DESIGNING A DEPRESSED SEWER SYSTEM FOR ENERGY-FREE WASTEWATER TRANSMISSION

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INTRODUCTION

A large urban area in Western Canada requires a new wastewater transmission system to circumvent a major river that separates the existing sewerage system and the wastewater treatment plant (WWTP). An inverted siphon design was deemed the most appropriate solution, wherein the flow is driven solely by the available elevation difference of 4.96 meters between the incoming inlet pipe and the downstream outlet pipe.

PROJECT SCOPE

1. Select number of barrels and their respective diameters so that they successfully transmit wastewater despite varying incoming flow conditions
2. Design the inlet chamber so that the barrels are invoked in a way that keeps the velocities in each are sufficiently high
3. Design the outlet structure to ensure sufficient flow continuity and provide access for inspection and maintenance needs.

DESIGN PROCESS

Flow Data Summarization

- Interpretation of historical flow data determined the minimum and peak incoming dry weather flows (DWF & PDWF).
- Calculation of design flows using Manning's Equation for Full Pipe Flow determined the maximum capacity of the system.
- Analysis of historical precipitation data determined the maximum predicted incoming combined storm flows.

Barrel Design

- Darcy-Weisbach Equation for flow used to compute barrel diameters to handle divided flows.
- Von Karmen Equation used to calculate pipe friction factor.
- Darcy-Weisbach Equation used to calculate friction loss
- Minor losses determined for entrance, elbows, and exit.
- Bernoulli's Equation used to iteratively check flow levels and energy equilibrium of the system.
- Discharge rate through commercially available barrel diameters used to check flow velocities for self-cleansing capacity.

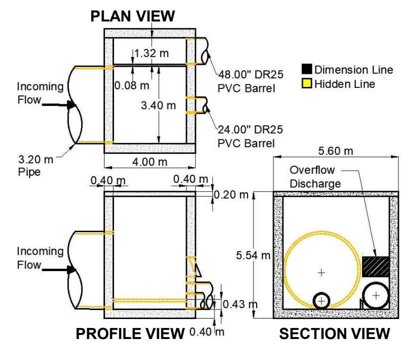
Inlet Chamber Design

- Chamber losses determined using methods outlined by Metcalf and Eddy, using velocity head from invoking flow and water passing over weir.
- Weir orientation determined from modelling experiments.
- Final barrel sizes and flows used to determine weir height and orientation, and chamber dimensions.

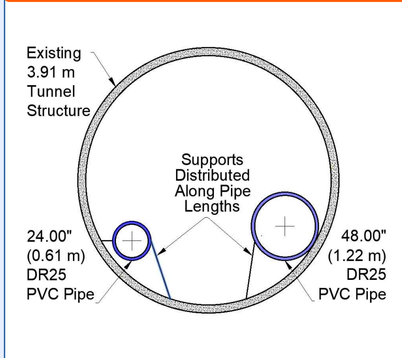
DESIGN DETAIL

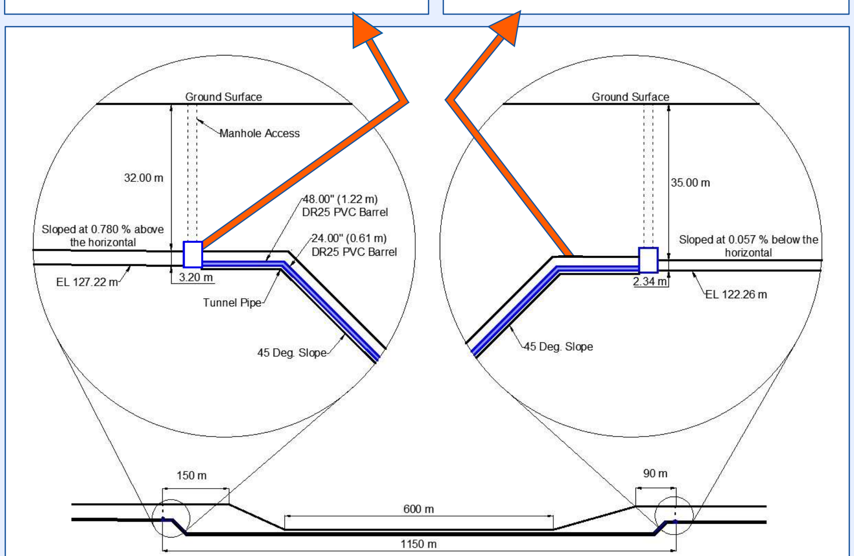
	Q_{MAX} (m^3/s)	Size (m)	Q_{MIN} (m^3/s)	v_{MIN} (m/s)	σ_{HOOP} (kPa)	T (kN)
Barrel 1	0.75	0.61 (24") DR25	0.83	2.60	2500	77.4
Barrel 2	3.65	1.22 (48") DR25	1.21	1.03	2500	300.3

Inlet Chamber Detail



Tunnel Cross-Section





Depressed Sewer Elevation View

DESIGN OVERVIEW

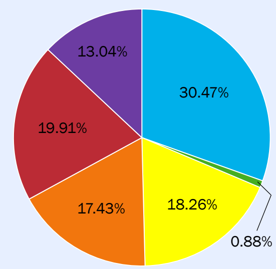
The sewer line, flowing full and under pressure, is below the HGL and EGL. Each drop in grade line represents a calculated minor loss (entrance, elbow, exit). The slope of the HGL and EGL represents the calculated pipe friction loss. The loss values vary with barrel size and inflow conditions.

Hydraulic and Energy Grade Line

COST ESTIMATE

Pipes	$2,290,639.48
Chambers	$66,049.88
Excavation	$1,372,414.23
Backfill	$1,310,288.49
Other	$1,496,176.03
Contingency	$755,908.81

TOTAL COST: $7,515,903.33



CONCLUSIONS & RECOMMENDATIONS

The recommended depressed sewer design will include a two-barrel PVC siphon system that will maintain adequate self-cleansing velocities of over 1m/s. The barrels, spanning 1150 meters, will run parallel in the existing tunnel that was constructed under the river.

The inlet chamber will be designed with one lateral overflow weir such that the pipes come into action successively as the incoming flow increases. The primary barrel will be invoked by DWF only, and the two barrels will handle the PDWF, and combined sewer flows up to system capacity of 4.4m^3/s. Incoming flows greater than the downstream pipe capacity will be diverted to the river through an ancillary pipe connected to the chamber.

REFERENCES AND VARIABLES

Metcalf and Eddy Inc 1972. Wastewater Engineering: Collection, Treatment, Disposal. McGraw-Hill, NY, 782 pp. (ISBN 07-041675-3)

Gupta, R.S., 2017. Hydrology & Hydraulic systems Fourth ed., Long Grove, Illinois: Waveland Press.

Hager W.H., 2010. Wastewater Hydraulics – Theory and Practice. Springer, New York, 652 pp.

Q_{MAX} is the maximum flow the barrel is designed to handle (m^3/s)

Q_{MIN} is the minimum DWF discharge used for the self-cleansing check (m^3/s)

v_{MIN} is the minimum settling velocity through the barrel (m/s)

σ_{HOOP} is the hoop stress acting perpendicular to the barrel (kPa)

T is the thrust force of the wastewater acting on each elbow, of which the thrust block is designed to resist (kN)