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VIDEO MONITORING TO DETECT SALTWATER INGRESS IN SEWER MAINS

New methods to detect Saltwater Ingress in Wastewater Mains

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ABSTRACT
Sydney Water has developed an innovative video monitoring unit called *SewCam*. It is designed to be set and retrieved in maintenance holes as an additional tool in source detection investigations for saltwater ingress (SWI). Historically detection of SWI relies on site inspections, flow gauges, conductivity logging and CCTV to detect SWI sources. *SewCam* provides a method of SWI detection that is safer, faster and cheaper to operate than traditional detections methods. Since its development *SewCam* has been successfully used to detect SWI sources in four Sewage Pumping Station (SPS) catchments.

INTRODUCTION
Sydney Water's wastewater system is subject to SWI in areas where its sewage network is located within the intertidal zones of harbour and foreshore areas. During high tide events, saltwater enters the sewage systems via faults and cracks in the sewers, maintenance holes, designed overflows and house service lines (HSL). Sydney Water maintains 678 SPS with 87 of these having the potential to be affected by SWI.

Impacts of SWI include extra flows of 1,900ML per annum, increased network and treatment operational costs of $590,000 per annum, and SPS pumping an additional 9,500 hours per annum. High saltwater concentrations in sewage are a barrier to reuse as recycled water and sewer-mining operations while also potentially impacting effectiveness of existing treatment plant processes. SWI increases the risk of dry weather overflows to waterways during alignment of high tide ingress and peak dry weather flows.

There is increased risk of raw sewage exfiltration to waterways during low tides from "leaky" sewer assets located around foreshore catchments (Mitchell et al., 2006). Sydney Water has a strategy and decision framework for the Management of Saltwater Ingress Reduction that puts priority on source detection investigations (Thang, 2015). Historically Sydney Water has relied on site inspections, flow gauges, conductivity logging and CCTV to detect sources of SWI.

Sydney Water has developed a set and retrieve video monitoring unit called *SewCam* which can be deployed in maintenance holes as an additional tool in source detection investigations. This innovative piece of technology has greatly increased the speed and effectiveness of source detection of SWI for rehabilitation.

METHODOLOGY/ PROCESS
Sydney Water network operators asked internal hydrographers about the availability of a video monitoring unit capable of deployment within Sydney Water's network assets. As nothing suitable was commercially available, a unit was developed internally.

This consisted of testing multiple cameras, some of which included infrared backlighting, cameras attached to bulky loggers, and units needing confined space entry for installation. GoPro® was selected for trial due to its high video quality, compact size and robustness. The unit was thoroughly tested in multiple locations with different mounting methods and sources of light as the GoPro® does not have an inbuilt light source. Sydney Water's Hydrometric Operation team gathered off-the-shelf products to create a camera setup called *SewCam* that is robust, cost effective, and easy to use, and that operates reliably in harsh sewer environments.

SewCam

SewCam is comprised of four components, as depicted in (Figure 1), which include a camera, light, batteries and housing. The unit is user friendly and easily deployed with plug and play cables. Typical installation time is 45 minutes. The unit can record footage for up to 24 hours or can take up to 10,000 still images at pre-selected intervals (Table 1).

Table 1. Components and specifications

Camera	Light
GoPro Hero 3+ Silver edition	IP68 Solid Mini LED Flood Light
WVGA 240 fps video capture	Item (H) 70mm x (W) 40mm (D) 55mm
60m Waterproof Housing	LED Lifespan 50000hr
64GB Micro-SD card	Light Rating Lumens 500lm
Longshot G3 external power lead	Equivalent Halogen Power 35W
Housing	**Battery**
Pelican protector case 1150	Batteries LiPo x 3
(21.1 x 14.7 x 9.5 cm) Interior	Voltage 11.1v : Max voltage 12.6v
(24 x 19.8 x 10.9 cm) Exterior	Mah 4200
0.8kg Weight	Size (L) 14mm x (W) 43mm x (H) 25mm
Crushproof and dustproof	Weight 341g

SEWCAM FOR SWI INVESTIGATION

While there are still occasions to obtain precise quantitative flow gauging and conductivity data, *SewCam* has proven itself to be the way forward for Sydney Water in capturing snap shot qualitative video recordings of live events within Sydney Water's assets. Wastewater telemetry data from SPS known to be affected by SWI is used during the planning phase to estimate tidal infiltration levels. Sewer assets within affected catchments below 1m AHD are identified using geospatial data from Sydney Water's GIS. Tidal forecasts are obtained from the Roads and Maritime Service NSW Tide predictions.

Figure 1. (Top) View inside of *SewCam* looking into the compartments containing GoPro®, 3x 12V batteries, light and housing. (Bottom) Front view of *SewCam*.

SewCam is typically deployed in maintenance holes along a sewer main and can narrow down point sources of SWI in one monitoring event. Larger catchments may require more than one monitoring event once affected sewer mains have been identified. Installed at strategic maintenance holes during high tide events, *SewCam* can identify SWI point sources from anywhere within the maintenance hole. *SewCam* can also identify SWI from any overflow structures and can identify affected sewer main inlets.

SewCam is installed by suspension from chains attached to the top of the maintenance hole (Figure 2) and (Figure 3). Video monitoring captures up to 24 hours on continuous footage, so when carried out in conjunction with a forecast high tide, can provide video evidence of SWI. Historically four techniques have been used to monitor for SWI; site inspections, flow gauging, conductivity logging and CCTV. *SewCam* has reduced the number of site inspections and provided Sydney Water with video monitoring of assets during high tide that were previously unsafe to access for site inspections (Figure 4). *SewCam* has replaced the need for short term flow gauging and conductivity logging to detect SWI. *SewCam* also provides better source information for future CCTV investigations if required.

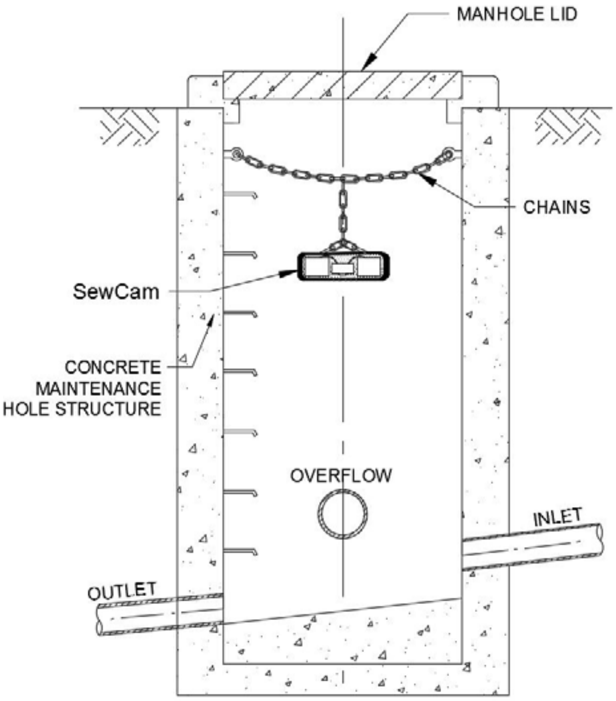

Figure 2. Diagram of *SewCam* hanging from a chain bolted to the top of a maintenance hole (manhole). Camera is pointed towards the overflow, inlet and outlets.

Typical planning, deployment, retrieval and analysis of a single *SewCam* monitoring event using up to four cameras takes one week with no need for confined space entries, making *SewCam* a safer, faster and cheaper alternative to traditional techniques.

Figure 3. Photo of *SewCam* deployed to monitor an overflow within a maintenance hole.

Figure 4. Maintenance hole engulfed with water at higher tides.

COMPARISON OF SEWCAM TO TRADITIONAL METHODS

Manual Site Inspection for SWI Investigation

Site inspection involves manually opening maintenance holes to inspect for SWI source and direction. It can only be carried out on SPS, maintenance holes and designed overflows. Effective inspections need to be completed during high tide periods where maintenance holes are accessible and preferably during core business hours when SWI can be observed visually entering sewer mains. In many cases maintenance holes can only be safely accessed during low tide periods when not engulfed in tidal water (Figure 5).

Figure 5. Accessible maintenance hole on harbour forshore. This can only be accessed during low tide as it is engulfed with tidal water at higher tides.

Typically, two field technicians are required for full days to complete site inspections. By comparison *SewCam* can be deployed at any time when safe access is possible.

Flow gauging and conductivity logging

Flow gauging and conductivity logging can provide quantitative data for flow and conductivity analysis when installed on strategic maintenance hole inlets within a SPS catchment (Table 2). Conductivity logging has the same access and safety issues as manual site inspections. In comparison, *SewCam* can be deployed in similar locations for qualitative monitoring at lower cost.

This requires two technicians to conduct confined space entries in maintenance holes to install multiple flow gauges and conductivity sensors on sewer main inlets (Figure 6). A typical catchment investigation requires multiple monitoring points for a period of four weeks of flow and conductivity monitoring to capture multiple tidal events during dry weather conditions. Analysis of these monitoring results are used to identify sewer mains within a catchment affected by SWI.

Figure 6. Technician occupying a confined space maintenance hole to install flow gauges and conductivity logging equipment.

CCTV

CCTV investigations are carried out on sewer mains that have been identified as being affected by SWI. This is still used following *SewCam* and is also used following flow and conductivity analysis or from site inspections. CCTV is used to locate the point source(s) of SWI into sewer mains for rehabilitation. CCTV is carried out when tidal heights are known to be infiltrating into sewer mains so point sources can be visible when CCTV cameras are moving through sewer mains. This can only be carried out from maintenance holes or inspection points that can be safely accessed (Figure 7). Timing this work during appropriate tidal heights is essential to effectively identify point sources of SWI. This generally results in long timelines when planning work on affected catchments to correlate appropriate tidal heights in dry weather conditions during daylight hours. A CCTV investigation costs roughly $1,500 for one sewer main during one tidal event.

Table 2. Raw data collected for flow and conductivity at one location for a seven-day period. Typically, multiple sites are monitored in a catchment for source detection investigation for SWI over a 4-week period to capture multiple tidal events.

Date	Discharge l/s	Discharge l/s	Discharge l/s	Conductivity mS/cm	Conductivity mS/cm	Conductivity mS/cm
	Max	Mean	Min	Max	Mean	Min
1/08/2008	8.1	1.6	0.1	42.8	4.9	0.4
2/08/2008	6.5	1.2	0.0	35.5	3.7	0.3
3/08/2008	na	na	na	36.7	3.5	0.2
4/08/2008	na	na	na	2.5	0.5	0.0
5/08/2008	2.2	0.7	0.2	1.0	0.7	0.5
6/08/2008	3.0	0.7	0.3	2.4	0.9	0.7
7/08/2008	2.2	0.8	0.2	2.9	1.1	0.9

Figure 7. CCTV camera and tractor unit getting ready to be deployed into a maintenance hole. Unit is deployed into the sewer main and tractor unit is driven upstream or downstream looking for SWI sources entering the sewer main.

RESULTS/ OUTCOMES

SewCam replaced traditional monitoring techniques when investigating SWI sources at SP0011, SP0108, SP0208 and SP0117. *SewCam* identified point sources of SWI within maintenance holes at SP0011, SP0108 and SP0208. *SewCam* isolated SWI affected sections of sewer main for CCTV investigation at SP0108, SP0208 and SP0117. Comparison of time, safety and costs were compared with traditional techniques in (Table 3).

SP0011

Source detection was carried out at the collecting maintenance hole to SP0011 (Figure 8). *SewCam* monitoring confirmed that SWI was entering from the overflow window (Figure 9) and the eastern sewer main is most affected by SWI. The detection of the overflow source alone is estimated at 8100KL per annum and represents 24% of SWI entering SP0011 catchment.

Table 3. Comparison of *SewCam* against Traditional Monitoring Techniques at four SPS

Source Detection using Traditional Monitoring				
SPS	**SP0011**	**SP0108**	**SP0117**	**SP0208**
No. Weeks	4	4	4	4
Confined Space Entries	3	6	2	2

Source Detection using SewCam Monitoring				
SPS	**SP0011**	**SP0108**	**SP0117**	**SP0208**
No. Weeks	1	2	2	2
Confined Space Entries	0	0	0	0

SewCam vs Traditional Monitoring Comparison				
SPS	**SP0011**	**SP0108**	**SP0117**	**SP0208**
Hours	74% ↓	71% ↓	62% ↓	56% ↓
Cost	90% ↓	84% ↓	88% ↓	66% ↓

Figure 8. MapInfo layer marking the maintenance hole where SWI source detection monitoring was completed for SP0011. *SewCam* monitoring demonstrated that SWI was entering the sewer main from the overflow structure connected to the overflow chamber and underground stormwater during peak tides above 2.0m.

Figure 6. (Left) Still frame from *SewCam* footage of SP0011 collecting maintenance hole at low tide. (Right) Still frame from *SewCam* footage of the same maintenance hole at high tide showing SWI entering via the overflow window not visible in the frame.

SP0108

Source detection was undertaken at SP0108 from five maintenance holes using *SewCam* (Figure 10). Monitoring confirmed that the overflow weir to SP0108 was a source of SWI and that the north-eastern and south-western sewer mains are affected by SWI. The south-western sewer main is estimated to contribute around 14,000KL per annum representing 17% of total SWI. The north-eastern sewer main is estimated to contribute 9,000KL per annum and represent 11% of total SWI. Remaining SWI is therefore isolated to sewer mains directly east of SP0108 as remaining sewer mains have been eliminated based on *SewCam* analysis.

SP0208

Source detection was undertaken at SP0208 from four maintenance holes using *SewCam* (Figure 11). Monitoring confirmed that the north-eastern sewer mains from SP0208 are most affected by SWI.

Figure 10. MapInfo layer marking the maintenance holes where SWI source detection monitoring was completed for SP0108. *SewCam* monitoring demonstrated that SWI is entering via the overflow weir, south-western and north-eastern sewer mains.

Monitoring of three maintenance holes along the north-eastern line identified a major SWI source from damaged maintenance hole benching (Figure 12) and isolated two sections of affected sewer main for CCTV investigation. CCTV investigation and site inspections confirmed two major SWI sources from damaged HSL. The cumulative effect of the three SWI sources has reduced SWI by 8,300KL per annum and represents a 58% reduction in total SWI.

Figure 11. MapInfo layer marking the maintenance holes where SWI source detection monitoring was completed for SP0208. *SewCam* monitoring demonstrated that SWI is entering via damaged maintenance hole benching and isolated two sections of sewer mains north-east of SP0208.

SP0117

Source detection was undertaken at SP0117 from three maintenance holes using *SewCam* (Figure 13). Monitoring confirmed that the southern sewer main is most affected by SWI and eliminated two overflow weirs as SWI sources. Monitoring of one maintenance hole on the southern sewer main confirmed that SWI is isolated between SP0117 and this point. Ongoing CCTV investigation will focus on this section of sewer main in source detection investigation.

CONCLUSION

SewCam has been successfully used to identify SWI source at four Sydney Water SPS catchments. Traditional monitoring techniques using manual inspection, flow gauging and conductivity logging was replaced with *SewCam* monitoring. The benefits of *SewCam* are:

- Immediate identification of three point sources of SWI
- Decreased the time it took to identify SWI source from 4 weeks to 2 weeks
- Eliminated the need for confined space entries
- Reduced the average monitoring cost by 82%
- Reduced the average monitoring hours by 66%
- Provided better source targeting information for CCTV sewer main investigations

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Figure 12. Still frame from *SewCam* footage from SP0208 maintenance hole with damaged benching. Black arrow indicates where SWI is entering from under the benching and into the channel.

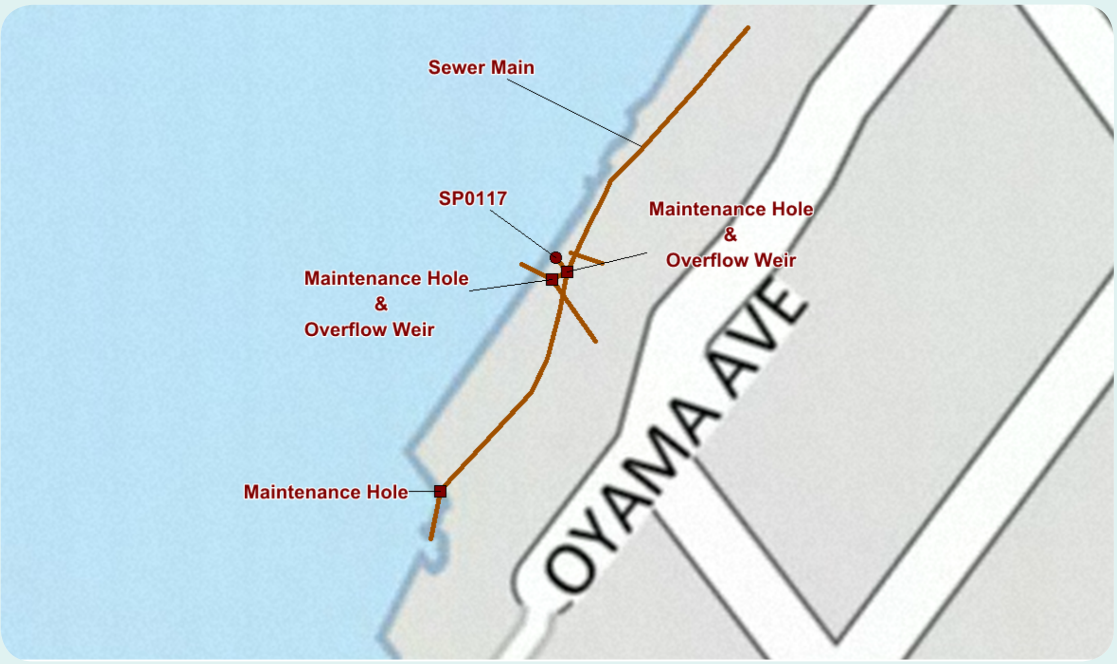

Figure 13. MapInfo layer marking the maintenance holes where SWI source detection monitoring was completed for SP0117. *SewCam* monitoring eliminated both overflows as a SWI source and confirmed that SWI is affecting the southern sewer main.

THE AUTHORS

Timothy Hill, Timothy has a degree in Environmental Science from Australian Catholic University. He joined Sydney Water in 2006 and has worked in analytical and field services for ten years. His focus has been around monitoring of environmental and waste waters in an assessment and reporting capacity. Timothy joined Network Services in 2016 working in Product and Business Programs and has been developing video monitoring capability to replace traditional monitoring techniques. His focus has been around the management of Saltwater Ingress, Silt, Pressure Main Contingency Planning and Emergency Response. Timothy is currently developing a program using drones for Water Sample Collection and Asset Inspections.

Jeremy Hearfield, Jeremy has a diploma of Water Operations specialising in Hydrography. He undertook a water operations trainee position with Sydney Water from 2009-2011 and has since worked as a Hydrographer. His main project roles have been the delivery of continuous monitoring of waste water assets, wet weather overflow abatement program, rainfall monitoring and special projects. Jeremy has been heavily involved with the design, construction, R&D and field rollout on the video monitoring device '*SewCam*'.

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