

## On-site Wastewater Management Training Course

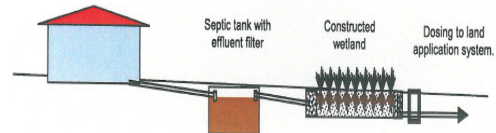
### Secondary Treatment; Constructed Wetlands

Honorary Associate Professor Phillip Geary  
School of Environmental & Life Sciences  
The University of Newcastle NSW

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### Constructed Wetlands (Reed Beds)

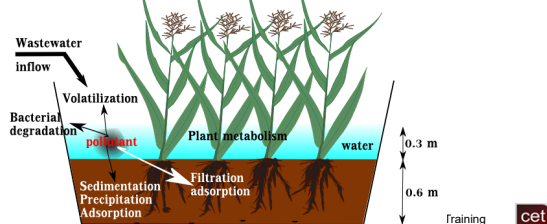
- Increasingly popular as a secondary treatment option to achieve secondary treatment (BOD, TSS and FC reduction)
- Low-maintenance and relatively inexpensive option
- Robust performance and seen as “natural” treatment - “ecotechnology”
- Local approvals for CWs may be granted for specific or innovative designs which consider site constraints, hydraulic load and required HRT



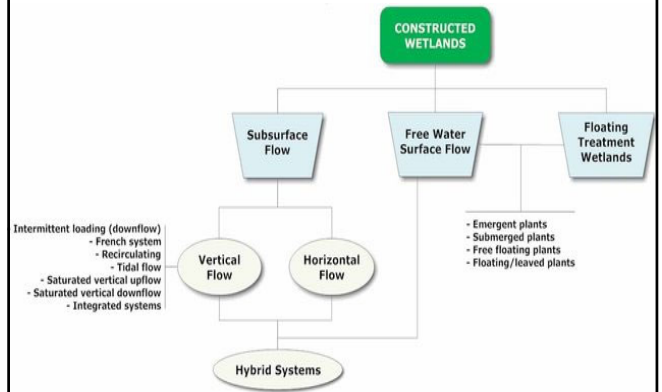
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### Treatment Processes in CW

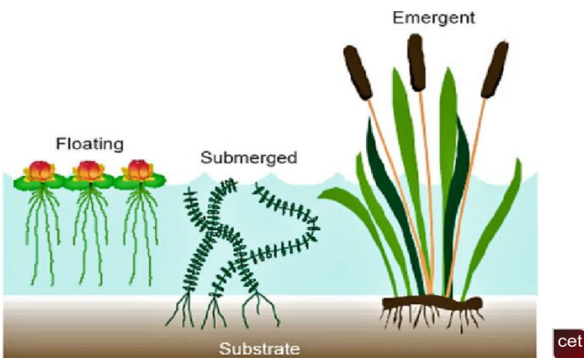
- Sedimentation, filtration and adsorption
- Gas loss/volatilization
- Uptake of metals and nutrients by plants
- Bacterial degradation due to: ultra-violet light exposure, die off & predation
- Decomposition of organic matter



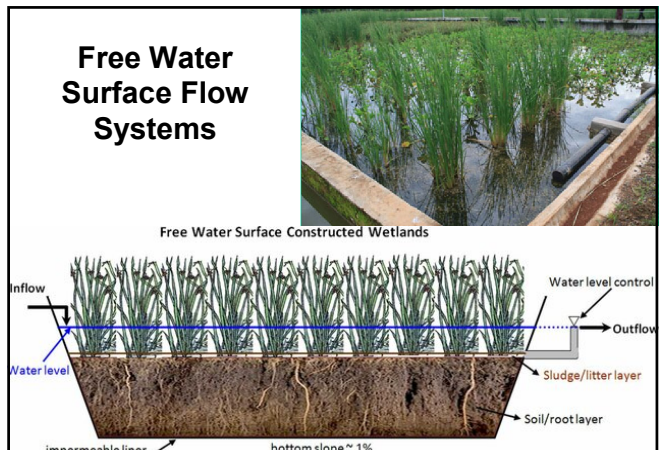
### CW Classification

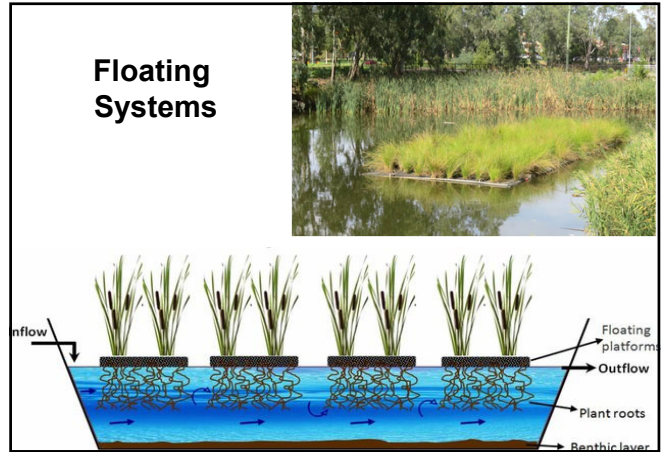
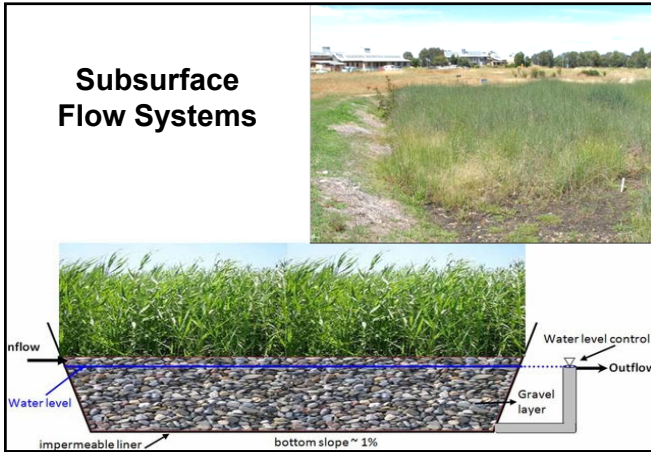


### Macrophyte Plants Cultivated in CW



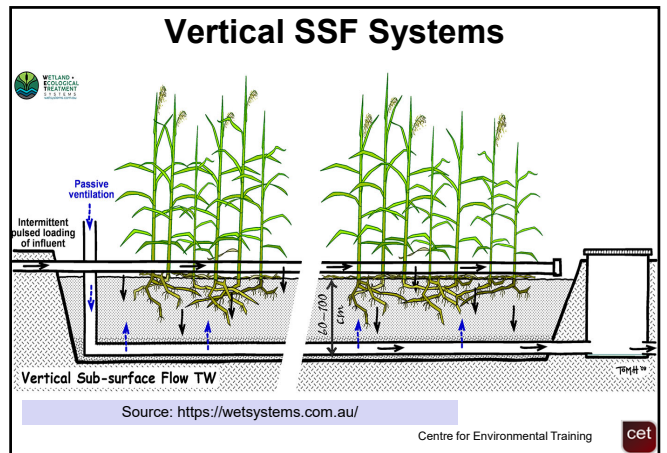
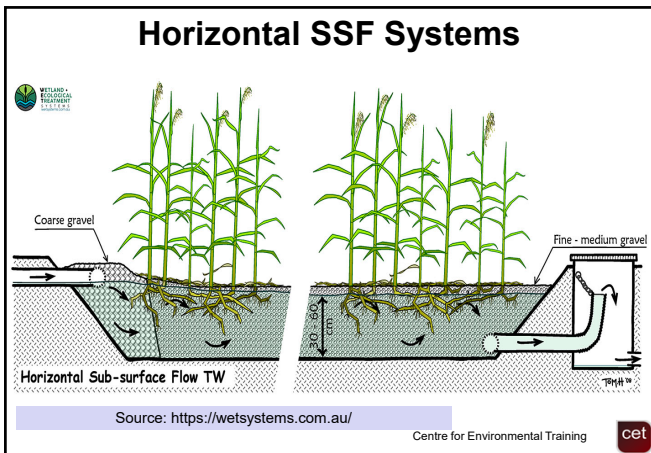
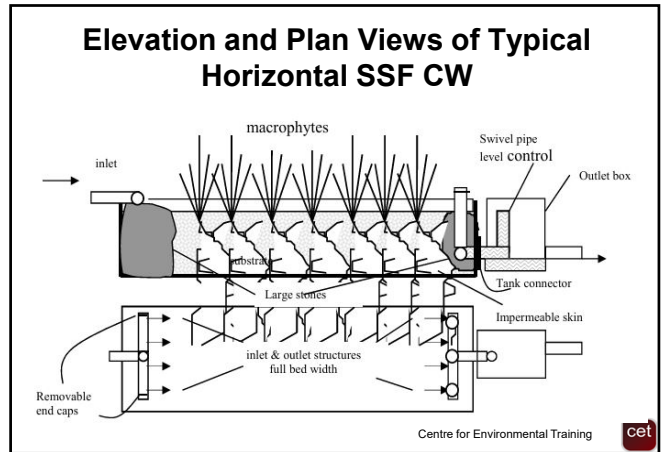
### Free Water Surface Flow Systems





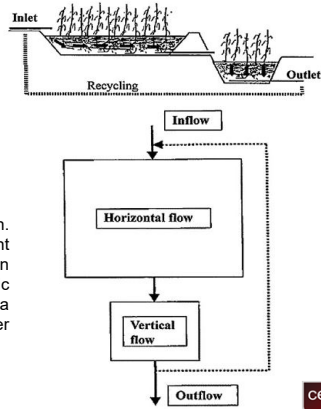
### SSF Systems

- Preferable for domestic on-site treatment
- Used for treating combined domestic load or greywater (also for excess from "dry" composting systems)
- Installed after primary treatment devices and considered a secondary treatment system
- Grease and fat removal in septic tank pre-wetland
- CW may be integrated with site landscape plan



## Hybrid CW System consisting of combined vertical and horizontal SSF systems

Designed to achieve N reduction. Nitrified effluent is returned to front end of system where denitrification can take place in less aerobic horizontal bed using inflow as a source of carbon needed for further treatment to occur.

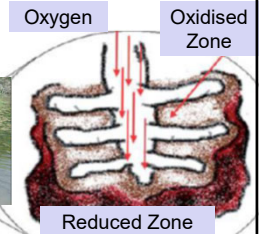


## What Do Plants Do?

- Control algal growth
- Take-up nutrients
- Provide an oxygen source
- Develop strong algal and bacterial biofilms in root zone where treatment occurs

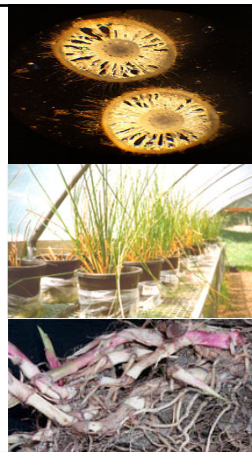


Source: Aqua Biofilter



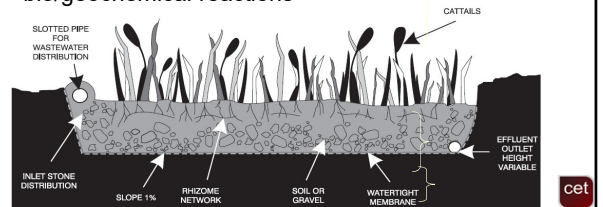
## What Do Plants Do?

- Transport gases to and from the root zone via **aerenchyma** which are airways running from the aerial parts of the plant to the roots
- Aerenchyma assist with gas diffusion
- Rhizomes provide sites for oxidation while adjacent soils remain anaerobic (biofilms grow on submersed stems and leaves)
- Bacteria colonise and perform a wide variety of chemical conversions

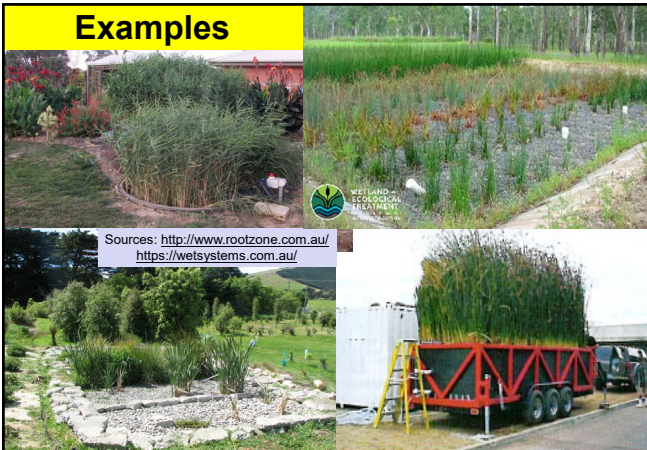


## Role of Substrate

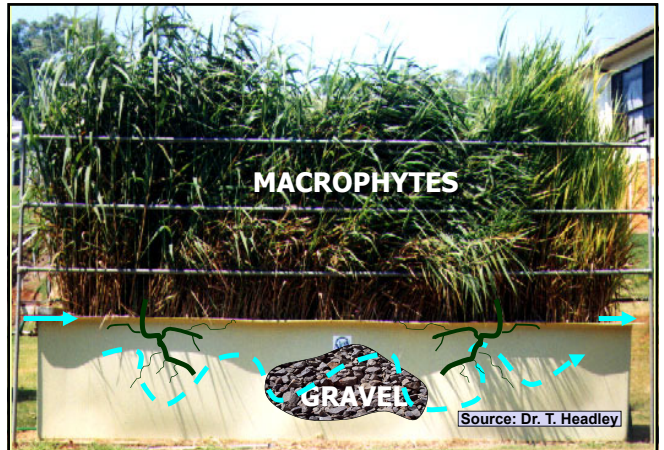
- Provide rooting medium for wetland plants
- Support nutrients for plant growth
- Provide capacity to store water in pore spaces
- Adsorb to limited degree contaminants and reduce effluent concentrations
- Buffers pH which assists in maintaining uniform bio/geochemical reactions



## Examples



## MACROPHYTES



### Aerated Wet Cell System

(UbiAqua 7.3 m<sup>3</sup>)

Approved for advanced secondary (AS1546.3)

Turbidity	TSS	BOD5	Ecoli	Dissolved Oxygen
<5 NTU	<5mg/Litre	<4.4mg/Litre	<10 du	>3.75mg/Litre

Average water quality test results

<https://www.ubiagua.com.au/aerated-wet-cell-treatment-system/>

### Precast Concrete Beds

(Graham's Precast Concrete Products 7.2 m<sup>3</sup>)

<https://grahamprecast.com.au/reed-beds/>

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### Modified Plant System for Greywater

Greywater Sources

Pre-treatment

Soil-box planter

Dispersion

Irrigation

Source: A. Dakers

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### Design Considerations

- Site selection/location
- Sizing for design hydraulic load and HRT (as treatment is a function of HRT)
- Prefabricated units to be used or excavation
- Impermeable liner or compacted clay required if excavation
- Design using multiple beds in series?
- Inlet structures to ensure uniform flow distribution
- Adjustable water level control
- Outlet/collection devices - dosing sump and pump well capacity
- Gravel sizes
- Plant species to be used and maintenance including vegetation and weed management

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### Domestic Sizing

- Sizing can be based on simple rule-of-thumb approaches for "typical" situations
- Design guidelines often suggest different specific area requirements for different Design Occupancies (EPs) to achieve a Secondary Quality (20/30) Standard, OR a specific HRT to achieve that standard
- Examples are:
  - 2 m<sup>2</sup> up to 6 m<sup>2</sup> of wetland treatment area per EP/day for combined wastewater
  - Minimum 5 days HRT typically recommended
  - For greywater design using 3 m<sup>2</sup>/EP/day

Source: <https://wetsystems.com.au/>

Examples	Combined Wastewater	Greywater Only
Area of Reed Bed	24 m <sup>2</sup>	17 m <sup>2</sup>

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### Example of SSF Area and Dimensions

BR/PE	Hydraulic Load (L/d)	Surface area (m <sup>2</sup> )	Suggested width (m)	Suggested length (m)	L:W ratio
3/5	900	30-33	4.5	7.2	1.6

Source: Table 1 in Tanner, C. Headley, T. & Dakers, A. (2011) Guideline for the Use of Horizontal SSF Constructed Wetlands in On-site Treatment of Household Wastewaters, NIWA, Hamilton, NZ

### Rule of Thumb Sizing (HRT 7 days)

Water Depth (m)	Surface Area/p All Wastewater (m <sup>2</sup> )	Surface Area/p Greywater (m <sup>2</sup> )
0.3	6.5	5
0.4	5	4
0.5	4	3
0.75	3	2.5

Source: Table 1 in Lismore City Council (2005) The Use of Reed Beds for the Treatment of Sewage and Wastewater from Domestic Households

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### Simple Sizing Approach

- Designs often site specific but minimum 5-day HRT to achieve Secondary Standard
- Volume (V) = (Hydraulic Residence Time × Daily Hydraulic Load) / Porosity of Substrate
- Example: CW system dosed with Primary treated effluent from 3-4 br house (EP 5) with on-site tank water supply (150 L/p/d)
  - Volume (V) = (5-days HRT × 5 EP design hydraulic load) = (5 days × 750 L/day) = 3750 L
- If porosity of substrate material is 50% or 0.5, then 7500 L or 7.5 m<sup>3</sup> is approximate volume required
- Suitable length:width ratios considered to be around 4:1 to 1:1
- Optimal depth of CW should not exceed 0.6 - 0.7 m
- Assume 0.6 m depth & dimensions of 6.5 m long and 2 m wide (L:W 3.3) to give volume 7.8 m<sup>3</sup> - a rough estimate!

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## Gravel Media and Plants

- Depth of gravel bed media typically 40 - 50 cm with water level maintained about 5 cm below gravel surface
- Plant selection - native wetland nursery species
- Low stature and high stature growth forms (*plants/m<sup>2</sup>*)
- Issue of plant senescence and on-going maintenance (including whether to harvest) plus managing invasive weeds

Zone	Gravel	Size Range (mm)	Porosity (%)
Inlet & outlet zones	Coarse	40-60	45
Main wetland	Fine, angular	10-20	40

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## Recommended Species

### Floating plants:

- *Lemna spp*, *Wolffia spp*

### Submergents:

- *Myriophyllum*
- *Potamogeton*

### Emergents:

- *Typha*
- *Phragmites*
- *Eleocharis*
- *Schoenoplectus*
- *Baumea*



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## CW Performance

- Properly designed, installed and serviced SSF CW can provide secondary or advanced treatment of primary treated effluent
- Able to produce 20/30 standard TSS/BOD; median levels of FC can be reduced by approx. 99% (2 log reduction)
- Rely on HRT to achieve level of treatment
- Reduction of N and P varies widely over time and is by biomass uptake and substrate adsorption
- Often variable for TP but initially high, later decreasing depending on substrate used; can be good for TN but dependent on oxidation and biochemical conversion of N
- Treated effluent should be discharged to an appropriate land application system

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## Further Reading

- Lismore City Council (2005) The Use of Reed Beds for the Treatment of Sewage and Wastewater from Domestic Households, Lismore NSW
- Stephanakis, A. (2016) Constructed Wetlands: Description and Benefits of an Eco-Tech Water Treatment System, Chapter 12 in Impact of Water Pollution on Human Health and Environmental Sustainability, IGI Global
- <https://www.igi-global.com/chapter/constructed-wetlands/140180>
- Tanner, C. Headley, T. & Dakers, A. (2011) Guideline for the Use of Horizontal SSF Constructed Wetlands in On-site Treatment of Household Wastewaters, NIWA, Hamilton, NZ
- <https://wetsystems.com.au/>; <http://www.rootzone.com.au/>
- <https://grahamsprecast.com.au/reed-beds/>
- <https://www.ubiaqua.com.au/aerated-wet-cell-treatment-system/>

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