CRC Water Sensitive Cities

Project B2.23 – Restoring urban freshwater ecosystems:

Informing management and planning

Project Update – June 2016

Project Leader: Peter Davies & Mike Grace

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Government of Western Australia Department of Water

There are two discrete project within B2.23:

Project a) is led by Mike Grace and based out of Monash University in Melbourne looking into Nitrogen transformation processes in wetlands.

Project b) is led by Peter Davies based out of UWA in Albany developing an urban river restoration decision support tool.

Both projects finish December 2016

Using stable isotopes to unravel nitrogen processing in wetlands

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MONASH University

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[1] Water Studies Centre, Monash University, Australia
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Constructed Wetlands

- Treat stormwater nitrogen loads
- Management of vegetation and sediment
- Monitoring – water quality

Denitrification

Assimilation

Constructed Wetlands

- Transformation will result in the enrichment of $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- in the residual pool

Denitrification $\delta^{15}N$ ~2‰

Assimilation $\delta^{15}N$ ~5-15‰

(Michener and Lajtha 2007, Kendell et al 2007)

Study Sites

Cascades on Clyde, Melbourne

Kelletts Drain, Melbourne

Anvil Way Compensation Basin, Perth

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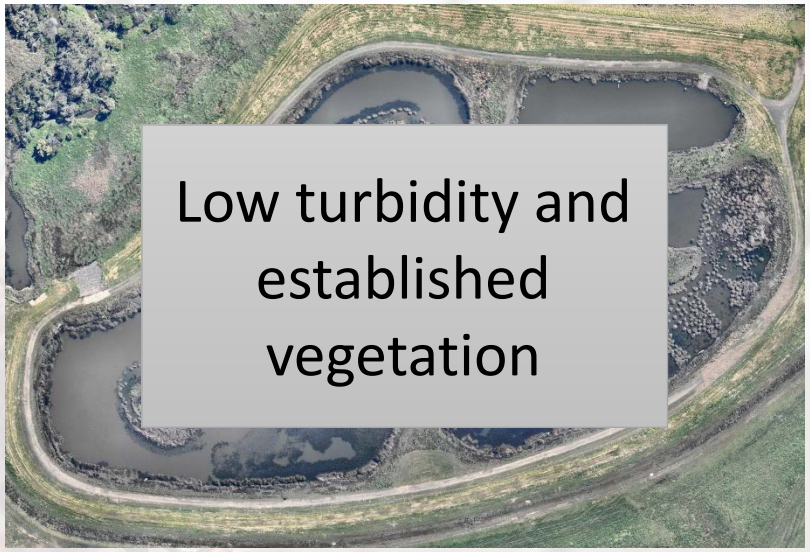
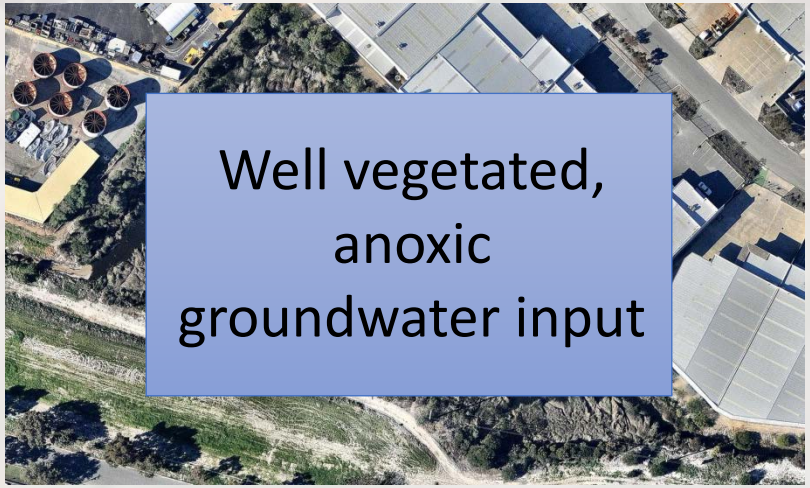
Cascades on Clyde, Melbourne

Kelletts Drain, Melbourne

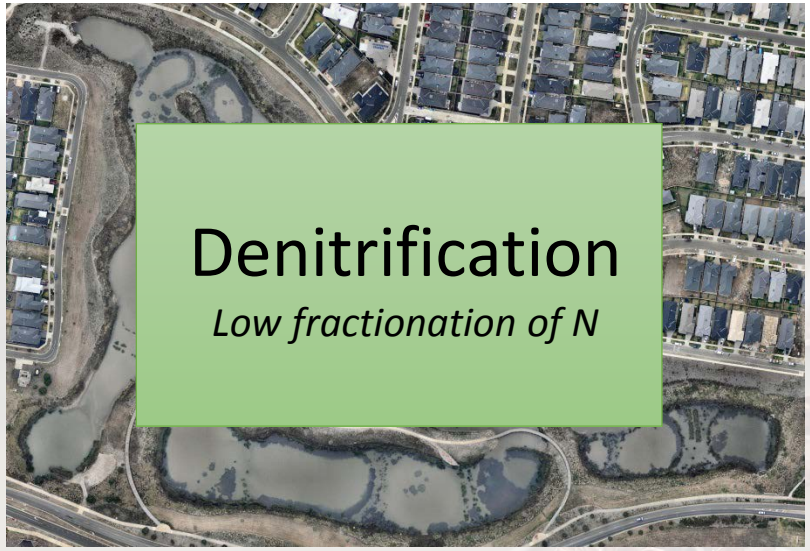


Anvil Way Compensation Basin, Perth



Hypotheses

Cascades on Clyde, Melbourne



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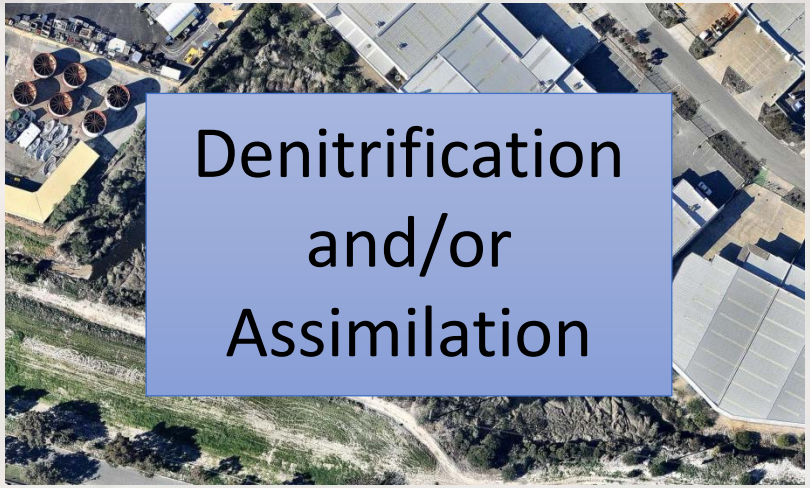
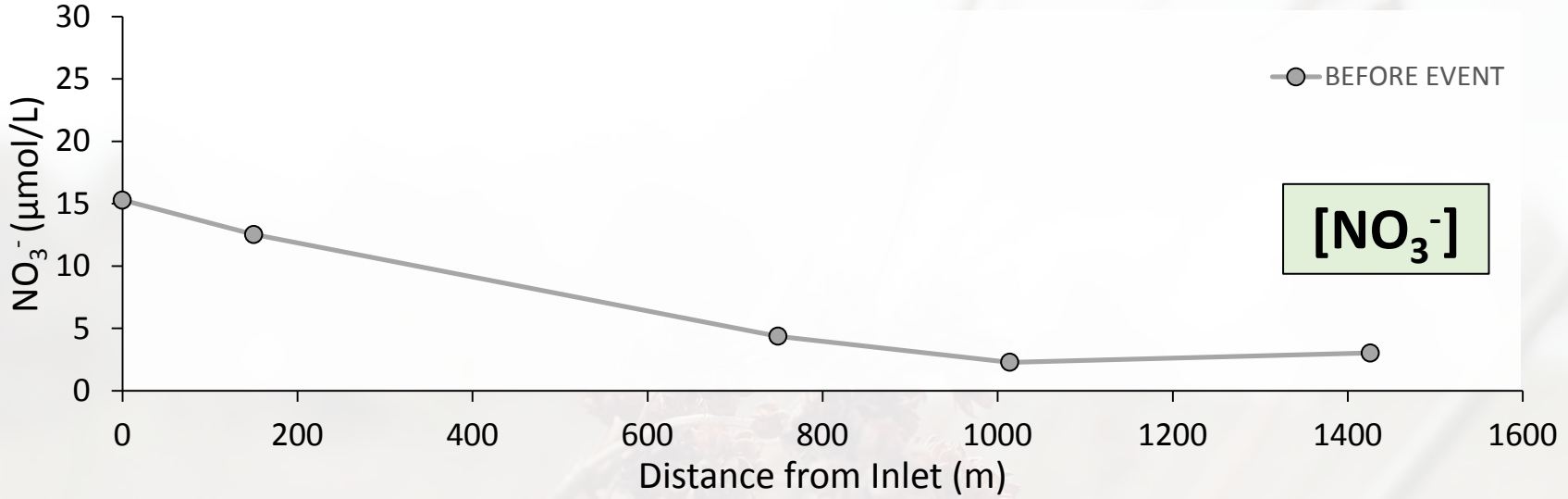
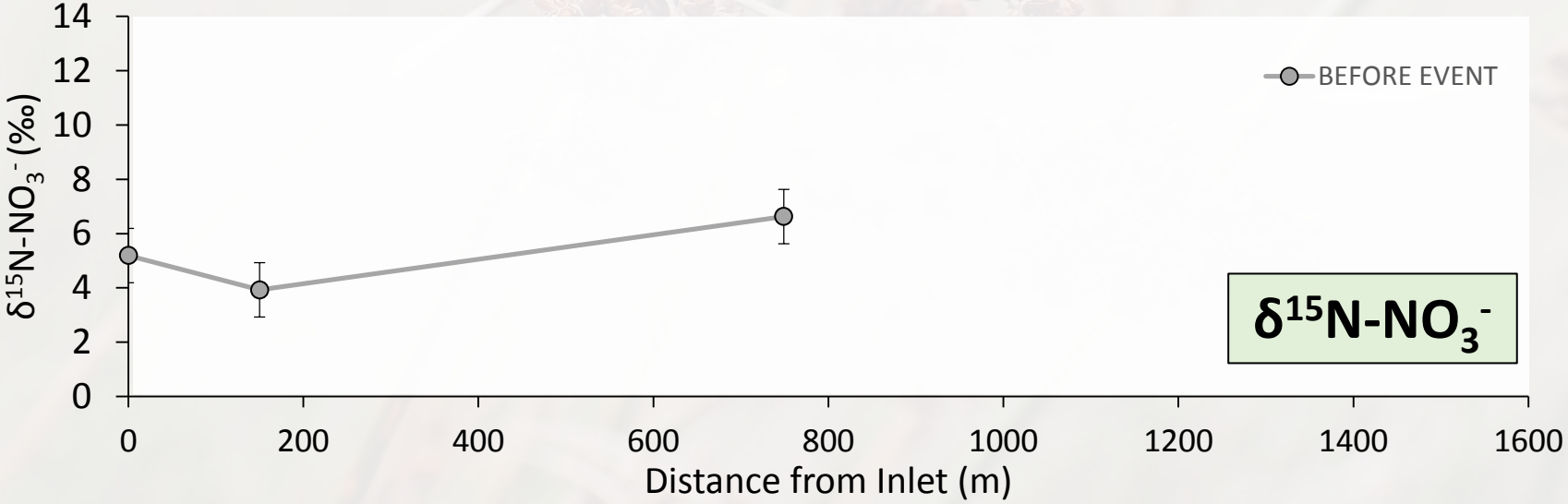
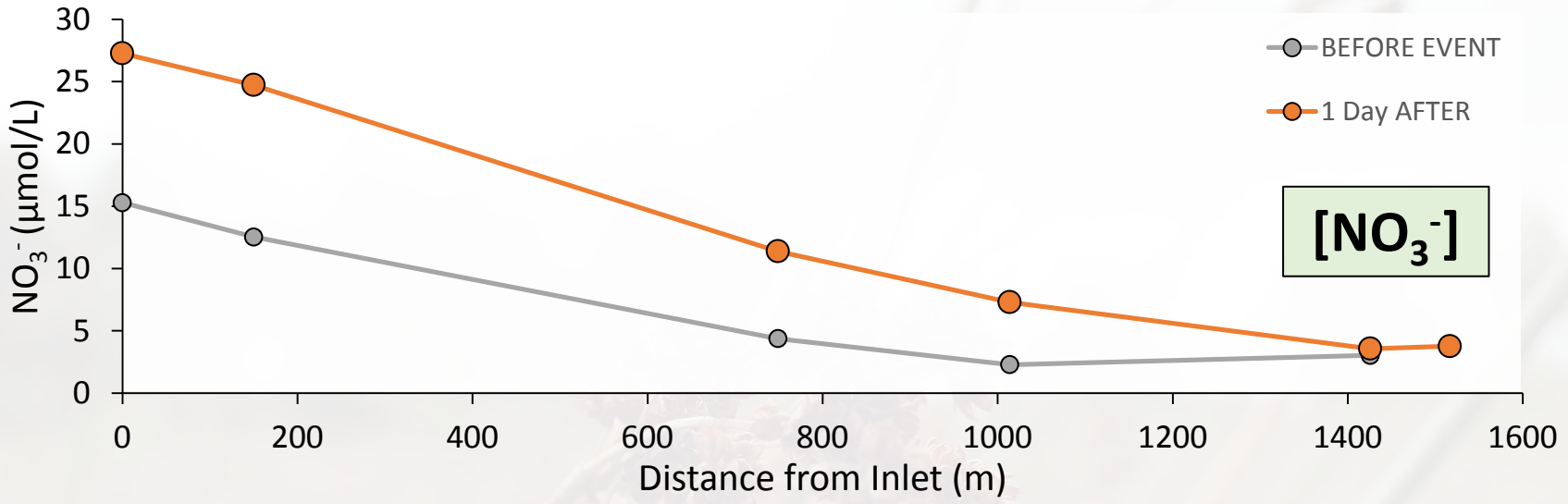


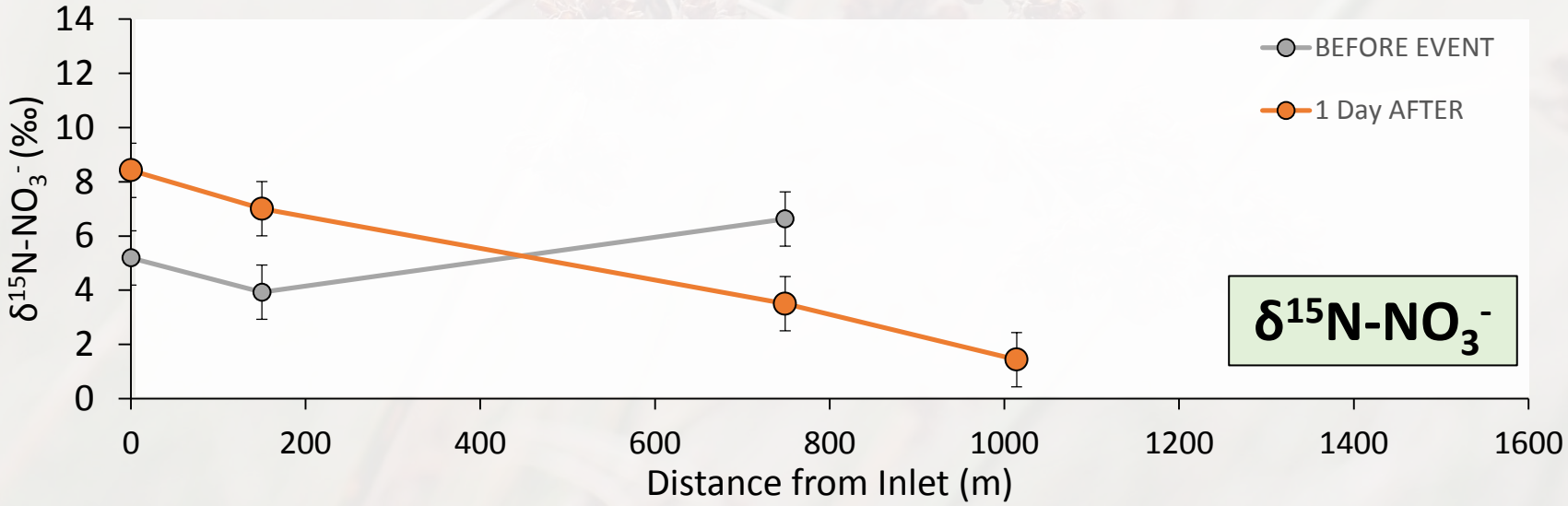
Cascades on Clyde



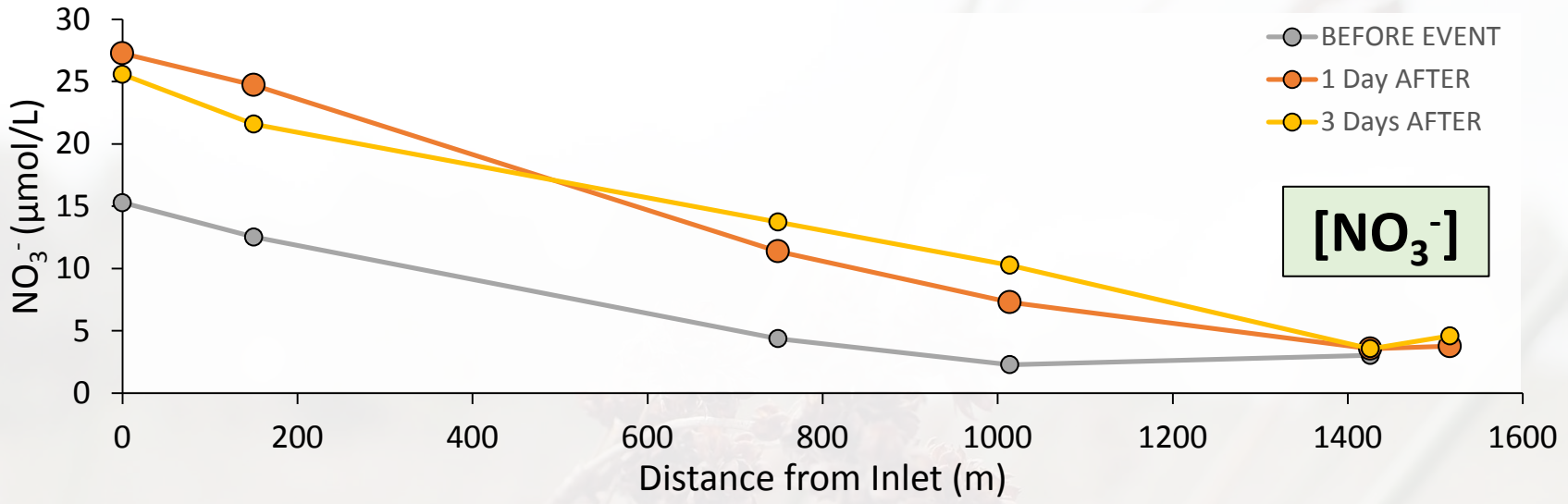


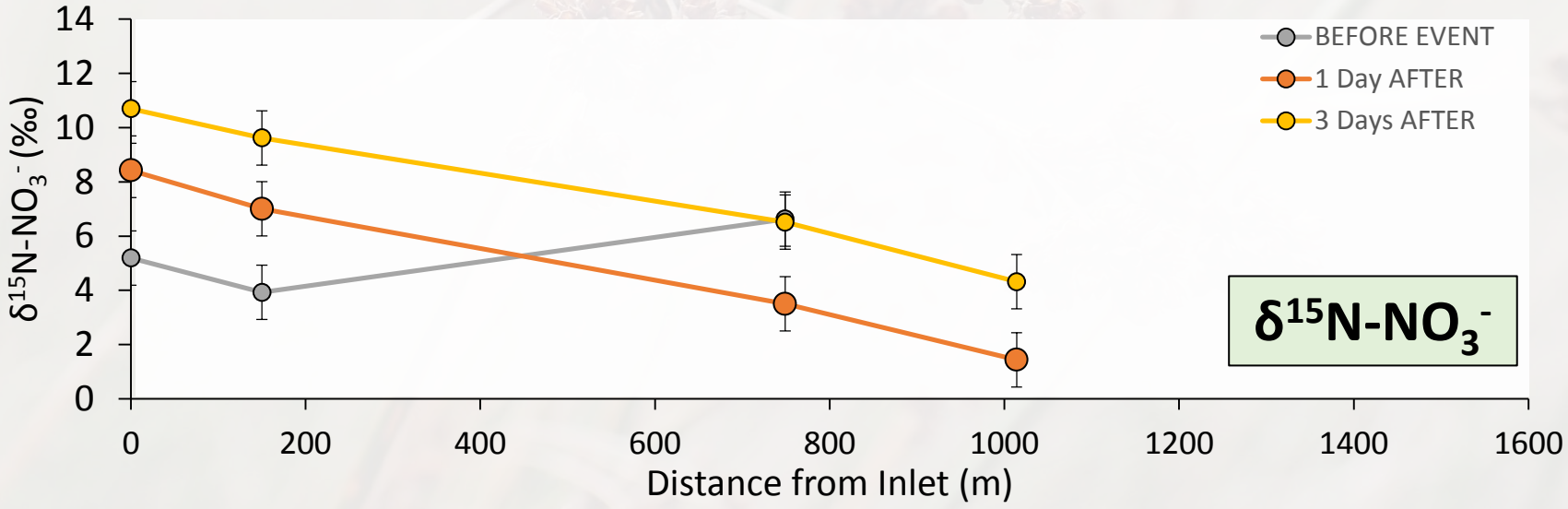
Cascades on Clyde





Cascades on Clyde

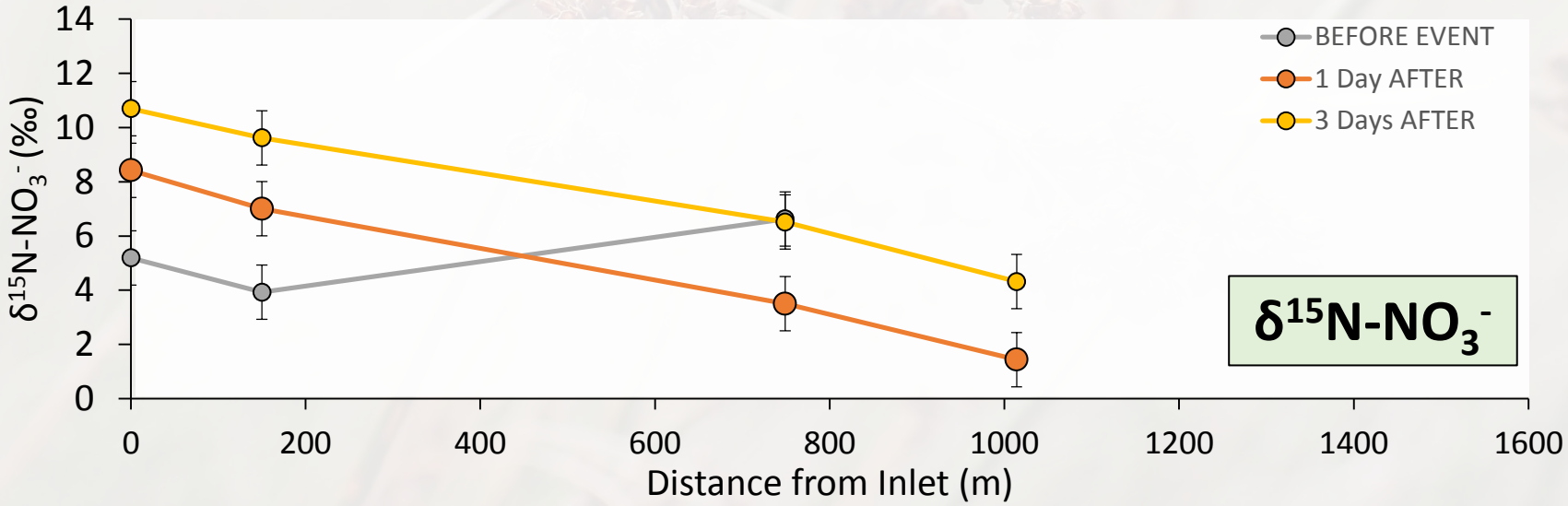




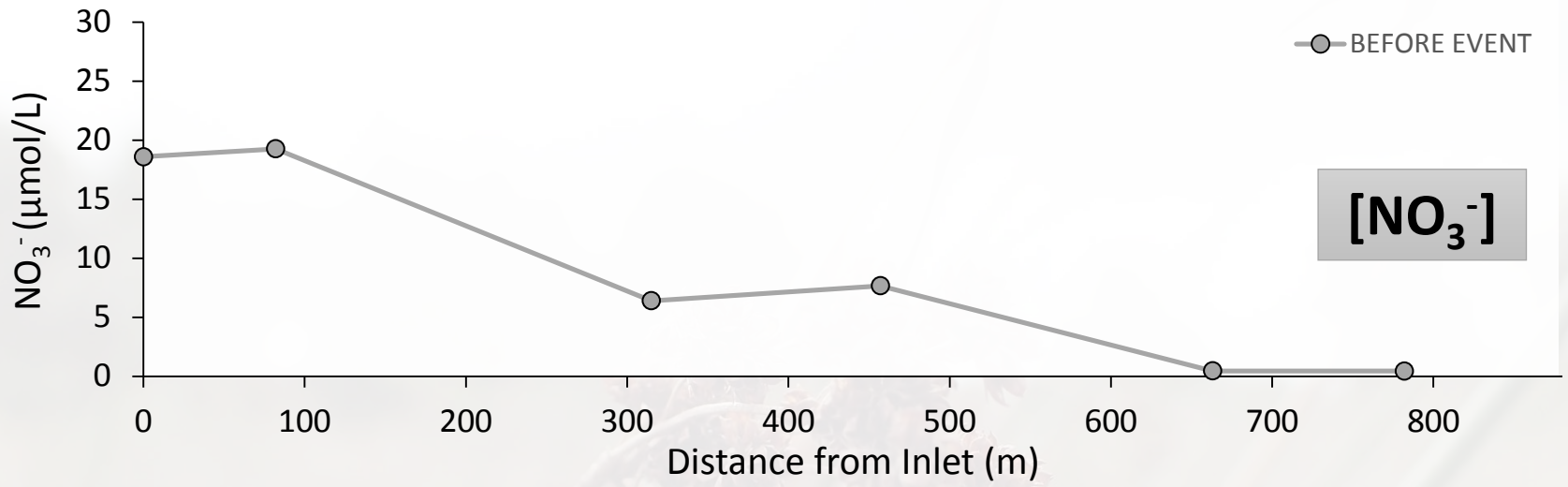
Cascades on Clyde

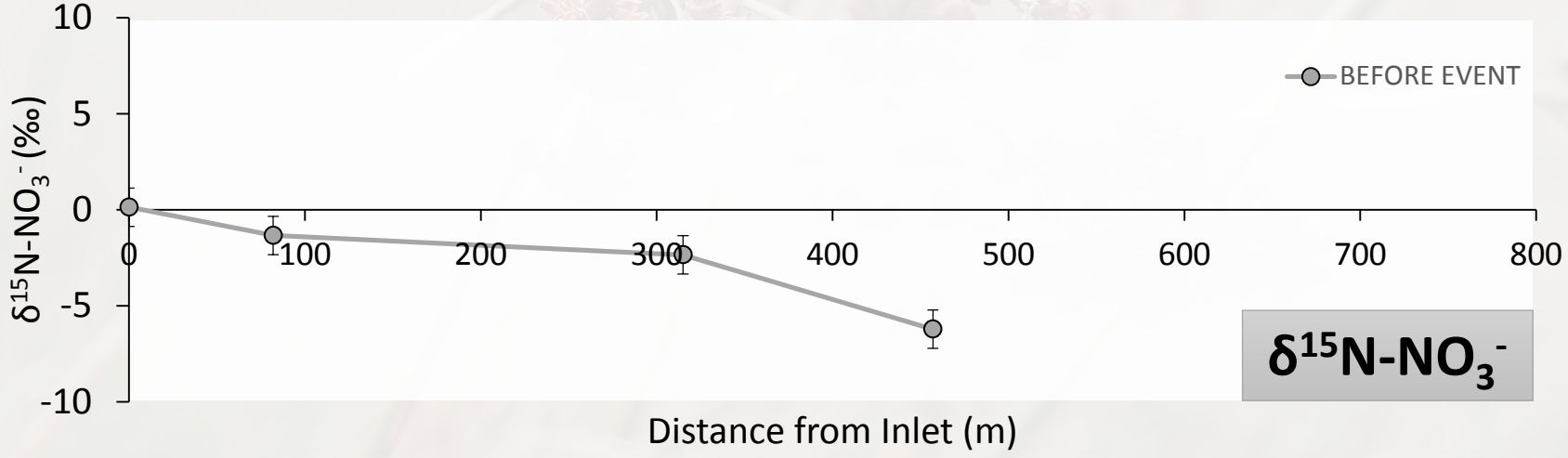
- **Nitrification** of ammonium is producing lighter NO_3^- decreasing the $\delta^{15}N\text{-}NO_3^-$ in the 'residual' pool

- Moving toward the outlet NO_3^- becomes more limited promoting **N_2 fixation** introducing lighter $\delta^{15}N$ into the system



Kelletts Drain





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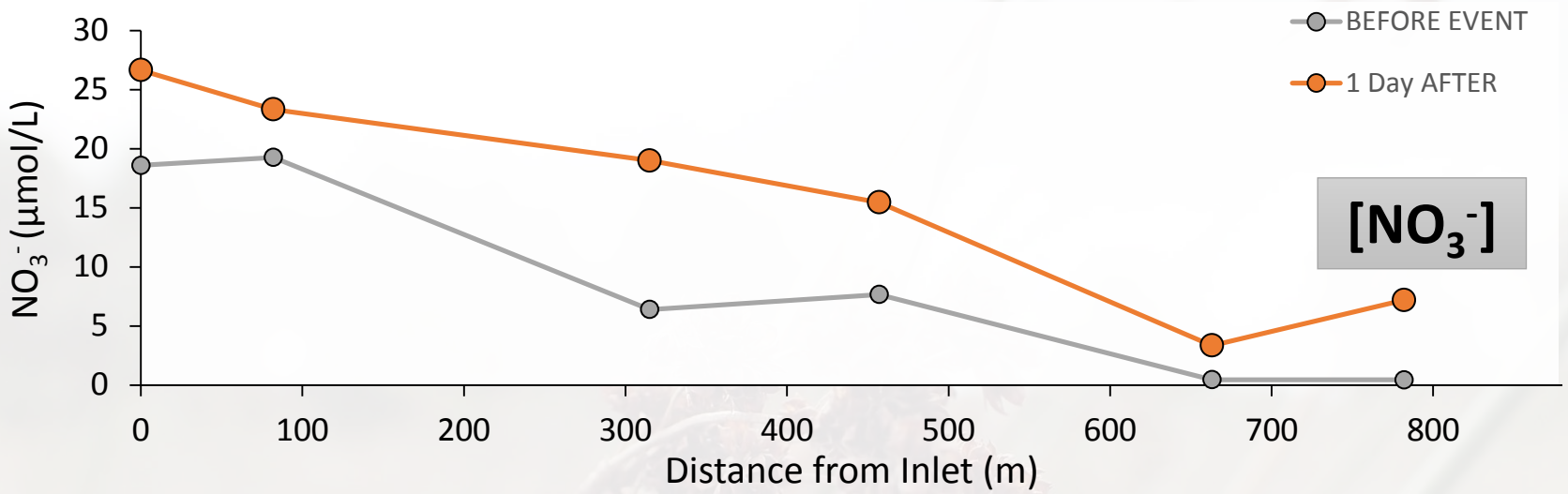
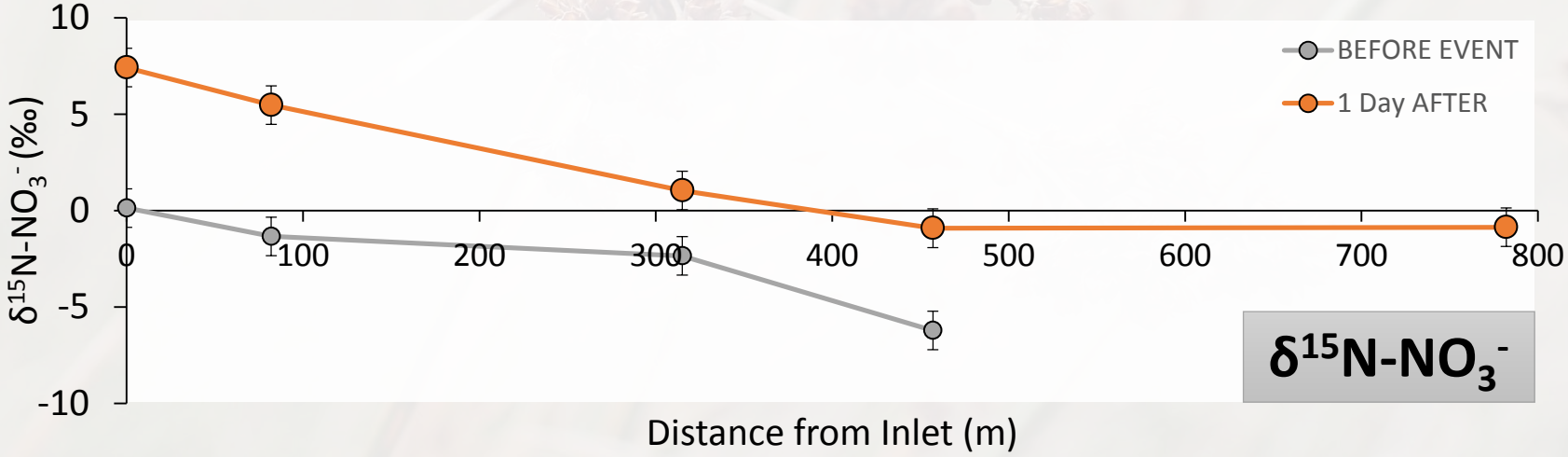
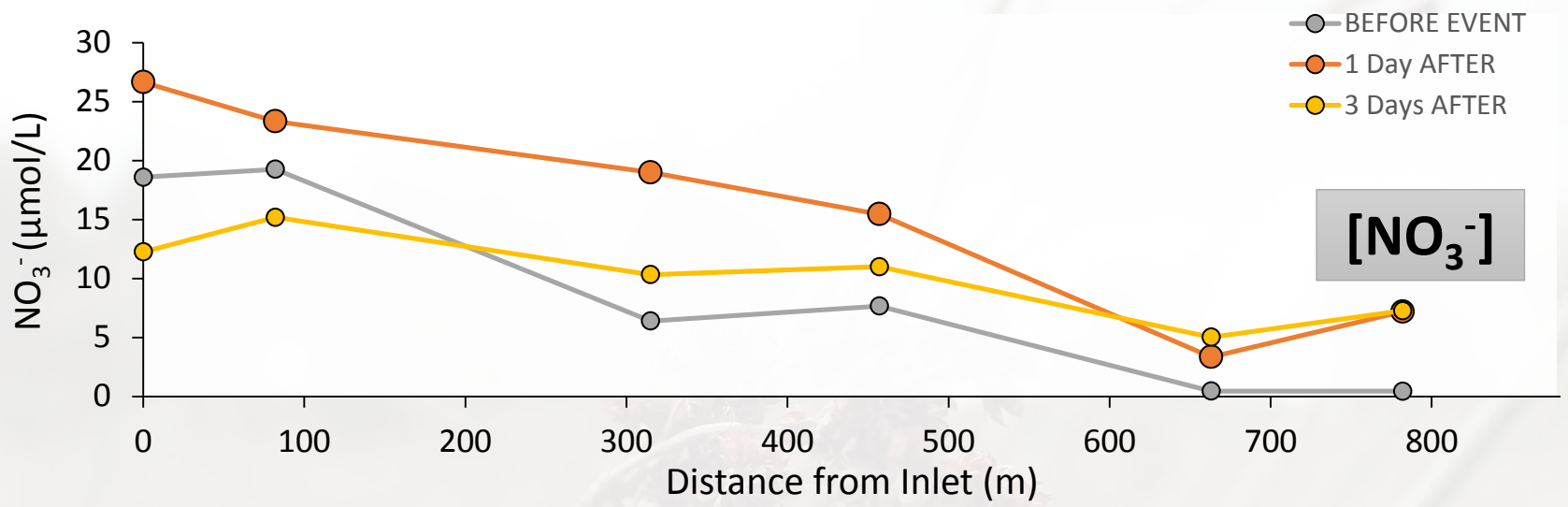
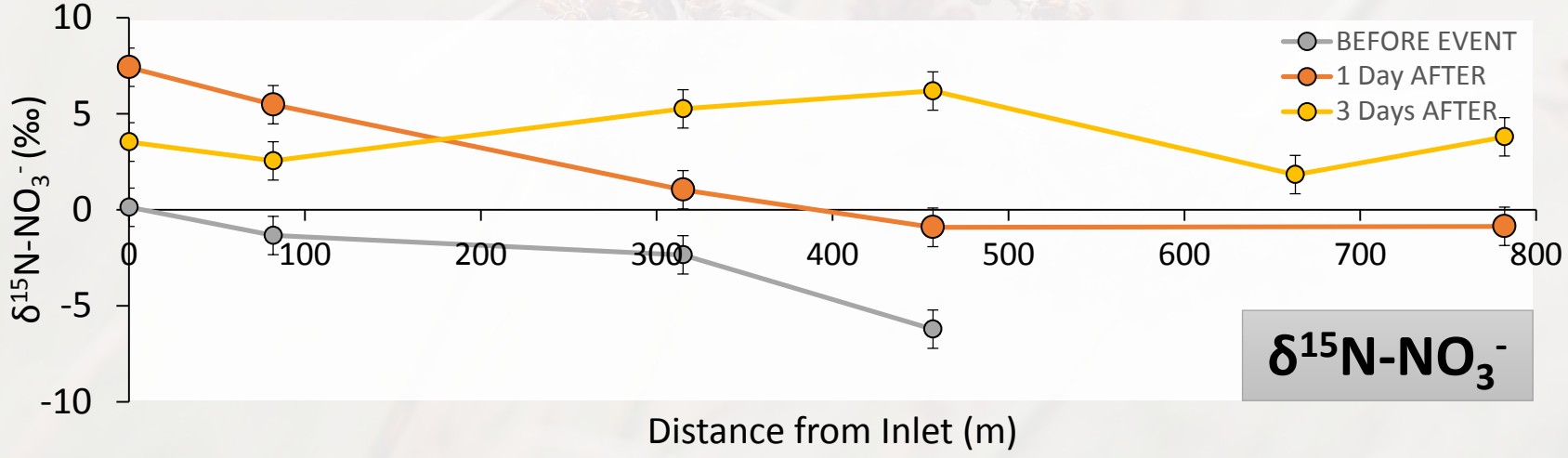




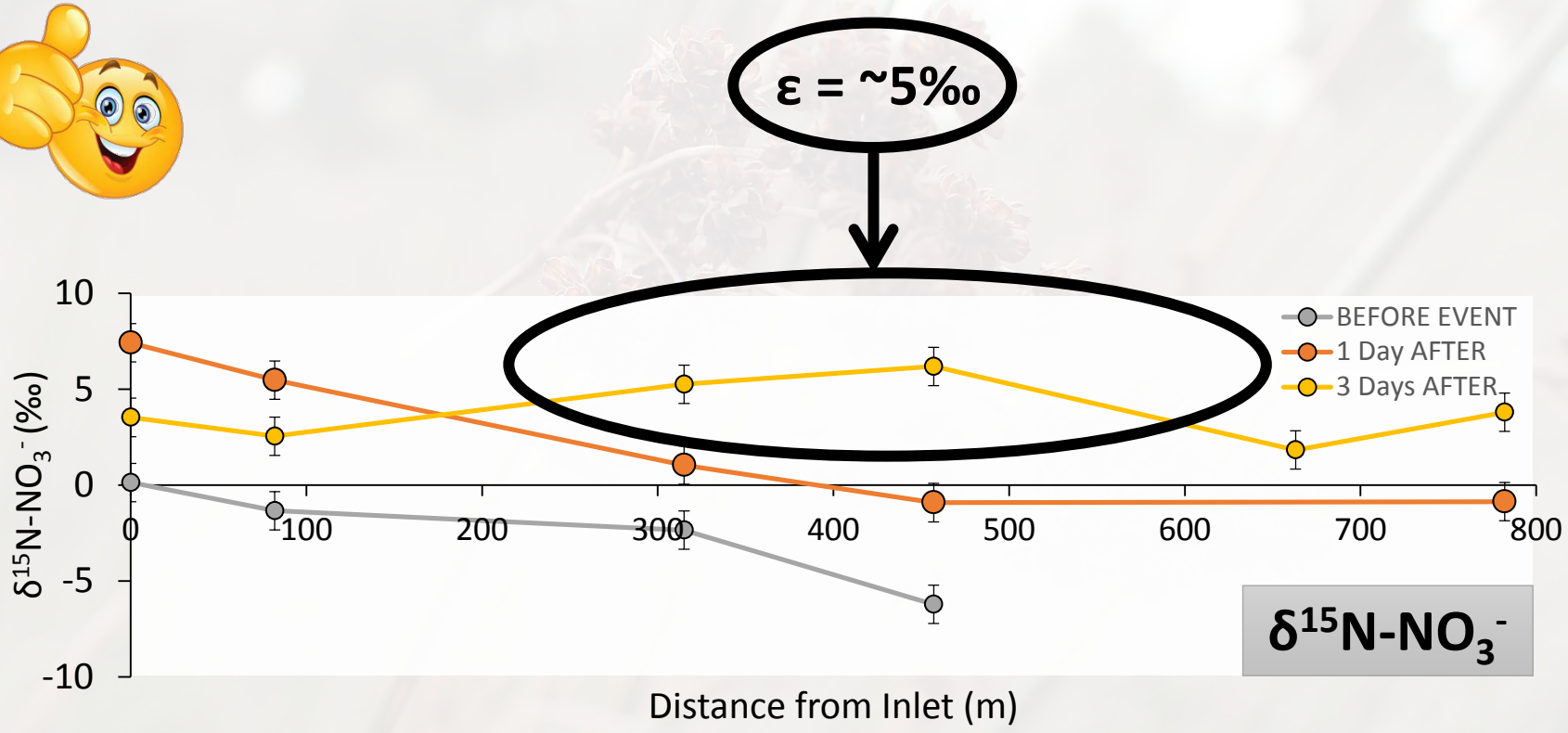
Kelletts Drain



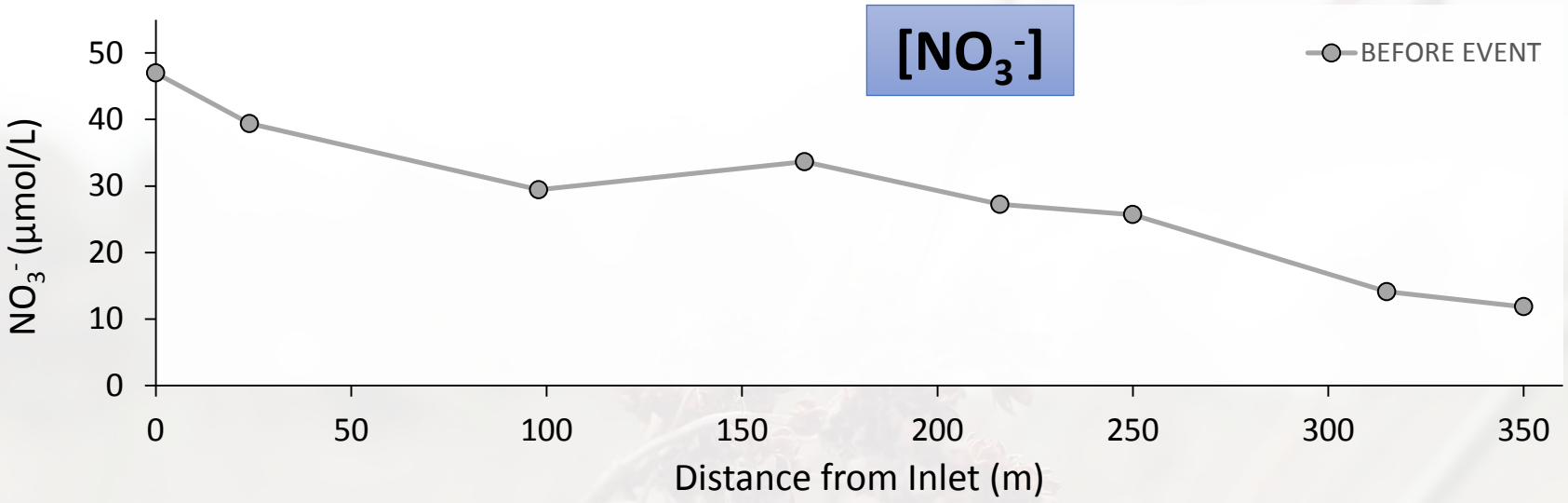


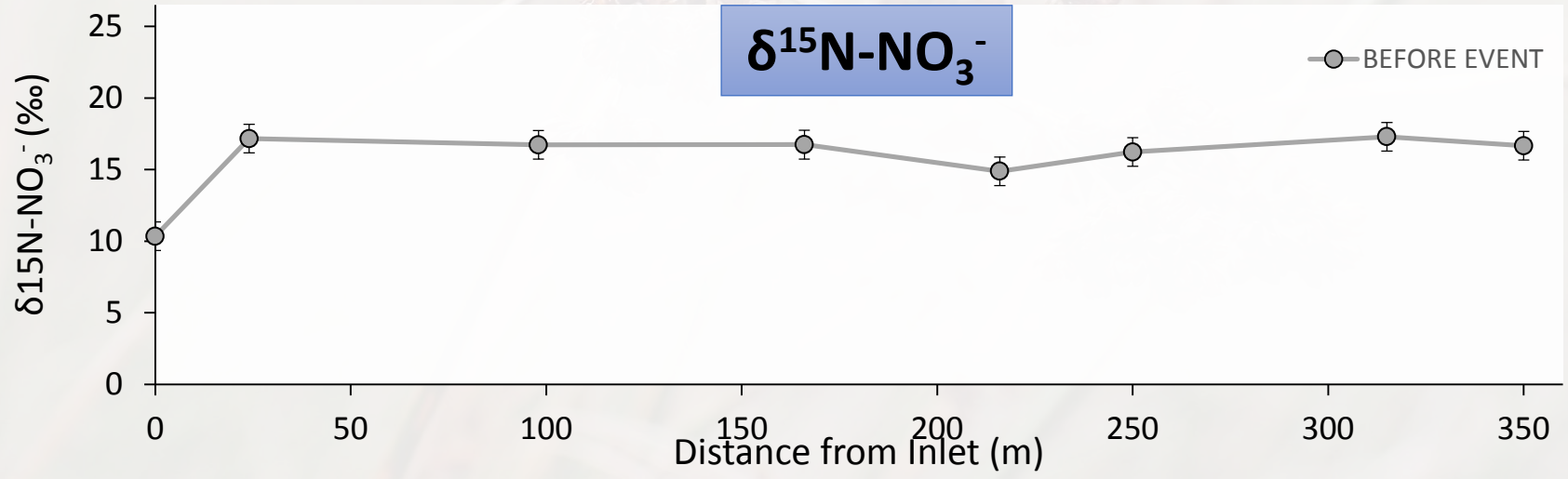
Kelletts Drain

- The residual NO_3^- gets heavier 3 days after the event which is consistent with **assimilation**

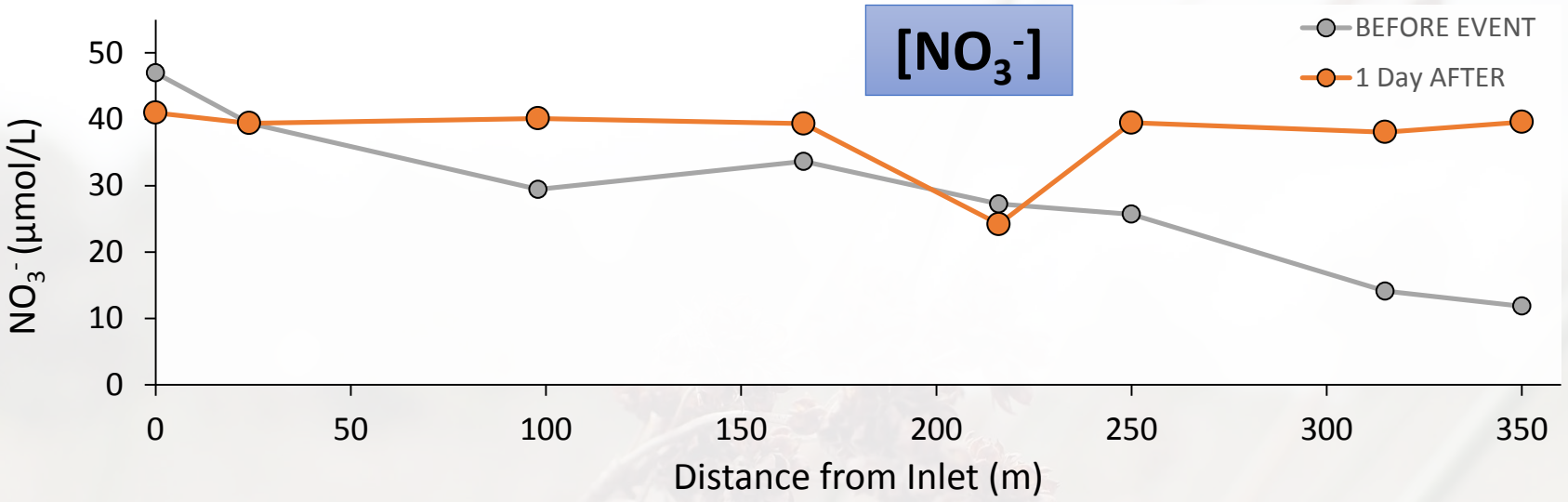


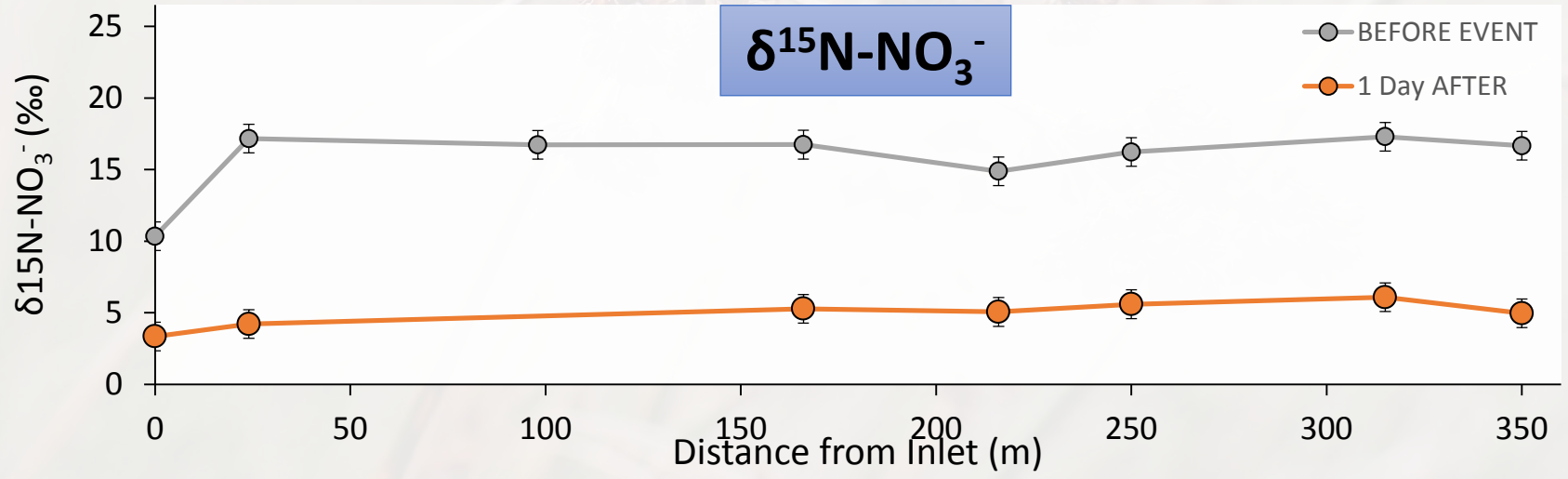
Anvil Way


[NO3-]
BEFORE EVENT
NO3- (µmol/L)
50
40
30
20
10
0
0
50
100
150
200
250
300
350
Distance from Inlet (m)

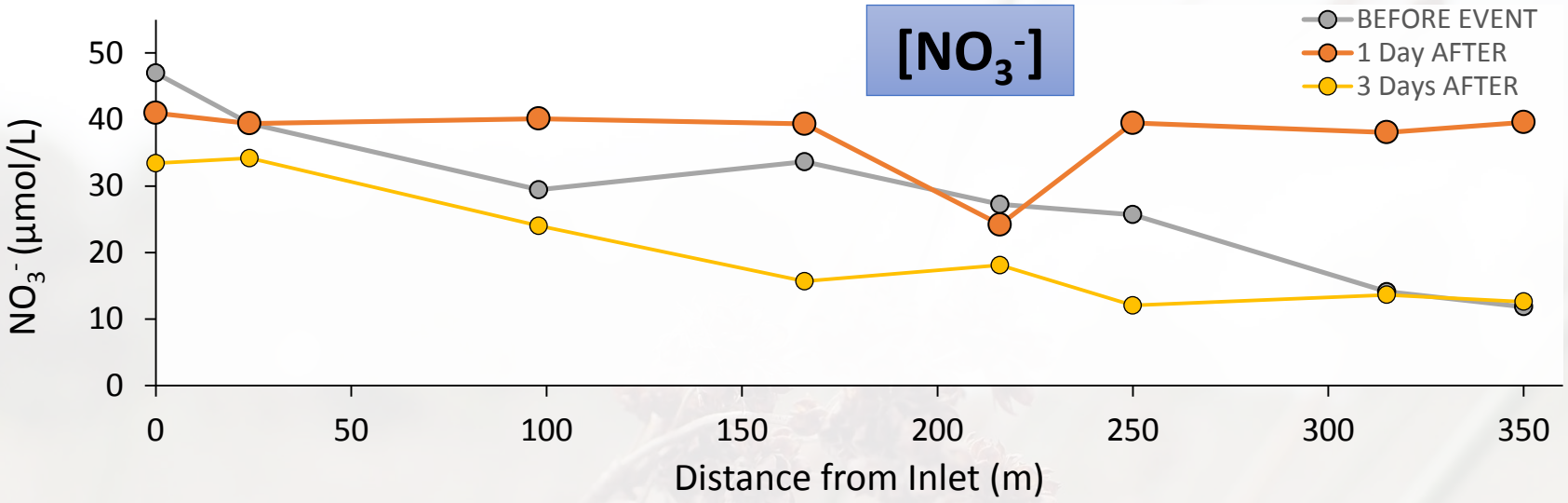

δ15N-NO3-
BEFORE EVENT
δ15N-NO3- (‰)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Distance from Inlet (m)

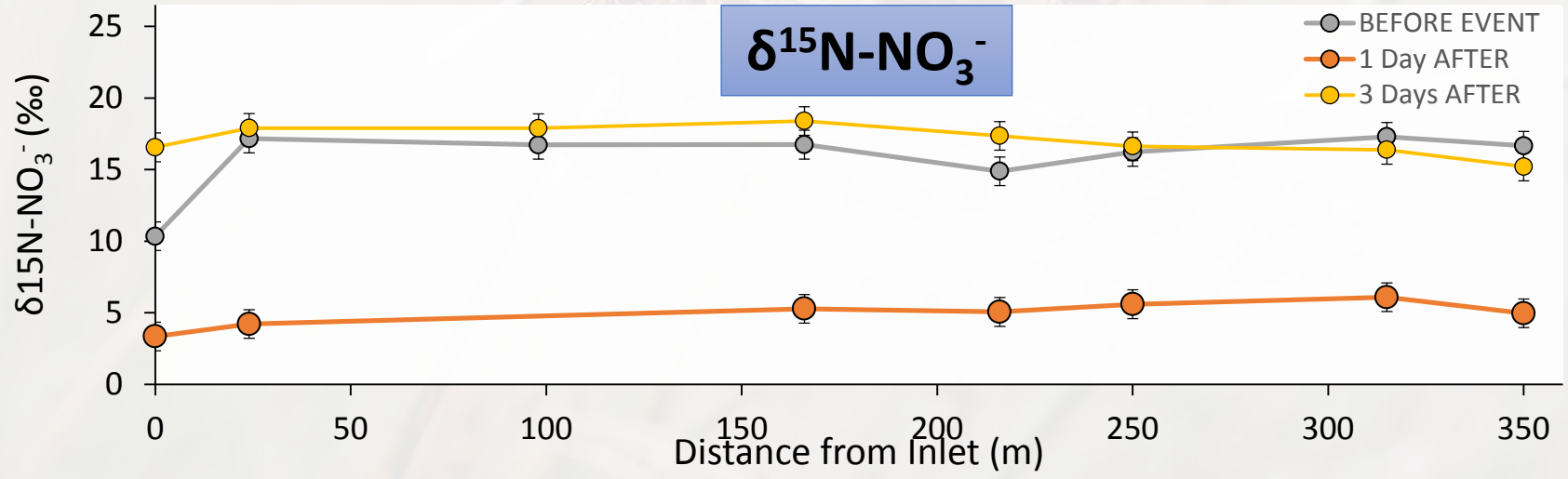
Anvil Way


[NO3-]
BEFORE EVENT
1 Day AFTER
NO3- (µmol/L)
0
10
20
30
40
50
0
50
100
150
200
250
300
350
Distance from Inlet (m)


δ15N-NO3-
BEFORE EVENT
1 Day AFTER
δ15N-NO3- (‰)
0
5
10
15
20
25
0
50
100
150
200
250
300
350
Distance from Inlet (m)

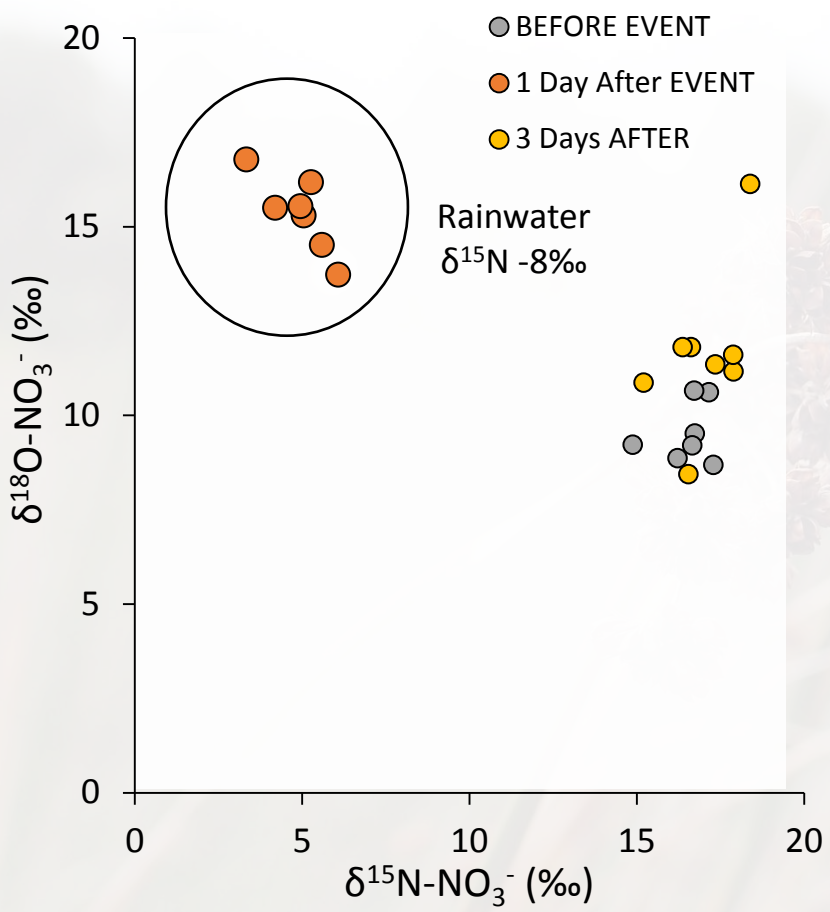
Anvil Way


[NO3-]
BEFORE EVENT
1 Day AFTER
3 Days AFTER
NO3- (µmol/L)
0
10
20
30
40
50
0
50
100
150
200
250
300
350
Distance from Inlet (m)


δ15N-NO3-
BEFORE EVENT
1 Day AFTER
3 Days AFTER
δ15N-NO3- (‰)
0
5
10
15
20
25
0
50
100
150
200
250
300
350
Distance from Inlet (m)

Anvil Way

$\delta^{18}O\text{-}NO_3^-$ vs $\delta^{15}N\text{-}NO_3^-$



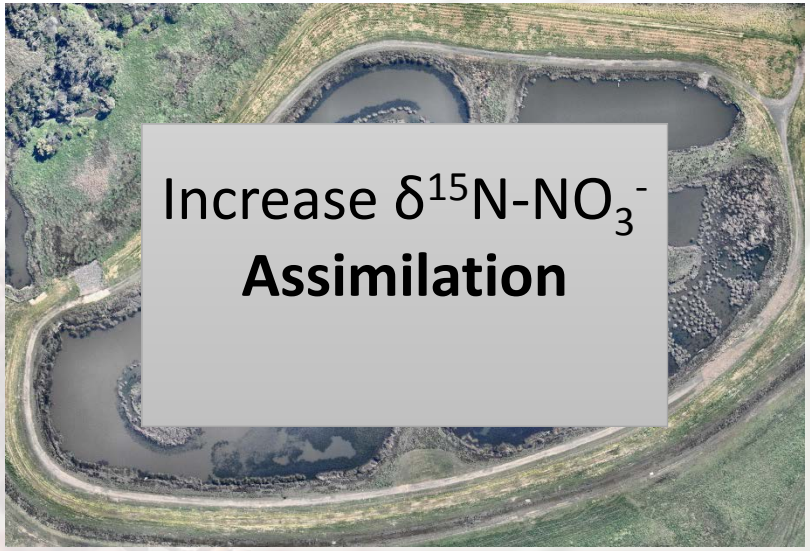
Error ± 1‰

- **Mixing** with rainwater and no observed transformation
- The $\delta^{15}N\text{-}NO_3^-$ moves back to the pre-event state
- $\delta^{15}N\text{-}NO_3^-$ is heavy because most of the drainage from upstream is supplied from groundwater

What did we see?

Cascades on Clyde, Melbourne

Kelletts Drain, Melbourne



Anvil Way Compensation Basin, Perth

Conclusions

- The use of **$\delta^{15}N$** and **$\delta^{18}O$ of NO_3^- (and** fractionation factors) for wetland components confirm the **assimilation** and **denitrification** *enrichment* trends observed in the literature

- Wetlands do NOT behave uniformly – vegetation/turbidity and water flow paths greatly influence how (and if) nitrogen is removed.

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Project Description

Project B – Developing urban river restoration decision support system is led by Peter Davies and undertaken by Dr Leah Beesley in Albany.

The Department of Water River Health team were introduced as co-delivery partners in 2015.

The objective of the project is to develop a suite of decision support tools
that can assist urban river managers to prioritise effective on ground activities
that will repair or protect the important "drivers" of stream ecosystems.

What do we mean by "driver"?

UWA: Leah Beesley, Peter D Davies, Neil Pettit & Paul Close
Dept. Water: Belinda Quinton, Tim Storer

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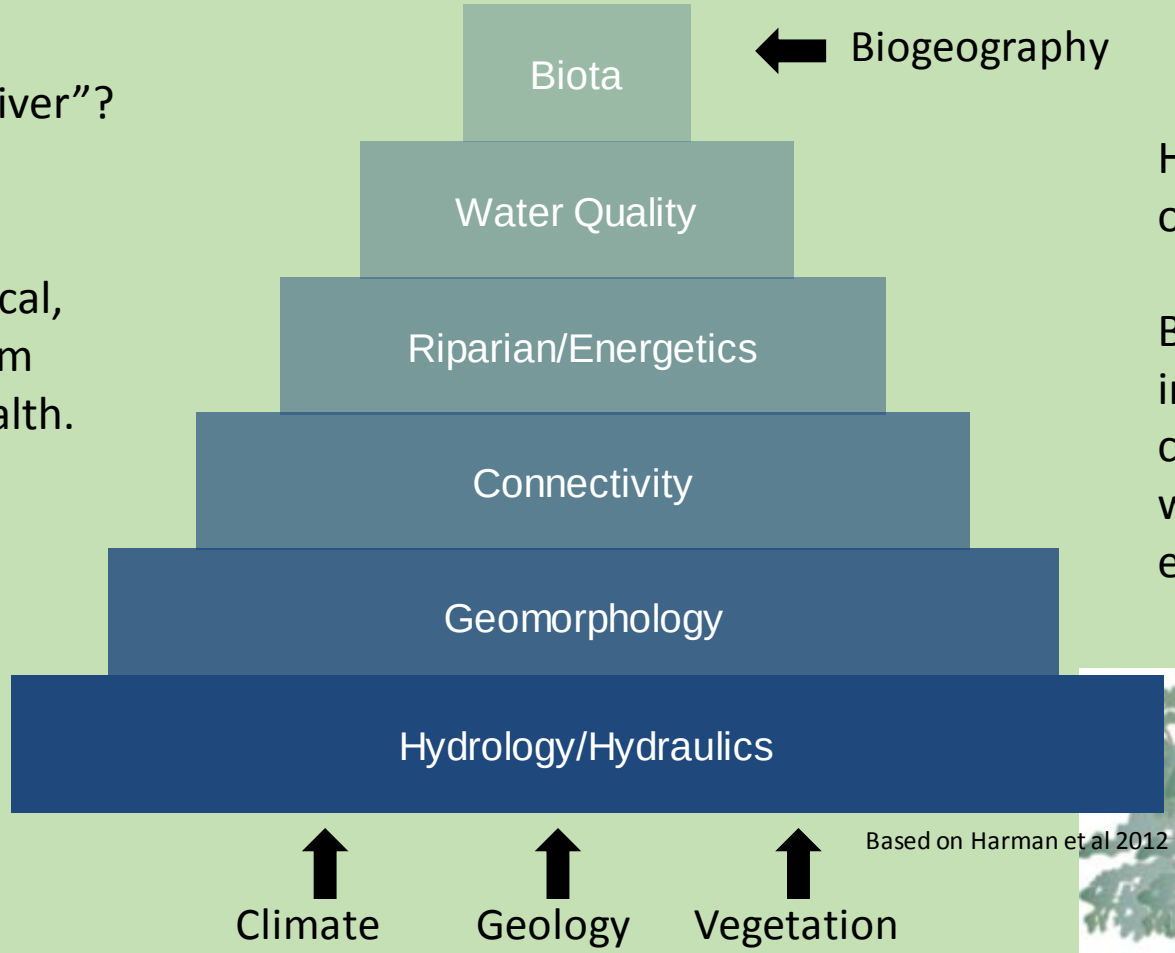
What do we mean by "driver"?

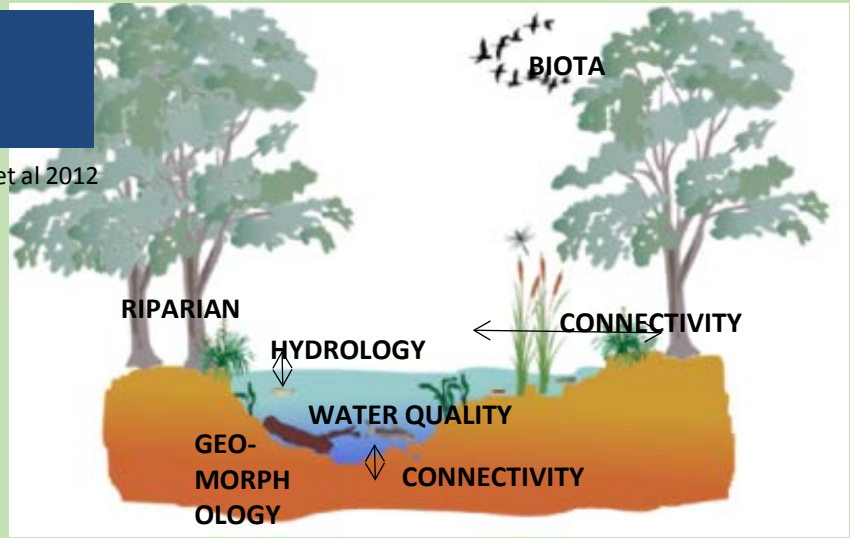
Components of the physical, chemical and biotic system that influence stream health.



Based on Harman et al 2012

Hydrology is the master driver of stream health….

But, if river managers are not in a position to alter the current state, what else can we do to still improve the ecological condition?



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Project Background

Can we do more in our urban stream than just 'pretty them up'? Can we improve ecosystem function?

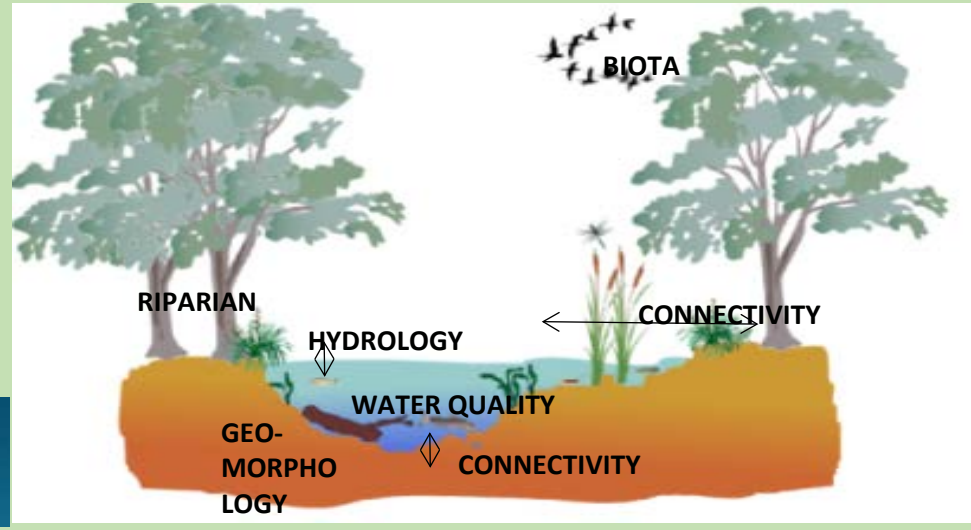
Much of the early work in this project focused on these drivers of stream health and exploring their capacity to recover from the stress of urbanisation. The reviews across multiple disciplines indicated that:

Management effort will yield greatest result when it targets ecosystem components that:

a) Exert significant influence on ecosystem function of a site,

b) Are highly altered from their aspired state, and

c) Have a good capacity to recover.



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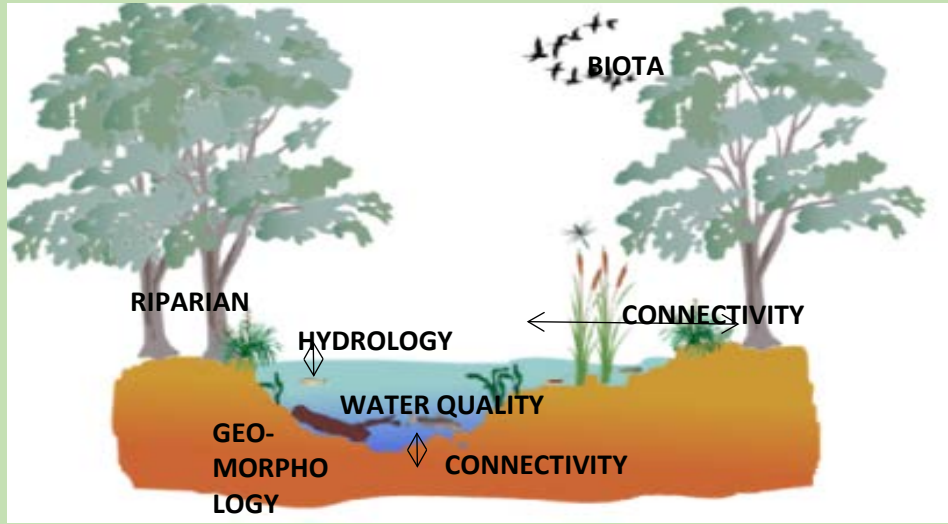
How does one figure this out?



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Project Background

During the development of a River Action Plan or River Restoration Plan, a systems assessment and prioritisation process is undertaken.

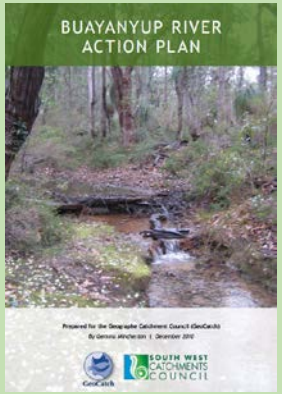
When data has been complied from the systems assessment, it can be challenging deciding what is important in rehabilitating or protecting the site.

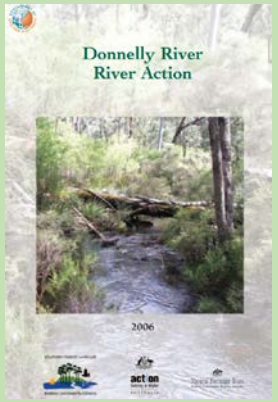
Identifying which suite of driver is important for a particular site is key.

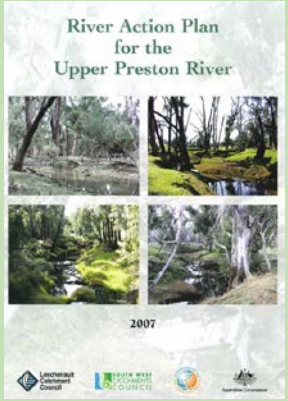
Early work developing typologies for this project identified that depending if you are in a headwater environment or lowland environment, surface runoff or groundwater driven environment, the relative influence of each driver, is different.

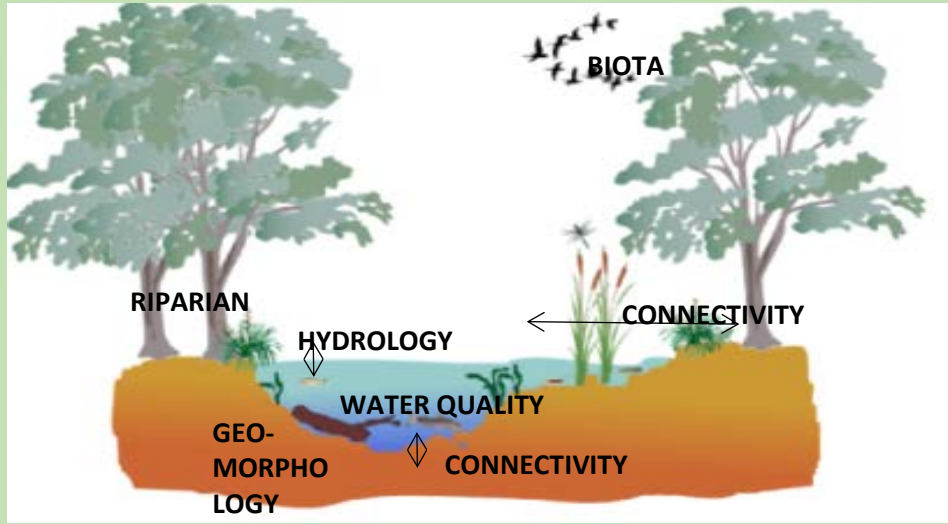
Management actions at one site, may be more or less beneficial at another site depending on the relative influence of the driver that the particular action targets.

1. *Exert significant influence on ecosystem function of a site,*
2. *Are highly altered from their aspired state,*
3. *Have a good capacity to recover.*









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B2.23 is developing an Urban Water Restoration Framework that guides managers through the system assessment and prioritisation process when developing a River Action Plan, with urban specific tools and guidelines along the way.

These supporting tools include:

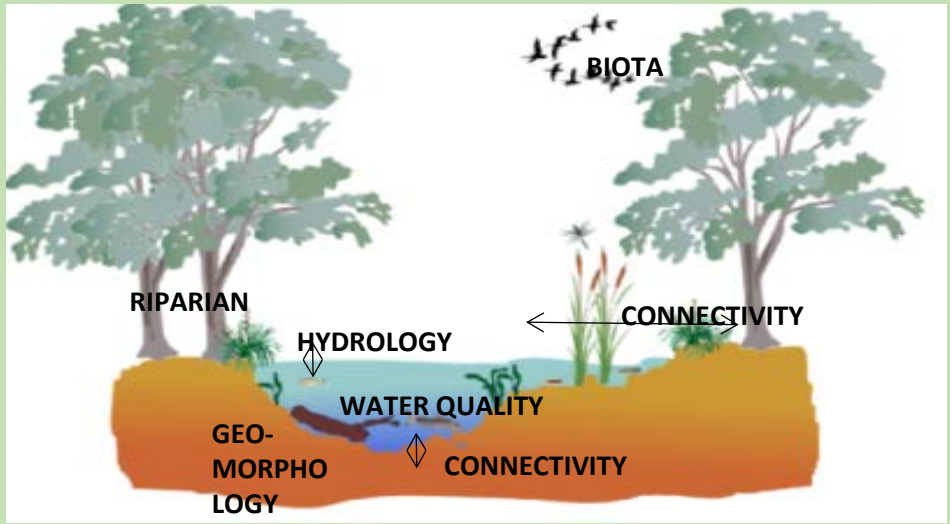
(i) 'RESTORE' - a tool that synthesizes multi-disciplinary current state of knowledge to guide the **prioritisation of important drivers and on-ground management actions**,

(ii) the determination of multiple **biotic indicators** of stream condition to help managers evaluate the state of urban waterways and restoration success,

(iii) an analytical framework that allow **site-specific reference condition to be predicted for biotic indicators**, and

(iv) guidelines for determining appropriate **riparian buffers**.

1. *Exert significant influence on ecosystem function of a site,*
2. *Are highly altered from their aspired state,*
3. *Have a good capacity to recover.*



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Restoration Framework...

Guiding managers along a restoration pathway

- *Background*
- *Management need*
- *Who should use this tool?*
- *What does it do?*
- *Instructions for use*
- *Supporting documents*
- *Scientific justification*

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What is the framework, & what does it do?

The *Framework* is a series of questions that directs managers to obtain the information required to assist them to make three key decisions.

Decision 1. which on-ground actions should be implemented to optimise ecological improvement or protection at their site, given urban constraints.

Decision 2. what ecological targets are being aimed for and what parameters (i.e., ecological indicators) should be monitored to assess the success of the intervention.

Decision 3. when and how should monitoring take place to evaluate the success of the restoration intervention.

The *Framework* uses knowledge from many sources to assist in the decision-making-process.

Framework Overview

Start the Framework

Framework overview…

The Restoration Framework guides managers through 11 steps.

Step 1. Explicitly state the goal or aims of your restoration activity

Step 2. Use the RESTORE tool to determine which ecosystem components are management priorities

Step 3. Identify the ecological elements you want to improve/protect/create for the priority ecosystem components

Step 4. Identify an ecological indicator to describe each ecological element

Step 5. Determine the aspirational condition for each indicator

Step 6. Determine the current condition of each indicator this will reveal how much the indicator has departed from aspiration

Step 7. Set a realistic target for each indicator given your management intervention

Step 8. Create a list of on-ground actions that should improve the ecological elements of interest (see BMP table)

Step 9. Refine targets given on-ground actions

Step 10. Implement on-ground actions

Step 11. Monitor ecological indicators at the appropriate spatial-temporal scale to evaluate success.

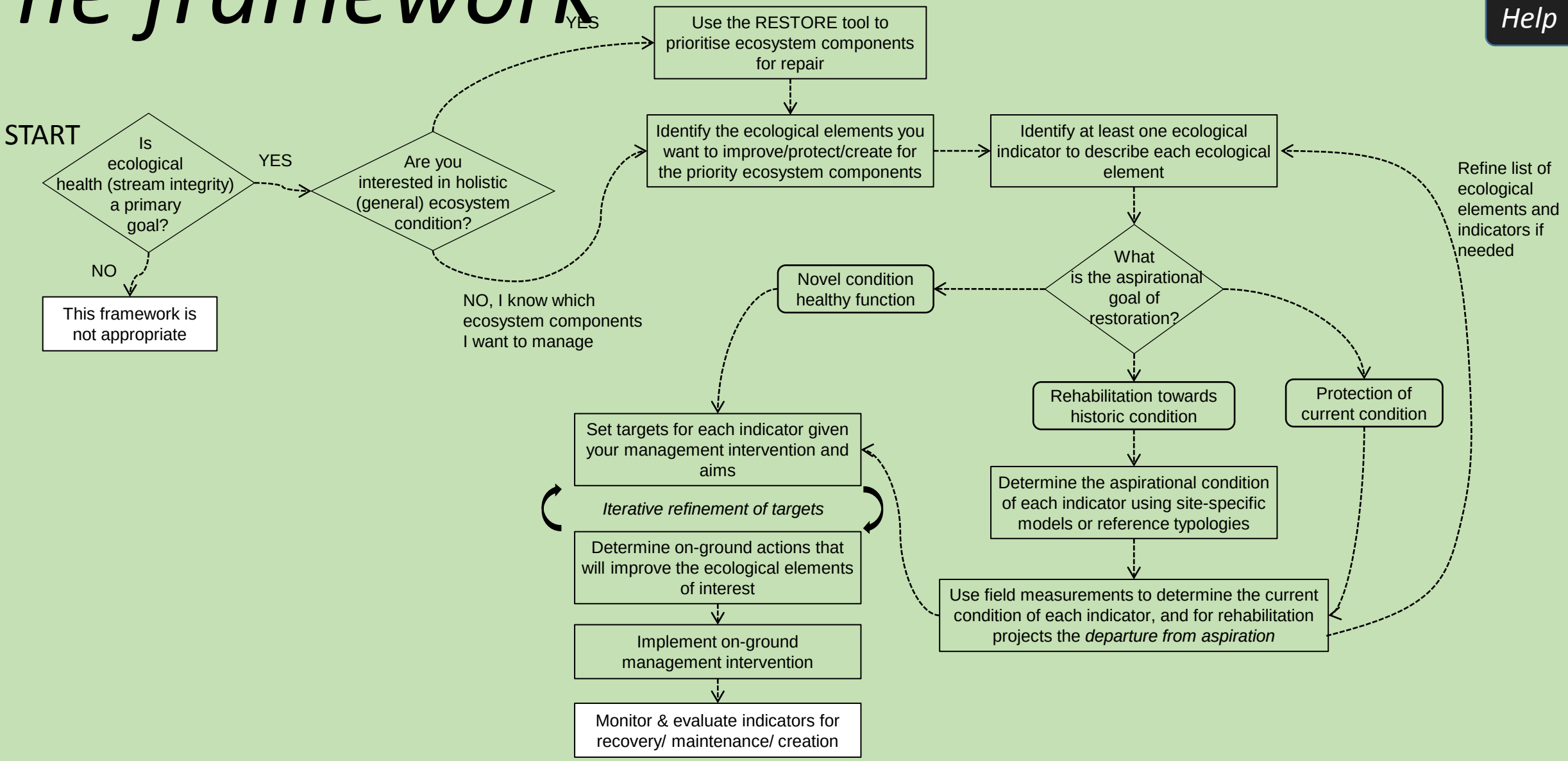
Start the Framework

See the Framework visually represented

The framework

Home

Help



Start the Framework

Step 1.

Setting the scene...

Home

Help

? *More information about the question*

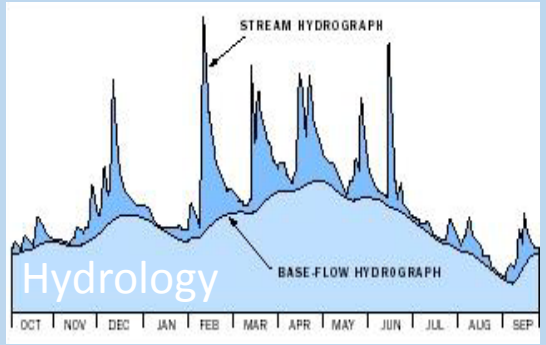
Provide information about your restoration activity and your goals.

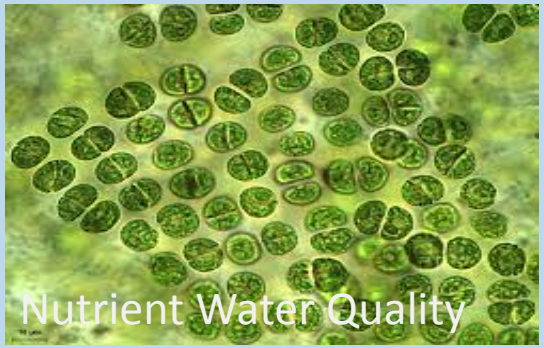
Question	***Answer (select)***
Are you wanting to protect, repair or create an urban waterway? ?	Rehabilitation
What is the aspirational goal for the site? ?	Historical reference condition

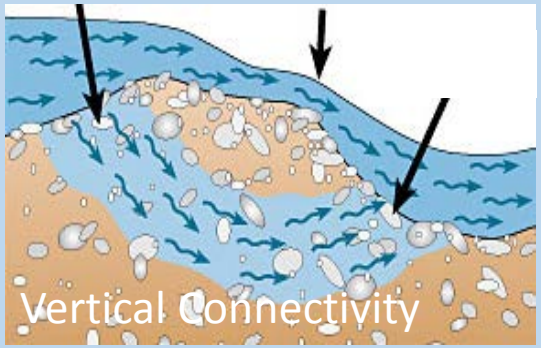
Go to RESTORE

RESTORE...

Optimising ecological gains to urban stream sites by prioritising the natural ecosystem components for repair







- *Management need*
- *Who should use this tool?*
- *How does the tool work?*
- *Instructions for use*
- *Supporting documents*
- *Restoration Framework*
- *Scientific justification*

Click here to begin

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What is RESTORE?

RESTORE is a conceptual tool that supports urban stream restoration.

The tool synthesizes existing knowledge from multiple disciplines and across multiple spatial scales of influence (site/reach → catchment/region) to determine *the ecological components that should be the focus of management attention*.

RESTORE's premise is that management effort will yield the largest ecological return when it targets ecosystem components that:

(i) exert significant influence on the ecosystem function of the site,
(ii) are highly altered, and
(iii) have a good capacity for recovery.

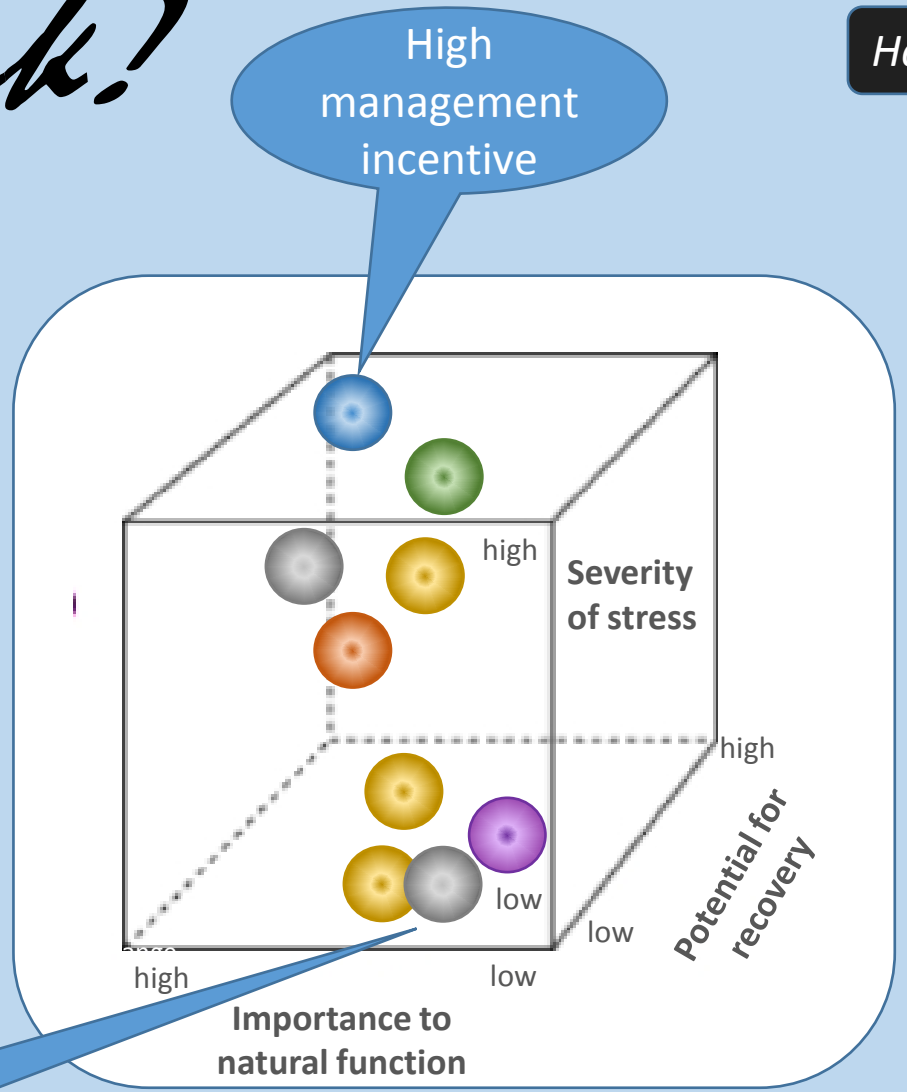
How does the tool work?

There are 9 components important to stream health:

biota
hydrology
riparian zone,
physical water quality
vertical connectivity.
nutrients
geomorphology
longitudinal connectivity
lateral connectivity

The tool ranks stream components according to three criteria:

Criterion 1. Importance to natural ecosystem function
Criterion 2. Severity of its departure from reference condition
Criterion 3. Potential for recovery



Prioritisation happens behind the scenes, all you need to do is answer a series of questions.

Click here to begin

Ecosystem components that receive a high score should be prioritised over components that receive a low score.

Knowledge underpinning the tool

The three criteria are prioritised using information about the environmental characteristics both today (current) and in the past (e.g. historical condition) and by information about urban development

Environmental characteristics

Large Scale Factors

- Climate
- Vegetation
- Geology
- Physiography
  Biogeography
- Prior agricultural land use

Meso & Fine Scale Factors

- Position in River Continuum
- Tributary effects
- Instream habitat attributes
- Etc.

Urban development & infrastructure

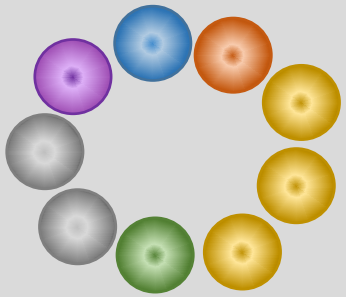
Large Scale Factors

- Area of urban catchment
- Type of stormwater management
- Future development projections of catchment
- Fragmentation of river network by roads
- Dam or barriers in catchment

Meso & Fine Scale Factors

- Distance from stream to urban development
- Stormwater drains at site
- Groundwater pumping nearby
- Leaky water and wastewater infrastructure
- Barriers to fish passage
- Flow regulating structure upstream

9 Ecosystem Components Driving Stream Function



Criterion 1. Importance to natural ecosystem function
Criterion 2. Severity of stress due to urban development
Criterion 3. Potential for recovery

Questions need to be answered from different spatial scales & different perspectives...

Home

Help

Current characteristics

Site

You need to answer questions about the current characteristics of your site and your aspirational condition.

Current condition:
32 site questions

Click here

Catchment

Current condition: 13 catchment questions

Click here

Historical or aspirational condition

Site

You need to answer questions about your site & the catchment it sits within.

Aspirational condition:
14 site questions

Click here

Catchment

Aspirational condition:
7 catchment questions

Click here

Site

Current environmental attributes of the site...

Home

Help

Instructions. Answer the questions below using the current physical attributes of the site. A visit to the site or GIS mapping may assist.

? *More information about the question*

How does this affect stream function?

Geomorphology

Question	Answer (select)
What is the stream order of the site?	3
What is the orientation of the stream channel?	East-west
What is channel sinuosity?	meandering
What is the material of the channel bed	Sand and gravel
What is the dominant geomorphic unit?	run
Is there much spatial complexity in geomorphic units?	Low complexity
What is the soil pH of the channel bank?	unknown
Is the site upstream of a knick point?	no

Riparian

Question	Answer (select)
What is the width of the riparian buffer?	10 – 50 m
Is the riparian zone trees, shrubs or grass?	forested
What is the dominant soil type of the riparian zone?	sand
What is the slope of the riparian zone?	< 10%
What % of the riparian veg. has been cleared?	>50%
What % of the riparian veg. is non-native?	>75-100%
What season does most leaf litter fall ?	autumn
How much organic matter is there in the soil?	low

Flow / WQ

Question	Answer (select)
Is flow perennial or intermittent?	perennial
Does the site experience protracted periods of low flow?	yes
Do low flows occur during warm months?	yes
Does the site experience high velocity scouring flows?	unknown
What is the min. depth to groundwater during the year?	2-4 m
Is the site connected downstream of a flow regulating structure?	no
How stained (coloured) is the water?	Deeply tannin stained
Is baseflow falling or rising?	rising

Others

Question	Answer (select)
Is the site near a tributary?	> 100 m from tributary
How much LWD is there in the channel?	< 1 piece per 10m
Has past agriculture led to elevated salinity?	yes
Are there ASS at the site or nearby upstream?	no
Is the site connected to a floodplain?	Not connected
Is there a natural recharge area nearby?	NA
Are there threatened or endangered species at the site?	Not at site, but in system
How far is the site to a refuge?	< 1 km

Site

Current urban attributes of the site and reach...

Home

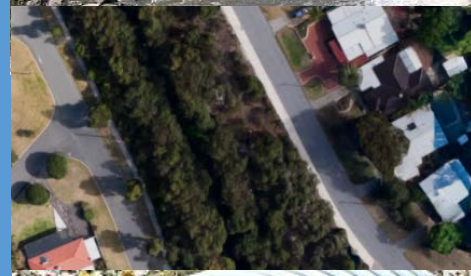
Help

Instructions. Answer the questions below using the current urban attributes of the site. A visit to the site or GIS mapping may assist.

? *More information about the question*

How does this affect stream function?

Question	Answer (select)
How close to the stream is urban development?	50-100 m
Do stormwater drains feed into the site or upstream?	At the site
Do subsurface drains feed into the site or upstream?	< 1 km upstream
Is groundwater pumped within 100m of the site?	Yes – residential bores
Do underground water mains and sewage infrastructure leak?	None or little leakage
Are there barriers to fish passage at the site	Yes – a culvert
Has the stream channel been revetted?	Rock lining in places
Could channel redesign cause a flood risk to people or infrastructure?	Highly unlikely
Is the site connected downstream of a flow regulating structure?	Yes, downstream of detention basin
Is the site close to an artificial aerator?	no
Are there levees or regulating structures preventing floodplain inundation?	no
Is there a point source WQ pollution occurring at the site or in the upstream reach?	Yes, industrial discharge
Is there a non-point source WQ pollution occurring at the site or in the upstream reach?	Yes, residential use of herb/pesticides



Catchment

Current environmental attributes of the catchment...

Home

Help

Instructions. Answer the questions below using the current physical attributes of the site. A visit to the site or GIS mapping may assist.

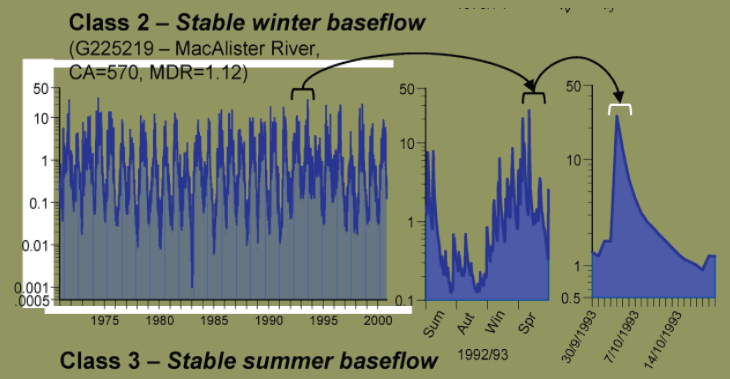
? *More information about the question*

How does this affect stream function?

	Question	Answer (select)
Geology/ Physiography	Is the catchment flat or steeply sloped? ?	Very flat (<1% slope)
	Is the soil permeability of the catchment low or high? ?	Sand, high permeability
Flow / water	Can rainfall intensity be high? ?	yes
	What is the flow class of your site? ?	Stable winter baseflow
	What is the min. depth to groundwater during the year? ?	2-4 m
	Is the climate drying? ?	markedly
Others	Is the aquatic food web of river system reliant on the migration of fish from the ocean/estuary? ?	unlikely
	Do biota of interest have a high capacity for dispersal? ?	unknown
	Are non-native aquatic species present downstream but not at your site? ?	yes

Stream Function: catchment slope affects how much rain flows over the surface (I.e. runoff) of the land, hence it affects stream flow. Flatter landscapes experience lower runoff than sloped landscapes.

Susceptibility to Urban Stress: studies have found that flat landscapes experience reduced peak discharges than sloped landscapes after urbanisation (Utz et al 2011, Hopkins 2015); therefore, sloped landscapes are more susceptible to urban flow stress.



Site

Current urban attributes of the catchment...

Home

Help

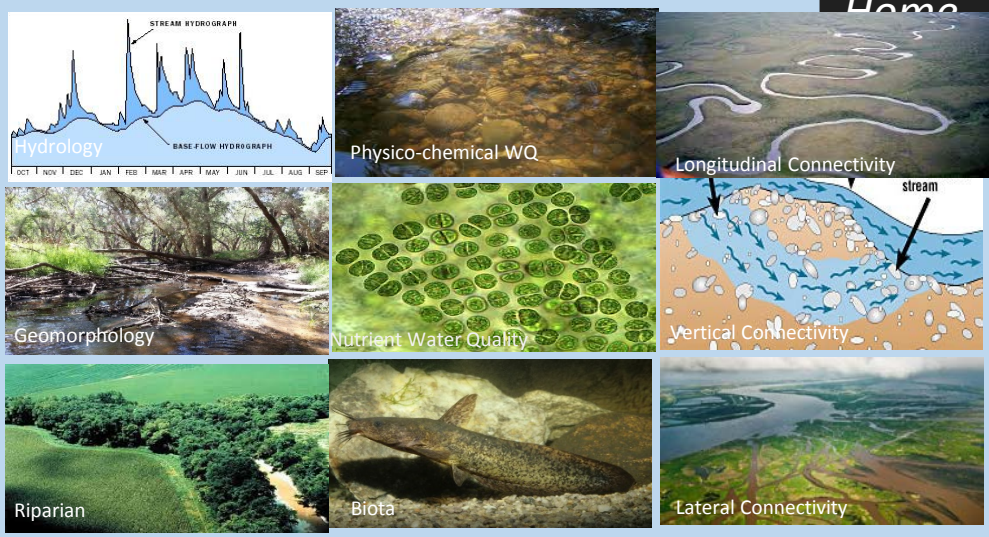
? More information about the question

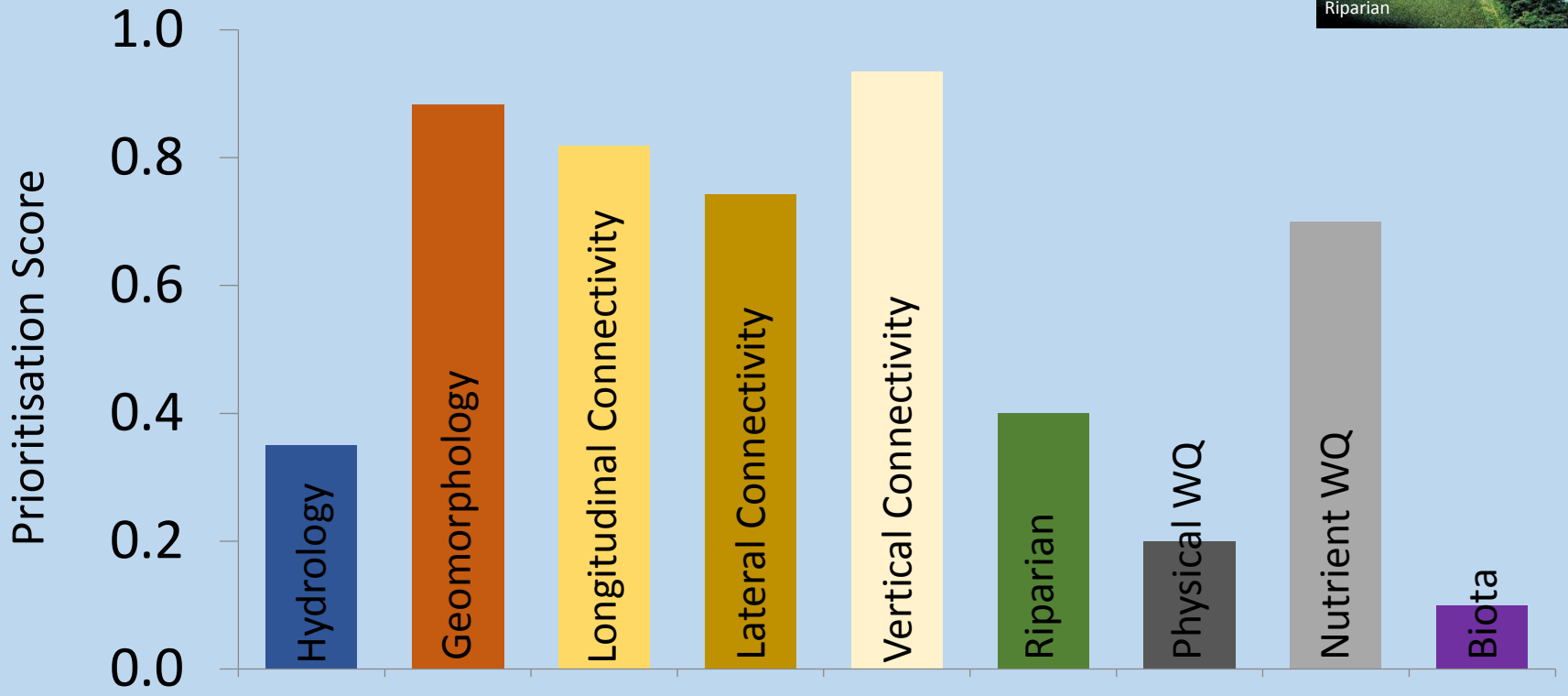
How does this affect stream health?

Instructions. Answer the questions below using the current urban attributes of the site. A visit to the site or GIS mapping may assist.

Question	Answer (select)
What % of the catchment is impervious?	10-30%
How large is the catchments' urban area?	<5km2
What is the dominant type of stormwater management?	Stormwater piped to drainage lines
What is the drainage density?	0.41 – 0.89 km km2
What % of natural vegetation has been cleared	75-100%
Could channel redesign cause a flood risk to people or infrastructure?	Highly unlikely
Is there currently, or likely to be, urban development in the upstream catchment?	No
Is there likely to be coarse sediment (sand, gravel) running into drainage lines associated with ongoing urban development?	NA
Is there likely to be fine sediment (silt) running into drainage lines associated with ongoing urban development or agriculture?	unknown
Is the river network upstream of the site highly fragmented by roads and other urban development?	yes, > 10 road crossings
Is much of the upstream river network buried?	yes, 10-50% is piped
Is there a dam upstream that is affecting the thermal or oxygen regime of the site?	no
Are there barriers upstream or downstream preventing the ingress of important species (e.g. native fish)	Yes, effect on fish unclear

Priotisation output...





The natural ecosystem components prioritised for repair at your restoration site

Step 2.

Management priorities...

Home

Help

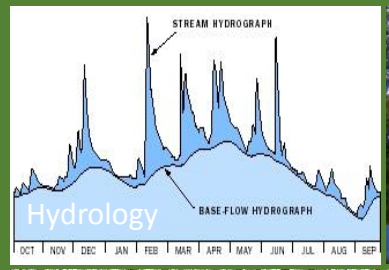
Resources

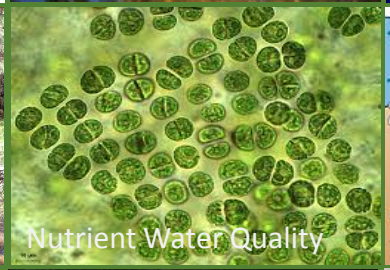
? More information about the question

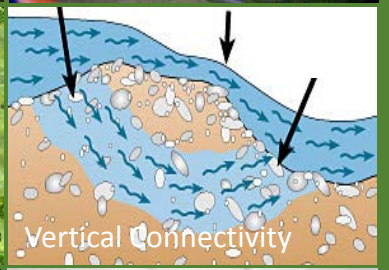
Using the output of RESTORE, provide information about the ecosystem components for management attention.

Question

Which ecosystem components are considered to be a management priority for your site? List in descending order of importance. ?







Answer (select)

Hydrology (flow)	Priority 1
Nutrients, Water Quality	Priority 2
Riparian	Priority 3
Vertical Connectivity	Priority 4
Physico-chemical, Water Quality	Priority 5
Geomorphology	Priority 6
Lateral Connectivity	Priority 7
Longitudinal Connectivity	Priority 8
Biota	Priority 9

Go to next step

Step 3.

Ecological elements for repair or protection...

Home

Help

Of your priority ecosystem components, choose elements are you interested in repairing, protecting or creating?

	Ecosystem Components	Element 1	Element 2	Element 3	Element 4
Priority 1	Hydrology (flow)	Flow volume	Flow velocity	Flow permanence	Rate of rise and fall
Priority 2	Nutrients, Water Quality	Nitrate	Phosphorus	Organic nitrogen	select
Priority 3	Riparian	Stream shading	Instream habitat creat...	Vegetation nativeness	Upstream continuity
Priority 4	Vertical Connectivity	Baseflow	Channel unit complexity	Bed material porosity	select
Priority 5	Physico-chemical, Water Quality	Temperature	Salinity	Heavy metals	select
Priority 6	Geomorphology	Channel unit complexity	Bank stability	select	select
Priority 7	Lateral Connectivity	select	select	select	select
Priority 8	Longitudinal Connectivity	select	select	select	select
Priority 9	Biota	Native species richness	select	select	select

! Element selection should reflect ecosystem component priorities. That is, you should select more elements for the ecosystem components considered to be a priority. The exception may be biota, which itself may not exert a marked influence on general stream function, it can provide a holistic description of stream condition (i.e. biota can synthesise improvement in multiple physical factors).

Go to next step

Step 4.

Ecological indicators...

Home

Help

? More information

For each of your priority elements, the tool automatically generates a list of potential ecological indicators. Select the ecological indicators that are relevant to your urban region.

Priority Elements	Ecological indicator	
Flow volume	Discharge (ML/d, ML/yr)	?
Flow permanence	# days no flow per year	?
Flow velocity	select	?
Rate of rise and fall	select	?
Nitrate	NOX	?
Phosphorus	Soluble Reactive P	?
Organic nitrogen	Total organic N (mg/L)	?
Stream shading	select	?
Instream habitat creat...	select	?
Vegetation nativeness	select	?
Upstream continuity	select	?
Baseflow	Baseflow index	?
...		
Biodiversity	SIGNAL	?

Biodiversity ecological indicators

Macroinvertebrates
SIGNAL. Suitable for south-eastern Australia, but not WA.
Macroinvertebrate family richness, suitable for all states.

Fish
Total native species richness. Suitable for all states.

Step 5.

Aspirational condition...

Home

Help

? More information about the question

If your goal is to Protect the health of a waterway not improve it skip to step 6. Go to step 6

If your goal is to create a novel living stream, e.g. a stream in an area where there has never been one (new development) skip to step 7. Go to step 7

*For each of your ecological indicators use the site-specific **Historical Condition Applications, Reference Typology** or **other tools** to determine your aspirational condition, and use field measurements to describe current condition. Models (i.e. apps) generating predictions that are site-specific should be used in preference to generic typologies where data permits.*

Ecological indicator	Tool	Aspirational condition
Discharge (ML/d, ML/yr)	Reference typology	enter
# days no flow per year	Reference typology	enter
select	Reference typology	enter
select	Reference typology	enter
Nitrate, Nitrite (NOX)	Historical condition application	enter
Soluble Reactive P	Historical condition application	enter
Total organic N (mg/L)	Historical condition application	enter
select	Historical condition application	enter
select	Historical condition application	enter
select	Historical condition application	enter
select	Historical condition application	enter
Baseflow index	Bhakasar et al. 2016 tool	enter
Native fish sp richness	Historical condition application	enter

Go to next step

Step 6.

Current condition...

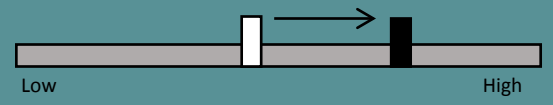
Home

Help

Next, you need to determine the current condition of the ecological indicators at your site. This can be achieved by field measurements or data recently collected from your site. Once the current condition is entered, the departure from reference will be automatically generated. NB. Departure from Aspiration will only be generated if your goal is rehabilitation.

Ecological indicator	Current condition	Departure from Aspiration
Discharge (ML/d, ML/yr)	enter	To be generated
# days no flow per year	enter	To be generated
	enter	To be generated
	enter	To be generated
Nitrate, Nitrite (NOX)	enter	To be generated
Soluble Reactive P	enter	To be generated
Total organic N (mg/L)	enter	To be generated
	enter	To be generated
	enter	To be generated
	enter	To be generated
	enter	To be generated
Baseflow index	enter	To be generated
Native fish sp richness	enter	To be generated

Example 1
Large increase



Example 2
Little change

Consider removing this parameter from your ecological indicator list unless future development is likely to cause stress to base flow.

Go to next step

Step 7.

Set realistic targets...

Next, you need to set realistic targets for each of your ecological indicators. These should be values you believe are attainable given your management interventions. Mathematical models may be able to assist you in creating realistic targets.

There are several factors you should consider when setting your target.

1. Whether the ecological indicator is shaped by small (e.g., site) or large (e.g., catchment) scale ecological processes

If small-scale processes are dominant, large improvements in the indicator can be achieved by on-ground actions at the site (e.g., stream shading) and targets can be ambitious. If large-scale processes are dominant, large improvements in the indicator are only possible if on-ground actions occur across the catchment. This may be very difficult to achieve, unless the catchment is very small. Consequently, targets for these indicators (e.g., flow) should be more conservative.

2. The scale of management intervention

If a management intervention is controlled by large-scale processes (e.g. catchment) then the greater the spatial scale of the intervention the more ambitious the target can be. Note that exceptions occur. For example, if an upstream weir can be controlled to manage flow to the stream site, then an ambitious target for flow could be set even though the spatial scale of influence is small (e.g. the weir).

3. The type of management intervention

Not all management interventions have the same capacity to deliver ecosystem improvements. If interventions are likely to have a strong direct effect on the indicator then targets can be ambitious, if interventions are likely to have a weak or indirect effect on the indicator then targets should be conservative.

4. Temporal aspects of recovery

Most ecological components are interdependent, and some are dominant, e.g., flow strongly affects geomorphology. Thus it may not be appropriate to set an ambitious target for certain indicators if influential components of the stream ecosystem have not already been repaired.

5. Future urban development

Future development within a restoration site's catchment will increase stress to many ecological indicators, particularly if they are related to catchment-scale processes (e.g. flow). In such instances a target of 'maintaining current condition' may be more appropriate than an 'improvement in condition'.

6. Legacies

Past land use change can leave long-lasting effects on stream ecosystems, which can make certain targets difficult to achieve. For example, agriculture can cause nutrient levels in soils and streams to remain elevated for decades. In such instances, targets must be adjusted down or the time-frame of achievement needs to be extended.

Step 8.

Create a list of suitable on-ground actions...

Home

Help

References recommending action

Guidelines for implementation

Next, you need to create a list of the management actions that can repair your ecological indicators (ecological elements). Use the dropdown meu to identify the ecosystem component and ecological element that describe each ecological indicator. A list of management actions will appear. You must then choose the management actions that can be implemented given fiscal and urban constraints. Drag and drop your list of on-ground actions to your cart.

Ecosystem Component

Nutrient Water Quality

Priority Element

Nitrate

Management objective

Reduction

Management strategies
Reduce nutrient input by people
Reduce the volume of stormwater
Clean stormwater prior to it reaching the stream network
Slow and reduce the transport of nutrient-rich groundwater
Increase nutrient processing and uptake in the riparian zone
Increase nutrient processing and uptake instream

On-ground action	Scale	Mechanism	Maintenance
Construct rain gardens	Street	Nutrients are reduced by filtering and trapping stormwater in sediment and plant media.	High – sediment and vegetation need to...
Construct vegetated swales	Street	Nutrients are reduced by reduced by trapping stormwater.	High – sediment and vegetation need to...
Construct wetland biofilters	Precinct	Nutrient uptake is enhanced by slowing the flow of water and creating areas rich in macrophytes.	High – sediment and vegetation need to...

On-ground action	Scale	Mechanism	Maintenance
Increase stormwater infiltration by various mechanisms. *LINK TO STORMWATER INFILTRATION*	Catchment	Increasing stormwater infiltration raises the water table which creates more anoxic soil in the riparian zone and improves denitrification.	See STORMWATER INFILTRATION
Plant native deep-rooted vegetation in riparian zone	Site	Deep-rooted vegetation increases the carbon content of riparian soils. It also increases the depth of the microbial active zone. Trees/shrubs will also uptake nutrients, particularly if fast growing.	Low – none required
Increase width of riparian buffer	Site		Low – trees bordering roads and paths...
Create trenches filled with sawdust	Site	Localised reduction in nitrate on other side of trench.	

Management action cart

Drag and drop actions in here...

raingardens

wetland biofilters

Plant native deep-rooted vegetation in riparian zone

Step 9.

Refine targets given management actions...

Next, revist your targets for each ecological indicator in light of the management actions you will implement. Targets may need to be refined.

Making Targets More Ambitious

If this tool has revealed there are management actions that you were not aware of that are highly effective, you may be able to make your targets more ambitious.

Making Targets Less Ambitious

If this tool has revealed that management actions you expected to implement are likely to have poor efficiency given your physiographic setting, you may decide not to implement them and may need to make your targets more conservative.

Step 9.

Implement on-ground actions...

Next, implement your on-ground management actions.

BUT before you do… consider if the timing of different actions can improve your chance of success.

Useful tips

1. channel reconfiguration is more likely to last if flow has already been fixed
2. replanting of native understory vegetation is more likely to be successful if weeds have been removed and overstorey vegetation is present to shade seedlings
3. implement destructive actions (e.g. channel modification) before you implement other actions

Step 10.

Monitoring and evaluation...

Finally, you need to monitor your ecological indicators to evaluate if you have reached your restoration/protection or creation target.

To do this you need to monitor at the appropriate spatio-temporal scale, i.e. in the appropriate locations at the appropriate times.

Where to sample?

You need to decide if you only need to sample at the site or at other 'control' sites as well. This will depend on how you plan to analyse your data.

Go to analysis information

You also need to decide how you place your sampling effort at the site. This will be determined by how variable the indicator is over fine scale (i.e. within your site). If the indicator is relatively constant across the site then it can be measured at one location.

Go to spatio-temporal variation of indicators

When to sample?

To know when to sample you need to know:

1) How much your indicator naturally changes through time unrelated to your management intervention (e.g. seasonally)

2) How much time it will take for intervention to cause a change in your indicator

To answer point 1 you need to understand to what extent your indicator changes hourly, daily, monthly, yearly. If change is considerable you need to standardise sampling so that you can control for these changes.

To answer point 2 you need to have some understanding of how long recovery will take. Some indicators may change relatively quickly (e.g. days to months), whereas others may take years or decades to recover. Resources should not be wasted measuring indicators that have not had sufficient time to respond.

Temporal response of indicators

B2.23 developed a urban water restoration framework that guides managers through the system assessment and prioritisation process when developing a River Action Plan, with tools and guidelines along the way.

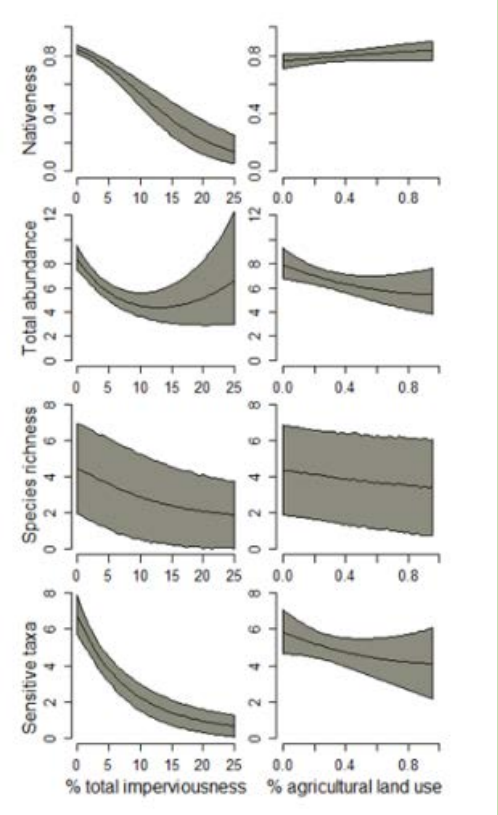
These supporting tools include:

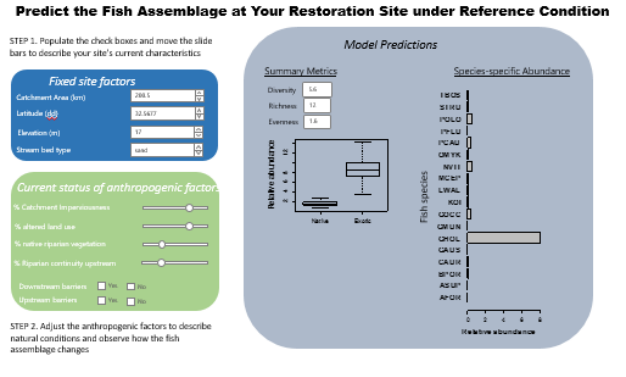
(i) 'RESTORE' - a tool that synthesizes multi-disciplinary current state of knowledge to guide the prioritisation of important drivers and on-ground management actions,

(ii) the determination of multiple Biotic indicators of stream condition to help managers evaluate the state of urban waterways and restoration success,

(iii) an analytical framework that allow site-specific reference condition to be predicted for biotic indicators, and

(iv) guidelines for determining appropriate riparian buffers.





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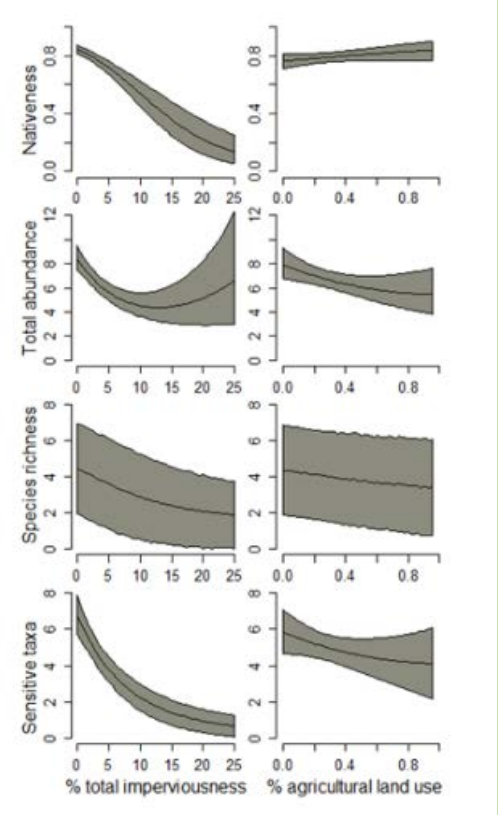
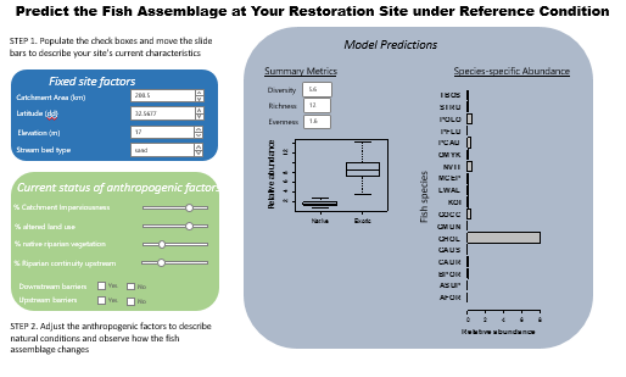
- Through the RESTORE tool, the restoration team can identify the important ecosystem components to repair at a site and optimise on-ground works.
- Monitoring can be optimised by identifying the most appropriate biotic indicators.
- Has the capacity to model reference conditions to support site restoration in areas with little or no data.
- Has guidelines regarding effective design dimensions for riparian buffers.





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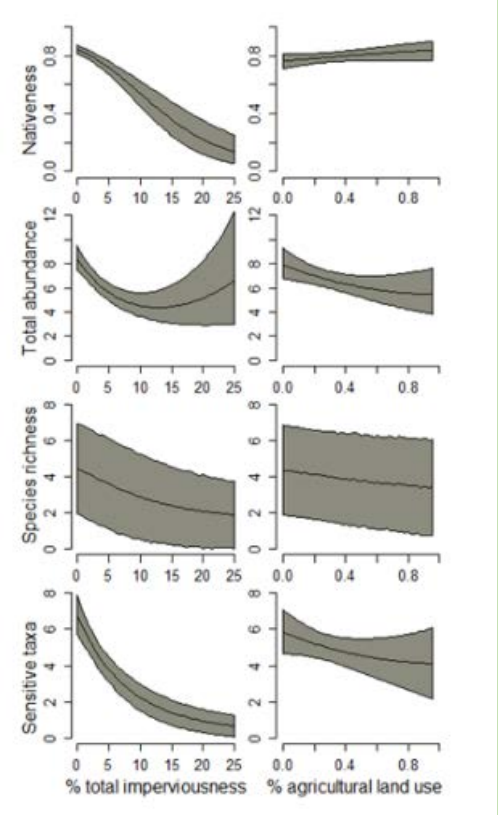
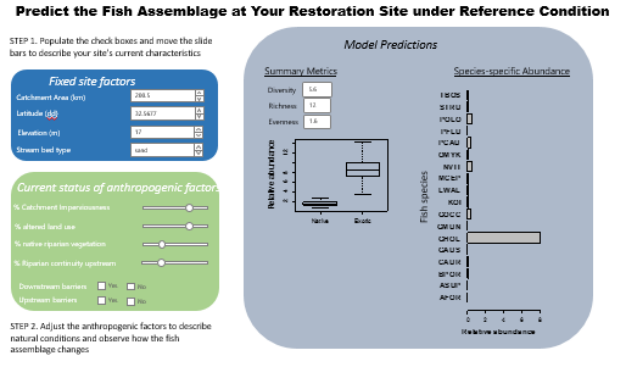
By December 31 – the framework and the restore tool will be embedded into literature and a suite of paper products. 5 papers to date have been submitted to journals.

The models will be held by Department of Water.

There is still a lot of work to undertake.





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Thank you.

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&
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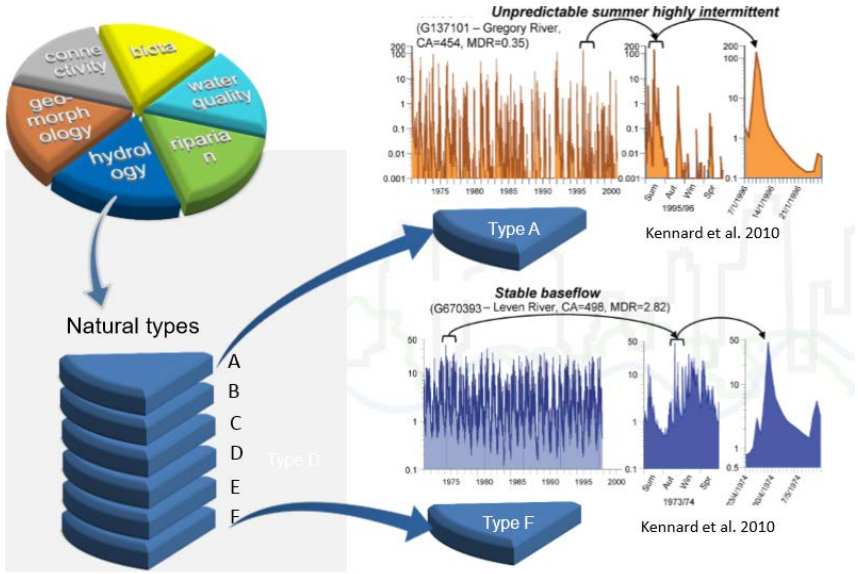
conne ctivity
biota
water quality
geo-morph ology
hydrol ogy
riparia n
Natural types
A
B
C
D
E
F
Type A
Type F
Unpredictable summer highly intermittent
(G137101 – Gregory River, CA=454, MDR=0.35)
Kennard et al. 2010
Stable baseflow
(G670393 – Leven River, CA=498, MDR=2.82)
Kennard et al. 2010


Magnitude
Frequency
Timing
Duration
Rate of rise & fall
Etc.