

Monday , 14 June 2021

THE EFFECT OF HYDROLOGICAL CHARACTERISTICS OF URBAN CATCHMENTS ON RESILIENCE OF STORMWATER MANAGEMENT SYSTEMS: A QUANTITATIVE APPROACH



ENGINEERING



Why SW Resilience ?

Urban Resilience

Urbanisation

Flood Hazard

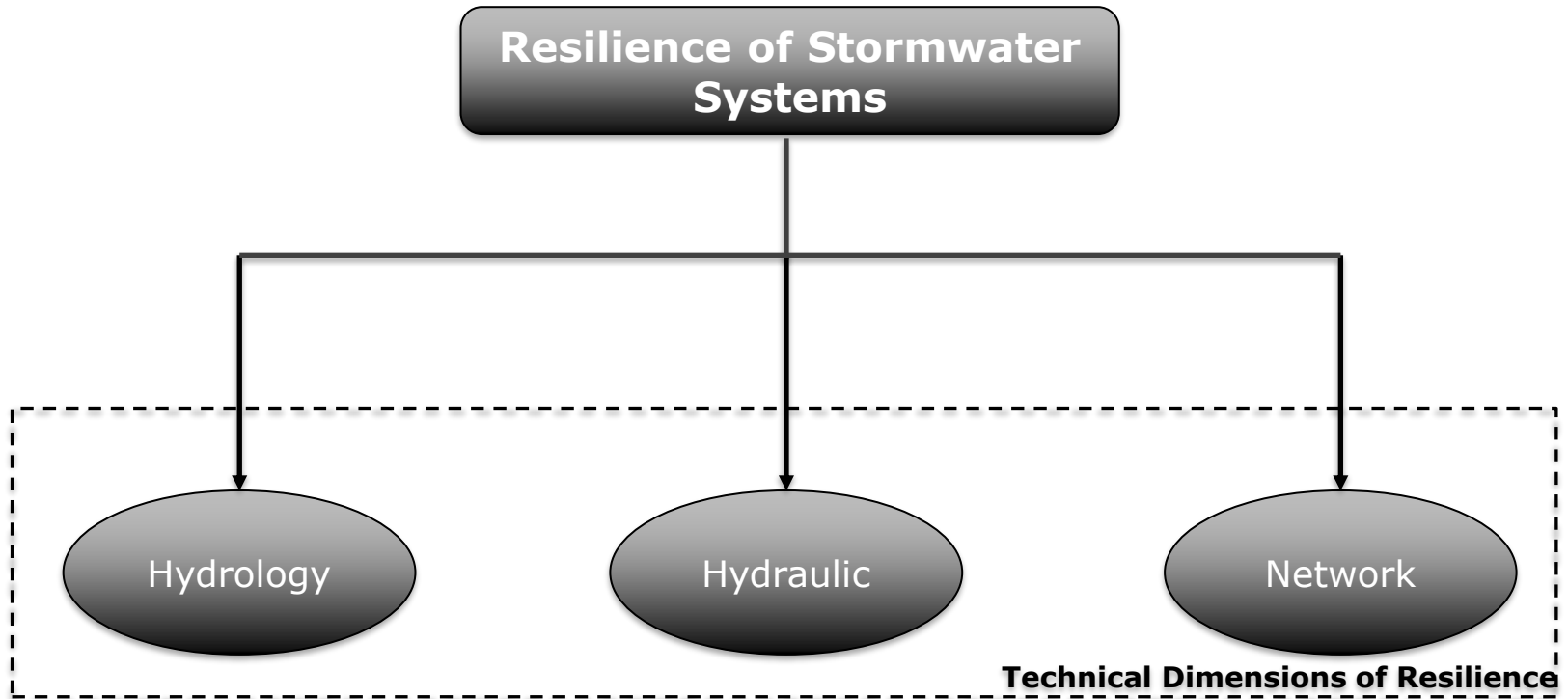
Climate Change



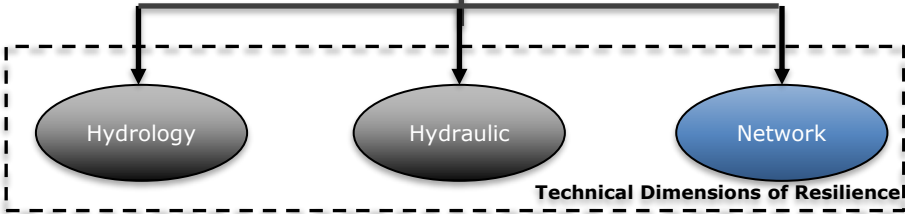
Photo: Paul Smith (Flicker)

Problems

- **How robust is the system**
- **How fast the system recovers**
- **Urbanization Impact**
- **Network Effect**
- **SW Device Influence**
- **How to Quantify**



Resilience of Stormwater Systems



Network Connectivity

Potential Load

Pipeline Properties

Potential redundancy

Edge failure probability

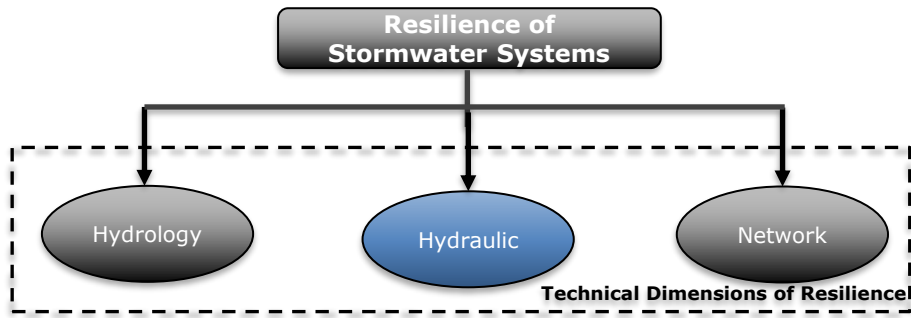
Weight of nodes (w_i)

Network failure factor (r)

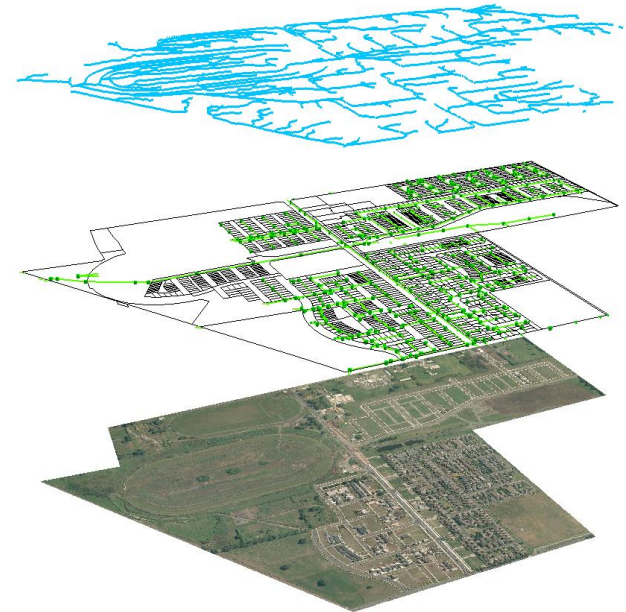
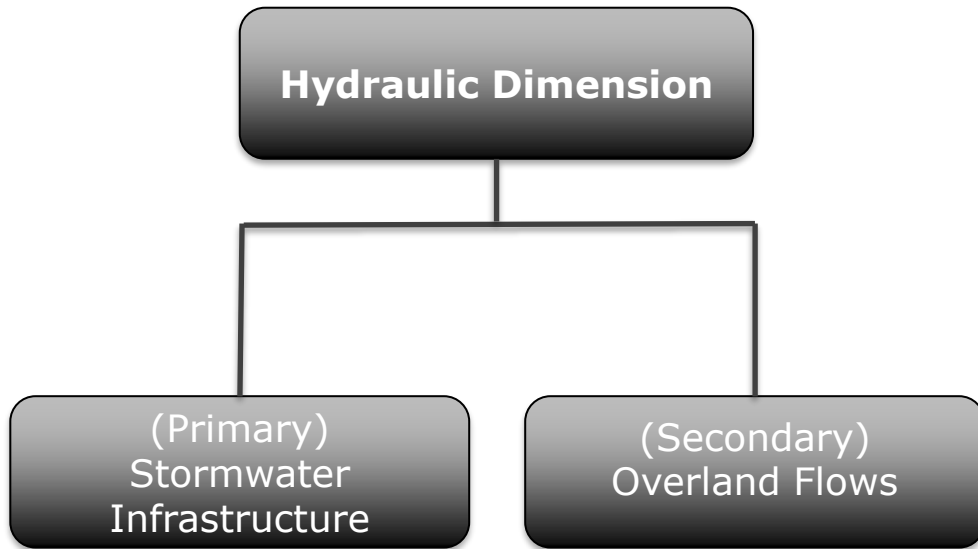
Degree of Resilience ($R(\%)$)

London

am

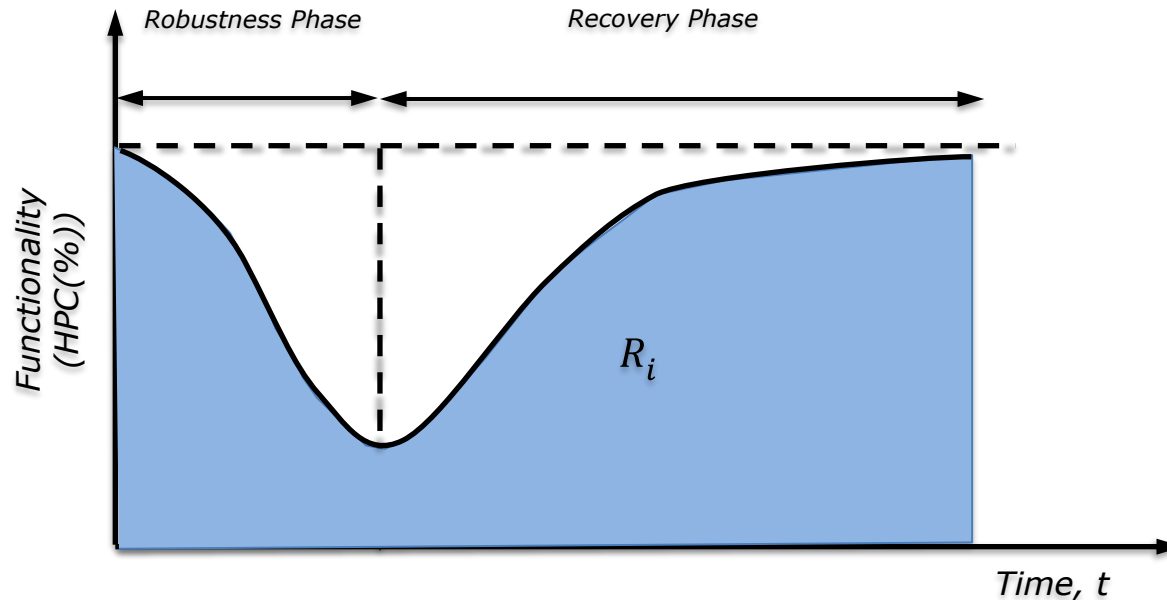


Hydraulic Dimension

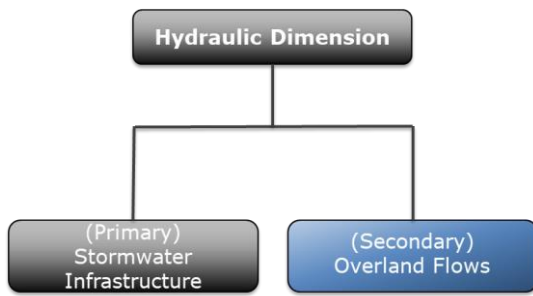


Addison Development, Takanini, Auckland

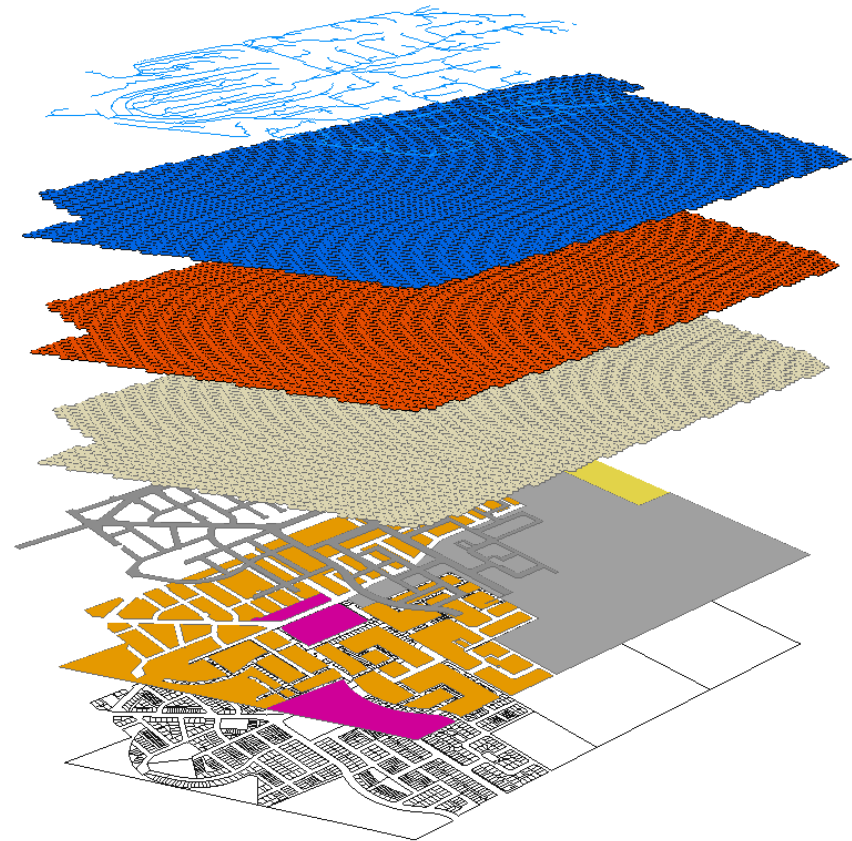
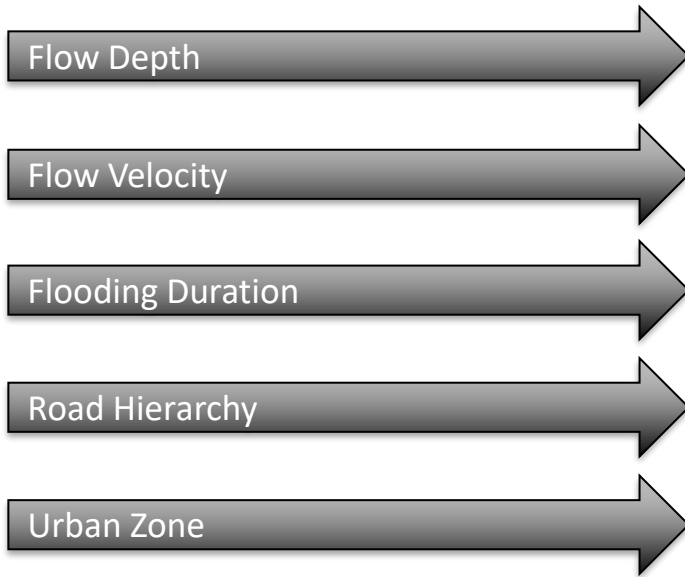
Hydraulic Dimension (Primary)

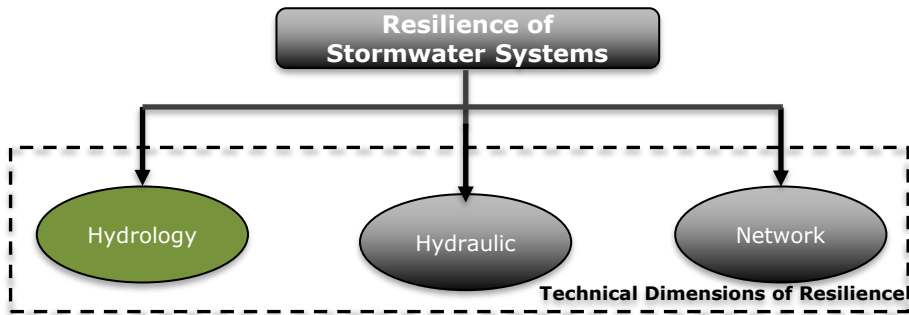


- N Valizadeh, A. Y. Shamseldin, L. Wotherspoon. (2019). Quantification of the hydraulic dimension of stormwater management system resilience to flooding. *Water Resource Management*, 33(13),4417-4429.
- N Valizadeh, A. Y. Shamseldin, L. Wotherspoon. (2018). A Resilience Based Assessment Method for Primary Stormwater Management System Urban Flood Control. *Stormwater Conference*, Queenstown, New Zealand

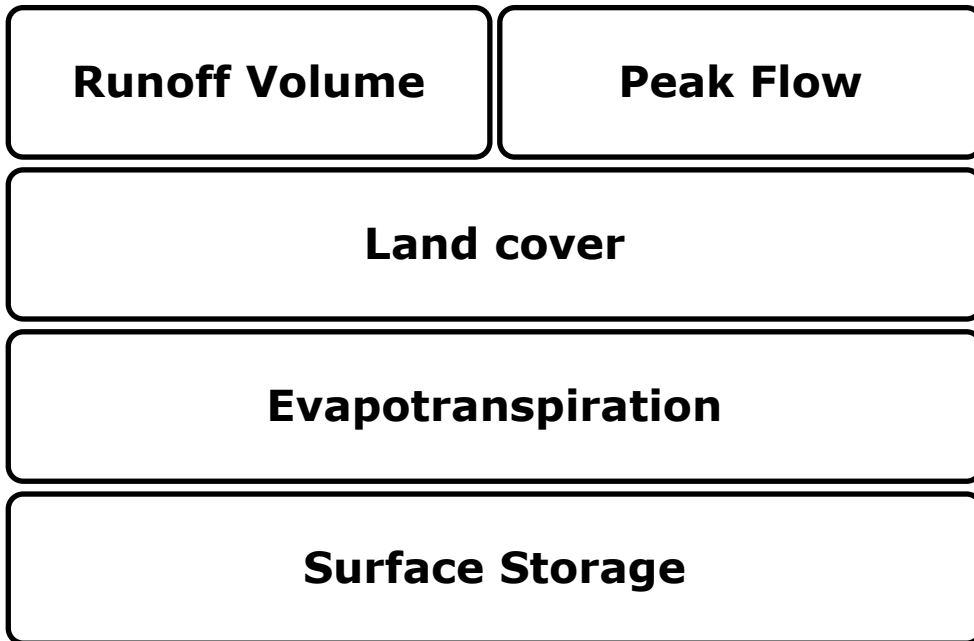


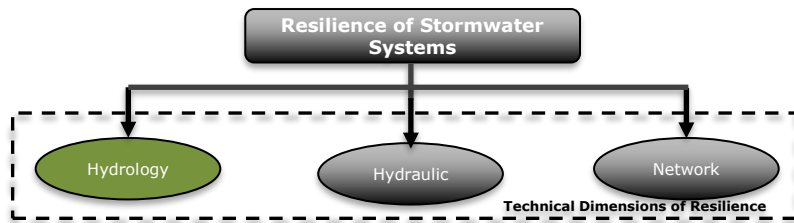
Hydraulic Dimension (Secondary)





Hydrological Dimension





Method

The approach was developed based on

- The runoff coefficient approach (Yao et al. (2015) and Chao Xu et al (2020))
- The resilience concept (Bruneau et al. (2013))

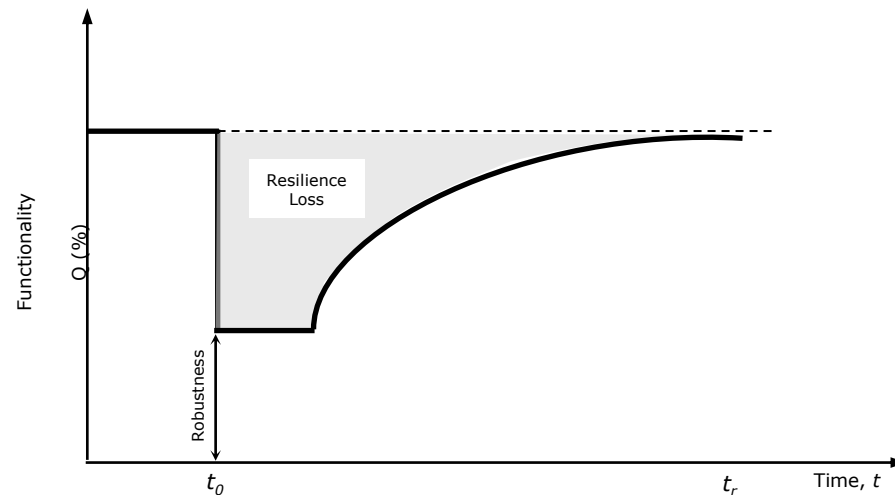
Chao Xu et al (2020)

$$R_c = \frac{\sum_i Q_{si} \cdot A_{si} - \sum_i Q_{bi} \cdot A_{bi}}{P \cdot A}$$

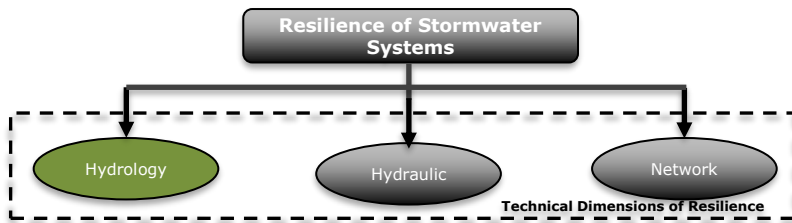
Yao et al. (2015)

$$C_r = \Delta V \cdot (0.001 \cdot P \cdot A)^{-1}$$

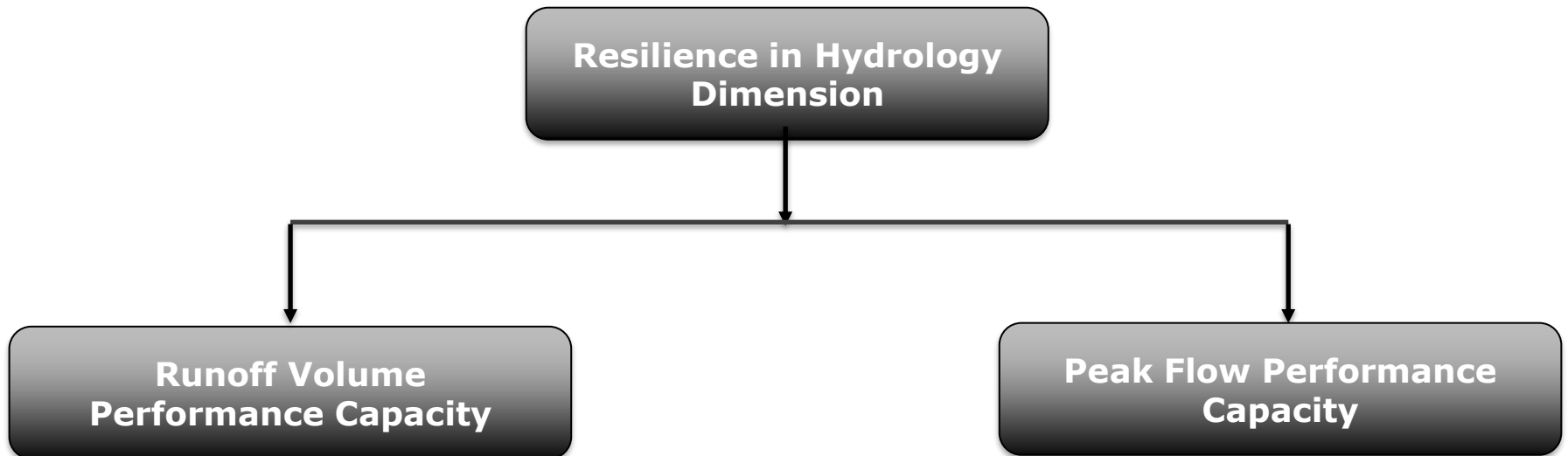
$$\Delta V = \sum_{i=1}^3 0.001 \cdot (Q_b - Q_i) \cdot A_i$$

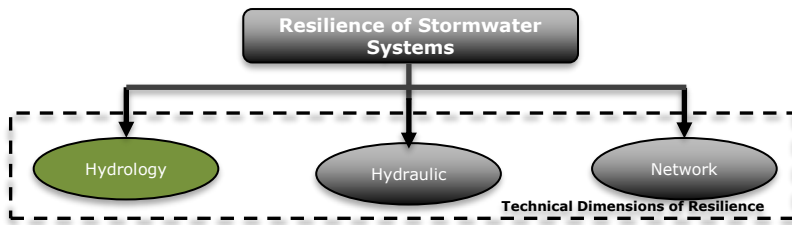


Schematic of the Resilience Concept Bruneau et al. (2013)

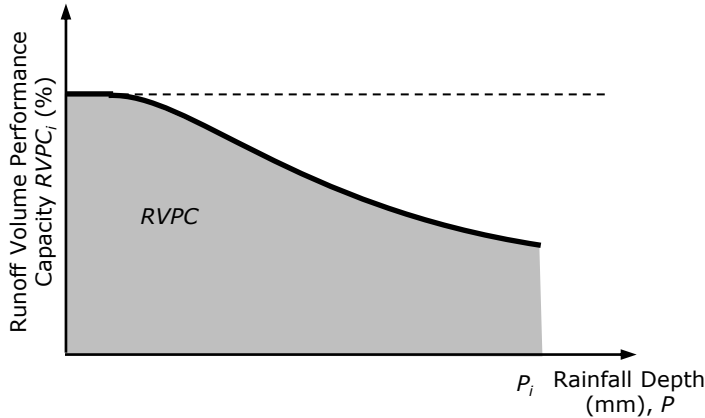


Resilience in Hydrology Dimension is quantified based on the change of urban catchment capacity in terms of stormwater runoff volume and peak flow compared with the undeveloped (greenfield) condition.

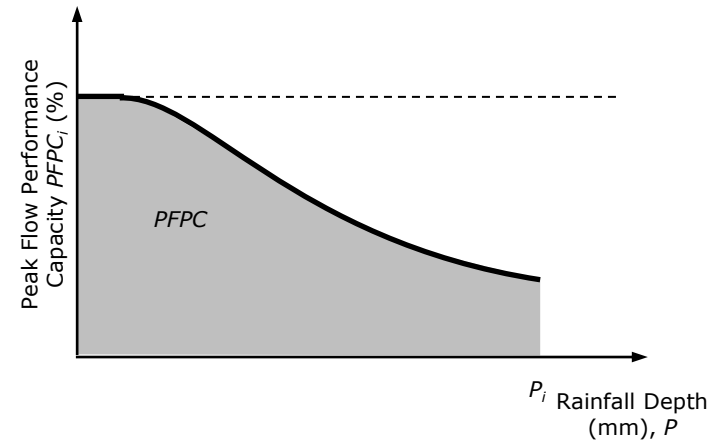




Runoff Volume Performance Capacity



Peak Flow Performance Capacity



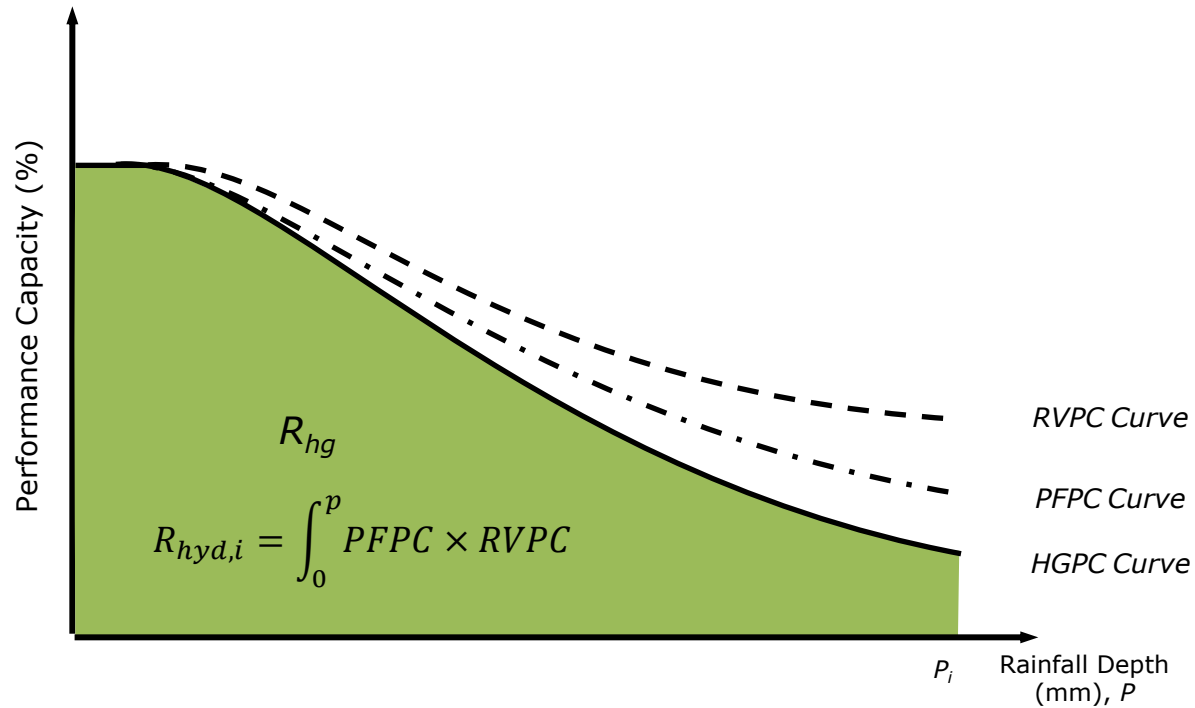
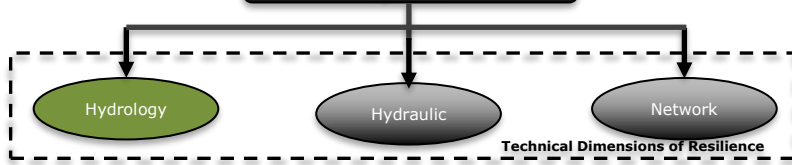
$$RVPC_i = \left(1 - \frac{V_D - V_G}{PA - V_G} \right) \times 100$$

$$PFPC_i = \left(\frac{q_D - q_G}{q_{CN100} - q_G} \right) \times 100$$

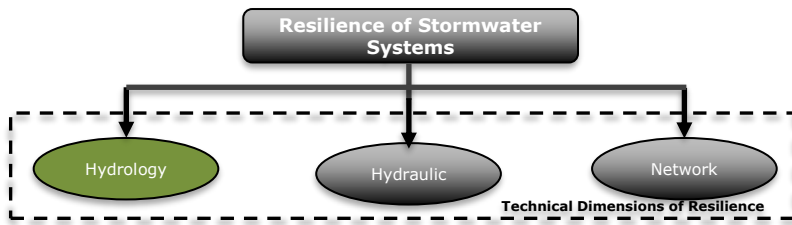
- P : Rainfall Depth
- A : Catchment Area
- V_G : Runoff Volume - Greenfield condition
- V_D : Runoff Volume - Developed condition

- q_G : Peak Flow - Greenfield condition
- q_D : Peak Flow - Developed condition
- q_{CN100} : Peak Flow - no abstraction

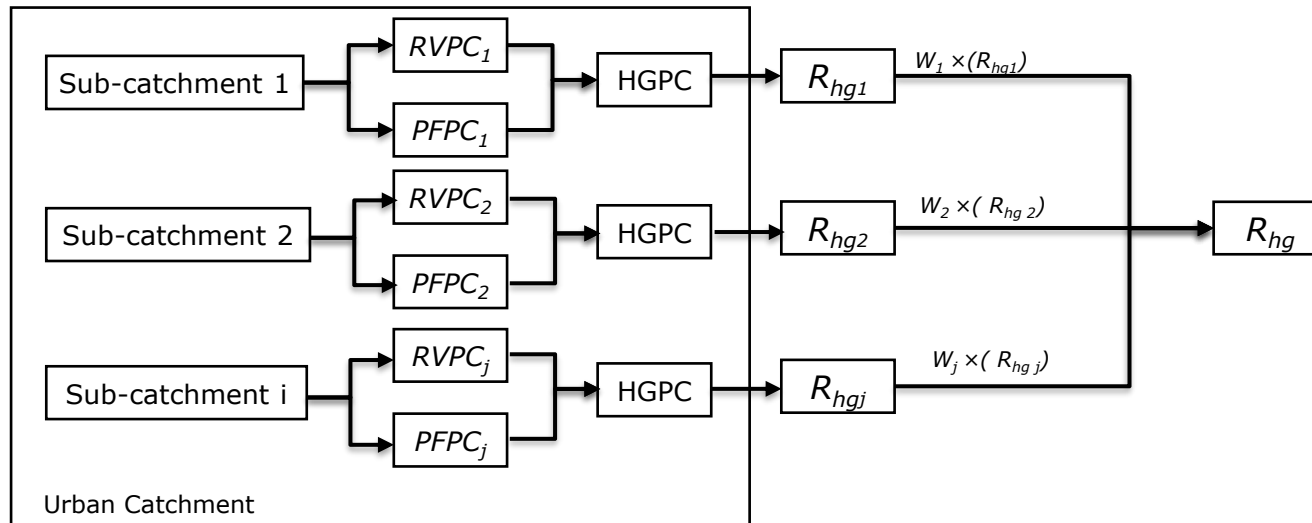
Resilience of Stormwater Systems



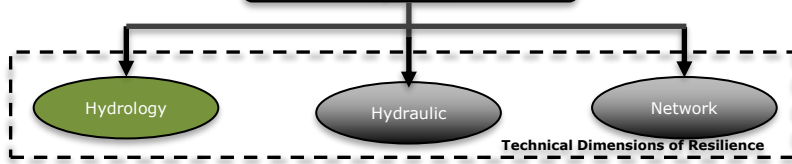
- RVPC: Runoff Volume Performance Capacity
- PFPC: Peak Flow Performance Capacity
- HGPC: Hydrology Performance Capacity
- R_{hg} : Resilience Degree in Hydrology Dimension



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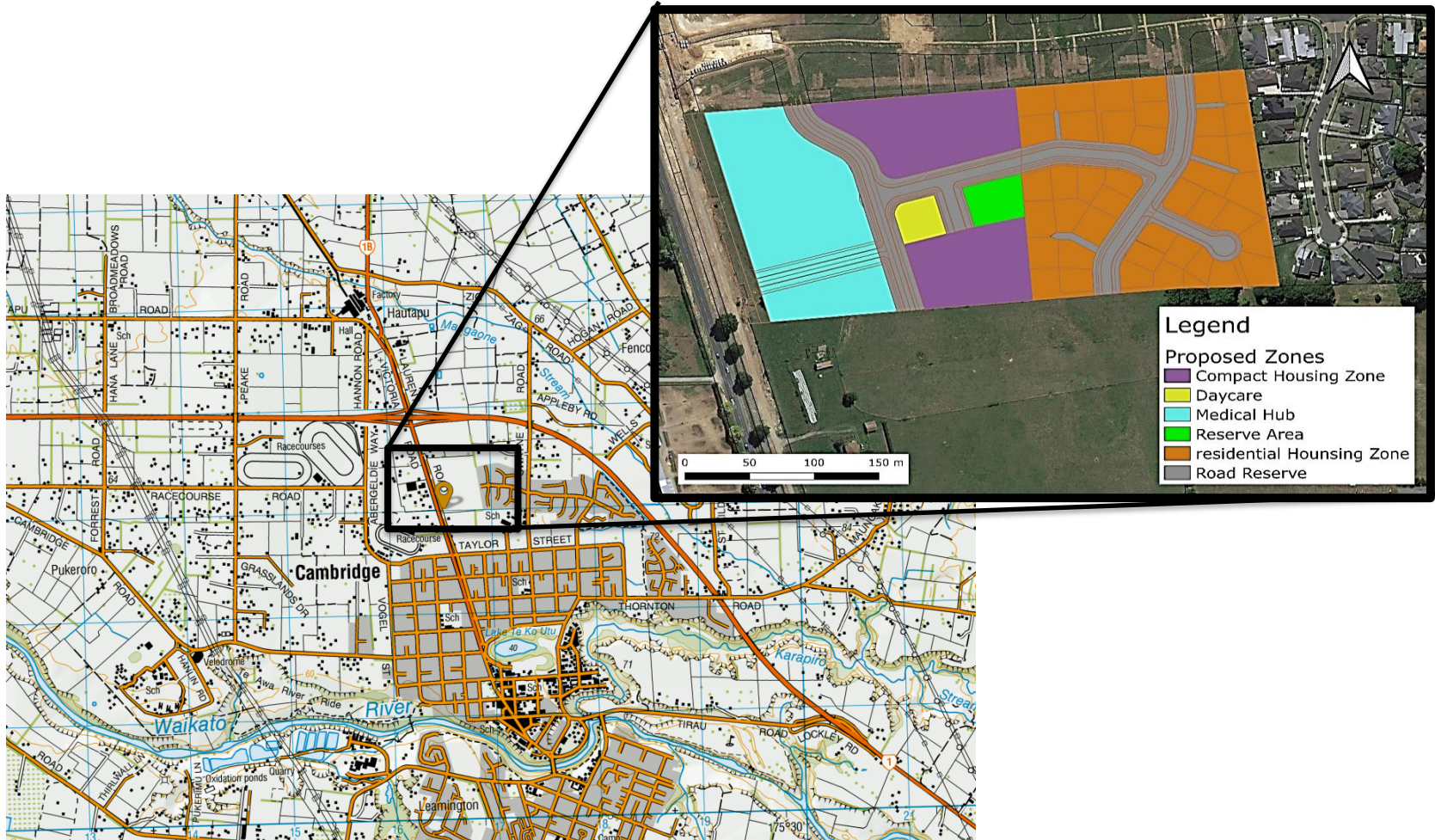


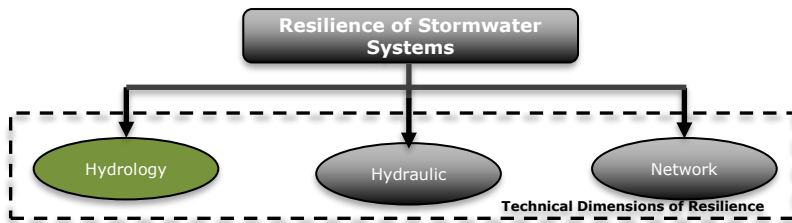
Resilience of Stormwater Systems



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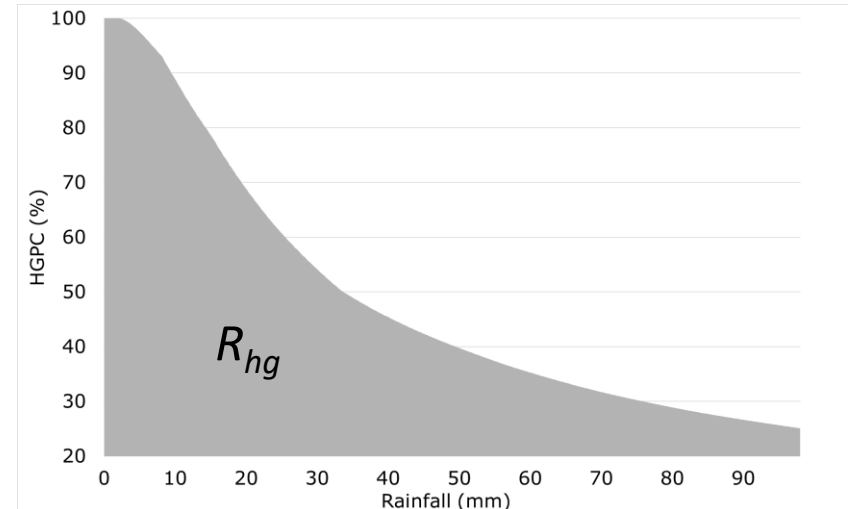
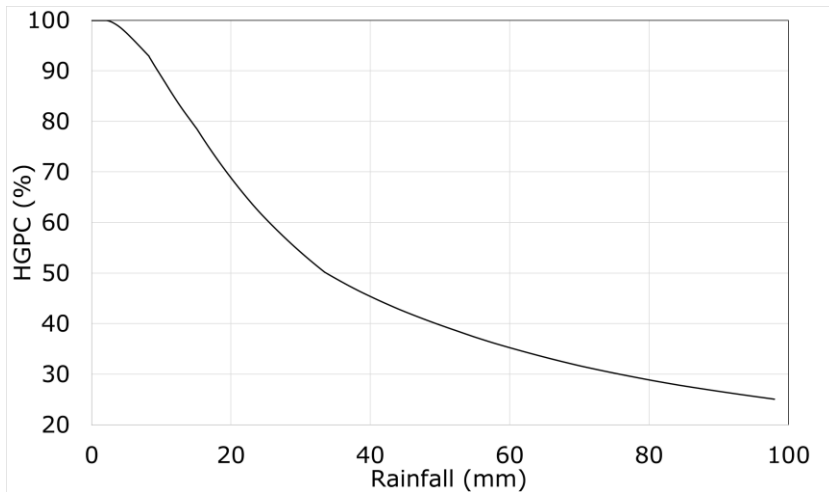
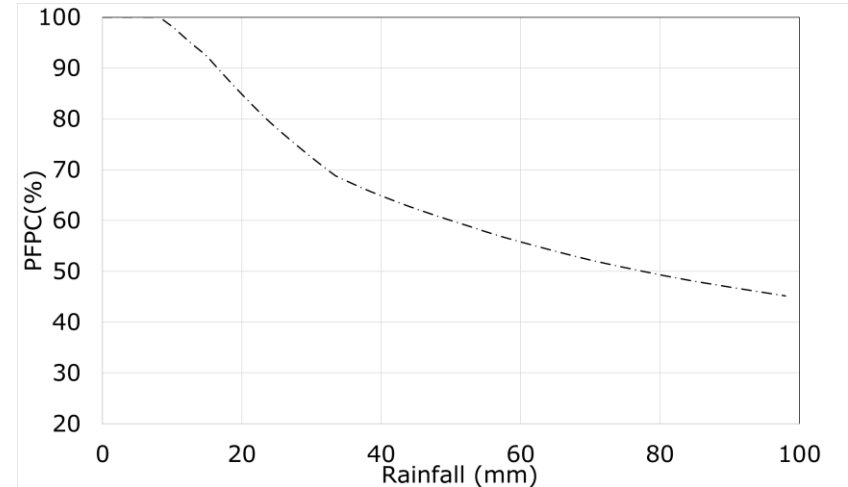
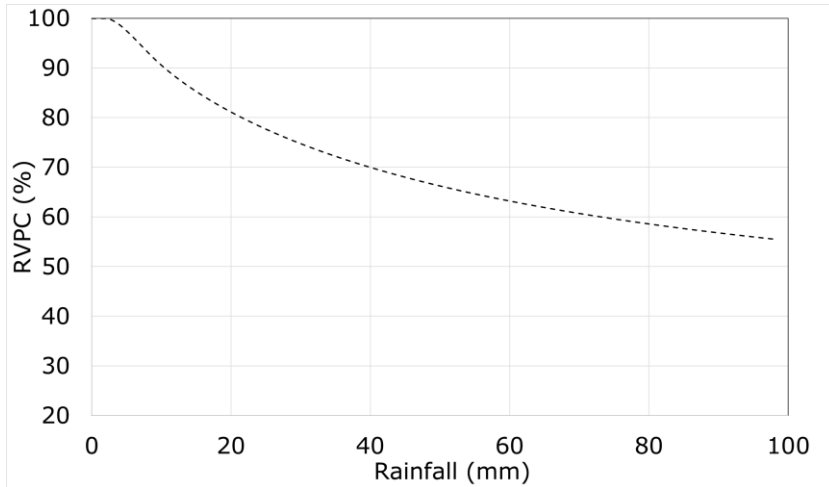
Case Study One



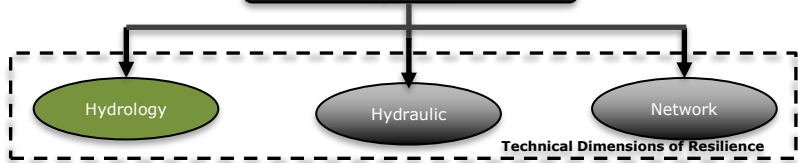


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Case Study One



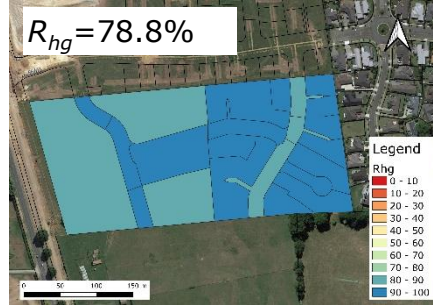
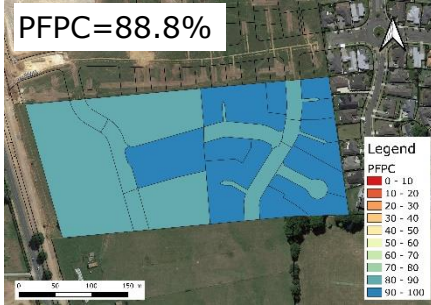
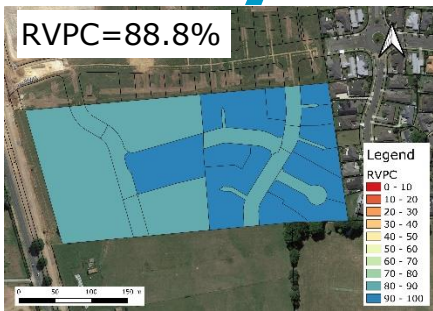
Resilience of Stormwater Systems



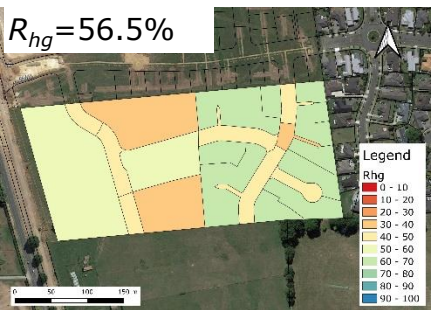
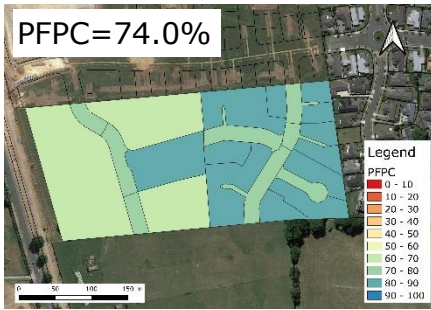
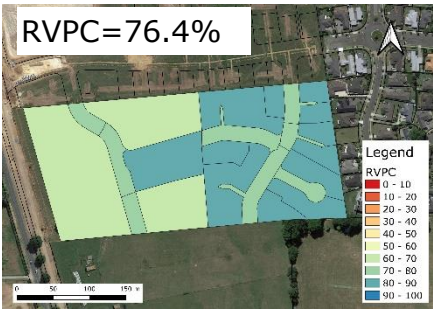
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Case Study One

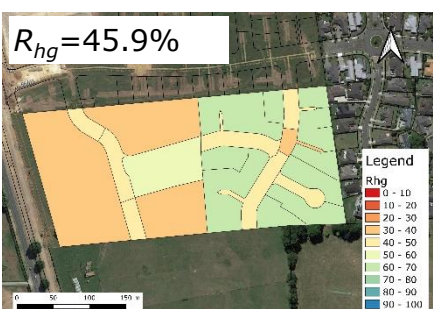
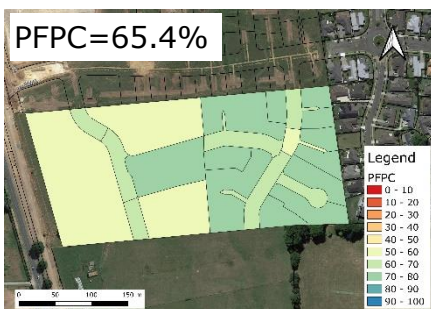
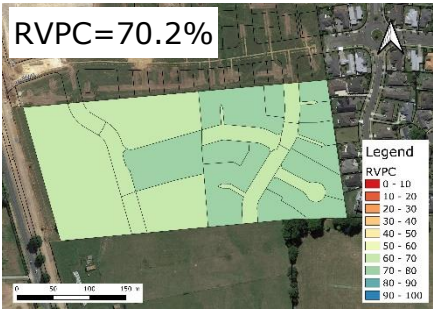
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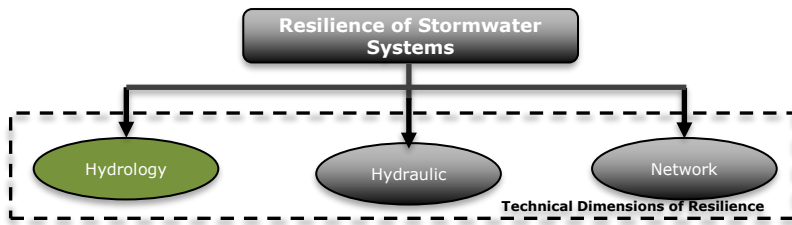


P=64mm



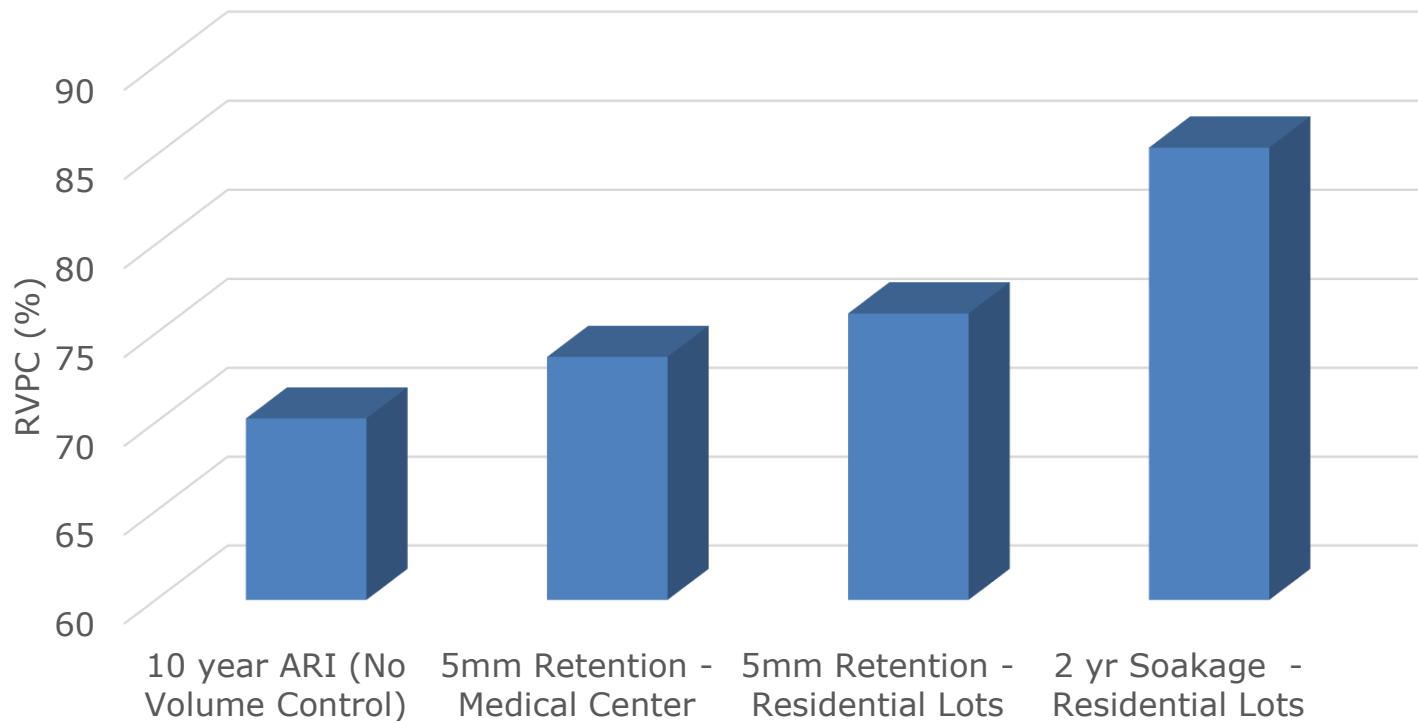
P=98mm



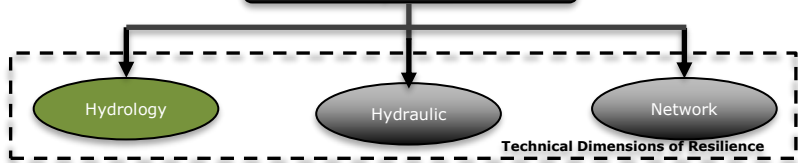


Case Study One

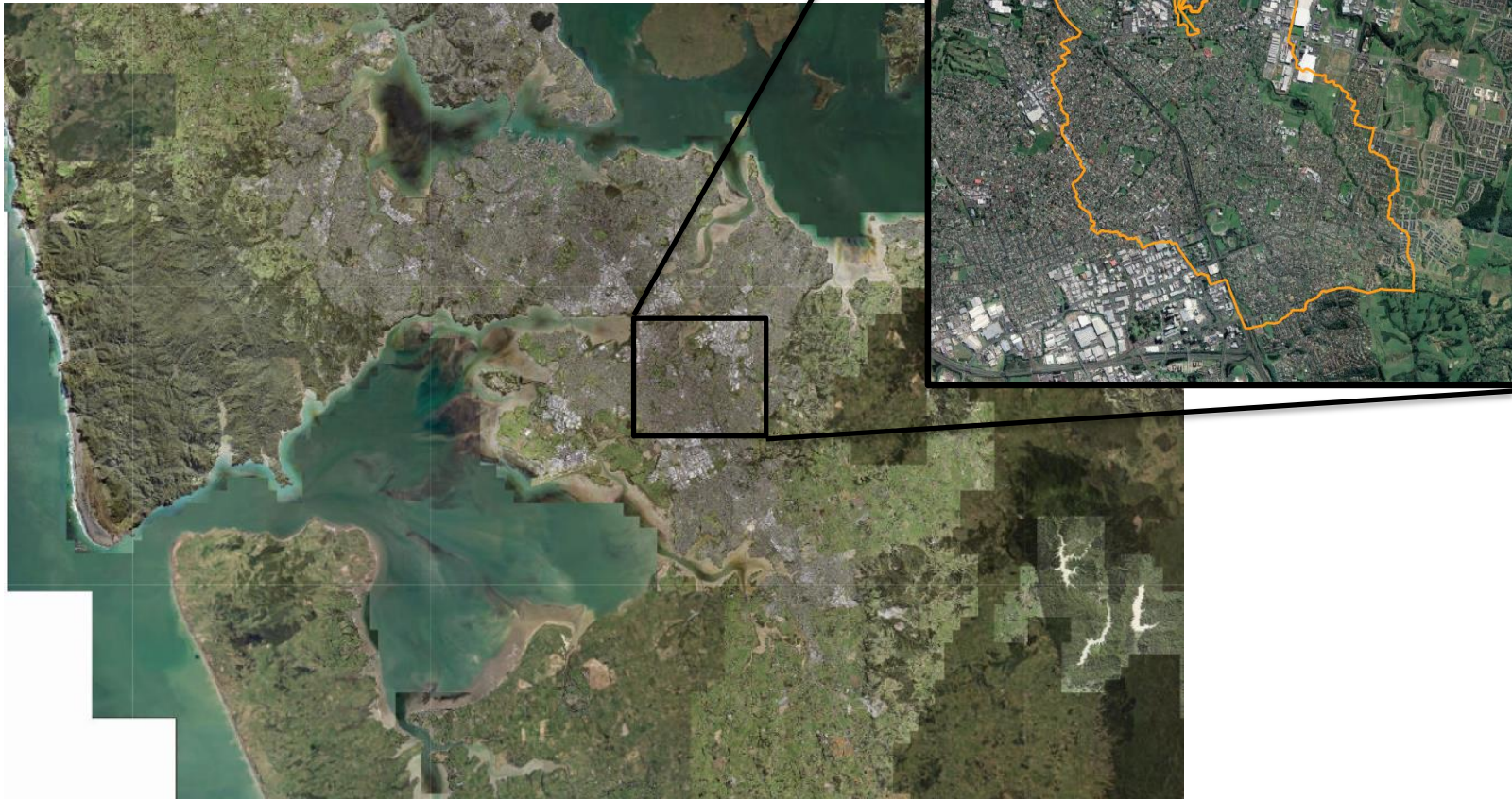
Volume Control Effect

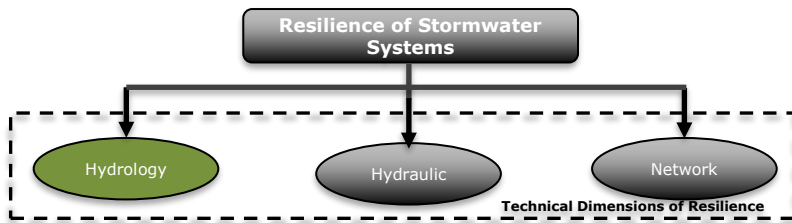


Resilience of Stormwater Systems



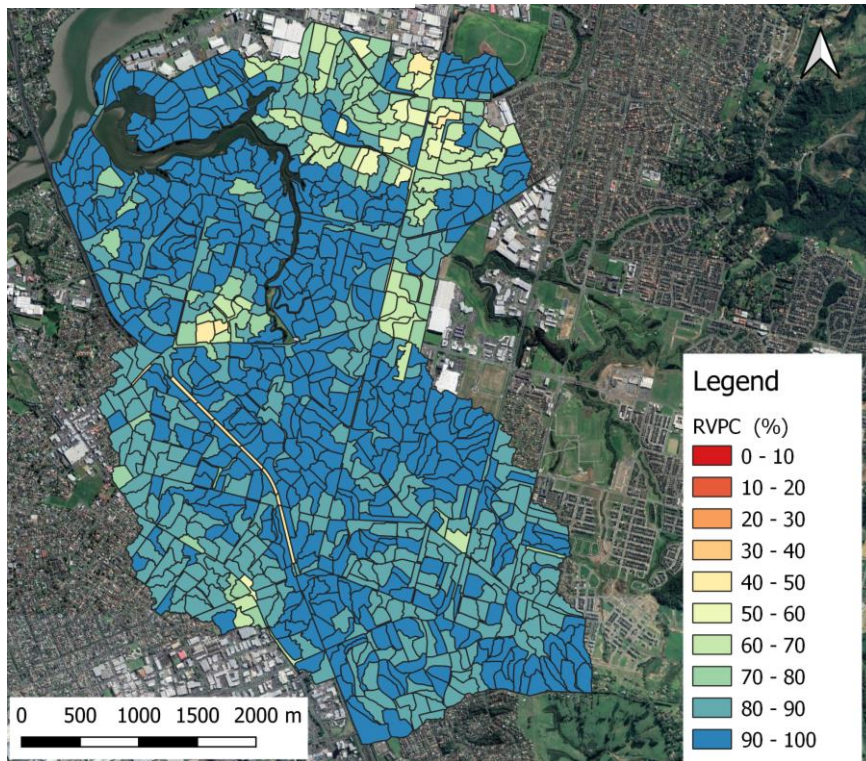
Case Study Two





Case Study Two

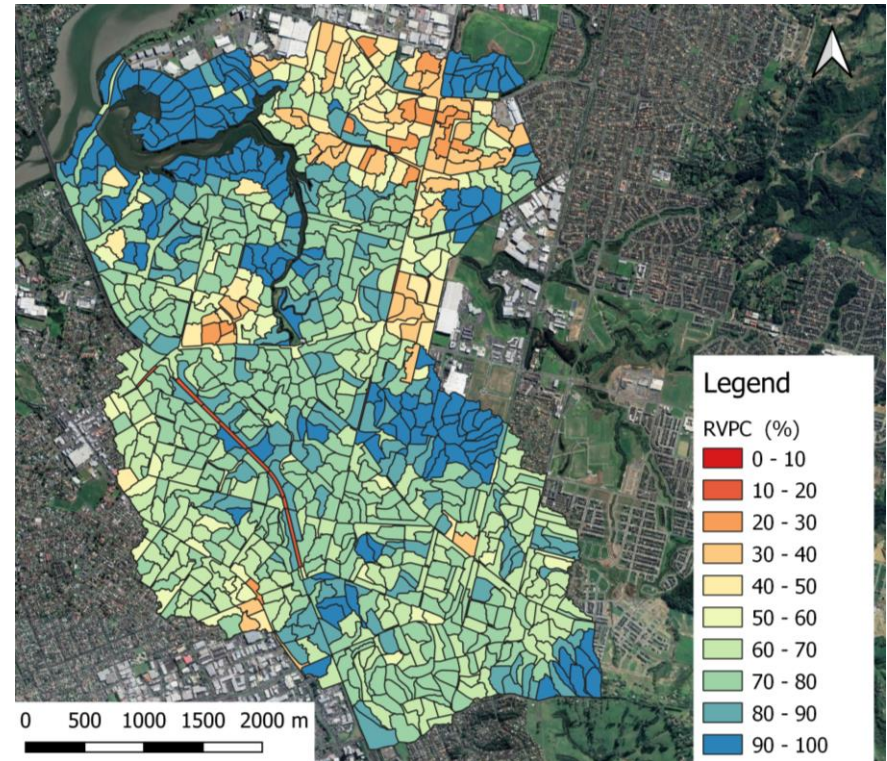
90th Percentile Rainfall



RVPC = 89%

The Sub catchment is provided by Auckland Council

10 year ARI



RVPC = 72%

Conclusion

- Provide a metric to evaluate the response of the system in rainfall events in terms of runoff volume and peak flow
- Provide spatial mapping for the catchment to show the loss of volume, peak flow and eventually the resilience of hydrology dimension
- Provide comparative studies for difference land use and stormwater devices
- A tool for proposed urban developments and/or improved catchment management
- Can be applied using standard industry software

Thank you

Questions?