Investigating nature-based solutions for volume reduction and climate change resilience

Our rain garden sucks!?

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James Lear

Outline

Objective: Demonstrate the importance and potential for volume reduction in nature-based solutions

- Why volume reduction?
- USA Case Study: Climate change impacts in the Charles River Catchment
- NZ regulation for volume reduction
- Evapotranspiration in green roofs vs. bioretention systems
- Our volume reduction investigation
    - Site description
    - Investigation and results
    - Conclusions and Future work

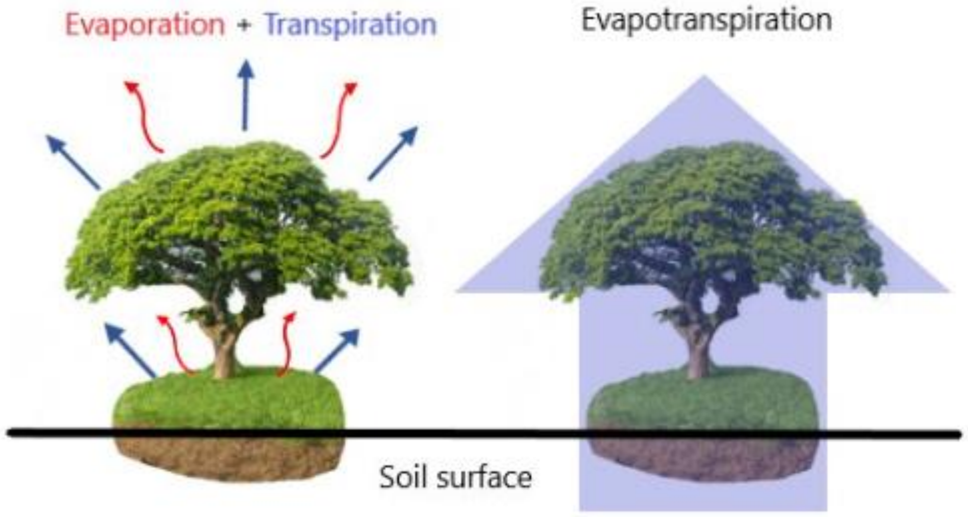


Image source: https://www.researchgate.net/publication/359613000_Estimation_methods_to_define_reference_evapotranspiration_a_comparative_perspective/figures?lo=1

Urban Volume Reduction

Why?

- Peak flow reduction
- Contaminant removal
- Habitat protection
- Maintain environment flows

How?

- Infiltration
- Water use

Evapotranspiration!!
(ET)

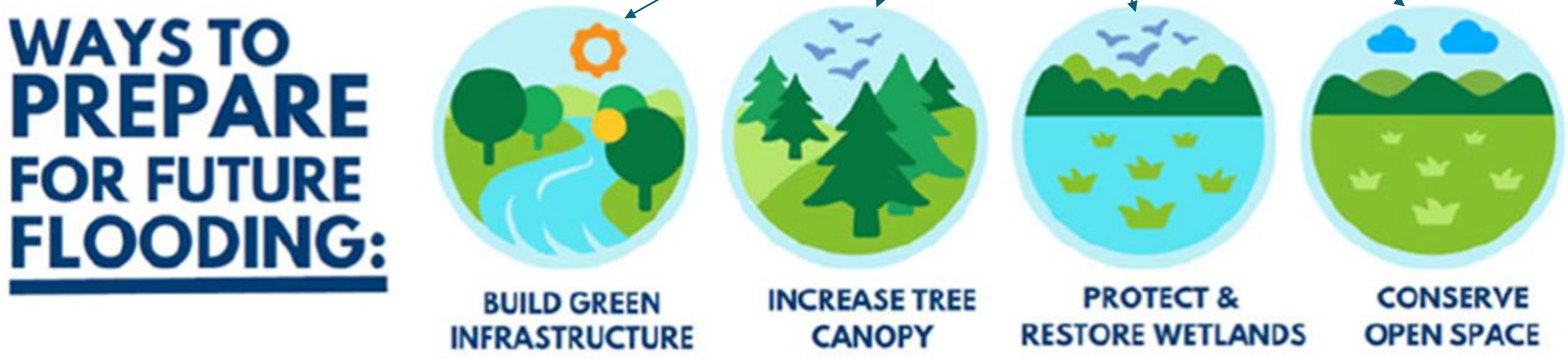
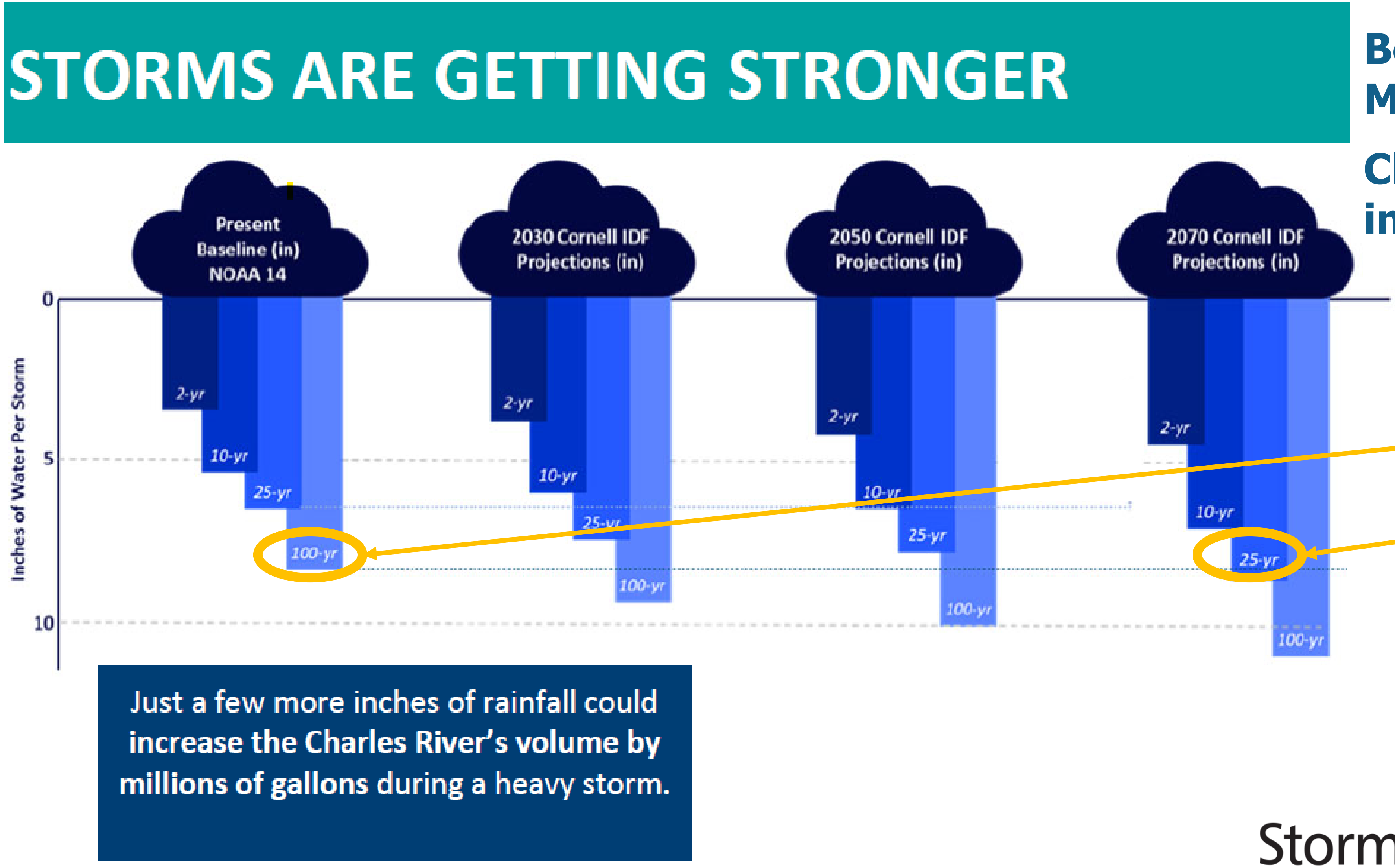


Image source: https://www.epa.gov/watershedacademy/nature-based-solutions-climate-resilience-webcast

Case Study: Charles River Catchment



Boston, Massachusetts

Climate change impacts

2024's 100yr = 2070's 25 yr

Source: https://www.epa.gov/watershedacademy/nature-based-solutions-climate-resilience-webcast

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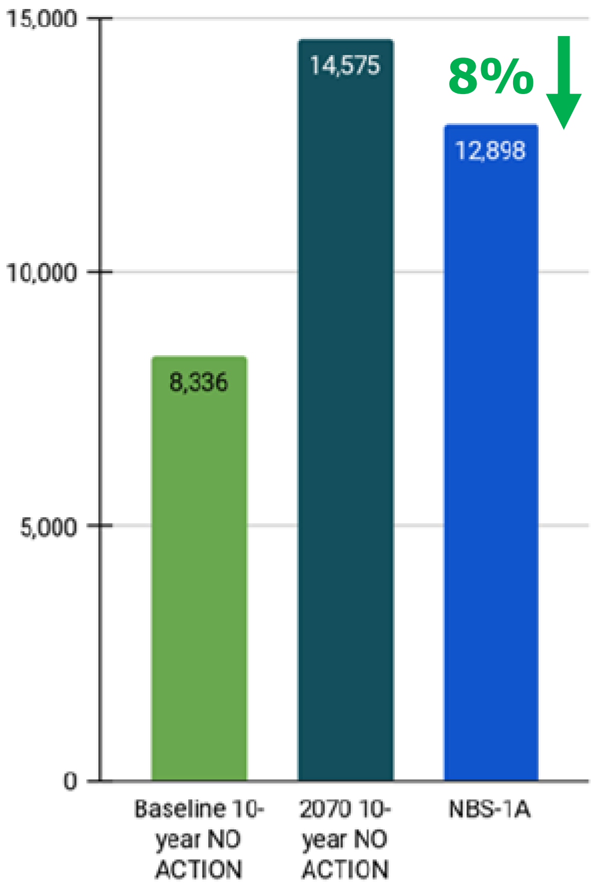

Total runoff volume during 10-year events

- NBS-1 A – Uses green stormwater infrastructure to **store** the **2070 2-year storm runoff** from 50% of all impervious cover
- **Reduce** future flooding impacts by updating regulations to require flood storage

Source: https://www.epa.gov/watershedacademy/nature-based-solutions-climate-resilience-webcast

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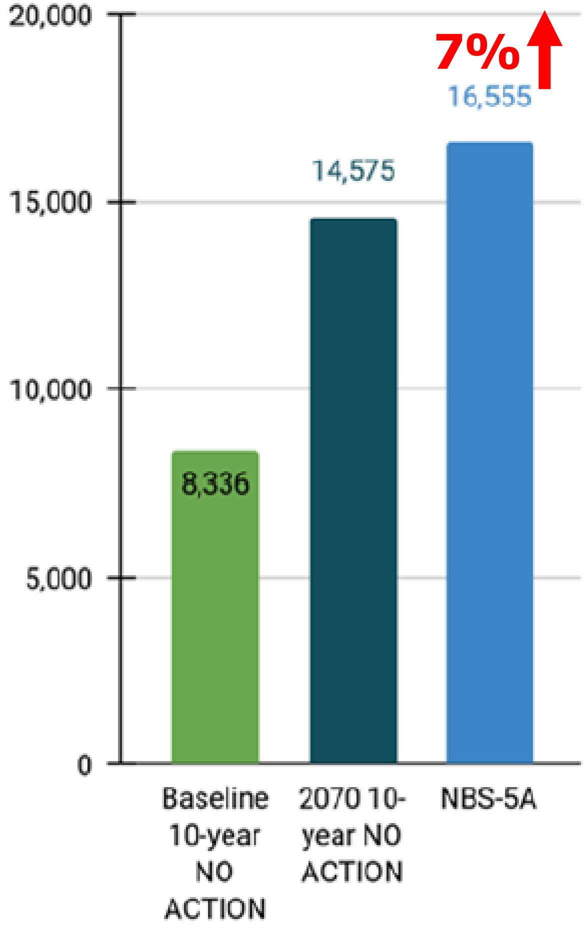
Case Study: Charles River Catchment



Total runoff volume during the 2070 10-year event

- NBS-5A – **Develop 15%** of current undeveloped or unprotected land
- **Exacerbates** future flooding impacts
- **Regulation required** to keep green space

Source: https://www.epa.gov/watershedacademy/nature-based-solutions-climate-resilience-webcast

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NZ Regulation Examples

- Stormwater Management Area Flow (SMAF) Requirements in Auckland – retention (5mm) detention (24 hours of the 90 or 95th percentile event)
  - I.e., **infiltration** and **water use**
- Waikato Regional Council objectives for **infiltration**: volume reduction, contaminant removal, and low stream flow augmentation

ET Knowledge Gap?
What if we could quantify ET and include in NZ regulations…

Source: https://www.epa.gov/watershedacademy/nature-based-solutions-climate-resilience-webcast

ET: Green Roofs vs. Bioretention

Green Roofs

- Well documented
- Designed for **retention**, not infiltration
- Engineered media to have high plant-available water (PAW)
- Volume reduction simple = depth of the rainfall / area of the depth of the rainfall

- Range from **30-86% volume reduction**
- Affected by conditions such as antecedent conditions, rain intensity and depth, wind speed, solar radiation, humidity
- Affected by media depth and water retention capacity, age, slope, type of vegetation

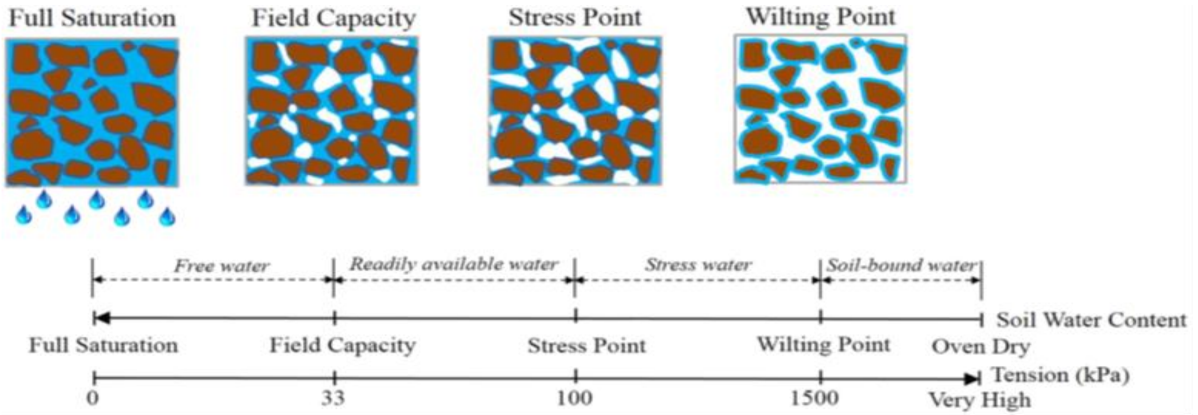
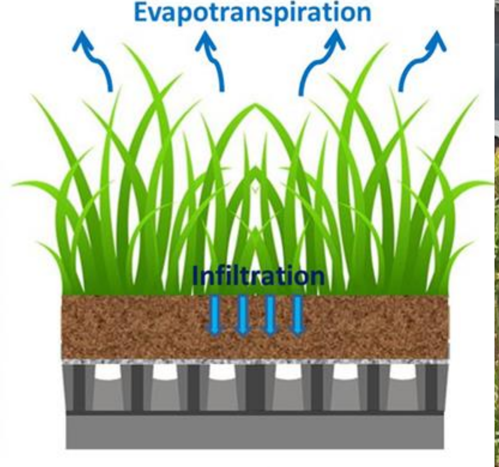
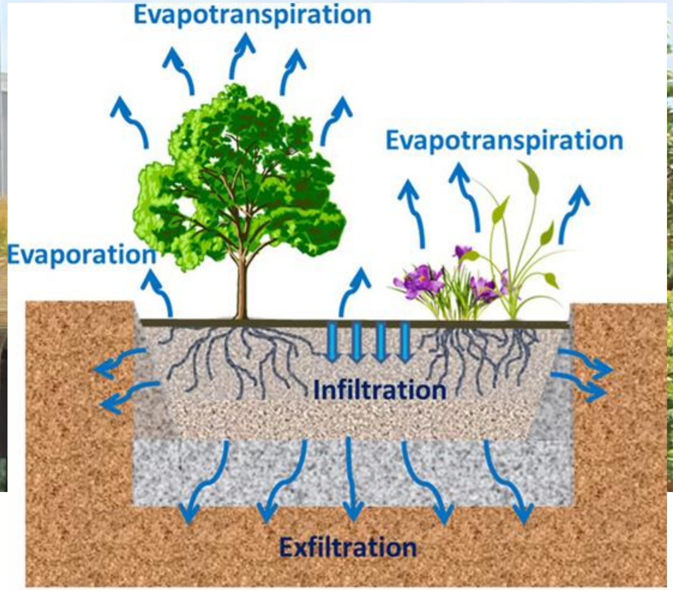


Image source: https://www.sciencedirect.com/science/article/pii/S0048969719328293



Green Roof



Rain Garden

ET: Green Roofs vs. Bioretention

Bioretention (Raingardens)

- Less well documented
- Designed for **infiltration**, not retention
- Media can be engineered to have high plant-available water (our system 10-20%)
- Volume reduction -> seems complicated (concentrated runoff)

- Range from **19-84% volume reduction**
- Some research suggests the simple temperature-based Hargreaves ET Model could be applicable
- Affected by conditions such as antecedent conditions, rain intensity and depth, wind speed, solar radiation, humidity

Diagram source: https://www.sciencedirect.com/science/article/pii/S0048969719328293

Recap

Objective: Demonstrated the importance and potential for volume reduction in nature-based solutions

- ✓ Why volume reduction?
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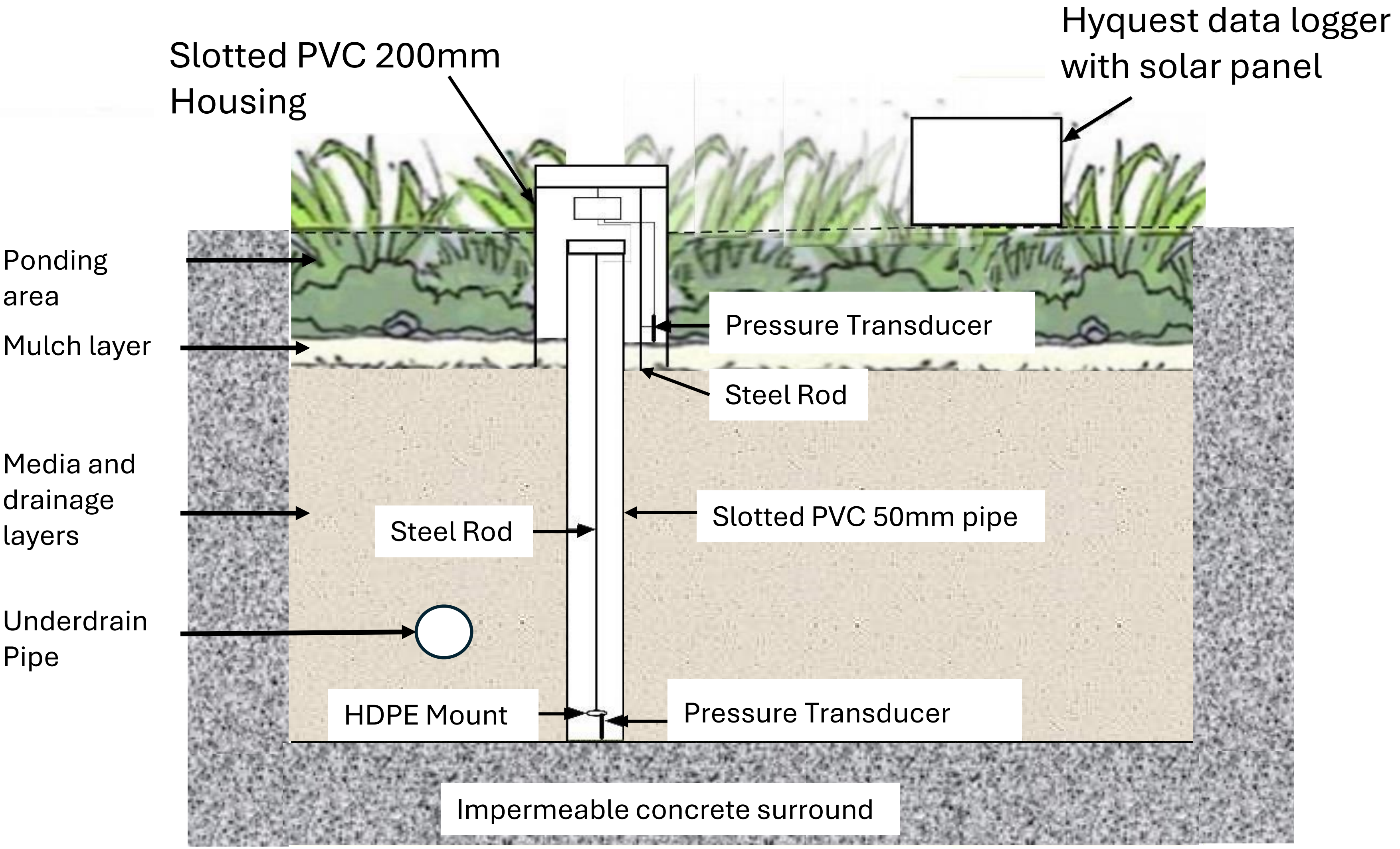
Site Description

- ADT ~16,000 vehicles
- 3709m^2 catchment
- 25m^2 High Flow Biofiltration System
- Discharge into Mahoenui Stream
- Design flow rate 10.6 l/s
- FOS 5 for high loading

Monitoring Equipment I

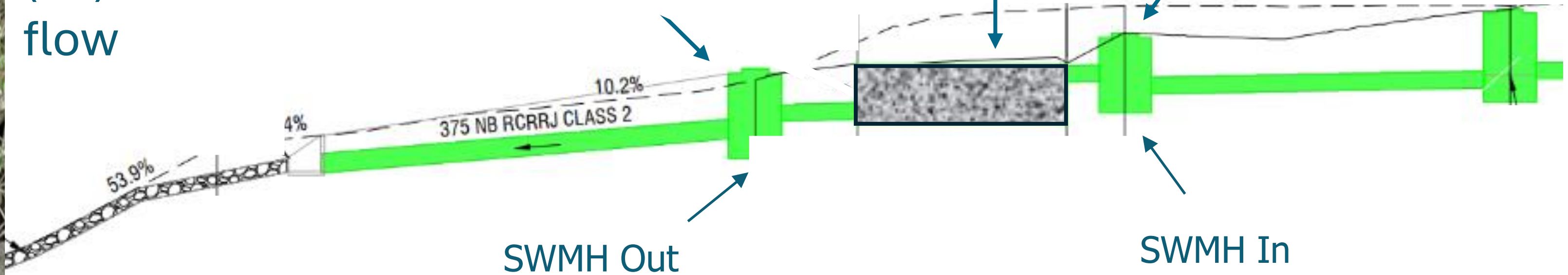


Monitoring Equipment II

HFBF System

120° V-Notch weir and Pressure Transducer to measure influent flow

120° V-Notch weir and Pressure Transducer (PT) to measure effluent flow



SWMH Out

SWMH In

PT Recording interval: 300 seconds (5 minutes)

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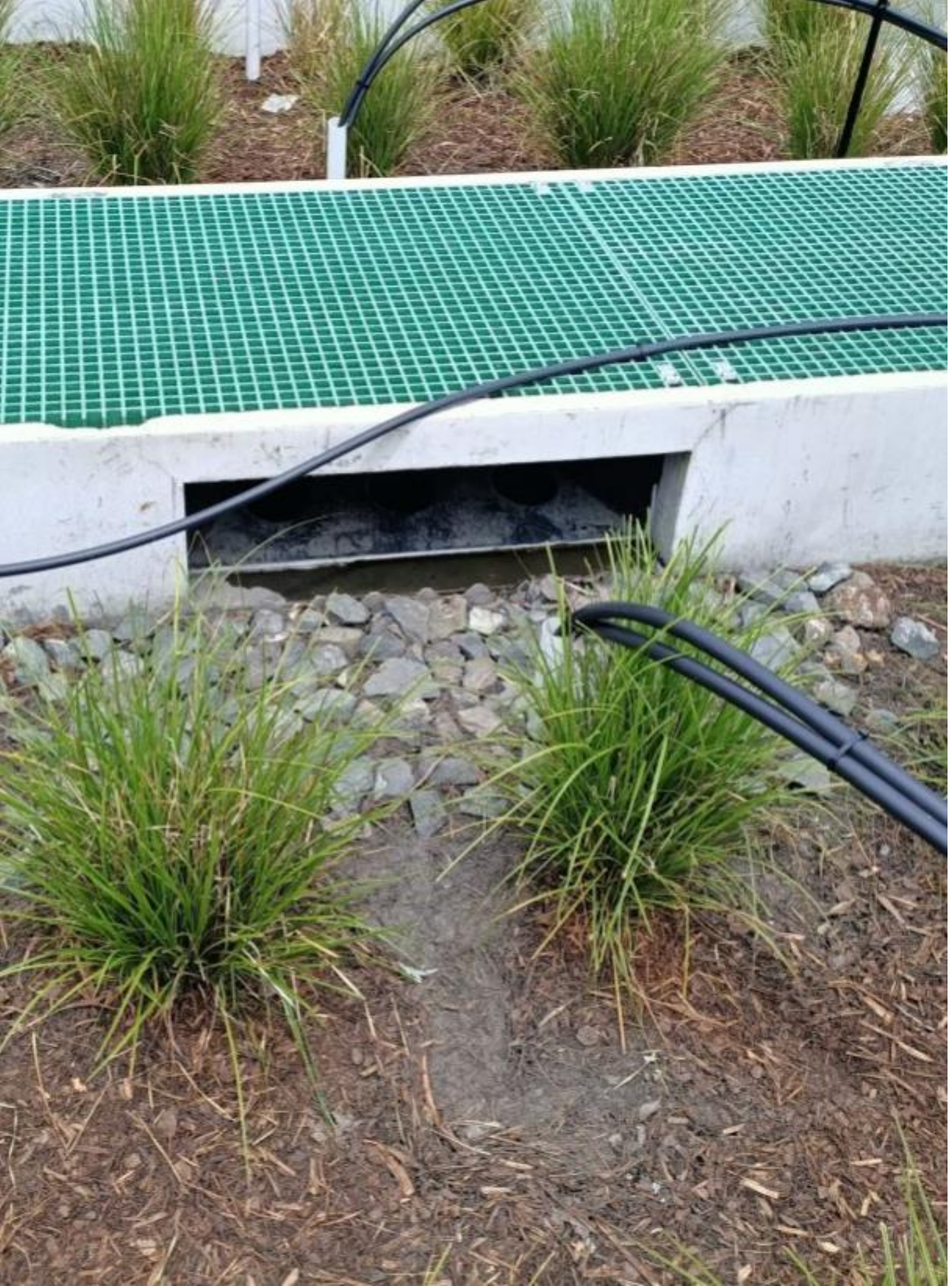


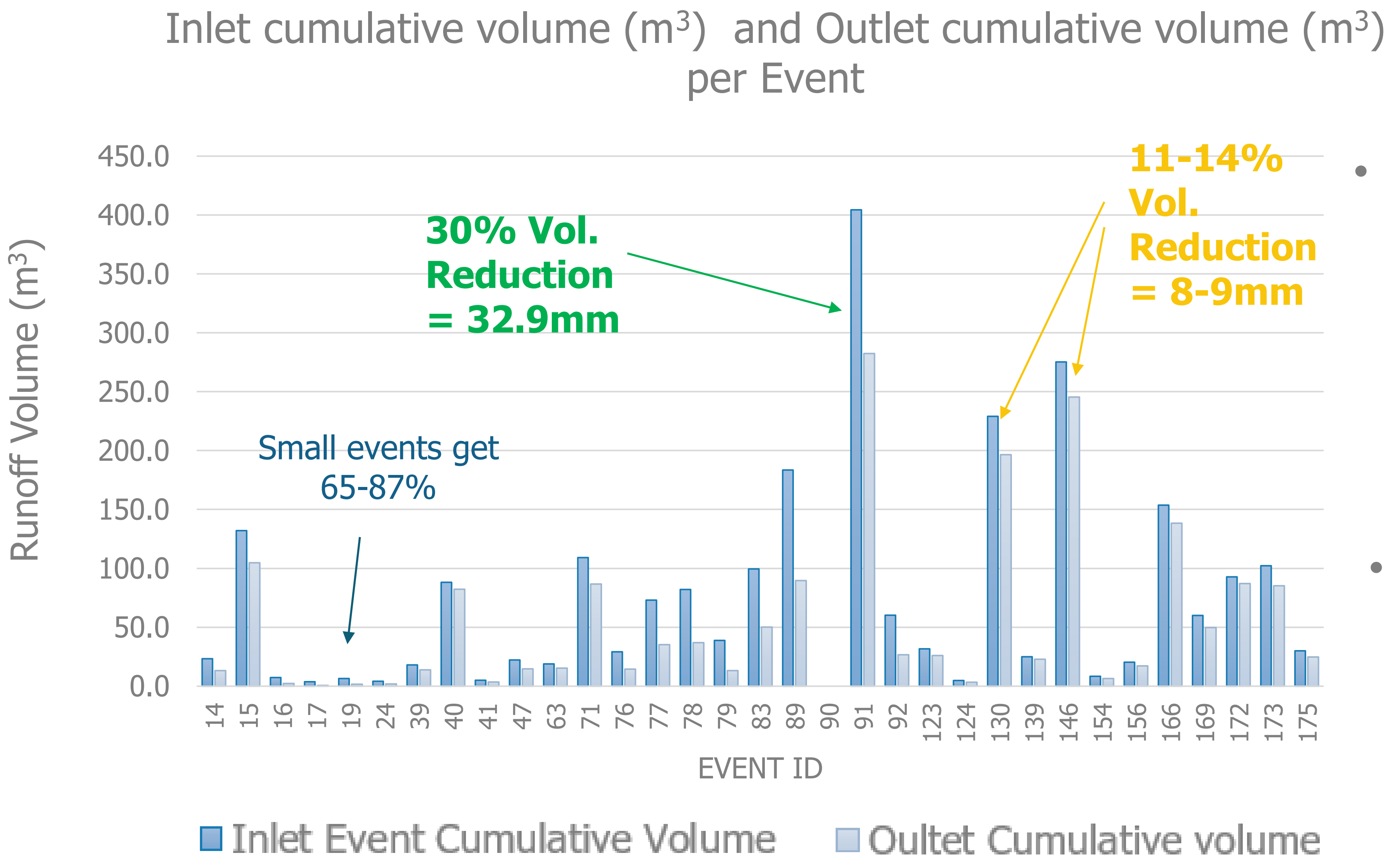
Methods I

- **Event segmentation**: 6 hours of no rainfall
- **Flow Rate:** 120° v-notch weir chart $Q = 2391\ H^{2.5}$
- **Volume and Volume Reduction:** the cumulative sum of flow rate multiplied by recording interval (300 seconds) with reduction being the percentage difference in the final cumulative volume between the inlet and the outlet
- **Runoff depth:** the cumulative volume of the event over the catchment area

Methods II

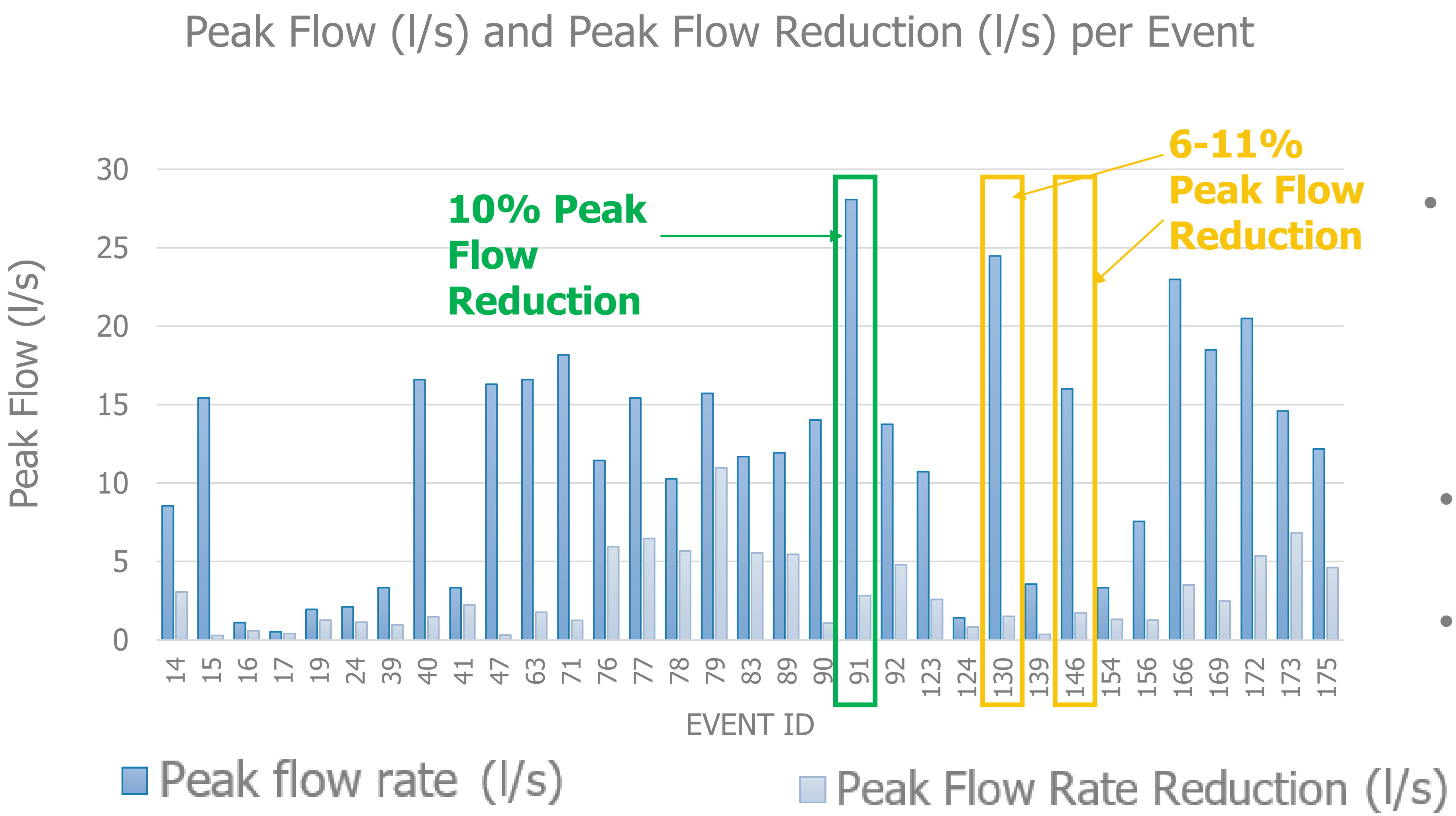
- **Peak Flow and Peak Flow Reduction:** maximum flow rate with the reduction being the difference between the inlet and outlet
- **Storm Depth:** Back calculated using TP108 and original design assumptions
- **Lag Time (detention proxy)**: the 'lag time' between peaks at the inlet and outlet
- **32 Events** considered in the results

Some spectacular results!



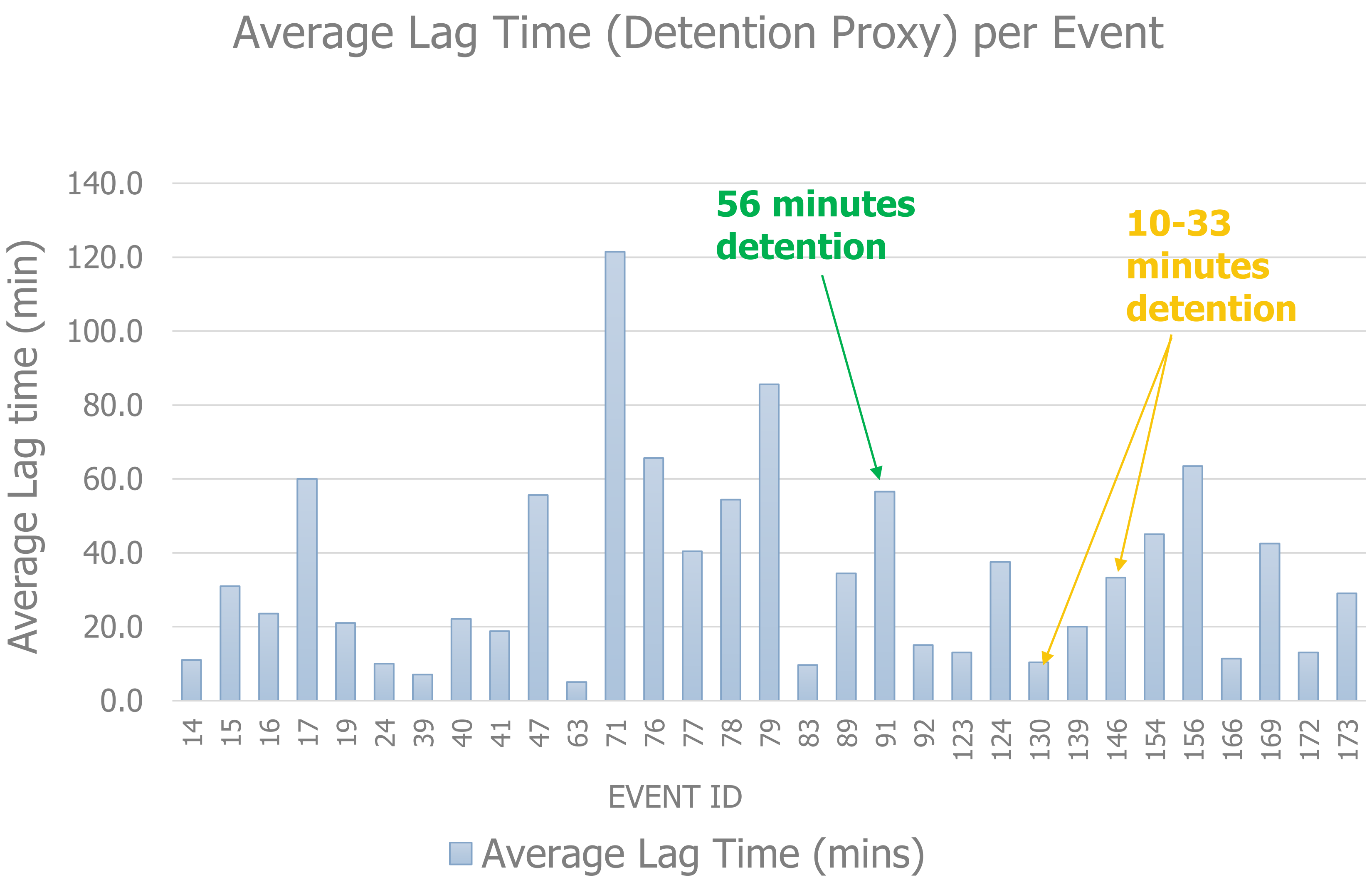
- SMAF 2 90th percentile storm is ≥26.2mm /24 hours
  - 11-30% runoff reduction
  - 32.9mm and 8-9mm
- Overall runoff reduction interquartile range 18-55% (mean of 36%)

Some less spectacular results!



- SMAF 2 90th percentile storms
  - Peak flows 16-28 l/s
  - Reduction 6-11%
- Overall range 1-88% (mean of 35.00%)
- Greater for smaller storms

Some useful results!



- Overall range from 5 to 121 minutes (mean ~30 minutes)
- SMAF 2 90th percentile storms with detention for 10-56 minutes
- SMAF 2 90th percentile average discharge/24hrs requires = 0.6 l/s
- Observed for SMAF 2 90th percentile or larger ranged from 1.2 – 2.3 l/s

Further data analysis…

- Wetter antecedent conditions had greater retention
- Media slightly hydrophobic after long dry periods
- Aligns with what we see when testing in the laboratory

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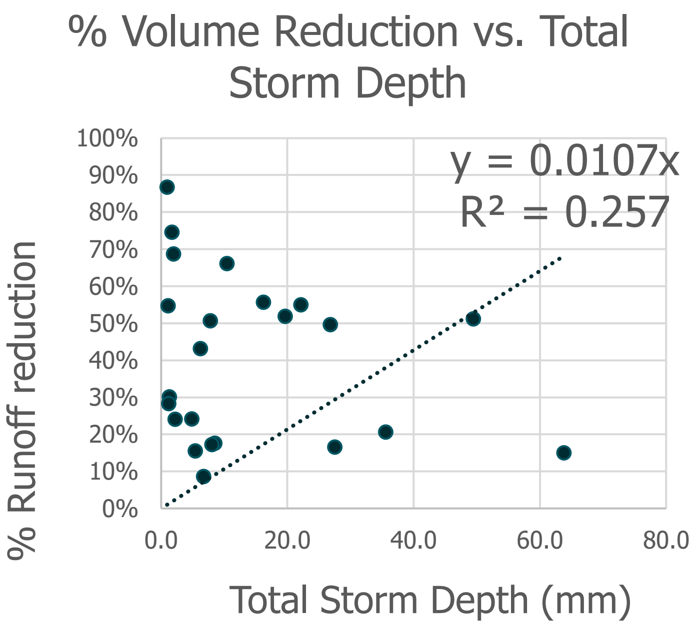
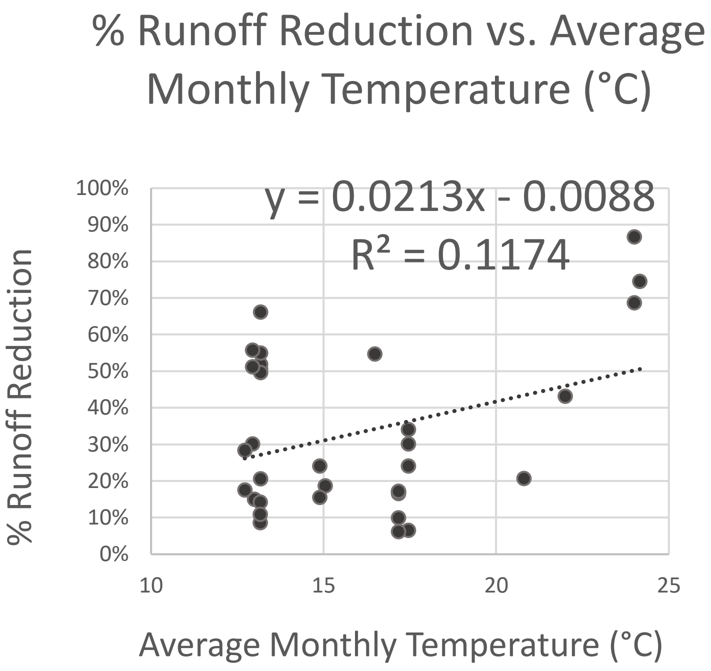
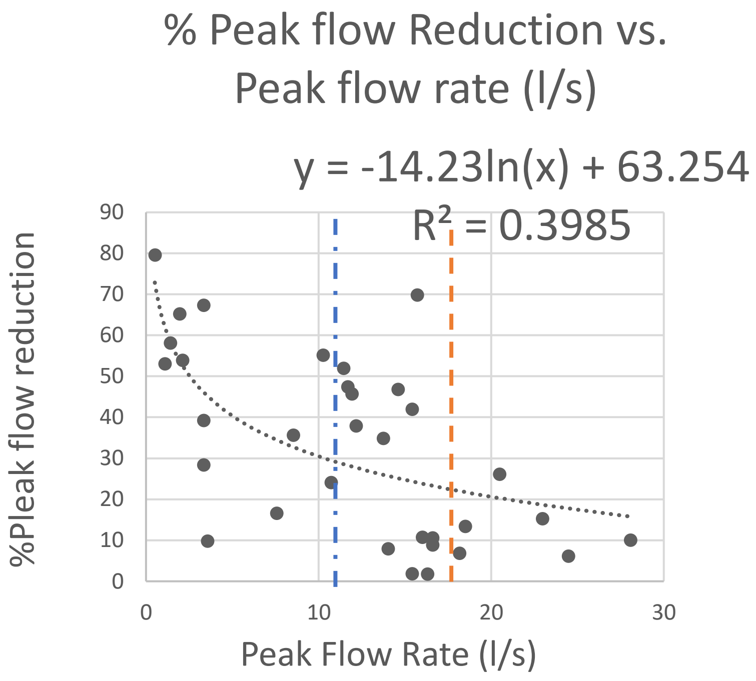
Looking for Correlations…



- Perhaps the media isn't getting saturated



- Interesting given that some research suggests a temperature-based ET model



- The system may be bypassing at 17 l/s

Conclusions

- Volume reduced by up to 120,000 L in a single event!
- Volume reduction is possible in a High Flow Biofiltration System!
  - Interquartile range 18-55%
  - Average volume reduction of 35%
- Peak flow reduction is also possible (but variable)!
  - 1-88%
- In 90th percentile for SMAF 2 Events:
  - Met retention requirements i.e., 5mm retention of a design storm (26.2mm/ 24 hr)
  - Did not meet SMAF 2 detention requirements i.e., average discharge of 0.6 l/s over 24 hours
    - Currently get 1.2 and 2.3 l/s average discharge for 24 hours

Considerations and Future Work

- Unsaturated flow may be affecting results
- 300sec time step and assumptions for volume calculation
- Data required for an ET model, such as the Hargreaves method, has not been collected to date

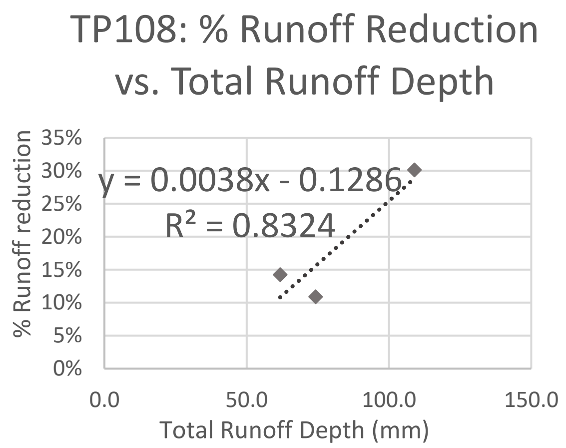
Future work

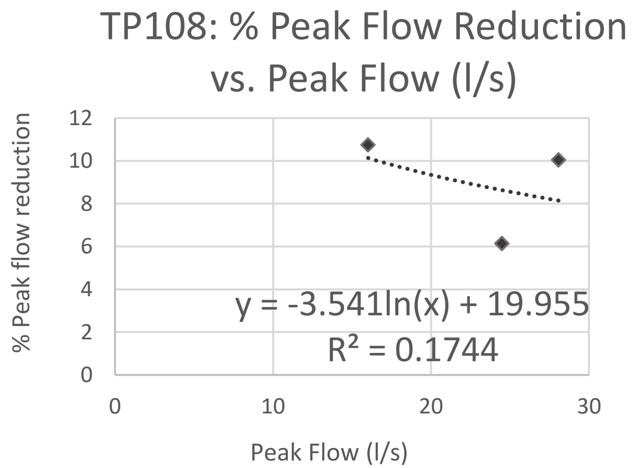
- More monitoring equipment on site
- Reduce PT recording interval to 60 seconds
- Monitor a site allowed to infiltrate as a comparison
- Look at how we can add detention to the unit
- Investigate the hydrophobic and hydrophilic states of the media

Our rain garden sucks!?
….but that's a good thing!!

Thank you!
Questions? Patai?

Design Storms

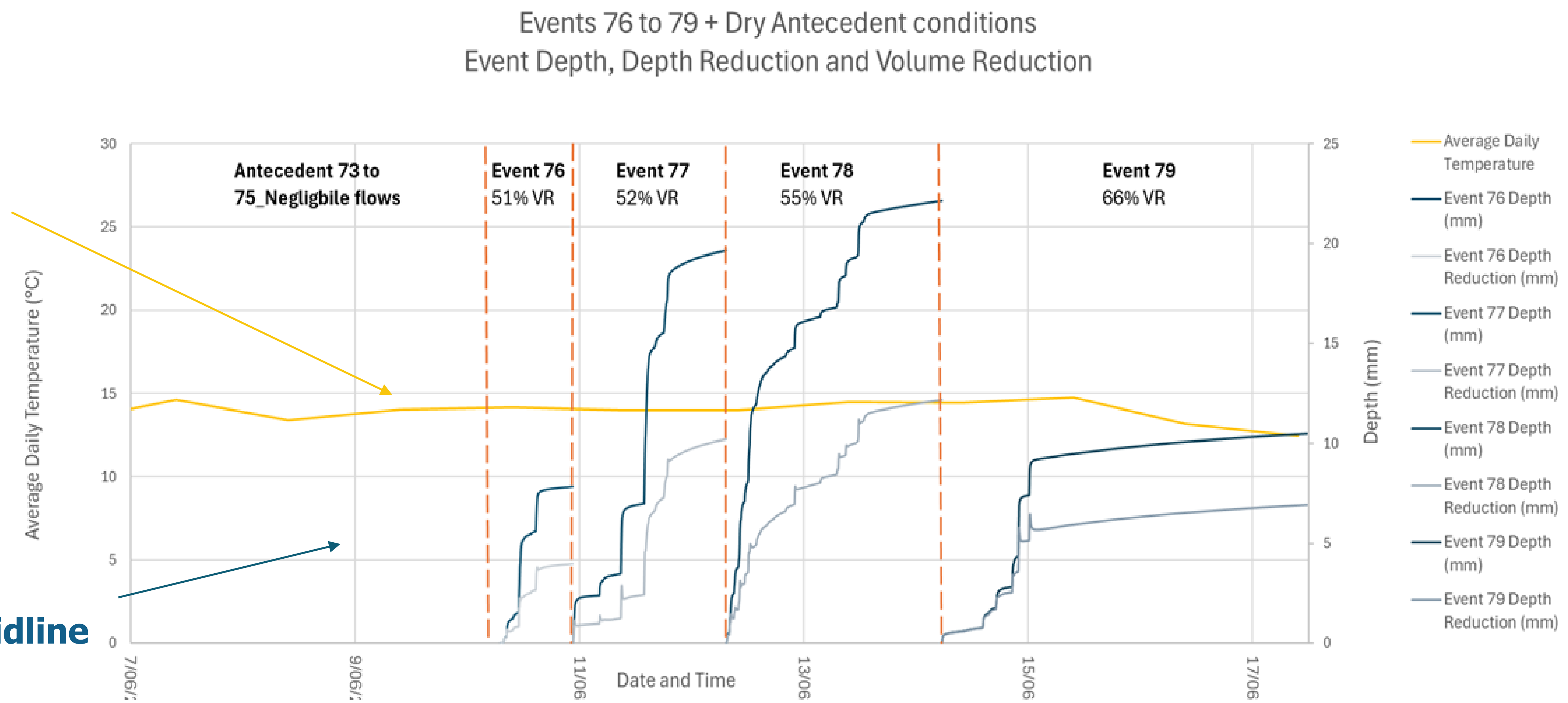




	EVENT ID		
	91	**130**	**146**
Start Time	11/7/2022 13:30	5/9/2022 5:50	30/9/2022 1:15
End Time	12/7/2022 23:05	6/9/2022 12:05	2/10/2022 10:00
Peak Flow Rate (l/s)	28.07	24.48	16.01
Peak Flow Rate Reduction (%)	10	6	11
Average Lag Time (Mins)	56.6	10.3	33.3
Event Duration (Hours)	33.6	30.3	56.8
% Volume reduction	30%	14%	11%
Average Monthly Temp. (°C)	13	13	13
Total Runoff Depth (mm)	109.0	61.8	74.2
Total Runoff Depth Reduction (mm)	32.9	8.8	8.1
Runoff Depth Over 24 Hours (mm)	77.9	49.0	31.4

Consecutive Events

Air temp
13 - 15°C



48 hrs per
vertical gridline

- General increase in %runoff reduction. Note antecedent conditions and duration for each event.
- Events with 20-22mm of runoff reduced by 52-55%.