Case study 3: In-line bioreactor bed Lower Burdekin

Project leader and partnerships	Department of Agriculture and Fisheries collaborating with Queensland University of Technology
Funding source	Department of Environment and Science (Queensland Government Reef Water Quality Program)
Project length	One and a half years (October 2018 – April 2020) of event-based monitoring completed Opportunity for continuation of monitoring
Region	Burdekin (Ayr)
Production system	Sugarcane
Date of installation	15th October 2018
Length of installation	Three working days for installation (2 weeks including design and site selection)
Bioreactor type	In-line drain bioreactor bed, below the floor of a pre-existing drain
Project objective	Research trial to quantify nitrate removal performance.

Summary of the landscape

The bed style bioreactor was located down slope from a 2.1 ha sugar cane paddock divided in two irrigation sets. Sugar cane was planted in the upslope block in May 2019 and was fallow prior to planting. The soil at the bioreactor site is a Kandosol. The bioreactor is situated on a natural slope and is not prone to flooding. The existing drain flows into a larger drain at the base of the block.

Average rainfall and temperature

The area can be classified as tropical savannah with maximum and minimum average annual temperatures of 29.4 °C and 18.7 °C, respectively, during 2010 to 2017. The mean annual rainfall during the same period was 834 mm.

Sizing and volume capacity

22 m long, 0.6 m deep, and 1.1 m wide. Approximately 14.5m^3 (softwood woodchip).

Design features

The bioreactor (Figure 1) features a gravel inlet, spoon drain overflow, piezometers at inlet, outlet and within woodchips and woodchip analysis piezometers. The outlet consisted of a single 50mm PVC outlet pipe 25m long that drains from the lowest point of the bioreactor.

Water source

The bioreactor received predominantly flood furrow irrigation run-off. The irrigation water is sourced from channel water and is pumped from a drain and applied to the paddock through gated pipes located at the top of the field. Irrigation water flows down furrows between the cane rows. When irrigation run-off reaches the bottom of the furrows it enters a collection drain and irrigation ceases. Irrigation usually lasts for 6 to 12 hours. The bioreactor also receives run-off from rainfall events with larger volumes predominantly in the wet season (November – April).

Construction methods and materials

A 45 m trench was mechanically excavated to permit the installation of a denitrification bed and associated sediment basin, inlet structure and outlet. As the trench was excavated on a slope, the depth (from the surface) ranged from 0.0 to 1.6 m. A laser level was used to ensure the bottom of the trench had a 0.5% slope (0.1 m height difference between the inlet and outlet location over 22 m). Heavy-duty builder plastic liner was laid in the trench to create a waterproof seal around the woodchip, to prevent water ingress via the soil profile or from the surface.

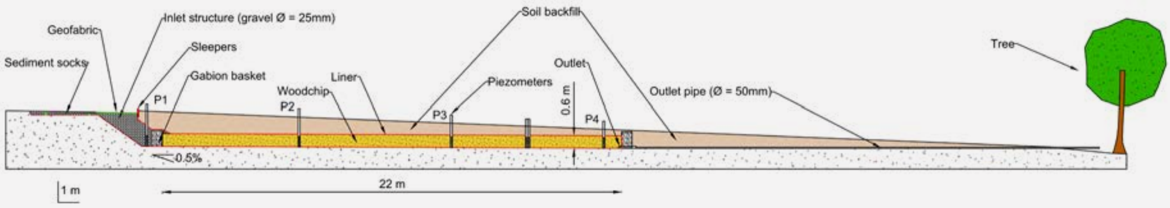

Figure 1 Design of the bioreactor bed showing key features. Source: QUT

Figure 2 Inlet structure showing washed river gravel and geofabric designed to capture fine sediment.

Four 100 mm (diameter) PVC piezometers for water sampling were installed in the centre of the bioreactor and at intervals along the length of the bioreactor. The first piezometer was positioned at the inlet (P1) to facilitate sampling of water entering the bioreactor and the fourth piezometer was at the outlet (P4) for monitoring water leaving the bioreactor. The piezometers were prepared by drilling 5 mm perforations around the base of the pipe for a 0.5 m length to allow for water sampling. Piezometers were wrapped in a 2 mm geo-fabric, to avoid fine particles entering the piezometers.

Figure 3 Bioreactor outlet showing single outlet pipe with valve to regulate flow, if required.

Three 100 mm piezometers were installed and mesh bags filled with woodchips were placed in the piezometers to enable woodchips to be collected and analysed for degradation.

The inlet structure (Figure 2) was constructed by excavating a funnel structure, which was sealed on the sides and at the bottom using heavy-duty plastic liner. A gabion basket (1.1 m long, 0.8 m deep, and 0.5 m wide) was placed to separate the inlet from the woodchip. The gabion basket was filled with rocks (diameter ≥75 mm). Washed river gravel (diameter = 25 mm) was positioned in the funnel inlet structure upslope of the gabion basket with a total volume of about 4.0 m^3. A sediment trap was installed upslope of the inlet structure to capture sediment in the run-off prior to entering the woodchip section of the bioreactor. The sediment trap was constructed using geo-fabric 'socks' filled with gravel and placed on the liner, perpendicular to the flow of the water. Additional gravel was placed on the top of the sediment socks to support water infiltration and sedimentation. An additional geo-fabric layer was placed on top of this gravel to prevent sediment build-up and to enable the geo-fabric to be readily replaced before each irrigation event.

The outlet of the bioreactor was a single, 25 m length of 50 mm PVC pipe connected perpendicularly to a pre-drilled 100 mm PVC pipe wrapped in geo-fabric. At the end of the 50 mm PVC pipe a valve was installed to adjust the outflow from the pipe if required (Figure 3). The 50 mm pipe passed through a gabion basket (1.1 m long, 0.8 m deep, and 0.5 m wide). The basket was installed to support the woodchip from moving downslope.

Figure 4 Bioreactor trench filled with woodchip, showing liner and piezometers.

The trench was backfilled with softwood woodchips (14.5 m^3) (Figure 4). Heavy-duty plastic liner was placed on the top of the woodchip and all gaps and joins sealed with plumbing sealant before backfilling with soil. A spoon drain (surface bypass drain) was constructed adjacent to the bioreactor to accommodate excess runoff and was paved with rock to minimise erosion.

Costs

	Item cost $	Cost $/m^3
Excavator inc. driver and float	3850	265
Woodchip inc. delivery	2000	137
Pipes	485	
Inlet gravel	313.5	
Laser level hire	375	
Materials (liner, sealant etc)	1326	
Total Cost	$8349	$575/m^3

Performance

Average influent nitrate concentration (mg N L^{-1})	1.3
Nitrate Removal Efficiency Average	84.30%
Nitrate Removal Efficiency Range	2.3 – 100%
Nitrate Removal Rate Average (g N m^{-3} d^{-1})	0.4
Nitrate Removal Rate Range (g N m^{-3} d^{-1})	0.0 – 1.8
Hydraulic Residence Time (Hours)	3.0 – 36.6
Carbon Longevity Average (Years)	16.3

Monitoring regime (intensity and frequency)

Event-based monitoring was conducted during each irrigation event. The following water quality parameters were analysed: nitrate, ammonium, dissolved organic carbon, dissolved oxygen, temperature, and dissolved greenhouse gas analysis (nitrous oxide, carbon dioxide, and methane).

Four pressure transducers were placed in each of the piezometers to monitor both water temperature and pressure.

Troubleshooting

Geofabric on the surface of the inlet structure needed to be replaced regularly after it became blocked with sediment.

There was a gradual reduction in hydraulic conductivity within bioreactor over time, leading to long hydraulic residence times. This was due to geofabric on the outlet pipes getting blocked. Removal of the geofabric restored flow through the bioreactor.

What would you do differently?

Create a larger sediment settlement basin and use multiple outlet pipes to ensure the bioreactor can continue to operate in the event of a blockage. Avoid installing geofabric in the interior of the bioreactor.

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