Whole of system simulation of catchment water quality treatment devices

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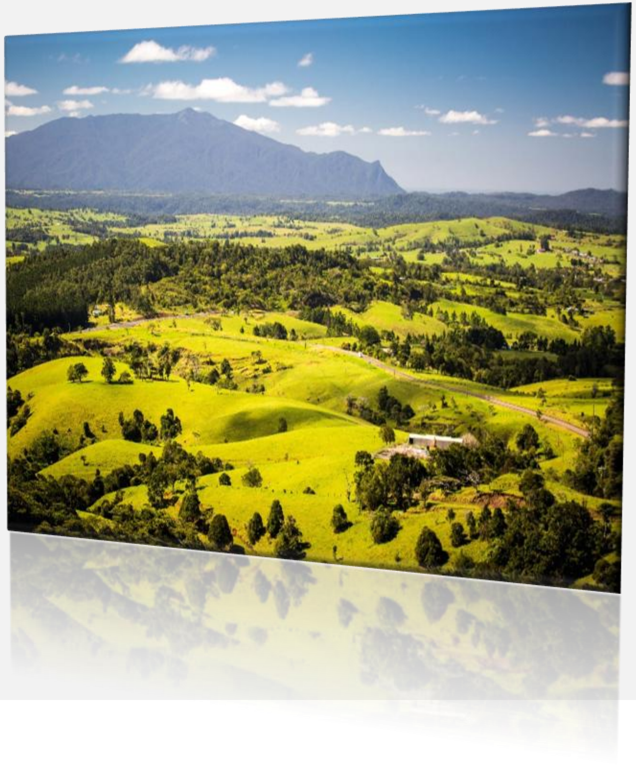
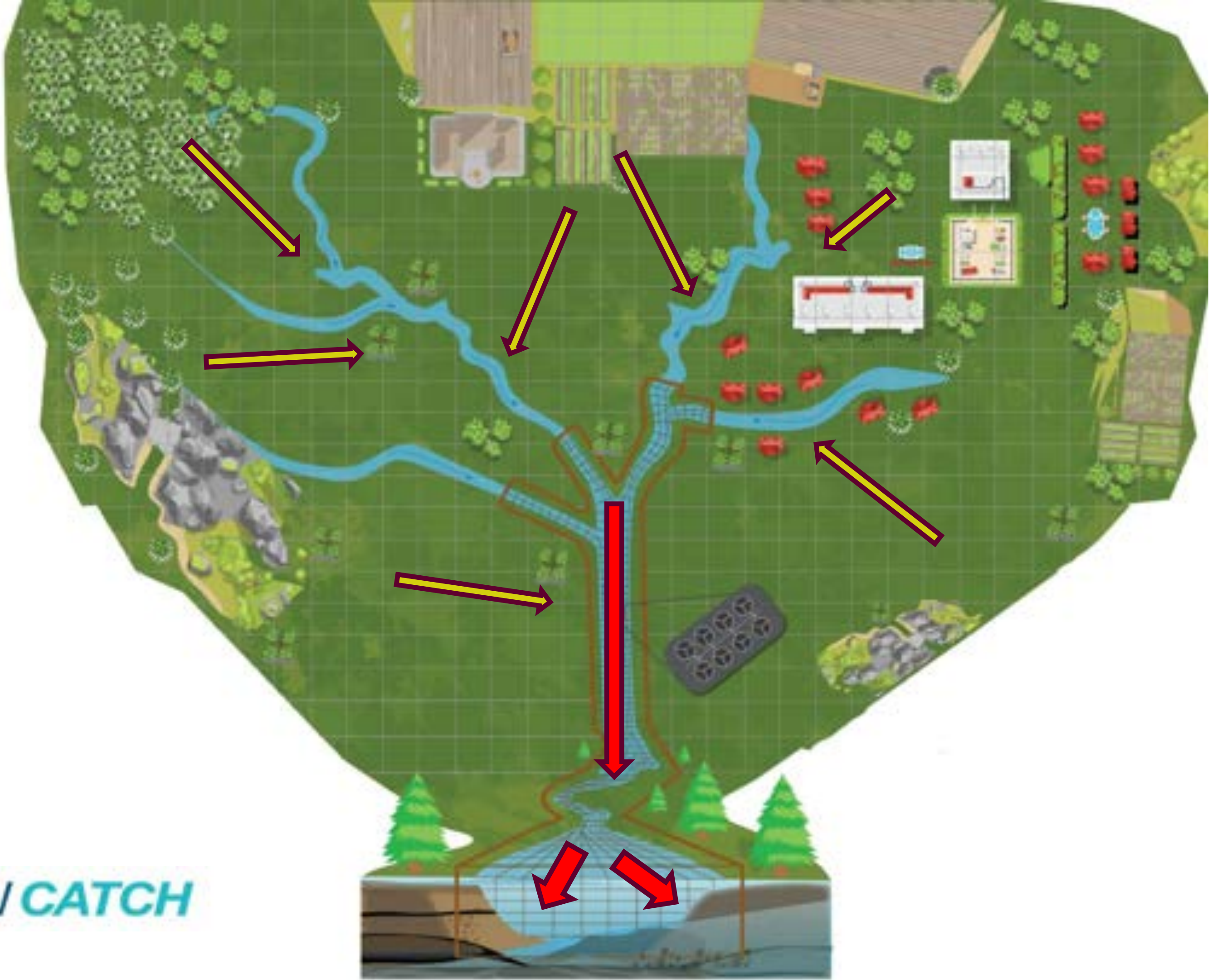
Agenda
Webinar Presentation Overview

- Context
  - Whole of catchment water quality simulation
  - Simulation of pollutant treatment
  - Historical setting and a current challenge
- Explore modern approaches through a real model application
  - Detailed simulation of dynamic pollutant treatment
- Key messages and wrap

Context
Whole of Catchment Water Quality Simulation

- What
  - Simulation of the passage of water and pollutants through a catchment from source to receiving waterway
- Why
  - Understand volume and mass fluxes
  - To mitigate negative impacts of catchment change
- End goal (mostly)
  - Protection of receiving waters





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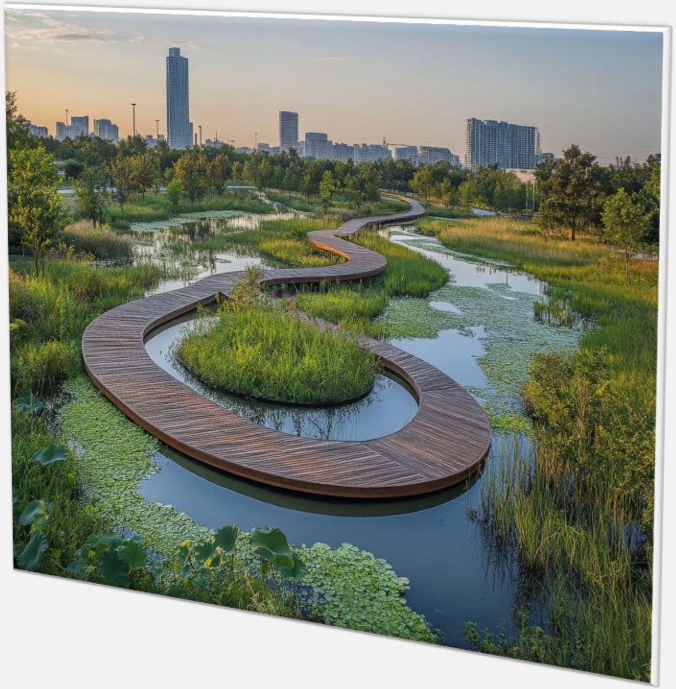
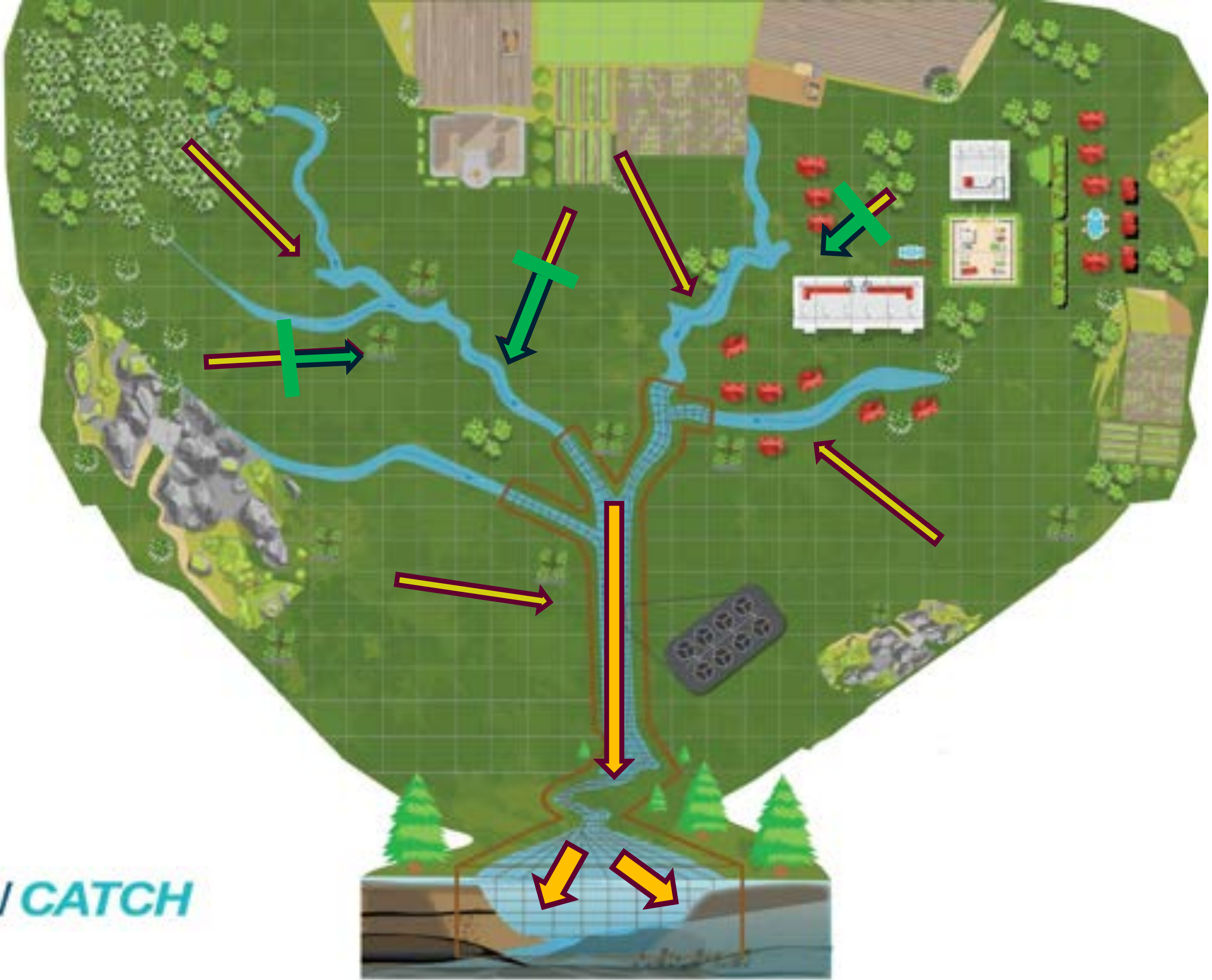
Context
Simulation of Treatment

- What
  - Simulation of the removal of pollutants through a catchment by existing or proposed interventions
    - Wetlands, swales, filter strips, bioretention etc
- Why
  - Optimise treatment catchment-wide – reduction of mass fluxes
- End goal (mostly)
  - Most effective protection / rehabilitation of receiving waters





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Context
Historical Setting – Catchment Water Simulation

- Primary (not sole) typical approach has been
  - Lumped hydrology ‘bucket model’
    - Subcatchment-wide averaging surface and subsurface
    - No explicit simulation of water hydraulics (depth, velocity) or travel pathways within a subcatchment
  - Daily or larger timestep
  - Subcatchments additive with lag to produce downstream volumetric timeseries

Context
Historical Setting – Catchment Pollutant Simulation

- Primary (not sole) typical approach has been
  - Lumped pollutant models
    - ‘End of pipe’ event mean and dry weather concentrations
    - Multiplied at end of pipe with lumped hydrology:
      lumped flow *x* event mean concentration = ???
  - Daily or larger timestep
  - Subcatchments additive with lag to produced downstream mass timeseries

Context

Historical Setting – Catchment Simulation

- Primary (not sole) typical approach benefits
  - Fast
  - Long term relative broadscale land use change simulations
- Primary (not sole) typical approach challenges
  - Loses on-ground connectivity between detail of hydraulics, water flow pathways and treatment intervention
    - Locations – what water flows (with pollutants) where
    - Dynamic performance – how does removal work under differing hydraulics?

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Context
Historical Setting – Catchment Simulation

- A current challenge is:
  - Attending to spatial and temporal detail of hydraulics and treatment
  - Connecting water movement to mass removal processes

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Real World Model Application

Whole of catchment water quality analysis

- Where
  - Norman Creek catchment, Brisbane, Australia
  - 30 km^2 catchment area with ~150m relief
  - Highly modified inner city suburbs
    - Residential
    - Industrial/hospitals/schools
    - Open space and forested

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Whole of catchment water quality analysis

- What (lots of choices!)
  - Sediment generated from roads
    - Motorway
    - Other roads
  - Removal of sediments through treatment
- Why
  - Roads are a major source of receiving waterway pollution
    - Sediment, heavy metals, hydrocarbons

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Whole of catchment water quality analysis

- How
  - TUFLOW CATCH
  - Integrated catchment and receiving model
  - Explicit and linked simulation of 2D
    - Catchment surface and subsurface hydraulics
    - Receiving hydrodynamics
    - Pollutant generation, transport and treatment
  - No average or lumping assumptions

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Real World Model Application

Whole of catchment water quality analysis

- Catchment model geometry (focus today)
  - 5m grid size – scale of spatial resolution
  - 2 soil layers
- Hydraulic data – all freely available
  - Digital elevation model
  - Gridded rainfall and evapotranspiration
  - Land use / cadastre / imperviousness
  - Key pipe networks

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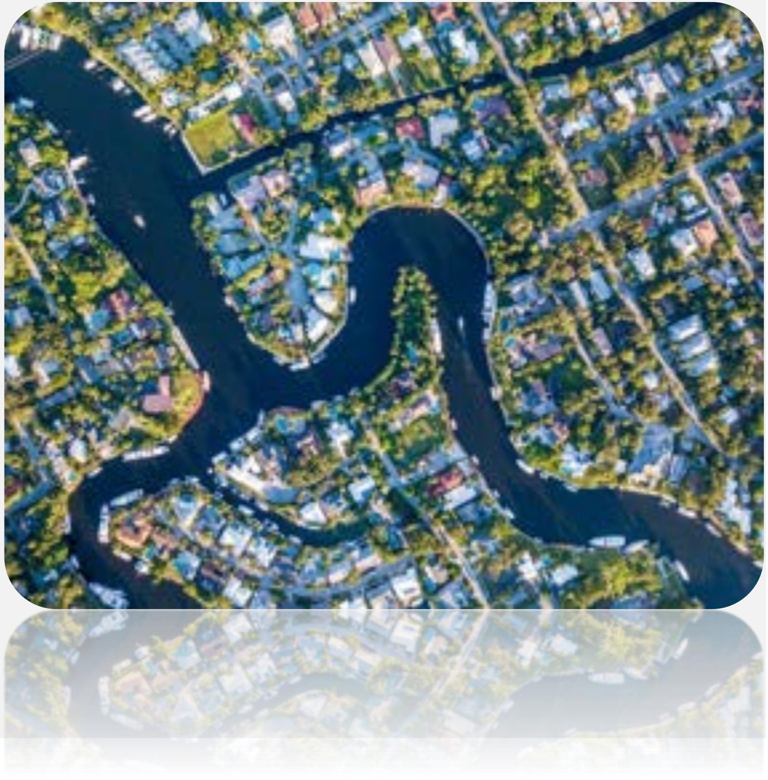
Real World Model Application

Whole of catchment water quality analysis

- Catchment model geometry (focus today)
  - 5m grid size – scale of spatial resolution
  - 2 soil layers
- Sediment data – experimental
  - Measured liberation rates
  - Different road types
  - Not averaged downstream concentrations



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Real World Model Application

Whole of catchment water quality analysis

- Sediment generation and transport in TUFLOW CATCH
  - One sediment fraction for Motorway and one for all other roads
  - Track sediment release, transport and treatment from both sources independently
    - Hydraulics and pollutant export explicitly simulated

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Real World Model Application

Whole of catchment water quality

- Sediment generation and transport in TUFLOW CATCH
  - Simulated one event for demonstration purposes
  - Multi-annual simulations for project applications
  - Added 3 new hypothetical treatment devices (wetlands)
  - Did not account for hydraulic throttling – but easily added

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Real World Model Application

Whole of catchment water quality

- Sediment removal in TUFLOW CATCH
  - 2D flow-concentration lookup table
  - Tracked pollutants from Motorway and other roads separately
  - Assess pollutant delivery to the creek
  - All wetlands were given the same lookup table

Pollutant Removal %		Concentration (mg/L)							
		1	10	20	30	40	50	60	80
Flow Rate (m^3/s)	0.1	50	55	60	65	70	75	80	90
	1	50	55	65	65	70	75	80	90
	2	40	45	55	55	60	65	70	80
	3	30	35	45	45	50	55	60	70
	4	20	25	35	35	40	45	50	60
	5	10	20	25	25	30	35	40	50
	10	0	5	10	20	25	30	35	40

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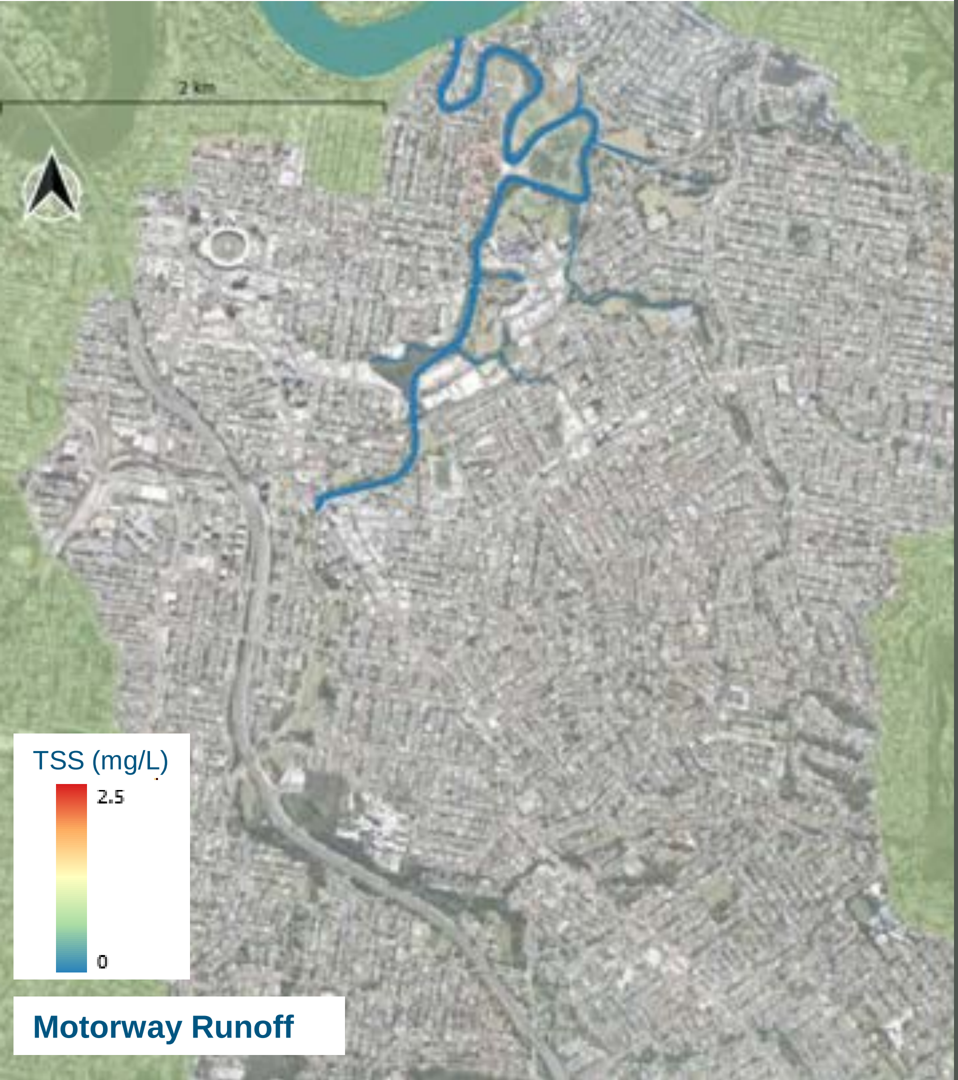
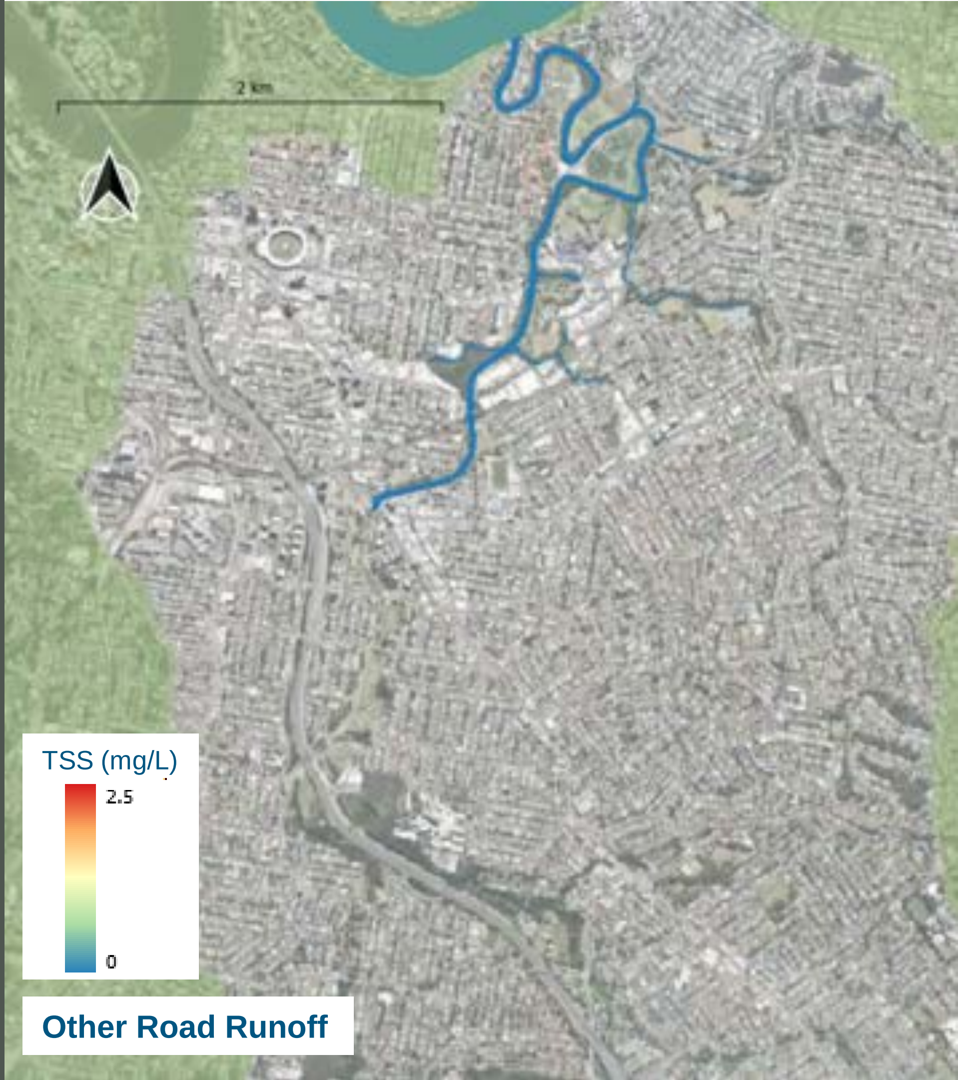
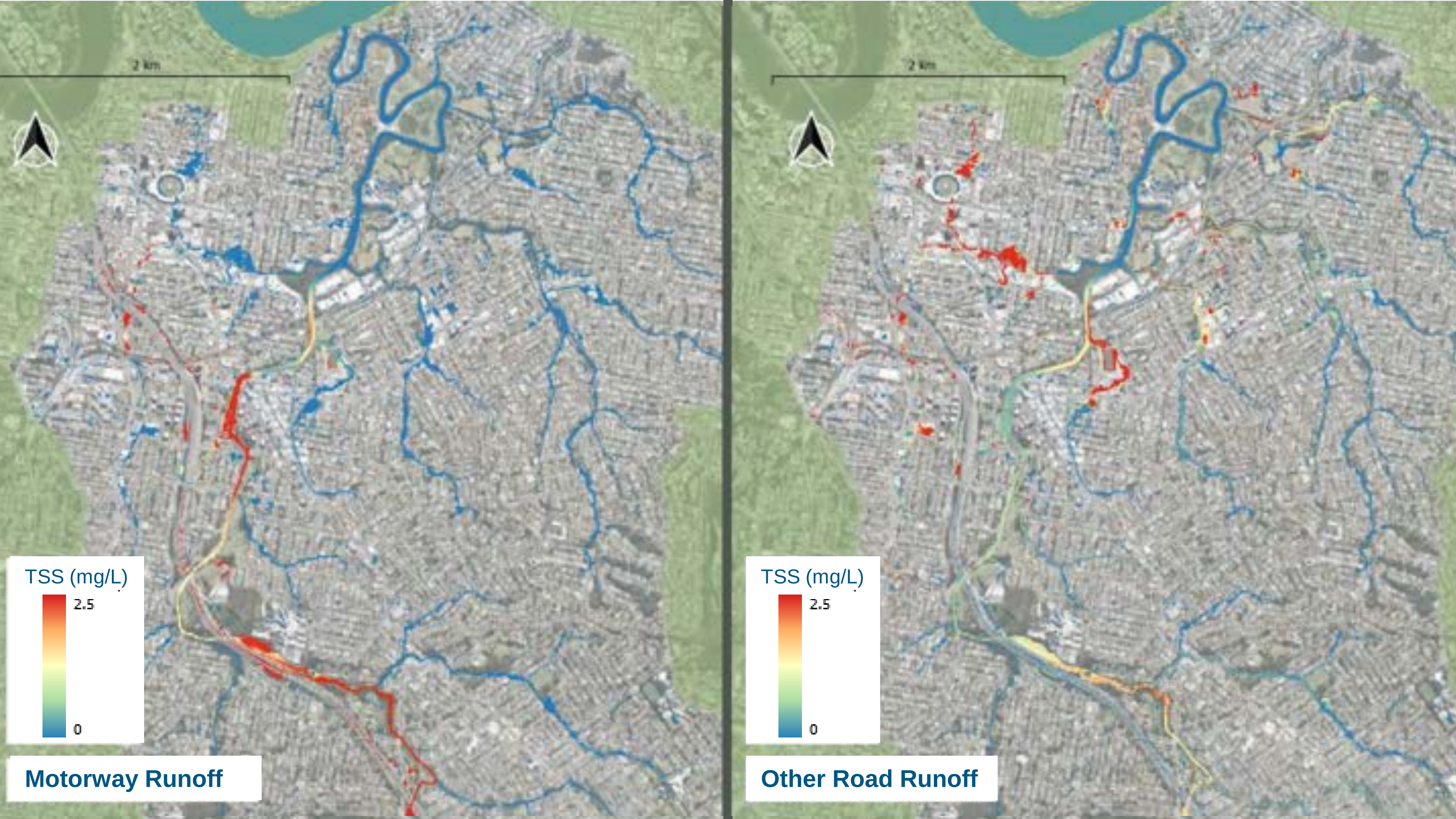
Whole of catchment water quality analysis

- The next slide presents animations of pollutants generated from:
  - Left panel: Motorway runoff only
  - Right panel: All other roads runoff only
- Note
  - Very different pollutant distributions between motorway and other roads
    - They need to be explicitly resolved, and not lumped
  - Seamless connectivity from source to Brisbane River


2 km
TSS (mg/L)
2.5
0
Motorway Runoff


2 km
TSS (mg/L)
2.5
0
Other Road Runoff


2 km
TSS (mg/L)
2.5
0
Motorway Runoff
2 km
TSS (mg/L)
2.5
0
Other Road Runoff

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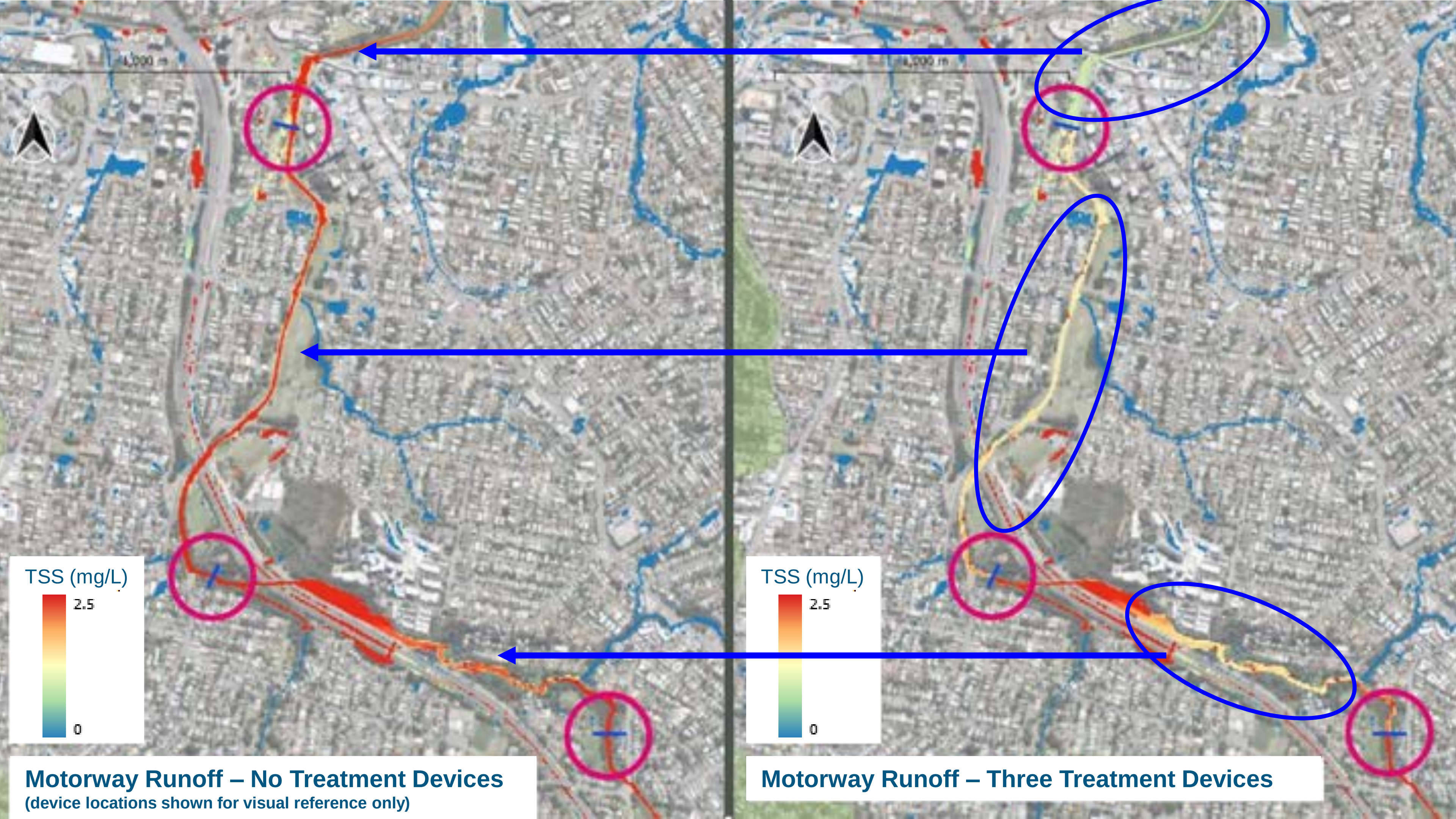
Real World Model Application

Whole of catchment water quality analysis

- The next slide presents animations of pollutants generated from:
  - Motorway only:
    - Left panel: Untreated (device locations shown only as points of reference)
    - Right panel: Treatment interventions in place (devices are at locations shown)
- Note:
  - Initially similar concentrations (hydraulic conditions not conducive to removal)
  - Later lower concentrations on the right panel (hydraulic conditions conducive to removal)


TSS (mg/L)
2.5
0
Motorway Runoff – No Treatment Devices
(device locations shown for visual reference only)


TSS (mg/L)
2.5
0
Motorway Runoff – Three Treatment Devices


TSS (mg/L)
2.5
0
Motorway Runoff – No Treatment Devices
(device locations shown for visual reference only)
TSS (mg/L)
2.5
0
Motorway Runoff – Three Treatment Devices

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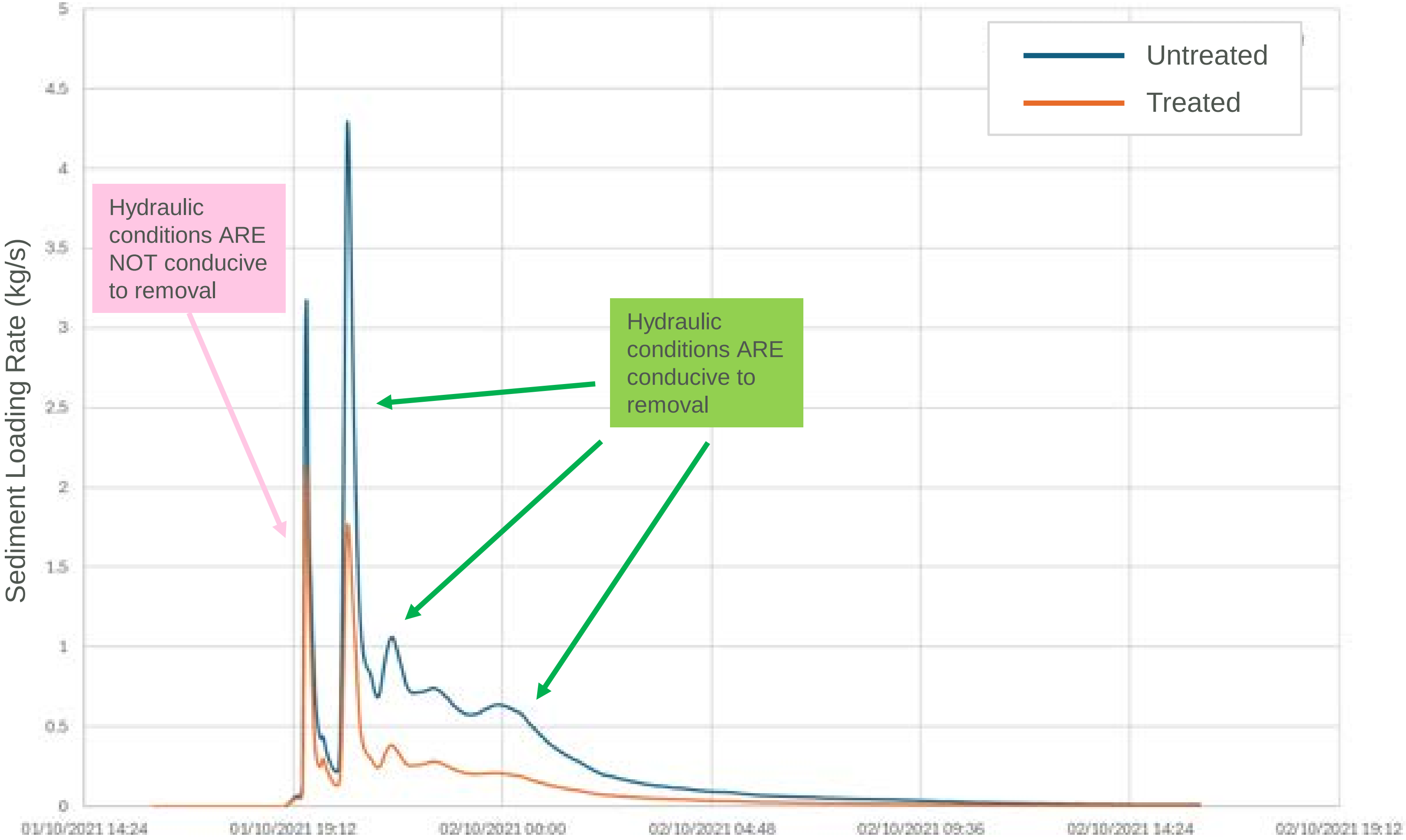
Real World Model Application

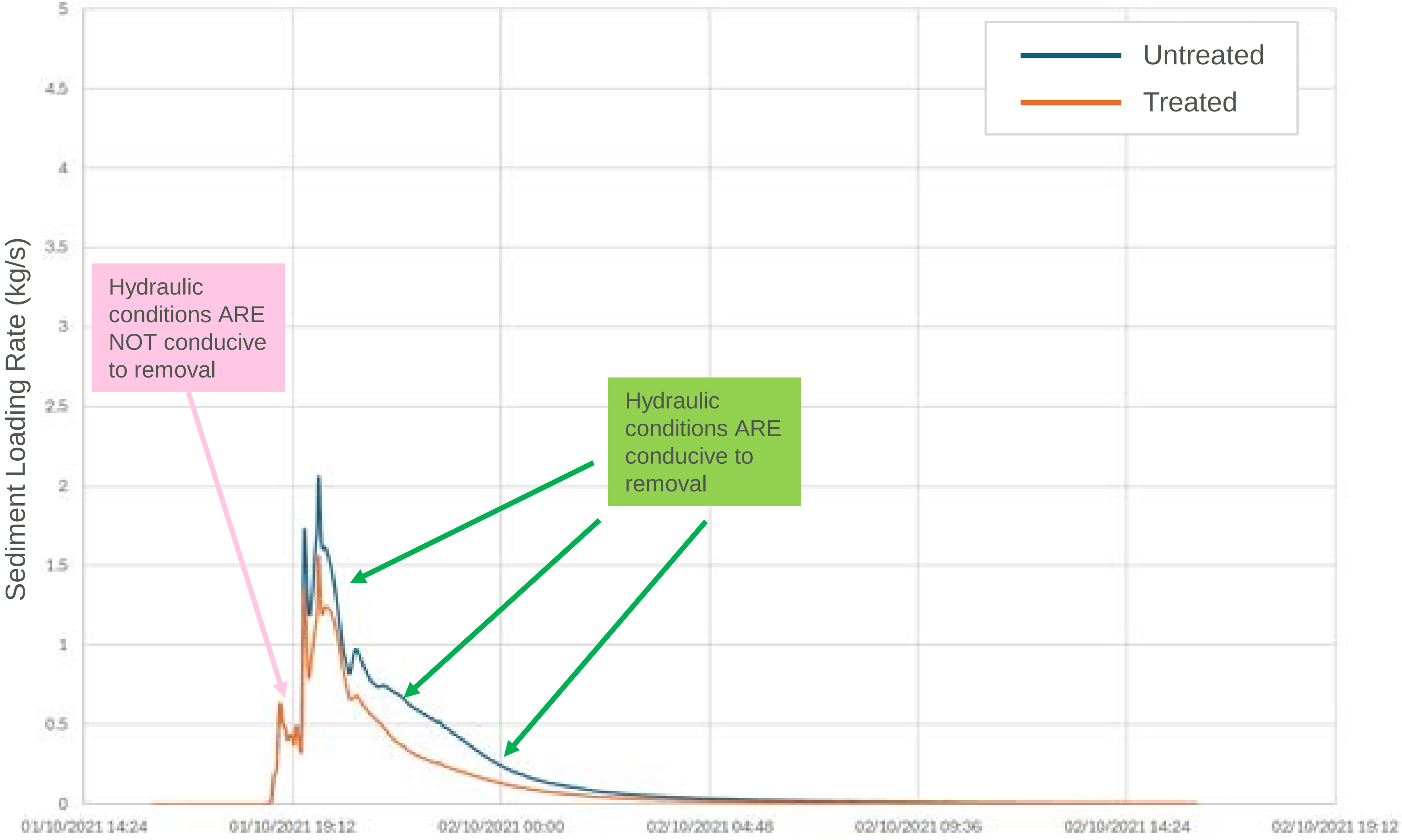
Whole of catchment water quality analysis

- The next slides are timeseries graphs reporting loading rates (kg/s) to Norman Creek
  - Graph 1: Motorway only
  - Graph 2: Other roads
  - In both graphs:
    - Blue line = untreated simulation result
    - Orange line = treated simulation result
- Note differences in removal due to hydraulic conditions

Motorway – Sediment Delivery to Norman Creek



Other Roads – Sediment Delivery to Norman Creek



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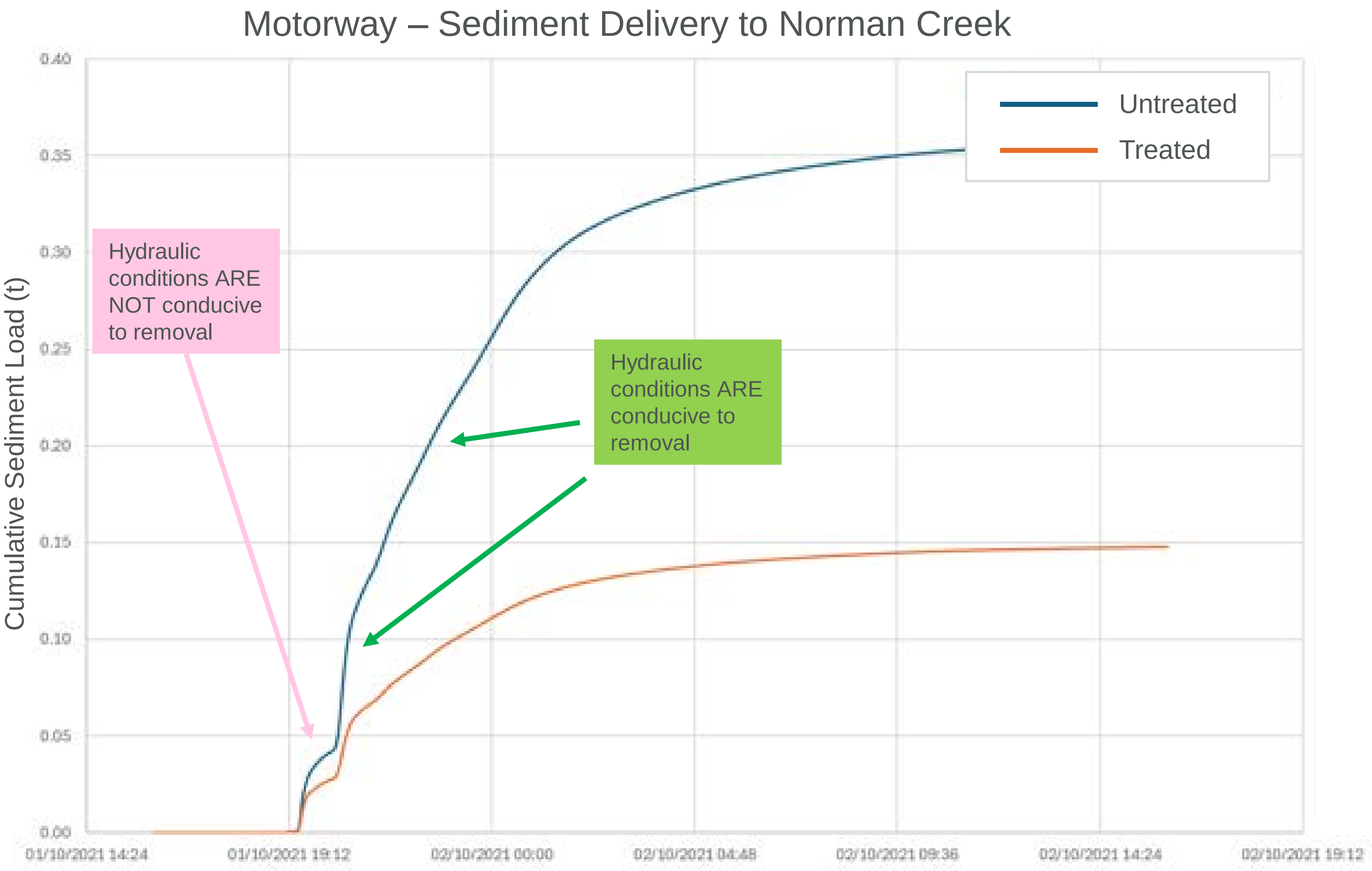
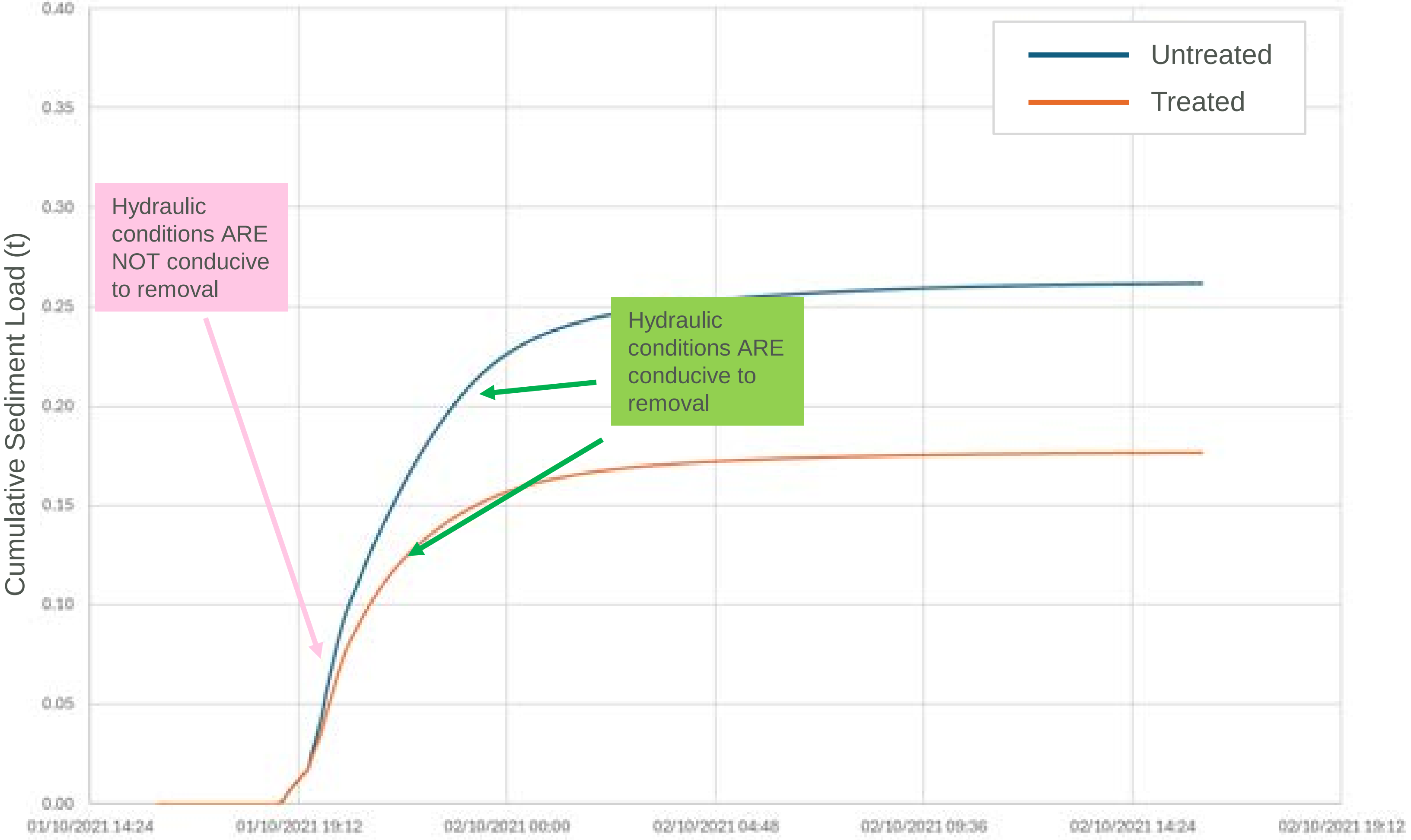
Real World Model Application

Whole of catchment water quality analysis

- The next slides are timeseries of cumulative sediment loads (t) to Norman Creek
  - Graph 1: Motorway only
  - Graph 2: Other roads
  - In both graphs:
    - Blue line = untreated simulation result
    - Orange line = treated simulation result
- Note differences in removal due to hydraulic conditions


Motorway – Sediment Delivery to Norman Creek
Cumulative Sediment Load (t)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
01/10/2021 14:24
01/10/2021 19:12
02/10/2021 00:00
02/10/2021 04:48
02/10/2021 09:36
02/10/2021 14:24
02/10/2021 19:12
Untreated
Treated
Hydraulic conditions ARE NOT conducive to removal
Hydraulic conditions ARE conducive to removal

Other Roads – Sediment Delivery to Norman Creek



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Real World Model Application

Whole of catchment water quality analysis

- Individual wetland performances, for different road sources

Road Scenario	Assessment Result		Wetland 1	Wetland 2	Wetland 3
Motorway	Cumulative Sediment Load (t)	Entering	0.19	0.26	0.21
		Leaving	0.07	0.09	0.03
	Treatment Efficiency (%)		63	65	86
Other Roads	Cumulative Sediment Load (t)	Entering	0.08	0.10	0.09
		Leaving	0.02	0.03	0.03
	Treatment Efficiency (%)		75	70	67

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Whole of catchment water quality analysis

- Sediment loads from the motorway are double those of other roads, and travel along different pathways
  - Provides clear planning focus for treatment
- Different wetlands have different removal efficiencies due to different hydraulic regimes
  - Only able to discern due to explicit spatial and temporal resolution of hydraulics and pollutant export
  - Lumping masks this vital information

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Wrap up

Whole of catchment water quality analysis

- Explicit spatial and temporal resolution of hydraulics and pollutant generation is critical for meaningful design and assessment of intervention measures
- Lumping can mask important variations and therefore understanding
- Use appropriate modelling tools to answer the questions being asked
  - Long term broad scale vs short term fine scale
  - Do not use broadscale tools to address fine scale questions
  - Fine scale tools might not suit very long term simulations
- Download TUFLOW CATCH and run our new tutorial for free to see for yourself!

Questions?