

Maximising Flood Model Value for Catchment and Water Quality Management

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Overview

- Introduction
- Catchment models overview
- Flood models as catchment pollutant tools
- Demonstration urban flood model
- Catchment pollutant model
- Results and wider applications

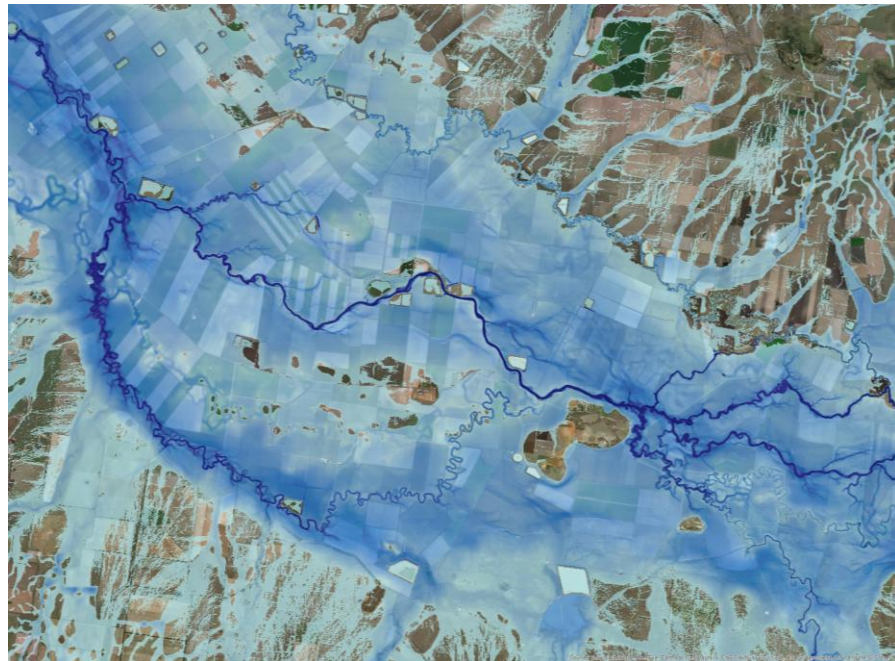


Introduction



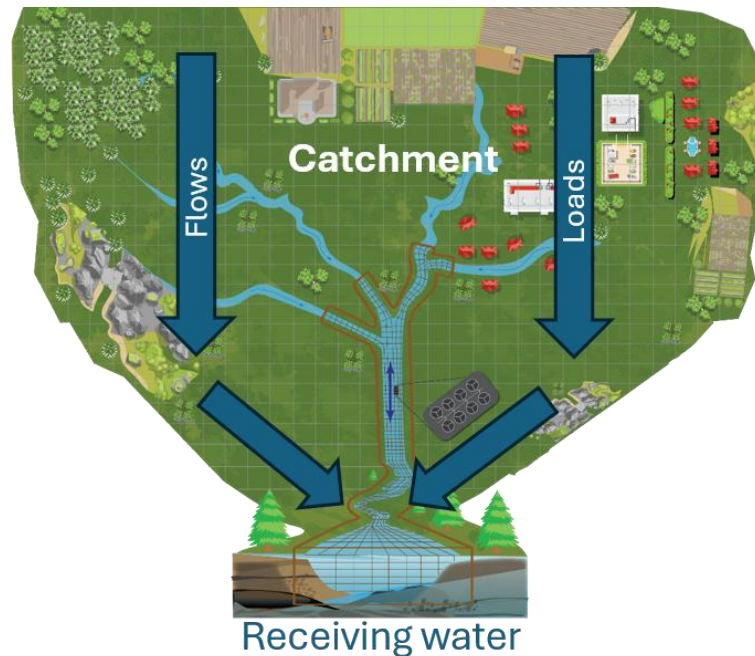
Value beyond flood assessment

- Flood models require substantial investment to develop
- They are typically built to answer a relatively narrow set of flood related questions
- Include a range of data that can be repurposed for catchment pollutant modelling
- An existing flood model may require a small number of modifications to act as a catchment pollutant tool



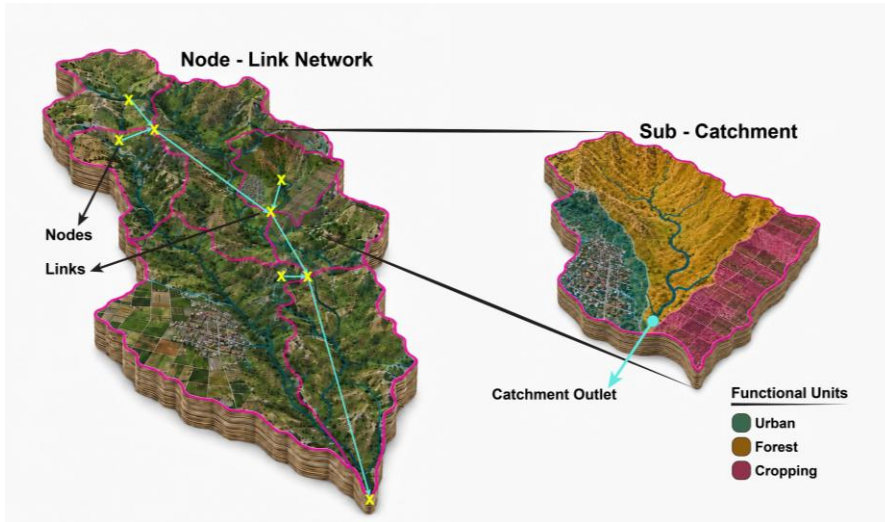
What is a catchment pollutant model

- Represent where pollutants originate and accumulate
- Simulate pollutant mobilisation by rainfall and runoff
- Transport pollutants through the catchment
- Estimate the timing, concentration and load of pollutants reaching downstream receiving waters



Catchment pollutant model types

Lumped



Spatially distributed (Urban)

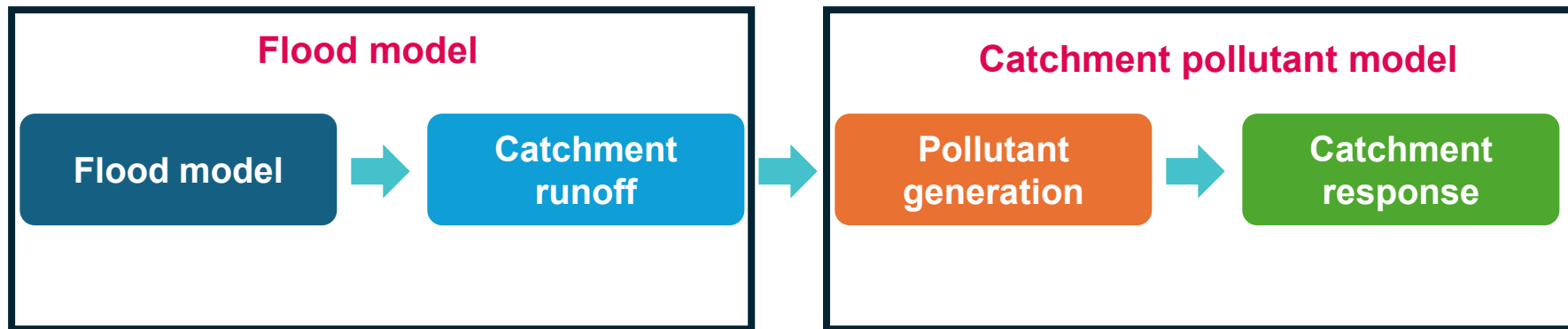


Flood model vs. catchment model

	Flood model	Catchment pollutant model
Purpose	Flood hazard, planning, evacuation	Local and receiving water quality, pollutant treatment design
Results of interest	Peak flood levels, velocities, peak flows, timing, flood extents	Flows, volumes, mass, concentrations
Simulation period	Hours to days	Days to decades
Cell size	2 to 30m	Lumped model or spatially distributed
Inflow boundary approach	Lumped, direct rainfall or a combination	Lumped, direct rainfall or a combination

From flood model to catchment model

Build on the existing hydraulic model rather than starting again



Catchment and water quality questions

- Where in the catchment do pollutants come from during a storm?
- What are the contributions from different nitrogen species to total nitrogen concentrations?
- When do different pollutant sources reach the receiving water?
- What is the mass (in kg) of pollutant reaching the receiving waters?
- Where can treatment devices be placed to maximise capture efficiency?



Flood models as catchment tools



Data an existing urban flood model may provide

Data

- Topography and bathymetry
- Landuse mapping (materials)
- Soil mapping
- Rainfall and inflow boundary conditions
- Stormwater network

Processes

- Runoff routing – direct rainfall
- Infiltration
- Overland flow connectivity
- Stormwater flows
- Sub-surface flows

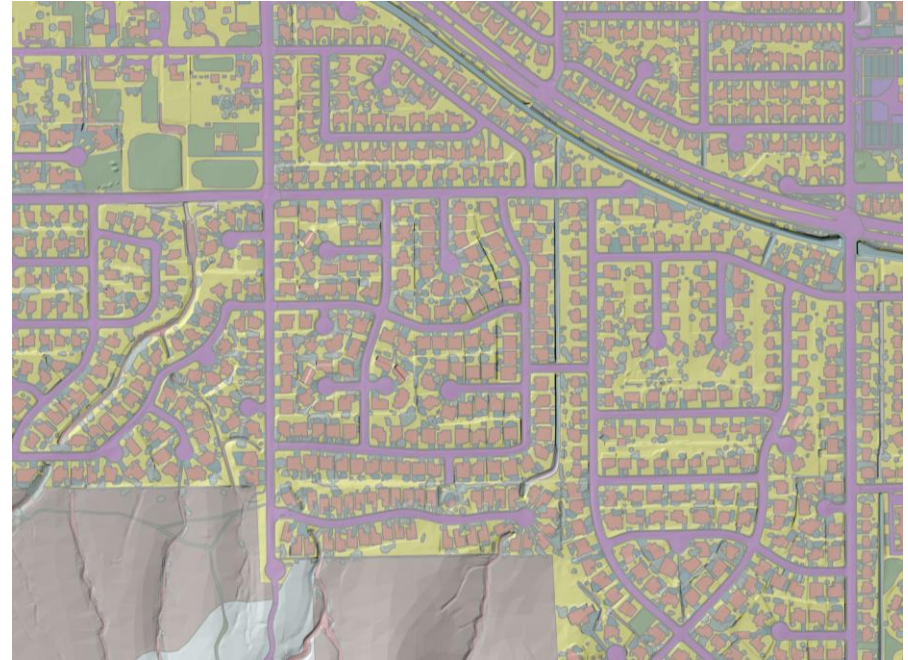
Existing surface mapping

- Topography
- Land use mapping (materials)
 - Hydraulic roughness
 - Pervious and impervious fractions
- Soil mapping
 - Infiltration



Pollutant source definition

- Land use (materials) used to define location of pollutants



Cell scale representation

- Topography
- Landuse
- Soils
- Pollutant properties
- Rainfall
- Water mass and pollutant mass tracked per cell



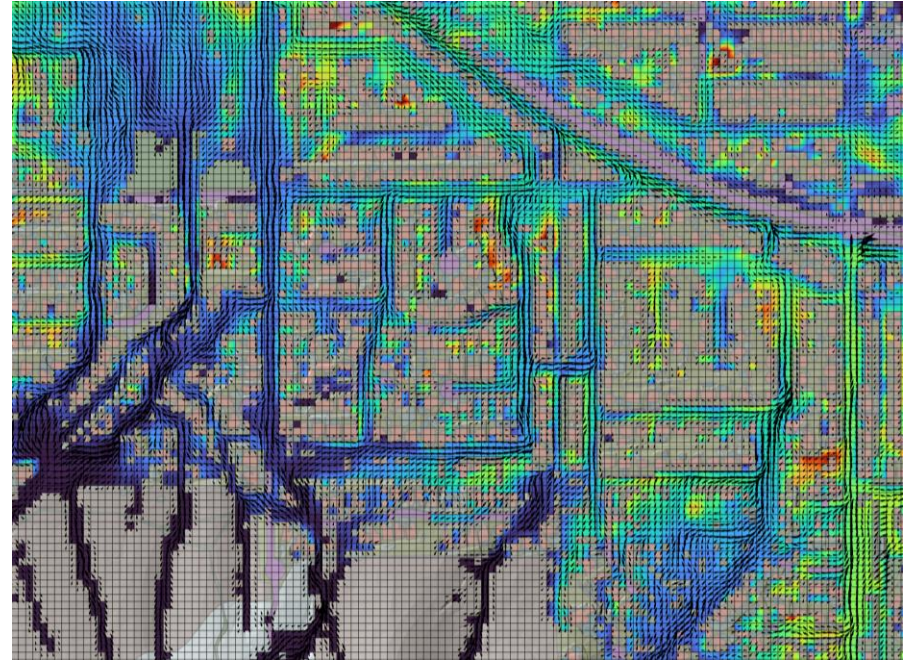
Surface flow and stormwater pathways

- Water movement following governing hydrodynamic equations of the flood model
- Overland flow
- Stormwater drainage
- Interflow/groundwater



Pollutant generation and transport

- Pollutant mass transport
 - Hydrodynamics
 - Pollutant loading
 - Advection dispersion
- Overland flow
- Stormwater drainage
- Interflow/groundwater

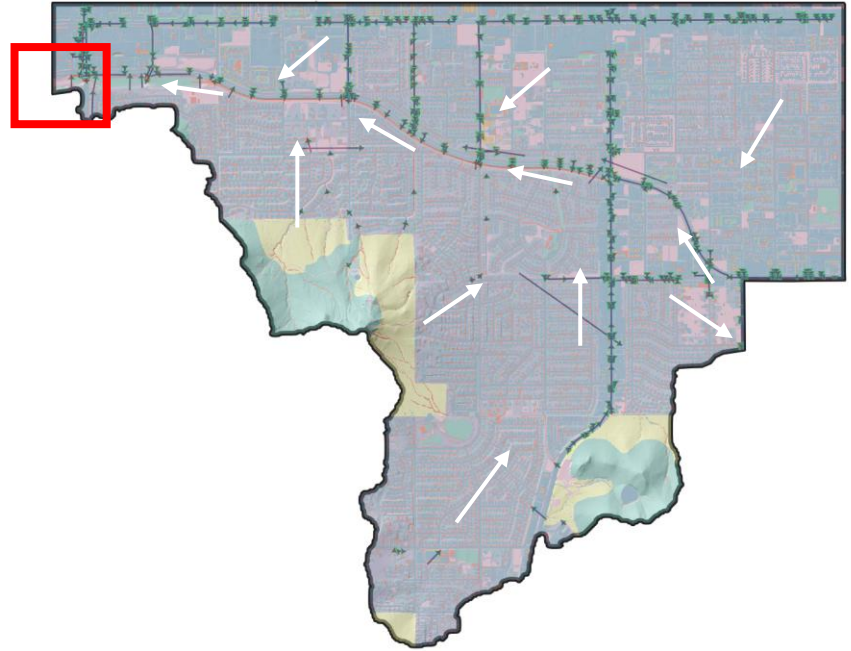


Demonstration urban flood model



Demonstration urban flood model

- TUFLOW HPC
- Urban catchment
- 11 km² catchment area
- 3 m horizontal resolution
- 1D pit and pipe network (trunk drainage)
- Cross drainage hydraulic structures
- Direct rainfall with mapped materials and soils



Optimising the existing urban flood model

- Answering different questions
- 2D cell size sensitivity testing
- Single rainfall event – 24hr simulation period
- Simulation of 3m, 6m, **10m**, 20m and 30m 2D cell size
- Runtime, hydraulic response, landcover, output size
- Additional checks could include:
 - Alternative antecedent conditions
 - Alternative events or event sequence (Intensity, duration, temporal pattern)

Observed runtimes

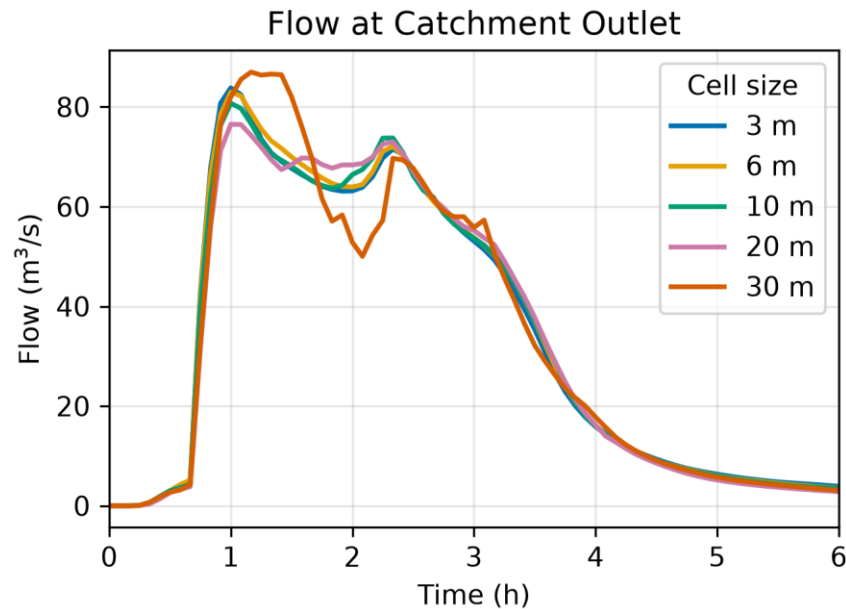
10m model

- 7.5x faster
- 24 hour simulation in 13 mins
- 107x real time

2D Cell Size	Number of 2D Cells	Runtime (mins)	Runtime ratio (sim:real)	Speed up
3m	1,230,000	98	15:1	N/A
6m	310,000	30	48:1	3.3
10m	110,000	13	107:1	7.5
20m	30,000	7	196:1	14.0
30m	10,000	6	232:1	16.3

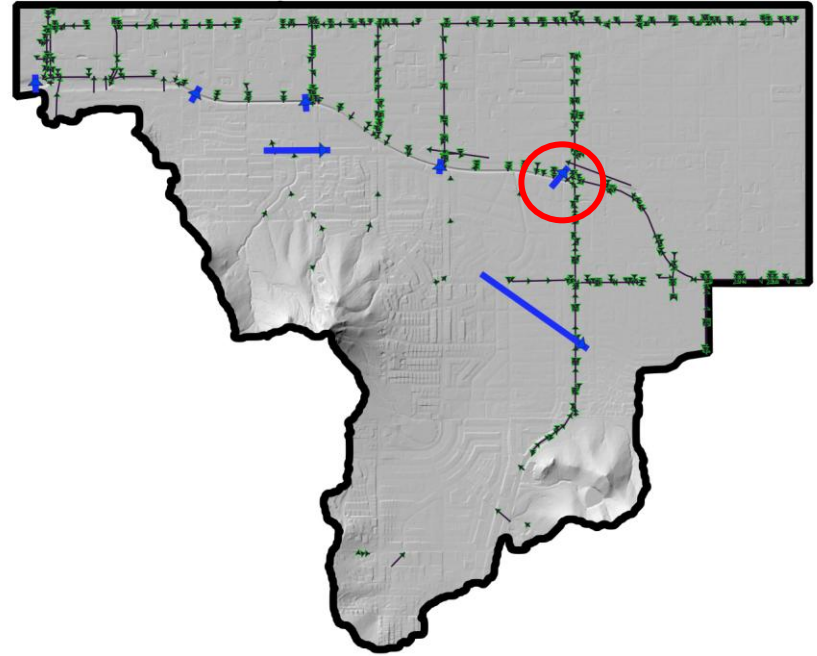
Catchment outlet response

- The 10 m model retains the timing and overall shape of the 3 m outlet hydrograph
- Peak flow difference: 3%
- Time-to-peak difference: > 1min
- Event volume difference: 0.17%



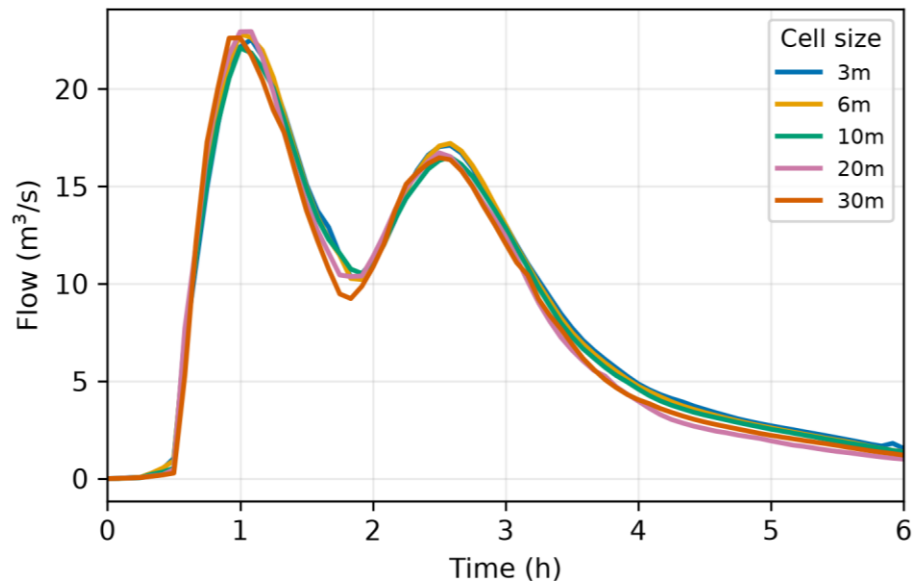
2D routing within the catchment

- Check key overland flow paths
- At regular intervals on the main channel

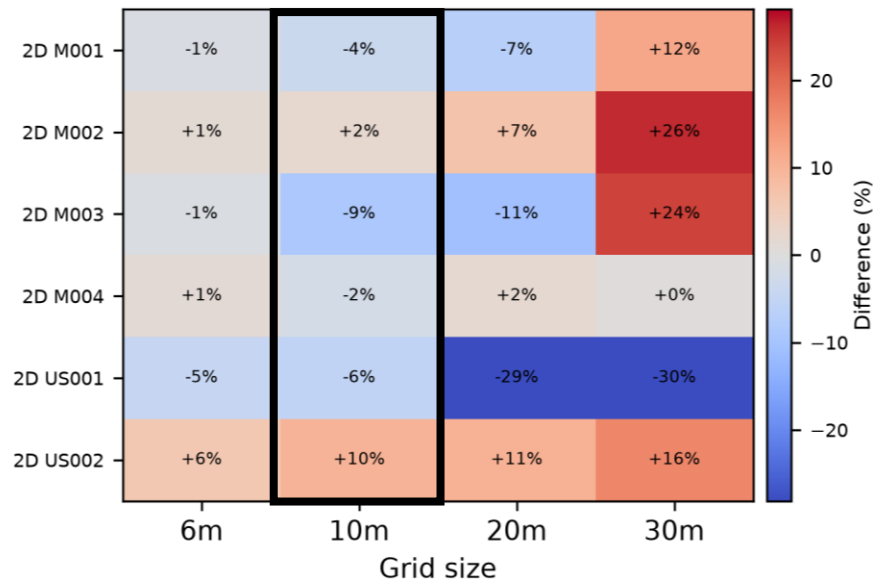


2D routing within the catchment

Flow at M004

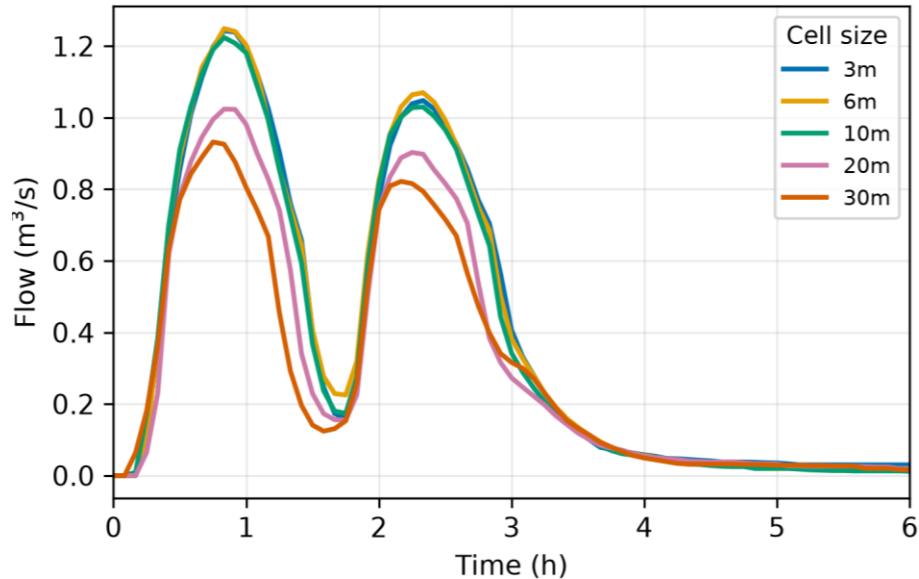


Peak Flow Difference vs 3m

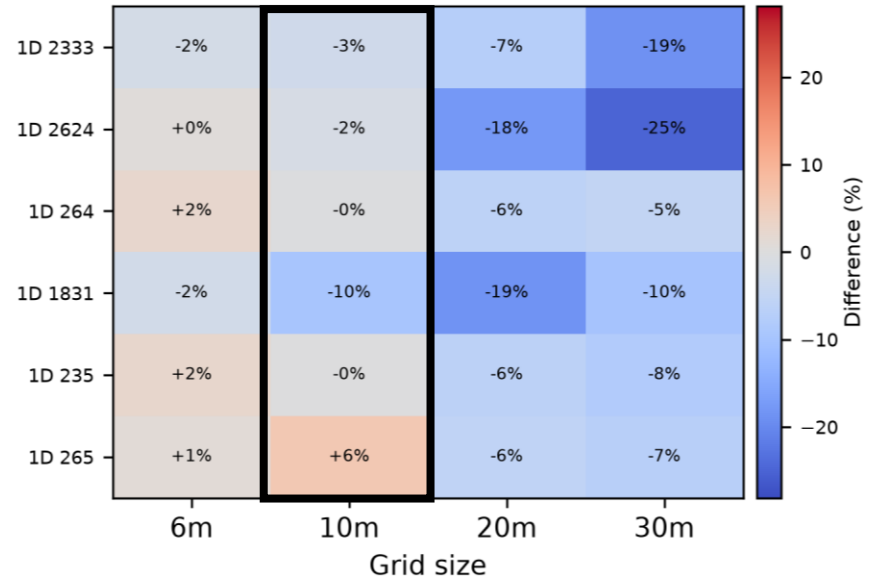


Response through the 1D network

Flow at 2624

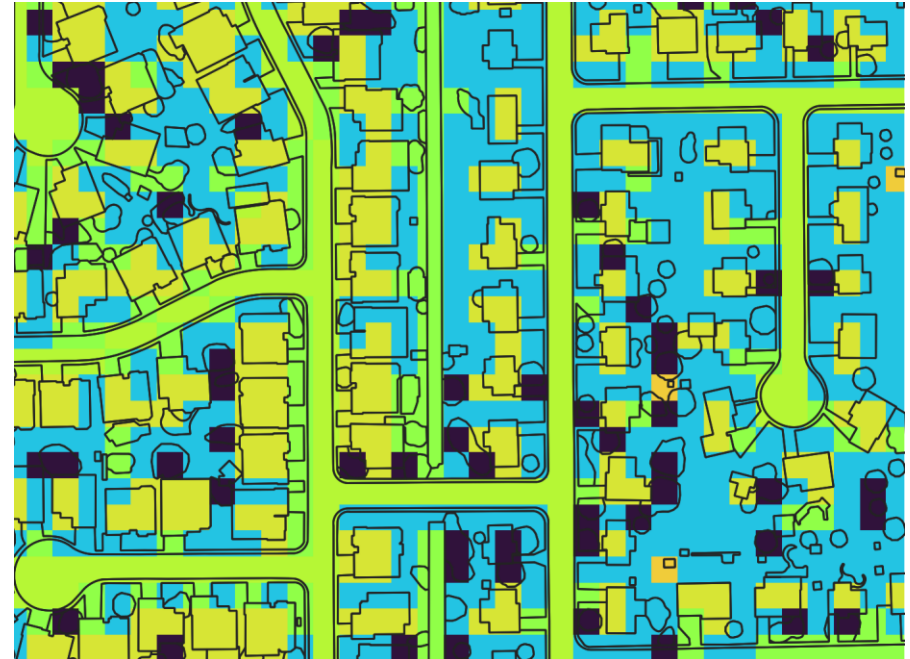


Peak Flow Difference vs 3m



Comparing landuse areas

Cell Size (m)	Urban Bare Ground (% Diff)	Roads (% Diff)
6	0.4	0.5
10	-0.1	0.6
20	3.9	0.1
30	2.5	4.2



10m resolution

Optimising the existing flood model

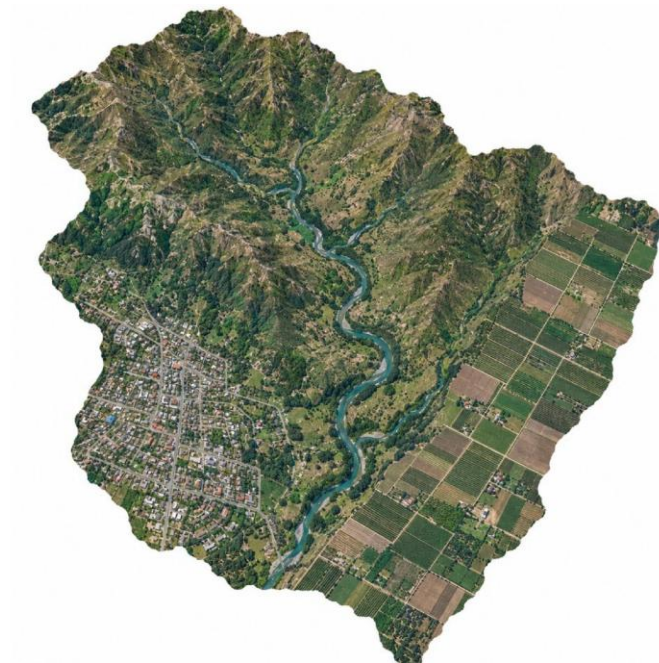
- 10m resolution adopted
- 91% fewer cells than the 3 m model
- 7.5 times faster
- Acceptable agreement at the outlet and selected 1D and 2D locations
- Landuse area well represented
- Suitable for catchment and pollutant simulations
- Allows for variability, sensitivity and scenario testing

Catchment pollutant model



Catchment modelling

- TUFLOW CATCH
- Modelled pollutants
- Pollutant loading methods
- Rainfall and antecedent soil conditions
- Model results



Modelled pollutants

- Nitrate
- Ammonium
- Dissolved organic nitrogen
- Particulate organic nitrogen
- Total nitrogen (Sum the above)



Pollutant sources

- Applied using the same conditions for each landuse
- Four pollutants tracked for each landuse, eight total



Pollutant loading methods

- Dry store: Available pollutant mass (kg/ha)
- Wet store: Pollutant mass that has been eroded or entrained into the flow (mg/L)
- Two methods available:
 1. Accumulation and washoff (Ammonium, nitrate and dissolved organic nitrogen)
 2. Bed shear stress (Particulate organic nitrogen)

Accumulation and Washoff

Not Washoff

Accumulation Rate (kg/ha/year)

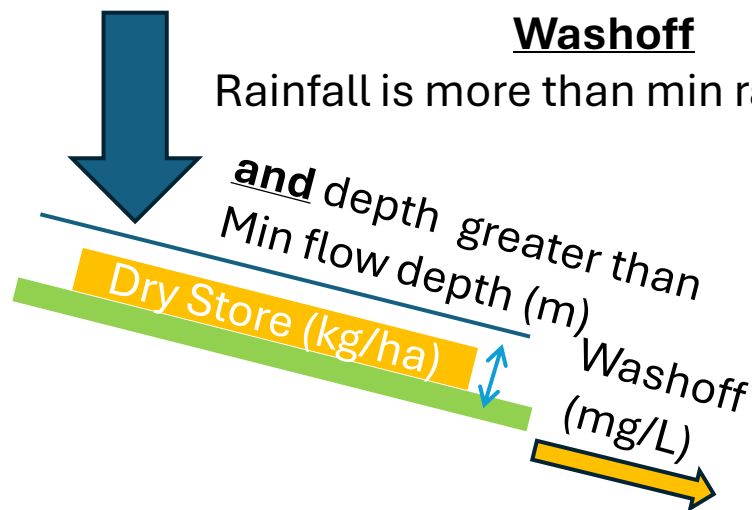


Settle velocity
(m/day)

Dry Store Limit (kg/ha)

Washoff

Rainfall is more than min rate (mm/hr)

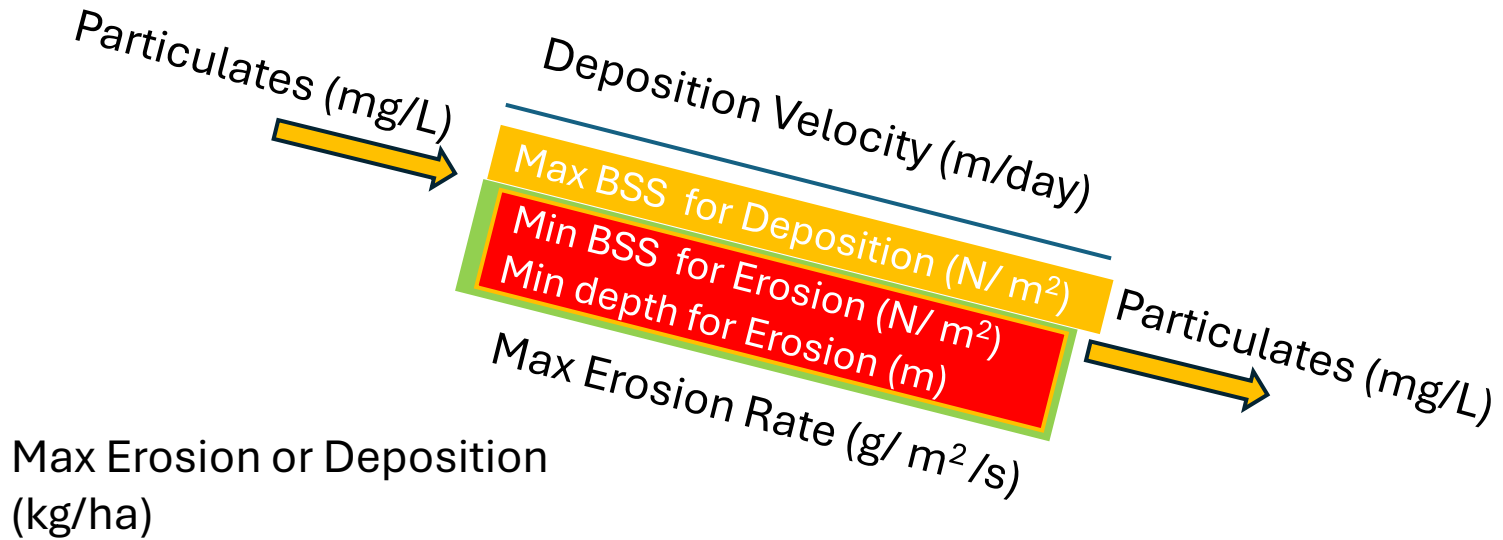


Accumulation and washoff configuration

- Warmup phase to build up dry store
- Activated by rainfall and depth thresholds
- Wash load
- Infiltration allowed

Pollutant	Dry store accumulation rate (kg/ha/yr)	Depth threshold (m)	Rain threshold (mm/hr)	Settling velocity (m/day)
Ammonium	1.5	0.005	5.0	0.0
Nitrate	2.0	0.005	5.0	0.0
Dissolved organic nitrogen	3.5	0.005	5.0	0.0

Bed shear stress



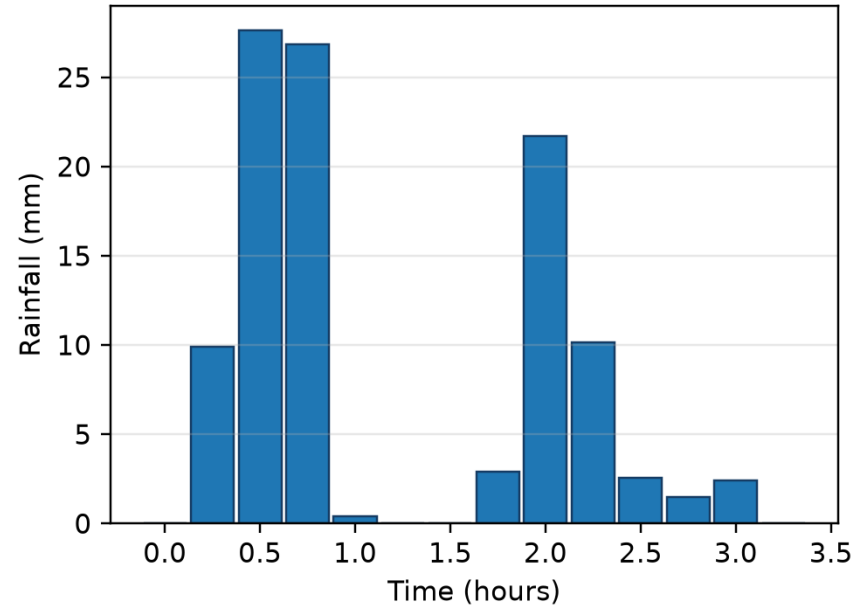
Shear stress, erosion and deposition configuration

- General parameters applied
- Activated by depth and critical shear stress
- Can deposit back into the dry store
- Infiltration switched off

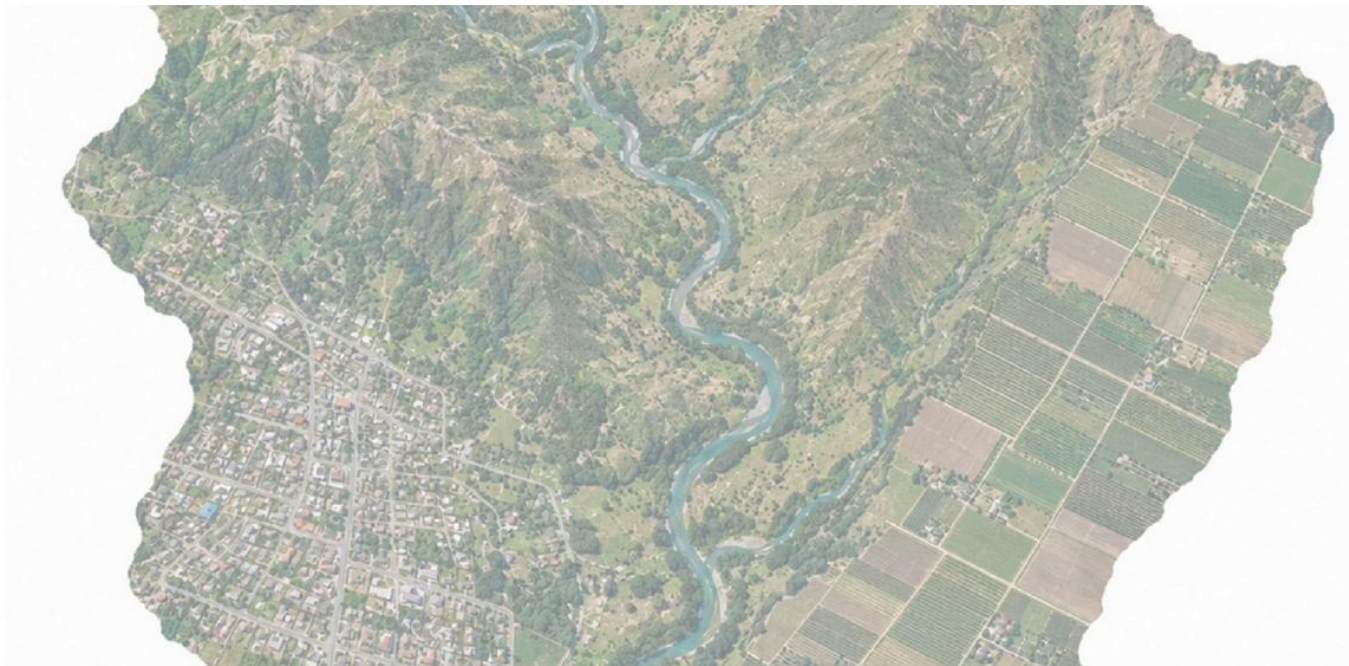
Pollutant	Depth threshold (m)	Critical shear stress erosion (Pa)	Settling Velocity (m/day)	Critical shear stress deposition (Pa)
Particulate organic nitrogen	0.05	0.5	0.1	0.1

Rainfall and soil antecedent conditions

- Spatially constant rainfall
- Example temporal pattern applied
- 20y, 3hr rainfall event (~110mm)
- 12 hour simulation period
- Dry catchment assumed

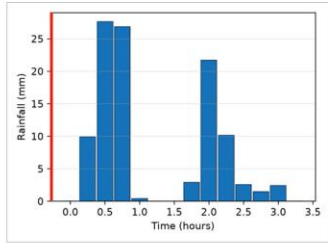
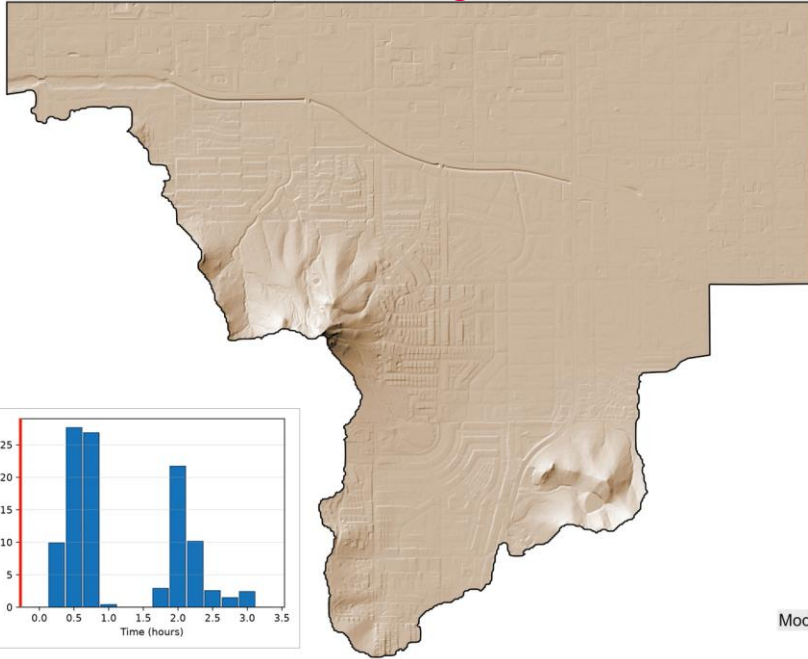


Catchment pollutant modelling results

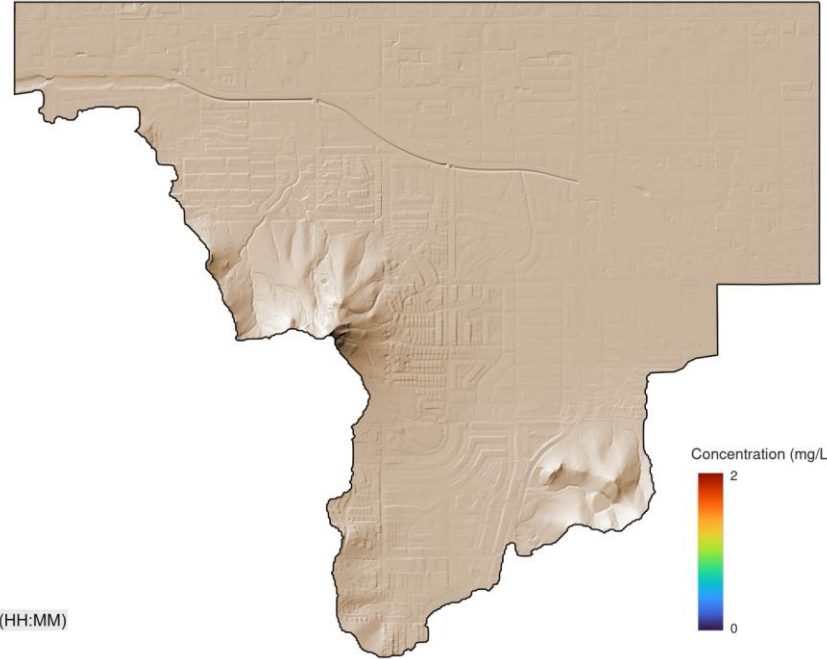


Dissolved nitrogen mobilisation

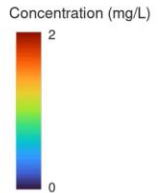
Urban bare ground



Roads

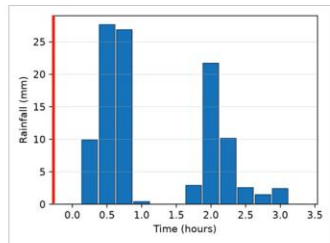
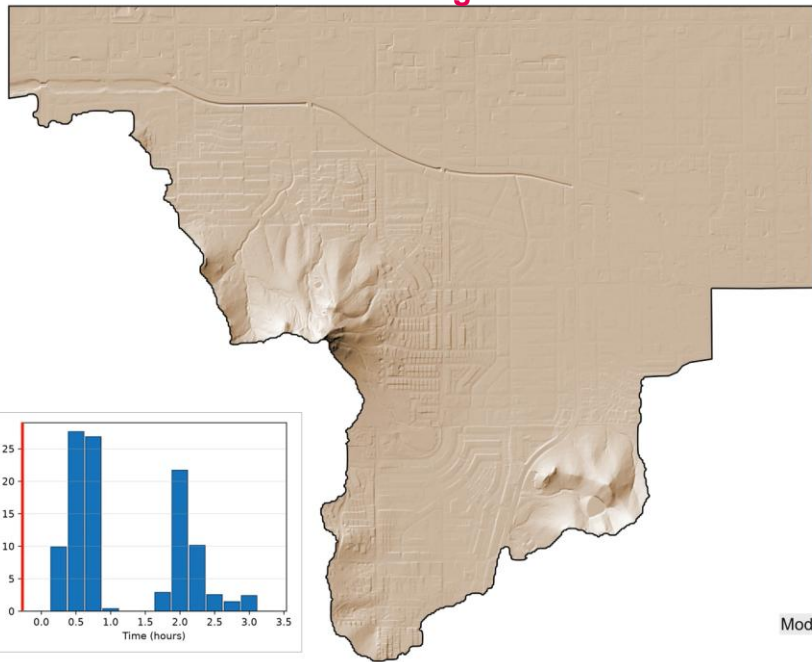


Model time: 00:00 (HH:MM)

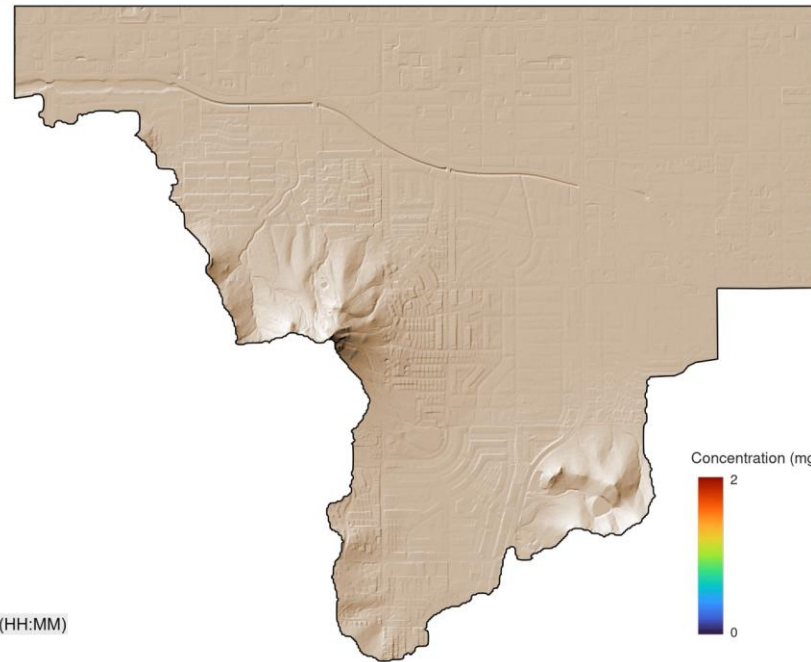


Particulate nitrogen mobilisation

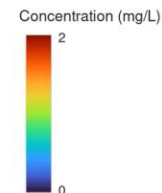
Urban bare ground



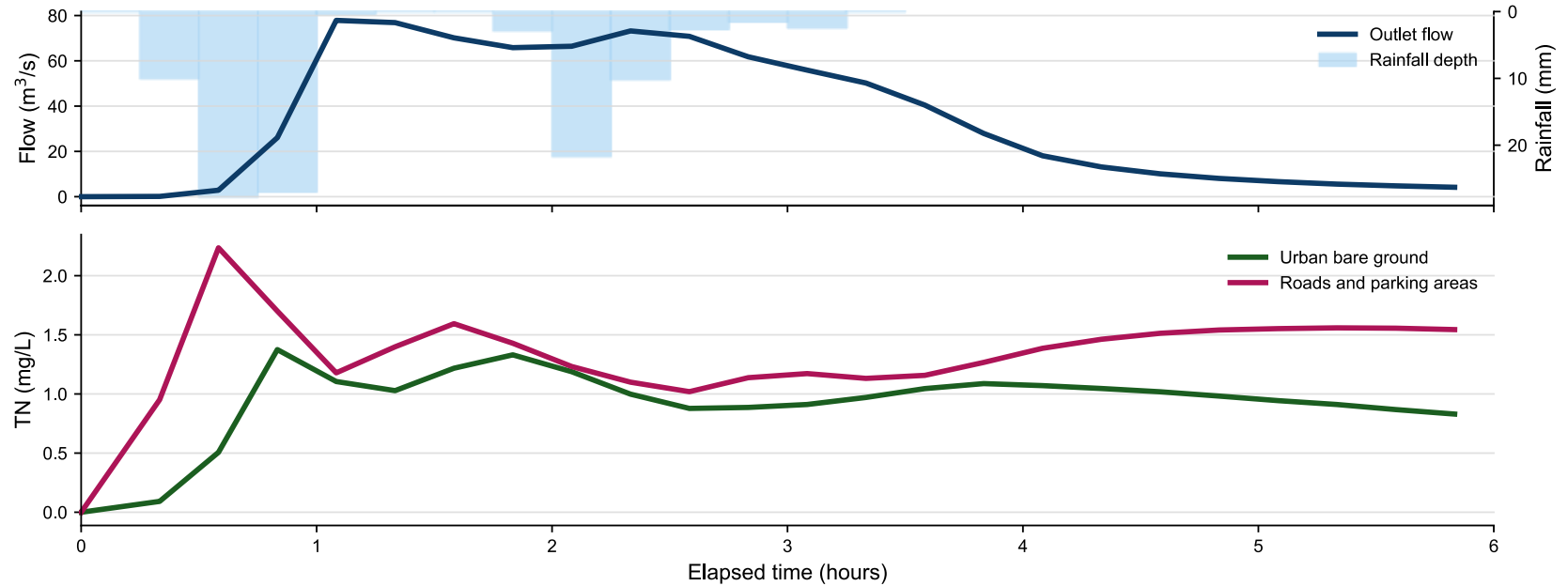
Roads



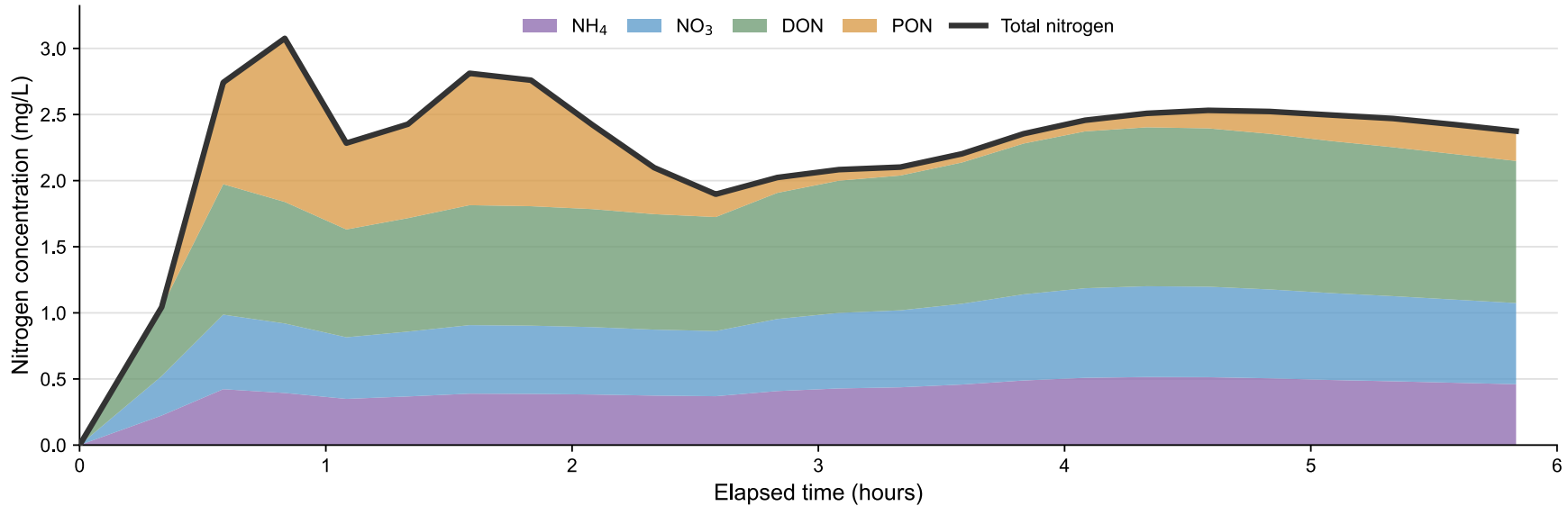
Model time: 00:00 (HH:MM)



Pollutant timing at outlet

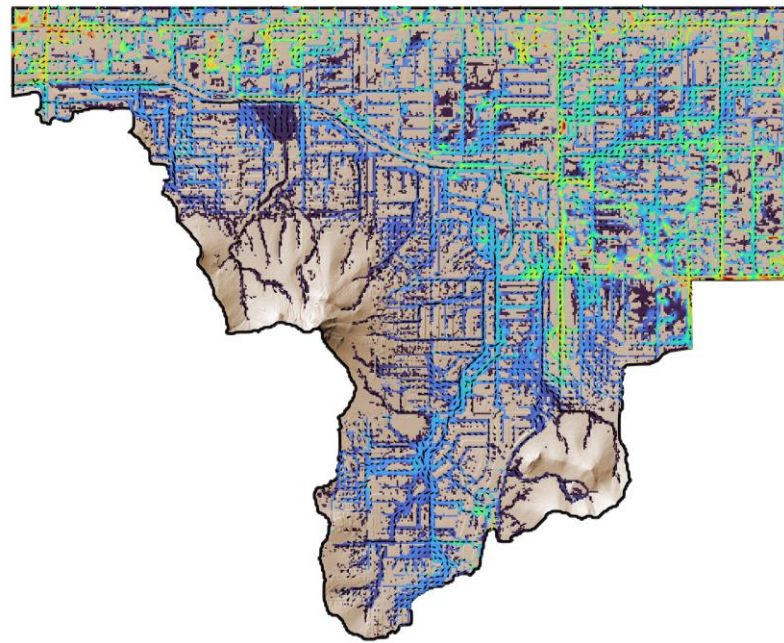


Nitrogen composition at the outlet



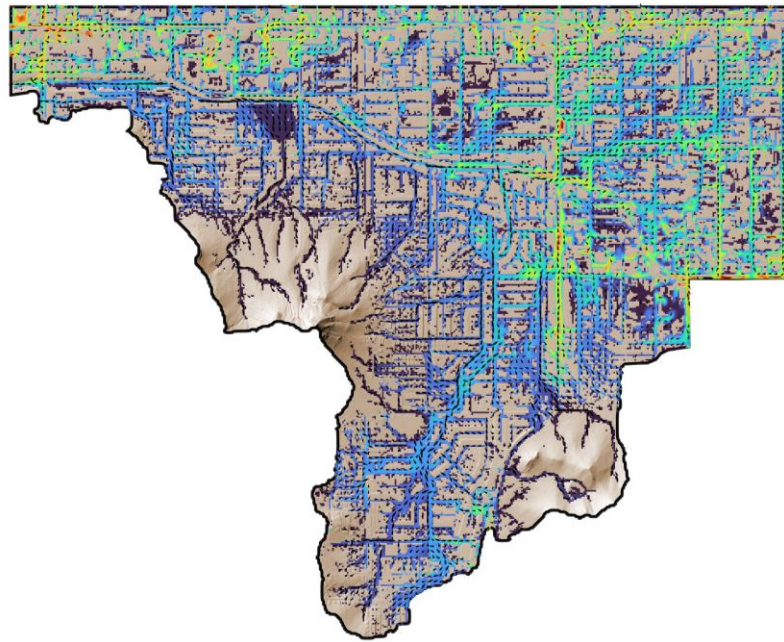
Where this approach adds value

- Concentrations change during the storm in response to hydraulic conditions
- Source areas show different timing at the outlet
- Separate tracers reveal changes in nitrogen composition
- The model represents complex 1D and 2D flowpaths
- Physics-based approach to pollutant mass modelling



Going further

- Receiving water quality modelling
- Pollutant treatment design
- Additional pollutant types
- Extending antecedent and rainfall variability
- Scenario analysis



Maximising value from existing flood models

- Flood models represent substantial investment in data, model development and hydraulic understanding
- Targeted modifications can add pollutant accumulation, mobilisation and transport capabilities
- The modified model can examine pollutant sources, hydraulic pathways and event loads
- Reusing the same model maintains consistency between flood, catchment and water quality investigations

Questions?

