



ROV-Based Leakage Detection in Water Conveyance Tunnels

Executive Summary

Leakage in water conveyance tunnels may indicate cracking, joint deterioration, lining defects, or other structural discontinuities. Localising active leakage within flooded tunnels is challenging due to restricted access, extended tunnel lengths, poor visibility, and limited positional reference.

ROV-based inspection provides a remote method for identifying and assessing suspected leakage zones using high-definition imaging, sonar, navigation systems, and controlled tracer-dye injection. Dye movement can confirm active leakage paths and indicate local flow direction, while sonar and navigation data support structural assessment and defect localisation. The resulting position-referenced dataset supports engineering evaluation, maintenance planning, and targeted repair.

ROV-Based Tunnel Inspection

Flooded tunnel inspection requires a platform capable of operating within confined environments while maintaining visual, acoustic, and navigational awareness.

A specialised Remotely Operated Vehicle can be equipped with high-definition cameras, forward looking multibeam sonar, 3D mapping sonar, and navigation sensors. Visual imaging enables identification of cracks, openings, lining damage, joints, and other surface defects. Forward looking multibeam sonar supports inspection under turbid or zero-visibility conditions, while 3D mapping sonar provides cross-sectional data for evaluating tunnel geometry and structural irregularities.

A Doppler Velocity Log can support vehicle displacement tracking and correlation of detected defects with tunnel chainage. Tether payout may provide an additional positional reference during long-range inspection.

Leakage Detection Using Dye Injection



Prior to deployment, tunnel drawings, previous inspection records, known defects, and external leakage observations are reviewed to identify probable leakage zones.

The ROV is navigated to the suspected defect area and a controlled quantity of tracer dye is released adjacent to the tunnel surface. When there is an active leakage path, local hydraulic flow draws the dye toward and into the crack, joint, or opening.

The observed suction and dye trajectory provide visual confirmation of active leakage and indicate the local flow direction. The process is recorded using the ROV camera for subsequent engineering analysis.

Where the dye disperses into the surrounding water without entering the defect, no active leakage is confirmed at that location under the observed hydraulic conditions, and the inspection proceeds to the next suspected zone.

Leakage Quantification

Recorded tracer movement can be analysed to estimate local flow velocity. The velocity flow is calculated using optical flow algorithms. So with known areas of leakage zones from forward looking multibeam sonar and other visual inspections can be combined with time reference, spatial scale, defect dimensions, and hydraulic parameters to calculate flow rate eventually.

Quantitative leakage estimates should be validated using suitable hydraulic analysis or independent measurements where higher measurement accuracy is required.

Tunnel Mapping and Defect Localisation

Sonar data acquired during the inspection can be processed to generate tunnel profiles and geometric representations of the inspected section. 3D mapping sonar data may be used to identify variations in tunnel cross-section, deformation, deposits, or other geometric anomalies.

Where sufficient spatial and navigation data are available, successive sonar profiles can also support three-dimensional reconstruction of the tunnel section.

Detected leakage points and structural defects can be referenced using DVL-derived navigation data, tunnel chainage, vehicle trajectory, and tether payout. This enables inspection findings to be spatially correlated with engineering drawings for maintenance and repair planning.

Conclusion



ROV-based inspection integrates visual imaging, acoustic sensing, navigation, and tracer-dye techniques for the investigation of leakage in flooded water conveyance tunnels.

The methodology enables active leakage paths to be confirmed, defects to be localised, tunnel geometry to be documented, and inspection findings to be referenced spatially. The resulting engineering dataset supports condition assessment, targeted maintenance, and subsequent structural or hydraulic investigation.