1 Metro Vancouver Case Study – Vancouver Sewage Area Infrastructure Vulnerability to Climate Change

1.1 Background

Within the First National Engineering Vulnerability Assessment, the Public Infrastructure Engineering Vulnerability Committee identifies stormwater and wastewater among the four priority classes of infrastructure to assess for vulnerability and adaptability to climate change.

The Vancouver Sewage Area (VSA) was selected as a case study in the stormwater and wastewater category. Kerr Wood Leidal Associates Ltd. and Associated Engineering (B.C.) Ltd. conducted the case study. The consultants used the Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment and various information sources (including sewerage-area personnel, climate models, a stakeholders' workshop and a wastewater-treatment plant tour).

Figure A- 11 Metro Vancouver area

1.2 Where, What and How

The VSA is bounded by Burrard Inlet (north), the Strait of Georgia (west) and the north arm of the Fraser River (south). Located within a west-coast marine climate zone, the area is subjected to generally west-to-east weather patterns, dominated by repeated cyclonic storms. Often high winds are accompanied by relatively high levels of precipitation, especially in the winter. Annual

total rainfall in the affected area is 1,881 mm and the average annual one-day maximum rainfall is 73.1 mm. The area's average low January temperature is minus 0.64°C and average high for the same month is
5.22°C. The summer high and low averages (in August) are 11.4°C and 23.47°C. The VSA covers 13,000 hectares and receives flows from the sewer system of the City of Vancouver, the University of British Columbia, the University Endowment Lands, and parts of the cities of Burnaby and Richmond.

The sewage area largely relies on a combined system that conveys both wastewater and stormwater in the same pipe. During heavy rainfall, overflows from the combined sewers, known as combined sewer overflows (CSOs), can be directed into waterways such as the Fraser River and Vancouver Harbour.

The Vancouver Sewage Area's major infrastructure consists of:

- the collection system

and

- the Iona Island Wastewater Treatment Plant (IIWWTP).

The collection system includes:

- combined trunk sewers carrying flow from municipal mains;
- four major combined sewer interceptors that gather flow and convey it to the Iona Island Wastewater Treatment Plant;
- Other collection components as noted in the following paragraph;
- About 16 overflow pipes that can discharge overflows into local receiving waters during significant rain events.

Collection components include designated pump stations and force mains (to raise sewage from areas at lower elevations); flow and level monitors; flow-control structures (weirs to limit or control flows) and grit chambers (to slow flows to drop out rocks and sand). The collection system relies on power sources (generally through BC Hydro); communication (including SCADA telemetry) and transportation networks (to carry response staff); support equipment and personnel, and record-keeping systems (including for weather data). Mains have a design life of up to 100 years and a large number of mains are nearing their design life.

The IIWWTP, built in the 1960s and since expanded six times, lies at the mouth of the north arm of the Fraser River where it flows into Georgia Strait. The plant serves a population of approximately 600,000 and it is the second largest such facility in Metro Vancouver, a regional government body with responsibilities that include managing five treatment plants. The Iona Island facility currently provides treatment to a primary level prior to discharging treatment flow at a depth of 90 metres in the Strait of Georgia via a 7.5-kilometre outfall (including a 4 km jetty and 3 km marine section). The plant treats more than 200 billion litres of wastewater a year. Expansion to accommodate population growth and upgrading to full secondary treatment is planned by approximately 2021.

Plant infrastructure includes screens (to remove coarse debris); centrifugal pumps; facilities for grit removal and chemically-enhanced primary treatment; and thickening, digestion and lagoon systems for sludge. Supporting equipment includes onsite pipelines, building, tankage, process equipment and standby generators. Many parts of the infrastructure will reach their expected service life in the relatively near term.

A Liquid Waste Management Plan (LWMP) commits Metro Vancouver by Jan. 31, 2012 to eliminate all sanitary sewer overflows (SSOs) during storm and snowmelt events of a magnitude that occur more frequently than one every five years on average. Metro Vancouver is also committed to eliminate CSOs by 2050. CSO reduction in the VSA is primarily being achieved by sewer separation (i.e., separating the combined sewer into separate sanitary and storm sewers, often with the existing regional sewer ultimately becoming a dedicated storm sewer).

Climate modeling done by OURANOS suggests that by 2020 and to a greater extent by 2050, the case-study region will experience:

- increased rainfall, including more frequent and more intense rainfall events;
- rises in the sea level; and
- increases in storm surges, floods, and extreme winds and gusts.

1.3 Technical Summary

Climate Modeling

The case study of the VSA infrastructure vulnerability and adaptability to climate change relies on climate modeling by OURANOS and use of the Canadian Regional Climate Model. The years 2020 and 2050 were selected as the bases for analysis. By 2020, much of the oldest piping used in the infrastructure will have reached the end of its normal design life. By 2050, it is planned in the VSA plans to eliminate combined sewer overflows by separating the majority of the contributing sewerage area.

Climate scenarios applied to Metro Vancouver point to:

- increased total amount of annual and seasonal rain (14 per cent by the 2050s);
- increased frequency and magnitude of rainfall events; and
- increased monthly average minimum and maximum temperatures increases – of 1.2 to 1.3° C by 2020 and 2.1 to 2.3° C by 2050.

The global sea level is forecast to rise 0.06 m by 2020 and 0.14 m by 2050. Parts of the case-study area, including Iona Island, are sinking while some adjacent areas are rising. It is important to note, however, that some more recent studies (Inter-Governmental Panel on Climate Change) project changes between 1980–2000 and 2090–2099 forecast significantly higher estimates of sea-level rise.

Other phenomena likely to increase due to climate change are: storm surges, floods and extreme winds and gusts. Average maximum length of dry spells may increase but the model results are inconclusive.

Cyclical atmospheric circulation patterns already impact the region’s precipitation, stream flow and sea levels. Phenomena with possible additive or mitigating effects on the impact of climate change are:

- El Niño and La Niña events;
- Pacific Decadal Oscillations (warming and cooling patterns of the Pacific historically occurring in 25-to-35-year phases).

Probability Scales

The case study employs two probability scales (Method A – Climate Probability Scale Factors and Method E – Response Severity Scale Factors) from the Protocol for Climate Change Infrastructure Vulnerability Assessment to gauge vulnerability of VSA infrastructure to climate change.

Scale	Method A Climate Probability Scale Factors	Method E Response Severity Scale Factors
0	Negligible or not applicable	Negligible or not applicable
1	Improbable/highly unlikely	Very low/Unlikely/Rare Measurable change
2	Remote	Low/Seldom/Marginal Change in Serviceability
3	Occasional	Occasional Loss some capacity
4	Moderate/possible	Moderate Loss of some capacity
5	Often	Likely Regular Loss of Capacity and Loss of Some Function
6	Probable	Major/Likely/Critical Loss of Function
7	Certain/Highly probable	Extreme/Frequent/ Continuous Loss of Asset

Only climate events likely to occur with greater frequency or intensity than at present are assessed. For this reason, the assessment does not cover extremely low temperatures and increased snowfall intensity. Climate-change scenarios indicate that such events are less likely to occur in the case-study area in the future.

Climate Change Impacts

Intense Rain

Climate change is expected to increase the frequency of intense rainfall events in the VSA.

Generally speaking, wastewater infrastructure is impacted most by rainstorm events (e.g., on a short-term, event basis) and to a lesser extent by total annual rainfall (e.g., in terms of long-term operating costs).

Intense rainfall events will reduce the capacity to convey sanitary flows to the treatment plant and increase the frequency and volume of CSOs. It is also likely to increase inflows and infiltration into the sewer system such as via storm-sewer cross-connections and flow through manhole lids.

Collection System

Increased rain with resulting higher flows and velocities in the sewers could impact collection infrastructure through:

- increased demand and wear on pumps and force mains;
- increased erosion at the mouth of the outflow pipe and higher flow also may turn overflows into choke points with flow surcharging upstream.;
- overflow of water through unbolted or unsealed manholes;
- failure of flow and level monitors with impact on sewer system SCADA operation;
- needed changes in operation or sizing of flow-control structures; and
- need for more frequent clearing of grit chambers to remove coarse material.

Treatment Plant

Constraints within the collection system limit amounts of wet-weather wastewater reaching IIWWTP. However, increased frequency and flow volumes related to intense rain still could affect the treatment process through:

- reduced performance of primary clarification, leading to increased contamination discharge into the marine environment;
- added transfer of grit to the anaerobic digester;
- reduced opportunities to take components (e.g., clarifiers and screens) out of operation for servicing, thereby risking greater operating difficulties;
- additional energy expended on pumping;
- increased wear and tear on liquid stream process mechanical components.

Total Annual / Seasonal Rain

Collection System

More rain and rainfall days, plus more intense rain events will reduce the number of days suitable for maintenance – potentially leaving trunk, interceptors and sanitary sewers as the most vulnerable components. (Increased rainfall actually might improve system performance by diluting wastewater and reducing its temperature. This would yield benefits through reduced corrosion and less odor.)

Treatment Plant

Additional rainwater will reach overflows and will not enter the wastewater treatment plant. However, some added water will reach the plant and influence:

- performance of the liquid-stream treatment process;
- capacity (including by displacing some wastewater that otherwise would have been treated); and
- increasing operating costs, including for pumping.

Sea-Level Elevation

Collection System

Rising sea levels could impact the collection system by affecting the hydraulics of outfalls but this effect likely will be minimal. A significant rise in sea level, if combined with high tide and storm surge, could allow seawater to enter the collection system but the expected impact would be minimal.

Treatment Plant

At the treatment plant, a sea-level rise could influence the ionic strength and relative ionic concentration in wastewater. This could impact performance by affecting the particle coagulation and flocculation in the primary clarifiers and gravity sludge thickeners. There is a low probability of such climatic effects.

A rising sea level may affect hydraulics of treatment-plant effluent disposal and require additional energy needed to pump effluent though the marine outfall. There is a high probability of such an effect but its severity may vary.

Moderate-severity effects are likely to be associated with rising sea levels as higher hydrostatic uplift forces affect below-grade pipelines, open channel conduits and structures lower than the current water table.

Flooding of buildings, tankage and process equipment presents a further risk from higher sea levels. Most of the treatment plant site is above 3.5m geodetic elevation but uncertainty exists because of sinking of land at the Iona Island site. Flooding due to rising sea levels is considered a remote possibility but would have severe impacts if it occurred.

Storm Surge

High tides and storm surges govern water levels on the Fraser River lower estuary. Higher extreme water levels caused by climate changes are expected to produce greater storm surges, or rises in level of the ocean caused by the decrease in atmospheric pressure associated with hurricanes and other storms. This will lead to increases in extreme static head and hamper effluent disposal into the ocean. Considering the system's current capacity and experience during storms, this warrants a "major response" severity factor.

Increased storm surge can impact the site in terms of flooding, particularly if combined with a large wave event.

British Columbia has adopted 2.9 m above geodetic elevation as a flood standard (without consideration of sea-level rise). Much of the Iona Island site, including the access road, lies only slightly above 3.5 metres. When considered in combination with land sinking in the area, the consultants "suggest that little margin may be available for the future." Bases on probability scales A and E, and a conservative assessment, they assigned a "probable" and "major response severity factor" to this situation.

Floods

Street flooding due to rain may cover pump stations (depending on design and location) and damage electrical equipment. Flooding could make it difficult to refuel standby power and hamper response by service crews. Pump failure could cause local environmental damage and human health risk. Though the impacts of such events are severe, the probability of vulnerability is assessed as moderate.

High Temperatures

Higher ambient temperatures will have some negative impacts, including increasing odor (due to increased fermentation) during the treatment process, influence the HVAC systems (affecting staff and process equipment) and increasing corrosion. Higher temperatures could benefit anaerobic sludge digestion. The probably climate effects upon the infrastructure from increased temperature are relatively low.

Drought

Longer periods of summer dry-weather could result in wastewater being less diluted by rain. This could influence the effluent quality and require more frequent use of chemically enhanced primary treatmen. However, the probability of climate change affecting the treatment plant in this way is considered remote and the severity response is low.

Wind

Higher winds could cause SCADA antenna damage and impede communications. In the absence of adequate backup, winds could also disrupt power needed for the collection system.

At the treatment plant, higher winds could slow settlement of solids in the sludge lagoons. Increased high winds could also increase the frequency of BC Hydro power loss. Without

Figure A- 13 Overflow

adequate power backup, operating effluent pumps could be difficult. More frequent bypass of effluent into the shore outfall may occur. The severity of this situation is linked to access to on-site power generation.

1.4 Policy Makers Executive Summary

General Climate-Change Impact

While climate changes are anticipated to impact Metro Vancouver, the region is not currently affected by ice storms, tornadoes, drought or extreme cold. Probabilities for such sudden weather events are likely to decrease for the Vancouver Sewage Area (VSA) with climate changes that are predicted to bring warmer and more rainy conditions.

Currently, flooding from the Fraser River and sea represents the highest magnitude threat to the VSA from sudden weather changes. Because of its location near the mouth of the Fraser River, the flooding threat from the river is associated with winter storm-surge conditions and not the snowmelt-generated freshet or spring breakup.

Climate-change effects upon the VSA will generally be gradual, and therefore allow the system to mitigate and adapt to the effects of these changes.

The most severe vulnerability rating relate to public health risks from contamination arising from overflows from combined sewer and wastewater sewers into spaces such as streets and basements. Extreme weather events also could delay construction and reduce opportunities for servicing, as well as increase wear and tear on equipment and add to insurance costs.

Specific Impacts on Vancouver Sewage Area Infrastructure

Some specific components of the VSA infrastructure are expected to be impacted by climates changes, notably changes associated with increases in overall rainfall and more frequent severe rainfall. However, the wastewater infrastructure tends to be affected to a greater degree by discrete rainstorm events than by the total annual rainfall handled.

Collection System

Anticipated increases in rainfall will affect the collection system by increasing flows under sewer configurations that a) involve combined wastewater and stormwater sewers, and b) those where the two flows are divided (i.e., separated). This should encourage acceleration of plans within the VSA for sewer separation to ensure elimination of CSOs by 2050. More study is needed to determine the extent of work required.

In addition to sewer separation, a number of other anticipated developments could affect the collection system by mitigating or intensifying possible impacts on the infrastructure from climate changes. These developments include:

- construction plans for additional and replacement sewage-system infrastructure;
- plans to reduce inflow and infiltration of wastewater flows into the sanitary sewers;
- population growth and impact on sewer loading;
- land use (e.g., increased runoff by addition of impervious areas, or decreased wastewater flows due to diminished industrial land use in Vancouver);
- water conservation resulting in decreased sanitary loading;
- seismic events leading to landslides or ground shifts affecting sewer line integrity.

Because several local sewage systems link with the VSA infrastructure, recommendations for the sewage area can be implemented most effectively through effective coordination with the affected municipalities. A comparable vulnerability study with the City of Vancouver may help more clearly identify actual vulnerability.

Iona Island Water Treatment Plant

Climate changes leading to storm surges could impact the VSA's Iona Island Wastewater Treatment Plant by affecting the current disposal system, which relies on a 7.5-kilometre outfall into Georgia Strait. This represents the highest area of climate change vulnerability for the treatment plant.

A lower order of vulnerability for the plant is associated with rises of the mean sea level. This issue requires more study. Similarly, lower levels of vulnerability relate to wet-weather waste flows.

The VSA collection system, along with some other Metro Vancouver facilities, is not adequately equipped with backup to deal with power failure. The treatment plant has an emergency response plan. However, the current availability of standby electrical power leaves the treatment plant somewhat vulnerable. This situation could become more acute as a result of climate changes and remedial action is recommended.

The age of the infrastructure and other issues, such as the possibility of seismic events, are vulnerability factors requiring further study and attention.

Figure A - 14 Water Treatment Plant

Mitigating and Favorable Factors

The aim in the VSA of separating wastewater and stormwater streams will reduce peak flows in the collection system and amounts delivered to the treatment plant. The expected reduction in flows to the plant will exceed the anticipated adverse impact on the treatment plant stemming from climate-based rainfall effects.

Plans to upgrade treatment within the VSA to secondary by approximately 2021 provide an opportunity to include climate-adaptation measures in the design.