Recent research on constructed stormwater wetlands

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VICTORIA State Government

Melbourne Water
Enhancing Life and Liveability

Today's research topics

- Developing simple indicators of nitrogen and phosphorus removal in constructed stormwater wetlands
- Factors influencing the water level regime and vegetation cover in constructed stormwater wetlands
- How do toxicants influence constructed stormwater wetland performance and maintenance?
- Real-time control and monitoring of stormwater wetlands to deliver their potential

Healthy Waterways Strategy 2018-2028

Port Phillip & Westernport, Victoria

Key Research Areas

Stormwater management and flooding

Improving our understanding of how system design to prevent flooding needs to be altered to accommodate the impacts of climate change

Improving stormwater treatment performance and determining the optimal maintenance of WSUD systems

Understanding the costs and benefits of various stormwater management interventions for biodiversity, amenity and recreational outcomes

Developing improved technologies and systems to support stormwater harvesting and re-use

Identifying and addressing institutional and structural barriers to implementation of IWM

Developing decision support tools to inform the most effective stormwater treatment systems and locations to protect waterway biodiversity, amenity and recreation

Developing simple indicators of nitrogen and phosphorus removal in constructed stormwater wetlands

THE UNIVERSITY OF MELBOURNE
Waterway Ecosystem Research Group
School of Agriculture, Food and Ecosystem Sciences

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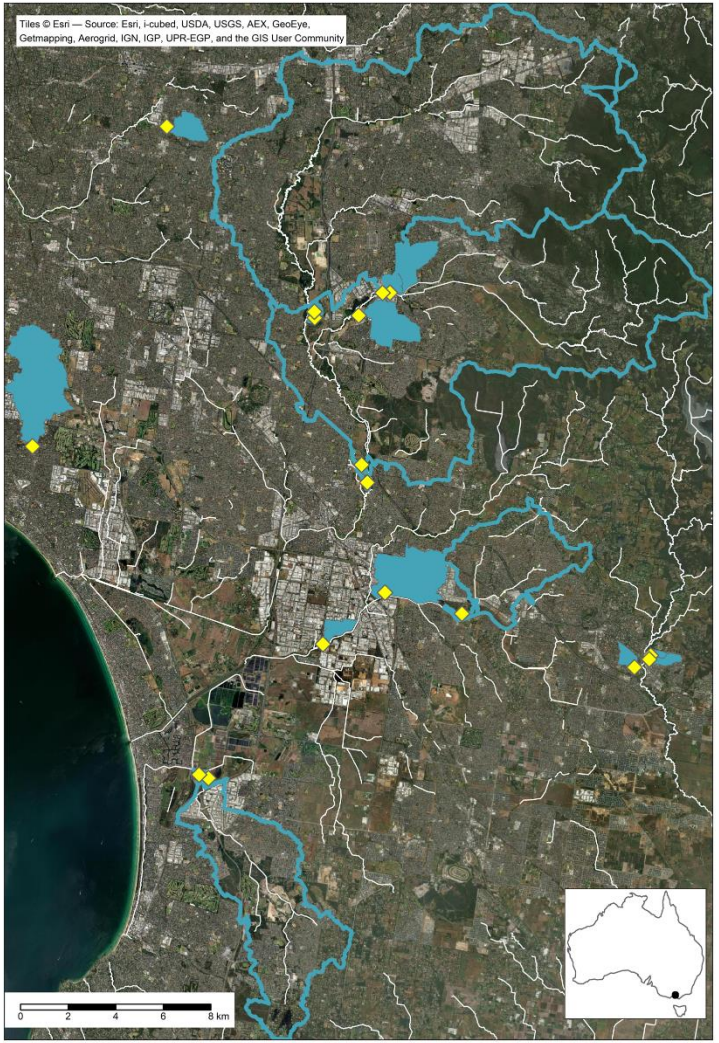
Aim & approach

Can we predict treatment performance from vegetation cover (and water level)?

- 17 wetlands
- 30 sampling events over 2 years
- Water level metrics (spells, recession, median)
- Vegetation cover (WAVE & GHD)



Sense checking the experimental approach

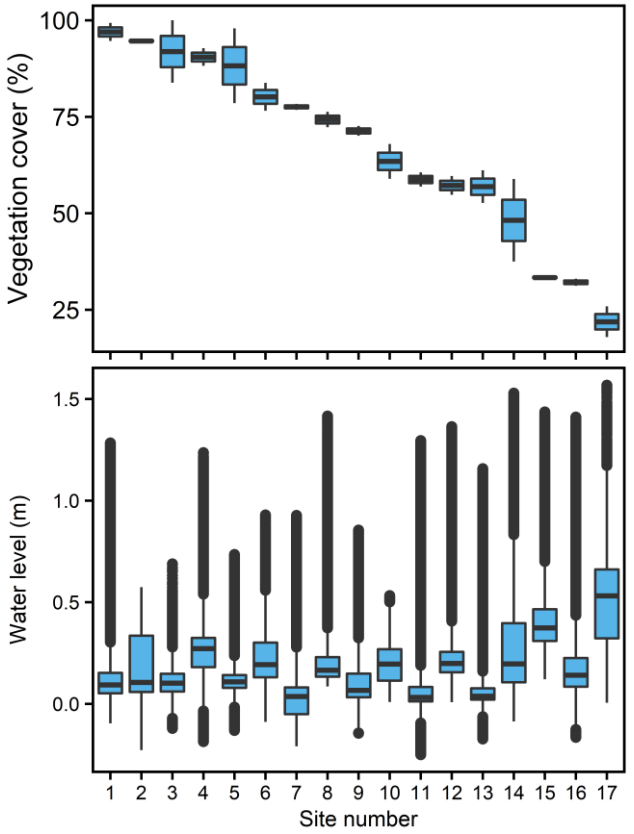
Will this work? What will it mean?

- Vegetation cover across the sites:

  26 – 98%

- Median water levels:

  0 – 0.5 m above the design normal water level (NWL)



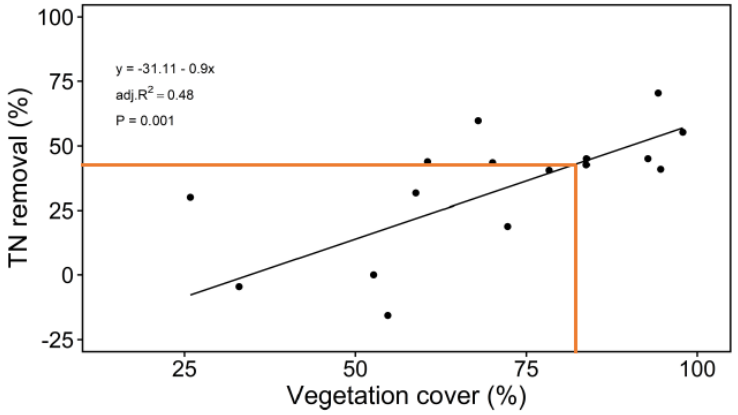
Water quality: overview

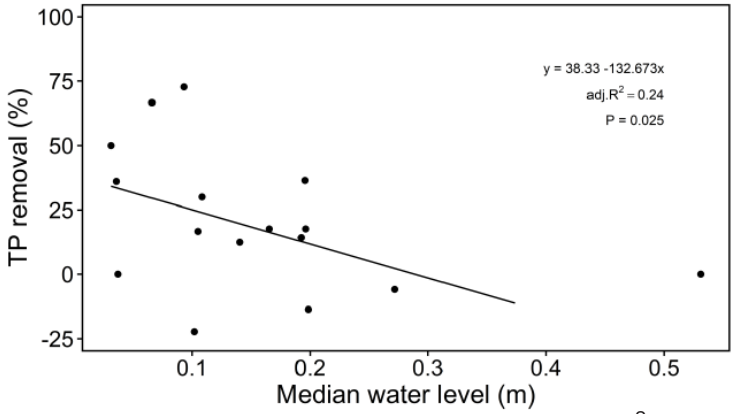
	Inlet (mg/L)	Outlet (mg/L)	BPEM/ANZG (mg/L)
TSS	22	21	30 / -
TP	0.10	0.09	0.19 / 0.05
TDP	0.036	0.022	- / -
TN	1.4	0.9	1.2 / 0.5
NO_x	0.64	0.11	- / 0.04
DON	0.44	0.42	- / -
PON	0.20	0.28	- / -

- Outlet TSS, TP and TN are less than BPEM targets
- Particulate N and P pass through (as does TSS)
- Retention of dissolved N and P better
- TN reduction driven by NO_x removal
- Organic N passes through

Water quality: digging a little deeper

- Vegetation cover is a good predictor of TN removal
  - Statistically significant for % removal, not for raw concentration
  - 10% vegetation reduction = 10% reduction in TN removal efficiency
- TSS and TP removal not related to vegetation cover
  - Marginally related to water level
- No sites with ”zero” vegetation cover, but
  - Likely that sites with low veg cover are generating N
  - “Leaky N” is organic (mainly dissolved)
- Backs requirements for a minimum of 80% vegetation cover for effective treatment
  - Of total asset area, not just planted zones





Factors influencing the water level regime and vegetation cover in constructed stormwater wetlands

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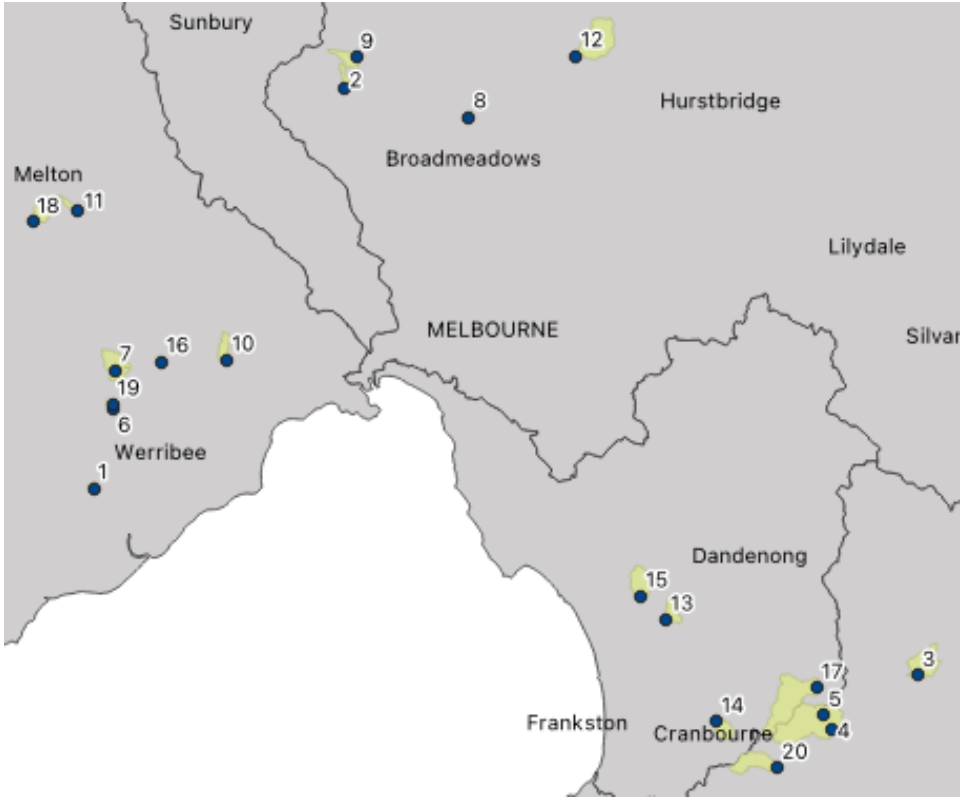
Water level monitoring of "developer wetlands"

Why?

- Check that wetlands are operating as intended
- Identify and fix any issues before they are handed over

Opportunity to explore the influence of design and catchment characteristics on water level regimes, e.g.

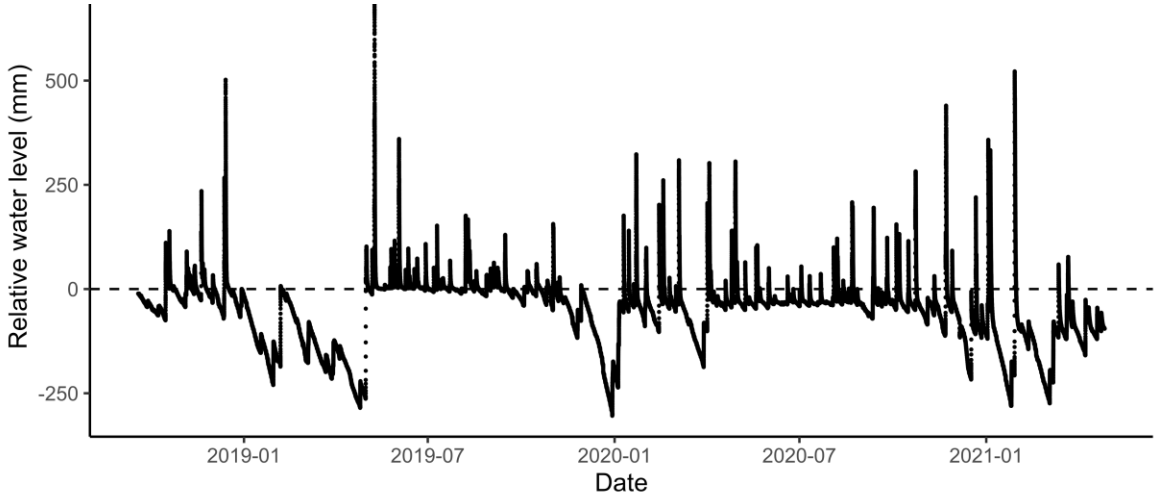
- Online/offline
- In/not in retarding basin
- With/without high flow bypass
- Outfall configuration



What do we mean by “water level regime”?

Typical elements:

- Normal water level (NWL)
- Periods of inundation
- Periods of drawdown
- Dry (no standing water)



Characterising the water level regime

MUSIC Auditor checks:

1. **Median water level**

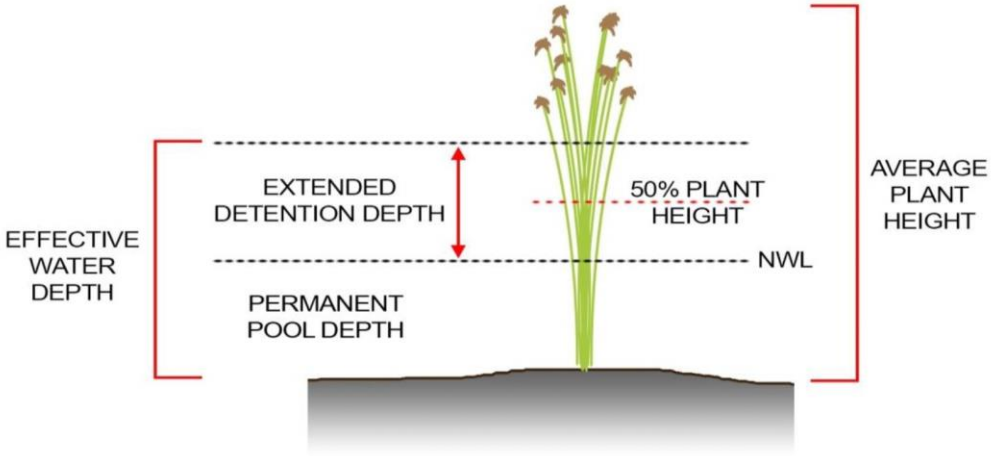
Should not be significantly above the design NWL

2. **Plant inundation frequency**

Water levels should not exceed 50% of the mature plant height more than 20% of the time

3. **Inundation spells**

Depths >300 mm above the NWL for >10 days should occur no more than once in 10 years

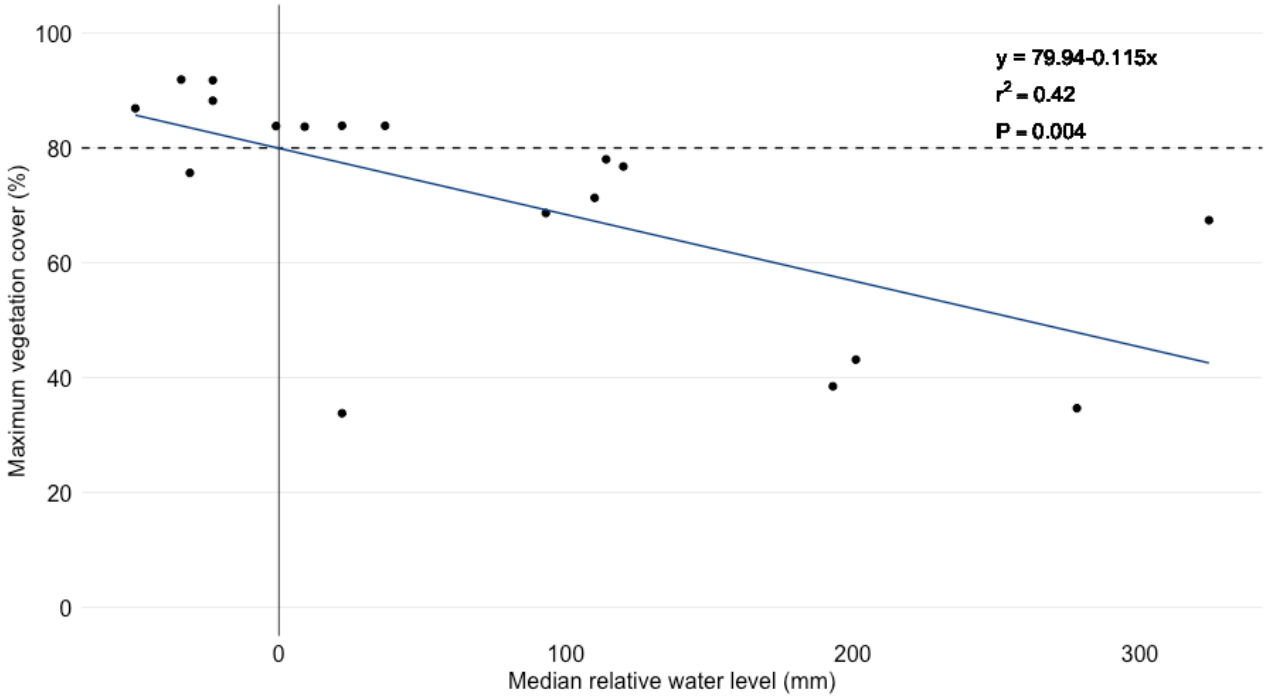


Relationship between water level and vegetation cover

Wetland	1	2	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Vegetation cover (%)	92	78	35	87	84	84	84	77	88	69	43	34	38	76	71	84	92	67
Median water level (mm)	-34	114	278	-50	9	37	22	120	-23	93	201	22	193	-31	110	-1	-23	324
Plant inundation frequency: shallow marsh	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	Y	Y	Y	Y
Plant inundation frequency: deep marsh	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	NA	Y	Y	Y	Y	Y	Y	Y
10+ day spells/yr >300mm	0	0	3.8	0	0	0	0	0	0	0	2.0	0	0.3	0	0	0	0	1.4

- Plant inundation frequency and spells check mostly ok
  - Don’t explain variation in vegetation cover
- Some alignment of high water levels and low vegetation cover
  - Median water level >100 mm above design NWL at 7 sites

Relationship between water level and vegetation cover



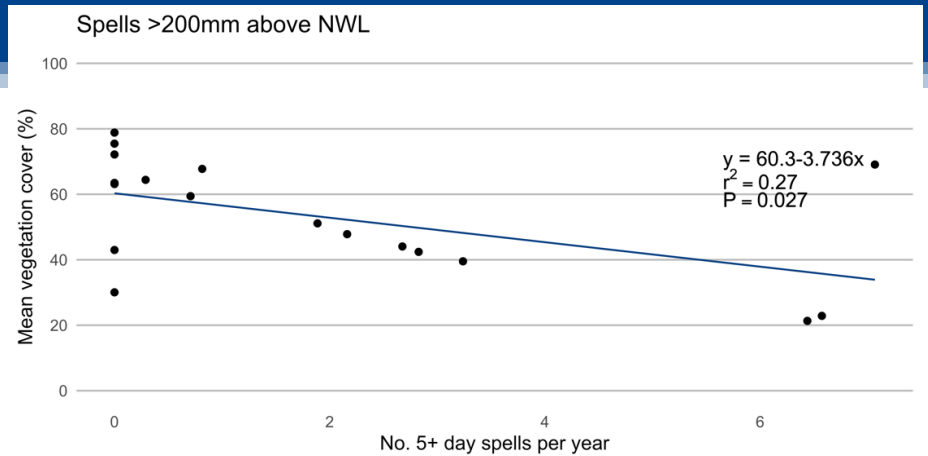
A bit more on spells…

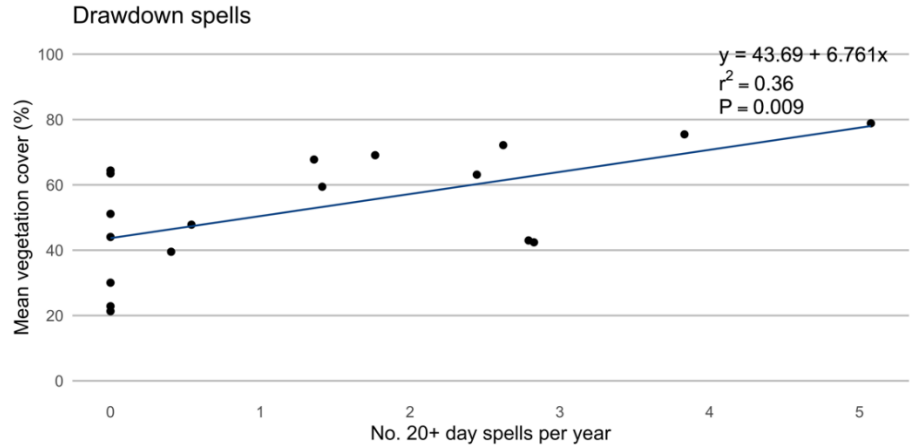
Depth:

- Inundation: 100 mm, 200 mm, 300 mm above NWL
- Drawdown: <NWL
- Dry (no standing water)

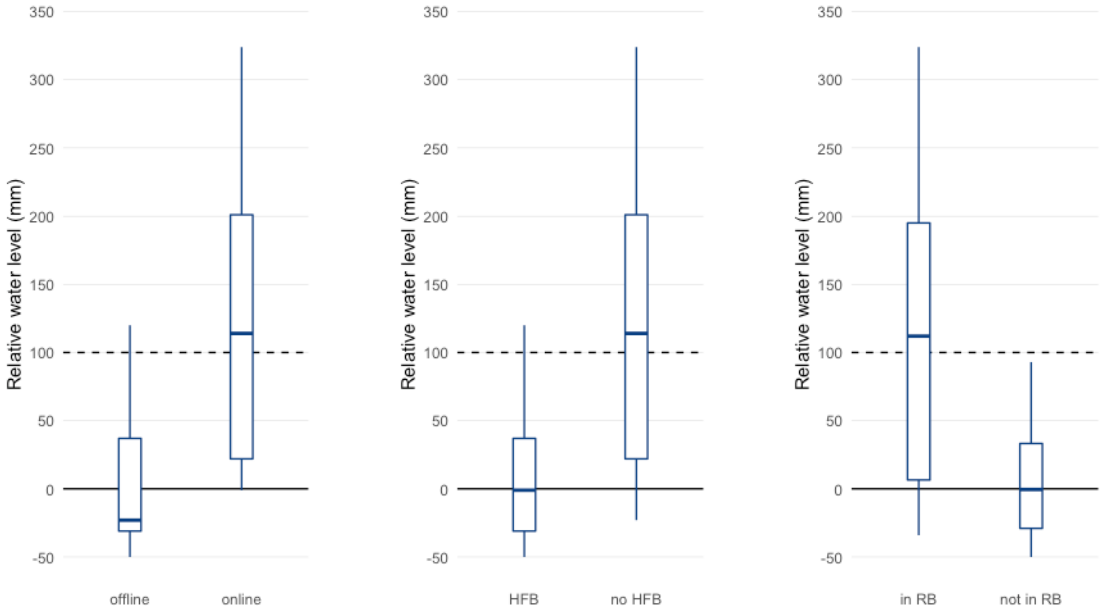
Duration:

- 5+, 10+, 20+ days





What's driving the water level regime?



Multiple influences, but we can see that higher water levels occur in:

- Online wetlands
- Wetlands without a high-flow bypass (HFB)
- Wetlands located in retarding basins (RB)

Summary & recommendations

- Vegetation cover clearly related to water level regime
- Water level characteristics linked to high vegetation cover:
  - Median water level within 100 mm of design NWL
  - Regular drawdown and drying spells
  - Rapid return to NWL following inundation
- Risk factors for unsuitable water level regime:
  - Online, no high-flow bypass, in retarding basin
- Continuously monitor constructed wetland water levels
  - *Likely* earlier indicator of potential problems than declining vegetation cover, plus informs corrective works

How do toxicants influence constructed stormwater wetland performance and maintenance?

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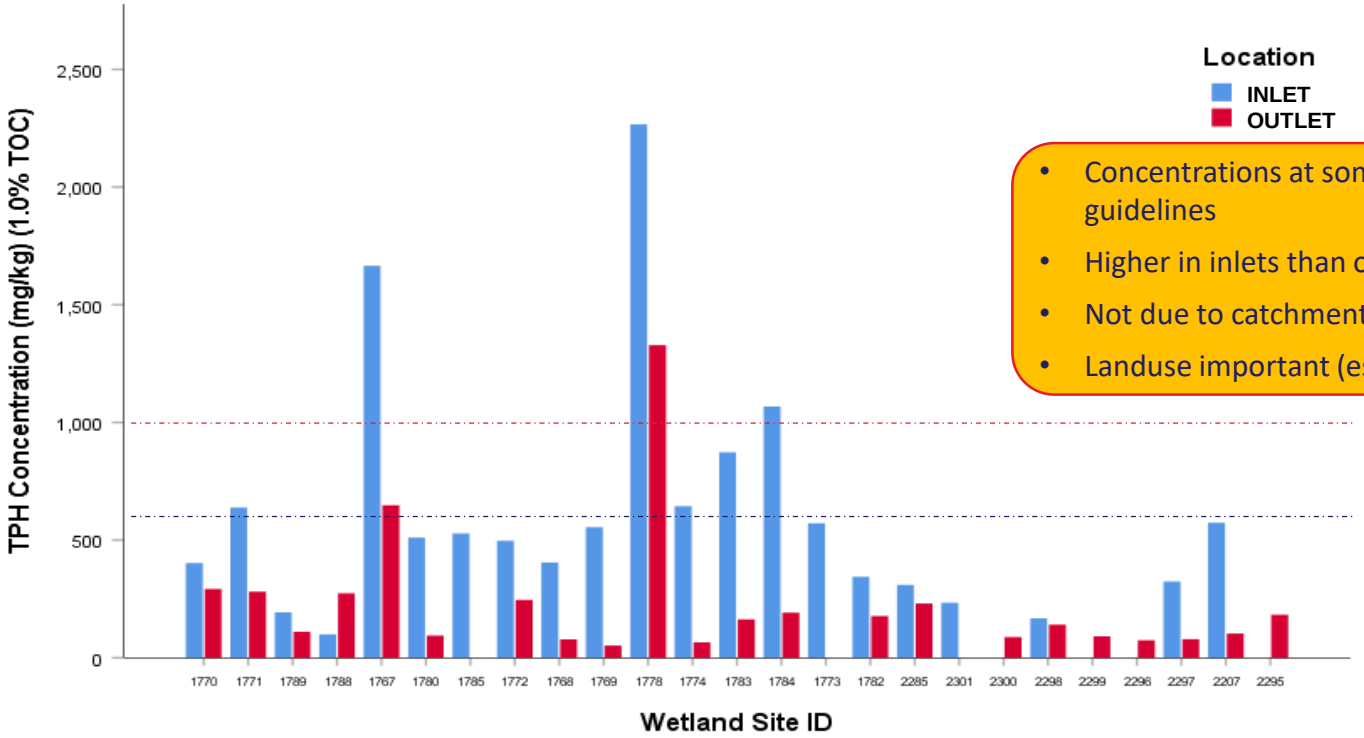
Toxicants in Constructed Wetlands

- How do toxicants influence constructed stormwater wetland performance and maintenance?
  - Which toxicants accumulate in sediments?
  - Which toxicants remain in the water column?
  - Where do the toxicants come from?
  - What are the priority chemicals affecting wetland performance and/or maintenance?
  - How do toxicants influence waste disposal costs?
  - Are the concentrations likely to be toxic to resident biota?
  - Are the concentrations likely to affect wetland performance (e.g. biofilms, veg cover)?

Total Petroleum Hydrocarbons in Sediments



- Concentrations at some sites exceed guidelines
- Higher in inlets than outlets
- Not due to catchment age
- Landuse important (esp. industrial)

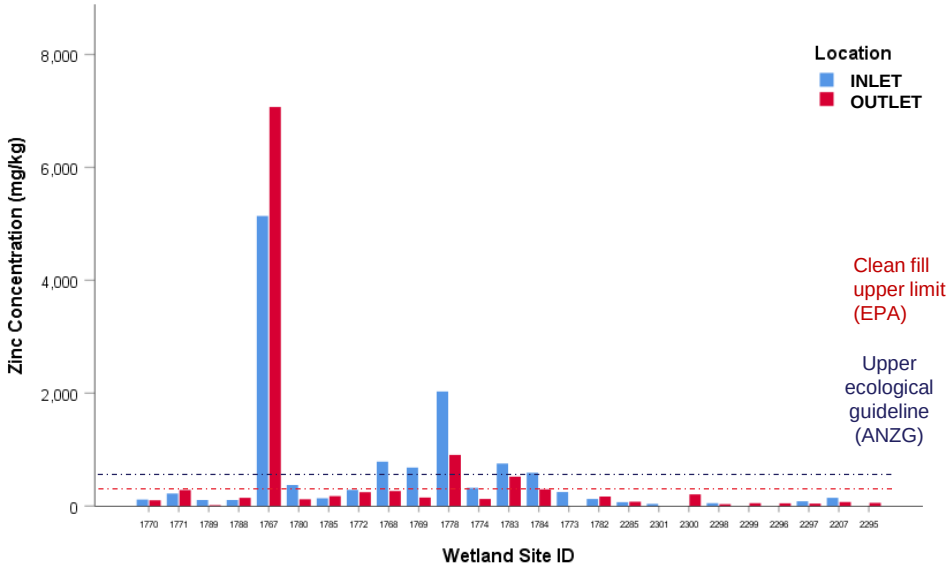
Clean fill upper limit (EPA)

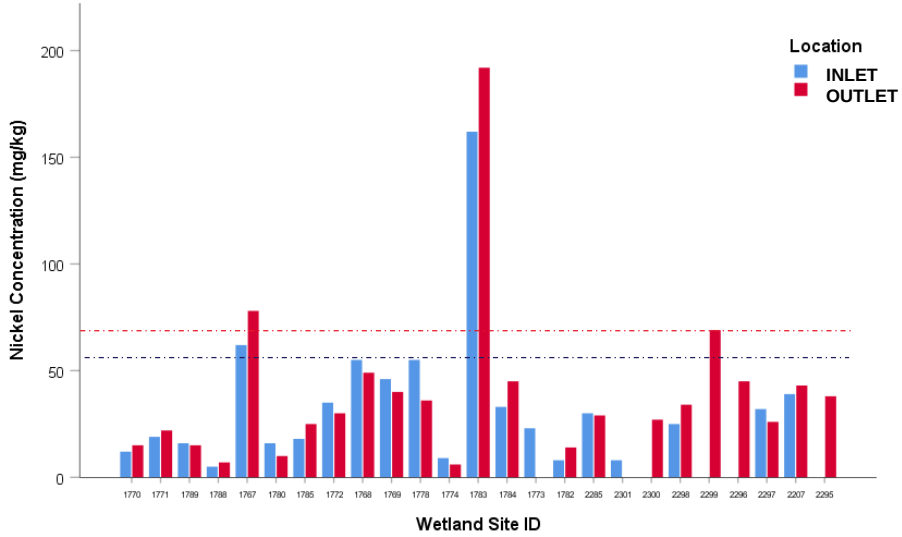
Upper ecological guideline (ANZG)

Catchment Age: Oldest → Youngest

Major Metals in Sediments

- Concentrations at some sites exceed guidelines
- Sometimes higher at outlets
- Not due to catchment age
- Landuse important (esp. industrial)

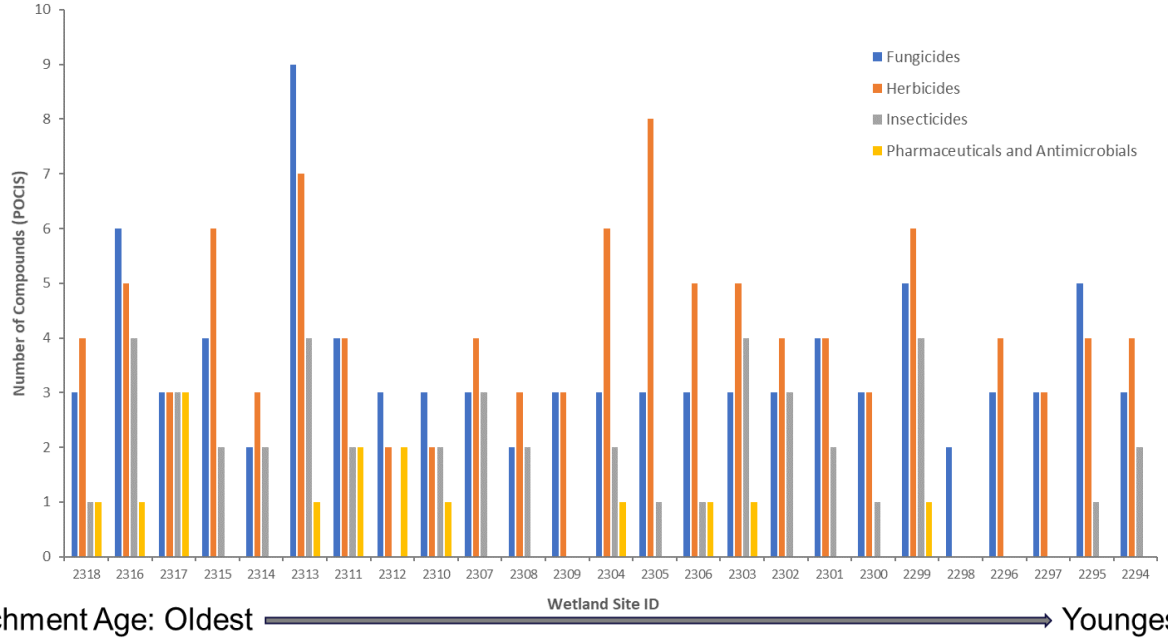




Catchment Age: Oldest → Youngest

Pesticides and Pharmaceuticals in Water:
POCIS

- Water soluble chemicals detected all sites
- Predominantly fungicides, herbicides and insecticides
- Few detections of pharmaceuticals
- Frequently detected chemicals – targets for further testing (concentration data, toxicity test data)



Chemical Group	Compound	Number of Detects	Percent Detects
Fungicides	Carbendazim	24	96
	Tebuconazole	24	96
	Propiconazole	17	68
	Metalaxyl	6	24
Herbicides	Diuron	23	92
	Simazine	19	76
	Metolachlor	15	60
	Atrazine	14	56
	Propyzamide	12	48
	Bromacil	6	24
Insecticides	Imidacloprid	16	64
	Chlorantaniliprole	13	52
	Thiamethoxam	9	36
Pharmaceuticals & Antimicrobials	Paracetamol	6	24

Implications for Stormwater Harvesting

- Presence of water soluble contaminants in outlet pools
- >50 pharmaceuticals and pesticides have been detected
- Include several fungicides, herbicides and insecticides

Chemical Group	Compound	Grab sample chemical analysis available (concentration data)	Ecological guidelines exist (or in progress) (ANZG, 2018)	Human health guidelines exist (ADWG, 2022)
Fungicides	Carbendazim	YES	✗	✓
	Iprodione		✗	✓
	Metalaxyl		✗	✗
	Propamocarb		✗	✗
	Propiconazole		✓	✓
	Tebuconazole		✗	✗
Herbicides	Atrazine		✓	✓
	Bromacil		✓	✓
	Diuron		✓	✓
	Ethofumesate		✗	✗
	Metolachlor		✓	✓
	Propyzamide		✗	✓
	Simazine		✓	✓
Insecticides	Buprofezin		✗	✗
	Chlorantraniliprole		✗	✓
	Fipronil		✓	✓
	Imidacloprid		✓	✓
	Thiamethoxam		✗	✗
Pharmaceuticals & Antimicrobials	Paracetamol		✗	✗

- *Are the concentrations high enough to be of concern? (human health/ecological)*
- *Are additional treatments required to get the treated stormwater to a quality good enough for reuse?*

Priority waste contaminant limits

- Disposal of contaminated sediments from wetlands is expensive
- Several toxicants exceed upper limits for clean fill
- Better understanding of where toxicants come from, and the prevailing concentrations in sediments will help inform suitable maintenance schedules and management options

Priority waste category	*Cost/tonne ($)
Category A	prohibited
Category B	257.76
Category C	105.90
Category D Industrial waste	105.90
Soil containing asbestos	30.96

*Priority waste rates 1 July 2021 to 30 June 2022 (2021–22)

https://www.epa.vic.gov.au/for-business/find-a-topic/landfill-guidance/waste-levy

CLEANFILL LIMITS

Contaminant	Fill material upper limit TC as dry weight (mg/kg)
Inorganic species	
Arsenic	20
Cadmium	3
Chromium (VI)	1
Copper	100
Lead	300
Mercury	1
Molybdenum	40
Nickel	60
Tin	50
Selenium	10
Silver	10
Zinc	200
Anions	
Cyanide	50
Fluoride	450
Organic species	
Phenols (halogenated)[1]	1
Phenols (non-halogenated)[2]	60
Monocyclic aromatic hydrocarbons[3]	7
Benzene	1
Polycyclic aromatic hydrocarbons[4]	20
Benzo(a)pyrene	1
C6-C9 petroleum hydrocarbons	100
C10-C36 petroleum hydrocarbons	1000
Polychlorinated biphenyls	2
Chlorinated hydrocarbons[5]	1
Pesticides	
Organochlorine pesticides[6]	1

EPA Victoria (2021) Waste disposal categories – characteristics and thresholds, Publication 1828.2 March 2021.

Metal Concentrations and Landuse

Spearman's correlations, major metal and landuses

	Copper	Lead	Nickel	Zinc
Effective Imperviousness Area (EIA %)	+++	++	++	++
All Industrial (%)	++	++	+	+++
Commercial & Public (%)	++	+++	+	+++
Roads (%)	+		+	
Railway (%)		+		+
Waterways (%)	- -	-		- -
Urban Grassland (%)	- -	- - -		- -

- Metal concentrations **increase** as these landuses increase in a catchment
- Metal concentrations **decrease** as these landuses increase in a catchment

Summary and Recommendations

- Several toxicants present in sediments and water of stormwater wetlands
- Some toxicants exceed ecological and waste disposal guideline values
  - Implications for wetland performance and maintenance (and stormwater reuse)
- Priority waste incurs additional disposal expenses. Several wetlands exceed clean fill guidelines.
  - Use knowledge of what toxicants are responsible to better target maintenance activities
- Metal concentrations are correlated with different landuses
  - Use knowledge of these associations to inform management decisions
- Research underway to determine toxic thresholds for common wetland toxicants to macrophytes and biofilms

Real-time monitoring and control of stormwater wetlands to deliver their potential

Professor David McCarthy

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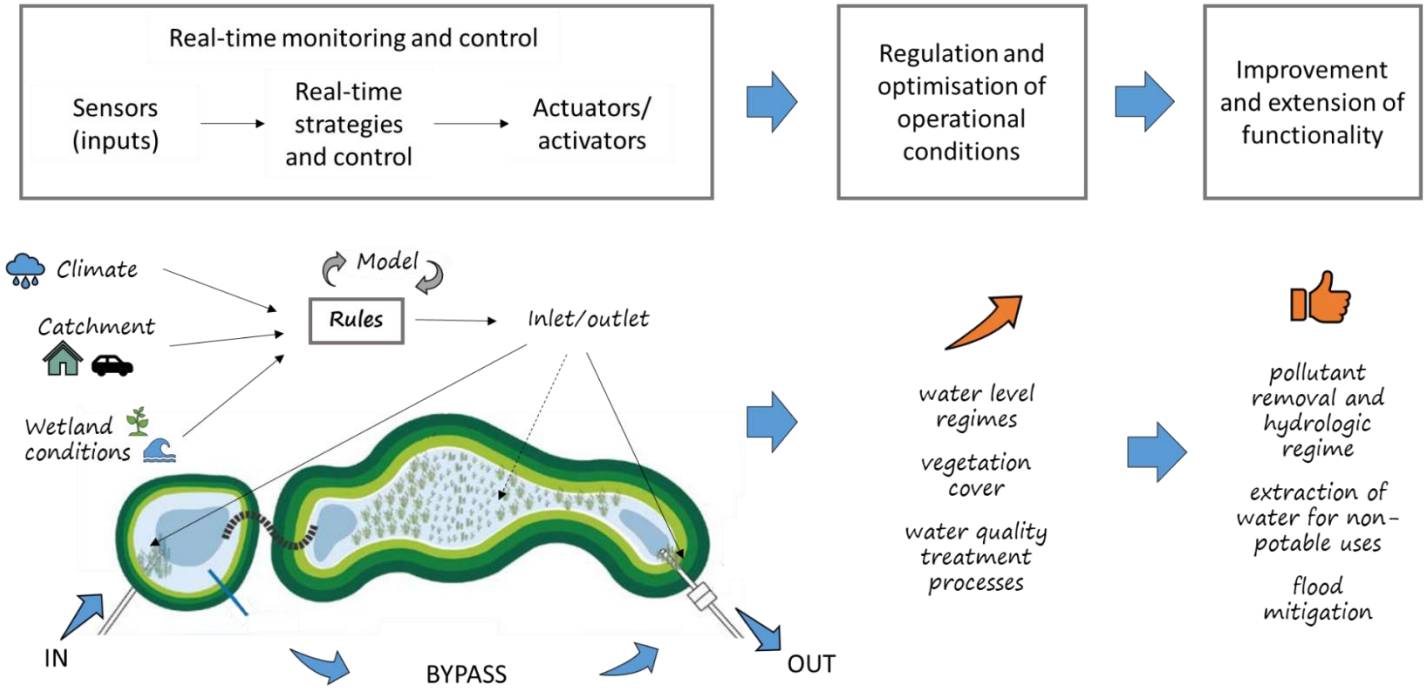
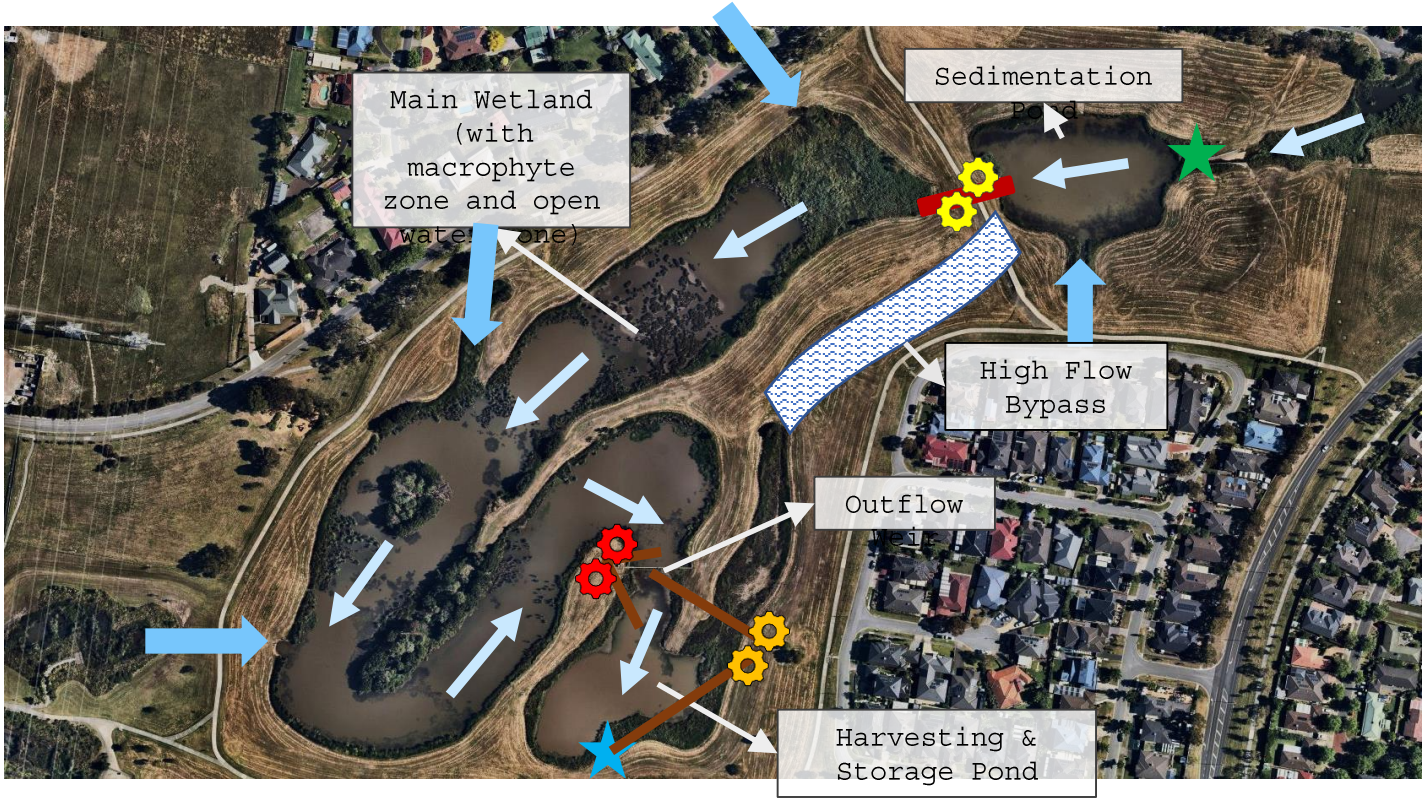
What will the research involve?

APPLYING DYNAMIC MONITORING AND CONTROL TO STORMWATER CONSTRUCTED WETLANDS



Troups Wetland project background



Legends

- Sedimentation Pond Inlet
- Harvesting Pond Outlet
- Flow Direction
- Other Stormwater Inflow
- Underground Pipe
- Inlet Control Actuator
- Outlet Control Actuator
- Baseflow Control Actuator

BoSL

EPHM Lab

Real-Time Monitoring

Real-Time Monitoring Sensor Locations
Troups Creek Wetland

- Low-Cost BoSL Radar Velocity and Depth Sensors
- Low-Cost BoSL Turbidity Sensors
- Greenspan Turbidity Sensors
- Greenspan Depth Sensors
- Wetland Inlet
- Wetland Outlet

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