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Newsletter

Pathways to water resilient South African cities (PaWS) project

Integrated water quality management for a water sensitive and resilient city

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This newsletter presents key results of ongoing water quality studies and monitoring taking place at a stormwater infiltration site in Mitchell's Plain, as part of the 'Pathways to water resilient South African cities (PaWS)' project. Recognising that water quality is not an isolated consideration in interconnected urban water systems – that also include treated effluent-fed rivers and stormwater infiltration to shallow groundwater discharge, sewer overflows, and effects of overburdened wastewater treatment plants – our upcoming webinar will also include speakers with great depth of knowledge on broader water quality issues in Cape Town.

This issue

Benefits and limitations of nature-based water quality improvement interventions

About the project

The 'Pathways to water resilient South African cities (PaWS)' project is a collaboration between UCT's Future Water Institute, and the University of Copenhagen, funded by Danida MFA. Drawing on physical experiments and governance and social processes, it explores the potential for existing flood attenuation infrastructure to be adapted towards water resilient cities (read more here).

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Introduction

Cape Town has committed to becoming a Water Sensitive City (WSC) as part of its 2019 Water Strategy to create a more sustainable and resilient water future. This strategy includes expanding stormwater infrastructure, diversifying water sources, and embracing alternative water solutions such as water reuse, desalination and groundwater recharge.

One innovative approach being explored is stormwater harvesting, with research showing that storing this water underground, e.g.in the Cape Flats Aquifer (CFA), is potentially more efficient than using traditional surface water storage options (Okedi 2016). But how can we maximize this potential whilst also ensuring that negative effects on groundwater quality are avoided?

Urban stormwater infiltration plays a crucial role in sustainable water management, but its effects on groundwater quality are complex and require further study. Research worldwide has shown that infiltration can alter groundwater biogeochemistry, yet the extent and duration of these changes remain uncertain. This newsletter highlights key insights from a detailed two-year study and subsequent monitoring at a stormwater infiltration site over Cape Town's Cape Flats Aquifer.

Understanding stormwater contaminants

Stormwater carries various pollutants, including total suspended solids, nutrients (such as nitrogen and phosphorus), organic carbon, trace elements (cadmium, copper, lead, etc.) and trace organics (also called contaminants of emerging concern, CECs). These contaminants exist in both dissolved and suspended forms, with the dissolved phase posing a greater risk to groundwater quality. Research indicates that stormwater infiltration can influence the chemical composition of groundwater, including changes in the composition of dissolved salts and shifts in oxidation-reduction conditions.

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Key factors affecting groundwater quality

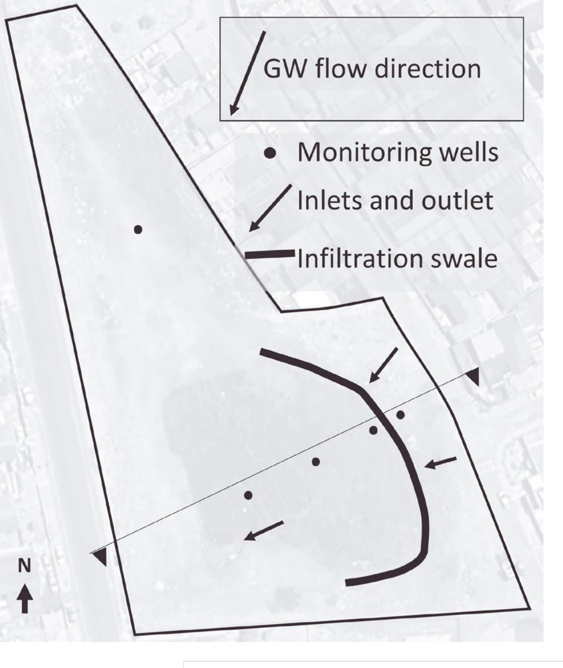
Several factors influence how stormwater infiltration could affect groundwater quality:

- **Soil and aquifer material:** Soil can both retain solids and contaminants and leach different chemicals and elements leading to changes in groundwater chemistry. Aquifer material can interact with the infiltrating water and changes in the geochemical conditions can lead to mobilisation of certain elements such as arsenic.
- **Oxygen levels & microbial activity:** Organic carbon in stormwater stimulates microbial processes which consume dissolved oxygen and can result in denitrification. Prolonged low oxygen conditions can lead to mobilisation of other elements.
- **Groundwater depth:** The thickness of the unsaturated soil layer as well as the soil composition influence the rate of groundwater recharge and determine how contaminants travel through the system and what biogeochemical transformations occur during infiltration.

Study site description

The study site is one of over 200 existing detention (mostly dry) stormwater ponds overlying the CFA, located in a low-income formal residential area of Mitchell's Plain, Cape Town, South Africa. This pond has been retrofitted with a low-cost, low-tech infiltration swale built together with local residents using sandbag technology. The resultant enhanced infiltration of stormwater, as well as the planting of indigenous species and a 'no-mow' strategy, has seen the site develop into a thriving wetland ecosystem.

The 90-meter-long infiltration swale runs along a contour in front of two inlets on the eastern side of the site, positioned at an elevation 1 meter higher than the centre of the pond. Covering a surface area of 9,950 m² and reaching a depth of approximately 3.1 meters at its centre, the site collects stormwater runoff from a 170,600 m² catchment area. Water flows into and along the swale where it is allowed to infiltrate and is retained to a design depth of 300 mm before overflowing via weirs at both ends. Stone riprap at the inlets and rock check dams within the swale help slow the flow, capturing litter and sediment. An excavated trench at the southern side of the site leads to the stormwater outlet rom where water flows into the piped stormwater network.



Groundwater levels and stormwater flows

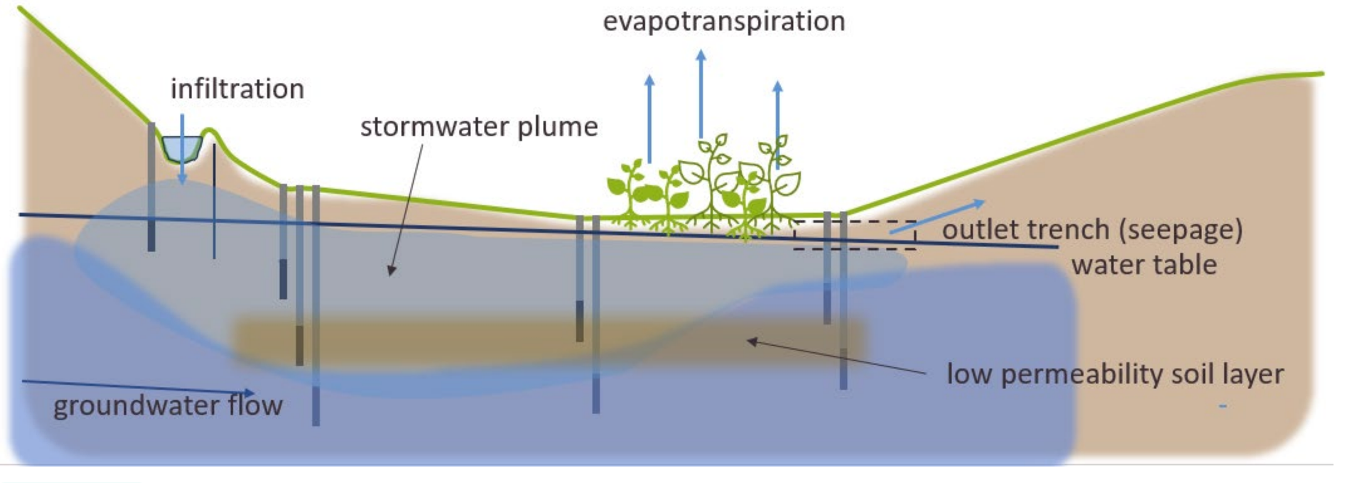
This site has shallow groundwater levels which ranged from 0.65 m below ground level and ground level in the central part of the basin over the monitoring period. The infiltration swale is elevated and the depth to groundwater below the swale ranged between ground level and 1.4 m below ground level. As can be expected the groundwater levels are lowest at the end of summer before the rainy season, and highest in the mid-to late wet season.

Water flows continuously into the piped stormwater network from the excavated trench and outlet during the late wet season and even into the summer months until the groundwater levels subside. This means that groundwater discharges into the stormwater network for part of the year. There is about 1 m elevation difference between the infiltration swale and the groundwater level at which the water will seep out of the soil into the outlet trench. Even when net stormwater infiltration (i.e. creating conditions for stormwater harvesting) is not possible due to elevated groundwater levels, stormwater infiltration and/or filtration can occur.

Stormwater and groundwater quality

Stormwater entering the system was found to have lower concentrations of electrical conductivity (EC), nitrate, and chloride than the background groundwater during monitoring. In contrast, the stormwater exhibited higher dissolved oxygen (DO), total organic carbon (TOC), ammonium, phosphorus, zinc, copper, and aluminium. Importantly, background groundwater has a much higher nitrate concentration (~15 mg/L as N) than the incoming stormwater.

The stormwater and groundwater were screened against a database of over 520 organic chemicals including pharmaceuticals, pesticides and other compounds as well as possible degradation products. There were 29 compounds in stormwater, 16 in the background groundwater, and 27 compounds near the infiltration swale. Concentrations of a target list of trace organics were monitored over one year. Acetaminophen (paracetamol), benzotriazole (antifungal), caffeine, and methaqualone (mandrax) were detected at the highest concentrations in both stormwater and groundwater.



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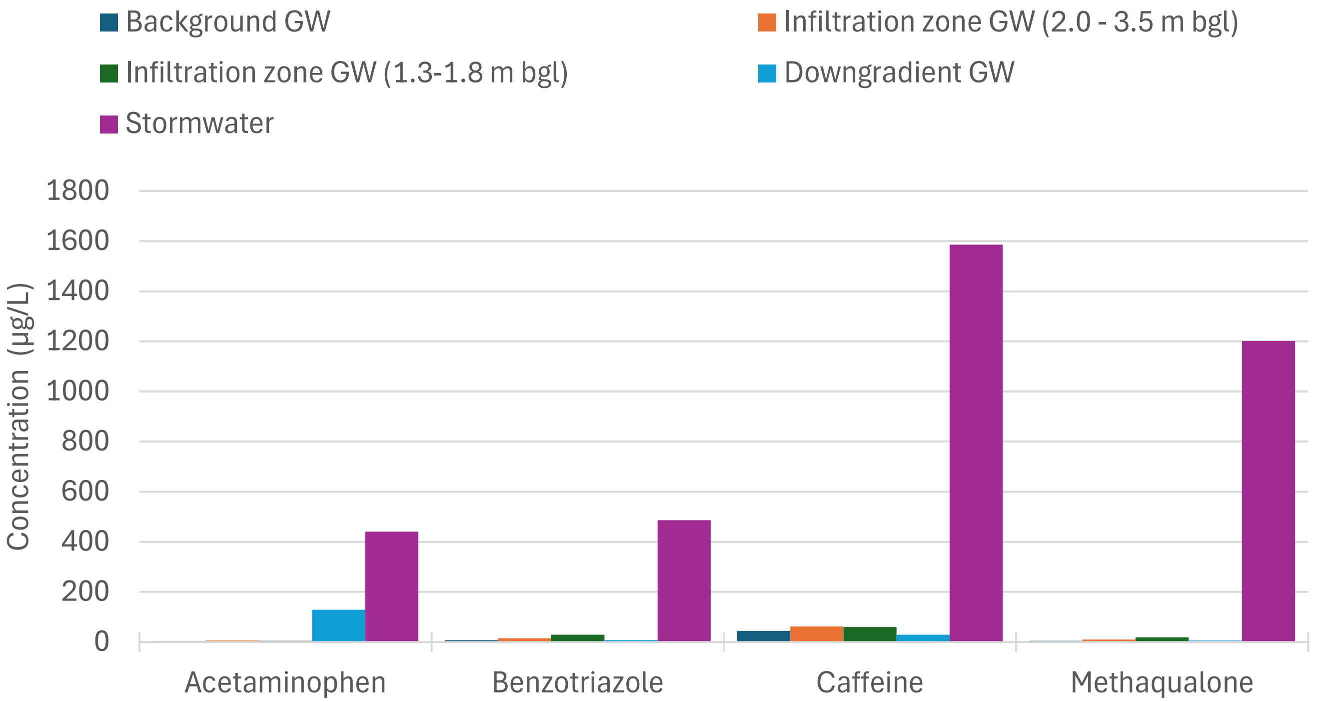
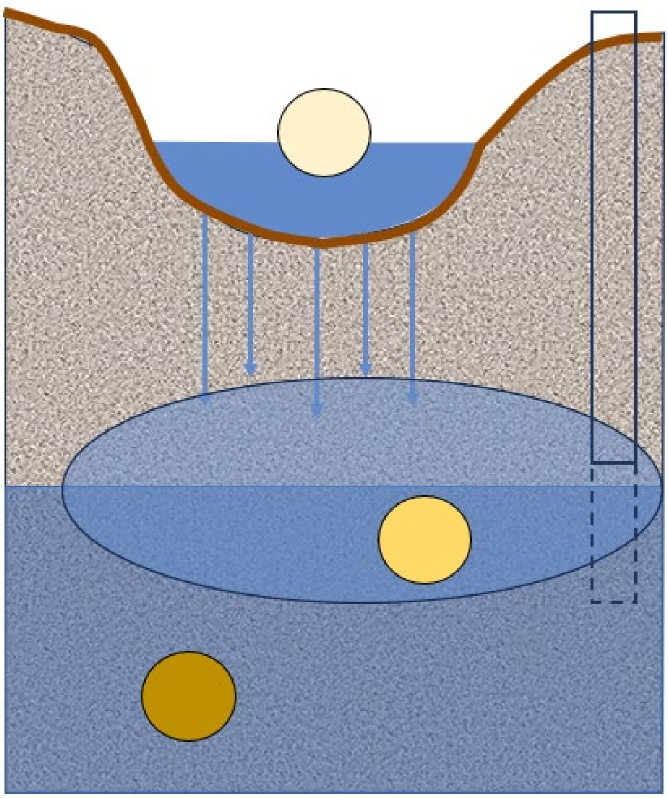


Median concentrations of selected CECs in stormwater and groundwater

Water quality treatment during infiltration

Chloride concentrations were used as a tracer to estimate the reduction in contaminant concentration during infiltration after accounting for dilution/mixing. This was possible because the chloride concentration in the stormwater was much lower than that in the groundwater, and the concentration in shallow wells after infiltration could be used to estimate the stormwater/groundwater mixing ratio. Ammonium, TOC, total dissolved phosphorus (TDP), aluminium, and zinc showed removal rates between 83-92%. The stormwater's dissolved oxygen (DO) was reduced by 54% during infiltration, and the nitrate concentration in the background groundwater was reduced by 13-74%, indicating denitrification in the shallow aquifer.



Stormwater quality at the outlet

Stormwater sampled at the outlet had lower concentrations of nutrients, TOC and all detected dissolved elements except manganese, iron, and nickel. There was visual evidence of iron and manganese precipitating out in the outlet trench after exposure to air. In August and September 2024 groundwater levels were very high across the site, with visible seepage of groundwater in the northern part of the site. The concentration of nitrate in the outlet was low for most of the monitoring period, however during the period of highly elevated groundwater levels, nitrate concentrations in the outlet were elevated (~2 mg/L) presumably originating from the groundwater. A flow measurement weir was constructed in 2024 resulting in some pooling of water behind the weir when the groundwater table is high.

Key Findings:

- Stormwater quality in this catchment is typical of a residential area
- High nitrate concentration in the groundwater (~15 mg/L as N)
- Lower nitrate levels below infiltration and wetland area (~ 5 mg/L as N)
- Evidence of denitrification in shallow infiltration area after stormwater infiltration
- Evidence of substantial contaminant removal during stormwater infiltration (TOC, ammonium, phosphate)
- CECs detected in both stormwater and groundwater but with much higher concentrations in stormwater
- Initial findings show no deterioration in groundwater quality from infiltration of stormwater

Future research and questions:

- Exploring the groundwater microbiome
- Understanding the soil's capacity for phosphate retention under both oxidizing and reducing environments
- Stormwater quality variations over time and space
- Determining the limitations of nature-based solutions for water quality improvement and what role they can play in a water resilient city

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Until the next edition……..

For reference:

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