STORMWATER CONSTRUCTED WETLAND DESIGN

FINAL REPORT

06047

Prepared for:

PANDA WASTE SERVICES

1850-65 65 65

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06047 Iuil 2006

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Project No:	06047
Report Title:	Panda Waste Constructed Wetland Design
Report Status:	FINAL
Date:	14 June 2006
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Abbreviations

BOD	Biochemical Oxygen Demand
BÓS	Bartley & O'Suilleabhain Environmental Engineering
cm/d	centimetres per day
HLR	Hydraulic Loading Rate
mm/hr	millimetres per hour
m	metres
m^2	metres squared (area)
m^3	cubic metres (volume)
m bgl	metres below ground level
m/yr	metres per year
NH_4-N	Ammonical Nitrogen
OD	Over Datum
P	Phosphorus
R.L.	Reduced Level
SS	Suspended Solids
W.T.	Water Table

Executive Summary

This report presents the design document for a free water surface, horizontal flow, constructed wetland at Panda Waste, Co. Meath. The system has been designed to act as component of the stormwater drainage system. The system has been designed to provide attenuation of flows within the drainage system and provide passive treatment to collected surface water before discharge to the watercourse.

Before this system is commissioned all existing stormwater tanks must be emptied, desludged and cleaned. It is imperative that the wetland is not supercharged, during the establishment phase, with stormwater that may have a historic fingerprint of contaminants. Once established, the vegetated system will have the capacity to retain and, for in some cases, degrade contaminants. However, future performance will be enhanced if the system is safeguarded during establishment.

Summary Design Data

- Stormwater runoff area = 35,000 m^2
- Constructed wetland design area = 1880 m^2
- Wetland/Runoff area ratio = 5%

Irish research data (TCD & NRA, Higgins & Johnston, 2006) demonstrates that a stormwater wetland sized at 2% of the catchment runoff area acts to reduce by 70 - 80% the concentrations of suspended solids, total phosphorus and heavy metals. Further evidence is presented in the international literature (Kadlec et al., 2000) in relation to proven efficiencies for nutrient and metal removal from surface flow treatment wetlands. Therefore, the design area is deemed appropriate from a treatment perspective.

In addition, the system's hydraulic capacity has been tested for both annual and critical storm durations.

- Panda Waste's stormwater constructed wetland volumetric capacity = 925 m^3
- Average annual hydraulic detention time = 19 days
- Average annual HLR = 18.6 m/yr (5 cm/d)

Based upon model simulations, it is therefore envisaged that this constructed wetland will operate within loading and detentions times corresponding to mean performance criteria for treatment wetlands.

Potential stormwater volumes generated by critical storms events have been determined, as follows:

- 1 in 1 Year Return Period (60 minute duration) = 347 m^3
- 1 in 5 Year Return Period (60 minute duration) = 536 m^3
- 1 in 30 Year Return Period (60 minute duration) = 910 m^3
- 1 in 100 Year Return Period (60 minute duration) = 1190 m^3

The designed wetland system is therefore deemed adequate to accommodate critical storm events.

1. Introduction

1.1. Background

Bartley & Ó Súilleabháin Environmental Engineering (BÓS) was commissioned by Panda Waste Services to design a constructed wetland (reed bed) to act as a component of the stormwater drainage system at Beauparc Business Park, Slane, Co. Meath (referred to hereafter in this report as 'the site'). Three existing stormwater attenuation tanks will precede the constructed wetland. Discharge from the wetland system will be to an existing surface water drain at the site.

1.2. Scope of work

This report presents the design document for a free water surface, horizontal flow, constructed wetland and includes details as follows:

1. Volumetric and area sizings, definition of depth profiles in individual wetland cells within the system and design of appropriate hydraulic control structures to control water flows between wetland cells and ultimate discharge from the system.
2. Stormwater simulations for annual scenario and critical events.
3. Outline of proposed construction protocols.

1.3. Site Characteristics

The proposed location for this constructed wetland is at the Panda Waste processing facility at Beauparc Business Park, Slane, Co.Meath. The national grid reference for the site is *NGR 297957 268590*.

The soils of the area are mapped as the Ashbourne Series (An Foras Taluntais, 1983), a gley, derived from limestone and shale drift and Irish sea drift. The glacial geology can be summarised as shale enriched compact till, with a heavy texture, slow permeability, high water table and a drainage classification of 'imperfectly to poorly drained'. The topography of the general area of the site has been described as 'limestone lowland with Namurian and Silurian shale hills', in which the soils are generally classified as Grey Brown Podzolics with Gleys in the flatter areas (An Foras Taluntais, 1983). The bedrock underlying the site is classified as Namurian Undifferentiated, which is a shale of Palaeozoic age, and the aquifer is designated as a Poor Aquifer, with bedrock generally unproductive except in local zones (www.gsi.ie). The site appears to lie within the catchment area of the River Boyne but is close to the catchment boundary of the River Nanny.

A site visit was undertaken on 2nd June 2006. This consisted of collation of relevant site data for design analysis, a general site walkover survey, a surface water features survey, logging of existing ditches and surface expressions of bedrock. Visual and hand sample analysis of the subsoil profile in the exposed ditch faces confirmed the findings of the desk study, that the subsoils have a high clay content. Surface water in the drainage ditches was 1.8 m bgl, approximately, which is assumed to provide an indication of saturated conditions in the subsoil and in this design case is assumed to represent the water table. The elevation of the watertable is determined to be 67.6 m OD, on average.

2 System Design

2.1 Design Criteria

- This constructed wetland has been designed as a system to attenuate and treat stormwater runoff from the paved areas of the Panda Waste Services facility. The design must service a hydraulic loading from a paved area of 35,000 m^2.

- Waste at the Panda Waste Services facility is processed indoors, with the exception of wood pallets, and the buildings are engineered with bunded underground structures. Therefore, stormwater management at this site is considered in the context of no potential for contamination with leachate from waste materials processed on site. Therefore, typical stormwater runoff hydrochemical characteristics have been adopted as the design influent characteristics.

- The chemical characteristic of Irish stormwater is not well documented. It is known that the hydrochemical characteristic of runoff is a function of traffic density and the associated pollutant hazards on site. An example of storm water hydrochemical composition is provided in Table 1 (sample of run-off from the N2, near Coolquoy, collected by Enterprise Ireland, June 2000). However, the chemical characteristic of stormwater varies widely and an average input characteristic is presented in Table 2, Section 2.2, for the design of the stormwater wetland for Panda Waste.

- Design effluent concentration data is dictated by the Waste Licence (Register Number 140-2) and are presented in Table 2, Section 2.2.

Table 1 Chemical analysis of storm water run-off from existing N2 (Roughan & O'Donovan, 2000).

Parameter	Result
Ph	6.3
Temperature, oC	9
Electrical conductivity, µS/cm, 20 °C	20
Biochemical oxygen demand, mg/l O_2	<2
Suspended solids, mg/l SS	>5
Ammonia, mg/l NH_4	<0.05
Phosphorus, total, mg/l P	<0.05
Nitrate, mg/l NO_3	0.4
Chloride, mg/l Cl	7
Sulphate, mg/l SO_4	5
Lead, mg/l Pb	<0.05
Iron, mg/l Fe	0.13
Total organic carbon, mg/l C	0.6
Odour	None
Hydrocarbons	No visible film

2.2 Constructed Wetland Sizing

The wetland design is based on iterations of the design area model/equation presented in numerous treatment wetlands design manuals (*e.g.* Kadlec *et al.*, 2000), as follows:

$$A = \frac{-Q}{K}\left[\ln\left(\frac{C_0 - C^*}{C_{in} - C^*}\right)\right] \qquad \text{Equation 1}$$

where,

A = Required area of constructed wetland (m^2)
Q = Design inflow to the wetland (m^{3}/yr)
K = Rate constant (m/yr) = Literature K values for P, NH_4-N, SS, BOD
C_o = Design discharge concentration (mg/l)
C_{in} = Design influent concentration (mg/l)
C^* = Background Concentration (mg/l) = Literature values for P, NH_4-N, SS, BOD

Simulation:

- The model is run for each parameter: P, NH4-N, BOD, SS.
- Simulation reiterations are performed, to include hydraulic requirements of rain falling directly on the wetland, until a stable area is yielded by model.
- Peak rainfall intensities for storm event scenarios, 1:1, 1:5, 1:30 and 1:100 year return periods, are simulated to determine the volumetric sizings required to ensure appropriate retention within the system for critical events. NERC (1975) methodologies have also been applied to prove the capacity of the system.
- For the characteristic influent and effluent strengths simulated in this design BOD was found to be limiting parameter, i.e. requires the largest area to treat the water to required discharge concentration.

Table 2 Design data and simulation results for the stormwater wetland at Panda Waste.

Parameter	**C_{in}** (mg/l)	**C_o** (mg/l)	**C*** (mg/l)	**Wetland Area** (m^2)
P	0.2	0.15[a]	0.05	1650
N	2	0.3	0.25	1300
SS	30	25	5	1540
BOD	80	35	5	**1680**

[a] Assumed, as concentration not specified in Waste Licence discharge criteria

The constructed wetland design surface area will be 1880 m^2.

2.3 Constructed Wetland Cell Configuration

- This design team suggests three wetland cells for the Panda Waste development. Cell 1 will act as the primary receiver. However, the system's pipe network will be engineered to facilitate bypassing cell 1, to cell 2, should maintenance be required. The system will be constructed by some excavation of beds and creation of embankments to contain the reed beds and influent stormwater. Design details are provided in Tables 3 and 4. The wetland system configuration is shown on the accompanying drawings of Site Layout and Constructed Wetland Sections. The first and final reedbed cells will contain portions that are deeper, in a central position, to aid denitrifying processes.

Table 3 Preliminary design details for the Panda Waste constructed wetland (refer to section drawing).

Cell No.	Area (m2)	Design Water Depth (m)	Elevation (m OD)			
			Inlet Pipe invert	Water level	Bed level	Outlet Pipe Invert level
1	825	0.3 - 1.2	69.3	69.2	68.9 & 68.2	69.2
2	525	0.4	69.1	69	68.6	69
3	400	0.3 - 0.8	68.9	68.8	68.4 & 67.8	68.8

Table 4 Inlet and outlet pipe details for the Panda Waste constructed wetland.

Panda Waste Stormwater Wetland Inlet and Outlet Pipe Details				
Pipe ID	**Pipe Diameter (mm)**	**Pipe Slope 1:X**	**Pipe length (m)**	**Fall**
Inlet cell 1	225	1:100	20.0	0.2
Inlet cell 2	225	1:100	4.5	0.045
Inlet cell 3	225	1:100	5.5	0.055
Outlet	375	1:100	60	0.6

- With respect to plant-life, acceptable design water depth ranges in a constructed wetland are 0.2 - 0.5 m. Deeper sections are not vegetated, by design.

- An artificial liner will be installed to ensure environmental protection. It is envisaged that a 2.5mm HDPE impermeable liner will be set on quarry dust. An experienced lining company will supply and install both the HDPE impermeable liner and protective geotextile layer. Pipe penetrations will be appropriately engineered.

2.4 Annual & Critical Event Stormwater Simulations

- The hydraulic capacity of the system has been tested with respect to both the generated annual hydraulic loading (after Kadlec et al., 2000) and for storm scenarios (after NERC, 1975).

- With respect to stormwater attenuation on site, the following capacities have been determined:
  - Existing Stormwater Tanks Capacity (3 on-site tanks) = 350 m^3
  - Constructed Wetland hydraulic capacity = 925 m^3
  - Total stormwater volume capacity on site = 1275 m^3

- With respect to average annual hydraulic loading, the following have been determined:
  - Average annual hydraulic detention time = 19 days
  - Average annual HLR = 18.6 m/yr (5 cm/d)

- These data suggest that this constructed wetland will operate within loading and detentions times corresponding to mean performance criteria for treatment wetlands.

- With respect to runoff from the paved areas (35,000 m^2), employing NERC data (1975), potential stormwater volumes generated by critical storms events have been calculated, as follows:

  - 1 in 1 Year Return Period (60 minute duration = 9.9 mm) = 347 m^3
  - 1 in 5 Year Return Period (60 minute duration = 15.3 mm) = 536 m^3
  - 1 in 30 Year Return Period (60 minute duration = 26 mm) = 910 m^3
  - 1 in 100 Year Return Period (60 minute duration= 34 mm) = 1190 m^3

- With respect to critical events, the designed constructed wetland can accommodate the 60 minute duration, 1 in 1 year, 1 in 5 year and 1 in 30 year return period storms.

- Construction phase will ensure drainage pipe network construction that facilitates bypassing the wetland and discharge directly to the final discharge point for rainfalls exceeding the 1 in 30 yr design scenario. The environmental risk associated with this scenario is deemed low because the 'first flush" of contaminants will have been carried to the wetland system by the runoff prior to system bypass.

- For a 'Time of Concentration' greater than 10 minutes a peak rainfall intensity of 25mm/hr should be adopted (DoEHLG, 2004). Therefore, for this design scenario the peak hydraulic capacity required is determined to be 875 m^3. For this design situation, the time of concentration is determined to be greater than 10 minutes because of the stormwater holding tanks on site. Therefore, a design rainfall intensity of 25 mm/hr was adopted. For this design scenario, the system is shown to have the capacity to retain the required hydraulic loading.

3 Design Conclusions

- Nutrient and suspended solids loadings to the wetland will be relatively low as a consequence of the nature of the stormwater influent and the influence of the stormwater tanks preceding the wetland.

- The total surface area of the constructed wetland cells will be 1880 m^2.

- The volumetric capacity of the wetland will be 925 m^3.

- This system has been modelled and drainage pipe network designed to accommodate hydraulic surges caused by critical storm events. However, pipe drainage networks must be constructed to facilitate bypassing of cells for future maintenance operations.

- In addition, it is recommended that extreme storm events, having a return period greater than 1:30 years, bypass the wetland system to prevent scour and sediment mobilisation to the receiving environment.

- The base of the wetland system will be engineered to prevent infiltration to the groundwater system. Soil and topsoil characteristics suggest that engineering of local soil could be an appropriate methodology for prevention of leaching to groundwater. However, management at the facility have indicated a preference for HDPE lining, which will ensure no leakage from the wetland.

- The wetland will be constructed, planted and established according to BÓS construction protocol specifications (available upon request). Indigenous species are favoured. The most robust species are cattails (Typha spp.), bulrush (Scirpus spp.) and common reed (Phragmites australis). Other plants such as waterlillies, wild iris and yellow flag will also be planted for the purposes of habitat generation and biodiversity.

4 Constructed Wetland Protocols

BÓS have developed protocols based on international best practice and experience in Ireland. These will be presented for approval prior to construction. The protocols provide details for each of the following:

1. Wetland System Construction
2. Sealing
3. Inlet Structures
4. Outlet Controls
5. Appropriate Plants & Methodologies
6. System Establishment
7. Monitoring & Aftercare

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