Polymer Addition to Increase Trunk Sewer Flow Capacity at the Resort Municipality of Whistler during the 2010 Winter Olympic Games

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ABSTRACT

In 2008, Kerr Wood Leidal Associates Ltd. developed a model of the Resort Municipality of Whistler (RMOW) trunk sewer and ran several scenarios using the forecasted trunk sewer flows of the 2010 Winter Olympic Games. This simulation found that there was a risk of trunk sewer overflow resulting from the inflow and infiltration associated with a rain on snow event. Upon consideration of many options, the RMOW wisely proceeded with the innovative and cost effective option of dosing polymer into the trunk sewer to increase its capacity. Polymer dosing trials conducted during February 2010 found that polymer dosing increased the capacity of the trunk sewer by 20-30\%. Testing showed a significant increase in flow velocity and reduction in flow level in the monitored manholes, suggesting that the polymer dosing would provide considerable additional capacity to the trunk sewer if used when sewer flows and levels reached critical capacity.

Keywords: Polymer dosing, trunk sewers, ionic polymer, trunk sewer capacity

INTRODUCTION

During the 2010 Winter Olympic Games in the Resort Municipality of Whistler (RMOW), the population was projected to reach 55,000-70,000 people, significantly more than its year round population of approximately 10,000. As a resort municipality, the trunk sewers are sized for swelling populations, however the Winter Olympic and Para-Olympic Games were expected to trigger a record number of visitors to Whistler. There was also a significant potential for the sanitary flows generated by the event to coincide with elevated inflow and infiltration (I/I) associated with a rain-on-snow event, resulting in an overload of the conveyance capacity of the existing trunk sewer system.

From 2007-2008, the RMOW engaged Kerr Wood Leidal Associates Ltd (KWL) to identify potential capacity constraints in the Whistler trunk sewer based on the projected Winter Olympic Games population. Based on the forecast flows and potential for a rain-on-snow event, KWL concluded that there was a risk of the Whistler trunk sewer overflowing during the Winter Olympic Games. In particular, seven sections were identified as areas of concern. Figure 1 shows a map detailing the seven sections.
The conventional approach to addressing sewer capacity shortfalls is to upgrade undersized sections with larger diameter pipe, or construct storage tanks which can be used to provide storage volume for flow attenuation to reduce peak flow rates. These approaches are typically followed to meet the long-term needs of municipalities, but are generally capital intensive. Indeed, the conventional options for increasing trunk sewer capacity involved capital expenditures in the order of $1M to $5M.

Note that many properties in the RMOW have basements or ground level floors. Pressurising the trunk sewer by sealing the manholes was not an option due to flooding issues.

Past research has indicated that the addition of polymeric chemicals into sewers results in dramatically reduced hydraulic grade lines for the same given flow rate, which effectively increases the capacity of the sewer. The option of polymer addition was particularly appealing for the Whistler trunk sewer since the duration of the Winter Olympic Games is in the order of eight weeks, and the low capital and operating cost of polymer dosing during this time is minimal compared to the required capital expenditure for upgrades to the trunk sewer or to provide storage reservoirs for peak balancing.

Researchers have demonstrated that sewer capacity could be increased by up to 37% with certain types of polymers under field trial conditions (Peters, 2005). Since the Whistler trunk sewer capacity shortfall was anticipated to reach approximately 30% during the Winter Olympics in several sections of pipe, this option had the potential to eliminate the capacity issues expected in Whistler for the duration of the Olympics. However, the previous research focussed on full pipe, force main conditions. The scenario in the

Figure 1. RMOW trunk sewer sections of concern as identified in an earlier KWL study.
RMOW represented a opportunity to pilot the polymer dosing technology on partial flow conditions.

The current accepted theory by which polymer addition increases sewer capacity is the reduction of frictional drag at the pipe wall in sewer flows. In turbulent flow, dissolved polymer molecules are believed to inhibit turbulent mixing at the laminar sub-layer along the pipe wall, which has the effect of reducing viscous shear stresses at the wall (Sellin & Mice, 1984). The reduced friction translates to a reduction of head loss within the pipe, which results in a lower hydraulic grade line for the same given flow rate. Ideal properties of a drag reducing polymer include high molecular weight, highly charged anionic polyacrylamide characteristics, long chains, short branches, and readily dissolvable.

CASE STUDIES

**Wessex Water Authority**
Dr. Robert Sellin from the University of Bristol has published numerous research papers related to polymer dosing in sewers. One of the main research papers produced by Dr. Sellin and his research team, “Applications of Polymer Drag Reduction to Sewer Flow Problems”, was based on a 10-year program in the 1980’s with the cooperation of the Wessex Water Authority, the University of Bristol, and the Bristol City council. Data collected from automatic dosing of a combined sewer in Bristol over the study period indicated that the capacity of a 300 mm sewer could increase by 20-40%.

**Lower South Platte Basin - Denver Metro Wastewater Reclamation District**
In 2000, the City of Denver, Colorado conducted a pilot testing program to examine the effectiveness of three different polymers in increasing the capacity of the Brantner Gulch Lift Station. The pilot testing showed that the lift station capacity could be increased up to 37% depending on the type and dose of anionic polymer added to the system. Due to the success of the pilot testing, the City implemented a full-scale polymer feed system in 2002.

ENVIRONMENTAL CONSIDERATIONS

The polymer dosed into the Whistler trunk sewer would ultimately discharge into the Whistler wastewater treatment plant in dilute concentrations. The polymer manufacturers indicate that their products are biodegradable, however the degree of biodegradability and the effect on the receiving environment was not investigated. Materials safety data sheet (MSDS) information for anionic polymers indicate that the chemicals are non-toxic at the proposed dose concentrations. Furthermore, dosing was infrequent and thus the potential for any chronic effects on the WWTP or receiving environment were minimal.

In terms of wastewater treatment, there are currently no regulations or guidelines related to discharge of anionic polymers, which are often used in enhanced primary treatment
systems, but at much more dilute concentrations than those proposed for the Whistler trunk sewer. There have been no known studies performed to date on the effect of anionic polymer addition to wastewater treatment and effluent quality at the proposed dose concentrations.

During the periods of polymer addition, RMOW staff observed no adverse effects to operations and performance in the WWTP that could be attributed to the polymer dosing.

2008-09 POLYMER DOSING TRIALS: PRE-OLYMPICS

Based on the recommendations of the feasibility study, RMOW commissioned the polymer dosing demonstration project in August 2008. The testing program included tasks such as selecting the polymer supplier, specifying and procuring chemical dosing equipment, selecting dosing and monitoring locations, and investigating the potential downstream effects of polymer on the Whistler WWTP operations.

Demonstration Trial Configuration
Case studies in Denver, Colorado and in Bristol, UK indicated that polymers from Ciba and Kemira showed the greatest promise in terms of increasing hydraulic capacity. Therefore, polymers from these two manufacturers were selected for testing in Whistler. A Spruce Grove dosing system was connected to the pump station force main discharge where dosing occurred only while the sewage pumps were operating.

Flow monitoring equipment was installed at manholes T4097, T3076, and T1027 along the trunk sewer, shown in Figure 2.
Velocity meters and ultrasonic level sensors were installed at each manhole location and were connected to data loggers for data collection. FlowWorks, an online data management tool, was used for data collection, manipulation, and database storage. This system enabled KWL to monitor changes to the sewer flow velocity and depth with polymer addition, and also to collect data during periods in which no dosing was occurring for comparison purposes.

The dosing system was designed for discharge to a manhole. Due to the requirement that polymers be well-mixed in the sewage, polymers at the Community pump station site were mixed with dilution water and passed through a static mixer prior to discharge to the manhole. When dosing, KWL was on site to manually initiate the polymer dosing. The polymer dosing was ramped up gradually over a period of half an hour to avoid sudden hydraulic surges, which occurred in previous dosing trails as a result of rapid changes in polymer concentration.

**TRIAL RESULTS**

It was found that the Kemira Superfloc A-1820, a dry flocculent, provided the greatest increase in trunk sewer capacity, with the largest increase observed at concentrations of 80-100 mg/L.

As a result of the initial 2008-2009 polymer dosing trials, the fluid’s velocity increased, the level decreased, and it was estimated that up to a 10% increase in full-pipe capacity could be reasonably expected using the Kemira product, see Figure 3. This increase in
capacity was calculated using an estimated Manning’s ‘n’ number, which defines the coefficient of roughness in the pipe and that has an impact on flow. A higher ‘n’ number indicates greater pipe roughness.

![Figure 3. Change in velocity and level at manhole 4079 during dosing](image)

Full pipe conditions were not observed because seasonal peak sewer flows were lower than anticipated during the polymer dosing demonstration trials due to reduced holiday occupancy. In the absence of tests during full pipe conditions, the estimated increase in full pipe capacity could not be confirmed.

When dosing was initiated, it was noted that even small doses of polymer caused a hydraulic surge in the trunk sewer, see Figure 4. It was noted that great care was required when ramping up dosing concentrations to avoid potential overflows as a result of the surge wave.
Several operational issues were observed at the dosing stations during the polymer dosing trials, most notably clogging of the dosing systems when using the Ciba polymer. The chemical supplier believed that, despite all precautions, one or more polymer totes were exposed to extremely low temperatures during transportation from the manufacturing site to Whistler. This resulted in unforeseen maintenance and downtime for the polymer dosing system. For this reason, a reduced number of tests with the Ciba product were carried out.

OLYMPIC GAMES FLOW MONITORING AND DATA LOGGING

Set Up
Three months prior to the commencement of the Olympic Games, KWL in conjunction with RMOW produced a re-commissioning and response plan to ensure that the polymer dosing systems were operational prior to the Olympic Games. In order to mitigate operational risks observed during the trial period (primarily blockages), component servicing and mechanical modifications to the polymer dosing equipment and associated pipe work were undertaken.

The modifications included:

- replacing all inline fittings to full bore fittings;
- servicing of polymer dosing pumps and replacement of key pump components; and
- modification of pipe work to enable easy isolation and flushing in the event of a blockage.

Figure 4. Surge effects when dosing is ramped up too fast
Flow monitoring equipment was installed in manholes T3076, T3079, and T4097 along the trunk sewer in the critical sewer sections identified by KWL, see Figure 2. Velocity meters and ultrasonic level sensors were installed at manholes T3079 and T4097 and a level sensor was installed in manhole T3076. Level sensors were also installed on the polymer totes to enable remote monitoring of polymer consumption, as well as to alarm any unforeseen power outages. FlowWorks data monitoring and reporting was used to remotely monitor all parameters measured.

**Flows During the Olympic Games**

Figure 5 shows the depths of manholes 3076. Several times, and for sometimes extended periods during the Winter Olympic Games, the level in manhole T3076 (diameter 675 mm) approached 600 mm, which was the agreed limit at which polymer dosing was to be activated. KWL mobilized to the site on several occasions when rain was forecast to monitor the sewer levels and to activate the dosing systems if required.

![Figure 5. Trunk sewer depths during the Olympic Games.](image)

The weather during the Olympic Games was relatively dry and there was minimal snow on the ground in and around Whistler Village. The sewer was nearly at capacity with the Village population’s sewage loading alone and, had there been a significant rain-on-snow event, it is likely that surcharging, backwatering, and possibly overflowing from the trunk sewer would have occurred; this would have necessitated the use of the polymer systems in an effort to mitigate these potential occurrences.

**POLYMER DOSING TRIAL AT HIGH SEWER FLOWS**
As the effect of dosing polymer into the trunk sewer at higher sewer flows could not be ascertained during the 2008/2009 trials due to lower than usual peak flows in the trunk sewer, RMOW approved KWL’s request to undertake a final polymer dosing trial on Friday, February 26\textsuperscript{th}, 2010.

The trial was undertaken during the morning diurnal peak. Both the Spruce Grove and Community Pump Station polymer systems were set to dose at an approximate effective concentration of 80 ppm. The polymer dosing was ramped up gradually over a period of half an hour to avoid sudden hydraulic surges as a result of polymer dosing previously observed during the dosing trials.

**Results**

Figures 6 and 7 illustrate the depth and velocity at manhole 3079 during the polymer dosing trial.

![Figure 6. Depth during the high flow polymer dosing trial in manhole 3079 on February 26, 2010](image-url)
As observed previously, upon commencement of the polymer dosing at very low dose rates, there was a surge in level and velocity in each of the manholes. Once this surge passed, the velocity of the trunk sewer increased and the manhole depth decreased correspondingly. This behavior confirms the aforementioned need to ramp up the chemical metering pumps to the intended set-points, so as to minimize this surge wave.

In order to estimate sewer capacity gains as a result of the polymer dosing, the depth to diameter ratio in manholes 3079 and 4097 was calculated based on data collected during the Winter Olympic Games and compared for polymer dosing and no polymer scenarios. Figure 8 illustrates the reduction in the depth to diameter ratio observed as a result of polymer dosing over a range of trunk sewer flows. The following capacity increases were observed: depth to diameter ratio, capacity increases in the order of 20% was observed in manhole 3079.
Theoretical and empirical data suggest that the polymer acts to dampen turbulence, and this is represented as an apparent reduction in pipe skin friction. Thus, it stands to reason and was demonstrated in these RMOW field trials, that a greater percentage increase in hydraulic capacity would be observed at a greater depth of flow.

Basic economic calculations yielded that, at trunk sewer flows between 15-20 MLD, the O&M costs are approximately $0.35/m^3. These calculations, however, are highly dependent on a number of factors such as the type of polymer used, equipment and level of sophistication, the particular physical features of the sewer, as well as the dosing regime utilized, i.e. dosing at peak flows only or throughout the day.

**CONCLUSIONS**

Polymer dosing into the Whistler trunk sewer proved to be a cost effective and innovative solution for RMOW to reduce the risk of possible sewer overflow in the event of a rain-on-snow event during the Winter Olympic Games.

The physical configuration of subject sewer sections must be carefully reviewed in order to gauge how sewer bottlenecks could potentially present localized, detrimental effects with the introduction of polymer dosing.

Depending on flows in the Whistler trunk sewer, the dosing trials demonstrated that polymer dosing has the potential to increase the capacity of the Whistler trunk sewer in the order of 30% velocity, 20% depth, and 10% depth to diameter ratio.
The 20% increase in trunk sewer capacity fell short of the predicted 37% increase in sewer capacity and 30% capacity deficiency in the RMOW’s trunk sewers. The reason for this shortcoming is likely due to differences in experimental conditions. Firstly, Peters (2005) injected polymer into force mains, which have a full more wetted perimeter and therefore the drag reducing polymers will have the more of an effect. Secondly, both Peters (2005) and Wesley (1983) conducted experiments in sewers that ranged from 300-600mm, whereas the RMOW dosed in trunks ranging from 600-675mm. Because the drag reduction per unit volume of water is less in a 600mm pipe when compared to a 300mm pipe, the effects of the polymer are more pronounced in smaller pipes. We expect the polymer dosing would have overcome the estimated capacity shortfalls if the pipes were flowing at full capacity.

Due to material costs, polymer dosing is not a cost effective long term solution for continually increasing the capacity of sewers. However polymer dosing is a feasible and economically viable solution in sewer systems that require temporary or periodic (e.g. storm flows or large even flows) capacity increase.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of the RMOW staff and their willingness to participate in this innovative solution.

REFERENCES
