Waste Food-Energy-Water Urban Living Labs - Mapping and Reducing Waste in the Food-Energy-Water Nexus: a case study of the Water Hub Urban Living Lab, South Africa

WASTE FEW ULL is a Belmont Forum funded international team of researchers and stakeholders aiming is to develop and test internationally applicable methods of identifying inefficiencies in a city-region's food-energy-water nexus. The team consists of an international network of industry/civic society-led Urban Living Labs (ULL) in four urban regions - UK (Bristol), Netherlands (Rotterdam), South Africa (Cape Town) and Brazil (São Paulo). START is supporting University of Cape Town in the Belmont Collaborative Research Action.

websites links: www.futurewater.uct.ac.za www.thewaterhub.org.za

Background information

Informal settlements in South Africa are generally established on land that is unsuitable for a housing development because these settlements are often located on floodplains and low-lying areas that are at risk of seasonal flooding. In South Africa, the development of Informal settlements in peri-urban areas of cities and towns is partly explained by rapid urbanisation and population growth, but mainly because unjust Apartheid laws that were used to control land ownership and movement of people based on racial classification. The institution of Apartheid was finally dismantled after the country's first democratic election in 1994, but the consequences of pursuing discriminatory laws of separate development remain and have become intractable. Despite significant political change, there is increasing evidence of inequality, inequity and conflicts that is observed particularly in securing land ownership and access to public services including water and sanitation systems. It is estimated that between 4 and 5 million people currently reside in informal settlements in South Africa.

Residents in informal settlements have limited access to what is known as basic sanitation and water services, but these facilities are often limited, dysfunctional at best, and most often pose a health and safety risk. In addition, formal stormwater drainage systems are seldom provided, and this leaves residents with little choice other than to dispose their unwanted water in the vicinity of their dwellings resulting in the discharge of contaminated water into nearby rivers or wetlands without any treatment.

The WASTE FEW ULL project aims to develop a deeper knowledge and understanding of treatment of water and the recovery of resources can be used as a catalyst for the recovery and reuse of nutrients and minerals for multiple co-benefits. This project builds on existing research work in using nature-based processes to clean and treat contaminated surface water runoff from an informal settlement. The urban living lab (ULL) is situated approximately 80km east of Cape Town on the site of an abandoned wastewater treatment plant. It is now referred to as the Water Hub and is being converted into a research and innovation centre. The first experiments were designed to treat water by using large cells that were filled with different natural media - stone aggregates and peach pips - placed into six large cells each being 40m^3 in volume. Approximately 50 000 to 80 000 litres of water are treated every week and used for irrigating food gardens with water qualities that comply with South African guidelines for irrigation. Thus far the study has identified different bacterium and microbial species that accumulate in the biofilm of these biofilters. What has surprised us is the ability of these nature-based filters to reduce extremely elevated nutrient concentrations to an acceptable quality: Total Nitrogen reduction between 65 and 85%; Total Phosphorous between 70 and 90%; and *Escherichia coli* bacteria reduction between 90 and 100%. The achievement of these and other results will help to advance the rationale for nature-based solutions (NbS) in Africa in the use of low-cost green infrastructure that can operate with a low energy demand, are simple to construction, and can be operated and managed at low cost with limited skills.

The site and situation of the Water Hub is also showcasing the benefits of decentralised systems and services. An important purpose of the ULL is to explore how resource-based circular economies have the potential to improve the livelihoods of the urban poor and to identify innovative pathways for transitioning to a more sustainable and equitable society. The ULL has potential to unlock multiple benefits that flow from the productive use of water, and its interconnection with food, energy and waste, and to achieve this in a collaborative effort involving researchers, stakeholders, social enterprises, community and government officials.

Research Aim

The aim of this project is embedded in a context as described above that could be labelled as a 'wicked problem'. It will be extremely disappointing if we are unable to shift from the acceptance of a wicked problem to a more sustainable and acceptable position. Thus, the aim of this project is to determine **how** a decentralised nature-based resource recovery centre (ULL) can support a transition toward a circular economy whereby critical natural resources and sustainable waste management are used to unlock multiple co-benefits and prioritises the inclusion of the urban poor. Thus far the research effort has established the potential to use NbS as an appropriate means for treating contaminated water and safe reuse of this water for irrigation and soil care. Next, and probably the most challenging part of the research project, is to learn how to co-develop an enabling environment for stakeholders and researchers to advance the transition towards a more desirable outcome in which waste recovery is integrated into the Food, Energy and Water nexus.

The overall aim is addressed by attending to three main themes in the study: (a) an analysis of the efficiency of nature-based processes in treating contaminated surface water from an informal settlement and safe reuse for irrigating food gardens; (b) a determination of the co-benefits of water reuse and resource recovery by incorporating stakeholder interests and perceptions; and (c) the development of indicators to inform an assessment tool for the purpose of guiding and directing governance and policy to achieve more circular economy in the Franschhoek valley.

The objectives are:

(a) To analyse the performance of NbS in the treatment of contaminated water and the safe reuse of this water;

(b) To map stakeholder interests, agency, levels of involvement and potential to establish partnerships;

(c) To co-develop a more inclusive sustainable, circular economy using a framework and assessment tools to determine baseline conditions, processes, and targeted outcomes, and to test elements of the tool as proof of concept.

Frameworks

The conceptual understanding of the project is informed by two frameworks. The first framework is used to consider how technical solutions are integrated into social and institutional solutions. A systemic adaptive system (ASA) positions water resources and services (SDG 6) with every other SDG in a complex socio-ecological system. Central to the conceptual framework is the notion that participatory governance and policies are crucial for building and supporting adaptive capacity toward better land, water and ecosystem regeneration and protection (Figure 1).

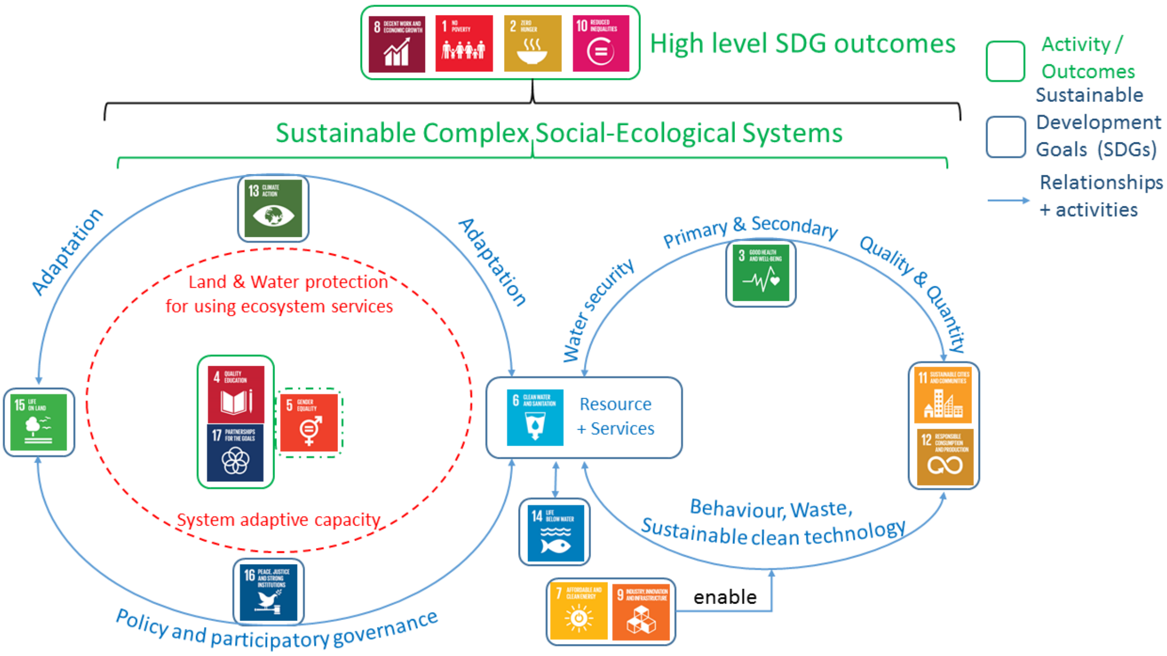


Figure 1 Overview of the Adaptive Systemic Approach (ASA) (ARUA, Centre of Excellence for Water, 2019).

The second framework is designed to develop the ASA further by incorporating nature-based solutions both as a technical response to addressing the problem of contaminated water and with a social and ecological purpose. The framework incorporates an assessment tool that is information in combination of collaboration with stakeholder and knowledge from the research literature. The NbS framework addresses the questions of how NbS can unlock multiple co-benefits that advance a transition toward a circular economy, and in the South African context, toward a more just, sustainable society (Figure 2).

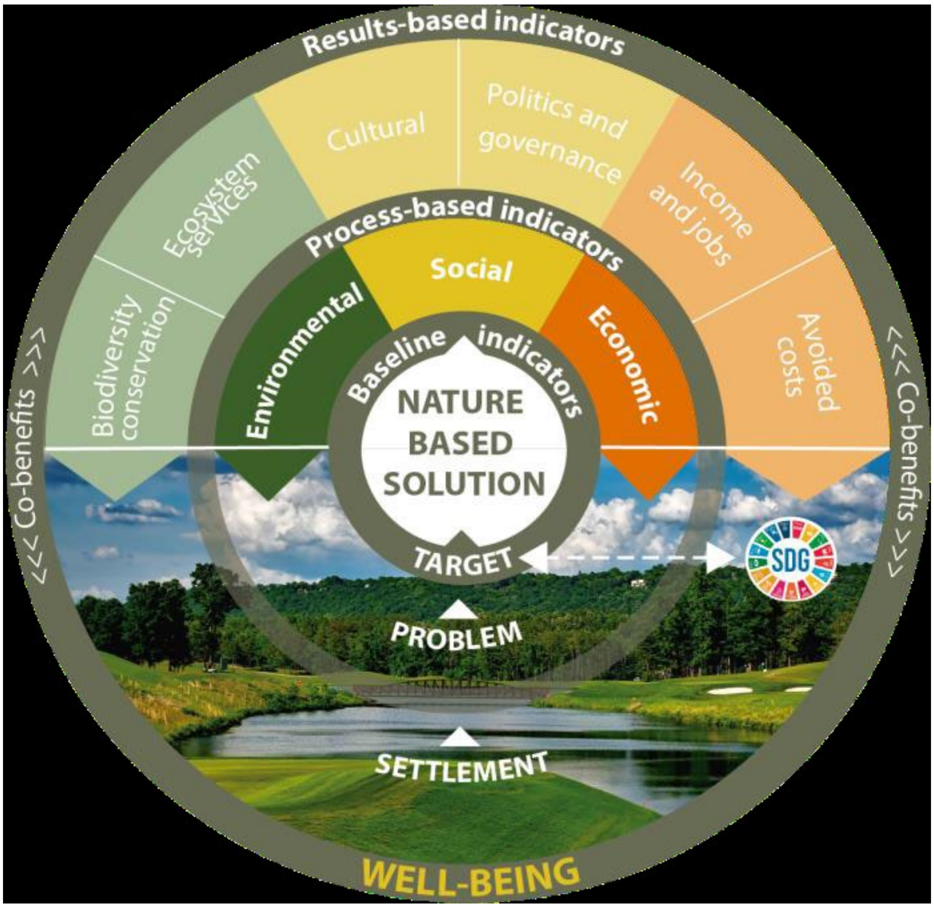


Figure 2 The conceptual framework that will be used to assess nature-based solutions (Latawiec et al., 2020).

Case study

The experimental site at the Water Hub was established on an old, abandoned wastewater treatment plant about 3km west of the formal town of Franschhoek, and less than 800m downslope of a low-cost housing estate and informal settlement. The separation of the formal town of Franschhoek, and the lower income settlement reflects the spatial divisions that were established during the Apartheid era and remain as such.

Franschhoek Valley in the Berg River Catchment

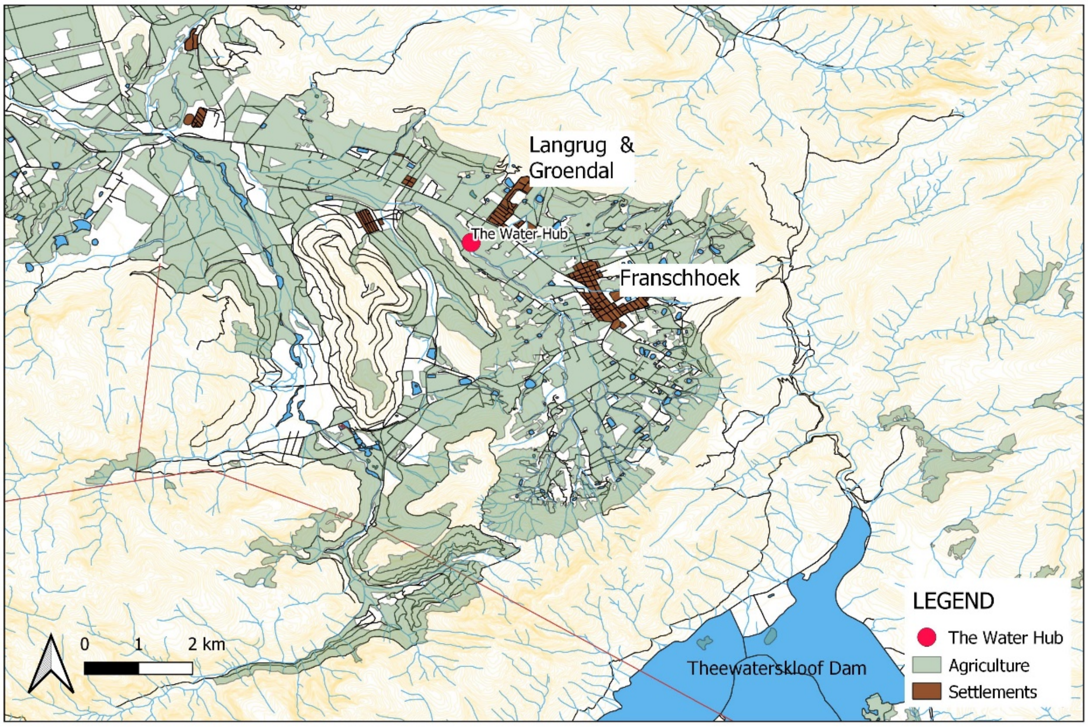


Figure 3 Land use and settlements in the Franschhoek valley.

The Stiebeuel River catchment drains an area of about 4.69 km^2 and discharges into Franschhoek River (Figure 4). The river originates in the Hawequas mountains and flows alongside the Langrug informal settlement with an average gradient of 1:12 (Armitage *et al.*, 2009). The first shack dwellings were erected in 1993. It now consists of densely packed structures that are made from materials such as corrugated iron, wood, plastic sheeting (Armitage *et al.*, 2009).

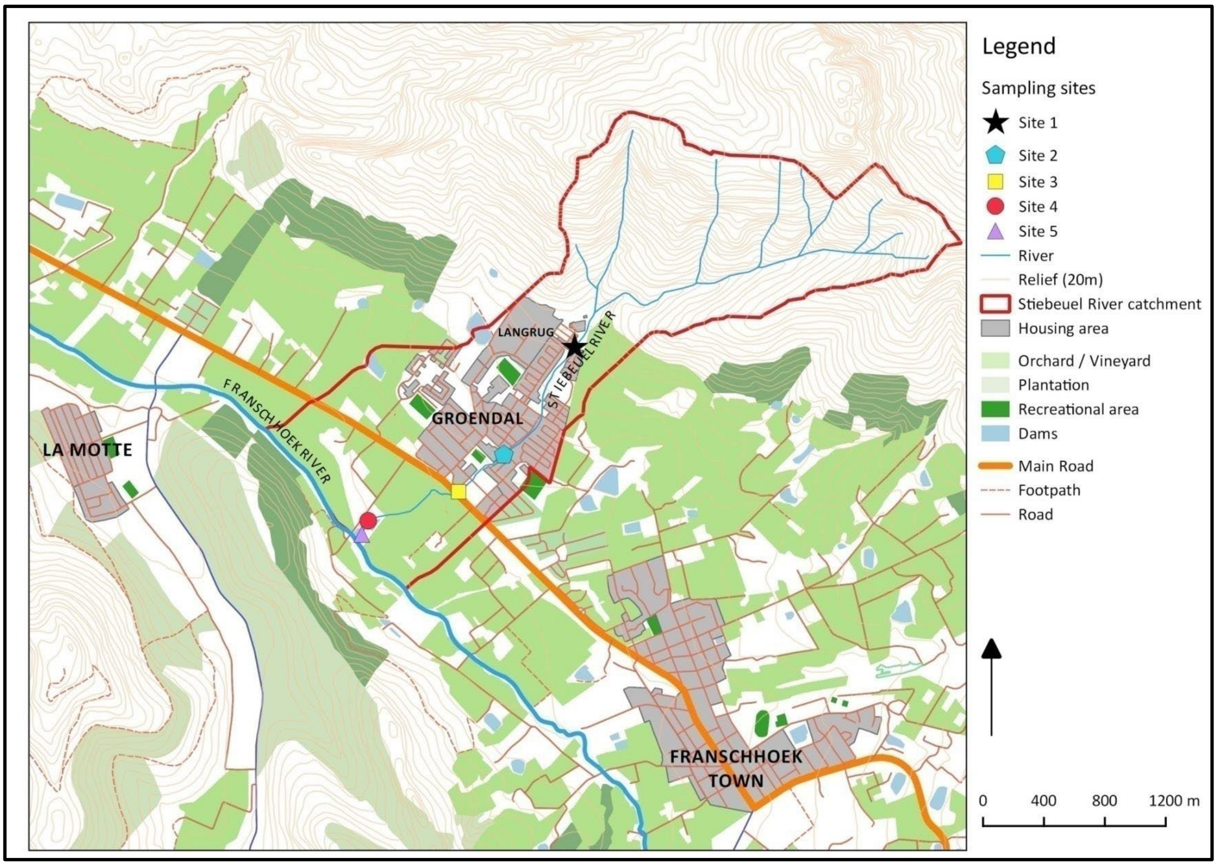


Figure 4 Stiebeuel catchment and location of the Water Hub.

Most of the population in Langrug informal settlement have moved come from rural parts of the Eastern Cape Province of South Africa. In early 1990s, people moved to this area seeking seasonal work in the agriculture sector. A visible Landsat 8 image shows that the expansion of informal settlement from 2001 to 2020 in which the footprint has doubled in size (Figure 5). According to the Stellenbosch municipality, in 2018 the total population of the informal settlement was 4 864, with a total of 1 807 shack dwellings and 150 waterborne communal toilets shared among the entire population (Stellenbosch Municipality Annual Report, 2018).

The Water Hub and surrounding: Visible Landsat 8 Image (USGS 05/12/2020)

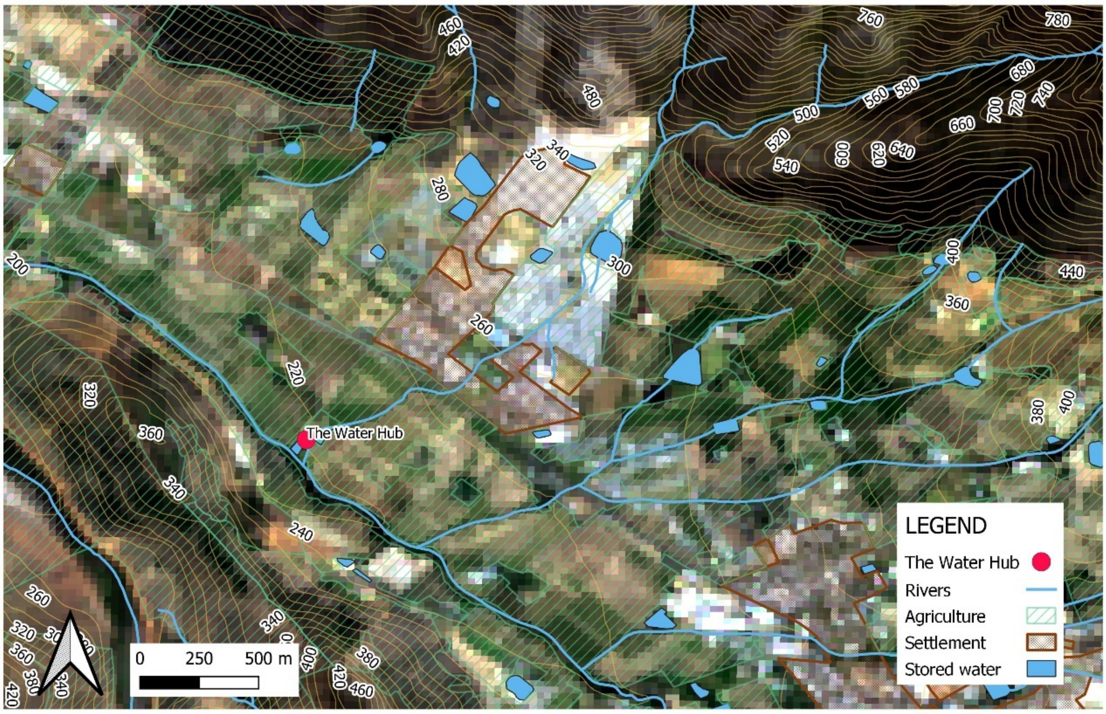


Figure 5 Expansion of Langrug informal settlement and RDP housing estate in Mooiwater to the east. The vector layer shows the extent of the built environment in 2001. Landsat 8 image shows the expansion in a lighter hue in December 2020 (Source: USGS Earth Explorer)

Most of the work thus far has focused on surface runoff flowing from the Langrug informal settlement (Figure 6). Elevated concentrations of nutrient runoff, microbiological and other emerging pollutants are transported as surface water and via stormwater to discharge contaminated water as greywater and blackwater into the Stiebeuel River.

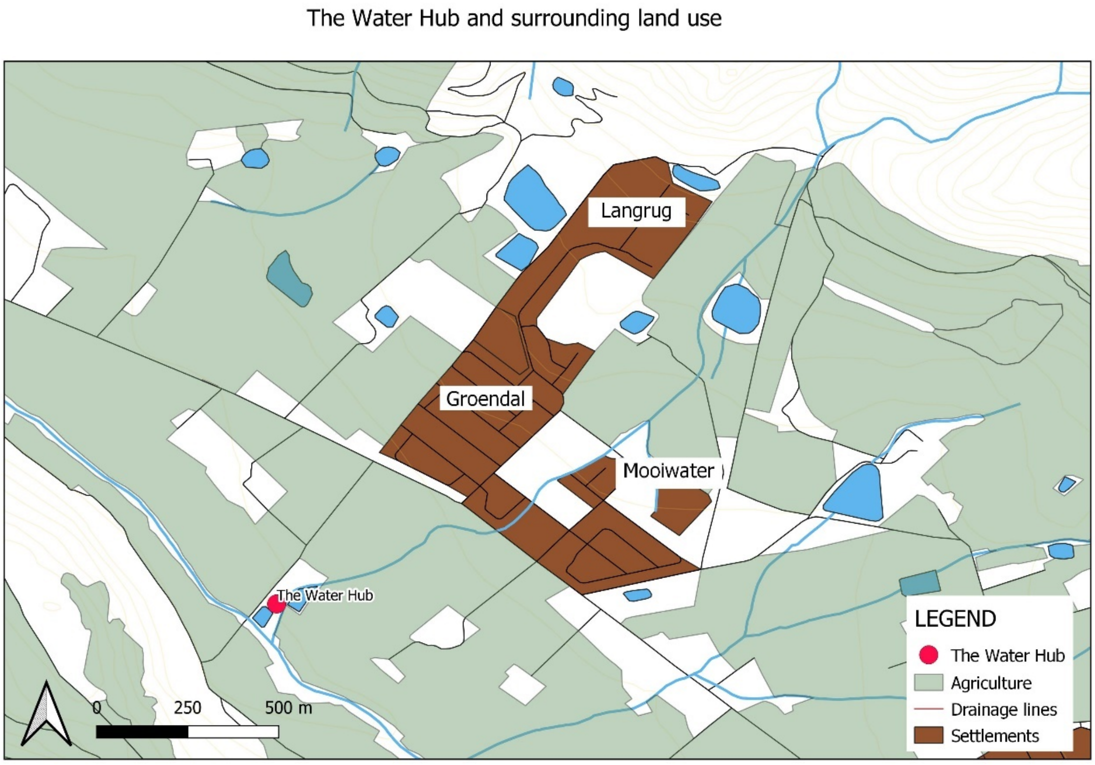


Figure 6 A enlarged map of the settlements and proximity of the Stiebeuel River and its discharge at the confluence of the Franschhoek River.

The site of the Water Hub was initially chosen to conduct experiments on how nature-based processes could degrade high concentrations of nutrients and to consider how treated water could be reused for other purposes. The work began by converting existing infrastructure into constructed wetlands, biofiltration cells and treatment trains to conduct controlled experiments. The site is approximately 2.7 ha and is surrounded by neighbouring vineyard farms that produce wine for local and export markets. The Department of Environmental Affairs and Development Planning, Western Cape Government, provided a seed fund to refurbish a small section of infrastructure on the site. The University of Cape Town Future Water research institute has taken the initiative to use the site for conducting a series of multidisciplinary research projects (Figure 7).

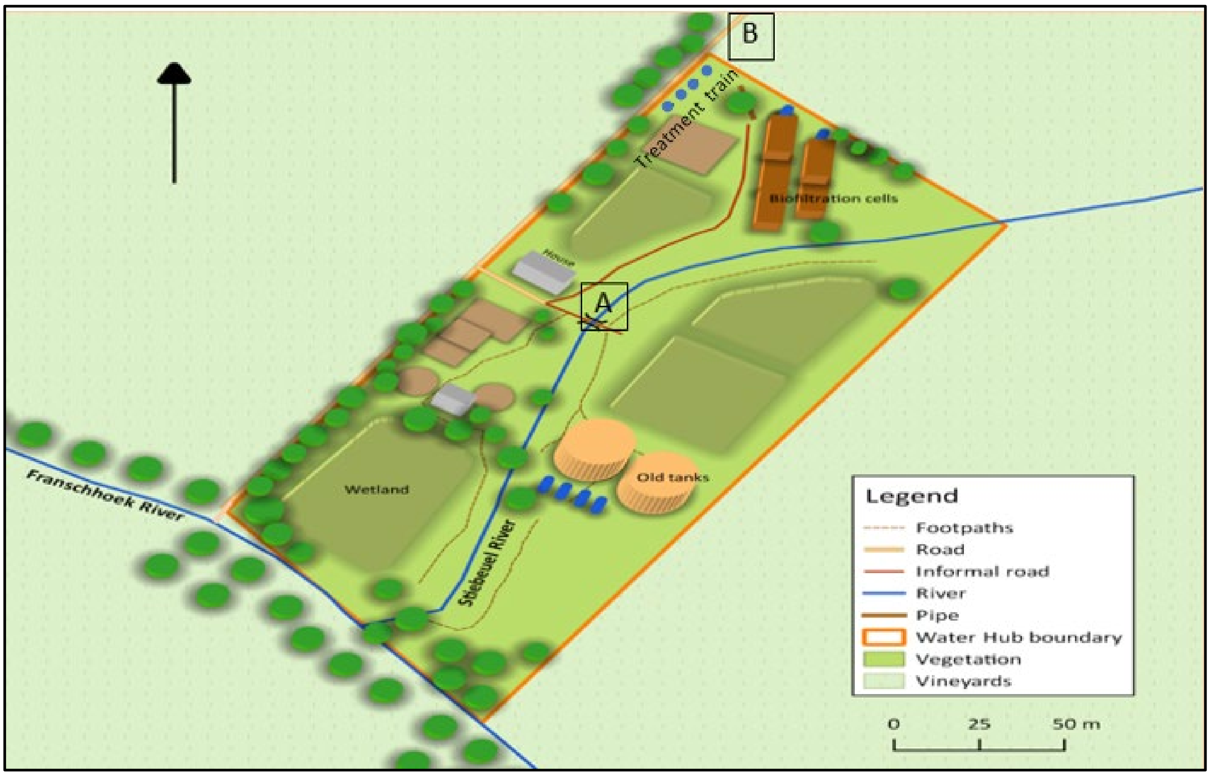


Figure 7 Existing infrastructure at the Water Hub site which is being gradually retrofitted to accommodate various NbS experiments.

Research Design

It is assumed that decentralised water treatment can be a catalyst for enabling development provided it can unlock multiple benefits, partnerships, and the sustainable reuse of natural resources. Over the last 3 years the researchers have made progress in the building a FEWW nexus based on an improved knowledge and understanding of nature-based processes and the safe reuse of treated water for growing edible crops, regenerating soil, and growing horticultural plants for riverine restoration work. The research work has amassed baseline evidence resulting in a deeper understanding of nature-based processes. However, and given the context, emerging pollutants of concern have received limited attention. These pollutants are persistent in the environment and resistant to typical environmental degradation processes. The toxicity, mobility and bioaccumulation of drugs and pharmaceutical chemical compounds and potential effects on the environment and human health are largely unknown.

The main challenge in the study, and especially during the Covid pandemic which has prohibited travel and community engagement, is to explore how work at the Water Hub is able to initiate and support a shift in thinking and practise toward a more inclusive circular economy resulting from opportunities of improved waste management and recovery of resources from waste. The 'how' question requires a deeper analysis of stakeholder interests and willing to become involved, as well as to assess the potential for stakeholders to become change agents. The development of an assessment tool will be used to determine the current state and interest of stakeholders, and to assess processes and outcomes that can sustain the transition to a more circular-based economy. It is assumed that an improved understanding of appropriate indicators and the assessment tool will develop clarity and insight about how systems need to adapt and change to support the well-being of vulnerable community who are co-beneficiaries of an emerging circular economy approach.

Research Methods

Over the past two years, researchers at UCT's Future Water Institute have collected and analysed data to understand the performance of biofiltration treatment systems. This work has already determined the extent to which constructed wetlands can able to clean contaminated runoff from the informal settlement of Langrug. The data includes water quality samples and measurement of the retention and flow of water treatment in a horizontally orientated, subsurface flow (HSSF) system. This data were used to develop a mass balance of the water quality and volume and to model the pollutant and water fluxes in these cells. The results show that inlet pollutant concentrations are substantially reduced, with outlet concentrations falling within an acceptable range for irrigation purposes. Data were also collected on successive harvests of vegetables and simultaneous analysis of soil, the latter to measure the effect of irrigation from treated water.

Until now, the WASTE FEW ULL project has focused on the biophysical and ecological research outcomes, but the main focus now is to explore the roles of actors and agents, and to understand how to support a transition to a circular economy. This will be undertaken by mapping stakeholders and their interests and, secondly, to identify those indicators that can be incorporated into an assessment tool that are capable of guiding outcomes towards an adaptive and resilient system through stakeholder collaboration and agreement. The identification of many role players and stakeholders is near completion but still needs further verification with meetings, interviews and potentially, a facilitated workshop of stakeholders (possible only when COVID lockdown are lifted).

The indicators will be informed from an international literature review and analysis, and followed by collaborations, a co-design approach and reaching agreements with key stakeholders who are the agents and actors of change, and willing. The selection of these stakeholders will be informed by the mapping process. Identifying and establishing indicators will be undertaken in smaller groups of stakeholders and facilitated by a researcher who has recently been appointed as a Research Assistant and who has the skills and abilities to successfully manage this research.

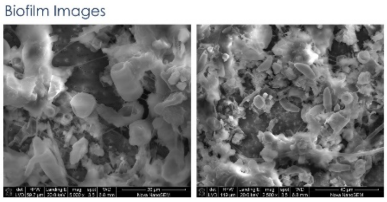
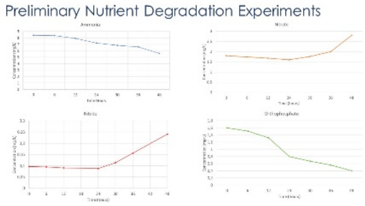
Data

Qualitative data collection will commence once the newly appointed RA has received ethical approval from the University of Cape Town to conduct research with human subjects. The university and its researchers are committed to a code of ethics that involves human participants and aims to conduct research with scholarly integrity and with respect for the dignity and self-esteem of the individual and for basic human rights with reference to clearly specified standards of conduct and procedures that ensure proper accountability. UCT affirms the requirement that all research involving human participants be subject to prior ethics review, according to faculty guidelines. Review might entail either the approval of research proposals or appropriate deliberative procedures for researchers. (http://www.uct.ac.za/about/policies#research)

Care is being taken to store all data on hard drives that are backup on a separate storage facility and on the University of Cape Town's Cloud Services data storage facilities.

A summary of some the research activities is captured in the photographic collage which represent some of research effort over the past year (Table 1).

Table 1 Photo collage showing various aspect of the project.

		
Large-scale Biofilters	Digital monitoring and logging water quality	Student involvement in sampling and testing
		
Microbial and biofilm studies using SEM microscopy	Lab scale model of large biofilters	Results of nutrient degradation studies
		
Constructing raised permaculture gardens	Gardens for testing uptake of chemicals and soil analysis	Composting bio-reactors: layers of brown, green, duckweed and manure
		
Compost from municipal organic waste and soil regeneration study	Riverine seedings grown hydroponically	Aquaponic study to determine uptake of ARVs in fish

Video link that presents some of the work at the site and progress to-date: https://www.youtube.com/watch?v=hPtaCmcpjBo

Stakeholder mapping

Table 2 presents an overview of key stakeholders who are currently involved in aspects of the project and others who will be invited to participate in planned workshop activities in the future.

Table 2: Social and institutional overview of the ULL

The Water Hub: case study

System analysis	Value chain	Agents of change
Non-market evaluation	Benefits of reduced pollution load and resource wastage. Cleaner rivers, recovery of ecological services and biodiversity.	Local residents affected by degraded conditions; farmers using water for irrigation; local and provincial authorities; natural processes.
Economic evaluation	Circular economy raises potential of urban poor to participate in formal economies through production of market goods: food, compost, recycling of organic waste.	Urban poor; formal businesses in the exchange of local goods and services.
Systems mapping	Stakeholder interest within a system of resource recovery and exchange.	Local residents including NGOs, churches, NPO, social enterprises (e.g. Y-Waste).
Resource recovery and flows	Nutrient recovery for vegetables production; organic waste diverted form landfill; improved waste management; local control over FEW and waste.	Local residents in formal and informal settlements; tourism industry; farmers; horticulturalists.
Social and environment benefit and return	Job creation; capacity building in FEW management; reduced carbon footprint; improving surface water quality.	Local authority; local residents esp urban poor; agricultural sector; tourism industry; research community.

Key references

Literature from research completed to-date

Cameron, K. J. (2018) *A bio-indicator assessment towards the rehabilitation of the Stiebeuel River, Franschhoek, South Africa*. University of Cape Town.

Charlesworth, S. M., Winter, K., Adam-Bradford, A., Mezue, M., McTough, M., Warwick, F. and Blackett, M. (2017) Sustainable drainage in Challenging Environments, *New Water Policy and Practice,* Vol 4 No 1 32-41

Fell, J., Pead, J. and Winter, K. (2019) Low-cost Flow Sensors: making smart water monitoring technology affordable, IEEE Consumer Electronics, 10.1109/MCE.2018.2867984 https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8570900&tag=1

Ghanashyam (2018) *The use of Biofiltration cells to Filter Contaminated Water flowing from a Slum Settlement in South Africa*. University of Cape Town.

Key literature that frames your research questions and research approach

Latawiec et al. (2020) 'Are nature-based solutions projects aligned with sustainability dimensions? Guide and evaluation from an innovative framework', *Environmental Science and Policy*, Press.

Other references

Armitage, N.P., Winter, K, Spiegel, A. & Kruger, E. (2009) Community-focused greywater management in two informal settlements in South Africa. Water Sci Technol (2009) 59 (12): 2341–2350. https://doi.org/10.2166/wst.2009.294

DEADP (2018) *FINAL REPORT IMPLEMENTATION OF THE GENIUS OF SPACE PROJECT*.

Jiusto, S. and Kenney, M. (2016) 'Hard rain gonna fall: Strategies for sustainable urban drainage in informal settlements', *Urban Water Journal*. Taylor Francis, 13(3), pp. 253–269. doi: 10.1080/1573062X.2014.991329.

Midgley, S. J. E. *et al.* (2020) 'Typologies of collaborative governance for scaling nature-based solutions in two strategic South African river systems Typologies of collaborative governance for scaling nature-based solutions in two strategic South African river systems Abstract', *In press*, pp. 1–77.

Mzini, L., and Winter, K. (2015) Analysis of grey-water used for irrigating vegetables and possible effects on soils in the vicinity of Umtata Dam, Eastern Cape, *Water SA Vol. 41 No. 1: 115–120*

Mzini, L., and Winter, K. (2015) Effects of irrigation water quality on vegetables Part 1: Yield and aesthetic appeal, *South African Journal of Plant and Soil, 32(1): 27–31*

Mzini, L., and Winter, K. (2015) Effects of irrigation water quality on vegetables Part 2: Chemical and nutritional content, *South African Journal of Plant and Soil, 32(1): 33–37*

Ramírez-Agudelo, N. A. *et al.* (2020) 'Nature-Based Solutions for Water Management in Peri-Urban Areas : Barriers and Lessons Learned from Implementation Experiences', *Sustainability*, 12(9799), pp. 1–36. doi: doi:10.3390/su12239799.

Raymond, C. M. *et al.* (2017) 'A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas', *Environmental Science and Policy*. Elsevier, 77(July), pp. 15–24. doi: 10.1016/j.envsci.2017.07.008.

Seddon, N. *et al.* (2020) 'Understanding the value and limits of nature-based solutions to climate change and other global challenges', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794). doi: 10.1098/rstb.2019.0120. 51

Stellenbosch Municipality (2011) *LANGRUG SETTLEMENT ENUMERATION REPORT Informal Settlement Network, Stellenbosch Municipality Langrug Community Leadership and Community Organisation Resource Centre*.

Wolfaardt, G. (2017) 'A case study of transdisciplinarity and biomimicry: The restoration of water systems using eco-machines within the informal Berg River community', (March). Available at: http://scholar.sun.ac.za/handle/10019.1/101120.

WWAP/UN-Water (2018) *Nature-Based Solutions for Water*. Paris, UNESCO.