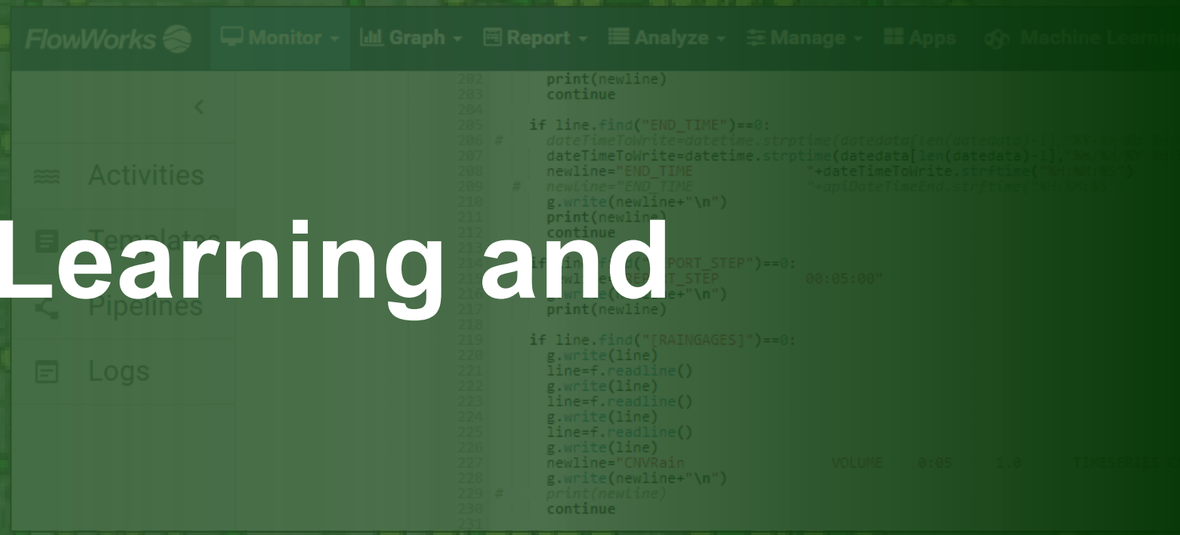
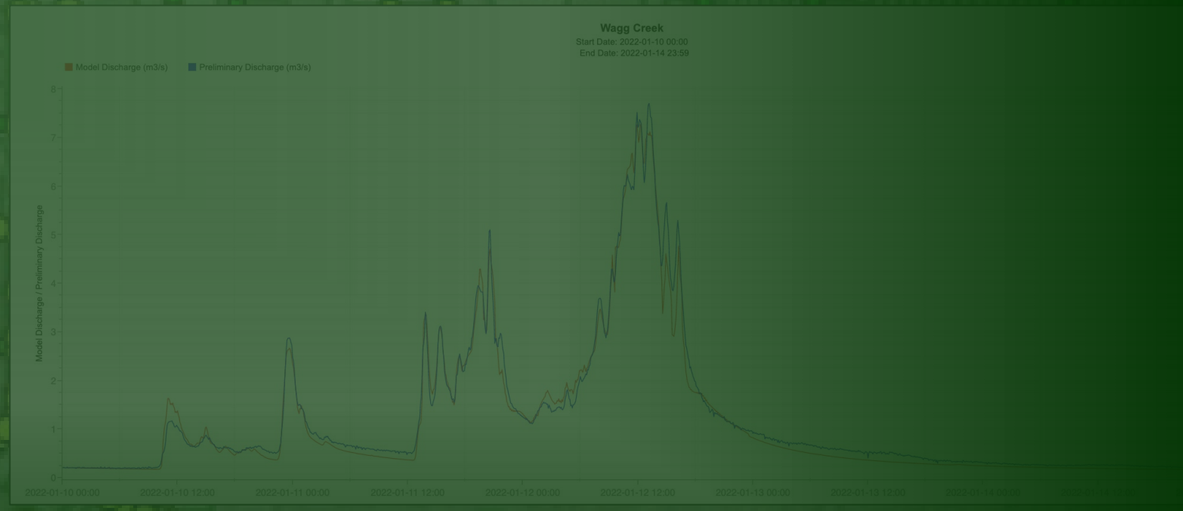
Real-time Machine Learning and SWMM Automation





NWWC 2023 – Niagara Falls

November 14, 2023

Greg Johnston (infinitii-ai)

Jeff Marvin, M.A.Sc., P.Eng. (KWL)

infinitii ai
make your data smarter

KERR WOOD LEIDAL
consulting engineers

Infinitii FlowWorks SaaS Based Application

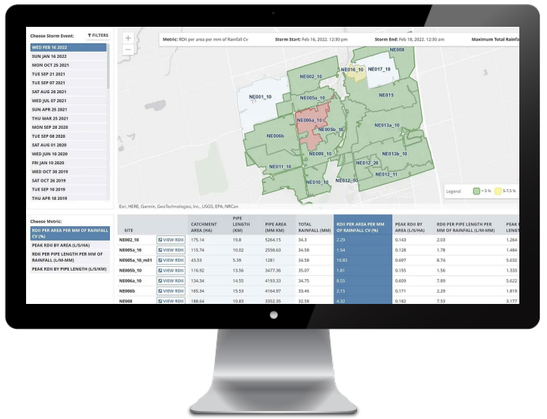
Data Collection

View all network data in one place

Data Visualization

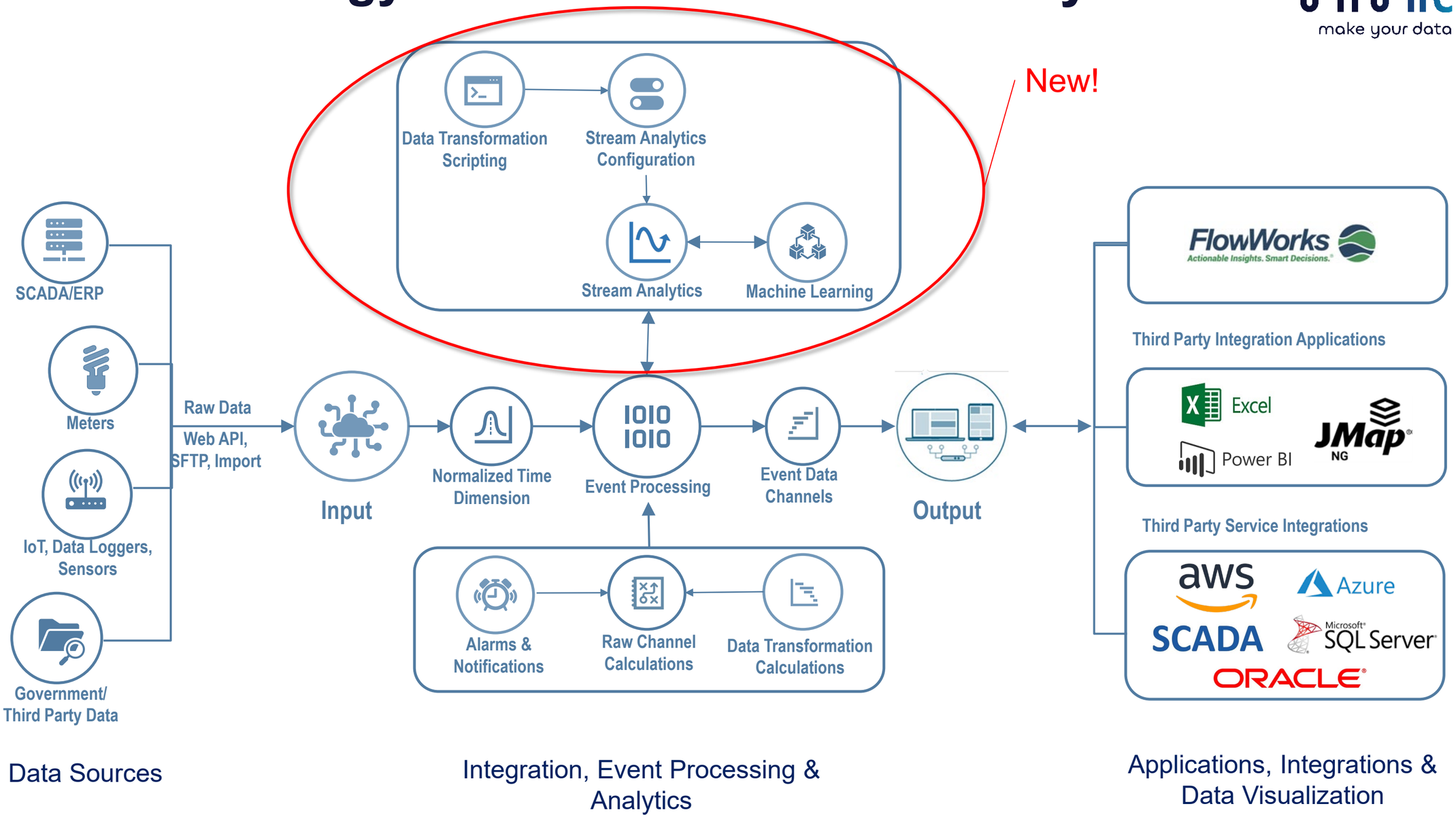
Review and set alarms on channels of data

Data Analysis

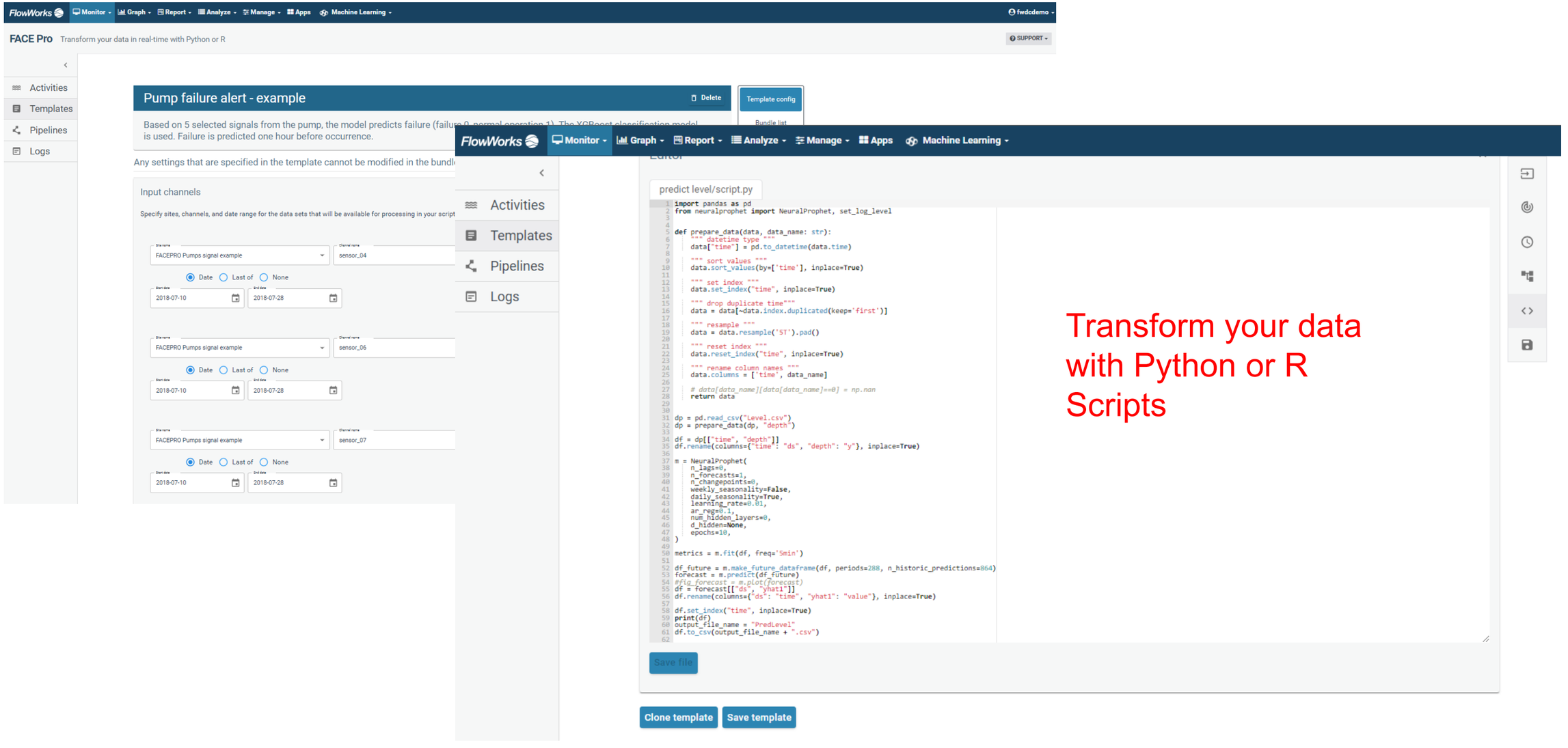


Analyze and predict through custom calculations

Infinintii.ai technology – ML and Advanced Analysis



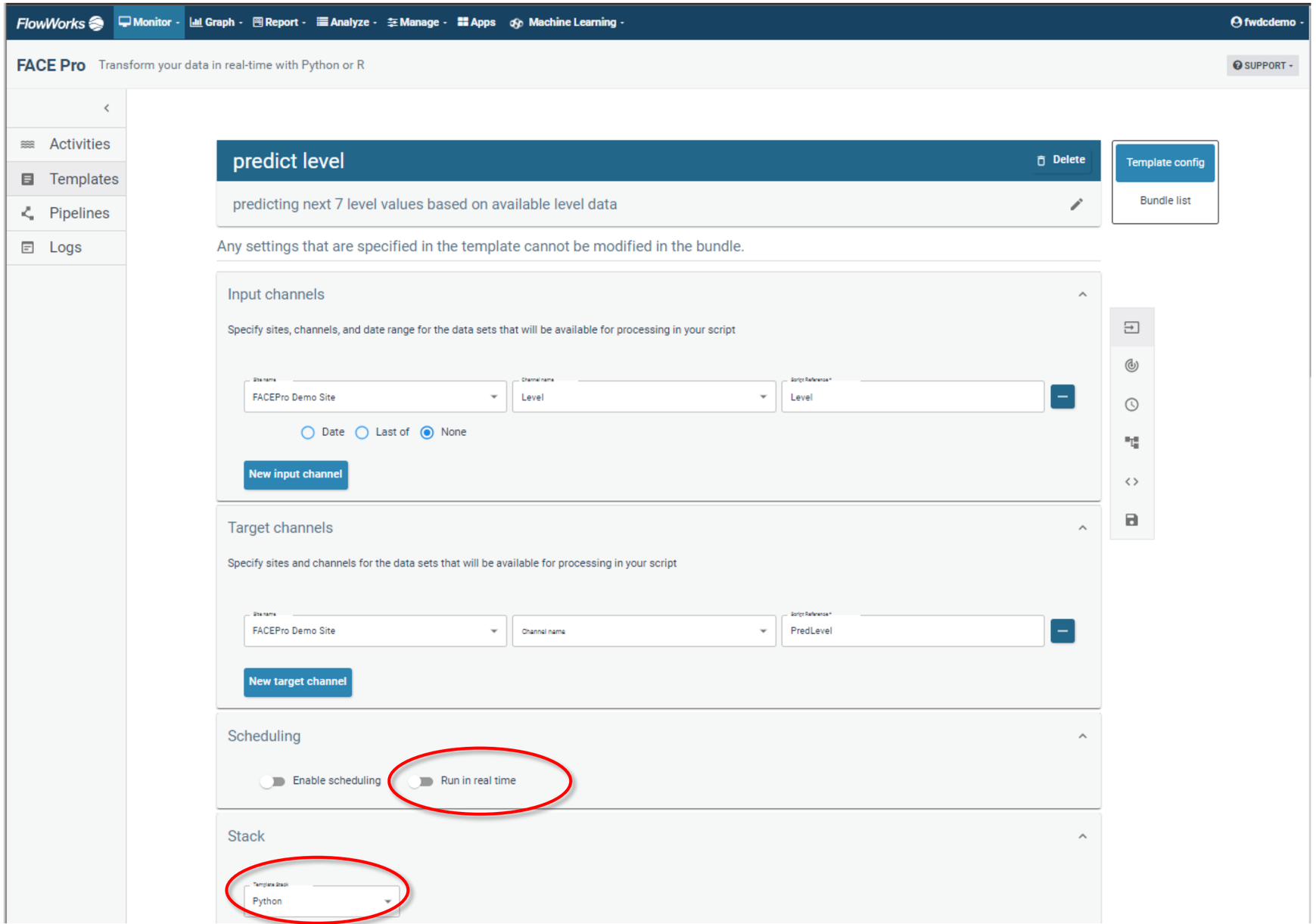
Face Pro – Feature for building and deploying advanced analytics



Transform your data with Python or R Scripts

Face Pro – Feature for building and deploying advanced analytics

infinitii ai
make your data smarter



Benefits Face Pro

- Create new calculated channels of information
- Create advanced data transformations for prediction or pattern recognition (i.e., using ML)
- “Operationalize” your off-line models to run in real time as data is collected (i.e., for streaming analytics)
- Take advantage of open-source code to apply to your data
- Use third party applications and API’s within the FlowWorks application

Using SWMM in Face Pro: Wagg Creek Case Study

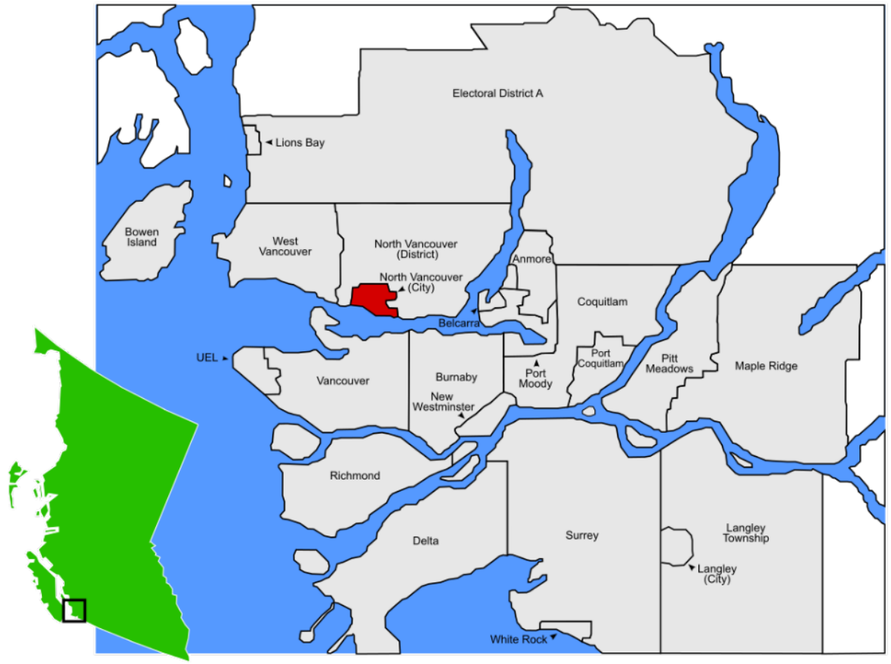
City of North Vancouver Questions to KWL

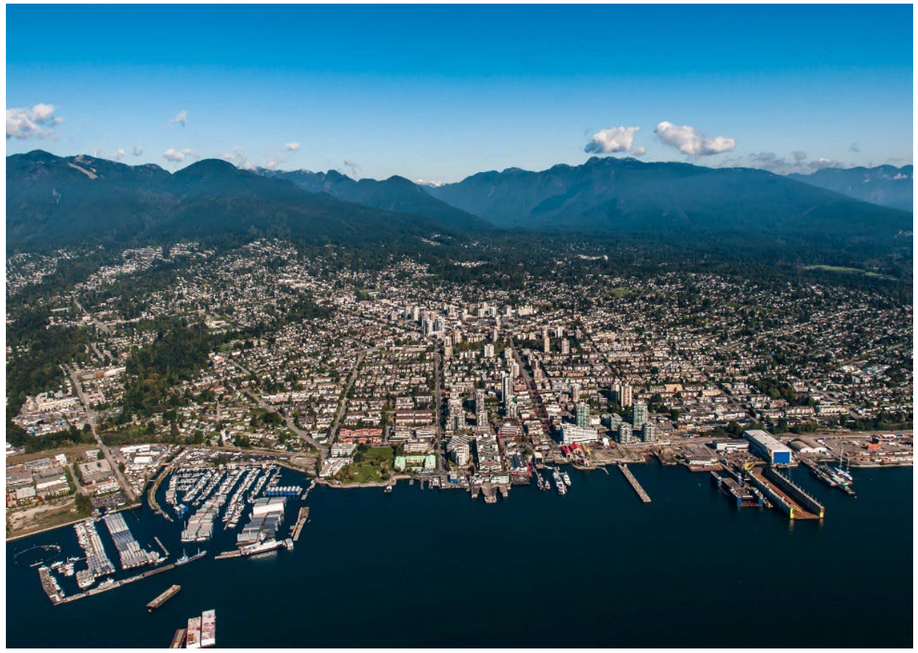
1. **Which tools are available to measure the impact of Green Infrastructure over time?**
2. **Can a real-time drainage model be used to set alarms at ungauged locations in the City?**
3. **Can a real-time drainage model be used to notify us if the flow monitoring sensors foul?**
4. **Can a real-time drainage model be used to predict 7-day flows based on weather models?**

The City of North Vancouver

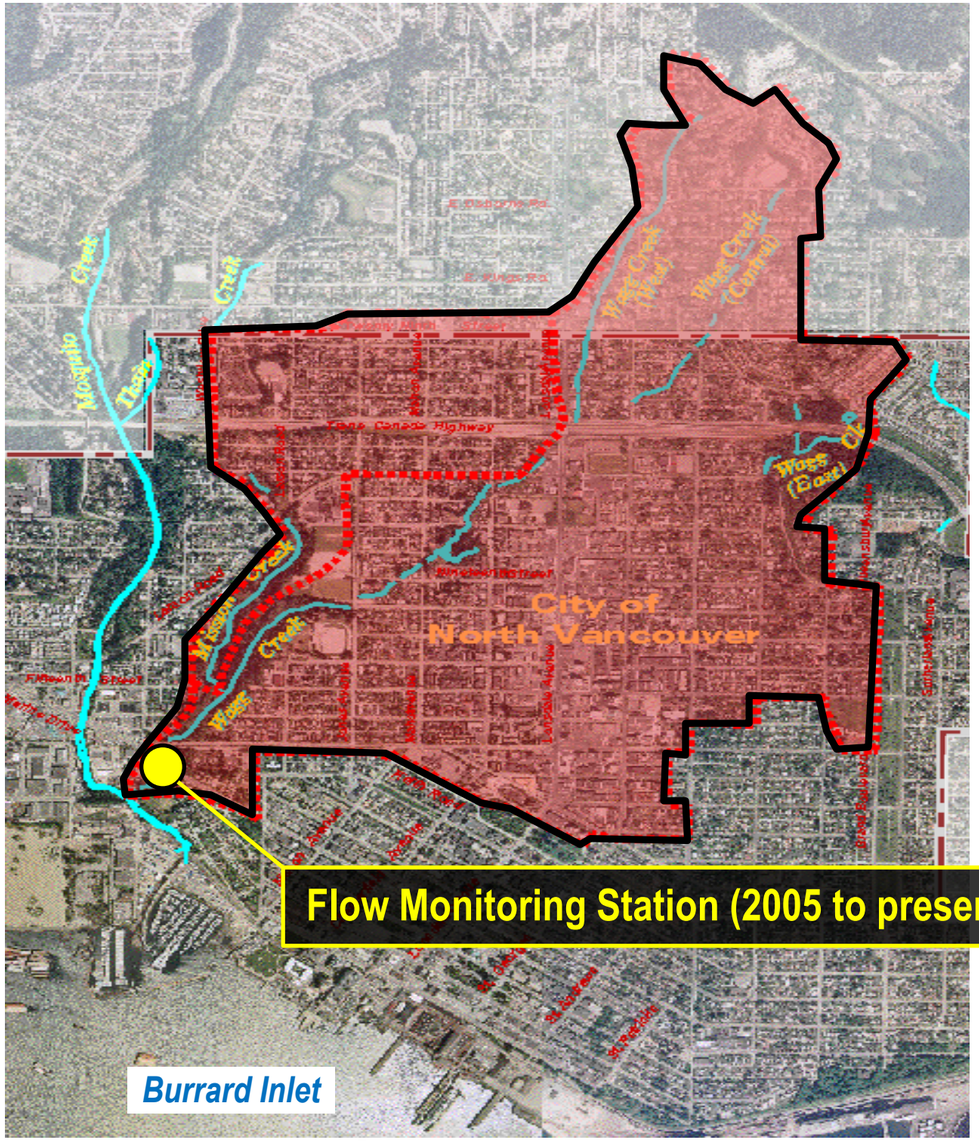
Population: 58,121 (2021)

Area: 11.83 km^2
Density: 4,913 people/km^2





Wagg Creek Watershed



- 100% Urban, Fully Developed Watershed
- Total Impervious Area (TIA) = 50%
- Drainage Area = 5 km^2

KERR WOOD LEIDAL
consulting engineers

Wagg Creek Watershed Planning History

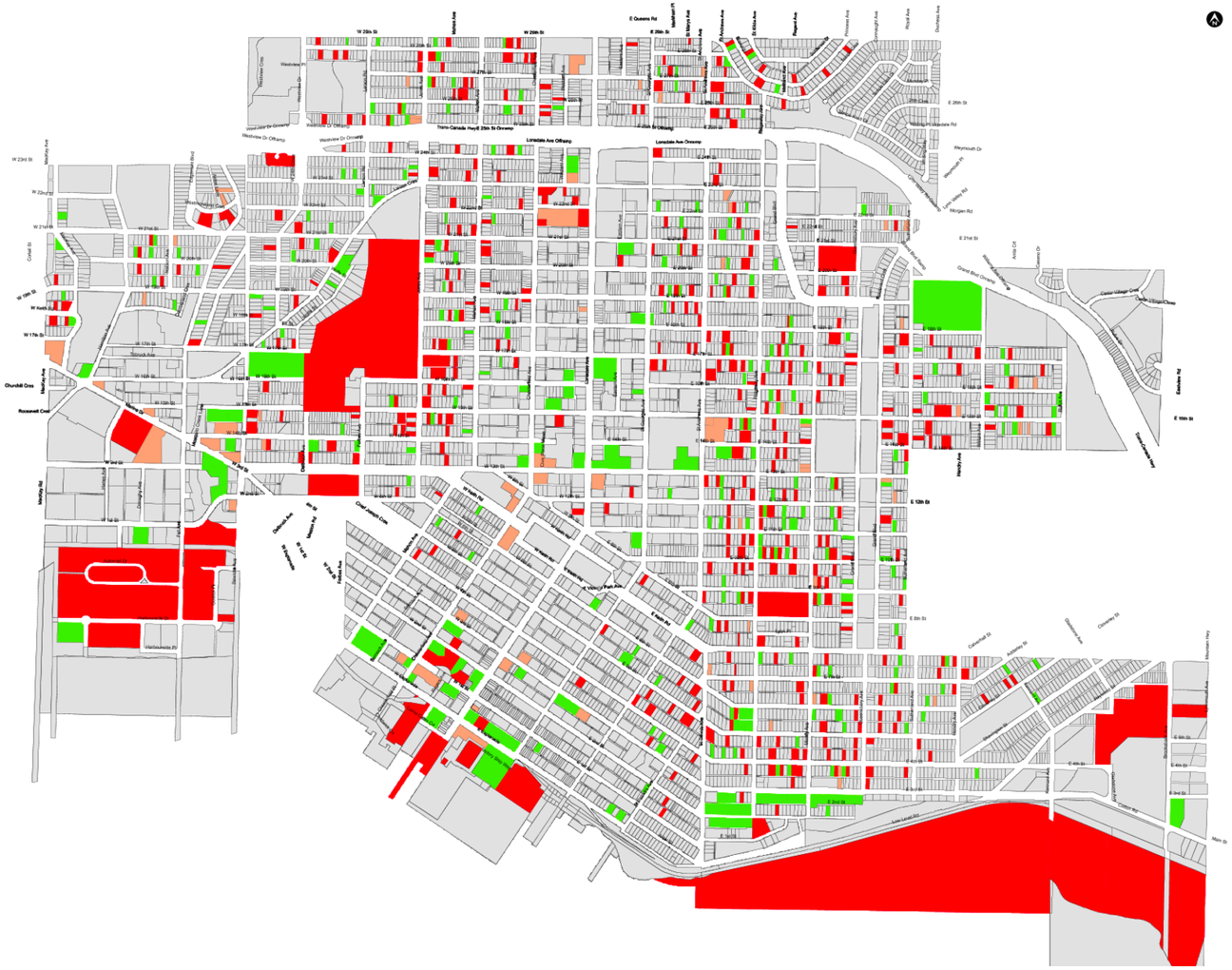
- **1996 – Master Drainage Plan (MDP)**:
  - Identified conveyance system upgrades to meet future development needs.

- **1999 – Integrated Stormwater Management Plan (ISMP)**:
  - Identified impacts of increased densification & impervious area on stream erosion & aquatic habitat.
  - ***New Drainage Criteria (2005 guidelines & 2014 bylaw):***
    - ***56 mm rainfall capture by stormwater source controls (Green Infrastructure)***
    - ***Impervious disconnection to pervious areas***

Examples of Wagg Creek Erosion – 1999

Important note: This erosion was not caused by a “flood event”, but by the continuous impact of a “flashier” hydrograph.

Stormwater Source Control Implementation (2010 to 2018)

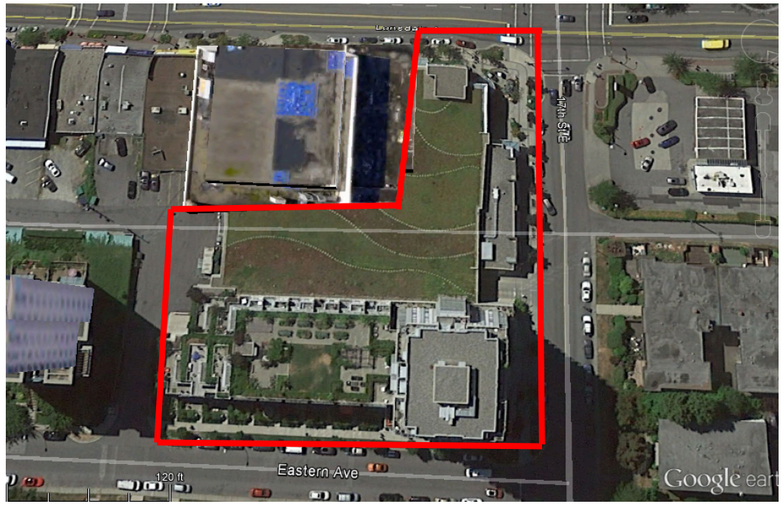


KERR WOOD LEIDAL
consulting engineers

Stormwater Source Control Implementation: Lots

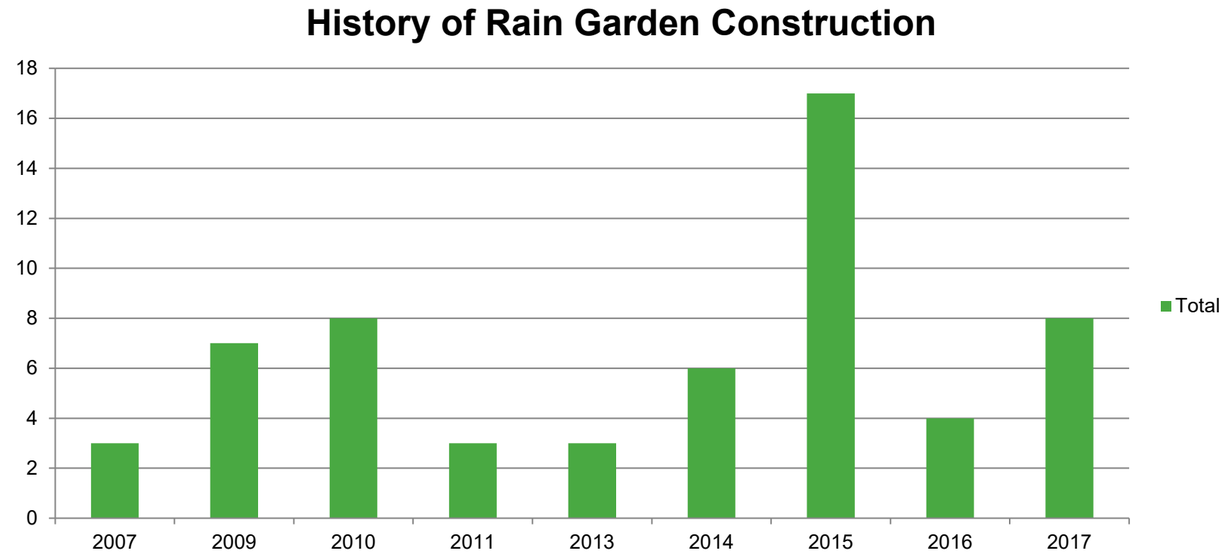
2003 – Parking Lot

2017 – Green Roof



KERR WOOD LEIDAL
consulting engineers

Examples of City-Owned Rain Gardens in Public ROW

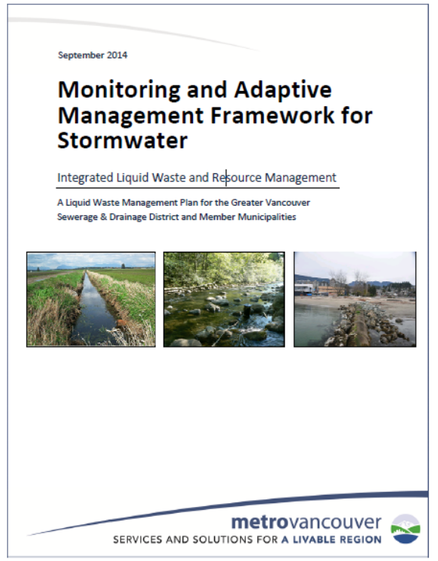


KERR WOOD LEIDAL
consulting engineers

Methods to Measure Changes in Wagg Creek Watershed Health

1. **Metro Vancouver's Management and Adaptive Monitoring Framework (MAMF):**
   - Trends from flow monitoring data
   - Benthic Index of Biotic Integrity (B-IBI)

2. **Measure impervious surface "disconnection":**
   - "Effective" Impervious Area (EIA)
   - Updated model calibration



Wagg Creek MAMF Trending (2005 – 2017)

MAMF Trending	Target	Result
Flashiness (TQMean)	Stable or Increasing	✓
Low Flow Pulse count (number)	stable or decreasing	✓
Low Flow Pulse duration (days)	Stable or Increasing	✓ ?
Summer baseflow (7 day)	Stable	✓ ?
Winter baseflow (7 day)	Stable or Increasing	✓
High flow Pulse count (number)	stable or decreasing	✗
High flow Pulse duration (days)	Stable or Increasing	✓ ?

- **Decreased flashiness**
- **Stable Low & High Flow Pulse Durations**
- **Increasing Summer Baseflows**
- **More frequent high flows, but less flashy**

KERR WOOD LEIDAL
consulting engineers

Summary of Benthic Index of Biotic Integrity (B-IBI)

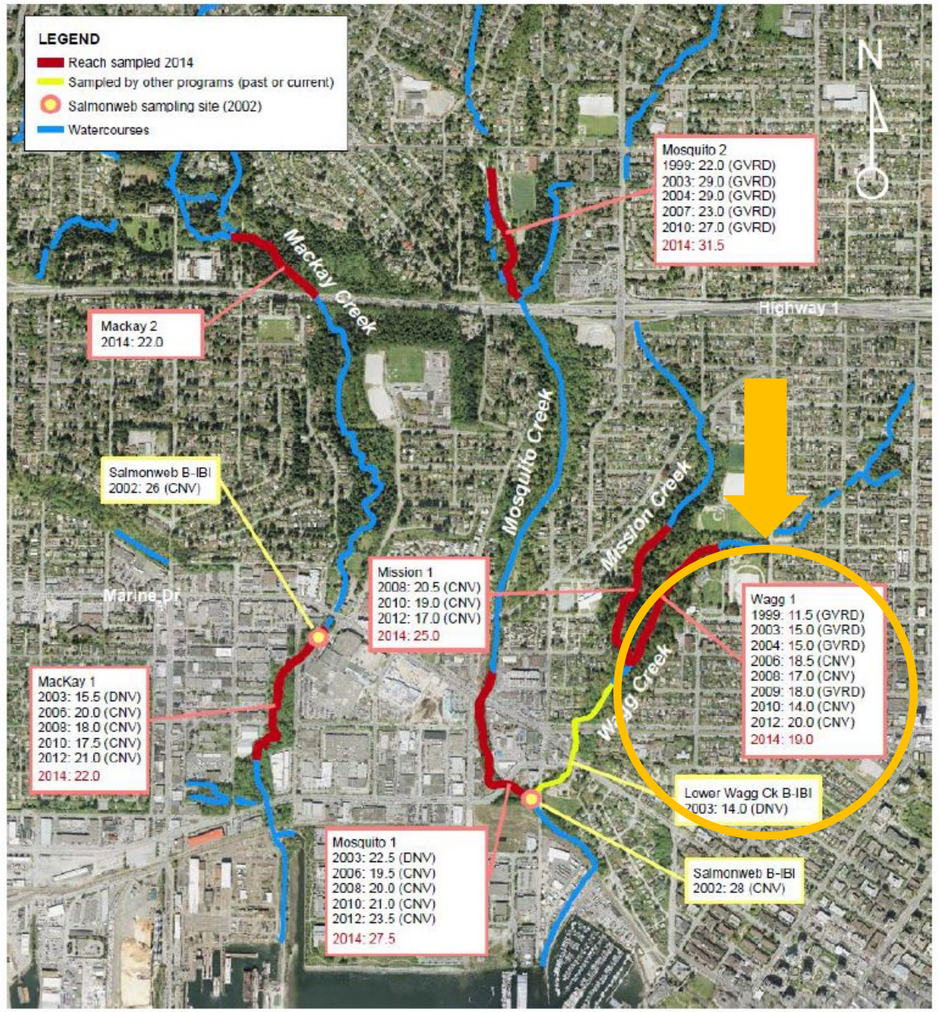
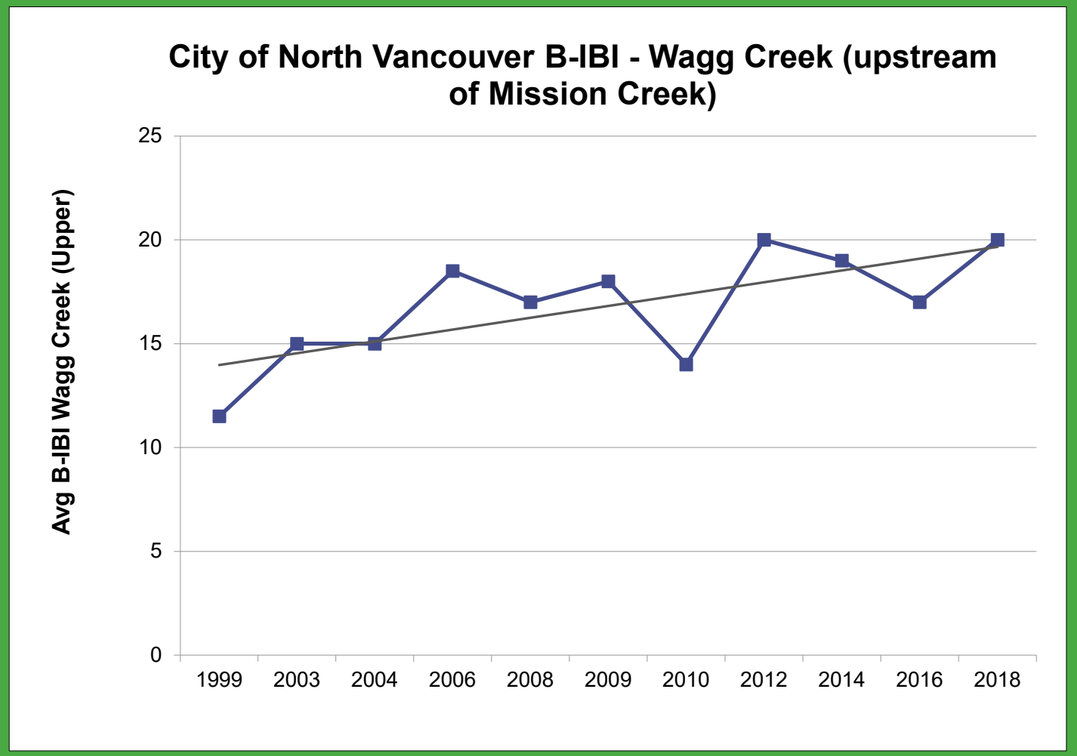


Figure C2-4: Results of 2014 Benthic Invertebrate Sampling in Comparison to Historical Data (all values as mean B-IBI)

KERR WOOD LEIDAL
consulting engineers

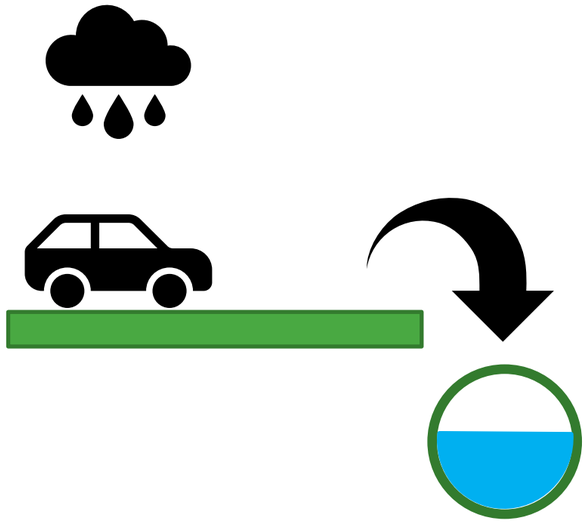
Wagg Creek B-IBI Results:

- 1999: 11.5
- Significant trend since 2012
- Still significant increase in 2018



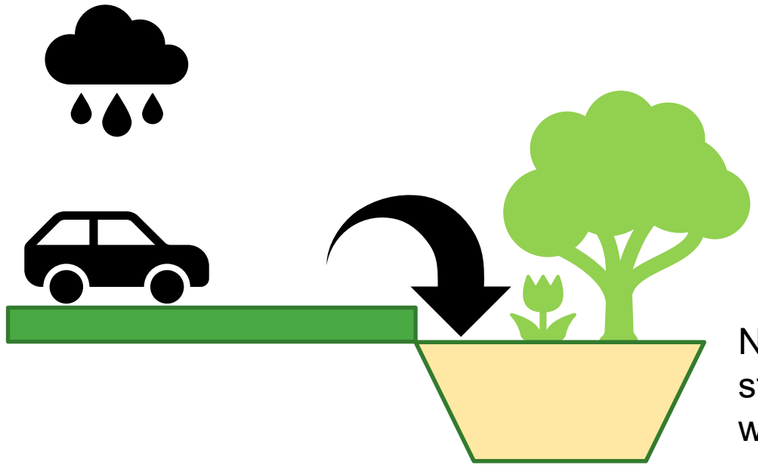
Effective Impervious Area (EIA) Calculation

Connected Impervious Area = EIA



Always runoff to storm sewer when soil is dry

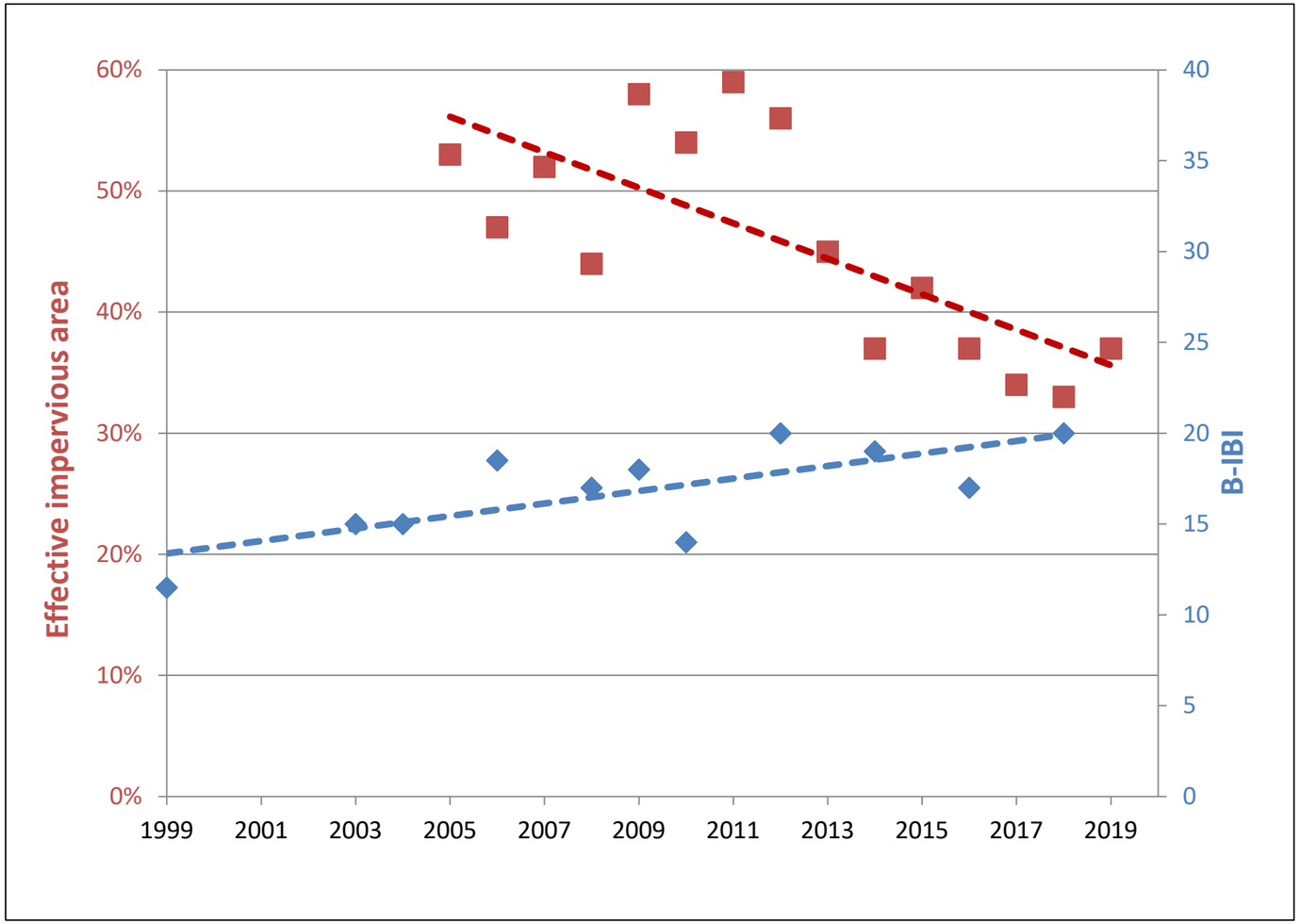
Disconnected Impervious Area = (TIA – EIA)



No runoff to storm sewer when soil is dry

Is there a way to use summer flow monitoring data to determine the level of disconnection in the watershed?

Effective Impervious Area (EIA) Results



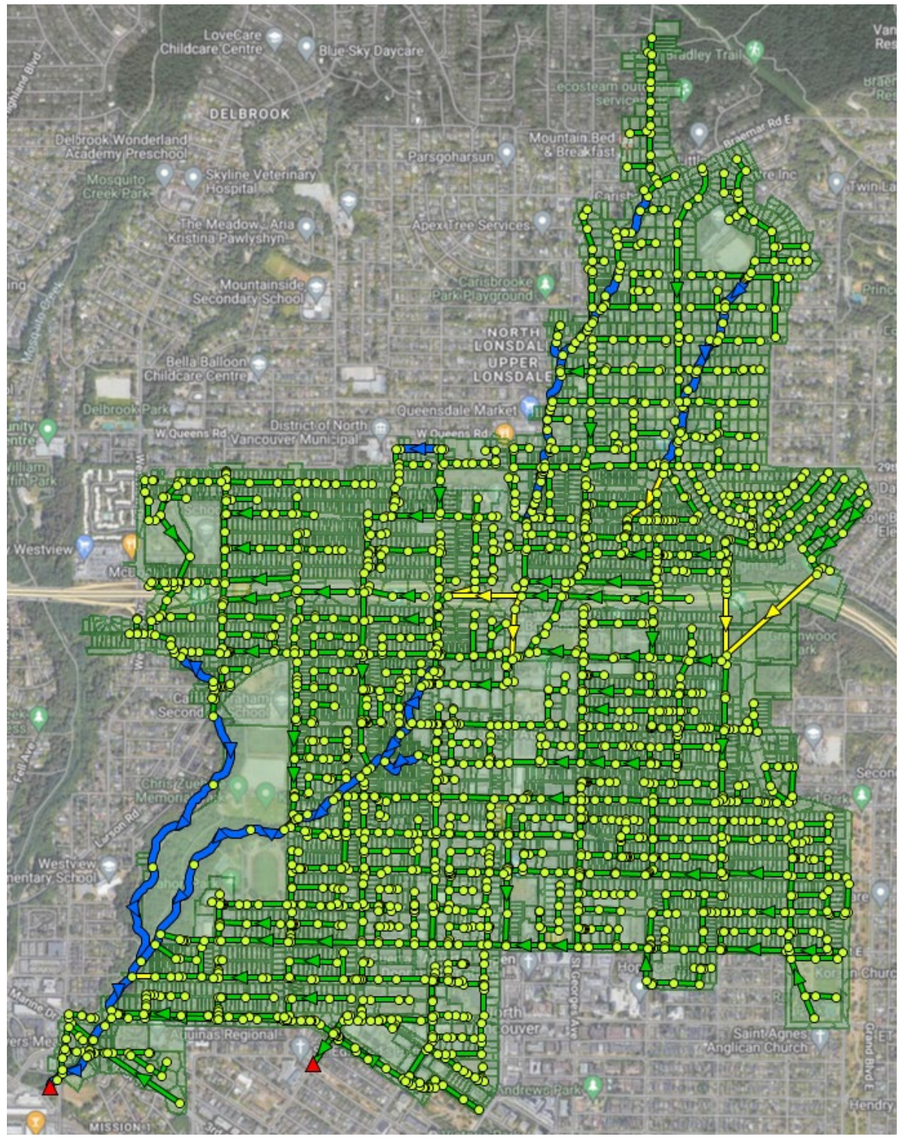
Evaluated summer rainfall events where:

- 2-Day Rainfall < Cumulative ET
- 2-Day Rainfall > 10 mm

$$EIA = \frac{\textit{streamflow volume (event) - baseflow}}{\textit{watershed area x (event rainfall – 5mm)}}$$

KERR WOOD LEIDAL
consulting engineers

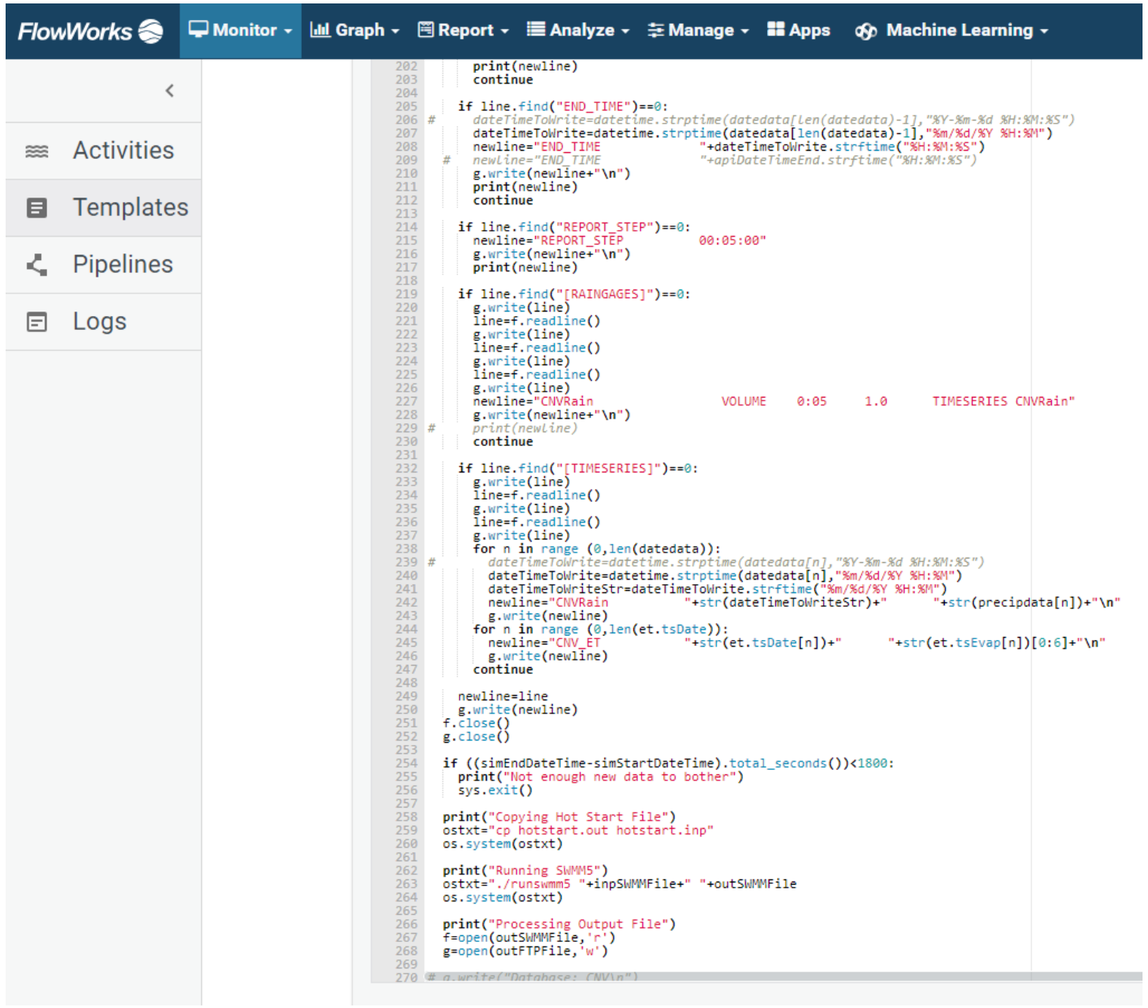
Wagg Creek SWMM Model



- Citywide model originally developed & calibrated following 1996 MDP
- Model has been kept up to date while remaining calibrated to older flow monitoring data
- Wagg Creek “sub-model” running with real-time & forecasted climate data inputs in FlowWorks through Face Pro

KERR WOOD LEIDAL
consulting engineers

Wagg Creek SWMM Model & Face Pro Integration

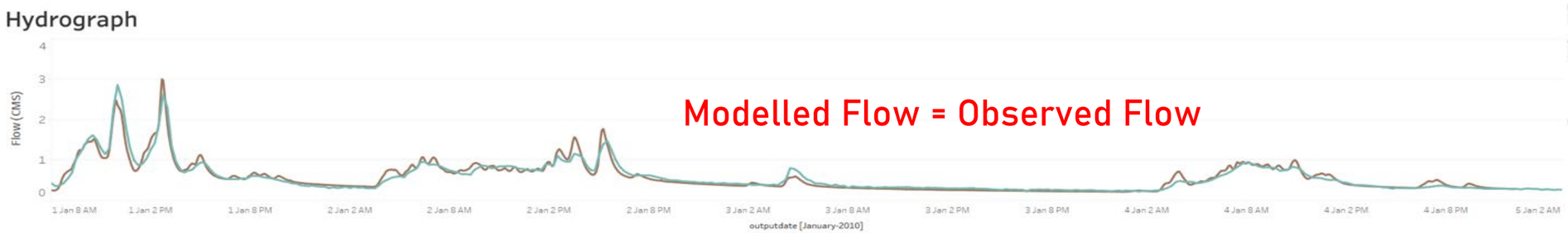


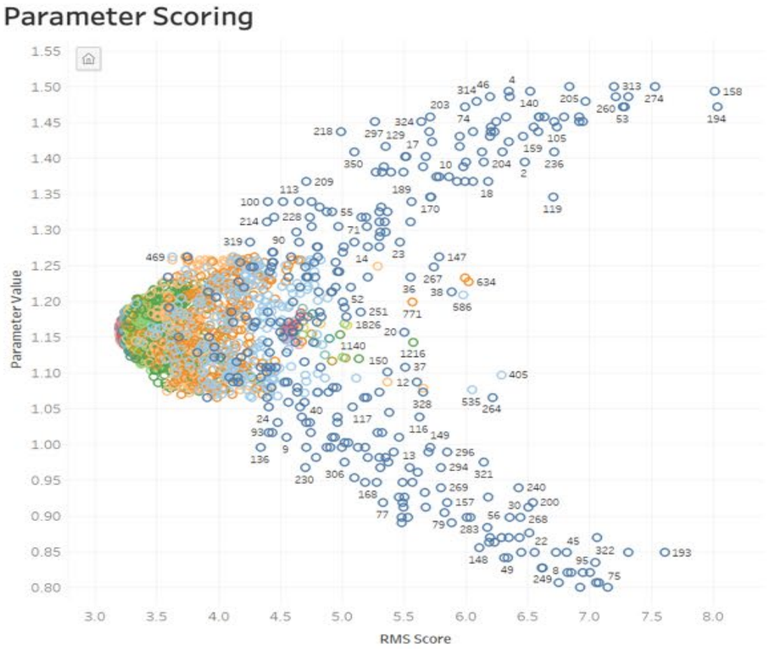
- Developed python code to:
  1. Download real-time/forecasted climate data
  2. Run SWMM model
  3. Push output data into FlowWorks
- Python code uploaded to Infinitii-ai's Face Pro to continuously run the SWMM model online
- PySWMM could also be used

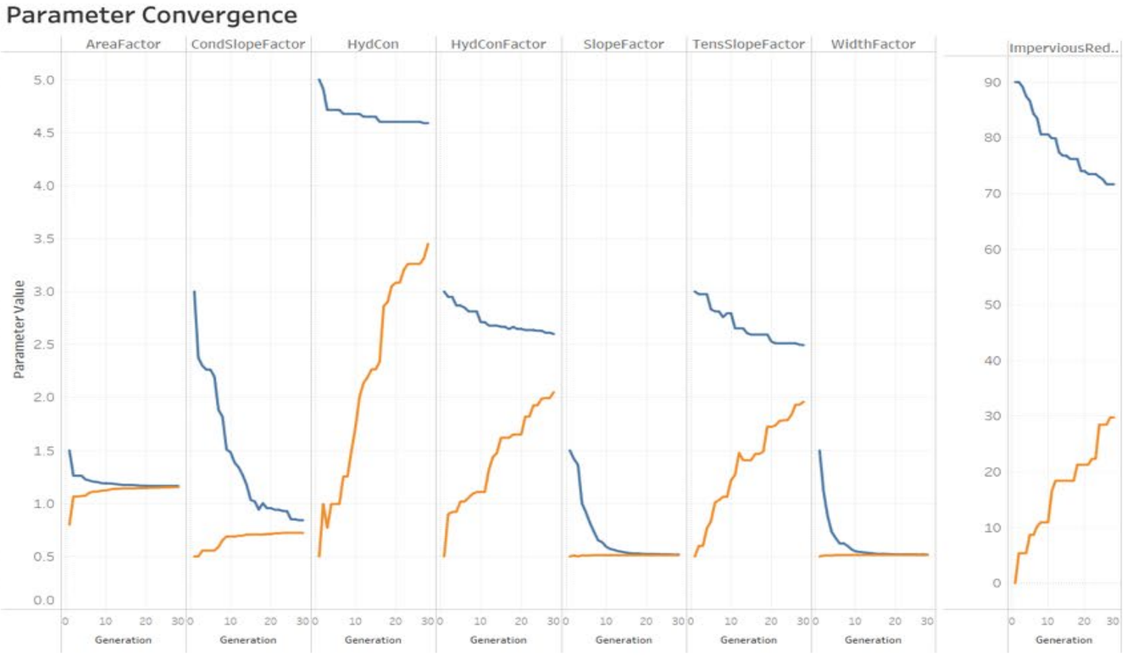
KERR WOOD LEIDAL
consulting engineers

Model Calibration to 2010 Flow Data

Parallax (KWL's auto-calibration tool)

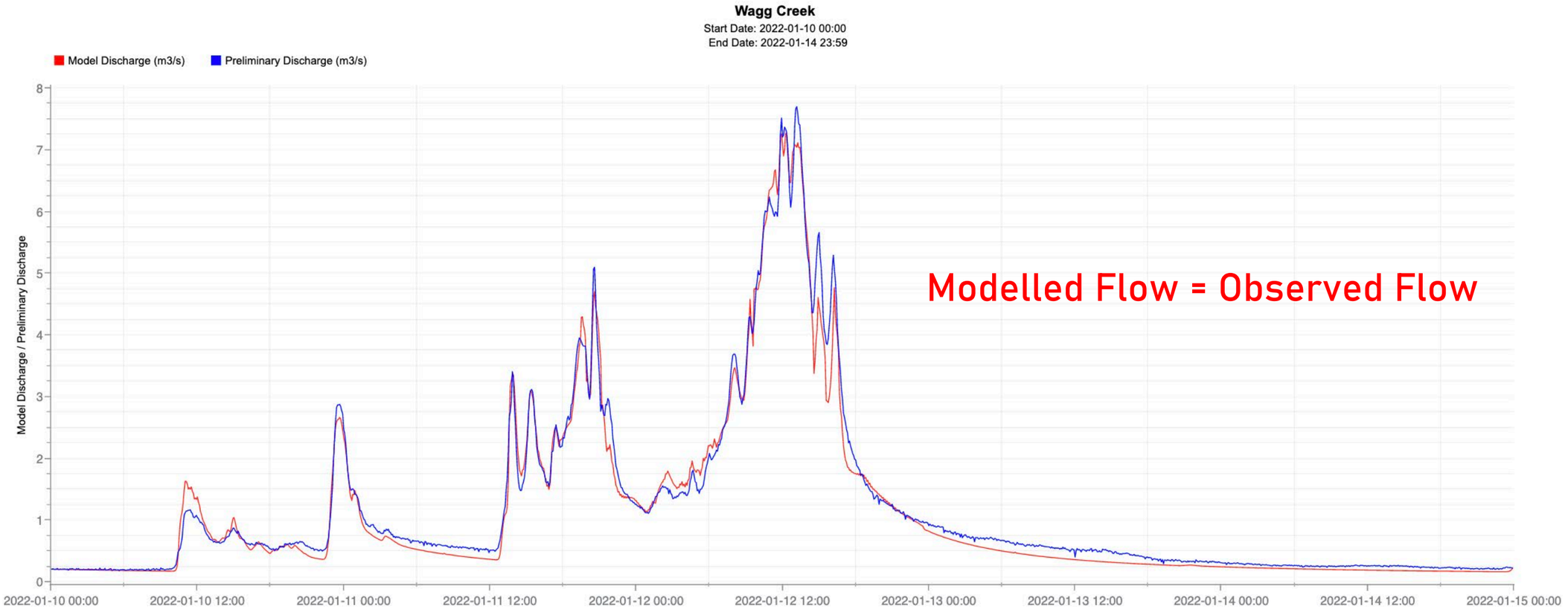






KERR WOOD LEIDAL
consulting engineers

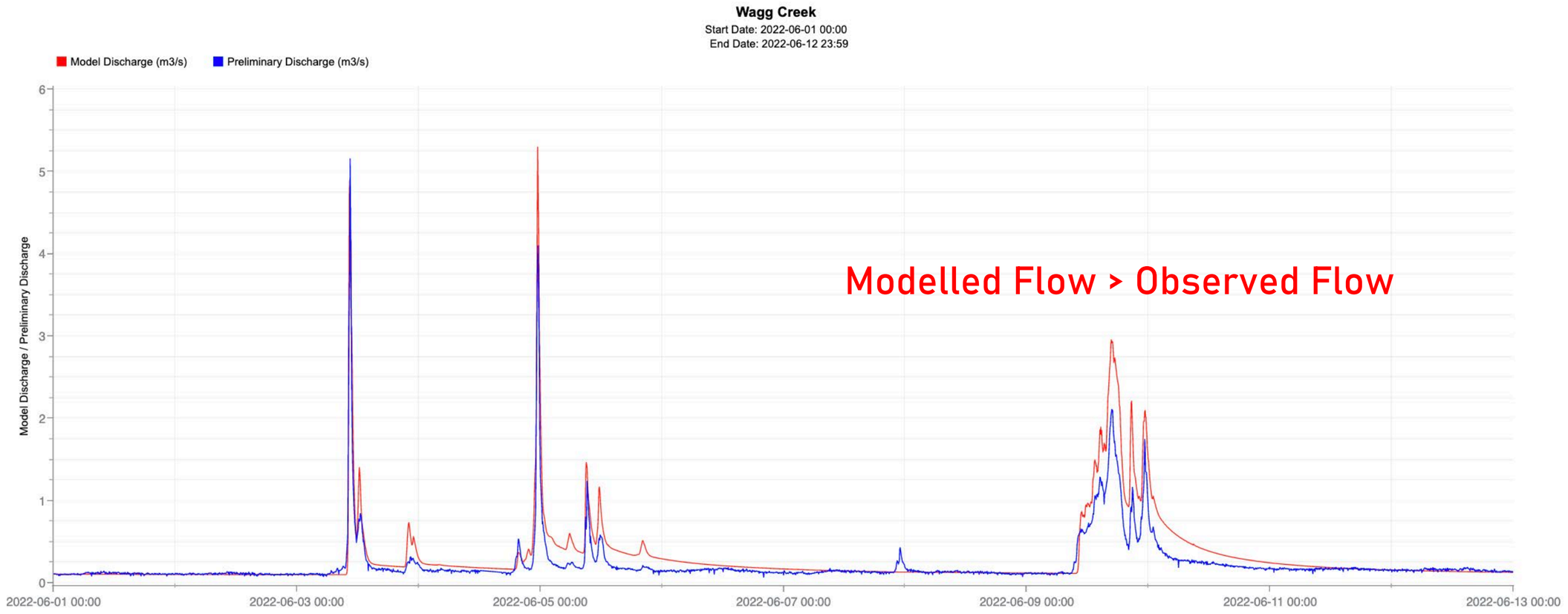
Modelled vs. Observed Flow in FlowWorks – Winter 2022



Modelled Flow = Observed Flow

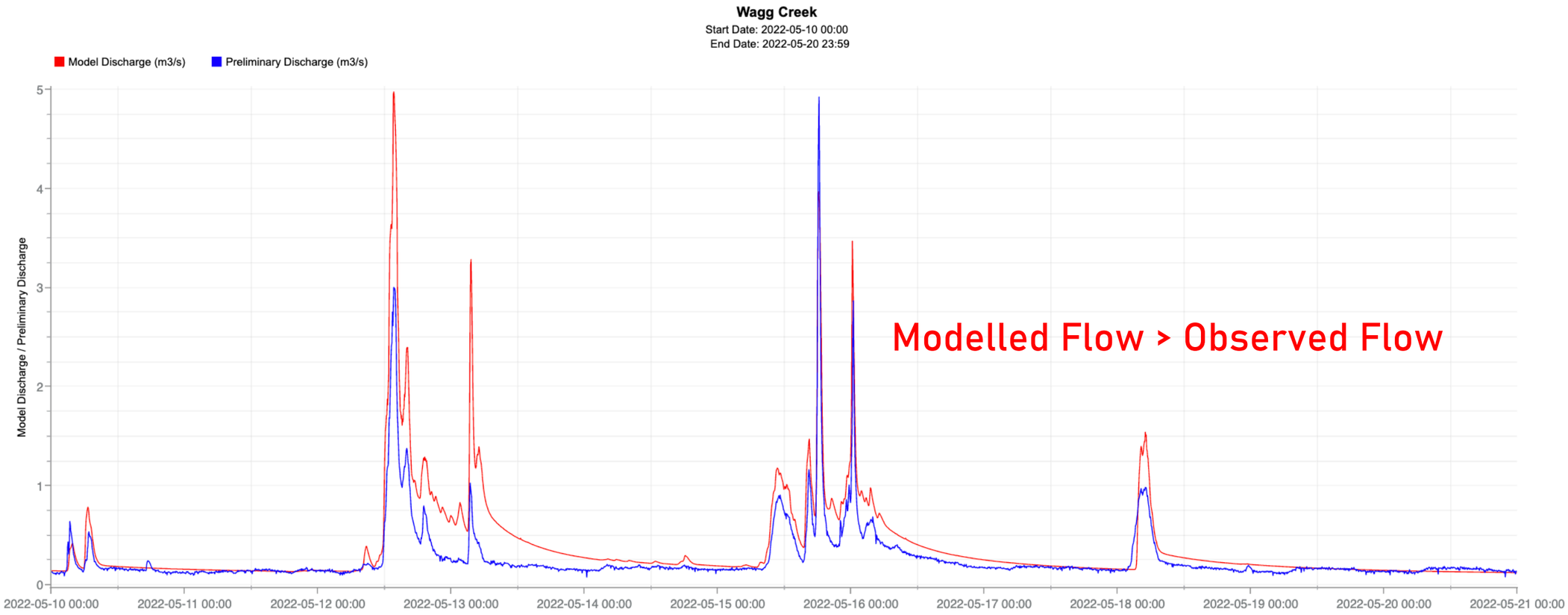
KERR WOOD LEIDAL
consulting engineers

Modelled vs. Observed Flow in FlowWorks – Spring 2021



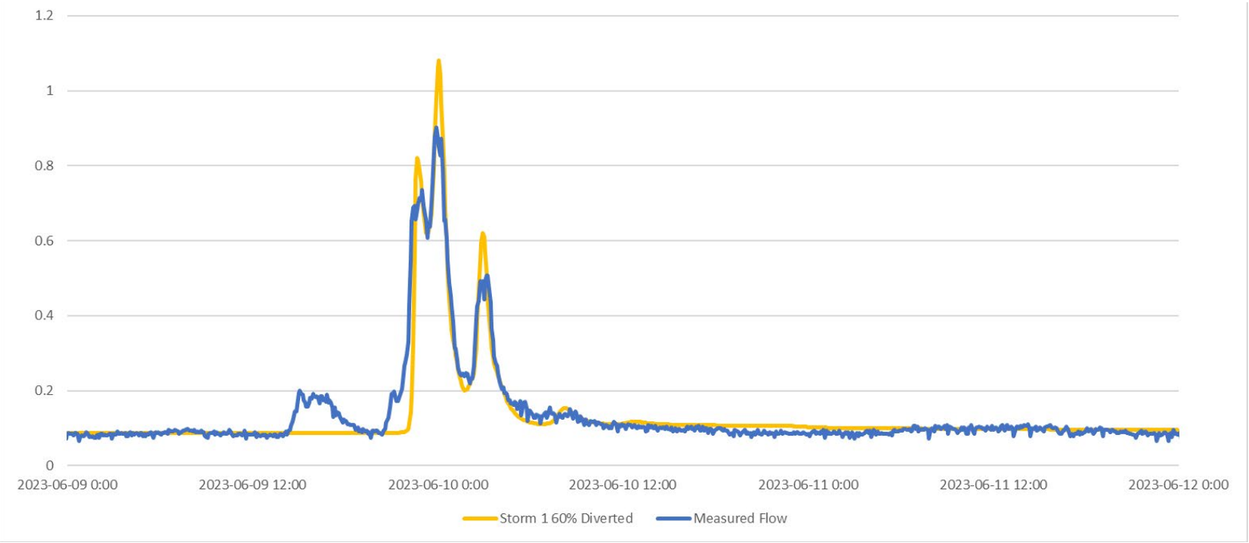
KERR WOOD LEIDAL
consulting engineers

Modelled vs. Observed Flow in FlowWorks – Spring 2022



KERR WOOD LEIDAL
consulting engineers

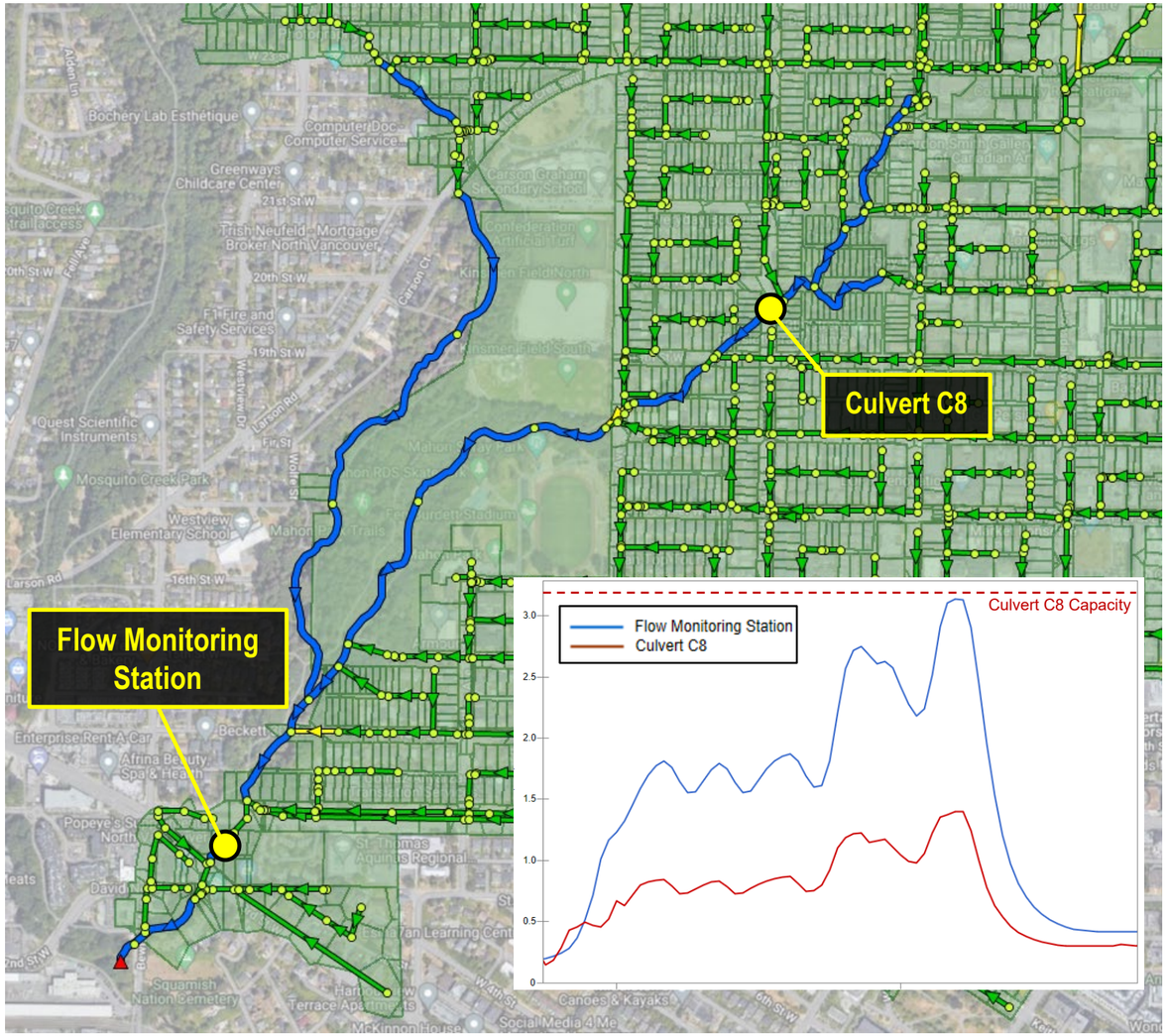
Wagg Creek SWMM Model
Updated 2023 Calibration



- **Calibration to 2000's data no longer valid – model flows are higher than monitored flows**
- **Updated calibration using 2023 data by increasing impervious disconnection in model**

KERR WOOD LEIDAL
consulting engineers

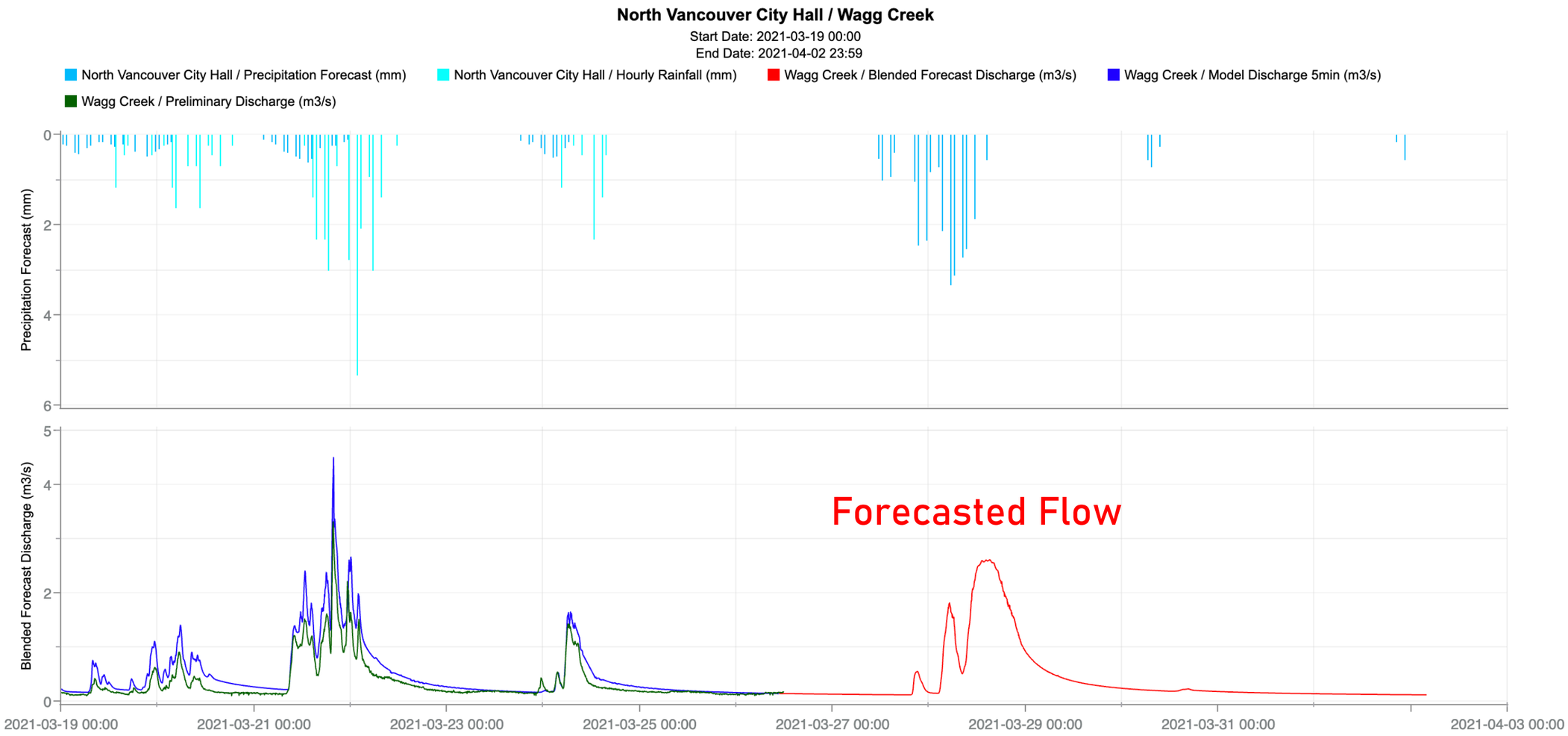
City of North Vancouver Benefits



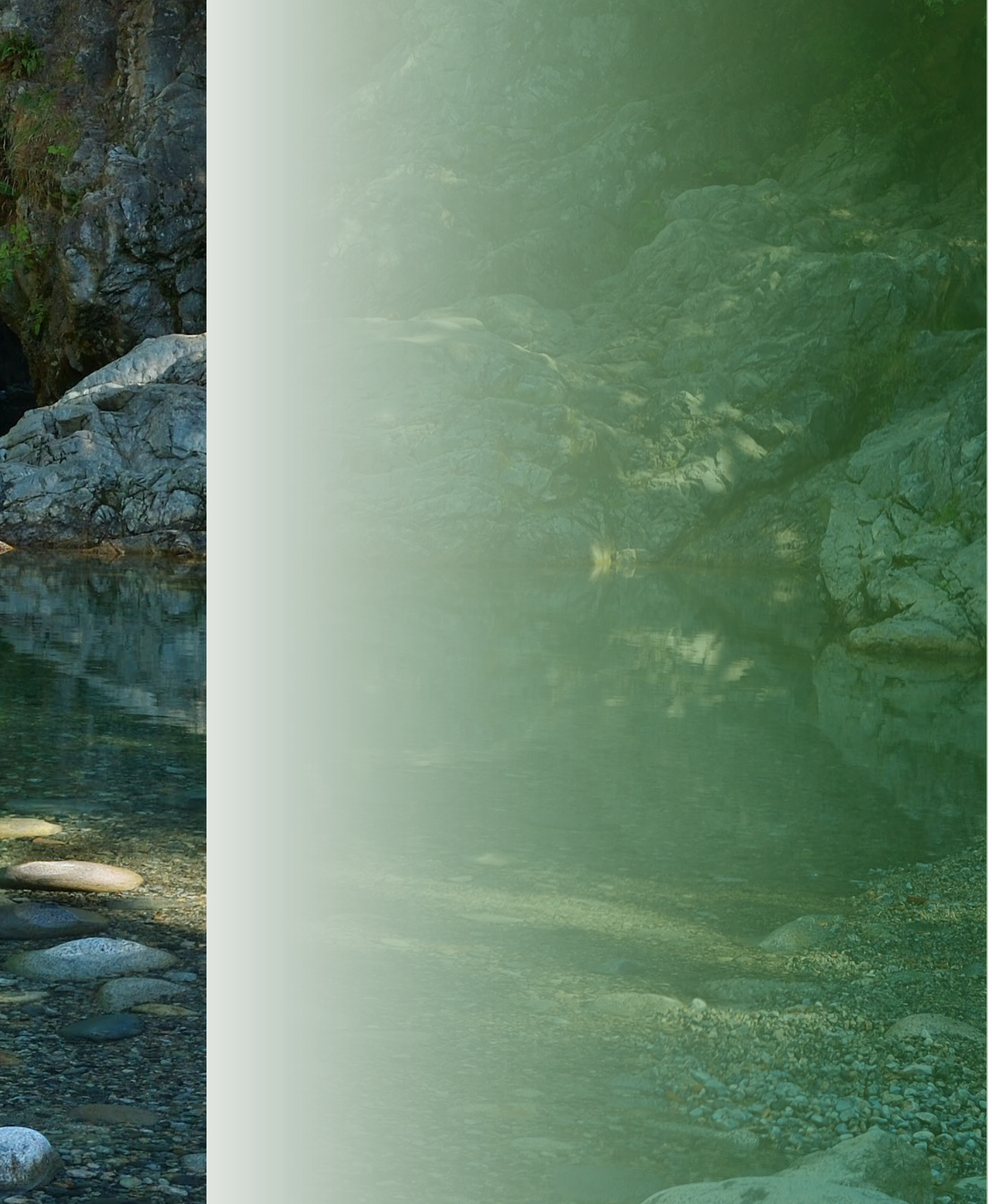
- Alarm when flow monitoring differs from model
- Provides more accurate/detailed flood estimates compared to flow monitoring alarms
- Alarm when flow at culvert location is greater than capacity or design flow.

KERR WOOD LEIDAL
consulting engineers

Flood Forecasting in FlowWorks



KERR WOOD LEIDAL
consulting engineers



Conclusions

1. The potential stream health benefits of impervious area disconnection and Green Infrastructure can be evaluated with long-term flow and B-IBI monitoring.

2. Real-time modelling can also be used to identify changes in rainfall responses as watershed characteristics change over time.

3. Face Pro can be used to run SWMM (or other models) online with output in FlowWorks for flood forecasting and real-time flow alarming purposes.

Questions?

Jeff Marvin, M.A.Sc., P.Eng.
Stormwater & Water Resources Engineer
Kerr Wood Leidal Associates Ltd.
jmarvin@kwl.ca

Greg Johnston
President, infinitii-ai
greg@infinitii.ai

Work completed for City of North Vancouver