A Hydrological Assessment of using Low Impact Development to Mitigate Future Flooding

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Pacific Institute for Climate Solutions
Knowledge. Insight. Action.

W-CIRC
Water & Climate Impacts Research Centre

Rain to Resource Workshop
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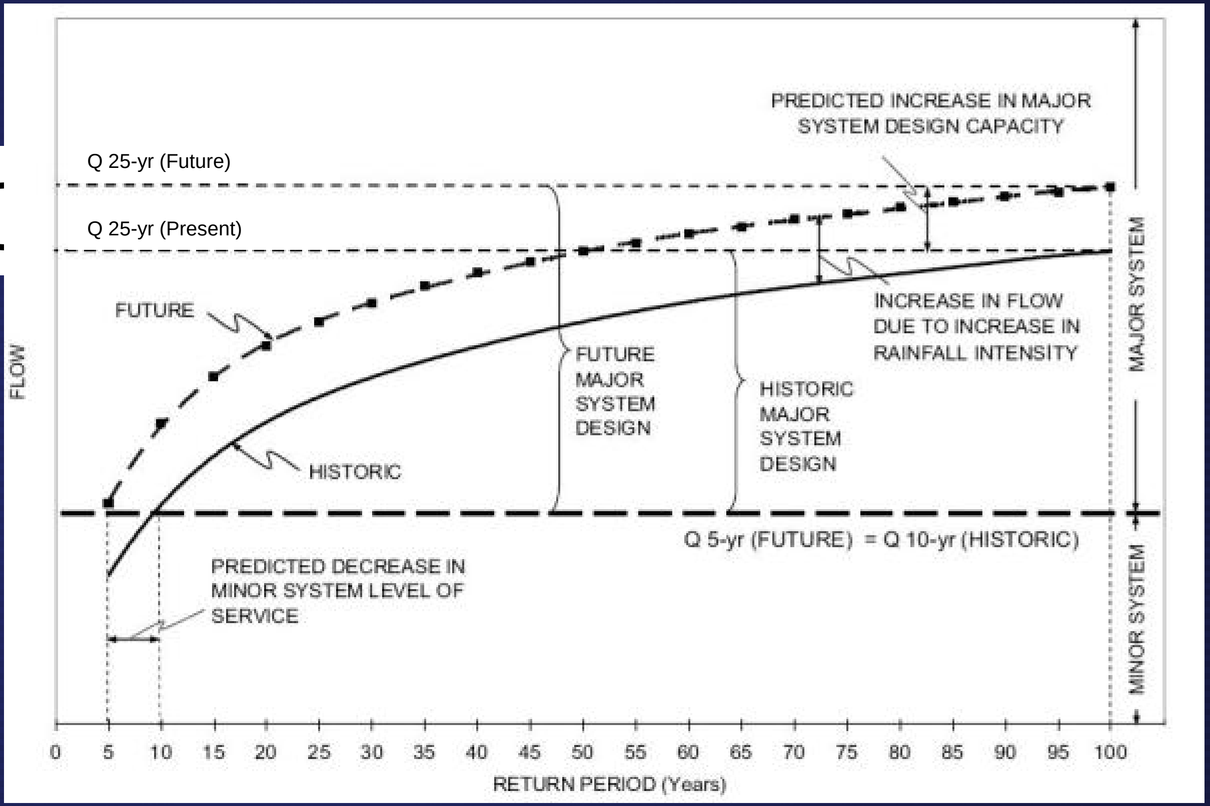
Research Project

Can Low Impact Development reduce future peak flow rates to current flow rates?

LID mitigation objective

- How much LID is needed?
- What types are best?
- Effective under what future climate scenarios?



Expected Changes in Extreme Event Frequency Curves (Arisz and Burrell, 2006)

Research Need

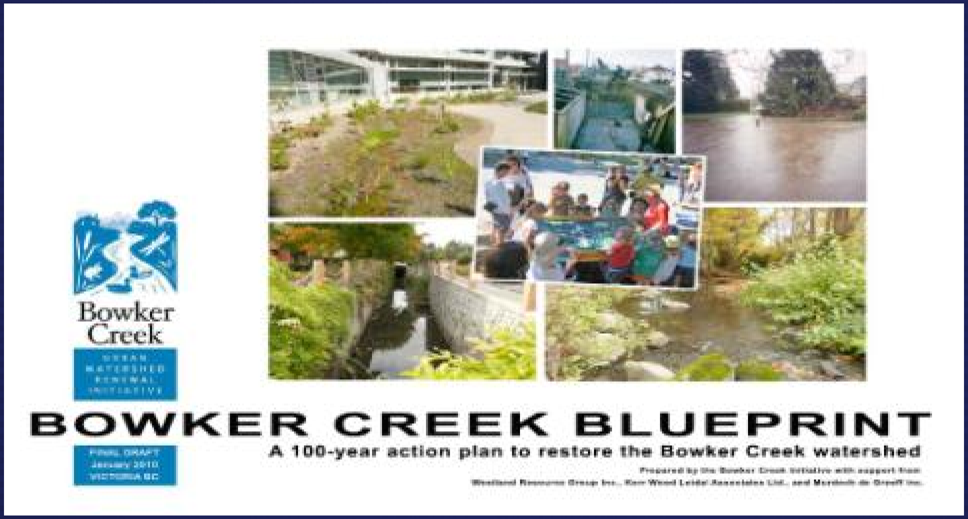
Climate Change

- Increased risk to public safety and infrastructure failure.
- Options needed to adapt to a changing climate
- Conventional engineering and/or Low Impact Development?

Applied Research

Research supports:

- Community and local government action to protect and restore the Bowker Creek Watershed.
- BC Living Water Smart: Adapting to climate change and reducing our impact on the environment will be a condition for receiving provincial infrastructure funding.

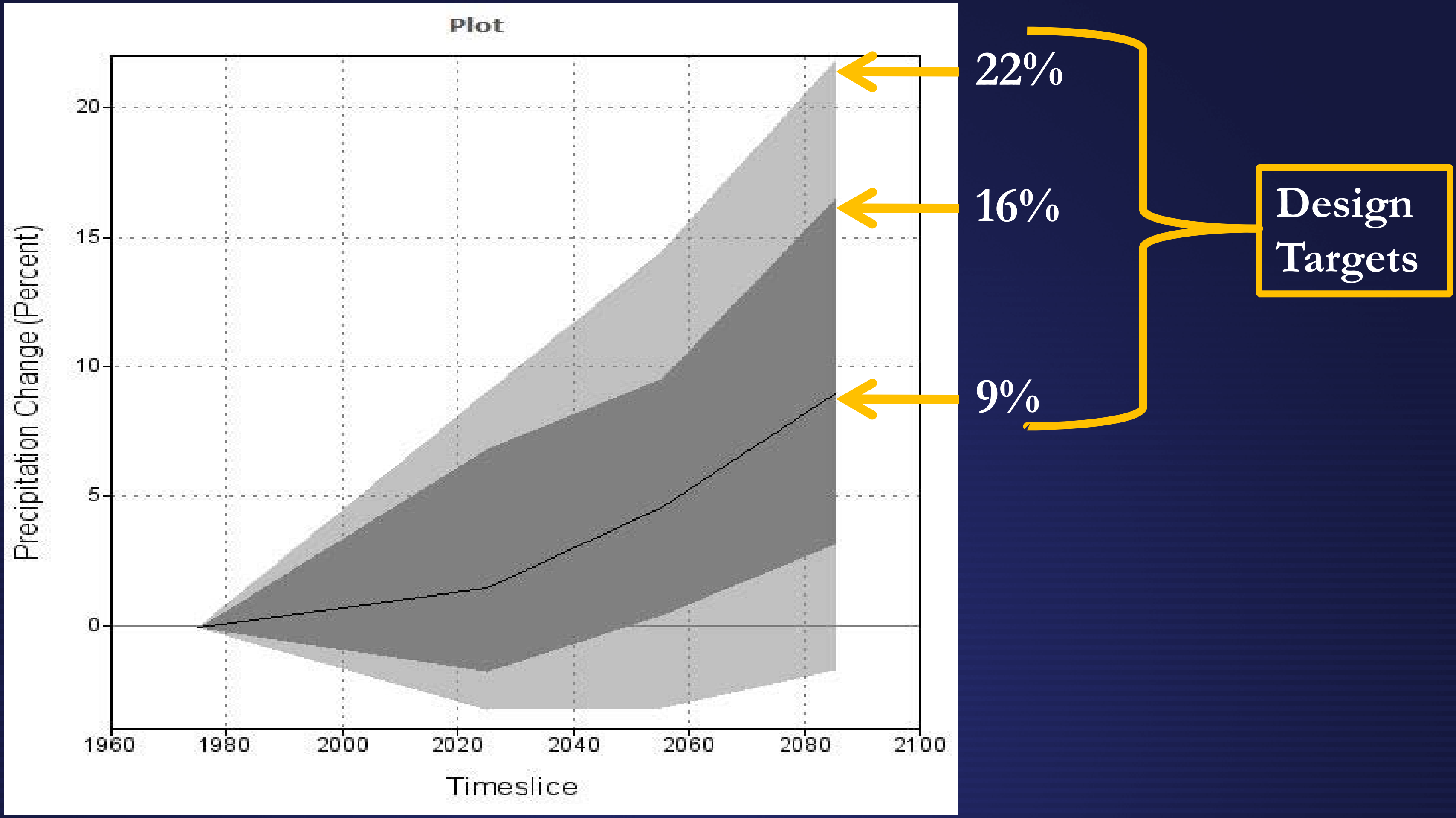


Increased Precipitation for Victoria, BC

Return Period	24-Hour Rainfall (mm)			Increase (mm)
	Existing	Future Median	Future 90th percentile	
25-Year*	90.6	98.8	120.5	8.2 – 29.9
50-Year	101.9	111.1	135.5	9.2 – 33.6
100-Year	113.2	123.4	150.1	10.2 – 37.3

- Key Assumption: Precipitation scenarios assume the statistical correlation between monthly precipitation and precipitation intensity remains reasonably constant.
- Design storm = 83,000 – 203,000m^3 of additional rainfall.
- To maintain the current level of service, this increase needs to be managed.

* Municipal design standard = 25-year, 24-hour event.



Projected winter (DJF) precipitation change for the CRD region in 2080, according PCIC's 15 GCM ensemble running IPCC A2 and B1 emissions scenarios.

The range of change is indicated as follows:

- Black line: median
- Dark grey shading: 25th to 75th percentiles
- Light grey shading: 10th to 90th percentiles

(Source: PCIC, 2010)

Potential Solution

Low Impact Development & Source Controls

Research focus

Source: www.WaterBalance.ca

Enhanced Top Soil

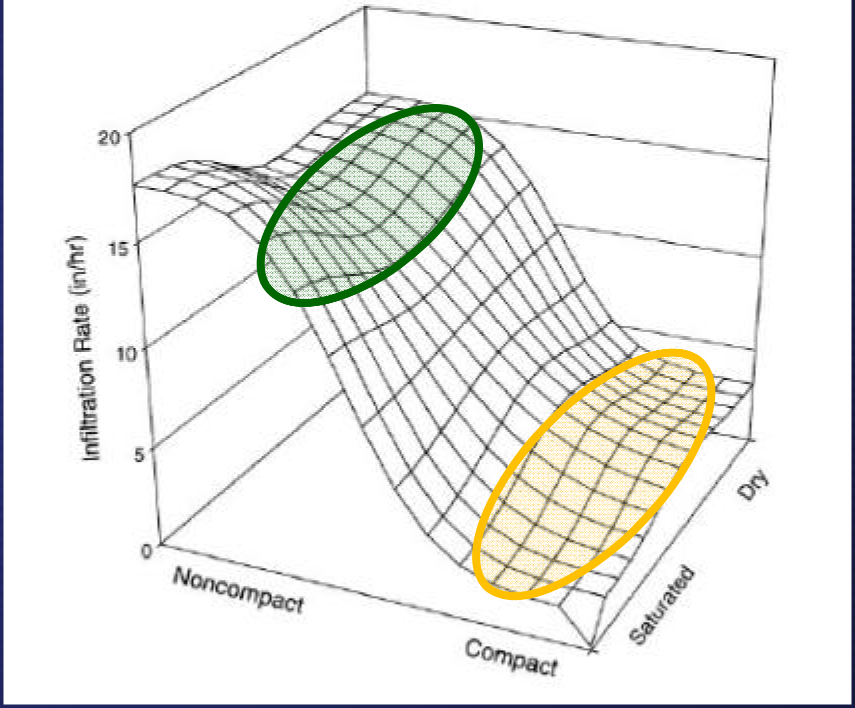
Enhanced tops soils reduce runoff by increasing infiltration rates

Current Soils

Enhanced Soils

Soil group	Soil texture	Mm/hr
A	Sand	200
A	Loamy sand	50
B	Sandy loam	25
B	Loam	12.7
C	Silt loam	6.3
C	Sandy clay loam	3.8
D	Clay loam and silty clay loam	2.3
D	Clay	1.3

Infiltration Rate by Soil Group/ Texture



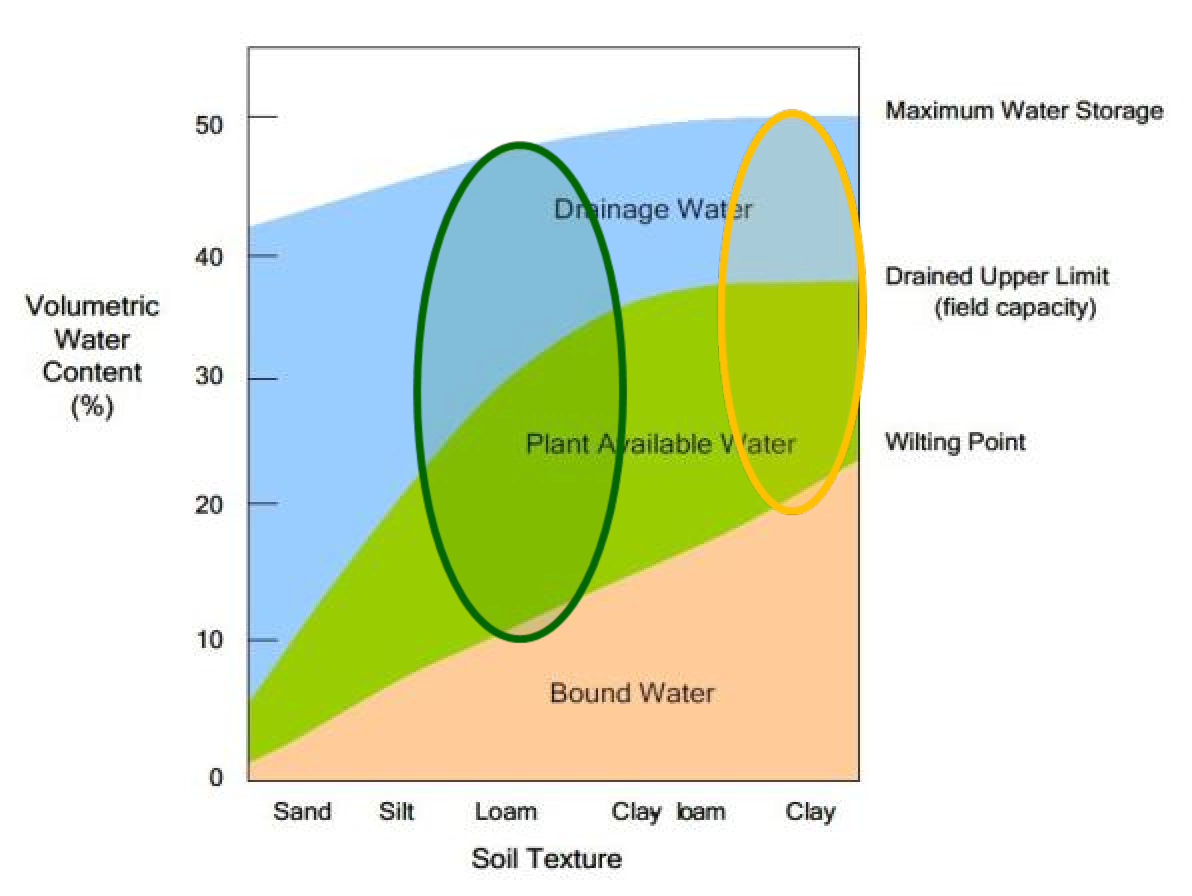
Infiltration Rate by Compaction/Moisture

Enhanced Top Soil

Enhanced top soils reduce runoff by increasing storage volume.

Current Soils

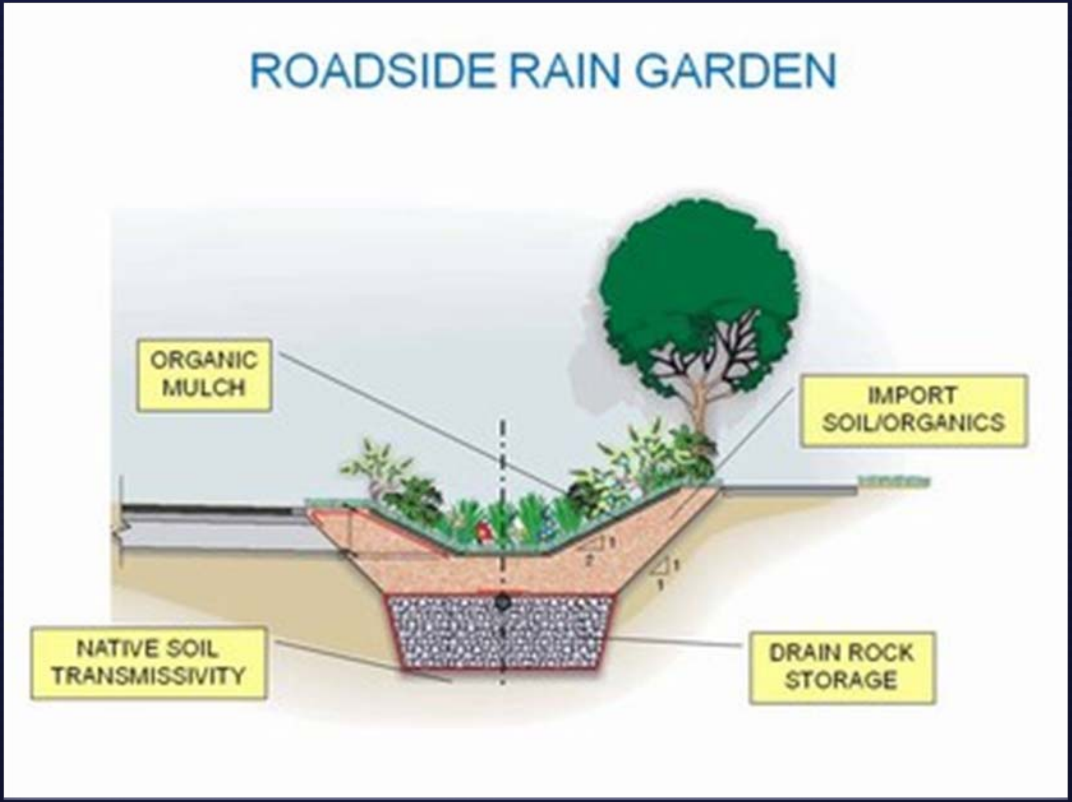
Enhanced Soils



Rain Gardens

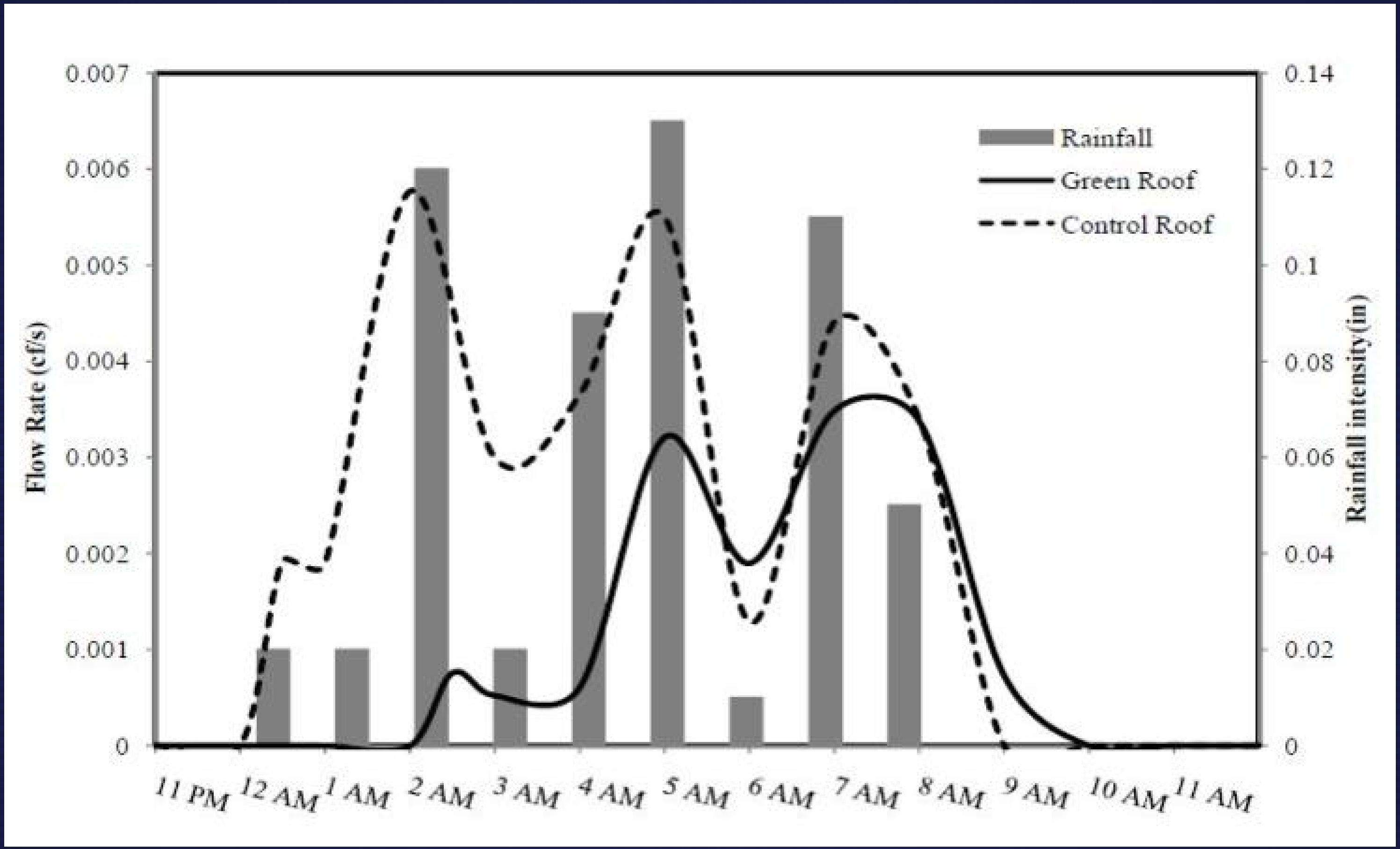
Reduce peak flows by:

- Detention/Retention
- Infiltration
- Evaportrasporation



Green Roofs

- Moderate Flow Rates

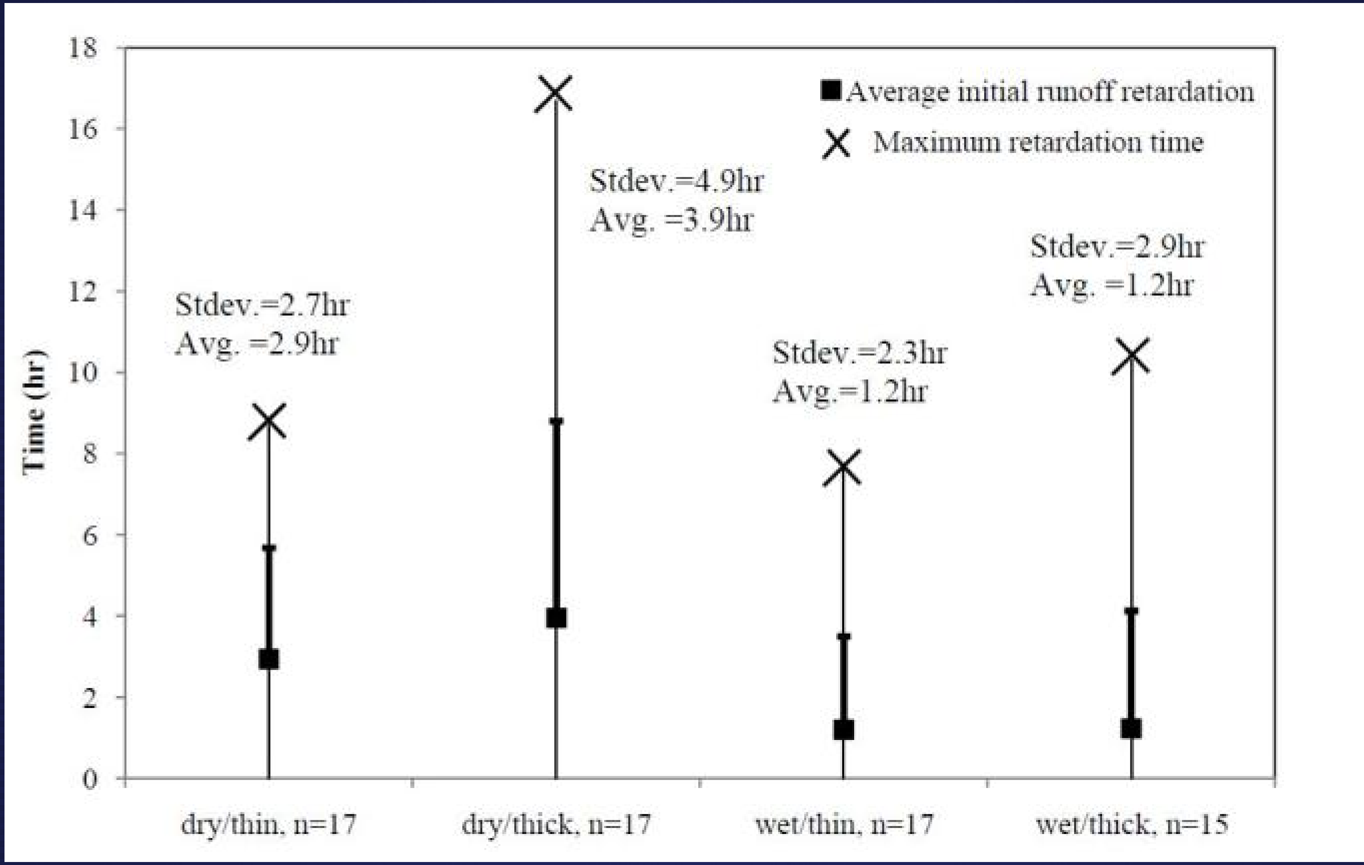


Runoff Flow Rates and Rainfall Intensity

Source: Neufeld et. al., 2009

Green Roofs

- Delay the time of concentration



Time of initial runoff retardation under different soil condition and thickness (Thin = 40mm, Thick = 140mm)

Source: Neufeld et. al., 2009

Source Controls

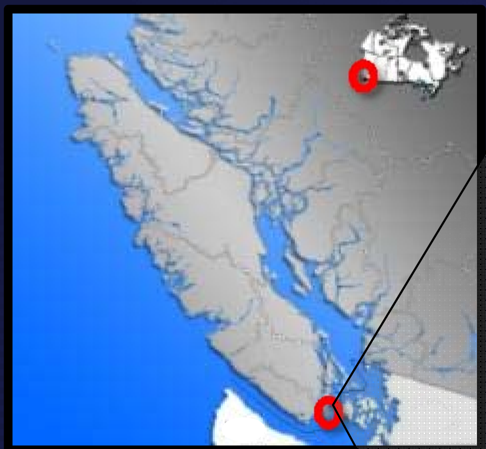
- There are many other source controls and best management practices that can be used to minimize rainwater runoff.
- Examples include:
  - Living Walls
  - Disconnected downspouts
  - Designing narrower streets
  - Rainwater harvesting
  - Bioswales
  - Permeable Pavements/Concrete/Pavers
- Not used in study

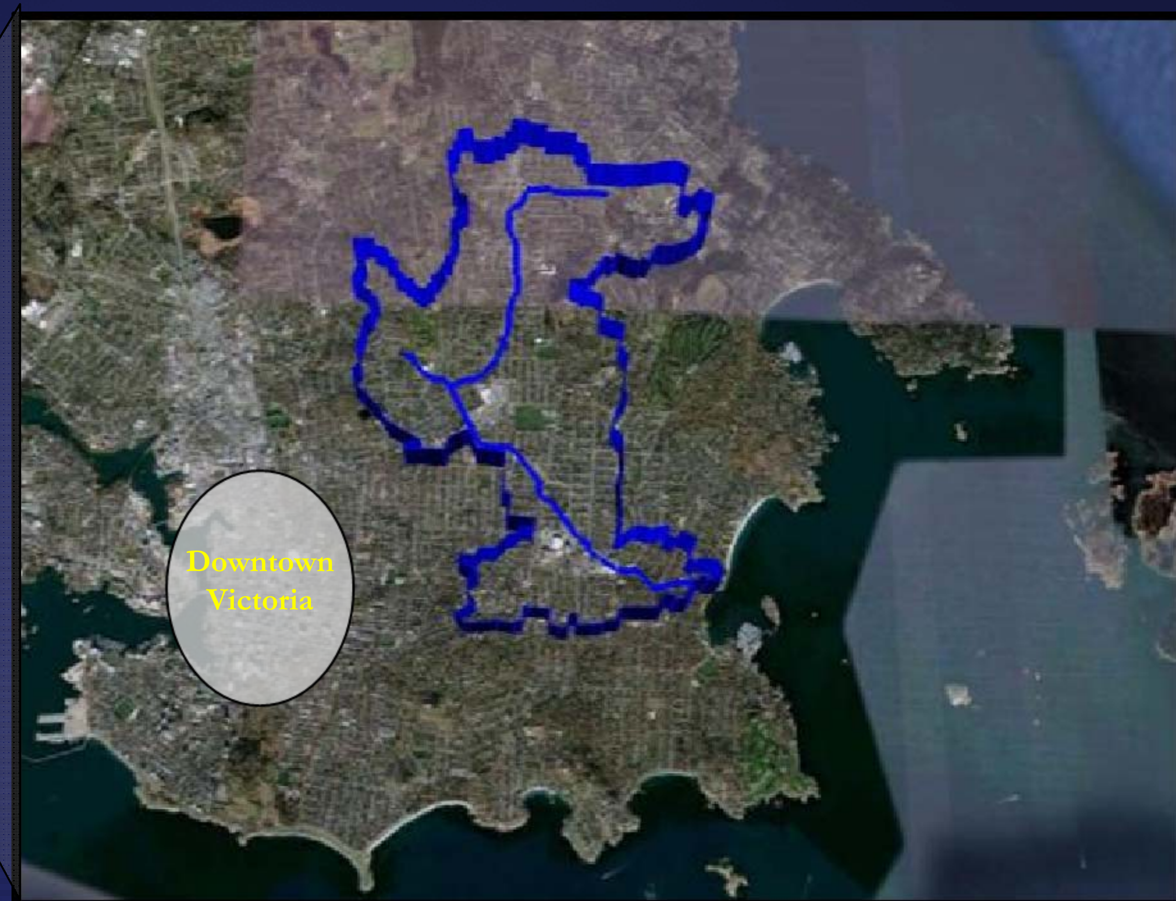
Methods

Case Study: Bowker Creek Watershed

- Located in Victoria, British Columbia
- Strong community watershed stewardship
  - Bowker Creek Initiative
  - Bowker Creek Blueprint
- Watershed goal: 30% effective impermeable area
- LID implemented throughout watershed
- Extensive flood impact analysis completed
  - Master Drainage Plan
- Research builds on previous modeling

Bowker Creek Watershed



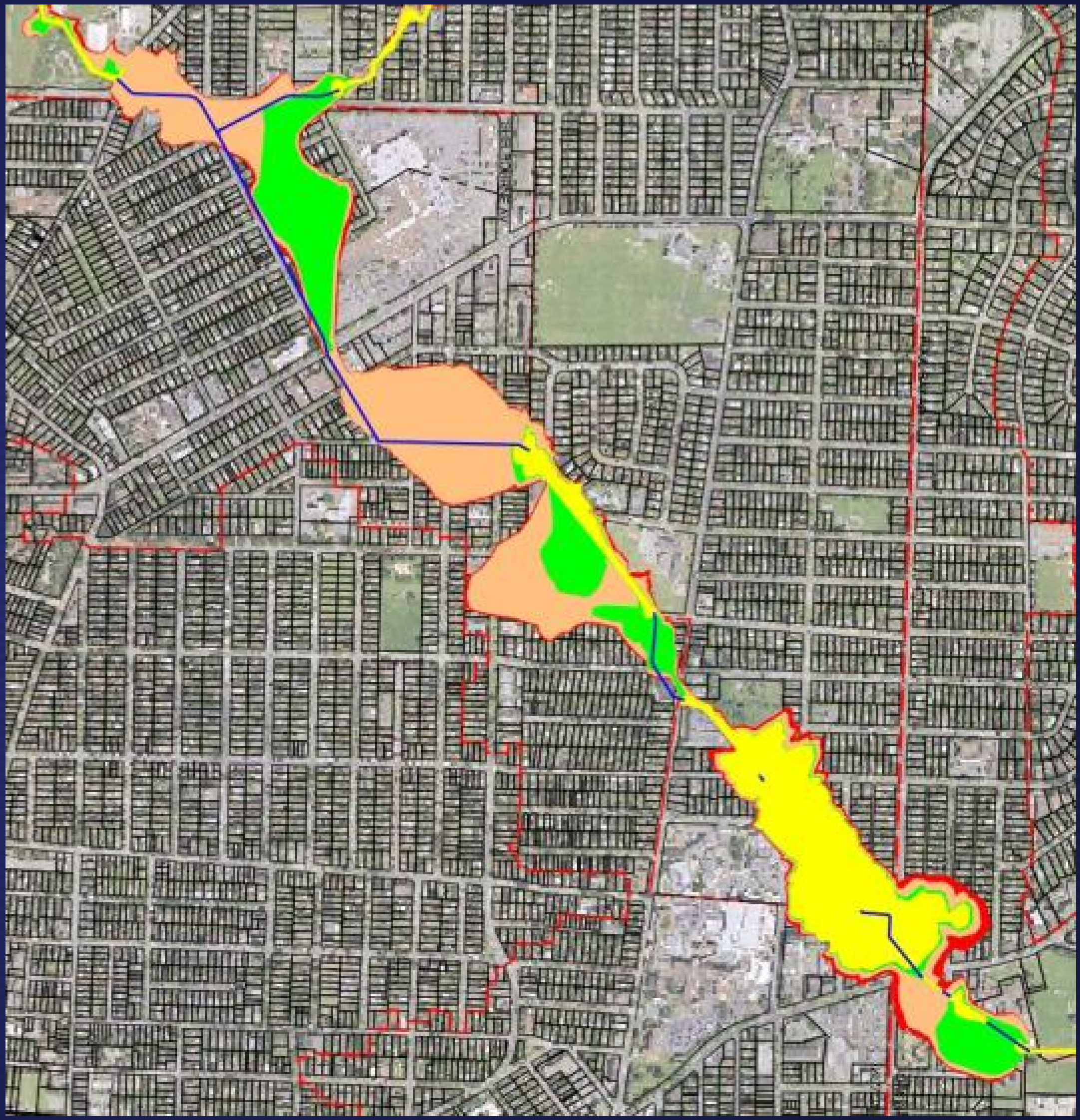


- 1018 ha. watershed
- 7.9 km long main channel
- 37% open channel
- Watershed is 50% impervious
- Soils are predominately clay with some rock outcroppings.
- Total average annual precipitation is 608mm.

Flood Impacts for Bowker Creek

Master Drainage Plan

- Predicted climate change for 2035
- Extent of flooding (return periods):
  - 10-year
  - 25-year
  - 100-year
  - 200-year

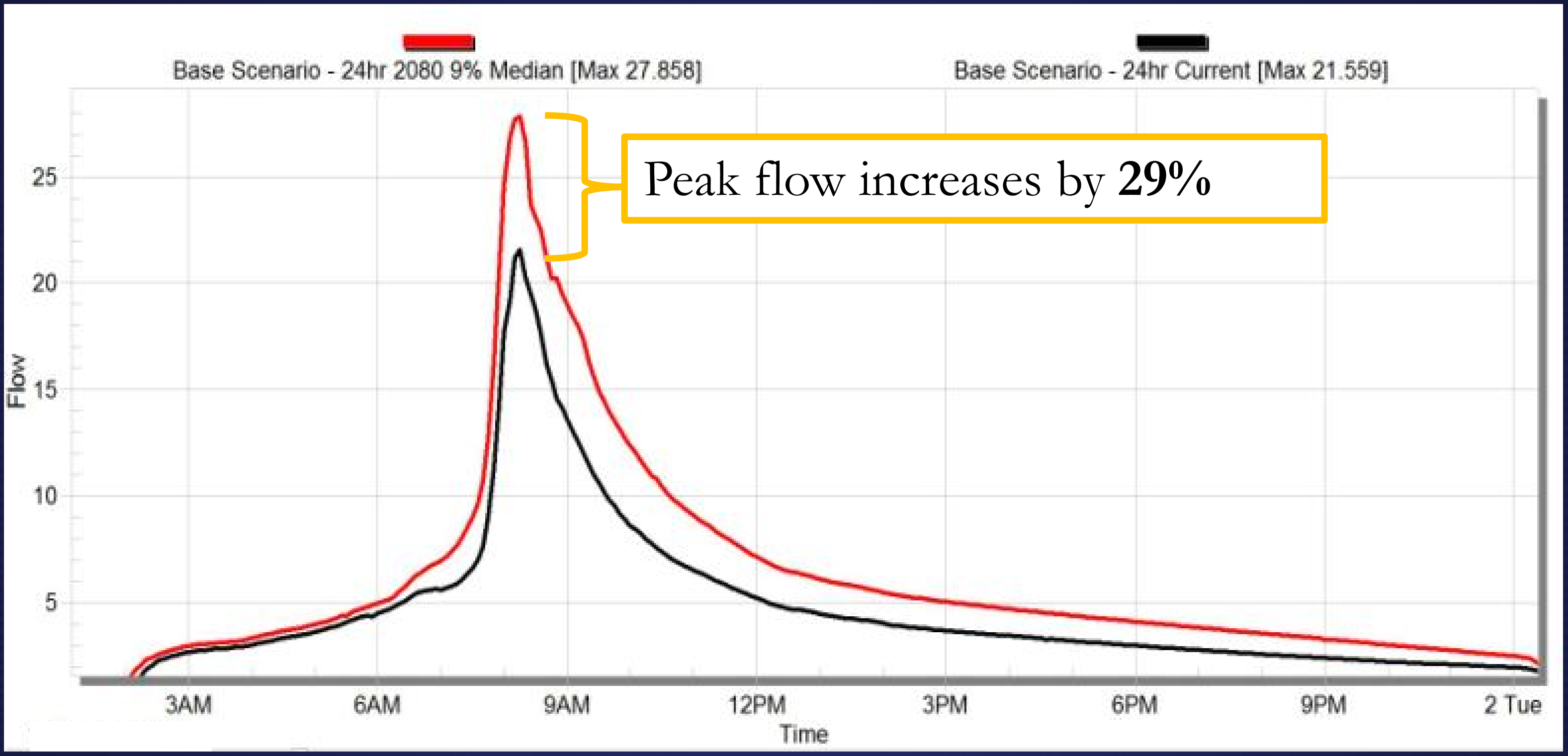


- Impacts for 2080?

(Source: Kerr Wood Liedal, 2007)

Peak Flow Rates with Climate Change

Peak Flow Rates: Current & Future 2080 median estimate (9% increase)

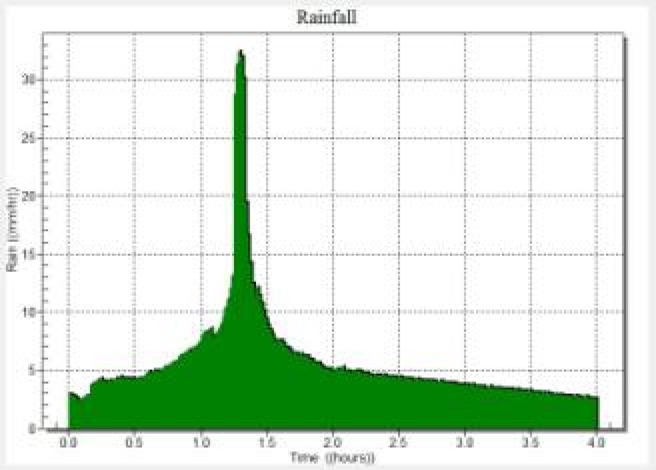


Research Methods
Hydrologic/Hydraulic Model

Run-off response generated using:

Design Storm

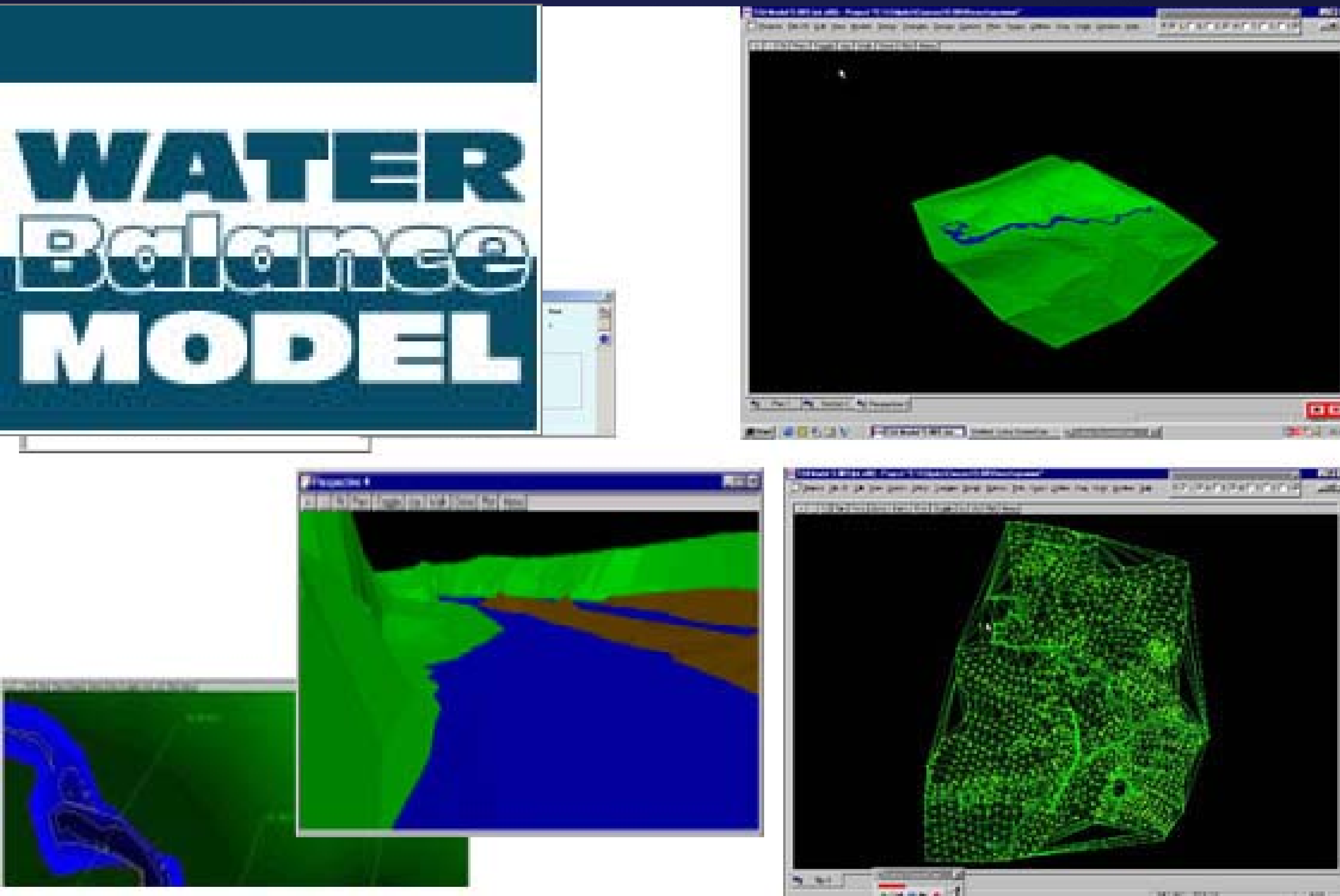
- Soil Conservation Service Type 1A design storm
- Focus is on design storm: 25-year, 24-hour storm event
- Other durations, frequencies also run.



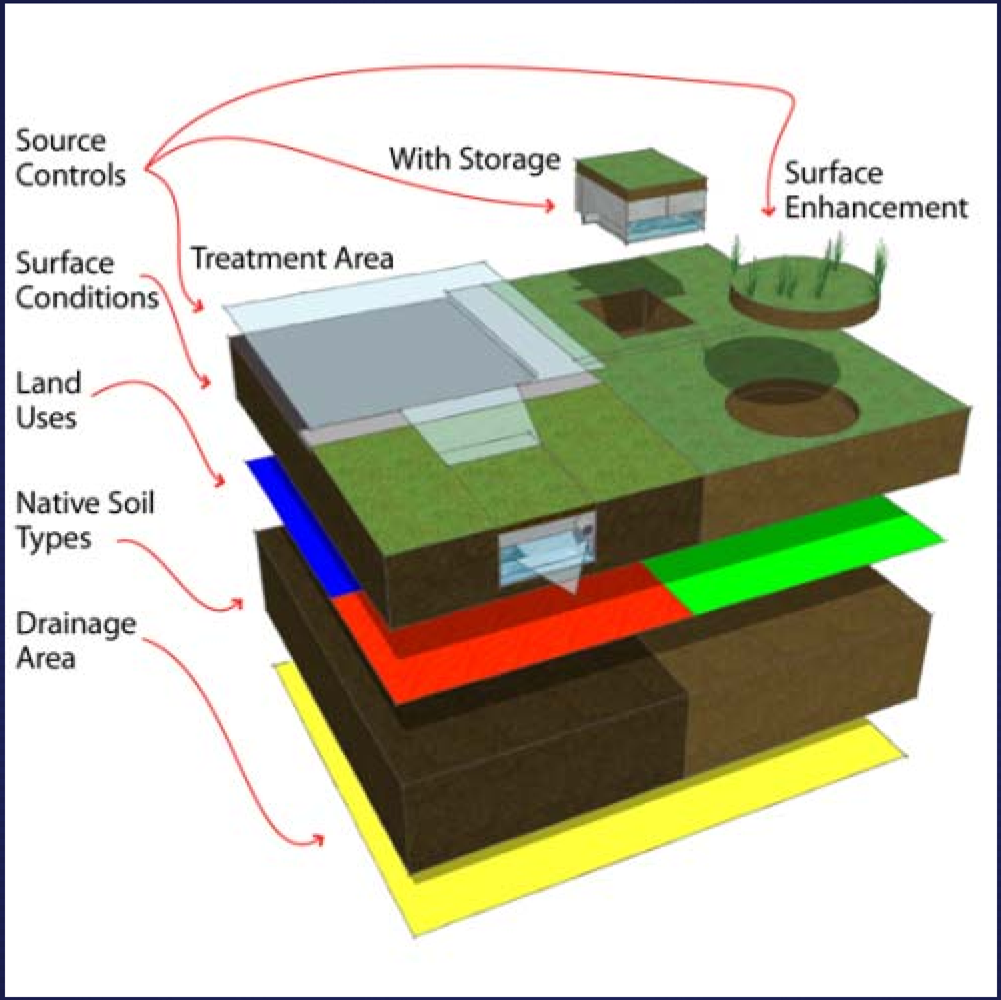
Continuous simulation

- Once model scenarios are refined using design storms, then exceedance curves will be generated using a 30 year climate record.

Modeling Software: XP-SWMM & WBM



Methods – Applying Source Controls



From www.waterbalance.ca

Methods - Enhanced Top Soil

Example:

1. Identify multi-family, single detached housing and institutional zones
2. Remove building footprints, road areas, water features, other impervious surfaces.
3. For remaining area, estimate lawn areas by analysing orthophotographs.
4. Run model using soil depth of **450mm**

Methods - Locating Rain gardens

LiDAR data used to delineate drainage vectors and runoff collection points

Trent St Rain Garden

Rain Gardens require space.

How much is needed?

Impervious area to Rain Garden area ratios range from:

- 50:1 Low traffic
- 20:1 High traffic

Source: Kerr Wood Leidal, 2010

Locating Rain gardens

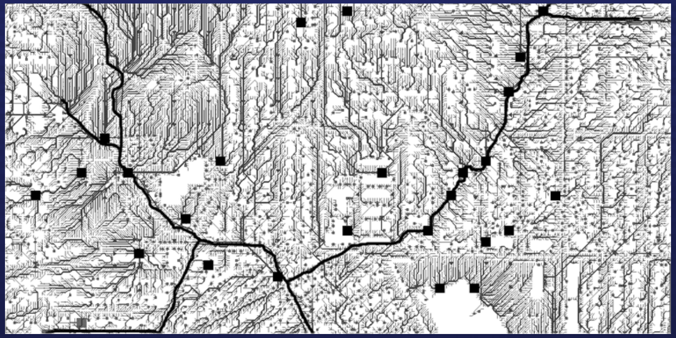
Smaller scale drainage vectors can be generated for micro-scale rainwater runoff analysis.

Image Credit: Taylor Davis

Rain gardens

- Rain gardens modeled for potential sites using:
  - Under-drain and overflow-drains
  - Short-term surface detention (15mm depth, drains within 48hrs)
  - Rock pit
  - Various soil depths

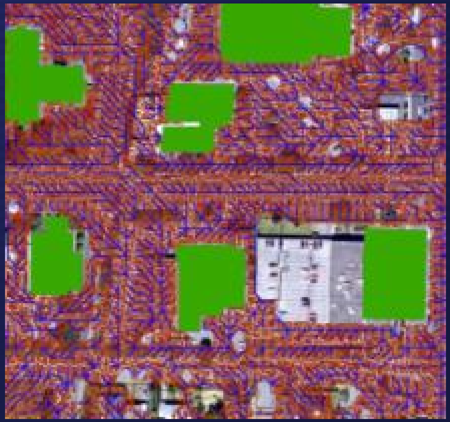
- Selection and classification routines performed based on e.g.:
  - Soil type
  - Proximity to impervious surfaces and density
  - Slope



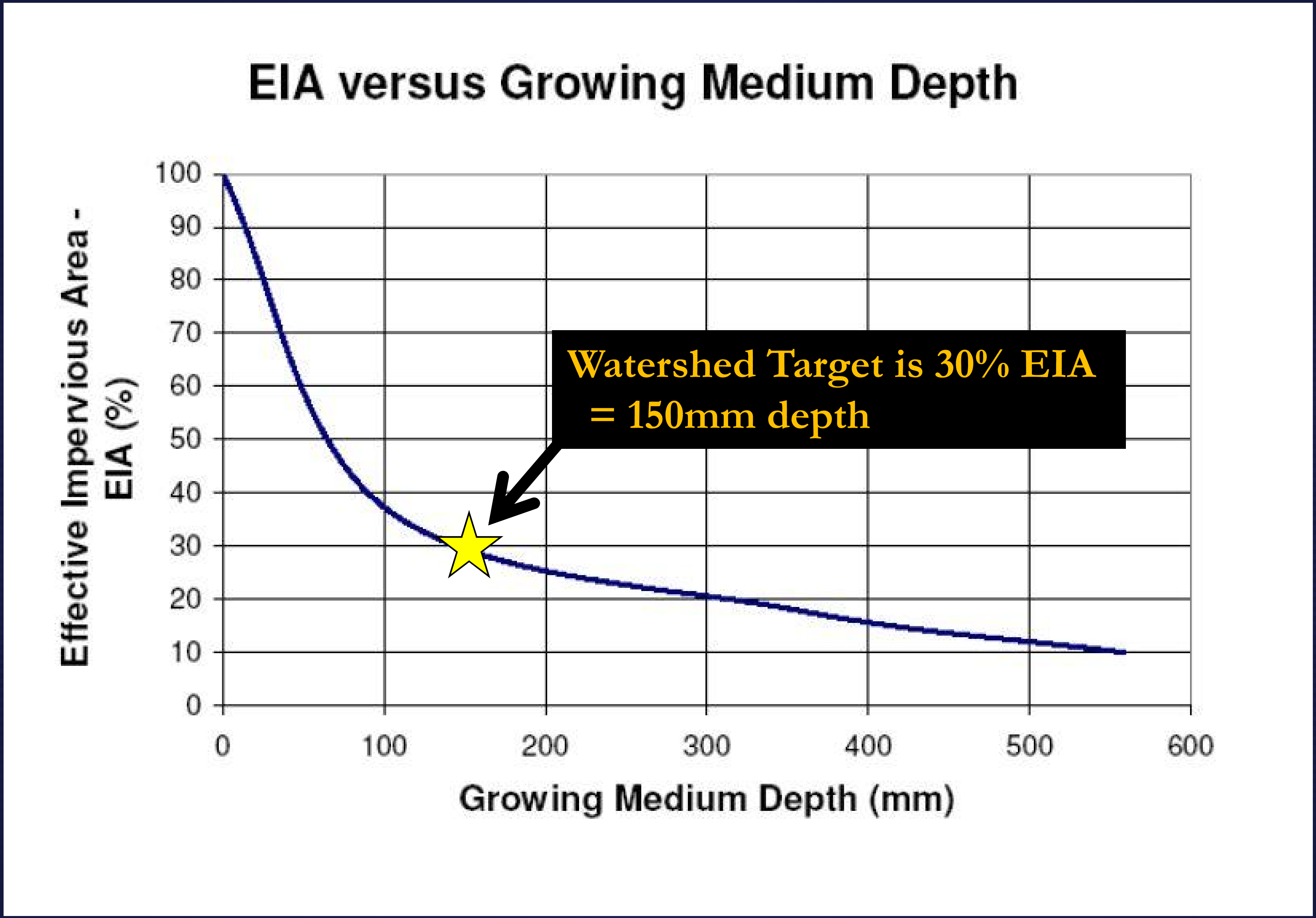
Source Control 3: Green Roofs

Example:

1. Identify Commercial, Industrial & Multi-family zoning (typically flat roofs)
2. Select building footprints
3. Use high-resolution LiDAR data to identify flat roofs
4. Calculate 80% of roof area (leave space for HVAC systems etc)
5. Run remaining areas in model.

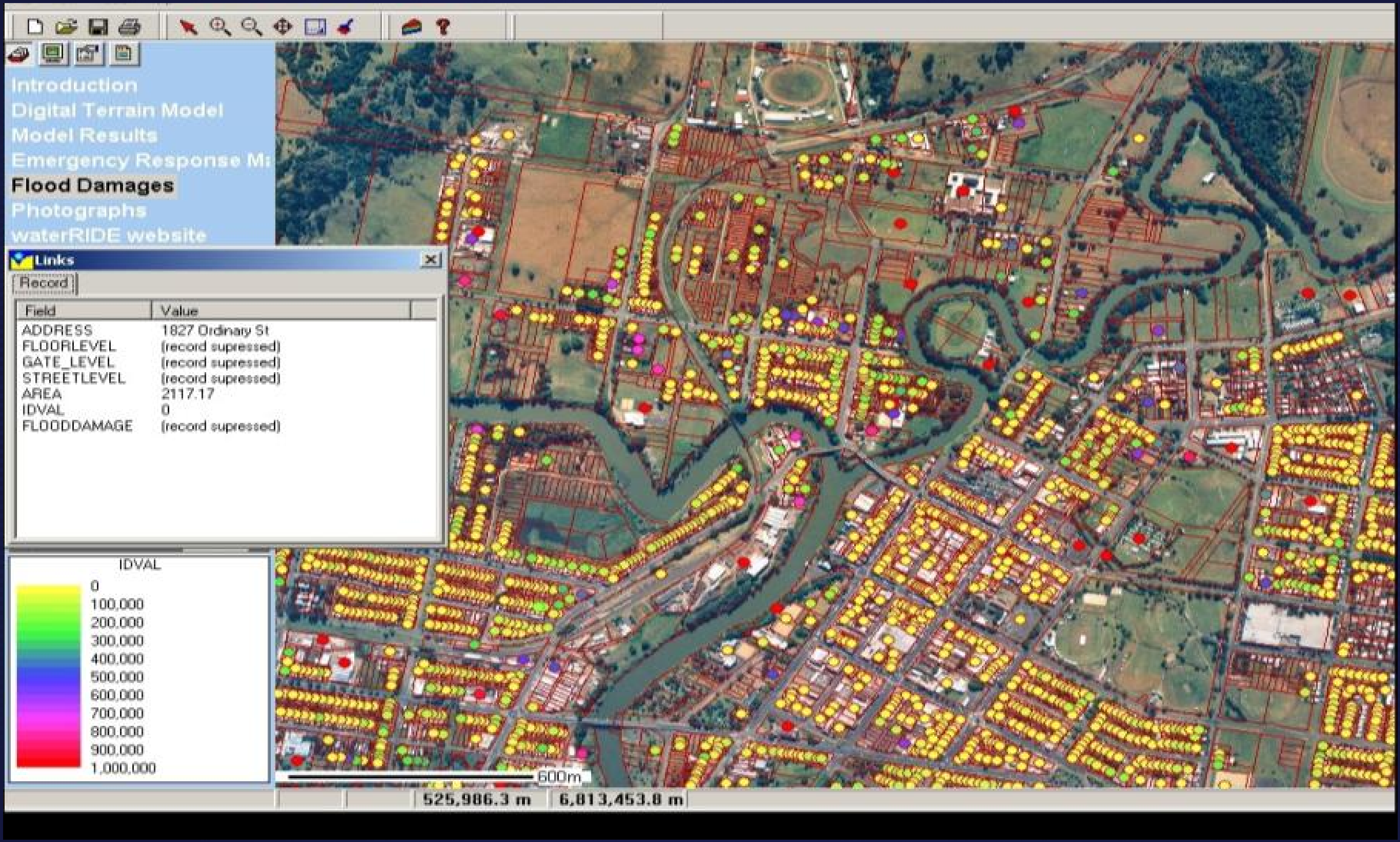


Green Roof



Source: Kerr Wood Leidal, 2004

Modeling the Cumulative Effect of 3 Source Controls

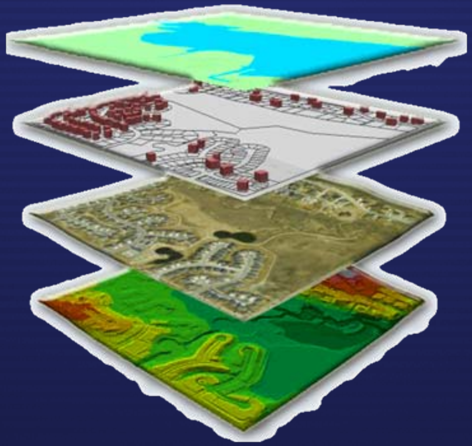


Scenario 1:

Climate Change: **9% increase** (median estimate)

Reducing Peak Flows requires:

- Top Soil: **11.3%** watershed area receives amended top soil
- Green Roof: **1.6%** of watershed area used for a green roof
- Rain gardens: **25.4%** of the watershed's <u>impervious areas</u> directed to rain gardens
  - Area ratio **40:1** (**0.3%** of watershed)



Scenario 2:

Climate Change: **16% increase** (75th percentile)

Reducing Peak Flows requires:

- Top Soil: **15.2%** watershed area receives amended top soil
- Green Roof: **2.3%** of watershed area used for a green roof
- Rain Gardens: **35.6%** of the watershed's impervious areas directed to rain gardens
  - Area ratio **30:1** (**0.6%** of watershed)

Note: location of LID facilities important!

- E.g. most suitable Green Roofs locations are in the upper watershed – **GOOD!**

What if…

Scenario 3: Maximum LID use, 90th percentile increase

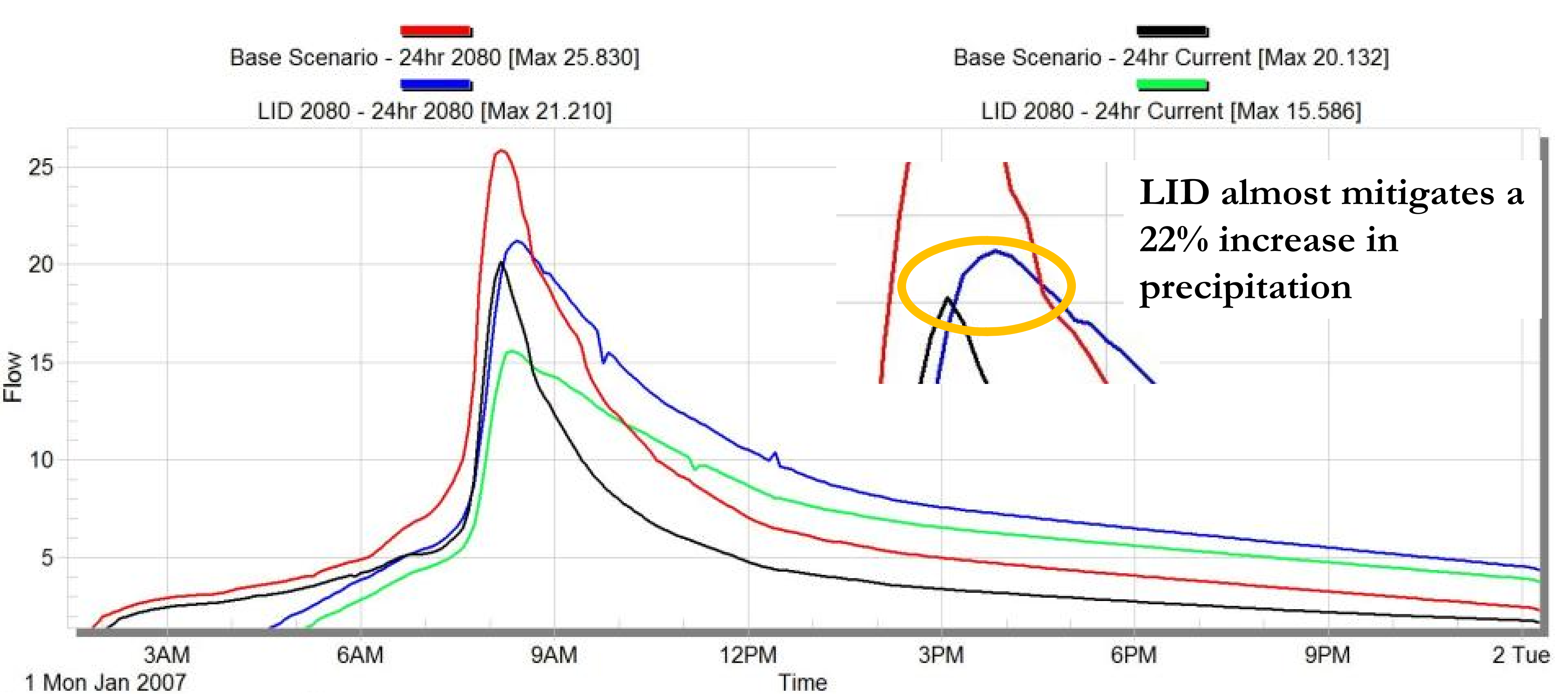
*All LID values are practical maximums based on suitable land areas and recommended design standards.

- Climate Change: **22% increase** (90th Percentile)
- Top Soil: **18.7%** watershed area receives amended top soil
- Green Roof: **2.8%** of watershed area suitable for green roofs
- Rain Gardens: **44.2%** of the watershed's impervious areas can be directed to rain gardens
    - Area ratio **25:1** (**0.9%** of watershed)

Note: Top Soil and Green roof maximums can be adequately estimated. Rain Garden maximum is uncertain. Implementation could exceed estimate.

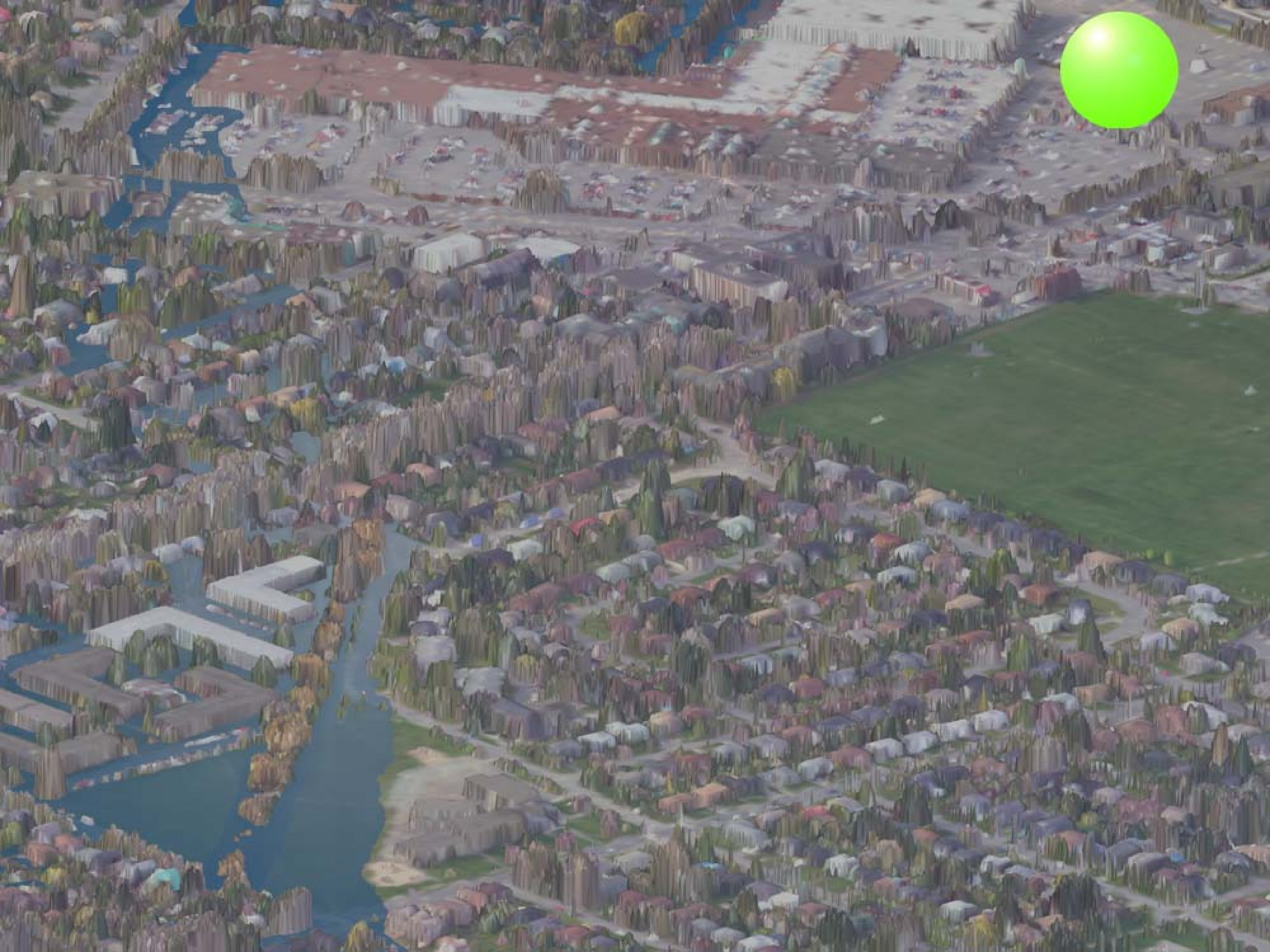
Preliminary Results

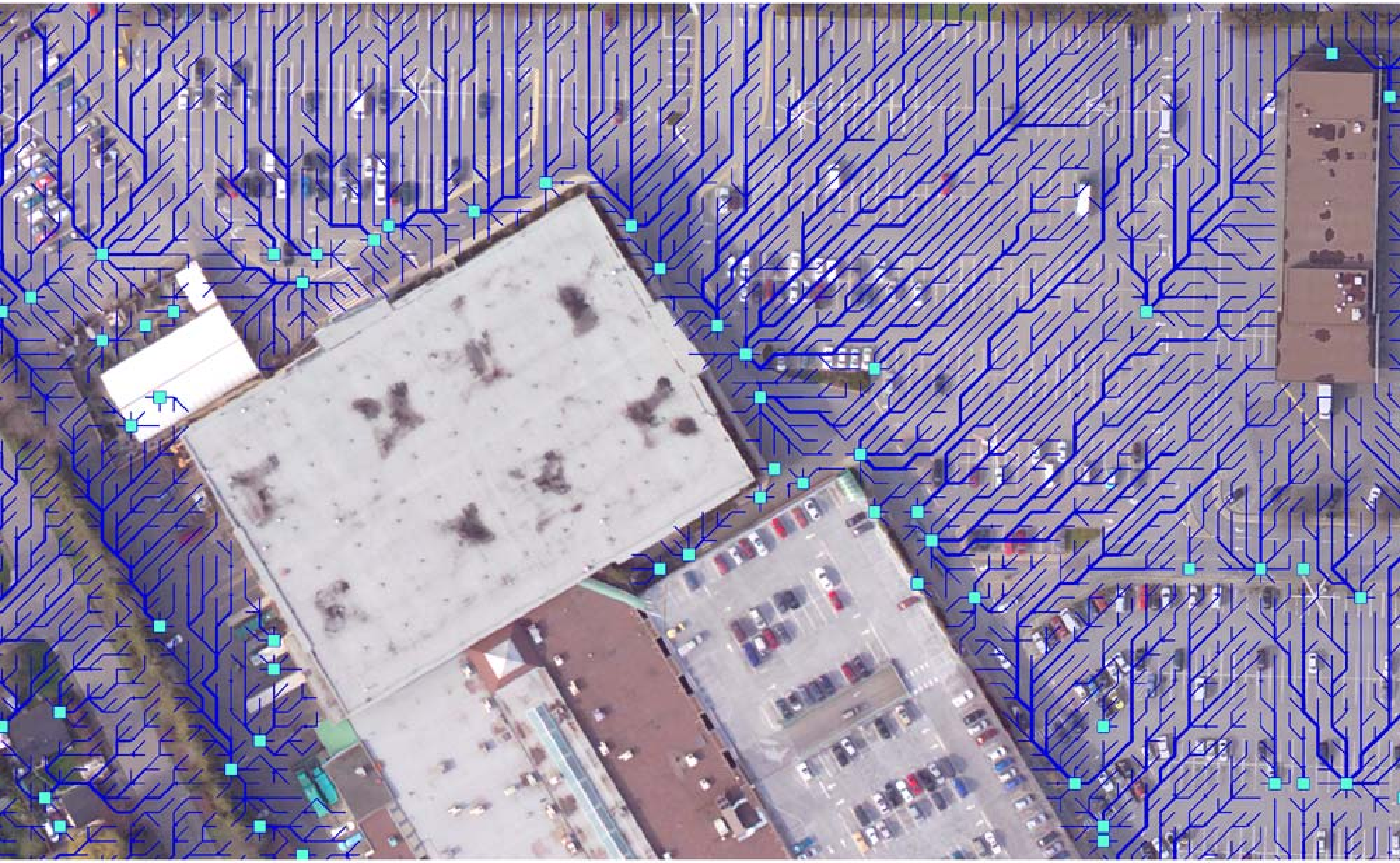
If precipitation increases by 22%, the model estimates that the maximum level of LID implementation will mitigate **95%** of the increased flows.

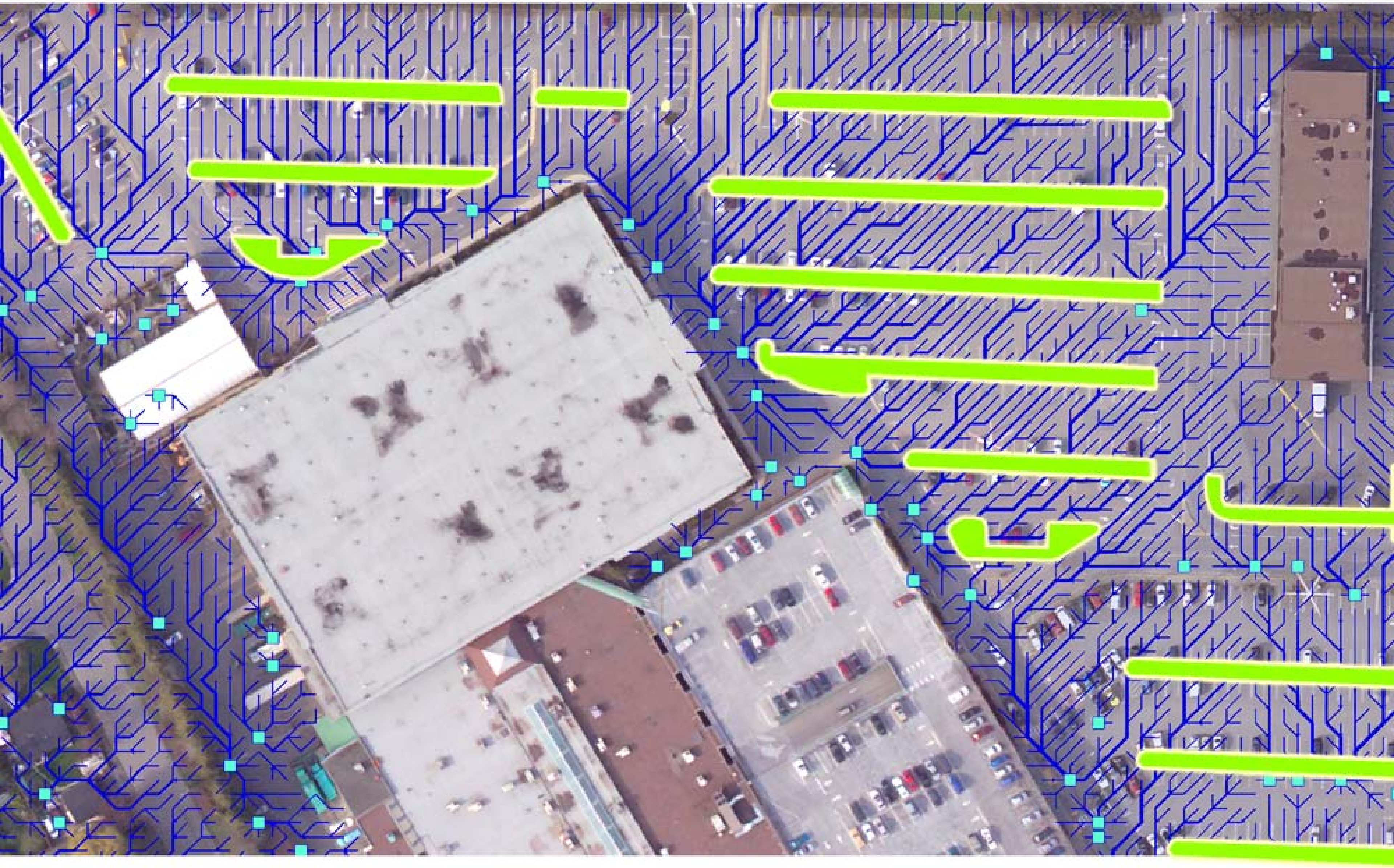


Flow rates for historical and future climate (90th percentile) with conventional and LID land use for the 25-year, 24-hour storm event using the SCS Type 1A design storm.

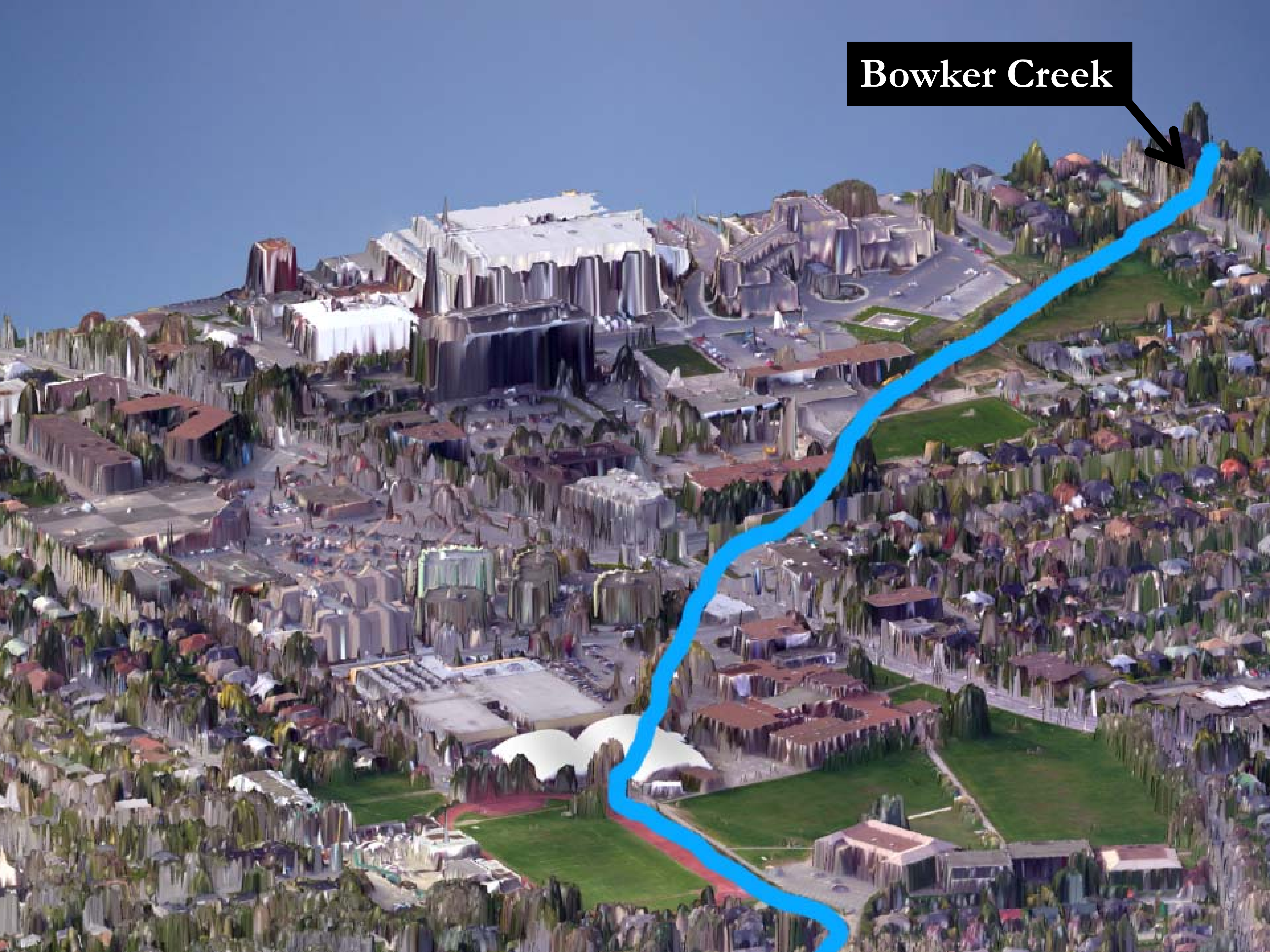
DAMAGE $

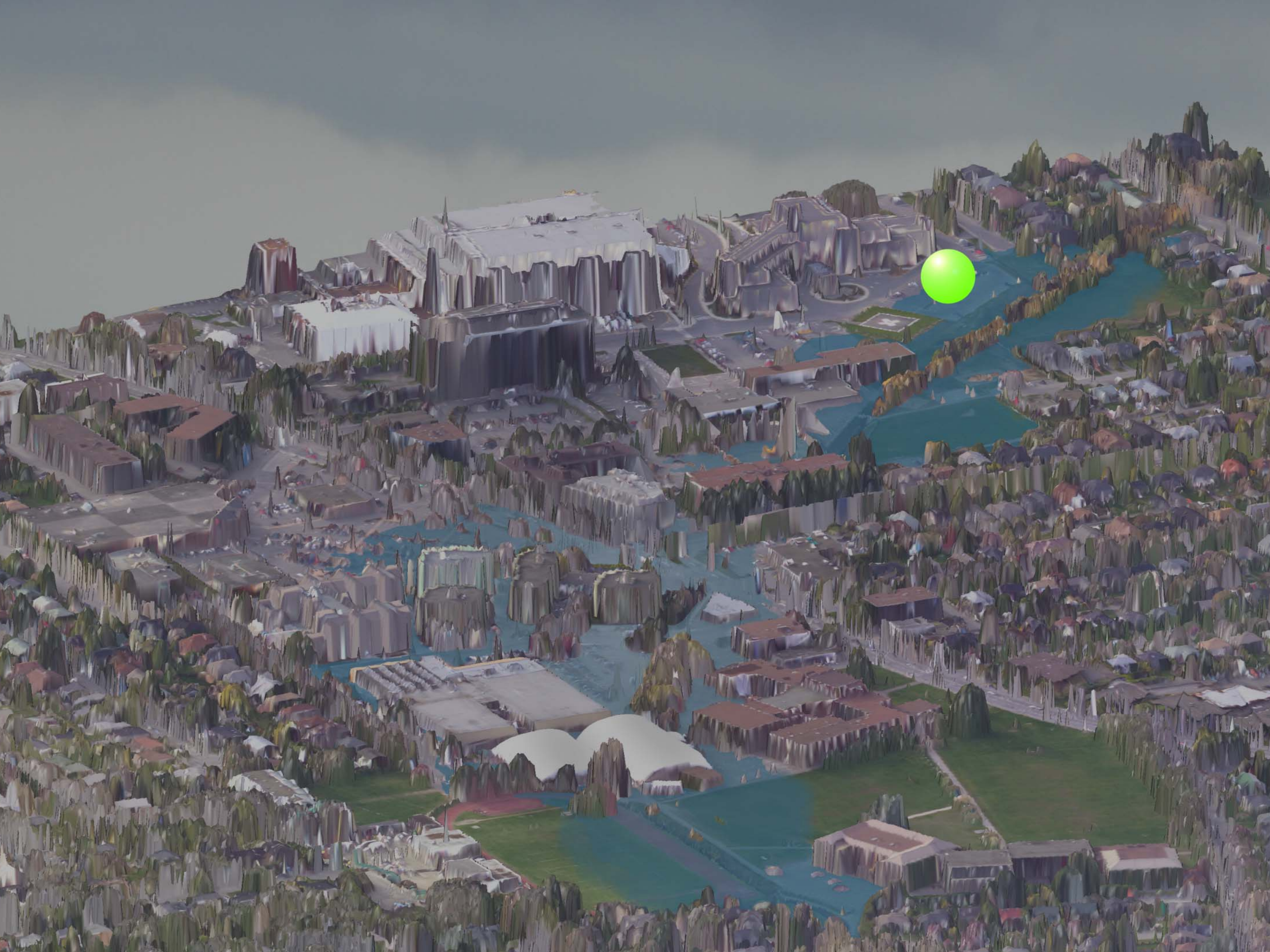


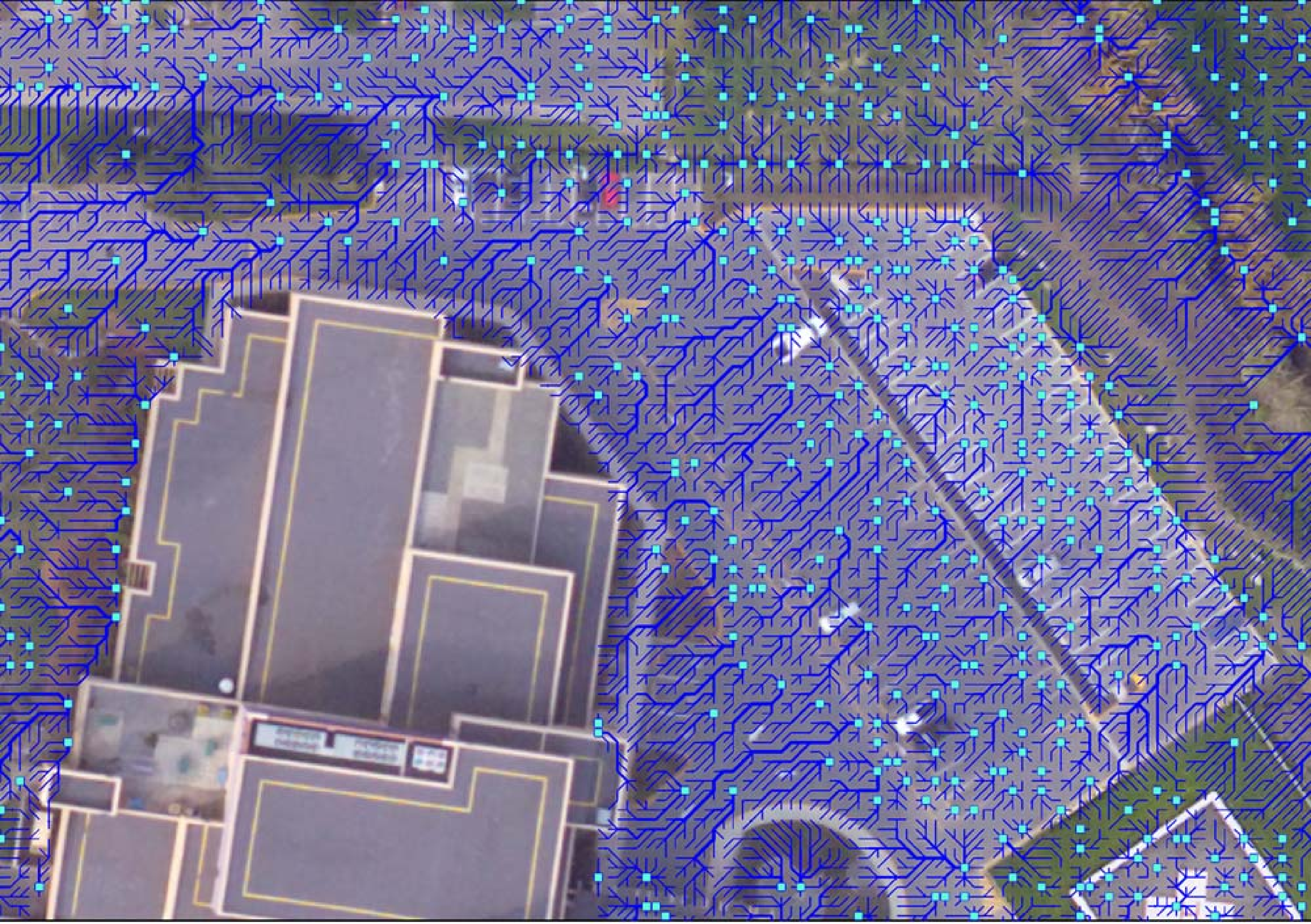


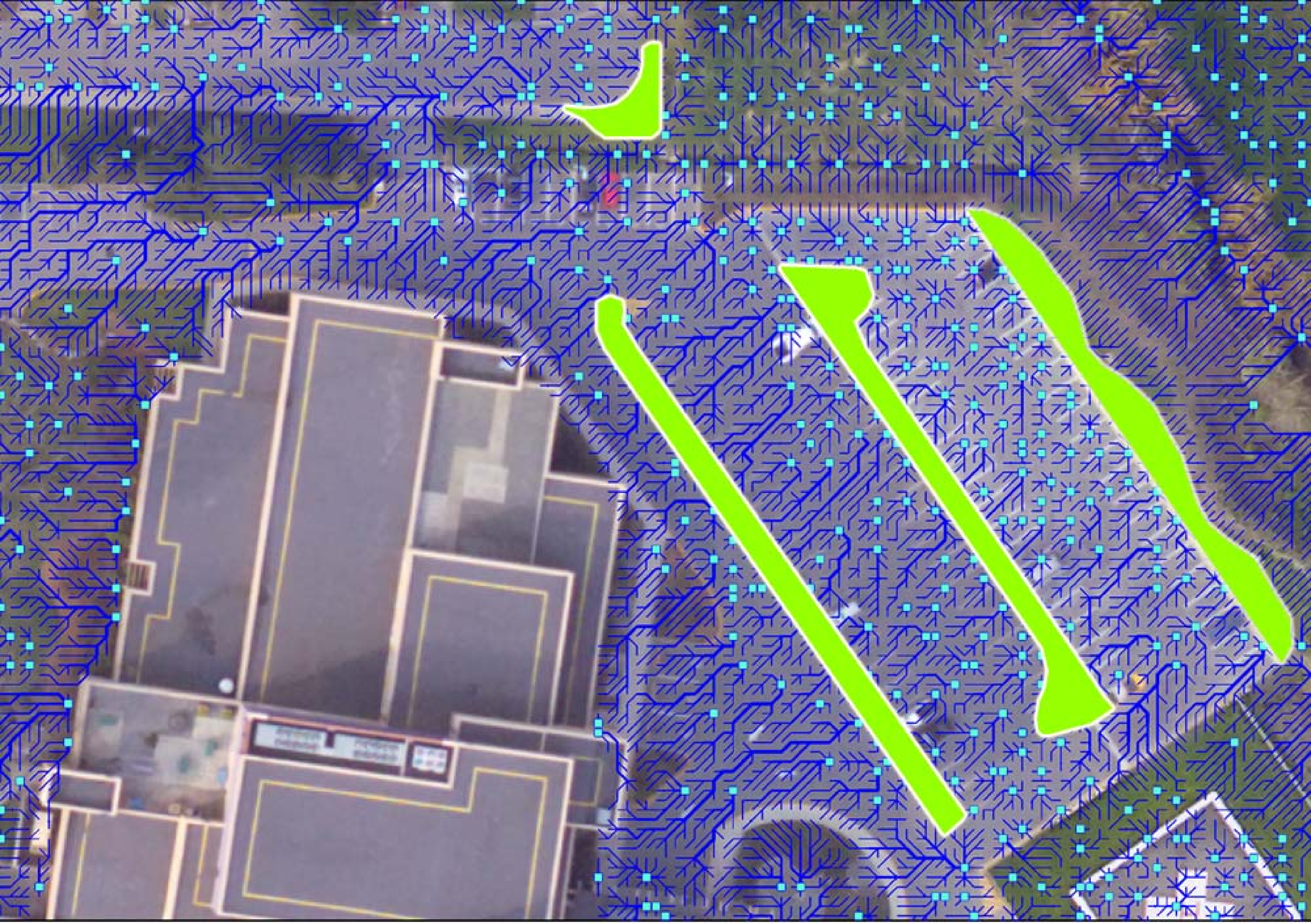


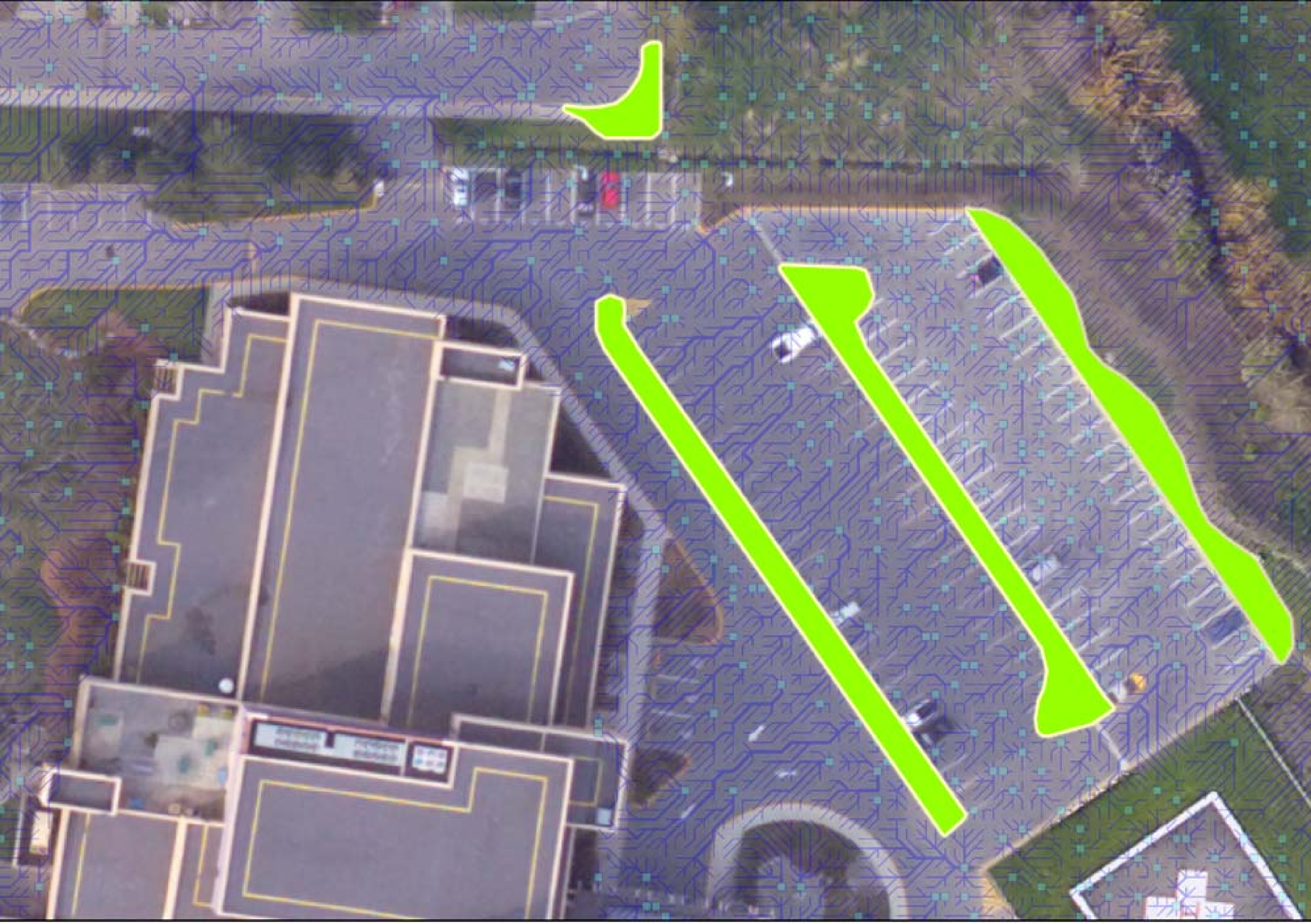
PREVENTION $

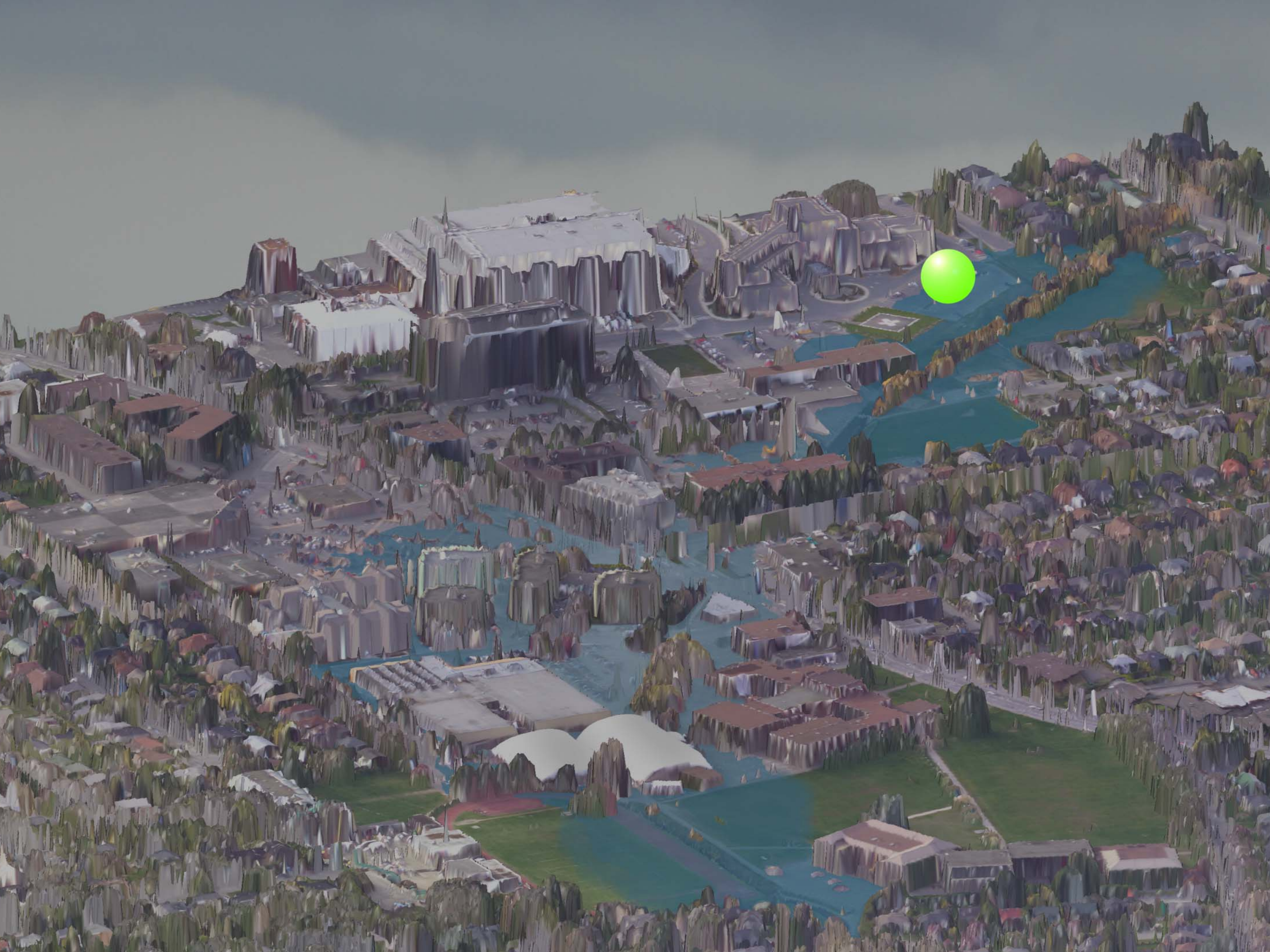

Bowker Creek

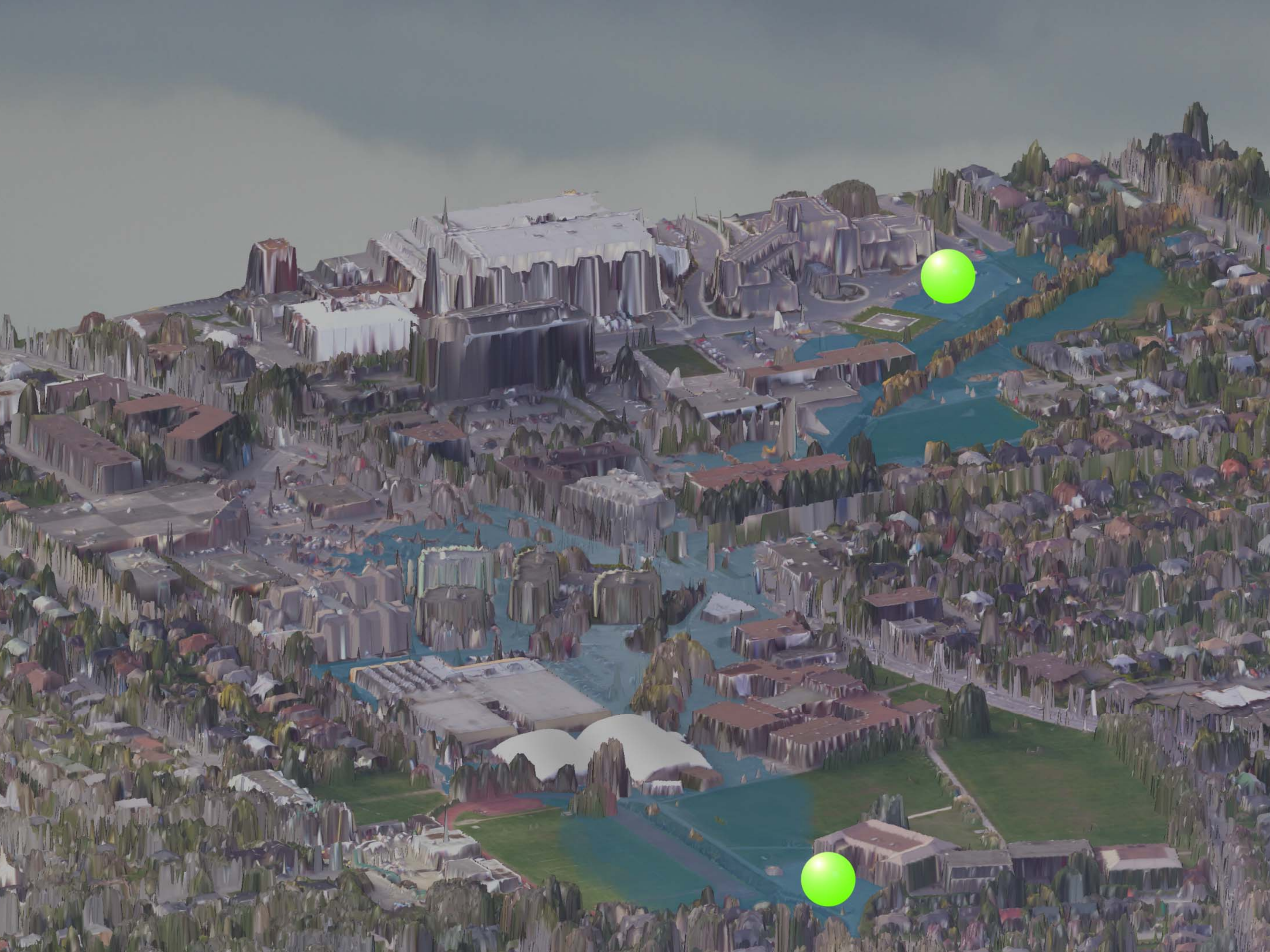


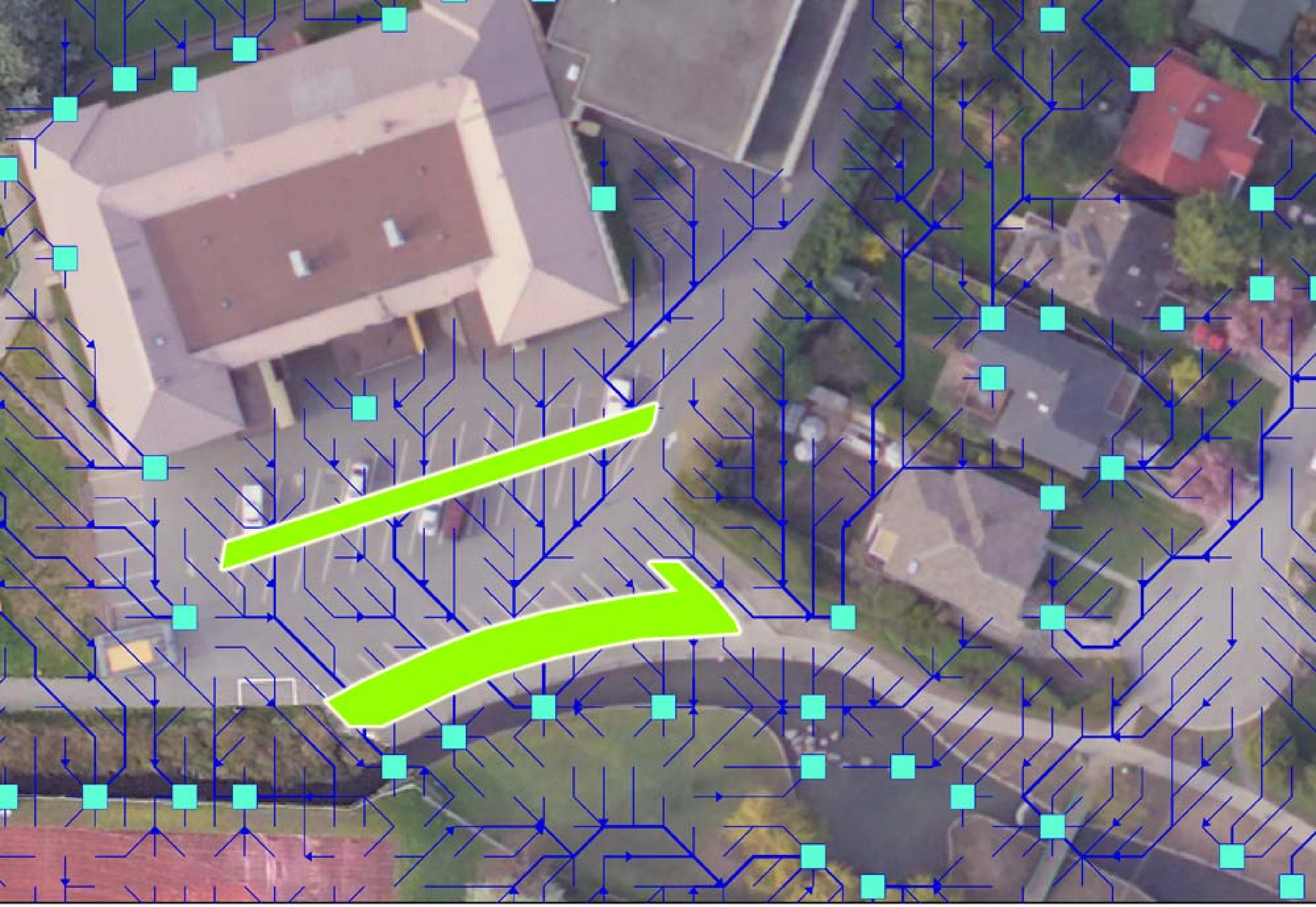






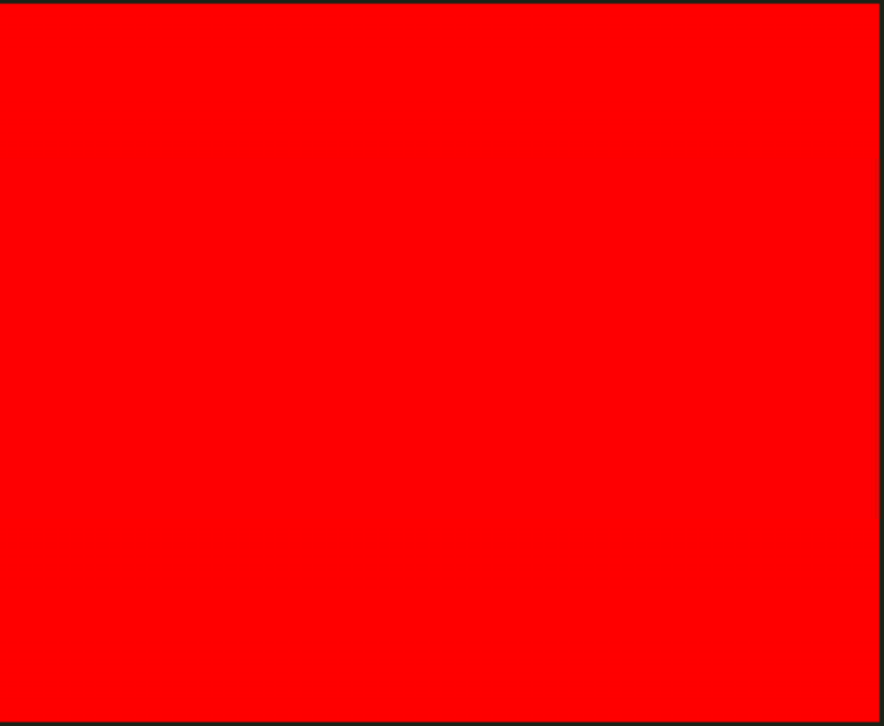







Bowker Creek


Bowker Creek
Image Credit: Taylor Davis

 = Damage $

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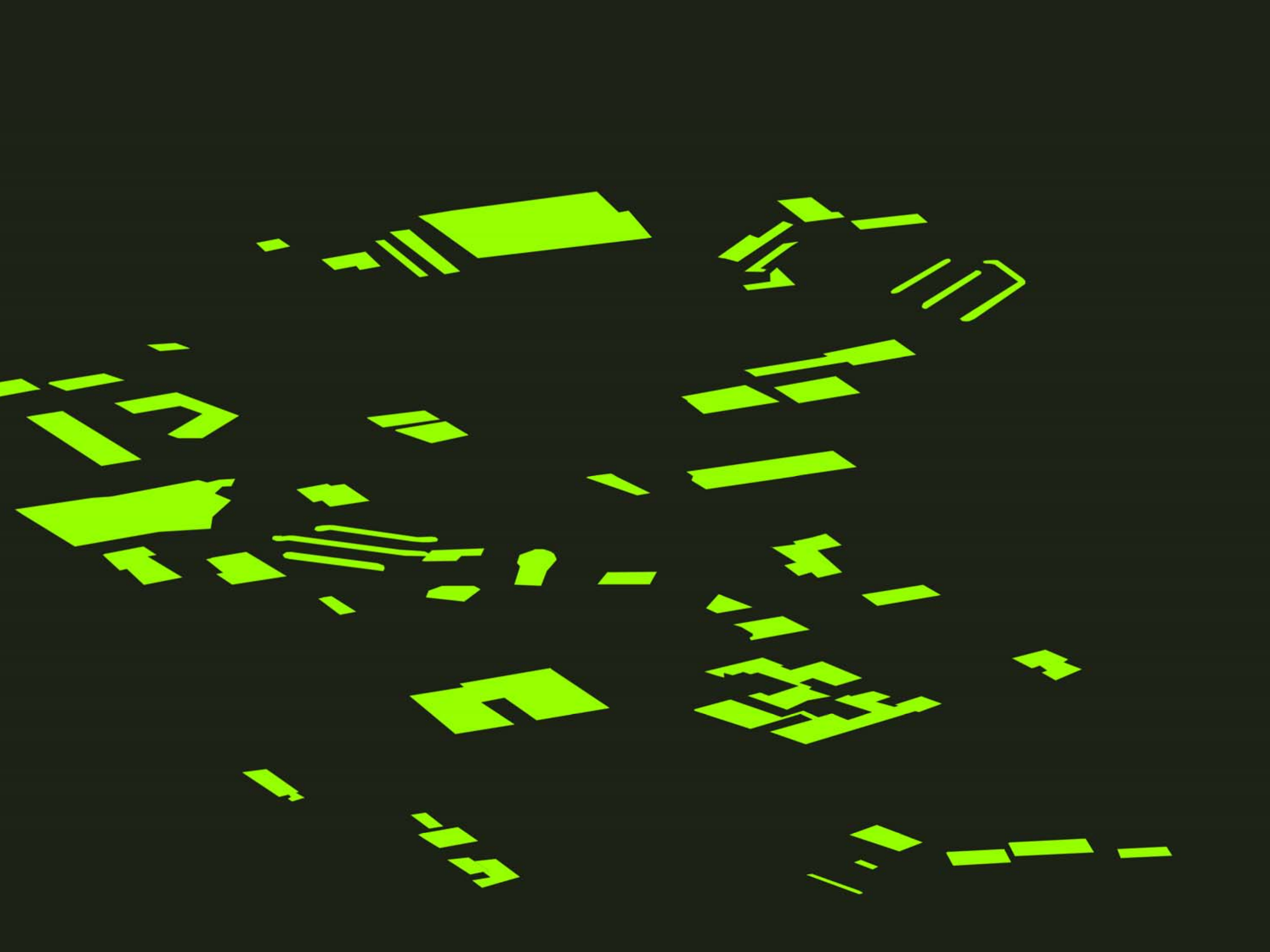

= Damage $

= Prevention $

Research Results

Results represent an applied approach. For example:

- Moist Soils
- Aggressive Design Storm (high intensity peak)
- Only modeled 3 Source Controls:
  - ➢ Top soil: limited soil depths to 450mm
  - ➢ Green roofs: limited to 80% suitable roof area
  - ➢ Rain Gardens: limited to 0.9% of watershed area.

Peak flows would decrease further if other LID source controls were used such as porous pavement, underground storage, disconnected downspouts, roadside swales, rainwater harvesting, tree canopy, etc..

Study only looked at Peak Flows. Other hydrological benefits were not assessed (water quality, summer base flows, volume reduction etc).

Research Results

Can support LID Policies and Bylaws that enhance LID implementation.

For example:

THE CORPORATION OF THE DISTRICT OF CENTRAL SAANICH

SURFACE WATER MANAGEMENT PLAN BYLAW NO. 1606, 2010

A Bylaw to Regulate and Require the Disposition of Surface
Water Run-off and Storm Water

CONSOLIDATED FOR CONVENIENCE
(Amended by Bylaw No. 1697)

- All surface water run-off and storm water on a parcel of land must be disposed of on the same parcel…
- In preparing surface water run-off plans, professional engineers must use the **Water Balance Model**, in conjunction with any other hydrologic analysis methods…

Conclusion

- LID provides an incremental and flexible approach for climate change adaptation.
- LID has a positive effect on the urban environment in general.
- LID offers a "no regrets" option for flood mitigation.
- **Preliminary results indicate that in the Bowker Creek watershed, LID can largely mitigate the adverse impacts of climate change.**

Funding Support

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Questions?