WATER INFRASTRUCTURE

Illegal discharges threatening urban water quality

A research project funded by the Water Research Commission (WRC) aimed to outline technically feasible and cost-effective procedures for detecting and removing illegal discharges into stormwater systems, and to provide guidance to municipalities tasked with controlling this source of water pollution. Article by Sue Matthews.

Polluted inflow from stormwater systems is the main cause of poor water quality in urban aquatic environments, but identifying the source of contamination is notoriously difficult. Where informal settlements occur in a drainage area, the lack of waste services and infrastructure typically means that sewage, greywater, solid waste and runoff all merge into one waste stream entering the stormwater system. But even in well-resourced areas, leaking sewers, blockages causing overflows, pump station failures and other inadvertent spills are major contributors to the pollution load, despite the fact that individual events may be intermittent or transitory. And then there are the deliberate illicit actions, such as connecting sewerage systems or factory floor drains to stormwater pipes, disposing of paint, used motor vehicle fluids and other wastes by pouring them down stormwater drains, as well as routinely discharging industrial effluent into the stormwater system.

Most of the above are illegal discharges, because according to municipal stormwater management bylaws in South Africa, no person without written consent from the Council may discharge – or permit to enter – anything but stormwater into the municipal stormwater system, with a few exceptions that include fire-fighting solutions and insignificant sources of pollution.

Municipalities are obligated to enforce the bylaws because the National Water Act requires that reasonable measures be taken to prevent substances other than stormwater from entering any stormwater drain or watercourse. Furthermore, waste and wastewater discharge and disposal into a water resource require a licence unless permissible under Schedule 1 of the Act or a General Authorisation, in which case particular limits and conditions apply. Effluent discharge into estuaries and the sea is also subject to the Coastal Waters Discharge Permit Regulations issued under the Integrated Coastal Management Act. All of this means that municipalities are accountable for the end-of-pipe discharge from their stormwater systems.

Locating individual pollution sources and tracking down transgressors of the law is easier said than done though, particularly since stormwater systems often have vast drainage areas, and most of the infrastructure is underground. Recently, a research project funded by the WRC aimed to provide guidance to municipalities by developing cost-effective procedures for what is widely known as IDDE – illegal discharge detection and elimination – in stormwater systems. The project was awarded to the Cape Peninsula University of Technology, with senior lecturer in the Department of Civil Engineering and Surveying, Yaw Owusu-Asante, leading a team of undergraduate and postgraduate students.

Discharges in informal settlement are typically diffuse, chronic and pervasive due to physical, institutional and socio-economic factors, and cannot be addressed through the normal municipal enforcement process.

The research began with a review of international literature, which revealed a key factor for successful implementation of IDDE programmes, especially pertinent to municipalities operating with limited resources and expertise. "An effective IDDE programme is founded on one basic principle," notes Owusu-Asante. "It ought to progress along a hierarchy of locations and procedures, commencing in higher potential risk areas in a catchment before moving to lower risk areas, and from using desktop assessment through to exploratory techniques and then confirmatory procedures."

Methodologies were therefore developed for each of these stages, and applied in a local case study to verify their feasibilities and challenges. Cape Town's Diep and Kuils River catchments were used for the case study, because they include the entire spectrum of land uses, socio-economic variations and housing types found in typical South African cities, and were ranked most vulnerable to pollution and of high priority for management intervention in a 2011 study undertaken for the municipality by PDNA. Guidelines were also provided for corrective measures to remove illegal discharges – the 'elimination' component of an IDDE programme – but these could not be tested given that the research team had no jurisdiction to access business properties for inspection purposes.

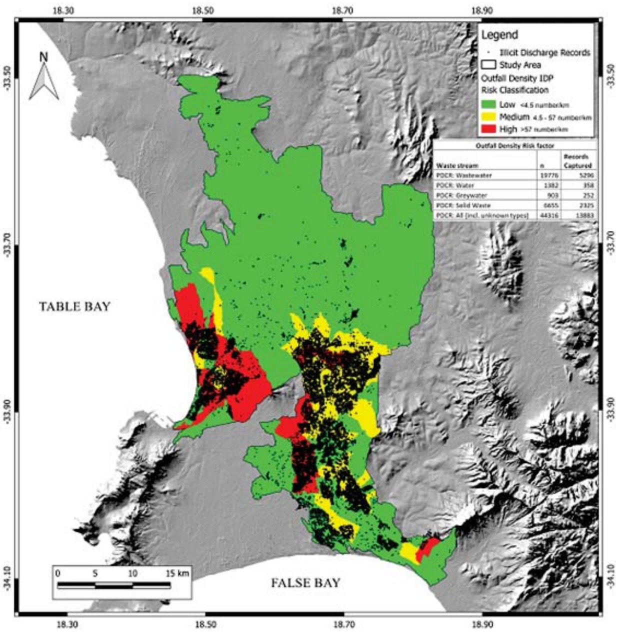
Risk mapping

The first stage of the recommended IDDE programme is a desktop assessment, which relies on existing datasets, reports and anecdotal information, along with maps showing stormwater and wastewater systems, as well as land uses or zoning. The research team used ArcGIS to compile all this data into spatial layers, each representing one of the 10 risk factors selected for the study – residential, commercial and industrial land use, population density, development age (or age of stormwater infrastructure), outfall density, aging sanitary infrastructure, drainage density, density of potential generating sites (fuel stations, restaurants, industrial plants and other facilities) and infrastructure access density (the number of access points to the stormwater system per square kilometer).

First, however, the risk factors were subject to a metric ranking process incorporating statistical analyses, so that each could be represented as low, medium or high risk of occurrence of illegal discharge. For population density, for example, areas with less than 580 people per square kilometre were classified as low risk, while those with more than 2 052 people per square kilometre were considered high risk, with anything in between falling into the medium risk category. In the case of the outfall density risk factor, sub-catchments with an average of less than 4.5 outfalls per kilometre of stream were classified as low risk, while those with an average exceeding 57 outfalls were considered high risk.

These individual spatial layers were each overlain by a spatial layer representing complaints records of past discharges, differentiated into four types – water, greywater, wastewater and solid waste. This allowed the risk factors' performance in predicting the occurrence or location of each type of illegal discharge to be tested through statistical analyses. The risk factors' relative 'weights', or importance in predicting the risks, were then determined and used to derive a composite score for each sub-catchment.

Tony Carnie



The spatial layer for outfall density illegal discharge potential, showing high (red), medium (yellow) and low (green) risk levels, overlain by records of illicit discharges (black).

These sub-catchment scores were in turn used to produce composite maps for the Kuils and Diep River catchments for each of the four types of discharge, as well as for the combined discharge. The maps revealed that illegal discharges were concentrated in areas with high population and drainage densities, probably because they provide more opportunities for illegal connections, dumping and spills to enter the stormwater system. Commercial areas seemed to have a higher risk of all four types of illegal discharge than the other categories of land use. Interestingly, development age and aging infrastructure did not appear to influence the locations of illegal discharges.

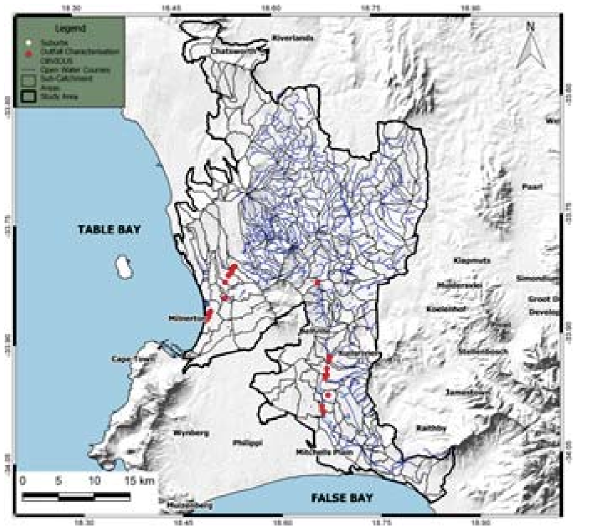
"This was a surprise because older developments occur in both the Diep and Kuils River catchments, and illegal discharges associated with failing infrastructure were expected," says Owusu-Asante. "The reasons for these weak associations could be attributed to infrastructure upgrade and replacement in recent times. Also, massive new developments may have masked the effects of aging infrastructure in the older parts of the catchments."

Outfall inspections

The desktop assessment and the resulting map would enable municipalities to prioritise high-risk areas when conducting the subsequent stages of the IDDE programme, beginning with the detection of illegal discharges at outfalls and monitoring of flow types. Initially, though, all outfalls should be inventoried as part of a screening run, so the research team set out to inspect every outfall within the metro area that discharged directly into the Diep and Kuils Rivers, or anywhere within their riverine corridors. This fieldwork was done at least 48 hours after runoff-generating rainfall to ensure that only non-stormwater flows were detected.

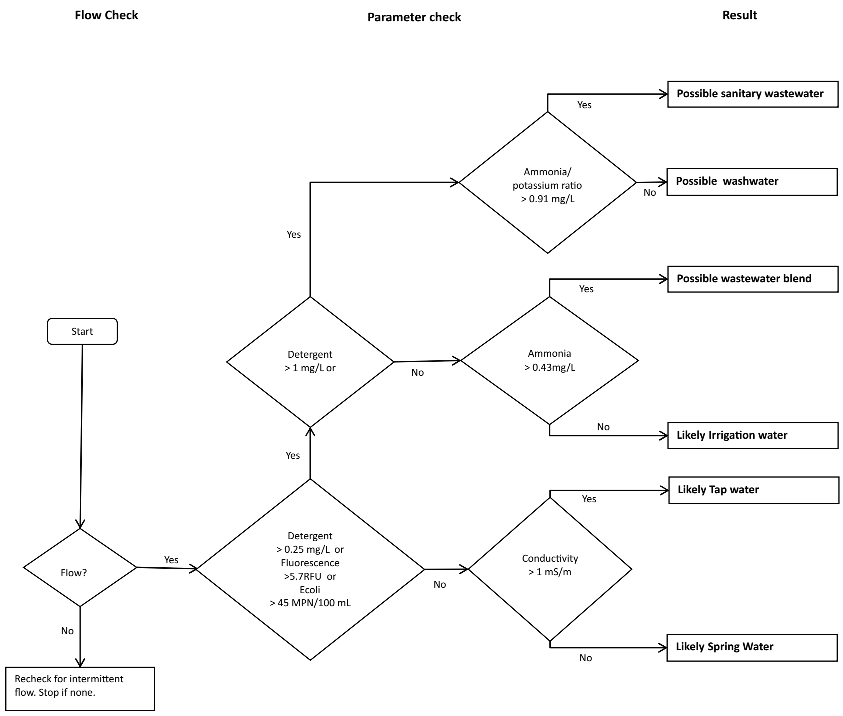
Using the City of Cape Town's stormwater plans as field maps, the team members walked along the rivers and located just under 200 outfalls. Non-stormwater flows were observed at over half of these – in fact, 21% had substantial flows exceeding 5 ℓ/s. All flows were sampled for laboratory analyses, and a comprehensive inspection form filled in to record the details of each outfall. This included any notes about the colour, odour or turbidity of the flow, as well as evidence of toilet paper, faecal matter, detergents, oil or grease, and excessive plant growth.

Since these observations and the physico-chemical parameters measured in the samples might not be sufficient to identify the type of discharge at the outfalls, samples of tap water, spring water, irrigation water from sprinkler runoff, car wash and laundry wastewater, four types of industrial effluent, and raw sewage inflow at a wastewater treatment works were also analysed so that a 'fingerprint library' could be developed. The analytical data were used to create box and whisker plots that allowed the various flow types to be identified. For example, the ammonia/potassium ratio for sewage was found to significantly different when compared to all the other flow types, while irrigation waters could be distinguished from sewage and wash-waters by ammonia, detergent and turbidity, and tap water and spring water could be differentiated on the basis of conductivity. However, detergent proved to be the parameter with the best overall potential as an indicator of illegal discharges because it classified all flow types.



The research team identified outfalls where illegal discharges were obvious, based on a screening inspection of outfalls in the Diep- and Kuils River, as well as laboratory analyses of outfall and reference samples.

Using this information, the research team developed a flowchart as a decision-making tool for identifying illegal discharges specific to Cape Town. This would ideally allow outfalls to be prioritised for long-term monitoring, but security concerns and the project's time constraints meant that two outfalls – both receiving discharges from Du Noon informal settlement in the Diep River catchment – were selected for intensive monitoring over a period of seven days. At these outfalls, a flow meter logged flows at 10-minute intervals, while an automatic water sampler installed in a nearby manhole collected samples at one-hour intervals. The monitoring results revealed that the discharges were mainly sewage, and most likely due to illegal connections to stormwater system drains.



A flowchart was developed as a decision-making tool to identify illegal discharges in Cape Town.

Source tracking

The next stage in the IDDE programme involves isolating or tracing the source of illegal discharges. This could be conducted if an illegal discharge has been detected through an outfall inspection, or even if a complaint has been received about a persistent problem. A combination of techniques might be needed to find the source, such as inspecting manholes, damming the flow with sandbags, using dye or smoke tracers, and conducting CCTV inspections of stormwater pipes.

The research team had already established that the discharges in the Du Noon informal settlement were diffuse, chronic and pervasive due to physical, institutional and socio-economic factors. Since it was recognised that the 'National strategy for managing the water quality effects of settlements' and supporting operational guidelines (DWAF, 1999) remains the most appropriate approach for dealing with such pollution, an alternative area was sought for the case study.

"For reasons including project time, budget constraints, safety and security, it was recommended in the Project Reference Group meeting that the source tracking investigations should be focused mostly in industrial and commercial areas," says Owusu-Asante. "Again, as there are no established legal authority to enable the research team to undertake inspection and monitoring at private and business properties, it was further recommended that the source tracking investigation should be confined to public roads that are accessible to the research team. In essence, this translated to tracing sources to segments of pipe mains rather than to the very sources where the discharges originate."

The investigation identified certain drainage areas and segments of the stormwater system that would allow the sources of illegal discharges to be pinpointed, if followed up by municipal staff. Apart from sewer overflows, the research team found evidence of dairy waste discharges and wash-water effluent from car wash centres.

Corrective action

The ultimate goal of an IDDE programme is to remove illegal discharges, and a mix of education and enforcement is the most common and cost-effective way of achieving this. Generally, a municipality would begin the enforcement process only if education has failed to achieve the desired outcome. The first step would be to send a summary letter to the property owner, explaining the problem and requesting that corrective measures are implemented within a specific time limit. Follow-up action, such as issuing summons and fines, would proceed in the event of non-compliance.

Sometimes, simple plumbing projects are all that is required to correct a problem, but others involve major excavation works and structural modifications, done by certified contractors with specialised equipment. Where the property owner fails to take corrective action even after the enforcement process has been completed, the municipality would be entitled to commission the work and recoup the costs from the property owner in accordance with the polluter pays principle.

Owusu-Asante points out that the research project provided a good starting point for a systematic methodology for detecting and removing contaminated discharges to urban watercourses, but there is a need for similar IDDE studies in other municipalities.

"A benchmarking survey of these future studies would result in an improved guidance manual that integrates results and other knowledge gained," he says. "More work is also needed to better quantify the pollutant removal and costs associated with correction of illegal discharges, to evaluate the effectiveness of proactive prevention strategies that rely on systematic inspections of the system rather than outfall monitoring and tracking, and to develop improved strategies for tracking down and eliminating these discharges."