CHAPTER 3

STUDY OF WASTE STABILISATION POND SYSTEMS IN THE UK

3.1 Introduction

The latest published data on waste stabilisation ponds in the UK are given by Mara *et al.* (1998). This study of UK pond systems was carried out between October 1999 and October 2000 with Tim Darlow (MRes student in the School of Civil Engineering). The study involved: the visiting of selected pond systems and the consultants who designed them, collecting new data and collating existing performance data.

Mara *et al*. (1998) reported the use of 19 systems; the new study revealed a further 20 systems bringing the total to 39. The locations of all these systems are shown in Figure 3.1.

3.2 Design criteria

The systems, all privately owned, have been designed by five consultancies and cater for populations ranging from 2-1000 p.e. The number of ponds per system varies between the consultancies as shown in Table 3.1.

Table 3.1 Summary of Waste Stabilisation Pond Systems in the UK by Consultant

Consultant	No. of systems	Populations served	No. of ponds in a typical system
Ebb 'n' Flow	18	2-50	2
Iris Water	11	35-500	3
Elemental Solutions	5	20-187	3
Watershed Systems	4	50-600	3
Cress Water	1	1000	4

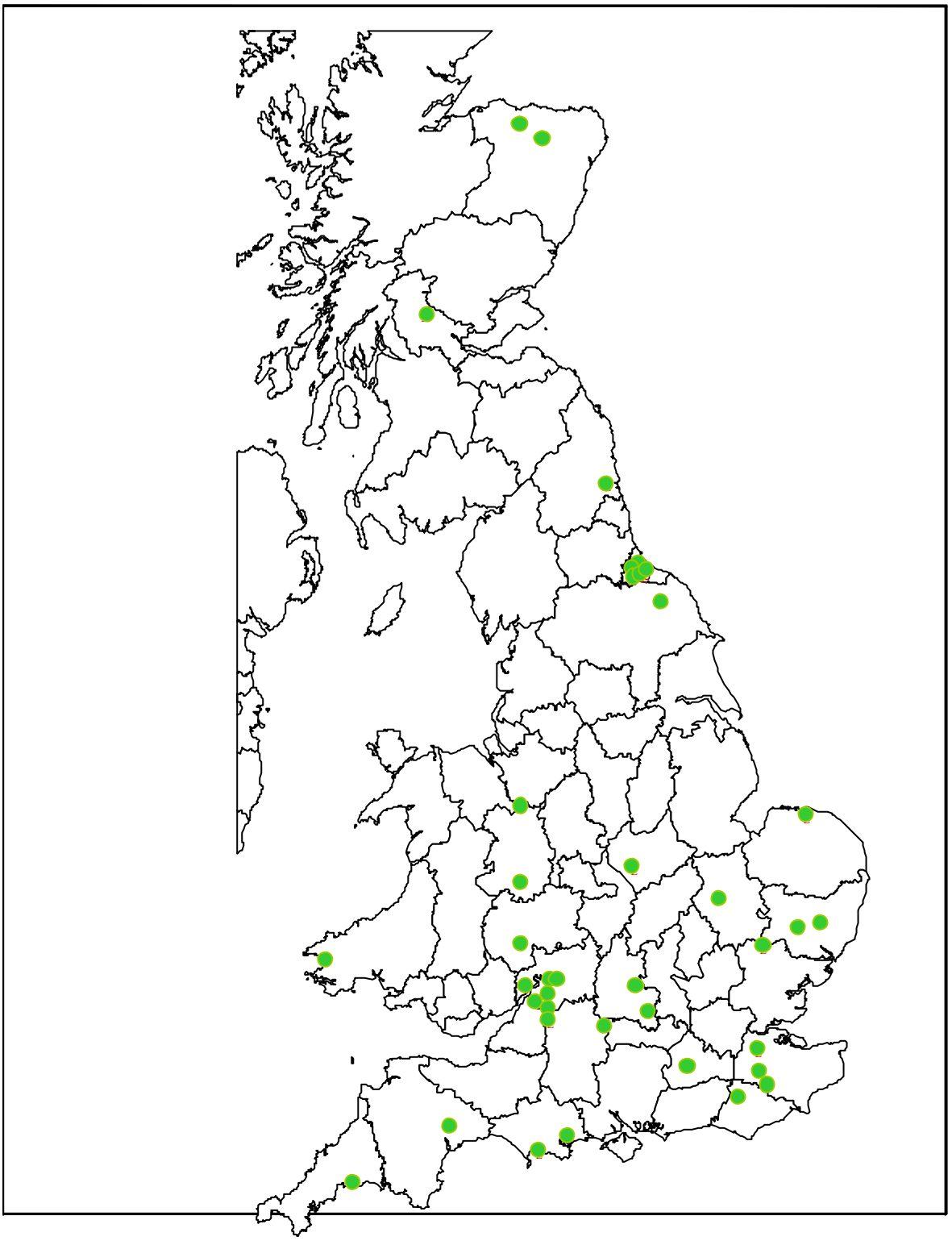

Figure 3.1 Waste stabilisation pond systems in the UK (October 2000)

Ebb 'n' Flow (based in Gloucestershire) specialise in small systems for one or two houses, but have also designed larger (uncommissioned) systems for up to 100 people. A typical system consists of a septic tank or digestion tank, followed by two ponds.

A digestion tank has a retention time of a day or so and retains screenings and some settleable solids. Most systems are in the owner's back garden and were added to upgrade a failing septic tank. The two ponds are separated by a horizontal flow reed bed and the design criterion is a hydraulic retention time >28 days. The average specific area for the facultative pond is 8 m^2/person (or 75 kg/ha.d)[1].

Iris Water, based in North Yorkshire, introduced facultative ponds to the UK with the Sturts Farm system in 1989. The typical layout of their systems is similar to the French design: three ponds in series, the first covering 50% of the total area. Over half of their systems are preceded by septic tanks, but the design surface BOD loading ignores this factor. The design areas of their primary facultative ponds range are 2.7 - 9.1 m^2 / person (66-219 kg / ha. d)[8] while the design area range for their secondary facultative ponds is 1.9–5.9 m^2 / person (101-320 kg / ha. d).[9]

Elemental Solutions (in Gloucestershire) have designed five waste stabilisation pond systems in the UK. Their systems usually include three ponds in series, the sizes of which are based on either hydraulic retention time (in the case of combined collection systems)[10], or surface BOD loading using German design criteria. The surface BOD loading for their first ponds range between 43-94 kg / ha. d.[2] This (lower) range reflects the use of hydraulic retention time design criteria to accommodate large rainwater contributions to the flow.

The largest (population) system in the UK is at the Welcome Break service station on the M40 in Oxfordshire designed by Cress Water (Worcester). This system of four ponds

[8] Assuming 60g BOD per person per day
[9] Assuming 60g BOD per person per day and no removal in the septic tank
[10] Combined systems include rainwater runoff

follows an aeration tank. The first pond was based on French design criteria: to take a BOD load of 100 kg /ha. d (assuming 1000 p.e. and a 75% removal from the aeration tank). The actual daily visitor numbers was 12 500, and the first pond received 600 kg BOD /ha. d. Consequently, surface aeration had to be added.

3.3 Aeration and assistance systems

Most of the waste stabilisation pond systems in the UK have assisted aeration to one or more of the ponds. The usual form of assistance is by flowform cascade, a novel form of surface aeration which involves circulating the water over a series of waterfalls. An example of a flowform cascade is shown in Figure 3.2. The pond water is drawn into a pump located in a gravel bed and pumped to the head of the cascade; oxygen is introduced as the water flows down the cascade. The momentum created by the flowform ensures that the pond is gently mixed. The pump operation is user-adjusted and the frequency varies from continuous to a couple of hours per day, depending on the system.

Figure 3.2 The flowform cascade to the facultative pond at Spring Cottage, Wiltshire.

3.4 Physical design

Ponds in the UK are usually round or kidney-shaped; they have horizontal reed beds at the end of each pond and are planted with wetland plant species around the edge. In this way they differ from standard systems in other countries and textbook design. The shape is designed to optimise mixing, reduce short-circuiting and to add to the aesthetics. The beautiful system at Botton Village shown in Figure 3.3 is a typical example.

Figure 3.3 The facultative pond at Botton Village, North Yorkshire

The use of reed beds at the end of each pond is unusual, but has been tried in France (see Lienard *et al.* (1993)). The design purpose of the beds varies between systems, but usually they are designed to remove nutrients, algae and pathogens from the pond effluent. The beds are typically planted with a range of plant species, for example common reed, reedmace and flag iris; and the diversity is intentionally increased across the system. The beds need annual maintenance and can take up a substantial area; the value of a reed bed on the first pond is questionable as it may quickly clog with algae and

other solids, especially if used with a primary facultative pond. Figure 3.3 shows the reed bed area of the pond in the foreground; this area clogged up regularly.

3.5 Pond performance

Data on the performance of UK systems are sparse and mainly limited to those routinely monitored by either the Environment Agency for England and Wales, or the Scottish Environmental Protection Agency as part of their discharge consent checks. Many systems discharge to the ground rather than water, so do not have a discharge consent and so there are no data available. Data were collected on selected systems as part of the study. Due to the variable use of flowform cascades in the UK, performance data from the full-scale systems should be used only with caution to predict the potential performance of unassisted ponds.

3.5.1 Westfield Farm (Kent)

The Westfield Farm system, commissioned in 1999, serves between 3-6 people and has two ponds in series following a septic tank. Pond 1 (Figure 3.4) has a specific area of 8.3 m^2/ person (60 kg/ha.d), is assisted by a five-tiered flowform cascade and has a horizontal flow reed bed at its outlet. The cascade operates 25% of the time. The site was visited in March 2000 at which time the DO concentration was measured at each tier of the cascade with a YSI Model 50 field DO meter. While operating, the cascade appeared to contribute significantly to the DO in the pond water as shown in Table 3.2.

Table 3.2 Contribution of the flowform cascade to DO in the first pond

Stage	DO mg/l
Top of the cascade	3.1
2nd tier	4.1
3rd tier	5.3
4th tier	6.4
5th tier	6.4
Pond water below cascade	7.0

The SS concentration was measured on site using a Palintest Turbidity Tube and COD samples were tested using a HACH DR/890 Colorimeter; the results are shown in Table 3.3. Pond 2 is an amenity for the residents, being inhabited by koi, toads and newts.

Figure 3.4 The facultative pond at Westfield Farm

Figure 3.5 The system at Halewell Hotel with the facultative pond in the foreground

3.5.2 Halewell (Gloucestershire)

Halewell is a hotel with a maximum occupancy of 20 residents (average 15). The pond system (Figure 3.5) was commissioned in 1996 and consists of two ponds separated by a horizontal flow reed bed. Pond 1 receives screened sewage from the property, has a specific area of 5.7 m^2/person (105 kg/ha.d) and is assisted by a 3-tier cascade. Pond 2 also has a 3-tier cascade and is inhabited by frogs and newts. Samples for BOD and SS were collected and stored in ice overnight, results for the first pond are shown in Table 3.3.

3.5.3 Spring Cottage (Wiltshire)

Commissioned in 1994, Spring Cottage is the smallest waste stabilisation pond system in the UK, serving 2 people. The system comprises a 1 m^3 digestion tank, a facultative pond (15 m^2) (Figure 3.6) and a maturation pond in series. The facultative pond is assisted by a 3-tier cascade and discharges to a baffled reed bed before reaching the maturation pond (which is used as a fish pond). Over the first 6 years of its life, between 30-45 cm of sludge accumulated in the facultative pond. Samples for BOD and SS were collected and stored in ice overnight; results for the facultative pond are shown in Table 3.3.

Figure 3.6 The facultative pond at Spring Cottage.

Table 3.3 The performance of the first ponds at three systems in the south of England

System	assistance[11]	type	estimated loading on first pond	estimated HRT on first pond	BOD in /out mg O_2 /l (removal)	SS in/out mg/l (removal)
Westfield Farm c. 1999 Kent	flowform (5)	2^o	65 kg/ha.d	27 days	COD removal (87 %)	150 in 1 out (99 %)
Halewell c.1996 Gloucestershire	flowform (3) + reed bed	1^o	105 kg / ha.d	23 days	520 in 14 out (97%)	976 in 8 out[12] (99%)
Spring Cottage c.1994 Wiltshire	flowform (3)	1^o	80 kg/ha.d	22 days	817 in 56 out (93%)	780 in 44 out (94%)

February and March are usually the time of year when the performance is at its worst, occurring at the end of the winter and before the growing season begins. These results show excellent removal for BOD and SS even at the worst time of the year. The reed beds at the end of the ponds work well for the removal of the algal SS generated in the pond. It should be noted, however, that these removal efficiencies are based on single spot samples of influent.

3.5.4 Botton Village (North Yorkshire)

The pond system at Botton Village was commissioned in 1997 and consists of three ponds in series separated by reed beds (shown in Figures 3.3 and 3.7). The system was designed for 220 people with a surface BOD loading on the first pond of 110 kg / ha. d. During the first year of operation, only half the design population was connected, but by 1999, the ponds were receiving their full design loading. The ponds were monitored during the winter of 1998/1999 with Mr Terence Thomson (an MEng student in the School of Civil Engineering); the results are summarised in Table 3.4. During the sampling period the ponds were unassisted.

[11] number in brackets denotes number of tiers
[12] After reed bed, 200 mg/l before (80% removal)

Table 3.4 The performance of the first pond at Botton Village during winter 1998/99

Month	% BOD removal[13]	% SS removal[14]	% NH_3-N removal[15]
Oct	80	62	-
Nov	83	78	58
Jan	-	69	18
Feb	72	66	27
Mar	80	72	33

The pond showed consistent removal of BOD and SS over the winter (around 80 and 70% respectively), while ammonia removal was much lower and more variable.

Figure 3.7 Ponds 2 and 3 at the Botton Village System

3.5.5 Larchfield (Middlesborough)

Larchfield Farm is located to the south of Middlesborough on Teesside. On the estate there are two waste stabilisation pond systems: Wheelhouse and Levenhouse. The Wheelhouse system, commissioned in 1993 was designed for 80 p.e.; for bakery, butchery and workshop effluents together with the effluent from the visitor's centre and

[13] Assume average influent BOD= 300 mg/l
[14] Assume average influent SS= 200 mg/l
[15] Assuming average influent Amm.N = 30 mg/l

restaurant. The wastewater from the butchery and workshops is pre-treated in a small anaerobic pond (Figure 3.8) before being combined with the sewage from the residential block, café and bakery. The combined flow is applied to three ponds in series. The first of these (Figure 3.9) is circular, assisted by a 7-tier flowform cascade and has a surface loading of 300 kg/ha.d. The next pond discharges to a wetland planted with iris and mint (mint is used for its bactericidal qualities). The final pond effluent flows through a reed bed before discharging to a beck via a land drain. During the summer of 2000, a parallel facultative pond was under construction.

The Levenhouse system serves a residential home for approximately 60 people and was commissioned in 1994. It consists of three ponds in series treating septic tank effluent. The facultative pond (Figure 3.10) is circular and has a specific area of 2.5 m^2 / person (approximately 200 kg / ha. d).

Between 1994 and 1998, Iris Water sampled from both systems and the analysis was performed by Analytical and Environmental Services Ltd, Cleveland, and Northumbrian Water Ltd. The results from this testing were provided by Mr Andrew Joiner of Iris Water; summary statistics are shown in Tables 3.5 and 3.6.

Table 3.5 Larchfield Wheelhouse System: effluent statistics for January 1994-December 1998. Source: Iris Water.

Parameter	Location	Mean concentration (mg/l)	range (mg/l)	Mean removal (%)[6,7,8]	range %	n
BOD	Pond 1 effluent	28	1-140	91	53-99.7	23
	Final effluent	9.8	2-30	97	90-99.3	25
SS	Pond 1 effluent	78	14-330	61	-65-93	21
	Final effluent	28	4-59	86	71-98	28
Amm.N*	Pond 1 effluent	14	0.5-36	53	-20-98	16
	Final effluent	1.5	0-5	95	83-100	15

* January 1994-June 1997 inclusive

Figure 3.8 The anaerobic pond at the Larchfield (Wheelhouse) system

Figure 3.9 The facultative pond at the Larchfield (Wheelhouse) system

Table 3.6 Larchfield Levenhouse System: effluent statistics for October 1996-December 1998. Source: Iris Water.

Parameter	Location	Mean concentration (mg/l)	range (mg/l)	Mean removal (%)[6,7,8]	range %	n
BOD	Pond 1 effluent	13	1-49	96	84-99.7	22
	Final effluent	6.4	1-20	98	93.99.7	22
SS	Pond 1 effluent	35	9-101	83	50-96	22
	Final effluent	18	1-44	91	78-99.5	22

The data fluctuated widely and no trends could be detected from either system. The facultative pond at the Wheelhouse had very variable performance for all parameters, probably as a result of the very high loading applied. The subsequent ponds appeared to compensate for this, leading to an excellent overall performance. The Levenhouse system had excellent removal for both SS and BOD and most of this could be attributed to the first pond.

Figure 3.10 The facultative pond at the Larchfield (Levenhouse) system

3.5.6 The Tigh Mor Trossachs system (Stirling, Central Scotland)

The pond system serving the Trossachs Hotel (Figure 3.11) was designed for 500 people. It has three ponds in series each assisted by flowform cascades. The surface BOD loading on the first pond is 219 kg / ha. d. The system has very tight consent standards to meet: BOD 20 mg/l; SS 30 mg / l; total phosphorus 3 mg/l (all 95 % compliance). Effluent data from SEPA between 1998-2000 show that the system met its BOD and SS consents at all times, but failed the phosphorus limits, by 1 mg/l or so, especially during the winter. Though not included in the consent, ammonia was monitored by SEPA, revealing that performance was very seasonal: the concentration sometimes exceeding 20 mg Amm.N /l. Effluent data are shown in Table 3.7.

Table 3.7 Effluent data from the Tigh Mor Trossachs System (Jan 98 -Mar 2000). Source: SEPA April 2000.

Date	BOD (mg/l)	SS (mg/l)	TP (mg/l)	NH_3-N (mg/l)
Jan 1998	<6	3.2	2.17	20.4
Mar	<6	2.4	3.41	22
May	5.8	17.3	1.7	0.77
July	<6	20.3	1.49	2.55
Sept	<6	18.3	.75	<0.1
Jan 1999	8.8	18.7	1.3	2.06
May	6.2	8.9	3.11	16
June	8.8	17.2	3.48	11.3
Sept	3.7	3.8	4	18.5
Oct	13	20.2	4.7	24.8
Nov	13	20	3.88	25.2
Jan 2000	6.3	6.4	2.5	17.9
Mar	4.8	8.1	2.36	16.8

Figure 3.11 The Tigh Mor Trossachs System

3.6 Summary

Waste stabilisation pond systems are spread throughout the UK, from Cornwall to the north of Scotland. They have been designed using different criteria and thus the surface BOD loading varies considerably. The interpretation of performance data is difficult due to the variable use of flowform cascades; however, the sparse data suggest that the systems perform well for BOD and SS removal all year, but with lower performance for nutrient removal during the winter. This agrees with the findings in other European countries.