

3.0 Hydrology & Hydrogeology of Sifton Bog ESA (Surface Water & Groundwater)

The hydrology of the Sifton Bog ESA is complicated and, as a result, has been studied for several decades. This chapter describes the movement of water over the land surface and through the peat and groundwater.

3.1 Surface Water

3.1.1 Catchment Area

Map 6 shows the hydrological catchment area of the Sifton Bog ESA and the major drainage inputs from overland surface runoff around the site. The catchment areas of kettle bogs tend to be small. Gartner Lee Associates Ltd. (1993) reported the Sifton Bog ESA catchment area was 45.2 ha in 1993, and estimated the historic catchment area at 53.7 ha. This basin is small considering the peat bog and surrounding mixed coniferous swamp thicket is only about 23 ha and the entire ESA is 50 ha (see section 5.2). This loss of catchment area could have resulted in decreased water inputs to the bog and surrounding swamps and thickets. Development usually results in increased surface runoff and point-source discharge, and decreased infiltration. Since the early 1990s, stormwater management facilities have been a requirement of new development to address these types of impacts.

3.1.2 Lagg Zone

As described in the previous chapter, Sifton Bog is a raised bog, meaning the centre of the bog is slightly higher in elevation than the outside edges. The bog's hydrology is shaped by the water mound and the peat that encloses it, water level fluctuations in the upper peat layer (acrotelm), and the presence of water tracks, trails and drains that lead into the bog centre and threaten its future. Bogs require a lagg zone at the margins of the water mound in order to function properly. This zone may be one to several metres wide and acts like a moat around a castle, protecting the water mound by collecting surface water run off from the catchment area and normal

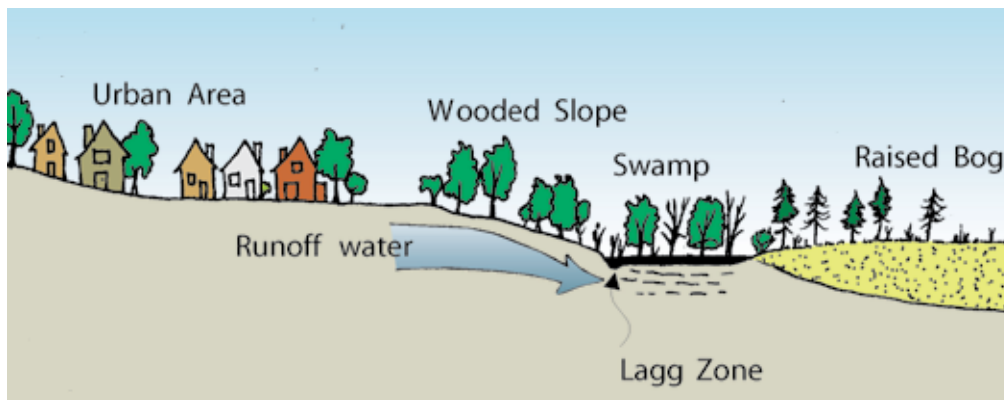


Figure 5. The lagg zone

discharge from the bog. The lagg zone is a built-in buffer that traps and prevents mineral nutrients and other pollutants from entering the water mound. However, this buffering function may be compromised in the late winter and spring if the surface is still frozen and meltwater can run freely over the lagg zone towards the bog centre (Figure 5).

3.1.3 Redmond's Pond Depth

The water depth of the pond today is considerably shallower than depths reported in the past (Table 4). Soundings taken in 1896 estimated the pond to be 7.3 m deep with 6 m of peat muck below (London Waterworks Commission 1896). The pond appears shallow in photos taken by Crawford around 1926 (Figure 14) because of the abundance of Southern Pond Lilies, which are unlikely to grow in very deep water. In 1979, geologic cross-sections developed by Gartner Lee Associates Ltd. show the pond's depth as 4 m, with 7 m of peat below the pond. In the fall of 2000 (a dry year), the pond was almost dry, as mudflats were visible (see photo below). In 2006, the water depth was estimated to be about 1.5 m and, in 2007, a dry year, it was about 1 m (Mike Knox, ESA Management Team, personal communication). This represents a trajectory of decreased water depth and increased accumulation of peat over time.

Table 4. Summary of Depth Records for Redmond's Pond

Year	Depth	Reference
1896	7.3 m	London Waterworks Commission, 1896
1926	<4 m	Observation based on photograph in Crawford's 1926 thesis (see Fig. 14)
1979	4 m	Gartner Lee Limited, 1979
2000	<1 m	UTRCA, visual inspection and photo (see below)
2006	~1.5 m	UTRCA, ESA Management Team, Personal Communication
2007	~1 m	UTRCA, ESA Management Team, Personal Communication

If the historical findings are accurate, the pond has become 3 - 6 m shallower over the last 100 years as muck builds up at the bottom. As described earlier in Figure 4, natural succession of kettle bogs often results in the filling-in of the open water. The timing of this eventuality is unknown and probably related to fluctuations in climate.

Interestingly enough, an overlay of airphotos from 1945 to 2007 shows Redmond's Pond to be about the same size (width and length) as it is today. The pond appears to be getting shallower, but not smaller in surface area. The small ponds to the southwest of Redmond's Pond have persisted over this time period as well.



Redmond's Pond in autumn 2000 (top) and autumn 2006 (bottom)

3.1.4 Other Ponds and Areas of Standing Water

Little is known about the pond located between Old Hyde Park Road and Hyde Park Road. It has not been measured or sampled. It appears to contain standing water year-round and may be a small kettle pond. There was a city well located in this area at one time.



Pond covered in duckweed between Old Hyde Park Road and Hyde Park Road, August 2006

Water levels in the Silver Maple swamps in the southwest corner of the ESA have not been consistently monitored over the years. Shallow ponds were hand-dug into the swamps sometime prior to the 1950s. The ponds hold water in the spring and summer and are often dry by fall. In the years when the Kirk Drain was reopened (approximately 1986 - 1991), the standing water dried up (Rosemary Dickinson, personal communication). After the drain was capped, water started to pond again and, in recent years (2006 - 2007), the swamp forest had standing water in the spring and early summer. It is very common for swamps to undergo wet and dry years in accordance with the weather.

3.2 Groundwater

Several shallow and deep monitoring wells (Map 3) have been installed and monitored in the Sifton Bog area since 1979 to gain an understanding of the groundwater conditions, especially as they may be impacted by land development. Information from the boreholes was also used to determine the geology of the site. Three cross-sectional diagrams of the bog and surroundings are included in Appendices L1 - L3 and Figure 6. These views show depth of peat, elevation of shallow and deep water tables, and underlying geology based on numerous boreholes installed by Gartner Lee Associates Ltd. (1979), Golder Associates (1992) and Applegate Groundwater Consultants (1998). Appendix L4 illustrates the location of all the bore holes installed since 1979.

3.2.1 Geology

The bedrock formation that underlies the Sifton Bog is the Dundee Formation. The bedrock is about 60 metres below grade and is characterized by limestone and dolostone, but some shale can also be associated with this formation (Applegate Groundwater Consultants 1999). Map 4 illustrates the physical setting of the London region. The bog is situated within an ancient river delta formation, washed over glacial ground moraine. The ground moraine, composed of clayey silt glacial till soils with random and discontinuous layers of silty and sandy soils, overlies the sands north and east of the bog. The deltaic soils are gravelly and sandy in texture with a variable thickness from nine metres to greater than 27 metres. These soils underlie the bog and are exposed at the surface southeast and south of the bog. Some were locally mined from a pit adjacent to Hyde Park Road. South and west of the bog, the lands slope gently towards the Thames River (Gartner Lee Associates Ltd. 1979, Applegate Groundwater Consultants 1998).

3.2.2 Peat

A mat of living *Sphagnum* moss, about two metres thick, occupies the bog area. The mat floats on the water along the perimeter of Redmond's Pond and on up to 10 m of peat. The depth of peat thins toward the outer edges of the kettle bog (see Appendices L1 and L2).

Two primary peat layers are present: the upper aerated acrotelm and the lower non-aerated catotelm (Figure 6). The acrotelm consists of freshly decomposing *Sphagnum* and other organic matter and is defined by the lowest level of the water table, excluding periods of extreme drought. Peat-forming aerobic bacteria and other micro-organisms are present in the acrotelm. Below the acrotelm is the permanently saturated peat, called the catotelm (Hebda *et al.* 2000). This layer contains more decomposed peat and, at the Sifton Bog, it appears as greenish-grey organic muck that is clayey with some silt. In the upper part, it has a very watery consistency that resembles a thick soup. The muck becomes more dense and firm with depth and with distance from the edge of the bog (Applegate Groundwater Consultants 1998). The lower catotelm is devoid of peat-forming aerobic bacteria. Biological decomposition by anaerobic microbes continues in the catotelm, but at a much slower rate than aerobic decomposition in the acrotelm.

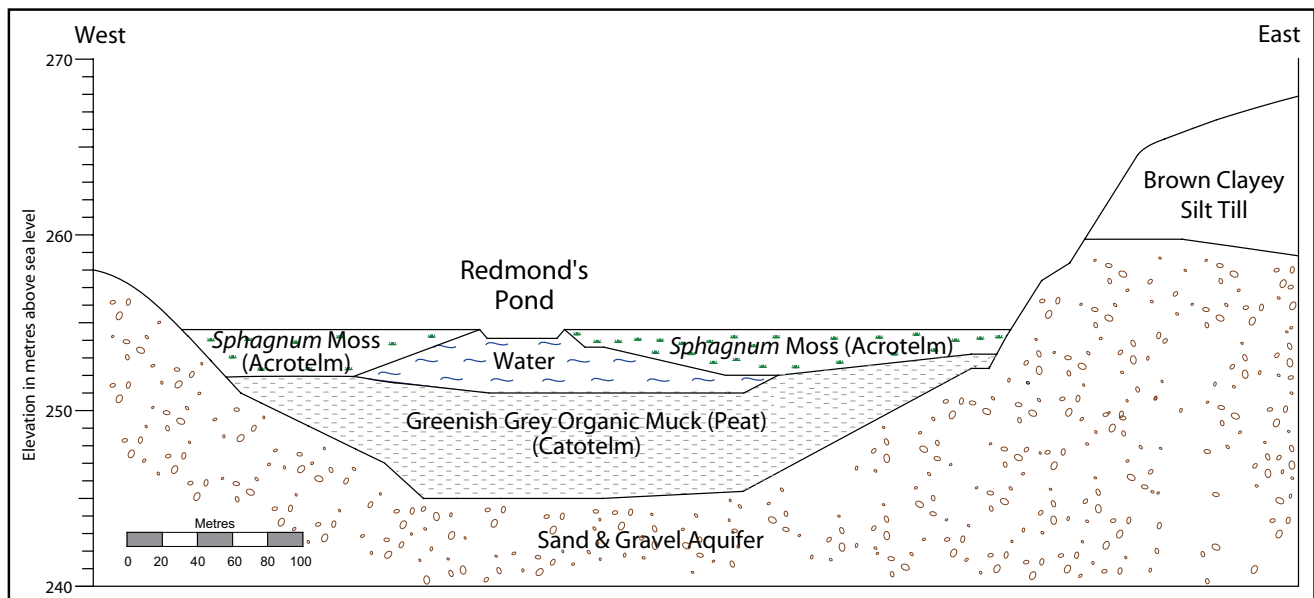


Figure 6. Geological cross-section of Sifton Bog ESA showing two major peat layers (Adapted from Applegate Groundwater Consultants, 1998)

Water easily infiltrates, draining downwards and laterally through the acrotelm. Most annual changes in water storage occur in this layer. Water flows less easily through the catotelm because of the small particle size of the decaying peat and compaction under the weight of peat alone (Hebda *et al.* 2000). The hydraulic conductivity (i.e., percolation rate of water through soil) of the muck is high in the upper watery part and decreases substantially with depth to about 10^{-6} cm/sec or less. The thick deposit of sand and fine gravel below the muck has a very high hydraulic conductivity, about 10^{-2} cm/sec. The upper portion of this sand and gravel deposit is referred to as the shallow aquifer and is generally unconfined in the vicinity of the bog.

3.2.3 Bog Groundwater Interactions with the Underlying Aquifer

Two monitoring wells that were completed in the sand and gravel beneath the bog indicated that the water level of Redmond's Pond is higher (approximately 0.85 m) than in the sand and gravel aquifer, thus confirming that the Sifton Bog is a raised bog. This difference in surface water and groundwater levels indicates that a downward hydraulic gradient exists from the pond to the underlying aquifer. Undisturbed, well-developed raised bogs are typically domed in cross-sectional profile. Sifton Bog is a raised bog that has developed a peat layer mound higher and wetter than the surrounding area and, thus, is recharged predominantly from precipitation

falling directly upon it (i.e., ombrotrophic bog). The slow downward movement of water recharges the groundwater below. Based upon data from the monitoring program, it appears that groundwater does not discharge to the bog (Applegate Groundwater Consultants 1998).

Infiltration of water is low on the tableland till soils and any water that does infiltrate moves vertically downward through the till and into the underlying sand and gravel aquifer. Precipitation that infiltrates to the subsurface on the tableland east of the bog does not contribute to the water balance of the bog proper. This was confirmed through an in-situ soil infiltration testing procedure by Applegate Groundwater Consultants (2000).

3.3 Water Budget

A water budget is an equation that describes the balance between water gains (inputs) and losses (outputs), and the resulting changes in the volume of water stored in a given system. The greatest water input to a raised bog is precipitation. Water loss occurs through evapotranspiration and lateral seepage through the upper peat layers. Vertical water losses through the more impermeable lower peat layer are low. The water not discharged or lost from the bog is accounted for in the water budget by a change in overall storage. Continued growth of peat-forming bog vegetation requires large volumes of water maintained as storage. A positive water balance and peat production that is in excess of decomposition is essential for bog formation (Mitch and Gosselink 1993). The water balance for Sifton Bog suggests a surplus of 360 - 460 mm of precipitation over evapotranspiration for an average year.

3.3.1 Groundwater and Surface Water Level Fluctuations

Figure 7 shows the fluctuations in water levels at Well 6S (shallow well behind St. Aidan's Church) between 1990 and 2006 compared to Redmond's Pond surface water levels. The automated data was averaged on a monthly basis and added to the manual data. Water levels vary seasonally, with the highest water levels occurring in the late winter and early spring and the lowest water levels in the summer and fall. There is an apparent decline in the water table between 1990 and 2006. There is insufficient data on water level trends in the Provincial Groundwater Monitoring Network within the Thames basin to comment on broad trends at this time.

The various water level investigations and monitoring of both shallow and deep wells on the tableland surrounding the bog since 1979 have demonstrated that groundwater does not discharge to the bog or is extremely limited. Therefore, the groundwater water chemistry probably does not negatively influence the water chemistry of the bog.

The elevation of the water level in Redmond's Pond has varied by up to 1.25 m since 1990 when measurements began to be taken by the UTRCA. Elevation measurements are generally between 254 and 255 m. The pond elevation corresponds to the bog water table (i.e., the water table is exposed at the surface). Golder Associates (1992) measured the pond's elevation at 254.38 m while the groundwater elevations in the surrounding monitoring wells located near the periphery of the ESA were slightly lower, around 254.0 m, and lower yet, 252.5 m, by the Silver Maple swamps in the southwest of the ESA. The bog is domed, accounting for the slight rise in elevation at Redmond's Pond.

Water level measurements have been taken about four times a year since 1990, with some interruptions due to budget cutbacks in the 1996 - 1999 period. Preliminary analysis of water levels versus precipitation does not show a good correlation because evapotranspiration cannot be accurately measured.

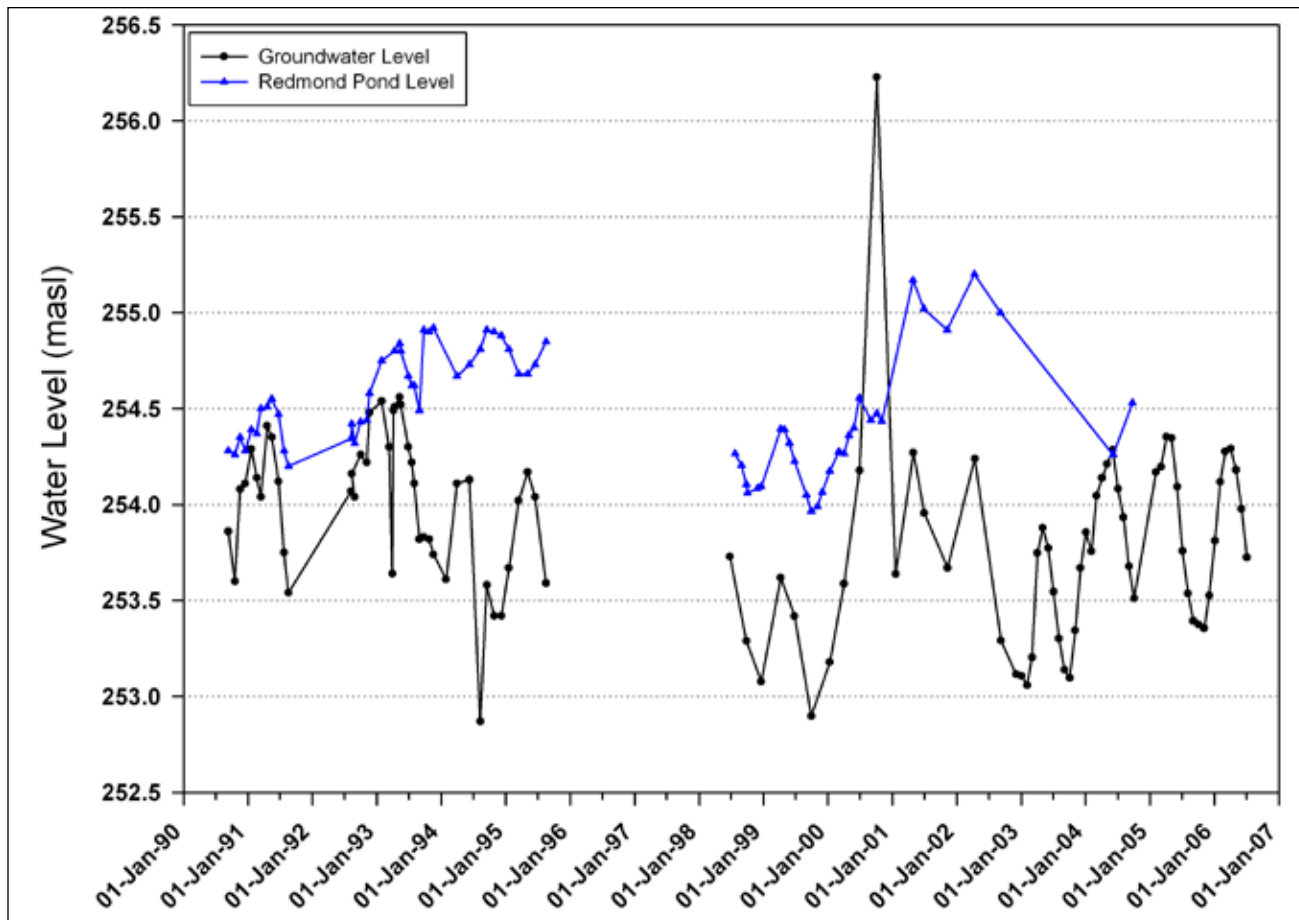


Figure 7. Water levels: groundwater (Well 6S) vs. surface water (Redmond's Pond), 1990 - 2006

3.3.2 Conceptual Water Budget for Pre- and Post Development

A water budget was completed by McCormick Rankin Corp. (1999) for the commercial and medium density residential development on the eastern tablelands. The methodology involved the following analyses:

- A conceptual water budget model was developed for the bog. The validity of the model was verified using existing monitoring data. The model was based on available precipitation and water level data to generate a predicted long-term record (1941 - 1998) of monthly water levels in the bog (Figure 8).
- A stormwater management strategy was developed to maintain the existing surplus currently directed to the bog, and to minimize potential contaminant loading.
- The conceptual water balance model was revised to include the proposed changes from development, generate the long-term series of water levels, and compare this to the simulation of existing conditions.
- A monitoring program was prepared to track water quality and water levels in the bog as they relate to inputs from the proposed development.
- A contingency plan was prepared that would be implemented if too little or too much water is introduced to the bog, or if the quality of runoff is below established targets.

Figure 8 shows the fluctuations in the bog water level in Redmond's Pond between 1940 and 1999 as modeled by McCormick Rankin. This long term simulation of existing conditions at the pond was done to calculate the water budget for the final development parcel (on tablelands east of the Sifton Bog ESA and west of Hyde Park Road). The lowest water level in Redmond's Pond was projected at 253.25 m from 1961 - 1964. The highest projected bog water level was 254.75 m in 1951, 1985, 1993 and 1996 - 1997. The model shows that when water levels are low, there is a greater difference between the pond and groundwater levels (e.g., 1960 - 1965) and when water levels are high, there is less of a difference (e.g., 1985, 1993). Further discussion is contained in Section 4.0.

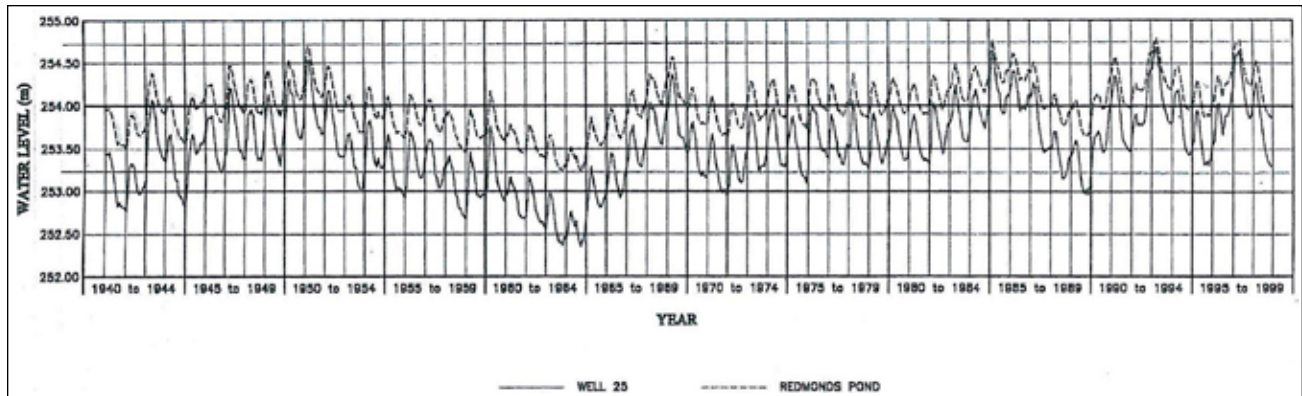


Figure 8. Long term simulation of water levels at Well 5 and Redmond's Pond (Source: McCormick Rankin Corporation 1999). Note: Well 5 was formerly called Well 25 (See Map 3).

3.3.3 Water Storage

Water storage capacity is a critical characteristic of peat bogs and a key parameter in their long-term sustainability. It is particularly important during summer drought or drought years. A summer water table that falls below 30 to 40 cm for a long time will jeopardize the ability of the bog to form peat. Woody species, such as shrubs and trees, will be favoured because they can extract moisture from deeper levels in the peat. Modelling changes in water storage permits an assessment of the risk to a peat body from serious disturbance by drought or human activity. Continued monitoring of water levels in the bog is required to evaluate potential risk.

Water is stored in bogs by either static storage or dynamic storage. Static storage occurs in the catotelm. This layer holds very large volumes of water that are discharged very slowly over time. The amount of water held in dynamic storage changes monthly and even daily. Water held in dynamic storage may be in three locations: the acrotelm, pools, and ditches. A highly functioning acrotelm can store a large volume of water and is characterized by slow to intermediate discharge rates. Shallow pools hold a moderate amount of water, while ditches and water tracks store very small volumes of water. Discharge from pools, ditches and tracks is rapid to immediate in rate.

An undisturbed acrotelm is essential to the continued existence and growth of a raised bog. Disturbance of this layer may lead to a lowering of the water table, a loss of stored water and a new hydrological equilibrium. This can result in changes to bog plant community composition and even cessation of peat formation. Observations made by Crawford (1926) point to the water level as one of the influential factors acting on the plants in the Sifton Bog.

3.3.4 Effects of Drainage

Ditches or drains are used to lower the water table in bogs and create the drier conditions required for peat harvesting, forestry and agricultural, or recreational use of the surrounding land. Drainage is the greatest threat to bog hydrology because it reduces water storage capacity. This affects both the composition and structure of the vegetation and the accumulation of peat. Drier conditions favour shrubs and trees and the loss of herbaceous plant species and *Sphagnum* mosses. Historical records indicate that attempts were made to drain the Sifton Bog to facilitate peat harvesting, Christmas tree harvesting, the cultivation of celery, and to access a potential source of water for City Water Works. Figure 9 illustrates the Kirk Drain, a clay tile drain installed in 1900 to 1902.

Shallow ephemeral water tracks form along trails made by people, animals and machinery or in ditches where peat has been eroded and compressed. At times of high water, the water collects in these low areas and can be seen to almost flow. This frequently occurred along the cinder trail that led to the original boardwalk (Bergsma 1993 personal observation).

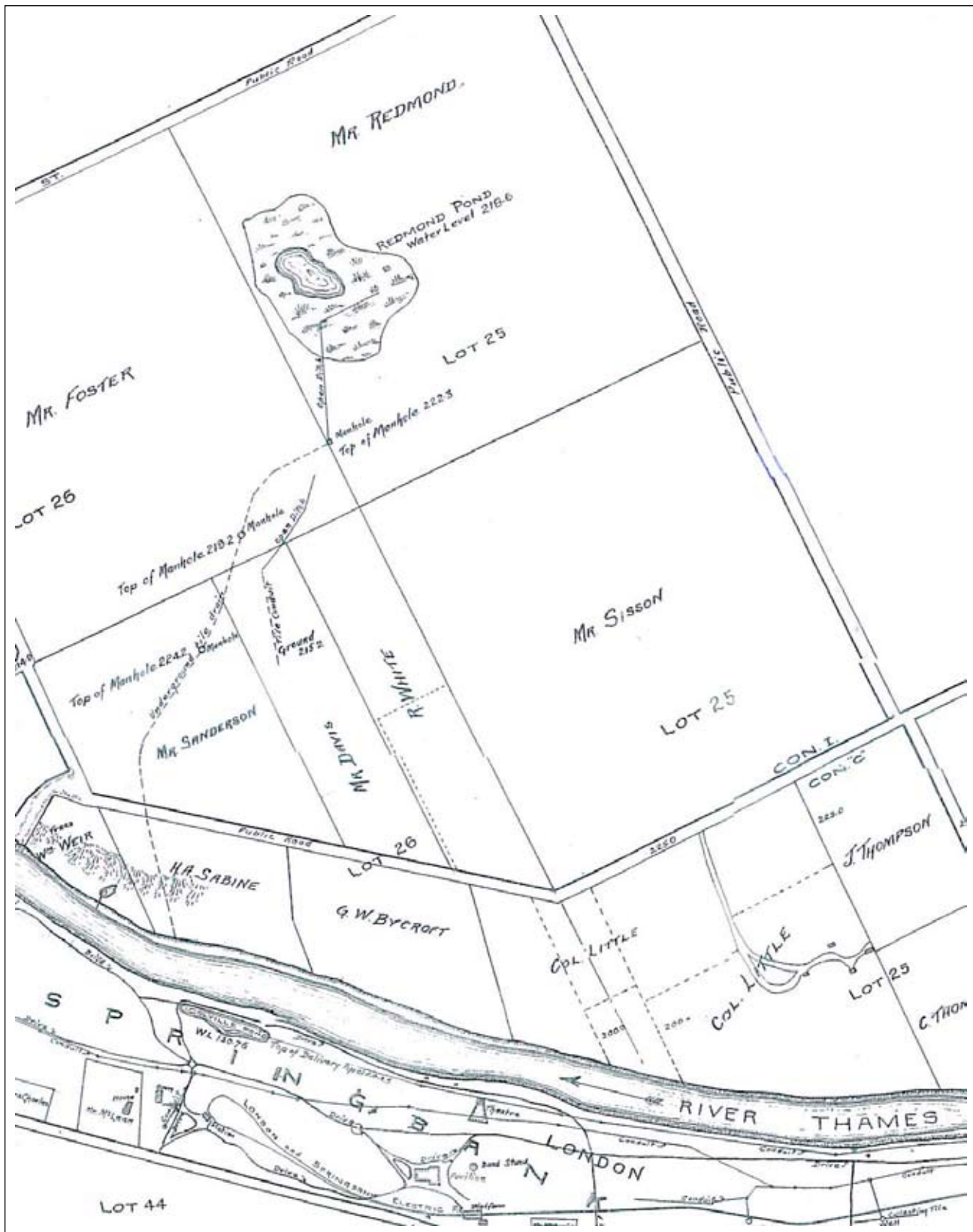


Figure 9. The Kirk Drain (1910 Water Works Map, City of London)

Note: The water level at Redmond's Pond is 218.6 ft, or 254.15 m. This value is remarkably consistent with the 254.1 m level surveyed in 1999 (see Appendix L1).