

# DESIGN CRITERIA ON CLOGGING OF SUBSURFACE FLOW CONSTRUCTED WETLANDS: FULL SCALE EXPERIENCES

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## ABSTRACT

The goal of this study was to assess the best operational and design strategies that can be applied to horizontal subsurface flow constructed wetlands (HSSF CWs) to minimize clogging development. The falling head method was used to extensively map the degree of clogging by means the hydraulic conductivity distribution in six mature, full-scale HSSF CWs. The state of clogging is affected directly by the solids loading rate, with lower conductivities for the wetlands in wich loads were higher. The distribution of clogging is affected by several factors such as inlet distributors (wich must ensure a uniform distribution), width to length ratio and location of inlet and outlet. The wastewater tends to cross through the path wich less resistance flow offers. In this sense wetlands constructed as channels (longer than wide) force the water to flow occupying the entire width of the bed.

## INTRODUCTION

Clogging is the main operational problem associated with horizontal subsurface flow constructed wetlands (HSSF CWs) for wastewater treatment. The financial investment involved in reversing clogging can represent a substantial fraction of the cost of a new system (Cooper, 2009), and for this reason it is essential to assess the degree of clogging in HSSF CWs to accurately determine whether intervention is required. In this study, the horizontal distribution of hydraulic conductivity was assessed in six HSSF CWs in order to determine the extent of clogging and to identify the factors affecting clogging distribution.

## METHODS

The main characteristics of the wetlands studied are summarized in Table 1. Saturated hydraulic conductivity was measured by means falling head method (Pedescoll et al., 2009) in a matrix of sampling points to obtain a distribution map of the clogging.

Table 1 Main characteristics of the wetlands studied

Wetland	Location	Time of operation (months)	Treatment	Solids Loading Rate (g TSS/m <sup>2</sup> d)	Solids accumulated (kg DM/m <sup>2</sup> )	Inlet distributor	W:L ratio
Verdú	Spain	60	Secondary	3.4 – 10.4	1.2 – 14	Perforated pipe	1:1
Corbins	Spain	60	Secondary	9.3 – 80.9	1.7 – 10	Channel	1:1
Gualba	Spain	12	Secondary	26.5 – 89.9	1.8 – 18	Channel	2:1
Arnes	Spain	120	Secondary	10.5 – 29.5	1.8 – 5.8	Perforated pipe	3:1 (1:3 per cell)
Fenny Compton	UK	192	Tertiary	-	-	Vertical riser pipe	3:1
Moreton Morrell	UK	180	Tertiary	-	2.4 – 9.4	Vertical riser pipe	1:1

## RESULTS AND DISCUSSION

The horizontal distribution of hydraulic conductivity is showed in a plant view (including dimensions and inlet and outlet location of the systems) of the wetlands studied in Figure 1. Hydraulic conductivity was ranged from 0 to 70 m/d (presented as a brown intensity in Figure 1), from clogged to unclogged areas, respectively.

### Effect of organic loading rate

Verdú and Corbins were constructed at the same time. However, hydraulic conductivity in Corbins was three times lower than verdú. Moreover, in Corbins almost 60% of the length presented hydraulic conductivities lower than 20 m/d while at verdú the extent of clogging was up 40% of the length (Pedescoll et al., 2009). This is related to the higher solids loading rate in Corbins (Table 1). Positive relationships between applied loads and the degree of clogging have also been reported in previous studies (Tanner and Sukias, 1995; Nguyen, 2000). Similarly, Gualba presented an advanced state of clogging in only one year of operation due to the high loads in the inlet. This is due to the lack of a primary treatment. Therefore it is recommended to use improved previous treatments in order to delay clogging appearance.

### Effect of inlet and outlet location

From the results of Fenny Compton and Moreton Morrell (Figure 1C and 1D) it can be observed that the water takes the most direct path between inlet point and outlet collection (considering that the areas of lower hydraulic conductivity are the most concentrated water flow). Other studies have shown the effect of the position of both the supplier of water and the output collector in the appearance of

preferential water paths and dead zones within the system (Chazarenc et al., 2003, Suliman et al., 2006), but with greater influence of the distribution at the entrance of the wetland.

#### Effect of inlet distributor

Among the distribution systems used in HSSF CWs, perforated pipes, with differential settlement on the ground, results in areas of high water inflow, in which the clogging is more pronounced. As in Arnes (Figure 1B) where the water distribution pipe (with one entry point per cell) was established so that the cells furthest from the point of entry receive a higher rate. Consequently, in parcel D the progress of clogging is more important. Vertical riser pipes, such in Moreton Morrell, require regular maintenance to avoid the complete clogging by the deposition of solid waste and plants. In fact, in that bed was observed that only one of the four entry points was operational. In contrast, distribution channels, which also require easy maintenance, are much more effective distributing water across the width of the wetland (Griffin et al., 2008). Specifically at Gualba (Figure 1A) was observed, despite the preferential paths and advanced clogging conditions, that the distribution of wastewater was visibly more uniform than in systems with other types of distribution.

#### Effect of width to length ratio

By decreasing the width to length ratio of the bed the water is forced to cross the wetland occupying the entire width of the bed, thus increasing the hydraulic efficiency (Jenkins and Greenway, 2005). Therefore, the distribution of clogging is more uniform as it can be observed in the parcels of Arnes (Figure 1B). This is an advantage for the operator in the case of performing actions to reverse clogging since it can more easily determine the extent of the problem and therefore reduce the budget to solve it.

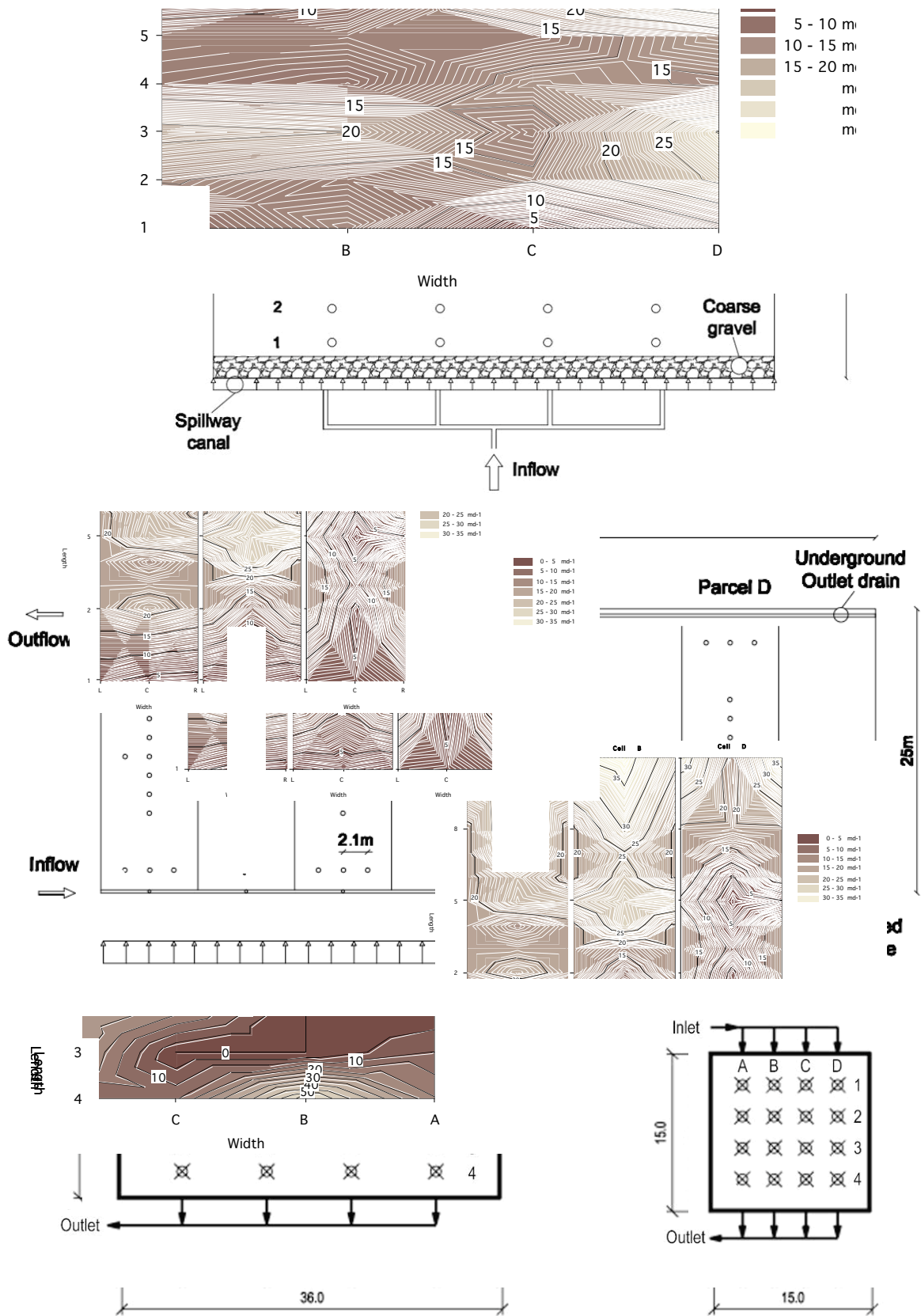


Figure 1 Plant view of the wetlands studied and hydraulic conductivity distribution A) Gualba; B) Arnes; C) Fenny Compton; D) Moreton Morrell

## CONCLUSIONS

From the evaluation of horizontal distribution of hydraulic conductivity in these six wetlands it is inferred that the solids loading rate affects the state of clogging, whereas the inlet and outlet location, inlet distribution and width to length ratio affect the distribution of clogging. Therefore, in order to delay clogging processes it is necessary to decrease the solids loading rate at the inlet of the bed. To prevent preferential flow paths, thus having a more homogeneous distribution of clogging (logically, from inlet to outlet) it is recommended to construct wetlands with width to length ratios higher than one and to apply channels as a inlet distributor systems.

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