Highbury
Continuous, Real-Time Inspection of a 4.2 km Tunnel

With new regulations in effect regarding the environment, public safety and the health and safety of workers, new technologies are being employed for inspection of our aging infrastructure. The simple means of inspection or intervention a few years ago are unacceptable with today's standards.

A case in point was the recent survey of the Highbury Interceptor Tunnel, conducted for the Greater Vancouver Regional District (GVRD). This sewer and drainage tunnel was last inspected in 1985, by three GVRD employees who literally walked the confined space of the 4.2 kilometre tunnel without any other points of egress. In order to provide access, all flow of raw sewage was temporarily diverted into the ocean. Both are techniques which would not be acceptable today.

The Highbury Interceptor tunnel was constructed in 1963. The tunnel section consists of a single 9'6" (2950 mm) diameter concrete tunnel with 15" thick walls reinforced with rebar. The tunnel conveys the combined storm and sanitary water flow from over 50% of the greater Vancouver area sewer region to the Iona Island Wastewater Treatment Plant. The tunnel section is 4193 metres (4.2 km) long and is 120 metres deep at its deepest point below the ground surface, with access only at the ends. Average flows in the tunnel vary between 2550 l/s and 6230 l/s, with flow velocities ranging from 1 to 3 metres per second. The depth of flow can vary dramatically near the downstream end, depending on weather conditions and Iona Island WWTP operations.

The challenge of the Highbury project was to remotely inspect and record tunnel integrity information without any interruption of the tunnel flow. The technical difficulties involved developing a remote means of recording survey data above and below the water in real time that was comprehensive and safe. Early in 2003 an RFP was let for this demanding project.

The GVRD required that the real time data collection and display would be carried out with a closed circuit television (CCTV) camera, and underwater surveying completed with profiling sonar. The instruments to do the task would have to fit in through the end portals with minimum disturbance to the neighborhood and street traffic. Survey work would be at speeds congruent of a detailed examination, with the ability to stop and go back and forth at the requirement of the GVRD inspection team. As well was the requirement to overcome any unknown hazards and retrieve all the components from the tunnel in the event of any equipment failures.

A unique team from AquaCoustic Remote Technologies Inc. and Frontier Geosciences Inc. met the development challenges. The companies combined their specialisations in sonar systems, remote vehicles, CCTV equipment, computer data acquisition, telemetry and field processing, smart sensor design, instrumentation, and power and data transmission systems, to assemble the remote system successfully deployed in the investigation.

Visual inspection consisted of a high quality video camera with independent aperture, zoom, focus, pan, and tilt capabilities. Sufficient light was required for colour rendering and detail where the closest point of approach may be 9 feet away (3meters). Redundant light sources were included in the event of a lamp failure. Even lighting gave a glare free, clear view without hotspots of intense light.

The rotating head sonar system was equipped with a pitch, roll and heading sensor. Due to the requirements for high resolution images and multiple, simultaneous recording of a variety of sensors, as well as remote system functions a composite 4.2 km fibre optic cable was utilized for control, sensor monitoring, electric power, and data acquisition.

The Survey

The survey was initiated by opening the north and south tunnel vaults. A drogue with a tool line attached was floated downstream to deploy the equipment. Once secured at the downstream end, the drogue rope and fibre optic cables were attached to the instrumentation platform. The instrumentation platform was then launched, controlled by the rope downstream and the fibre optic cable upstream. Data acquisition was then commenced.

The winches were operated at variable velocity and constant torque to maintain a constant 7-m/min inspection speed. The winches were set to automatically maintain a constant load on the platform during the inspection run. During the survey, the cable payout and winch load data from the downstream vault system were relayed by cellular telephone telemetry to the control booth, which provided detailed operational information to the winch observers at either end.

The instrumentation on the platform acquired video images and sonar data in real time. Other telemetry information relayed back to the control booth included cable tension fore and aft, acoustic left side, right side and crown distances, boat attitude, sonar pitch and roll information, temperature and voltages in the platform. Telemetry from the control booth to the platform included sonar control, pan, tilt, zoom and iris control for the camera, and control of light operations. In all, 160 gigabytes of data were stored on the hard disk in the control booth. Video images were stored digitally on hard drive and on two analogue tape drives in Super VHS format. Winch payout distances and tensions were recorded digitally. The fiber optic winch was controlled via a remote cable from the control room

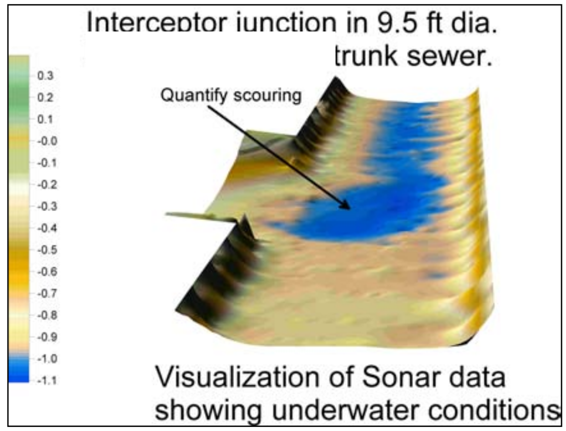
The inspection consultant technician from M.J. Pawlowski and Associates, and GVRD personnel observed the real time video, sonar, data and made written logs of the observations. The video assessment and inspection reports were text coded in accordance with the Water Research Centre's *Manual of Sewer Condition Classification, 1993 edition and 1996 addendum*. Scores and grades were assigned in accordance with the *WRc. Sewer Rehabilitation Manual, 4th edition*.

Video Technology

Due to the large diameter pipe, conventional sewer cameras do not have sufficient light, iris or pan/tilt speed, as well as zoom control to focus on small features, which at the closest point of approach could be 9 feet (3 metres) away. A camera was modified to support its own lights and withstand the environment. Redundancy in the system was built in to allow for equipment failure without interruption of the survey.

Sonar technology

The sonar head was positioned underwater generated an acoustic pulse in a narrow cone. A profile of the tunnel floor was built as the sonar head swept about the longitudinal axis of the sonar enclosure. The tunnel profile was calculated using the angle of the profile head relative to vertical, the speed of sound in water, the travel time, pitch, roll and heading information. Side to side displacement was corrected to the tunnel wall. The overall accuracy was considered to be better than ±0.5%.



Summary

Of all the technical aspects of concern in the project, the most onerous was heat. The water and air in the tunnel was about 28 degrees Celsius. Any outside cold air entering the tunnel would produce very thick fog. As well safe operation temperature of the electronics required exceptionally large and efficient passive radiators to keep the package temperature under 40 degrees Celsius.

All components of the survey including deployment mechanisms, instrumentation, data acquisition and transmission worked exceptionally well. The floating platform was very stable, and the camera and lights produced exceptional video of the tunnel wall. Simultaneously, excellent sonar images were produced of the tunnel floor. The absence of visible structural defects indicated that the tunnel is in apparent good structural condition.

The utilization of this profiling system has specific application to long or short tunnels and pipelines of various dimensions. The acquisition electronics and retrieval systems are flexible and can be configured for a variety of conditions. The data can be recorded continuously over relatively short or extremely long transects. The Highbury Tunnel investigation utilized only two access points for the successful execution of the investigation.

We wish to express our gratitude to the numerous GVRD personnel who provided valuable assistance in on-site operations. Special thank are due Mssr's Bill Ferg, Ray McCurrach and Gary Solon who provided suggestions and valuable logistics and supervisory assistance to the acquisition team.