwater management system for the landfill that complied with the new requirements. The proposed ECL stormwater management system consisted of two stormwater wet ponds (north and south), drainage ditches that convey stormwater to the ponds and the re-alignment of Forest Lawn Creek. To improve the ponds' offsite release water quality, AMEC proposed that the design incorporate elements of a constructed wetland into the ponds to meet Alberta Environment's surface water quality limits stated in the landfill's Approval.

The figure on the next page shows the ECL site and the various components of the stormwater management system. Prior to this project, Elliston Pond discharged to a ditch running along the west side of 68th Street to Forest Lawn Creek, which flowed across the south portion of the landfill site. As this portion of the landfill is needed for landfiling purposes, the City decided to re-align the creek to the east boundary of the landfill. The City also took advantage of the re-alignment to construct a stormwater wetland (68th Street Expansion Wetland) to provide additional capacity for Elliston Pond and improve the water quality of stormwater to be released to the re-aligned creek. With the creek re-alignment completed, the major sources of water to the creek are stormwater releases from the 68th Street Expansion Wetland and the ECL ponds.

AMEC's strategy for the design of the ECL ponds was to utilize a combination of biochemical analysis and computational fluid dynamics (CFD) to design a system to effectively manage additional contaminants that are typically not found in stormwater generated by residential areas while minimizing sediment transport within the pond. Our design achieved this goal by maximizing flow contact with a densely vegetated section incorporated into each pond (constructed wetland system). This design allowed AMEC to create a long-term sustainable treatment process for managing stormwater at ECL. For the design of the re-aligned section of Forest Lawn Creek, AMEC used a meandering section and bio-engineered shorelines to create important ecological features.



SCALE
1:10 000
0 100 200m

LEGEND:

LANDFILL BOUNDARY

EAST CALGARY STORMWATER MANAGEMENT SYSTEM



1. Innovation

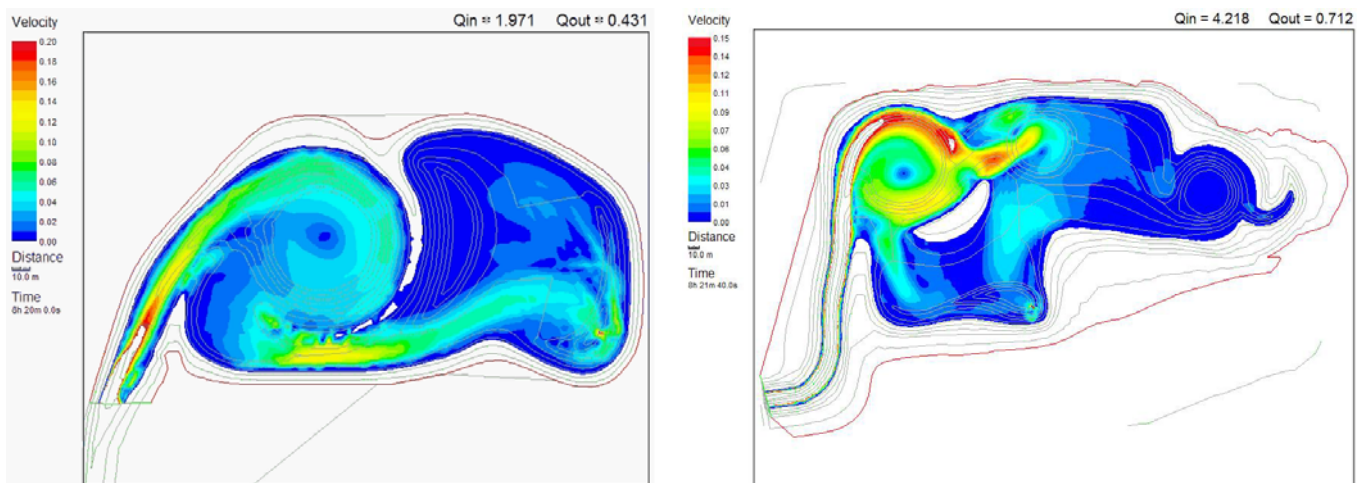
Traditionally, stormwater ponds in Alberta have been used to manage surface water runoff from subdivision roads and streets in order to reduce the impact of increased peak flows on our rivers and streams and protect properties against extreme flood events. By implementing this method of stormwater management, the discharges from an urbanized basin are attenuated and erosion and sedimentation in streams and rivers are reduced. The ECL project represents the first landfill in Alberta that used biochemical analyses to determine the contaminants to be treated and CFD modelling to optimize the flow regime within a storm pond. Furthermore, the project includes the engineered re-alignment of a creek that was designed to mimic a natural waterway.

To determine the contaminants to design for, AMEC analyzed water quality data from the ECL and other landfill sites in Calgary. The parameters that exceeded applicable regulatory criteria were identified. The parameters found to be in exceedance were examined in order to establish a design basis for the constructed wetland elements within each pond. AMEC concluded that the removal of total suspended solids (TSS) would provide adequate treatment for the discharges from the ponds to meet federal and provincial water quality criteria because the pollutants found to be in exceedance are known to strongly adsorb to suspended sediments. Removal of the suspended sediments would therefore equate to removal of the identified contaminants.

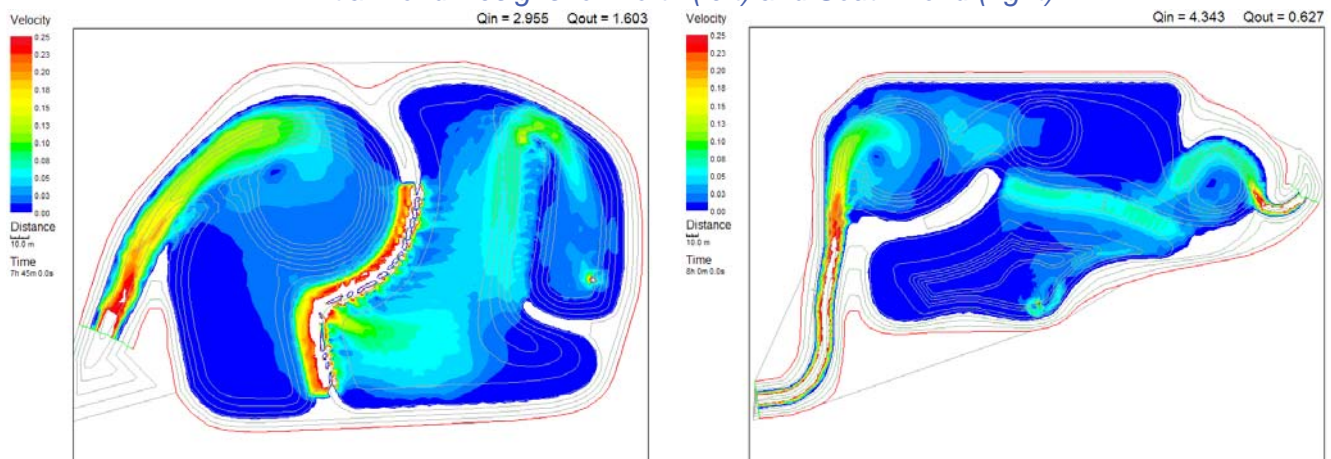
The goal of the CFD modelling exercise was to iteratively adjust the flow paths and depths within each pond to optimize the hydraulic condition for sedimentation and to minimize re-suspension and flushing zones. The CFD model, River2D, is a two-dimensional, depth averaged, finite element, hydrodynamic model. River2D was originally designed for river and stream modelling but was applied to the pond modelling because of its capabilities for computing velocities and depths and its ability to indicate areas of high and low flows.

An initial configuration of the North and South Ponds that was created by AMEC was modelled with River2D. The modelling results from this initial assessment revealed severe short-cutting patterns, short residence times and poor settling performance within the ponds. This exercise helped the team test the pond configuration before detailed design was conducted.

Using the results of this assessment, both the North and South Ponds were reconfigured to maximize aerial usage and residence time, and reduce discharge velocities around the outlet. The new designs were modelled and iteratively modified to ensure optimal hydraulic conditions for particulate settling and minimal re-suspension and flushing zones. The iterative modelling exercise for the redesigned ponds enabled a significant improvement in hydraulic dispersion and spatial optimization.



Initial Pond Designs for North (left) and South Pond (right)



Final Pond Designs for North (left) and South Pond (right)

Traditionally, storm ponds are designed and constructed with a granular shoreline to minimize erosion. At ECL, the ponds and creek have a bio-engineered shoreline created from a combination of bio-degradable erosion control blankets, aquatic vegetation and shrub plantings. This design feature enhances the treatment capability of the pond while providing a more natural appearance to the facility.



Shoreline of Re-aligned Forest Lawn Creek

The combination of biochemical analyses and CFD modelling provides a total paradigm shift on how stormwater ponds can be designed to maximize their treatment capability. Pond designs can be evaluated through modelling to eliminate ineffective configurations that lead to short-circuiting and sediment re-suspension. All this can now be determined prior to detailed design and construction.

As regulatory agencies move towards more stringent total suspended solids and contaminant removal requirements, the application of biochemical expertise and CFD modelling to runoff management systems will be a very important tool in optimizing pond utilization and thus, stormwater treatment. The water quality data that will be obtained from this project will be an Albertan example for stormwater treatment at a landfill and this data can be applied to the biochemical analyses of new and existing landfills. Also, ponds built in residential areas can improve release water quality by implementing similar vegetative features rather than the current practise of using granular shoreline.

2. Complexity

The primary objective behind the design of the ECL stormwater management system was to safeguard the water quality of receiving streams. The wetlands within each pond will enhance the pollutant removal and increase aquatic habitat value. To develop this system, an integrated team of specialists, including water resources engineers, wetland specialists, and landscape architects, was required. In particular, AMEC combined its international expertise on the use of constructed wetlands to treat landfill leachate and its local expertise on the design of the constructed wetland component within each pond to ensure suitability for the site conditions.

AMEC's landscape plan will complement and support the surrounding landscape long after the landfill is closed. For this reason, it was important that our design considers how the pond and creek will fit into a 150 m natural corridor that the City has planned to run north to south along the east boundary of the landfill. In addition, the pond was designed to reduce long-term maintenance efforts since frequent dredging and restoration of planted areas within each pond is considered neither sustainable nor cost effective, from an environmental management perspective.



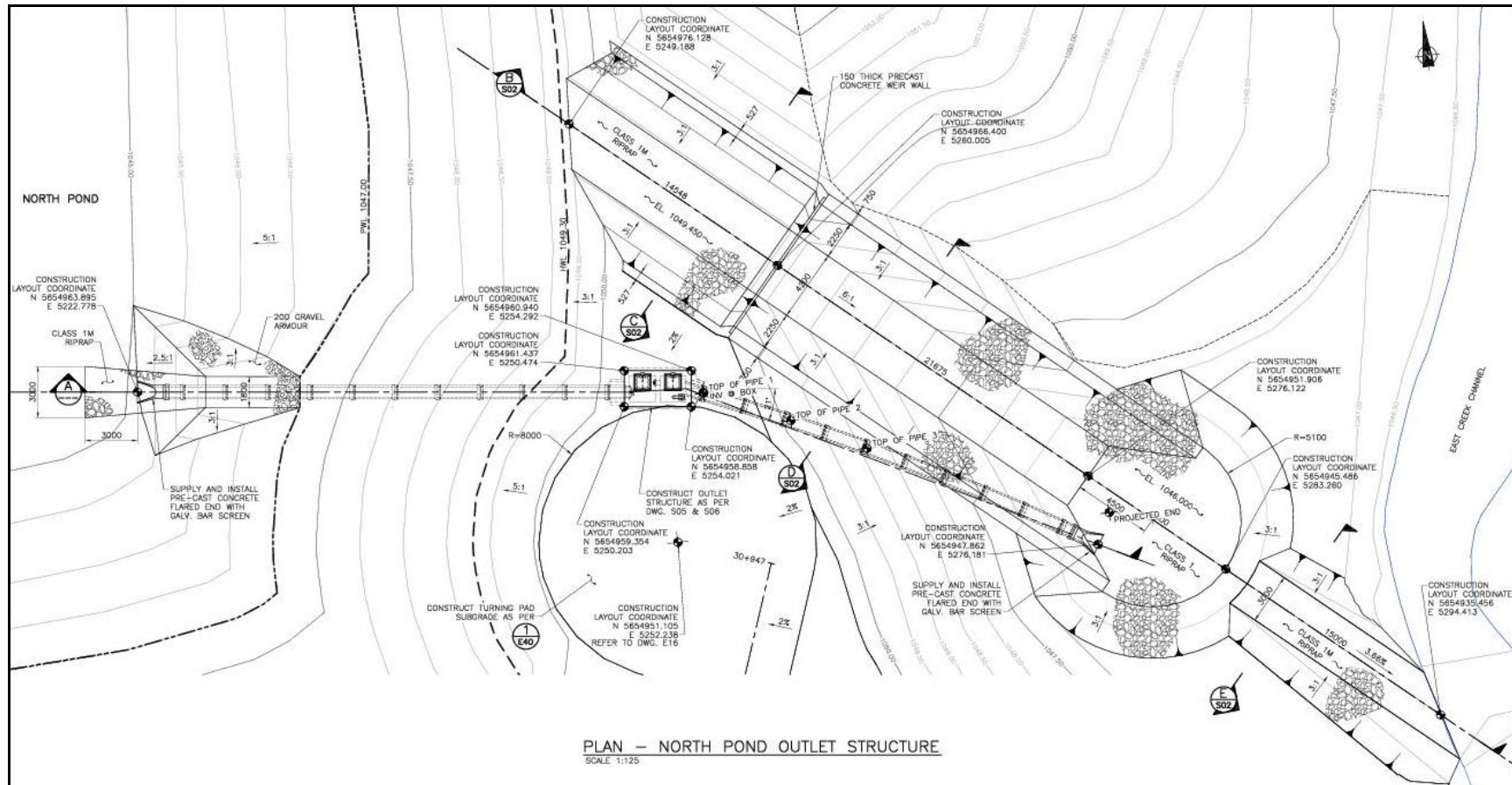
AMEC also developed a 3-dimensional (3D) design of the ponds that included a layered point system to minimize construction effort. This approach reduced the number of construction control points by two-thirds, and correspondingly, lowered the project's survey costs. The 3D drawings were also converted into a Triangulated Irregular Network (3D surface) that were input directly to GPS-based construction equipment that increased construction efficiency by minimizing layout errors and reducing costs. The 2 km long creek re-alignment was designed to resemble a natural creek. The objective was to divert stormwater released from the Elliston Pond around the landfill in an environmentally sensitive manner. The design features a naturalized and meandering channel with a floodplain and includes other ecological features, such as submerged aquatic and emergent plantings, deep and shallow pools and riparian zones, which create a durable habitat. The creek also provides the necessary capacity to convey low probability floods.

Stormwater treatment using constructed wetlands is not an exact science but can produce predictable release water quality. Factors that could affect the release water quality include the inflow pollutant characteristics and loading rates. Prior to commencing this project, there was only limited data that could accurately define the water quality at ECL, and this data was available only for a limited period of time. Water quality analyses usually require extensive data set that allows the engineer to determine trends, average, maximum and minimum concentrations, and seasonal variations. Since the waste received at any landfill are in many ways unique to that landfill, extra care was required when using water quality data obtained from another landfill to determine anticipated conditions at the ECL.

After AMEC identified the contaminants of concern and completed the CFD modelling, the next step was to determine plausible removal efficiency for each pond in order to ensure that the treatment system can meet regulatory requirements.

There were only a few research papers that have estimated pollutant uptake rates of wetland plants. This lack of information, in addition to limited water quality data, made selecting the wetland plants even more difficult. AMEC was able to draw on its international and local experience in landfill leachate treatment and constructed wetland design to determine the treatment capacity of the wetlands.

Translating the hydraulic modelling results into a sustainable natural design was another challenge that AMEC faced in carrying out this project. The plantings in the wetland are required to provide not only aesthetic and treatment functions but also to minimize erosion of the pond shorelines. However, there are no set design guidelines that AMEC could follow. In this regard, the experience of our wetland specialists was valuable to the project team in identifying plants that could perform the necessary functions.



North Pond Outlet Structure and Emergency Spillway



3. Environmental Impact

The variability of rainfall amount, duration and pollutant concentration presents a significant design challenge for engineers. Stormwater released from a landfill site will convey pollutants in the form of oxygen-demanding substances, nutrients, heavy metals and other contaminated materials that can negatively impact the ecosystem residing in or relying upon the aquatic system. To deal with this issue, source control of pollutants is preferred but conditions at the ECL make this approach unfeasible. Since Alberta Environment requires that the one in 25-year rainfall event be stored and tested with respect to specific water quality requirements before it is released offsite the most feasible option to meet this requirement was a stormwater pond with an integrated wetland system to provide water quality enhancement.

Studies of the performance of constructed wetlands suggest that total suspended solids (TSS) can be reduced by 95%, copper by 85%, zinc by 87%, and total phosphorus by 89%. When compared to other types of natural treatment systems, sedimentation basins and detention ponds can reduce TSS by 79% and 92%, respectively, compared to 95% removal efficiency for constructed wetlands (Minton 2005). Upon completion of the biochemical analyses, AMEC concluded that TSS removal was the priority water quality management parameter since many pollutants at the landfill absorb strongly to suspend sediments. Thus TSS was the driver for optimal hydraulic efficiency within each pond.

The ECL ponds have the capability to provide water quality enhancement while providing necessary flood control. Water quality enhancements are affected by more than just the treatment processes that occur with the constructed wetland system. The influent characteristics, pollutant loading rates, climate and aerial extent of the constructed wetland system also play a role in the amount of pollutant removal. When designed, operated and maintained properly, constructed wetlands have performed within predictable ranges of effluent values and meet regulatory limits. By significantly reducing the delivery of many pollutants, the implemented stormwater ponds will improve the water quality of the receiving waters.



North Pond after Construction Completion



4. Social and Economic Benefits

Cleaner Water and Air

The use of vegetative elements to provide primary treatment of stormwater ensures that cleaner water is released to downstream natural water bodies. The Forest Lawn Creek eventually empties to the Bow River and it is important to downstream water users and aquatic ecosystem that pollutants are prevented from getting into the river. Moreover, the vegetation provides cleaner air that improves the air quality by filtration of air pollutants.

Community Benefits

The ECL stormwater system will eventually be incorporated into a regional park system that will run along the Stoney Trail right of way. The ponds and creek will become part of a 150 m wide natural corridor that will join with the proposed Forest Lawn Creek Legacy Park to be located south of the landfill. The 2 km stretch of the realigned creek will connect a regional pathway system that will include several viewpoints and interpretative plaques for users. Together with the legacy park, the ECL stormwater management project will add to the aquatic and wildlife habitats, aesthetic function and recreational value of the proposed park system along the eastern boundary of Calgary.

Also, the wildlife in this area will have access to additional habitat areas as the eastern part of Calgary becomes more developed and other natural areas, including wetlands, are confined or removed.

Flood Protection

The ECL stormwater system forms part of the floodway for about 4200 ha of the northeast quadrant of the City of Calgary. Flow from this area of Calgary is collected and stored in Elliston Pond and the 68th Street Expansion Wetland, which then discharged to the north end of the re-aligned Forest Lawn Creek. Beyond the one in 100-year rainfall event, the creek will provide a route for water to travel away from the homes and businesses located in this area of Calgary.

Benefit to Future Landfills

As regulatory requirements for landfills become more stringent for stormwater releases to natural water bodies, the ECL project will serve as an example for other landfills within Alberta. The knowledge that will be gained from the monitoring and testing to be conducted at this landfill will be an excellent resource for engineers looking to improve on the treatment capability of constructed wetlands. The monitoring plan that was prepared by the City will include water quality testing to ensure that water released to the re-aligned creek meets the landfill's water quality criteria.



South Pond near Completion

5. Meeting and Exceeding Owner's Needs

The City has had a myriad of problems at another landfill and was therefore keenly interested in developing a stormwater management system requires the least amount of maintenance and repairs. The use of constructed wetlands represented an economical and cost effective solution for the City as operation and maintenance costs are kept to a minimum as the wetland requires little or no maintenance.

The engineer's estimate for the construction of the stormwater ponds and associated drainage systems was \$6.61 million dollars and the average of the 5 bids received was \$6.65 million with the lowest bid being \$5.11 million. The project is completed and the maintenance phase of the wetlands is now in progress. To date, approximately \$4.3 million has been expended and it is projected that the project will be completed about 12% under the lowest bid price.

The overall objective of the project was to provide volume control and improved discharge water quality at the East Calgary landfill. The stormwater management system designed by AMEC meets this objective.

AMEC actively controlled the project cost and schedule using the Earned Value Technique (EVT). EVT is an integrated cost/schedule management system for accessing and quantifying work completed. In using this method, EVT compares the cost of work done and the cost of work planned against the actual cost of achieving that work to obtain a cost performance index and the cost of schedule performance index, respectively. This approach allowed AMEC to anticipate upcoming tasks that might impact completing the project on time, and therefore, manage changes to keep the project under budget.

The client's goal was to have the earthworks and structural portion of the of the projects completed by October 31, 2010 so that rain water from spring and summer rainfall can be used for the landscaping that was scheduled for the summer of 2011. Otherwise, the City was faced with a potential cost of \$100,000 to transport water to the landfill if the project schedule was to



be met. The project was delayed beyond the 31 October deadline because of weather delays as Calgary had a wetter than usual month of September. In fact, the contractor lost 19 working days to bad weather at the peak of construction. For the project to meeting the spring landscaping schedule, the contractor continued work until December 2010.

The landscaping for the north and south ponds was to be completed by 31 July 2011. The north pond landscaping was completed before the scheduled deadline while that of the south pond was only partly completed as a result of excessive water that entered the pond from the nearby creek.



South Pond Access Road Construction



Re-aligned Forest Lawn Creek



Conclusion

AMEC developed a stormwater management system to treat surface water runoff at the ECL, a Class II municipal landfill. The system included two storm ponds, drainage ditches and the re-alignment of Forest Lawn Creek. For the first time in Alberta, a combination of biochemical analyses and CFD modelling were used to determine contaminants of concern and optimize the hydraulics of a landfill storm pond in order to meet stringent regulatory requirements.

Some of the key issues that AMEC resolved throughout this process were using the variable and limited water quality data available for biochemical analyses, estimating the treatment efficiency of the ponds to meet Alberta Environment requirements, and translating the hydraulic modelling results into a sustainable natural design. During construction, the collaborative group expanded to include landscape architects, contractors and landscapers, ensuring that the scheduling of construction maintained the integrity of the ponds and creek.



Acknowledgement

AMEC would like to acknowledge and thank our partners on this innovative and exciting project:

The City of Calgary

Riparia

818 Studio Ltd.

Kidco Construction Limited

Wilco Contractors Southwest Inc.

AlphaBetter Landscaping Inc.



Reference

Minton G.R., 2005. Stormwater Treatment. Sheridan Books Inc, Maryland.