Guidance on developing infrastructure adaptation scenarios for Bogor's water sensitive transition

Scenario Modelling to shape Urban Planning

For Greater Bogor to leapfrog towards a WSC, the primary challenge is overcoming the business-as-usual mindset to water management, and understanding the compounding effects of population growth and climate change stresses on business-as-usual practices.

This factsheet explains the role of infrastructure scenario modelling in the planning process and how decisions on city development infrastructure investment can be supported by a focus on quality data and modeling. Used effectively, modelling approaches can drive a deeper understanding of the connection between the water system, land use, urban design and technology. Furthermore, our research has found that involving stakeholders early on in the modelling process can improve the quality of options developed, increase water literacy and significantly influence the success of water resource management projects.

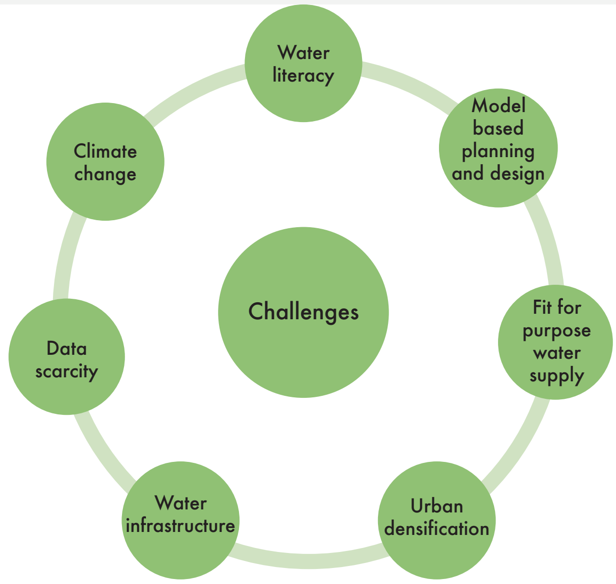


Fig. 1: Key challenges for Bogor's leapfrogging strategy from an infrastructure adaptation perspective

Future Scenarios: Impact of population growth and urbanisation on water systems in Greater Bogor

Impact on water system	Example causes
Increasing propensity for flooding due to:	» Loss of situ (lakes) & reduced capacity of the system to retain floodwaters » Increased runoff volumes due to increases in impervious surface » Increasing levels of litter clogging drainage channels & rivers » Irrigation and drainage channels designed for agricultural purposes perform poorly as storm-water drainage networks
Increasing pollution of the water system and increasing risk of chronic exposure to pathogens and toxins due to:	» Greywater & sewage discharges into the open channel drainage rivers & local waterways » Leaky septic tanks & infrequent desludging results in leaching sewage into adjacent soils & underground water and then into rivers, situ, etc. » Higher levels of surface flow, which collects pollution from many sources
Diminishing capacity to meet water supply demands due to:	» Increases in impervious surface coverage reducing levels of groundwater recharge » Demand increase through population growth
Increasing environmental degradation due to:	» Increased urban runoff contributing to increased stream erosion & higher levels of surface flow » Reduction of green and blue spaces and loss of ecosystems and biodiversity
Reduced urban amenity	» Loss of situ as well as smaller green and blue recreational spaces diminishes the liveability, attractiveness and value of the urban landscape & impacts quality of life, health & well-being of communities

Opportunity 1: Establishing Robust Data Platforms

For city development planners to tackle climate change and population growth they need access to robust data platforms and quality standards and guidelines that are locally appropriate. Throughout Indonesia, the Meteorology, Climatology and Geophysical Agency (BMKG) is responsible for the collection, quality control and storage of meteorological and climatological data. Local government agencies and research bodies also collect and hold localised data sets. For Greater Bogor, a coordinated approach to data collection, quality control, interpretation, storage and dissemination will better inform water policy, city development and infrastructure design, and is critical for Bogors transition to a WSC. In particular, our research suggests that establishing a detailed understanding of drainage, sewage and water monitoring networks and their performance under the future burdens of climate change and population growth, could be achieved through the guidance of a government-industry-academic task force of 'Water Champions'. In addition, the surging capability of mobile devices presents an opportunity for crowd sourcing of data for Great Bogor. Examples include, monitoring river gauge height through mobile photography, calculating streamflow through videos, determining real time flood extent and depth via geo-located photos, and monitoring rainfall through interference signals of mobile phone towers.

Figure 2: Flooding in Bogor may become increasingly common ("Bogor Flooded, Three People Killed," 2017)

Opportunity 2: Data driven improvements in Water Literacy and Community Capital

Water literacy is the measure by which community, water professionals and government stakeholders understand the connections between water, climate change, population growth, and other water related issues. Access to data relating to drought, flood, litter and water security supports water literacy and helps stakeholders make informed decisions to improve preparedness for and responsiveness to severe weather conditions and extreme events. Developing water literacy around contamination of key water assets by domestic solid waste and waste water, would help ease maintenance requirements, improve the effectiveness and efficiency of key water assets, and improve the capacity of drainage systems to convey water. Developing a better understanding of the relationship between urban development, climate change and the effective implementation of water sensitive urban design (WSUD), can also help to tackle issues of sanitation, increased urban flooding, environmental degradation, stress on water resources, and loss of urban amenities.

Fig. 3: Solid waste polluting and blocking waterways

Fig. 4: An unhealthy Ciliwung River near Pulo Geulis, (Photo:Raul Marino)

Modelling communities' receptivity to implementation of green infrastructure

By asking questions about community members' perceptions of major water issues, researchers were able to establish their perceptions on how litter, rainwater harvesting, and control of urban densification can contribute to flood mitigation strategies, and also their perceptions on the ability of technology or policy to contribute to flood mitigation. Using an interactive tool, participants then visualised flood impacts for different climate scenarios and storm intensities. By testing a range of percentages of litter and rain tank adoption scenarios, participants were found to alter their thoughts about potential flood mitigation strategies, and some showed high levels of water literacy by proclaiming that an "integrated solution that considers litter, rainwater harvesting and managing urban densification will provide the best solution".

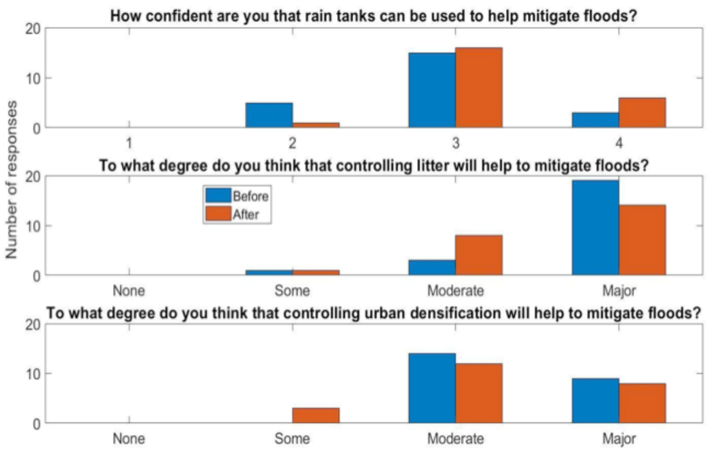


Fig. 5: Stakeholders' perceptions on flood mitigation options before and after interaction with visualisations

Receptivity Modelling

Through receptivity modelling workshops and other forums, participants have expressed concerns about the use of rainwater tanks to harvest rainwater. Community perceptions are significant barriers to implementing rain tank solutions and improving understanding of potential solutions will help to improve receptivity and uptake.

Concerns	Solution
Mosquito breeding ground.	First flush, mesh screen. Maintenance every 2 to 3 years.
Roofs are dirty and home of the animals, won't the water be dirty?	First flush separator will remove organic material. Not all roof types are suitable though.
Why use rainwater when we can use groundwater?	Reduce stress on city water supply systems and local aquifers. If used correctly quality may be better than groundwater.
Take up too much space.	Water balance modelling has shown that for a typical house, a small 400-litre tank can make a big impact.
Acid rain.	Rainwater would not be proposed for drink water. It is good for toilet flushing.

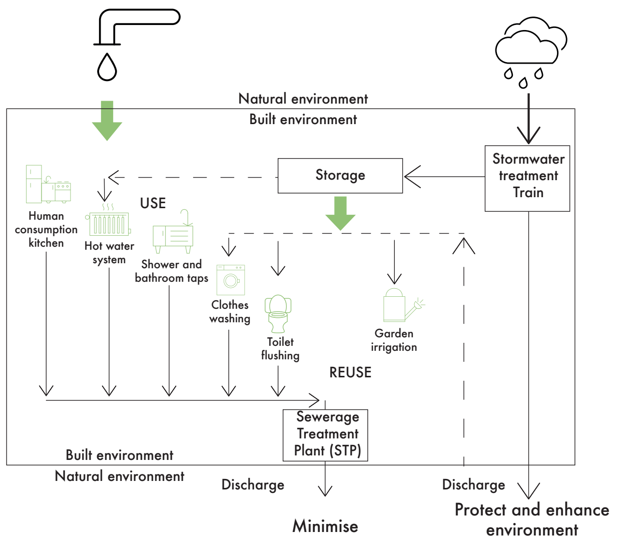


Fig. 6: Representation of a fit-for-purpose water supply system courtesy of (T. Wong, 2006)

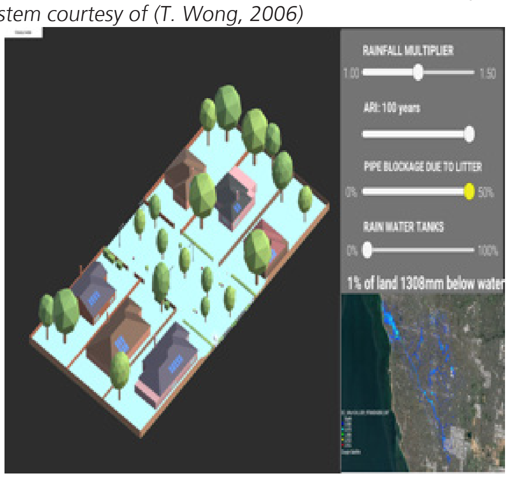


Fig. 7: Interactive display of flood mitigation options under various scenarios

The security of Greater Bogor's future water supply is challenged by decreasing water quality and increasing demand. To design infrastructure options that are resilient under various climate change and urbanisation scenarios, opportunities exist for Bogor to promote adaptive water sensitive infrastructure by modelling numerous uncertain scenarios and testing possible adaptation pathways where integrated multi-purpose infrastructure elements are installed. For example, to reduce stress on the piped city water supply, adopting a fit-for-purpose water usage approach is recommended, where the quality of water supplied for a given demand need only meet the minimum quality requirements for that purpose (Figure 6). For example non-potable water sourced from greywater is fit for the purposes of toilet flushing.

Green infrastructure interventions such as rain tanks, wetlands and retention ponds can also be used to offset the increase in impervious surfaces and adapt to changing runoff regimes. Our modelling research demonstrates that flood waters can be mitigated through the implementation of green infrastructure technologies and proper catchment management strategies (see info boxes).

Water Balance Modelling

To develop urban designs and recommendations for the selected case study sites our researchers applied a water balance model, or WBM, to evaluate the water cycle at each site and quantify the current demand for drinking water and sanitation, incorporating population growth and rain tank interventions. Assuming an increase in rainfall of 25% and city population more than doubling from 12,258 in 2018 to 26,631 in 2045, water balance modelling of Cibinong Situ Front City found that retrofitting each residential building with small 400-litre rainwater tanks (which would collect enough rainwater for flushing toilets for 75% of the year) could reduce household imported water demands by 35%. This strategy would significantly reduce the stress placed on the city water supply and local groundwater aquifers. Water balance modelling also demonstrated that between 2018 and 2045 Greater Bogor will face significant increases in imported water, stormwater runoff and wastewater discharge due to the impacts of climate change and urban densification. Consequently, strategies to offset these increasing stresses need to be developed.

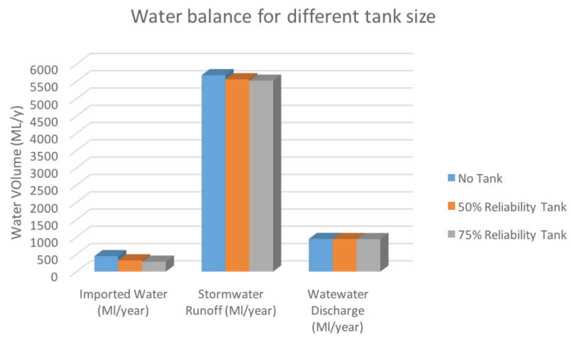


Fig. 8: Water balance for different tank sizes in Cibinong situ front city Aquacycle model

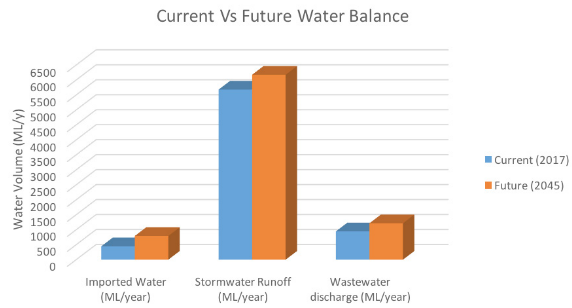


Fig. 9: Comparison of current and future water balances for Cibinong situ front city

Fig. 11: Breakdown of areas for Cibinong Situ Front City aquacycle model

Modelling tools to evaluate the performance of green infrastructure and optimise its design and location

Our researchers have developed a GIS based tool called 'Green Infrastructure Tool Based on Location Analysis' or GITBoLA for short, that uses spatial multicriteria decision analysis of several variables to determine the suitable placement of green infrastructure within a catchment. Data needed for the tool includes digital elevation models, land use, impervious cover, land ownership, river network, soil type, and depth of groundwater. GITBoLA has been used by UWC researchers to model the ideal locations for wetlands, bioretention systems and green roofs for the master plan of Situ Front City (see Figure 10).

The Storm Water Management Model (SWMM), developed by the US EPA, has also been used to evaluate the effectiveness of selected green infrastructure in managing and controlling urban stormwater.

Using several rainfall scenarios, the SWMM simulated stormwater scenarios in Situ Front City, Cibinong, and showed that:

- Constructed wetlands have the most capacity to reduce stormwater discharges;
- Grassed swales can also reduce stormwater discharges but are the least effective technology analysed; and
- Bioretention systems, which are spread out all over the catchment, are able to most effectively reduce stormwater discharges per square metre occupied.

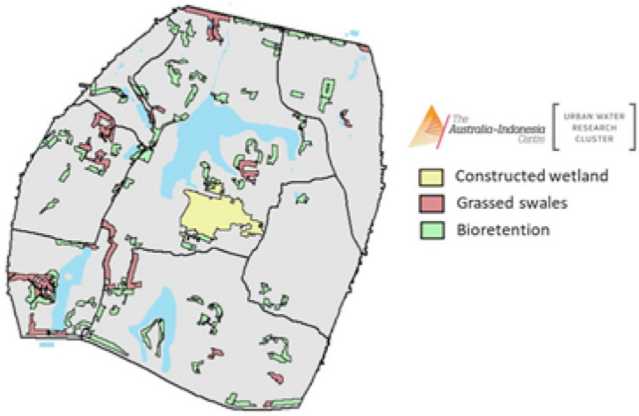
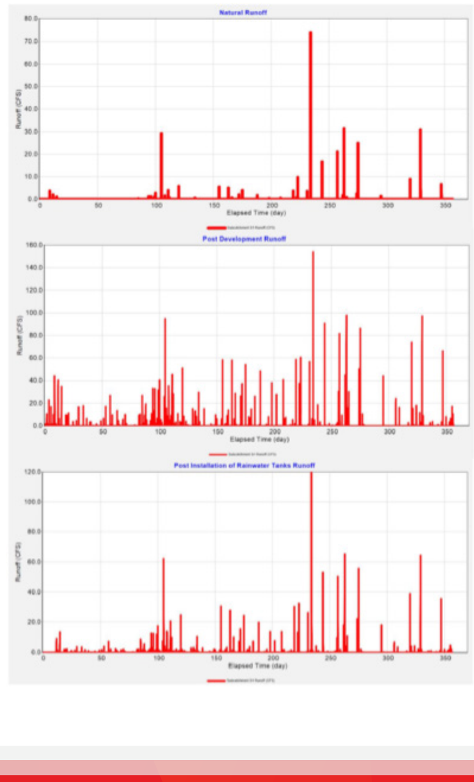


Fig. 10: GITBoLA output Map of Constructed Wetland, Bioretention, and Grassed Swales for Situ Front City Cibinong

Opportunity 4: Scenario Modelling to inform city development, planning and design

Modelling numerous adaptation pathways under a variety of climate change, population growth and urbanisation scenarios allows urban planners to develop contingency plans for an uncertain future and advise policymakers on how to regulate new development to ensure a water sensitive approach is applied. Modelling can also be used to assess the security of safe and secure water supplies given a variety of supply and demand scenarios. Including stakeholder input in planning, modelling and design processes increases water literacy and the community's all-important connection with water.

Fig. 13: Annual runoff for sub-catchment in Cibinong (a) Prior to any development (b) Post development, and (c) Post development and the inclusion of rainwater tanks.



Modelling Impacts of Urbanisation on the Water System

To assess and understand the impact of land use on the water system, our research has tailored the DAnCE4Water model, developed by the CRCWSC, to the context of Bogor. Based on open data and various tools, DAnCE4Water enables stakeholders to assesses the impact of a range of urban planning decisions on the urban water system and identifies potential adaptation options. Using DAnCE4Water modelling to demonstrate the impact of urban development for Cibinong and Great Bogor areas, researchers observed both increases in future water demand and growing fraction of impervious surfaces linked to population growth. Combined with increasing rainfall frequency and resulting increasing magnitude of runoff events, urban development modelling showed a greater future propensity for flooding in Bogor. By retrofitting each house with a rain tank, DAnCE4Water modelling demonstrated that peak flows and frequency of runoff could be reduced through this infrastructure intervention.