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A Pollution Chronology for Maiden Erlegh Lake, Berkshire.

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1. INTRODUCTION

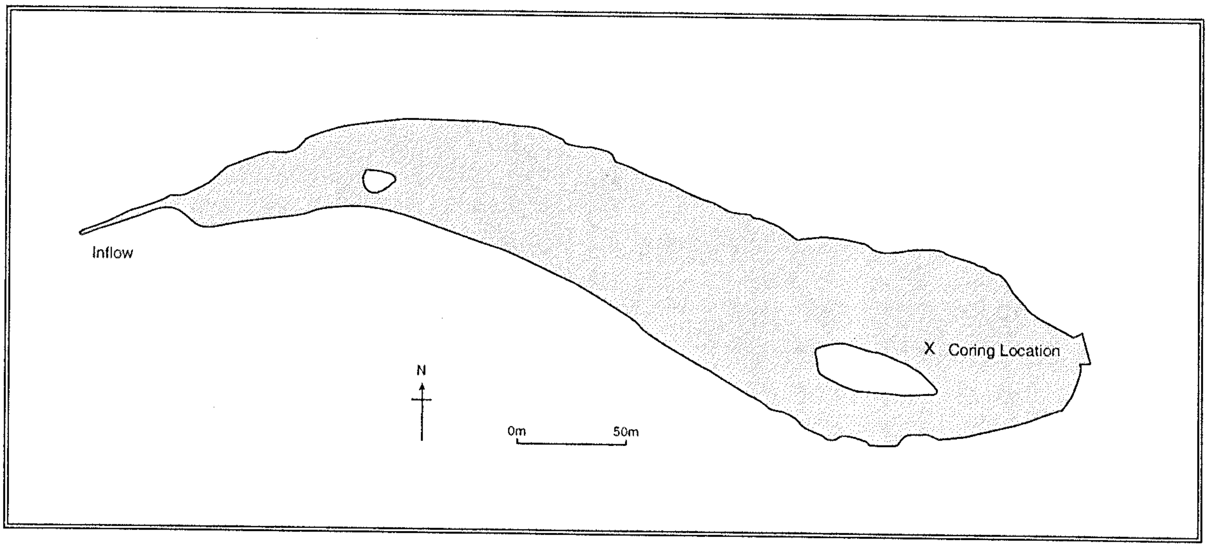
1.1 SITE

Maiden Erlegh Lake, National Grid Reference SU 749710, is a small 1.62 ha lake, situated about 4 km SE of central Reading, Berks, in the Earley area of the town. It forms much of the Western end of Maiden Erlegh Park, a Local Nature Reserve containing ancient woodland, modern woodland and grassland (Mannion 1998). Beyond a wooded lakeside fringe of less than 100 m the catchment is exclusively urban, with the lake fed by a small piped stream, storm drains, road and land drainage and possibly some small springs. Over a man-made weir the lake feeds the Maiden Erlegh Brook/Silverdale Road Drain which flows through the remainder of the Park then residential land before entering the Lodden c. 1.5 km to the East (Harrington-Vale, 1995).

1.2 PROJECT

Reading University and Earley Town Council commissioned a study of the Maiden Erlegh Lake sediment record in order to better understand the lake's recent history and pollution record. Spheroidal carbonaceous particle analysis, core lithostratigraphy and basic water chemistry analyses were chosen as suitable methods towards this goal.

Figure 1. Maiden Erlegh Lake and coring location.



2. METHODS

2.1 CORING: Sediment coring was performed on 15th December 1998 using a Modified Livingstone Corer, (Livingstone, 1955). After unsuccessfully attempting to core the area directly south of the main island, cores were taken from 90 cm water depth at the Eastern end of the lake, 10/15 m to the NE of the island in an area believed to be unaffected by recent dredging activities (Local water bailiff, pers comm). The exact coring location is shown in Figure 1. Two cores were taken, MAID1 and MAID2. MAID2 was slightly longer and therefore used as the mastercore. All subsequent analysis and discussion relate to this core.

2.2 EXTRUSION: Having been transported upright to the Environmental Change Research Centre MAID2 was extruded in the laboratory at 0.5 cm vertical intervals over the surface 0-5 cm and 1.0 cm intervals thereafter until the bottom of the sequence at 87 cm.

2.3 LITHOSTRATIGRAPHIC ANALYSES The percentage dry weight (%dw) for each sample was calculated by weighing approximately 1g of wet sediment in a pre-weighed crucible from each pre-homogenised sediment layer, drying the sediment at 105° for at least 16 hours, then reweighing the crucible and dry sediment. Approximate organic matter content was then determined (as percentage loss on ignition - %loi) by placing the crucible containing the dried sediment in a muffle furnace at 550° for a further 3 hours then reweighing.

2.4 SCP Spheroidal Carbonaceous Particle (SCP) analysis was carried out on the surface sediment, 2 cm depth and then at every 5 cm to the bottom of the core - a total of 20 levels. The quantitative preparation technique removing the unwanted fractions of the sediment followed that of Rose (1990) and involved selective attack on the pre-weighed dry sediments by nitric, hydrofluoric and hydrochloric acids in order to remove the organic matter, mineral and biogenic silicates and carbonate minerals respectively. A weighed sub-sample of the resulting suspension was evaporated onto a coverslip, mounted with Naphrax onto a microscope slide and SCPs counted at 400x magnification using a light microscope.

2.5 WATER CHEMISTRY

Water samples were taken from the inflow, the outflow and the centre of the lake using 1 litre acid washed bottles which were immediately chilled and stored in the dark. pH, conductivity and total alkalinity measurements were made in the laboratory directly on return from Reading and sub-samples frozen for subsequent SRP analysis.

2.5.1 TOTAL ALKALINITY Analysis of total alkalinity followed that described by Wetzel and Likens (1991) and involved acid titration against the water sample in the presence of methyl red/bromo-cresol green indicator.

2.5.2 TOTAL PHOSPHORUS (TP) TP analysis followed methodology developed by Johnes & Heathwaite (1992) and involved microwave digestion of unfiltered samples and phosphate standards with the addition of the oxidising agent sodium hydroxide. Measurements were then made using a UV/visible spectrophotometer.

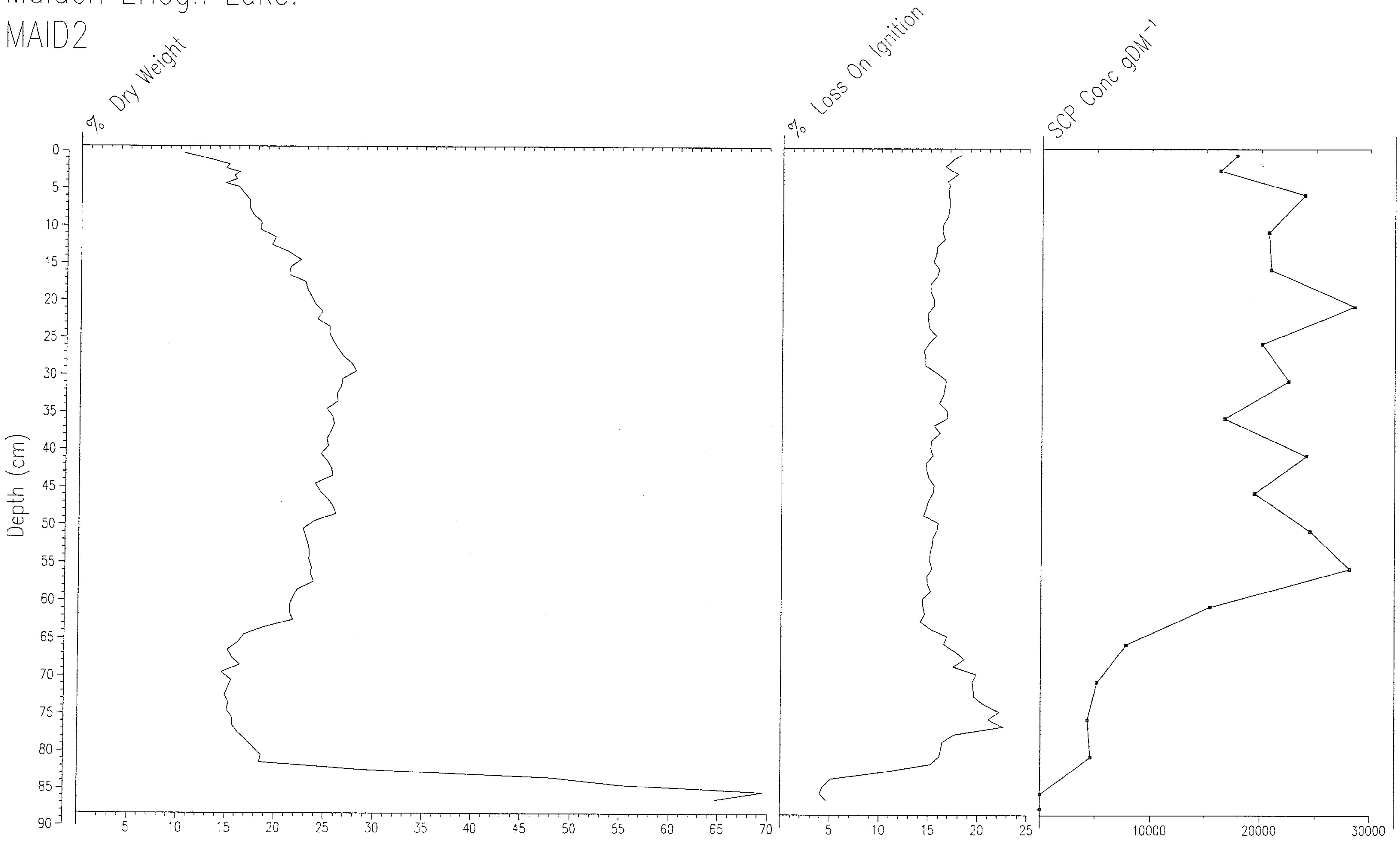
2.5.3 SOLUBLE REACTIVE PHOSPHORUS (SRP) SRP analysis was performed according to APHA's methods (1989), utilising sulphuric acid, ammonium molybdate, ascorbic acid and potassium antimonyl tartrate reagents in order to obtain SRP values read against those of a phosphate standard calibration set.

3. RESULTS

3.1 LITHOSTRATIGRAPHY

The % dry weight and % loss on ignition data for MAID2 are shown in Figure 2. The %loi values at the base of the core are very low at c. 5 %, but increase rapidly forming a peak from about 80 cm to 62 cm. From 62 cm up to the surface of the core %loi values increase steadily but very slightly from c. 14 % to c.17 %. The %dw values at the bottom of the core are extremely high, reaching nearly 70 % at their peak. The peak is short-lived however, and values are back down to c.20 % by 80 cm.

Figure 2.
Maiden Erlegh Lake.
MAID2



From 80 cm to 62 cm there is a decrease coincident with the increase in %loi at these levels. From 62 cm upwards the %dw gradually increases, reaching a peak of c.28 % at 30 cm before declining more rapidly to the surface of the profile.

3.2 SPHEROIDAL CARBONACEOUS PARTICLES

The SCP results for the core MAID2 are illustrated in Figure 2. and are expressed in terms of concentration of particles per gram of sediment dry mass. The actual values are shown in the appendix. At the bottom of the profile two levels have no SCPs at all, 85 cm and 87 cm. From 80 cm to 65 cm the concentrations gradually increase whilst from 65 cm to 55 cm there is a more rapid increase to a maximum of c. 28000 particles gDM^{-1}. Moving upwards concentrations decrease for 10 cm before the profile becomes less consistent, undulating up and down between 45 cm and the surface, with another peak at 20 cm.

3.3 WATER CHEMISTRY

The water chemistry results are shown in Table 1. In all analyses except TP the lake and the outflow tend to mirror each other whilst the inflow is conspicuously different, exhibiting significantly higher SRP, alkalinity and conductivity but lower pH.

Table 1.

	Soluble Reactive P ($\mu g\ l^{-1}$)	**Total P** ($\mu g\ l^{-1}$)	**pH**	**Total Alkalinity** ($mg\ l^{-1}\ CaCO_3$)	**Conductivity** ($\mu\ S\ cm^{-1}$)
INFLOW	116	148	7.83	178	707
LAKE	18	182	7.94	147	577
OUTFLOW	18	118	7.90	144	579

4. DISCUSSION

Spheroidal carbonaceous particles are produced by the high temperature combustion of fossil fuels, principally coal and oil, by the power generation and other industries. Alongside the other by-products from this process such as SO_2, NO_x and CO_2 gases and inorganic ash spheres (IAS), SCPs are emitted into the environment and are widely dispersed. Unlike the gaseous emissions however, SCPs can both accumulate where they land and are relatively simple to extract from soil or lake sediments, being mainly composed of chemically resilient elemental carbon(Goldberg, 1985). As SCPs are readily identifiable, have no natural sources and have been produced by industry at differing rates through time they can provide a good record of the extent of the atmospherically deposited contamination a lake has received (Battarbee *et al*, 1988) and through a knowledge of production trends provide a means of approximately dating lake sediments (Rose *et al.*, 1995).

SCP concentration profiles in UK lake sediments generally show a number of common features that correspond with historical changes within the power production industry: the start of the profile echoing the start of high temperature fossil fuel combustion dated around the mid 19th century, a rapid rise in SCP concentrations commensurate with increasing energy demand post World War II and finally a peak that relates to the timing of improvements in particle arresting techniques and changing energy production trends. Rose *et al.*,(1995) show this to occur at around 1969 in the SE of England.

In MAID2 the bottom two levels counted had no SCPs at all. This was not unexpected as the lake is lined with puddled clay (Harrington-Vale, 1995), the clay forming the bottom of the MAID2 sequence as clearly demonstrated by the very pronounced %dw peak below 82 cm. The first occurrence of SCPs is at 80 cm and at a concentration of over 4000 SCPs gDM^{-1}. This demonstrates that the lake was receiving a significant input of atmospheric contamination immediately after the clay lining was put in and moreover that this was some considerable time after SCP production commenced in the mid nineteenth century. Putting a more exact date to the base of the sediment necessitated turning to local historical records which showed what appeared to be two possibly alternatives: that the sequence base dated to the time in which the Maiden Erlegh Estate and Lake was owned by John Hargreaves, who purchased the site in 1878 rebuilding the mansion and altering other areas on the estate (Local History Record, 1960, History of Maiden Erlegh, In press) or to the time of the Estate's most famous owner

Solly Joel, who owned the site from 1903 until his death in 1931. Various sources (Berkshire Mercury 13/7/78, Reading Chronicle 2/6/78, Earley Town Council, 1998) describe the major alterations Solly Joel made to the estate but an interview with a Mr Harry Chapple (Reading Chronicle, 11/4/69) seems to strongly suggest the profile's beginning as being sometime shortly after 1903:

"Soon after the purchase a Croyden firm started working on the estate. Apart from redecorations, they laid a drainage system with filter beds and built stabling and garages. They also cleaned the lake and built an island in the centre."

This timing would tend to fit the extent of tail truncation seen on the MAID2 SCP profile when compared to the longer tails of many other more complete profiles (Rose *et al,* 1995). Moving further up the profile the next commonly distinguishable feature, that of the more rapid post war increase in SCP concentrations, would seem to occur at around 65 cm. This would suggest an accumulation rate of c. 3.8 mm yr^{-1} between here and the base of the core. If 65 cm does indeed represent c. 1950 and the accumulation rate stayed similar then major change occurred within the catchment between this depth and 60 cm with the demolition of the estate manor house to the North of the lake and the construction of a large housing estate in its place in the early 1960s (Earley Town Council, 1998). The end of the %loi peak at this level (and a change in sediment colour from black to dark brown) would tend to support this hypothesis of catchment change. Slightly further up the profile at 55 cm an SCP peak occurs. On work in Hampstead Bathing Pond in London, Rose *et al.* (1995) found the SCP peak to correspond to 1969 ±2. If MAID2 were to follow this trend then an increased accumulation rate of c. 5 mm yr^{-1} could be calculated, which would suggest that housing development within the catchment may already have been having an effect on the lake's trophic status and/or sediment input levels. Further development followed in the south of the catchment in 1977 with the construction of what was until recently the largest private housing development in Europe, that of Lower Earley. From this stage upwards the SCP profile becomes much less distinct. This may be a result of rising sediment accumulation rates that can reduce per-sample SCP concentrations and is an effect that has been seen in other eutrophic lowland lakes (Bennion *et al* 1996, Henderson, 1995).

Using the surface and 55 cm dating horizons a sediment accumulation rate of c. 18 mm yr^{-1} can be calculated for the most recent period of lake history. Though this rate is not unprecedented, for example in Marsworth Reservior (Bennion, 1994), there is however a strong possibility that this is an overestimate, as the lake was extensively dredged in 1988. Major disturbance of nearby sediment may well have resulted in re-suspension and associated settling out, augmenting the natural sediment profile.

Worthy of note is that SCP concentration levels throughout the profile are relatively high compared to other sites in the UK (Rose *et al*, 1995), reflecting the industrialised nature of the area in general and more specifically, later in the profile, the proximity of the site to the power station at Earley, once the largest power station within the county (Berkshire County Council, 1997).

Using the modified OECD lake trophy classification system (OECD, 1982) Maiden Erlegh Lake would be classified as hypertrophic (TP > 100μg l^{-1}) having a TP value of 182 μg l^{-1}. This is consistent with the inferred high sediment accumulation rates found towards the top of the sediment core. In a study of 123 randomly selected artificial lowland water bodies in the SE of England Bennion *et al* (1997) found the mean TP of the sites to be 135 μg l^{-1} and thus Maiden Erlegh can be seen as not atypical for the region. In the lake itself only c.10 % of the TP consisted of biologically available SRP whereas in the inflow the figure was closer to 80 %. A major source of P in the catchment on the date of sampling would appear to be the inflow stream with an SRP value of 116 μg l^{-1}. Determining whether or not this is representative of normal conditions or merely an event would necessitate further monitoring of water chemistry. Other determinands were all within the normal ranges for a shallow urban lake (Bennion *et al* 1997).

5. ACKNOWLEDGEMENTS

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7. APPENDIX

Table 1.

Spheroidal Carbonaceous Particle Data for Maiden Erlegh Lake.

Mean depth	SCP Conc gDM^{-1}
0.25	17758
2.25	16241
5.5	23932
10.5	20654
15.5	20859
20.5	28534
25.5	20080
30.5	22473
35.5	16693
40.5	24137
45.5	19411
50.5	24495
55.5	28128
60.5	15401
65.5	7784
70.5	5119
75.5	4292
80.5	4578
85.5	0
87.5	0