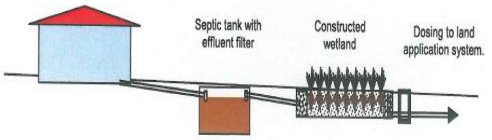
On-site Wastewater Management Training Course

Secondary Treatment; Constructed Wetlands

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

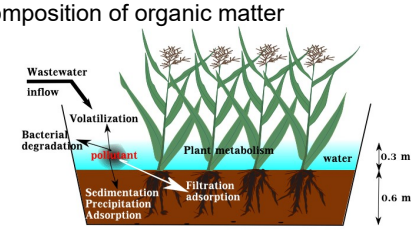
Constructed Wetlands (Reed Beds)

- Increasingly popular as a secondary treatment option to achieve secondary or advanced treatment (BOD, TSS and FC reduction)
- Low-maintenance, relatively inexpensive treatment & robust performance - a "natural" treatment - "ecotechnology"
- As with all on-site systems, refer to state agency websites for accredited or approved systems; in NSW local approvals for CWs can be given based on specific or unique designs by experienced professionals which consider site constraints, design hydraulic load and HRT

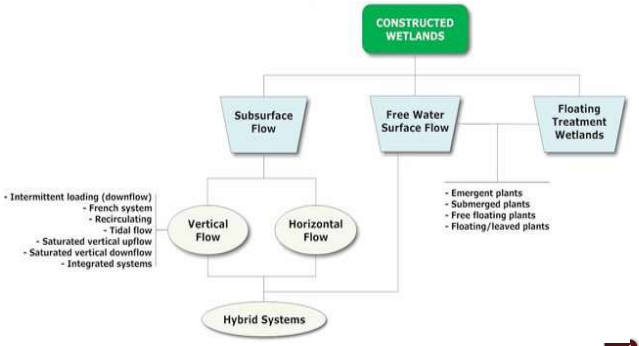


Treatment Processes in CW

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

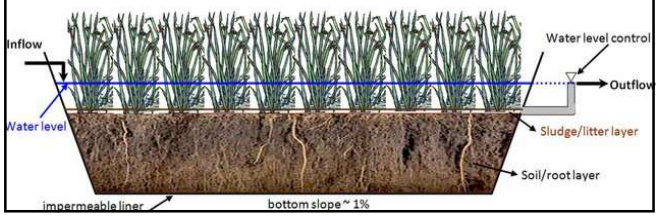


CW Classification

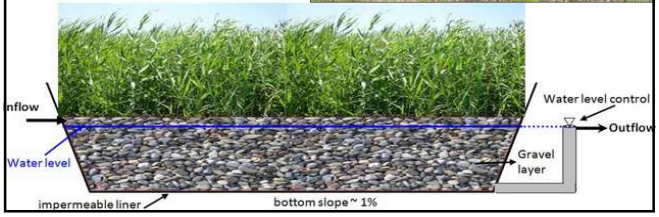


Free Water Surface Flow Systems

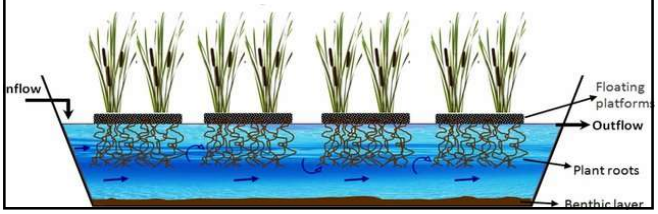
Free Water Surface Constructed Wetlands



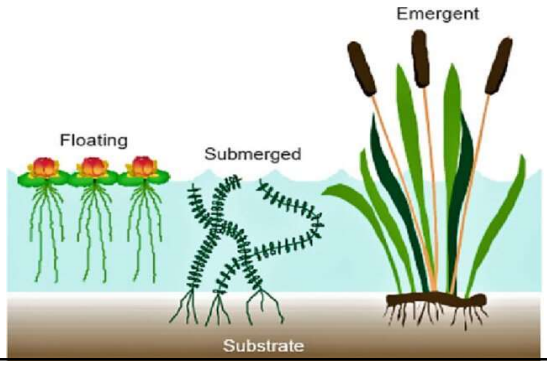
Subsurface Flow Systems



Floating Systems



Macrophyte Plants Cultivated in CW



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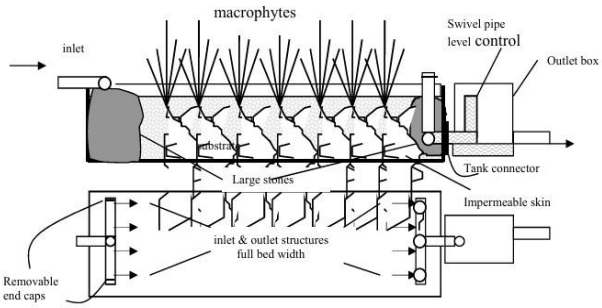
SSF Systems

- Preferable for <u>domestic</u> 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

Elevation and Plan Views of Typical Horizontal SSF CW



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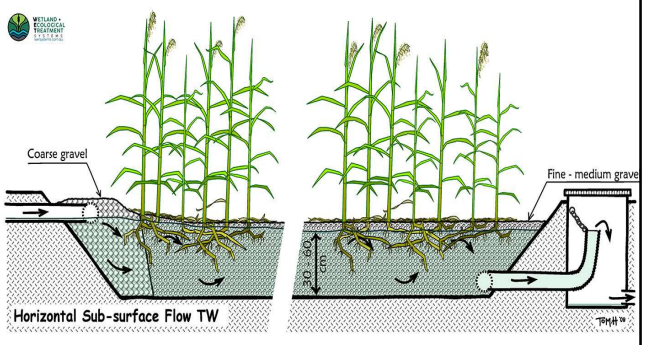
Horizontal SSF Systems



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

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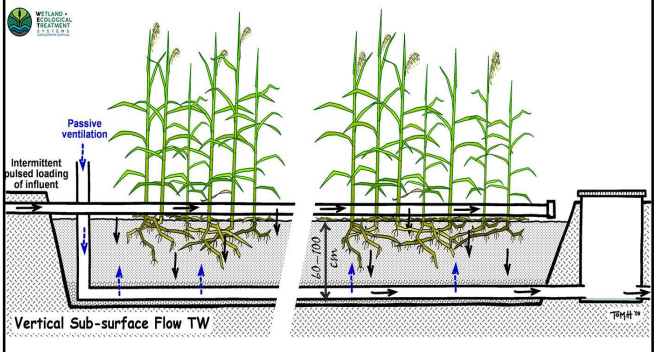
Vertical SSF Systems



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

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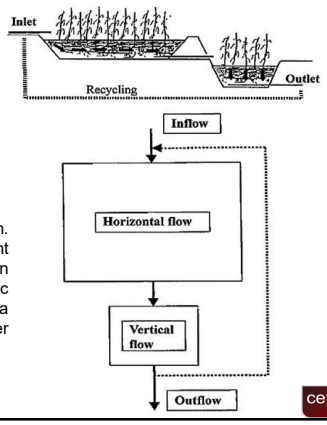
Hybrid CW System consisting of combined vertical and horizontal SSF systems

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.



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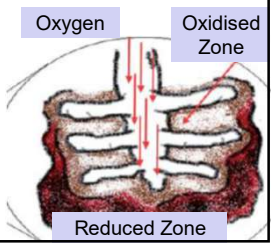
What Do Plants Do?

- 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

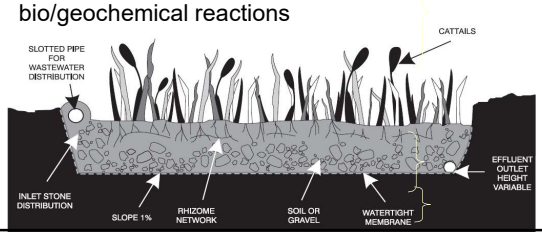


What Do Plants Do?

- 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



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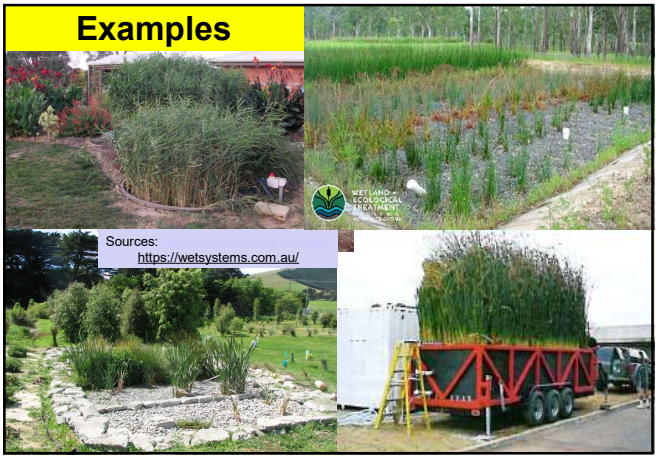
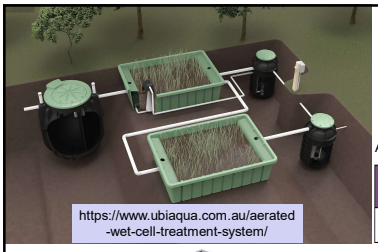
Examples



Sources:
https://wetsystems.com.au/

Source: Dr. T. Headley



https://www.ubiaqua.com.au/aerated-wet-cell-treatment-system/

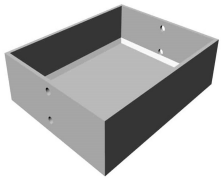
Aerated Wet Cell System

(UbiAqua 7.3 m³)

Approved for advanced secondary (AS1546.3)

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

Average water quality test results

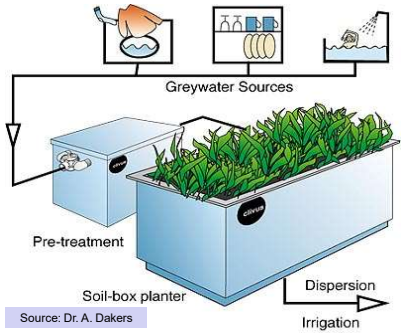


https://grahamsprecast.com.au/reed-beds/

Precast Concrete Beds

(Graham's Precast Concrete Products 7.2 m³)

Modified Plant System for Greywater



Source: Dr. A. Dakers

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

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 m² up to 6 m² of wetland treatment area per EP/day for combined wastewater
  - Minimum 5 days HRT typically recommended
  - For greywater design using 3 m² EP/day

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

Examples	Combined Wastewater	Greywater Only
Area of Reed Bed	24 m²	17 m²

Example of SSF Area and Dimensions

BR/ EP	Hydraulic Load (L/d)	Surface area (m²)	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 (m²) All Wastewater	Surface Area/p (m²) Greywater
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

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-br house (EP 5) with on-site tank water supply (120 L/p/d)
- Volume (V) = (5-days HRT × 5 EP design hydraulic load)
  = (5 days × 600 L/day) = 3000 L
- If porosity of substrate material is 50% or 0.5, then 6,000 L or 6 m³ 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 5 m long and 2 m wide (L:W 2.5:1) to give volume 6 m³ - a rough estimate!

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
- Appropriate macrophyte species planted at a density of 4 plants/m^2
- Consider issue of plant senescence and on-going maintenance (including whether to harvest) plus management of 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*
- *Potamageton*

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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