

Staunton Country Park

‘Lake’ Assessment Technical Note

6 November 2023

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1 Executive Summary

The brief was to undertake a study to assess and identify potential causes of periodic low water levels within the lake. The study was to be set out in a technical note format.

The objective of the study was to appraise site characteristics, based on site reconnaissance and desk study information, to assess factors that may influence the lake's water levels as well as to outline recommendations and next steps.

The potential causes of water loss have been explored and appraised. Summary of findings including scale of impact on lake water levels and perceived benefit in exploring mitigation measures further with respect to each water loss factor are set out in table below.

Item	Causes of water loss	Scale of impact on lake water levels	Should factor be considered further?
i	Evaporation from water surfaces	High	No*
ii	Infiltration	Low	No
iii	Seepage	Low	Yes
iv	Outlet configurations	Negligible	No
v	Catchment leakage	Moderate	No
vi	Catchment initial losses	Moderate	No
*Since the scale of impact is deemed to be high, using alternative water sources (e.g. mains supply) could be considered to help maintain lake water levels in dry periods, but the required volumes would be large and may be costly to implement, thus while this approach may be possible it is not recommended			

Based on the findings, it is recommended that remedial works are carried out to address observed defects at the lake to maintain the structure and avoid failure while also possibly reducing seepage losses, thus helping to address water loss and low water level issues at the lake.

In addition, the following actions are recommended to retain the lake and associated watercourses in good condition, albeit not specifically addressing water loss issues at the lake:

- i. Undertake remedial works in the watercourse channel downstream of the lake, local to 300mm diameter outlet pipe, to remove the formed plunge pool. Also, introduce erosion control measures to mitigate such features occurring in future.
- ii. Clear debris (e.g. bricks and branches) from the watercourse channel downstream of the lake, and ensure regular ongoing vegetation management is undertaken in the near vicinity to mitigate accumulation of debris.

2 Introduction

2.1 Background

- 2.1.1 Hampshire County Council's (HCC) Hampshire Engineering Services (HES) have been appointed by HCC Property Services to provide technical input with respect to water level issues associated with the lake at Staunton Country Park, Havant, herein referred to as 'the site'.

2.2 Brief

- 2.2.1 The brief was to undertake a study to assess and identify potential causes of periodic low water levels within the lake. The study was to be set out in a technical note format.
- 2.2.2 The objective of the study was to appraise site characteristics, based on site reconnaissance and desk study information, to assess factors that may influence the lake's water levels as well as to outline recommendations and next steps.

2.3 Exclusions & Limitations

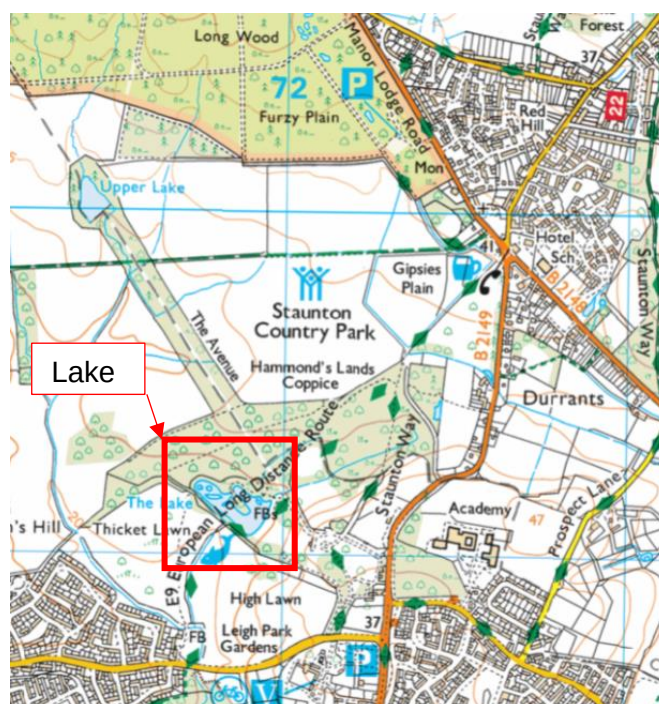
- 2.3.1 Detailed hydraulic modelling for the lake and its catchment were excluded from the scope of this study because there was no perceived benefit, thus modelling has not been undertaken.
- 2.3.2 This document is based on the interpretation and assessment of publicly available information and data provided by third parties. Whilst every care has been taken to ensure this information is accurate and up to date, the accuracy of third-party data cannot be guaranteed, and the findings of this report may change if the data is amended or updated after it has been reviewed.

3 Site Background

3.1 Site Location

- 3.1.1 Staunton Country Park is located within the north part of Havant, approximately 2.8km north of Havant town centre and approximately 2.1km south-west of Rowlands Castle village centre; refer to Figure 1.
- 3.1.2 Residential properties and Havant Academy school grounds are located to the east of the site. Staunton Farm and residential properties are found to the south and south-west respectively. To the north and west, the site is adjacent to areas of woodland and grassland; this area is the proposed location of Havant Thicket Reservoir, which has been granted planning permission and could be open fully to the public in 2029.

Figure 1 – Site location plan



3.2 Site Description

- 3.2.1 Staunton Country Park provides amenity function through its gardens and parkland, ornamental lake, and café and visitor facilities.
- 3.2.2 The ornamental lake, also known as Leigh Water, covers an area of approximately 3.5 acres and contains several islands. One island is

accessible via a small pedestrian bridge, also known as Chinese Bridge. The lake provides an angling function and supports a mixed coarse fishery.

- 3.2.3 Historically, the site locale was a 1400-acre estate built in the 19th century, comprising a house, gardens, parkland, ornamental lake, and various outbuildings. Anecdotally, as part of extensive landscaping works at the site, the lake underwent several iterations of changes within the 19th century, including an expansion and addition of masonry walls to the perimeter. The estate was sold to Portsmouth City in 1944, and residential properties were built in the surrounding area over a period in circa late 1940's and 1950's. The gardens and lake at the site became a country park in 1987.

4 Site Characteristics

4.1 Topography

- 4.1.1 A topographical survey was carried by SUMO Survey Services in September 2016. The survey data extents were localised to the area around the lake, including sections of the upstream and downstream watercourses. The survey data is contained in Appendix A.
- 4.1.2 The survey data indicates top-of-bank/wall levels around the perimeter of the lake; the lowest level found to be 22.78m AOD at the southern edge, and a narrow section of wall was indicated to have a level of 22.57m AOD, however this was associated with an overflow spillway at the south-western edge of the lake. The data also indicates a steep bank along the southern and south-western edges of the lake, near the downstream watercourse; the level difference between top of bank (lake perimeter) and bottom of bank (downstream watercourse) ranging from approximately 1.1 to 2.6m.
- 4.1.3 Environment Agency Light Detecting and Ranging (LiDAR) Digital Terrain Model (DTM) level data has been reviewed for the site. The levels are qualitatively consistent with those recorded in the topographic survey.
- 4.1.4 In addition, the survey data indicates base-of-lake levels around the perimeter of the lake. The levels indicate varying water depths of between approximately 0.4 to 1.8m around the lake perimeter with deeper depths found local to the southern and eastern edges and shallower depths found local to the western and northern edges.
- 4.1.5 Furthermore, is worth noting that in an exceedance event, such as extreme storm event, outlet blockage, or lake failure, water would breach the southern edge of the lake and flow in a southerly direction towards the downstream watercourse.

4.2 Geology & Hydrogeology

- 4.2.1 The British Geological Survey (BGS) Geoindex Onshore¹ mapping indicates the site is predominately underlain by superficial deposits of Head, which typically comprises clay, silt, sand and gravel. The mapping indicates that superficial deposits overlie bedrock of London Clay Formation, which typically comprises clay, silt and sand.
- 4.2.2 BGS borehole records indicate no records within the site boundary. BGS borehole record SU70NW319, taken from October 1977, is located approximately 400m west of the site. The data indicates different layers of strata, of varying thickness, comprising clay, silt and sand, and closely resembling characteristics of the superficial deposits and bedrock as identified from BGS mapping for the site. The borehole was formed at a ground level of 19.60m AOD and was bored to a depth of 34.40m below ground level (bgl). Bands of clay were encountered from the surface to a depth of 9.50m bgl, which overlaid bands of silt and sand between 9.50m and 14.30m bgl, which overlaid further bands of clay to the base of the borehole. Artesian water was encountered at a depth of around 12.50m bgl which corresponds with the bands of silt and sand.
- 4.2.3 DEFRA's Magic Map² indicates that the superficial deposits of Head are classified as a Secondary (undifferentiated) aquifer. The bedrock deposits of London Clay Formation are classified as an unproductive aquifer.
- 4.2.4 DEFRA's Magic Map indicates the site is within Source Protection Zone 1 – Subsurface Activity. The site is within a Low Groundwater Vulnerability Zone.

4.3 Existing Watercourses & Water Bodies

- 4.3.1 OS mapping indicates that there are watercourses and water bodies located within, and in the vicinity of, the site.
- 4.3.2 OS mapping indicates the lake, at Staunton Country Park, as the main water body in the locality. The mapping indicates two watercourses immediately

¹ British Geological Survey (BGS) Geoindex Onshore viewer.
<http://mapapps2.bgs.ac.uk/geoindex/home.html> (Accessed: September 2023)

² Department for Environment, Food and Rural Affairs (DEFRA) Magic Map.
<https://magic.defra.gov.uk/MagicMap.aspx> (Accessed: September 2023)

upstream and north and north-east of the lake, flowing in a southerly direction into the lake; the mapping also indicates one watercourse immediately downstream and south of the lake flowing in a southerly direction toward Riders Lane (river).

4.3.3 Furthermore, OS mapping indicates Riders Lane (river) is located approximately 350m south of the site at its nearest point. At this point, Riders Lane (river) is defined as a Main River in accordance with the records maintained by the Environment Agency. It is noted to be flowing in a southerly direction before confluence with Hermitage Stream, a Main River, which latterly flows into Langstone Harbour.

4.3.4 The findings from OS mapping are broadly consistent with topographical survey data and observations from site reconnaissance. However, a third watercourse was observed upstream and north-west of the lake (west of Chinese Bridge), flowing in a southerly direction into the lake via pipe outlet; this is also shown on topographical survey data.

4.4 Existing Sewer & Drainage Infrastructure

4.4.1 Sewer asset records and as-built drainage records for the site locale have not been reviewed as part of this study. Hence, there is currently no evidence to support the existence of a private surface water drain or public sewer within the site that is hydraulically linked to the lake.

4.4.2 Based on site reconnaissance, multiple small diameter pipe outlets were observed protruding from the lake wall on western side of the lake. The site operatives confirmed these outlets corresponded with land drainage features serving the slope area between the lake and former house.

4.5 Existing Artificial Sources

4.5.1 There are no known canals or boreholes, within, or in the near vicinity of, the site. However, the lake is possibly defined as a Small Raised Reservoir (SRR). The reservoir classification is largely dictated by the maximum storage capacity of water above ground level and in this instance the capacity of the lake is not known with certainty. This is discussed further in Section 6.6.

5 Site Reconnaissance

5.1 Background

- 5.1.1 Site reconnaissance was carried out in November 2022 and August 2023. On both occasions weather conditions were sunny and dry.
- 5.1.2 The purpose of the visit in November 2022 was to observe the lake structure and water levels, during the winter period, and to develop the scope for this document. The visit was localised to the lake and no intrusive inspections or measurements were undertaken.
- 5.1.3 The purpose of the visit in August 2023 was to observe the lake structure and water levels, during the summer period, and to take measurements of the on-line outlet in the manhole chamber; the chamber cover had previously been stuck for a long period of time and had only been recently freed and lifted. Also, the visit enabled a more thorough investigation of the catchment and watercourse inlets to better understand context.

5.2 Observations

- 5.2.1 During the site reconnaissance undertaken in August 2023, several observations were made local to the lake and its catchment; these are summarised below. Note that a selection of photographs from this reconnaissance are included in Appendix B.
- a) The watercourse immediately upstream and north-east of the lake was observed to have a small flow of water.
 - b) The watercourse immediately upstream and north of the lake was observed to be dry with no flows.
 - c) The watercourse immediately upstream and north-west of the lake (west of Chinese Bridge), and associated pipe outlet, was observed to be dry with no flows. This watercourse discharges to the lake via a short section of 150mm/225mm diameter pipe.
 - d) Land drainage outlets on the western side of the lake were mostly dry, bar the southern-most land drainage outlet which showed a very small trickle of flow.

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- e) At the on-line outlet, the manhole chamber was lifted, and a vertically orientated 300mm diameter pipe weir crest was observed. The weir crest level was observed to be approximately 0.33m below the cover level. Also, the water level was approximately 0.05m below the weir crest level, hence the weir was not flowing.
 - f) A 300mm diameter pipe outlet was observed local to the downstream watercourse, south of the lake; it is assumed to have connectivity with the lake's on-line pipe weir outlet. The pipe outlet was not flowing.
 - g) The downstream watercourse, south of the lake, was observed to be dry with no flows. There was evidence of scour in the channel immediately adjacent the outlet pipe where a plunge pool has formed; this has likely been caused by high velocities from the outlet over a long period of time. Furthermore, the watercourse channel contained debris and was heavily obscured by dense vegetation.
 - h) To the southern edge of the lake, the embankment and associated toe appeared to be both intact and dry, where not obscured by vegetation.
 - i) At the off-line outlet, the water level in the lake was noticeably lower than the spillway crest level. The spillway crest corresponds with a small section of the lake's perimeter footpath. Hence, at ground level, the spillway weir was dry with no flows.
 - j) The small ditch channel adjacent the off-line outlet (i.e., spillway) was observed to be wet with a small yet constant trickle of flow moving in a southern direction away from the lake; it is assumed that the water flow was from lake. Water was observed emerging from the bagwork underneath the spillway. The extent of wetness within the small ditch channel extended approximately 3m south into the adjacent woodland/scrub area at which point the ground surface was dry.
 - k) The masonry wall running along part of the lake's perimeter was mostly observable on the western and southern sides; some small sections were observed on the eastern and northern sides but were mostly obscured by

earth or vegetation. Where walls were observable above the water line, they appeared to be vertical in profile and mostly intact. However, several tree stumps were observed growing through the lake wall and in these places localised sections of wall appeared to have been displaced.

- l) A 'Well House' chamber structure is located approximately 50m north of lake. Anecdotally, this provided water supply to the house. The 'Well House' has an overflow channel which has connectivity with the north-east watercourse upstream of the lake. The chamber structure is covered with a grating; water was observed within the chamber, but no water was observed flowing from the chamber, hence the overflow channel was dry.
- m) A spring-like feature was observed in the field approximately 200m north-west of the lake; the water source is unknown. Water was observed overtopping an above ground trough feature and flowing overland and downhill towards the watercourse immediately upstream and north-east of the lake. Also, iron staining was observed at ground level local to the trough and in the overland flow route downstream.

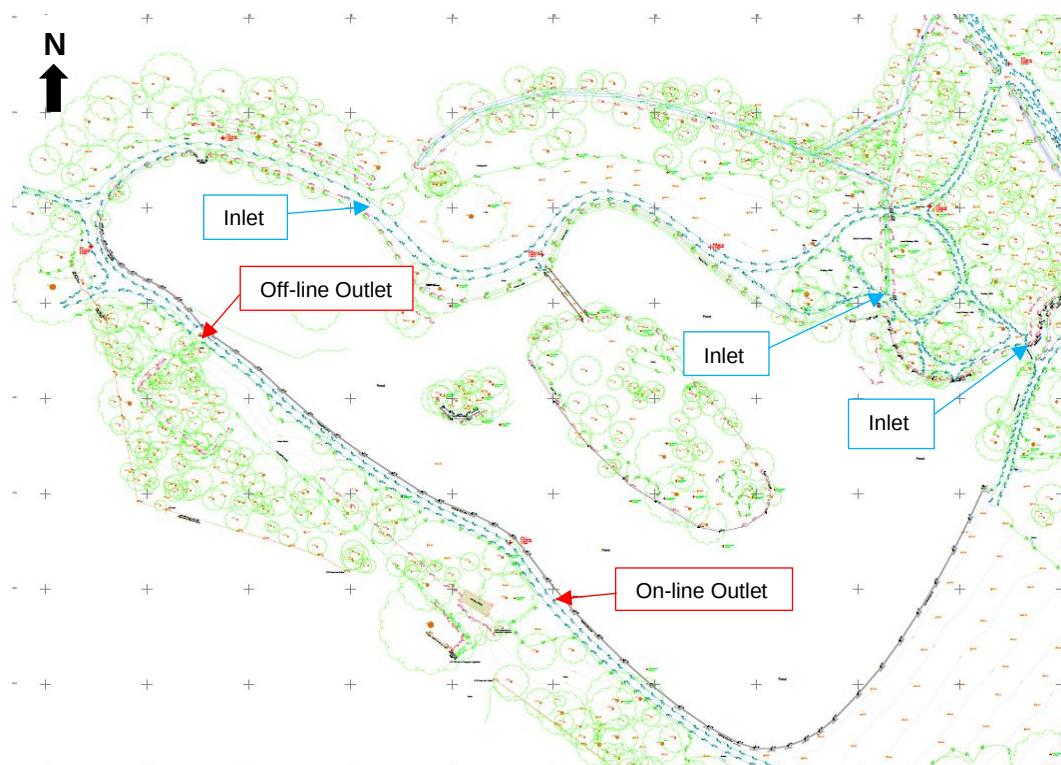
6 Lake Characteristics

6.1 Construction

- 6.1.1 Based on Steve Jones'³ historical records, it is understood the lake was a man-made feature, dug out by hand, and constructed between 1828 and 1836 as an ornamental feature. Also, it is understood the lake was formed on the site of a small pond which was used as an animal watering hole.
- 6.1.2 As per Section 4.1.5, based on BGS mapping and nearby borehole record, the lake locale was originally underlain by predominantly clay subsoils. Hence, since the lake was man-made and excavated in situ, it is likely the lake base and sides bound in situ clay material. Where ground levels have been raised to the form the elevated embankment on the southern side of the lake, it is likely this would have utilised site-won materials, namely clay.
- 6.1.3 Anecdotally, the lake underwent a series of expansions in the mid to late 19th century, and the masonry walls were subsequently added to the lake perimeter. The construction methodology for the walls is not known, but it is possible that when they were constructed, site-won materials, namely clay, would have been used as backfill.
- 6.1.4 Given that lake construction commenced almost 200 years ago, and subsequent expansion works have been undertaken since, it is not known whether lake lining works have been undertaken any point to prevent water loss to the ground.

³ Jones, S. (n.d.) Leigh Park Estate Garden Features & Follies - Havant Borough Council History Booklet No. 94. <https://thespring.co.uk/wp-content/uploads/2021/06/94-leigh-park-estate-garden-features-and-follies.pdf> (Accessed: September 2023)

Figure 2 – Plan showing lake inlets and outlets



6.2 Inlets

6.2.1 The lake is primarily fed by three known watercourse inlets. For inlet locations refer to Figure 2.

6.2.2 Two watercourses were observed to contribute the majority of flows into the lake, namely the north and north-eastern watercourses. A third watercourse (west of Chinese Bridge) was also observed to contribute flows to the lake. Topographical data suggests this watercourse intercepts runoff from the woodland area to the north-west of the lake, and in addition, has connectivity with the northern watercourse and likely primarily functions as a relief channel by receiving overspill from the northern watercourse in less frequent storm events.

6.2.3 Multiple land drainage outlets were observed to contribute flows into the lake. The outlets were protruding from the wall at intermittent points around the western side of the lake.

6.3 Outlets

6.3.1 The lake has two known outlets, both of which are understood to have connectivity with the watercourse downstream and to the south of the lake

which flows in a southerly direction toward Riders Lane (river). For outlet locations refer to Figure 2.

- 6.3.2 An on-line outlet is in a manhole chamber on the south-eastern edge of the lake. The outlet comprises a vertically oriented 300mm diameter pipe which acts like a weir; it is assumed the pipe weir has direct connectivity with the 300mm diameter pipe which discharges into the downstream watercourse. The crest level of the pipe weir in the chamber was measured to be at approximately 22.45m AOD. Based on the survey data, the crest is approximately 0.33m below the lowest surveyed top-of-bank/wall level.
- 6.3.3 An off-line outlet is in the form of an overflow spillway comprising a weir on the south-western edge of the lake. The spillway comprises a trapezoidal weir with a relatively narrow crest of approximately 1.5m wide at a level of 22.57m AOD. The spillway discharges into a small ditch channel which has connectivity with the downstream watercourse. Based on the survey data, the crest is approximately 0.21m below the lowest surveyed top-of-bank/wall level.
- 6.3.4 The on-line outlet's pipe weir has the lowest crest level and thus is deemed to primarily govern the lake's water levels. Hence, should water level drop below approximately 22.45m AOD, no water flow discharges from the lake to the downstream watercourse.

6.4 Levels and Depths

- 6.4.1 As per Section 4.1, topographical survey data indicated the lowest top-of-wall/bank level associated with the lake is approximately 22.78m AOD and corresponds with the top-of-wall level at the southern edge of the lake. A narrow section of wall has a top-of-wall level of approximately 22.57m AOD, but this corresponds with a localised overflow spillway formed within the wall at the south-western edge of the lake. Furthermore, data indicated varying water depths between approximately 0.4 to 1.8m around the lake with deeper depths found near the southern and eastern edges and shallower depths found near the western and northern edges.

6.4.2 In 2023, water depths around the perimeter of lake were estimated using a probe at regular intervals. The depths were approximated using the top-of-wall/bank as a datum. The data from the 2023 investigations are qualitatively consistent with data from 2016 topographical survey data, though with a few minor variations potentially attributed to debris and sediment deposition. For the purposes of this study, lake depths will be based on 2016 data since it is more comprehensive and deemed representative.

6.5 Storage Volume

6.5.1 Using the 2016 topographical survey data and Civils3D software, the lake's storage characteristics have been estimated for three scenarios, as listed below, and corresponding values are shown in Table 1:

- i. Maximum lake storage before lake overtopping
- ii. Maximum lake storage before triggering off-line outlet
- iii. Maximum lake storage before triggering on-line outlet

Table 1 – Estimated lake storage volume characteristics

Scenario	Water Level (m AOD)	Water Level Surface Area (m ²)	Estimated Lake Storage Volume (m ³)
i.	22.78	13,483	13,398
ii.	22.57	13,471	10,552
iii.	22.45	13,462	8,938

6.5.2 Estimations in Table 1 are based on the lake's water surface areas commensurate with each level, and water depth data for the lake perimeter. In lieu of depth data within the open water areas, depths have been interpolated between available data points at the lake perimeter and islands.

6.6 Reservoir Definition

6.6.1 In England, at present, a Large Raised Reservoir (LRR) is defined as holding, or having the potential to hold, more than 25,000 cubic metres of water above ground level. A reservoir that is able to hold between 10,000 and 25,000 cubic metres of water above ground level is known as a Small Raised Reservoir (SRR). Currently, there are different requirements for LRRs and reservoirs that hold less than 25,000 cubic metres of water above ground level; all LRRs must be registered with the Environment Agency (EA)

and thus are regulated, while reservoirs with a capacity of under 25,000 cubic metres of water above ground do not have to register with the EA and thus are unregulated⁴.

- 6.6.2 As per Section 4.5, the storage volumes assessment estimates the lake has a maximum capacity of approximately 13,400 cubic metres of water above ground level. On this basis, the lake would be regarded as an SSR and thus would be unregulated at present. However, more detailed assessments of the lake would be required to define reservoir status with more certainty.
- 6.6.3 It is worth noting that Department for Environment, Food and Rural Affairs (Defra) and Environment Agency (EA) are currently actively pursuing reservoir safety reform in England⁵. The outcome of this programme may result in legislative changes. As part of proposals, there is a chance that the regulation requirements for SRRs, such as the lake, may change in the next few years. Therefore, there may be a need for the lake to be registered and regulated by an appropriate overseeing organisation, such as the EA.

⁴ Department for Environment, Food and Rural Affairs (Defra) and Environment Agency (EA). Reservoirs: owner and operator requirements; <https://www.gov.uk/guidance/reservoirs-owner-and-operator-requirements> (Accessed: September 2023)

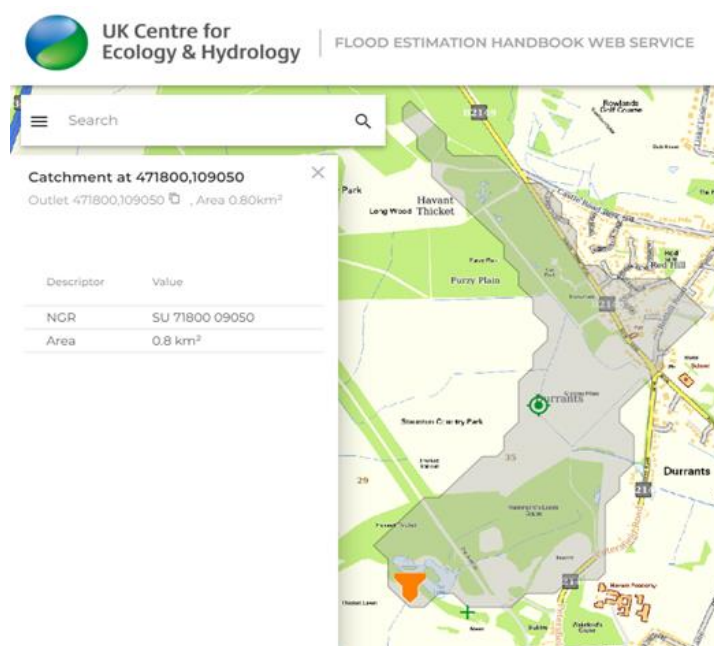
⁵ Defra and EA. Reservoir safety reform programme update; <https://www.gov.uk/government/publications/defra-and-the-environment-agency-reservoir-safety-reform-programme-update/reservoir-safety-reform-programme-update#programme-timeline> (Accessed: September 2023)

7 Hydrological Assessment

7.1 Catchment Description

- 7.1.1 The catchment is predominantly undeveloped greenfield land comprising areas of grassland and woodland. The catchment contains a relatively small area of development at the northern edge which comprises some residential dwellings and a short length of carriageway (Manor Lodge Road, B2149).
- 7.1.2 Based on present-day mapping (2023), the catchment consists of approximately 50% grassland, 40% woodland tree cover, approximately 10% urban development (including roads and buildings).
- 7.1.3 UK Centre for Ecology & Hydrology (UKCEH) Flood Estimation Handbook Web Service⁶ mapping indicates the lake's upstream catchment area is estimated to be approximately 0.8km²; refer to Figure 3. The catchment boundary was taken based on a point commensurate with the on-line outlet from the lake. The catchment boundary is derived using UKCEH's Integrated Hydrology Digital Terrain Model which is understood to use the EA's Light Detecting and Ranging (LiDAR) Digital Terrain Model topographical data.

Figure 3 – Lake catchment extents



⁶ UK Centre for Ecology & Hydrology (CEH) Flood Estimation Handbook Web Service.
<https://fehweb.ceh.ac.uk/Map> (Accessed: September 2023)

7.2 Hydrology

- 7.2.1 In addition to the information in Section 7.1, hydrological characteristics for the catchment were determined using UKSuDS' online tools⁷ and MicroDrainage's Source Control software; key parameters and corresponding values are shown in Table 2.

Table 2 – Catchment hydrological characteristics

Parameter	Value
Catchment Area (km ²)	0.8
Standard Annual Average Rainfall, SAAR (mm)	779
Catchment Wetness Index, CWI	115.194
Standard Percentage Runoff, SPR	0.47 (47%)
URBAN	0.10 (10%)

- 7.2.2 The FSR percentage runoff (PR) equation has been used to estimate the amount of runoff generated across the catchment. The equation assumed average monthly rainfall derived from SAAR and uses parameter values as per Table 2. Hence, the estimated PR value was approximately 50%.
- 7.2.3 The estimated PR value suggests that approximately half of the rainfall that falls on the catchment contributes to runoff generation. However, this is indicative only and actual runoff flows and volumes may be significantly influenced by frequency and intensity of storm events, land use and cover, and the effect of hydrological processes. Hence, it is possible that actual catchment runoff may differ and be significantly less than estimated.

7.3 Climate Change

- 7.3.1 UK Climate Projections 2018 (UKCP18) were developed by the Met Office Hadley Centre, in partnership with Defra, BEIS, the Devolved Administrations and the Environment Agency, and has been extensively peer reviewed by an independent science panel. UKCP18 data illustrates a range of future climate scenarios until 2100 which indicate increasing summer temperatures, more extreme rainfall patterns (e.g. wetter winters and drier summers) and rising sea levels are all predicted.

⁷ HR Wallingford UKSuDS Greenfield Runoff Rate Estimate Tool.
<https://www.uksuds.com/tools/greenfield-runoff-rate-estimation> (Accessed: September 2023)

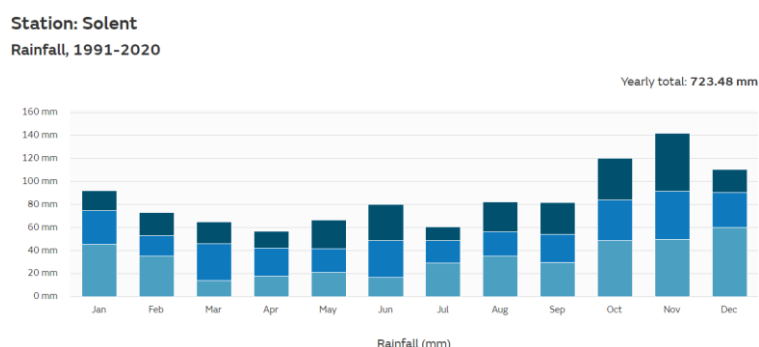
7.3.2 The UK has recently experienced long periods of high temperatures and low rainfall which resulted in the implementation of drought zones and hose-pipe bans. For example, based on UKCEH⁸, the summer period of 2022 (June-August) was registered as the fifth driest for England and Wales in a series of data starting from 1836. While based on previous climate data this specific instance could potentially be viewed as a one-off, with the projected effects of climate change set out in UKCP18, these instances are likely to become more frequent and may represent the future norm.

7.4 Rainfall

7.4.1 Met Office⁹ climate data has been reviewed to understand typical long-term rainfall patterns in the local area. The nearest weather station is Solent MRSC, which is located at Solent Airport, Lee-on-the-Solent, approximately 18km south-west of the site. For the purposes of this study, in lieu of site-specific rainfall data, this data is deemed representative of the site.

7.4.2 The rainfall data for the latest climate period of 1991-2020 is shown in Figure 4. The graph comprises bars made up of three colours: light, mid and dark blue, which represent 20th percentile, average and 80% percentile data values respectively. The Met Office estimates that for each month represented, there is a 20% (1 in 5-year) annual probability that rainfall would either be below the 20th percentile or above the 80th percentile.

Figure 4 – Monthly rainfall data over the period between 1991-2020

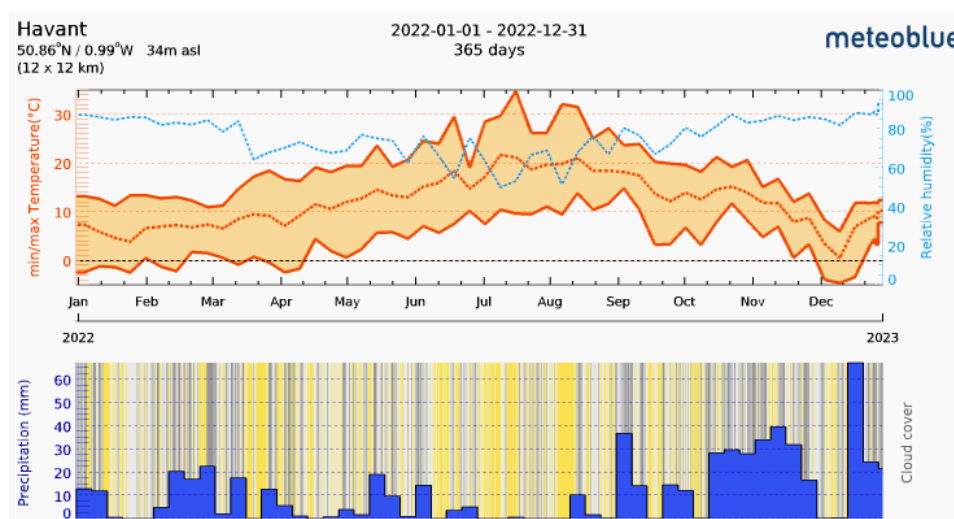


⁸ UK Centre for Ecology & Hydrology (CEH) Why we are still in drought despite recent rain. <https://www.ceh.ac.uk/news-and-media/blogs/why-we-are-still-drought-despite-recent-rain> (Accessed: September 2023)

⁹ Met Office Climate Research Data Solent MRSC. <https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcp1h90k5> (Accessed: September 2023)

- 7.4.3 The average rainfall data indicates the month yielding the lowest rainfall is April at 41.45mm, while the month yielding the highest rainfall is November at 90.78mm.
- 7.4.4 The average rainfall data demonstrates that the months of October to January (around winter season) typically yield highest rainfall with an approximate average of 85mm per month, while the months of February to September (around summer season) typically yield lowest rainfall with an approximate average of 55mm per month. Consequently, a relatively large proportion of the annual rainfall (approximately 40%) is anticipated to occur within a relatively short period of time, namely the four months including October to January.
- 7.4.5 Meteoblue¹⁰ weather data has been reviewed to understand shorter-term rainfall patterns in over smaller measured increments of time over a one-year period, in the local area. The data is taken from a weather station located in Havant and is shown in Figure 5. For this study, 2022 data has been reviewed as it is the most recent complete year, and it corresponds with a period of extreme weather events coinciding with anecdotal low water levels at the lake; this will be discussed further in Section 7.

Figure 5 – 2022 temperature and rainfall data for Havant



¹⁰ Meteoblue Weather Archive Havant.

https://www.meteoblue.com/en/weather/archive/export/havant_united-kingdom_2647317?fcstlength=1y&year=2022&month=4 (Accessed: September 2023)

- 7.4.6 The weather data for 2022 demonstrates a prolonged period of low precipitation (e.g. rainfall) over five months of April to August. The data shows that the months of April, July and August yielded negligible rainfall, while the months of May and June yielded a small amount of rainfall, noticeably below average for the equivalent typical month. Therefore, over the consecutive five-month period actual rainfall was significantly less than the typical average.

8 Hydraulic Assessment

8.1 Considerations

- 8.1.1 Detailed hydraulic modelling for the lake and its catchment were excluded from the scope of this study because there was no perceived benefit, thus modelling has not been undertaken.
- 8.1.2 Prior to the commencement of this study, in lieu of detailed modelling, it was anticipated that it may be possible to undertake high-level hydraulic calculations for lake to assess inflow and outflow characteristics and their influence on water levels. However, as the study progressed, it became clear that site-specific characteristics are complex and lots of assumptions would be required, thus calculation outputs would likely be inaccurate and unreliable. Hence, high-level hydraulic calculations for lake have not been undertaken as part of this study.
- 8.1.3 While high-level hydraulic calculations for the lake have been discounted, a series of hypothetical testing has been carried out on other key independent factors to appraise the potential impact with respect to water loss and low water levels at the lake.
- 8.1.4 It is important to note that the lake was originally intended to be an ornamental feature and not an engineered reservoir. Hence, when the idea of the lake was conceived hydrological and hydraulic factors were not likely considered, so the resultant shape, storage capacity and outlet arrangements are essentially arbitrary, and its performance is inadvertent.

8.2 Evaporation Losses

- 8.2.1 Research by Lapworth¹¹ conducted at Kempton Park reservoir, a 16-hectare man-made reservoir near London, indicates that between 1956 and 1962 the rate of evaporation ranged between 12.5 to 140mm per month, which works out approximately between 0.4 to 4.6mm per day. Furthermore, guidance prepared by Chartered Institution of Water and Environmental Management

¹¹ Lapworth, C. F. (1965). Evaporation from a reservoir near London. Journal of the Institution of Water Engineers, 19, 163-181.

(CIWEM)¹² indicates the rate of evaporation can range from between 0 to 0.5mm per day and 2.5 to 3.0mm per day for typical winter and summer periods respectively.

- 8.2.2 The potential impact of evaporation losses has been considered worthy of hypothetical testing. Evaporation loss volume has been estimated based on a water level of 22.45m AOD when the lake outlets are not active (Scenario iii as per Section 6.5). The testing uses upper evaporation rates for a typical winter and summer respectively as per CIWEM's guidance, as well as an assumed extreme summer rate derived from Lapworth's data.

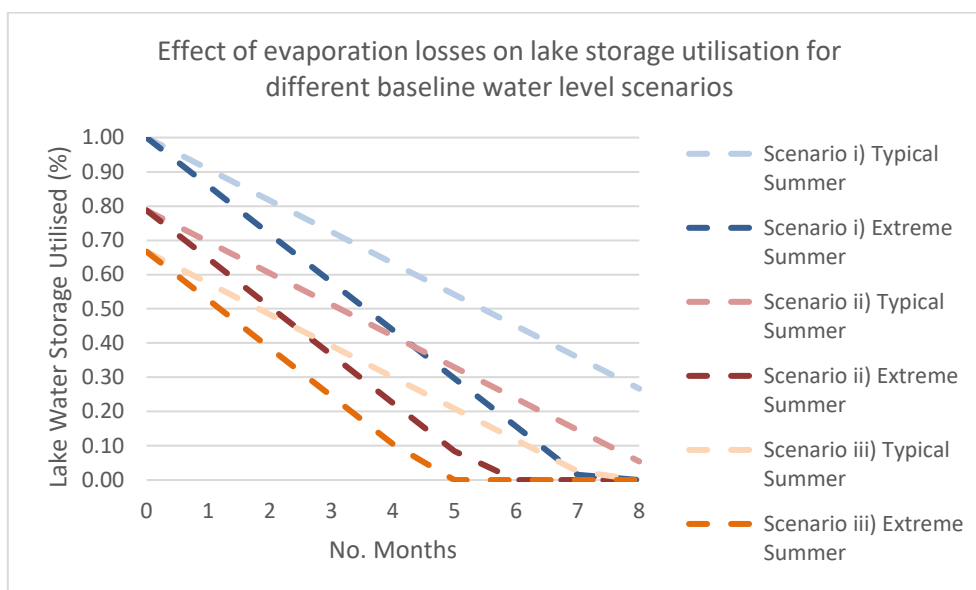
Table 3 – Estimated evaporation volume loss assessment

Lake Water Surface Area For Evaporation (m ²)	Evaporation Loss Volume, Per Average Month (m ³)		
	Typical Winter [rate 0.5mm/day]	Typical Summer [rate 3.0mm/day]	Extreme Summer [rate 4.6mm/day]
13,462	205	1,228	1,884

- 8.2.3 When comparing the data in Table 3 with Table 1, the average summer month evaporation loss volume is approximately between 9 to 14% (typical summer) and 14 to 21% (extreme summer) of the lake storage volume for Scenarios i to iii respectively, which is a relatively significant loss.
- 8.2.4 For graphic representation of evaporation loss trends refer to Figure 6. For this assessment it was assumed the lake experienced negligible inflows and outflows, and summer evaporation rates (typical and extreme) remained static over the evaluated period.

Figure 6 – Graph showing effects of evaporation loss on the lake

¹² Chartered Institution of Water and Environmental Management (CIWEM) Rainfall Modelling Guide 2016.
<https://www.ciwem.org/assets/pdf/Special%20Interest%20Groups/Urban%20Drainage%20Group/CIWEM-UDG-Rainfall-Guide-2016.pdf> (Accessed: September 2023)



8.2.5 Referring to Figure 6, taking Scenario iii as a theoretical worst-case baseline, for a typical summer period the lake would lose half its water volume in approximately 3.5 months and its whole water volume in approximately 7 months; for an extreme summer period the lake would lose half its water volume in approximately 2.5 months and its whole water volume in approximately 4.75 months. While these are hypothetical situations based on conservative assumptions, they are possible, and given the likely impacts of climate change on future weather patterns, the extreme situation tests may well become the future norm.

8.3 Infiltration Losses

8.3.1 The potential impact of water loss through infiltration to subsoils has been considered worthy of hypothetical testing. Infiltration loss volume has been estimated based on a water level of 22.45m AOD when the lake outlets are not active (Scenario iii as per Section 6.5). The infiltration rate for clay is based on conservative value selected from Table 25.1 of The SuDS Manual¹³. It is assumed the wall structure around the side of the lake is permeable and abuts natural subsoils comprising clay.

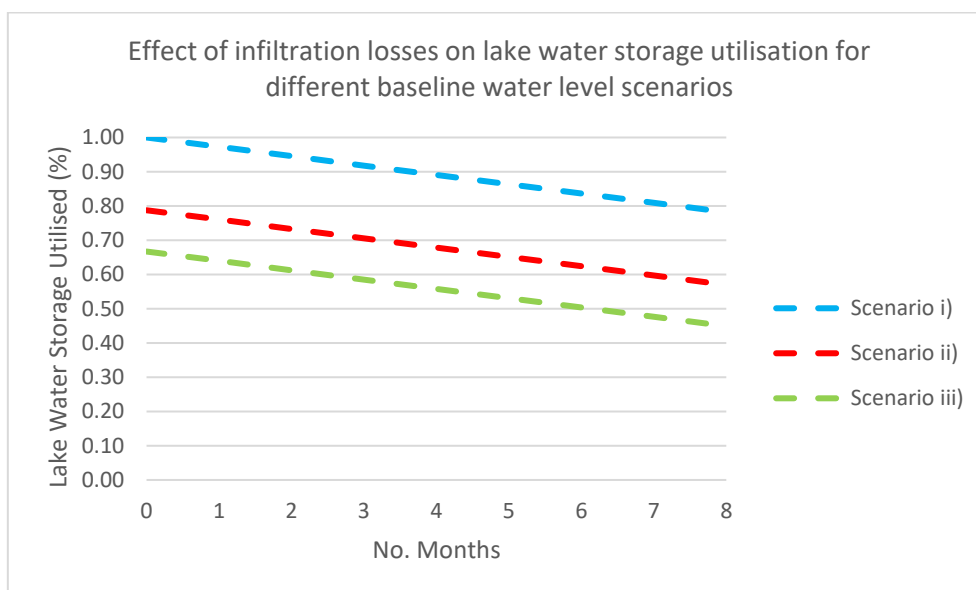
¹³ Woods Ballard, B, Wilson, S, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R, Kellagher, R (2015). The SuDS Manual, C753, CIRIA: London.

Table 4 – Estimated infiltration volume loss assessment

Lake Water Surface Area For Infiltration					Infiltration Rate, m/s	Infiltration Loss Volume, Per Average Month (m ³)
Base Area (m ²)	Perimeter (m)	Average Depth (m)	Side Area (m ²)	Total Area [Base & Side] (m ²)		
13,462	630	0.66	418	13,880	1x10 ⁻⁸	365

- 8.3.2 When comparing the data in Table 4 with Table 1, the average monthly infiltration loss volume is approximately between 3 to 4% of the gross lake storage volume for Scenarios i to iii respectively, which is a relatively small loss.
- 8.3.3 For graphic representation of infiltration loss trends refer to Figure 7. For this assessment it was assumed the lake experienced negligible inflows and outflows, and monthly infiltration discharge volume remained static over the evaluated period.

Figure 7 – Graph showing effects of infiltration loss on the lake



- 8.3.4 Referring to Figure 7, taking Scenario iii as a theoretical worst-case baseline, the lake would lose approximately a fifth of its water volume within a 6-month period. This is a relatively small loss, but compounded with other water loss mechanism would not be an insignificant factor.

9 Appraisal of Low Water Level Causes

9.1 Summary of Low Water Level Causes

9.1.1 Potential causes of water loss and corresponding low water levels at the lake, in the present day, have been considered and are as follows.

- i. Evaporation from water surfaces
- ii. Infiltration
- iii. Seepage
- iv. Outlet configurations
- v. Catchment leakage
- vi. Catchment initial losses

9.2 Evaporation from Water Surface

9.2.1 Evaporation is a process in which liquid changes to a gas and it is a key part of the hydrologic cycle. For water bodies, such as lakes and reservoirs, evaporation losses often play a significant role in water loss¹⁴. The rate of evaporation from water bodies can be affected by several factors, including size of water body surface area, temperature, humidity, and wind.

9.2.2 In Section 8.2, the effects of evaporation losses on the lake water storage volumes were hypothetically tested. The results indicated that monthly evaporation volumes losses were approximately up to 14% and 21% of the lake storage volume for typical and extreme summer events respectively. This scale of losses is deemed relatively significant.

9.2.3 Based on anecdotal information, lake water levels were very low in mid to late 2022 and intervention measures were employed to maintain the fish stock. In Section 7.3, it was established that extreme weather occurred in the summer of 2022, namely low rainfall over a consecutive five-month period. Considering the hypothetical testing results in Section 8.2, it is reasonable to presume that the lake inflow/outflow regime and an extreme summer

¹⁴ Britannica, T. Editors of Encyclopaedia (2023, August 9). reservoir. Encyclopedia Britannica. <https://www.britannica.com/technology/reservoir> (Accessed: September 2023)

evaporation rate assumptions are likely to be representative of events that transpired in 2022, and thus it is theoretically possible that a significant proportion of lake water volume may have evaporated over a 4-5 month period. Consequently, given the similar periods of measured low rainfall in 2022 and hypothetical extreme summer evaporation, the anecdotal low lake water levels were likely primarily caused by evaporation.

9.2.4 Therefore, evaporation losses are considered to have a high impact on water loss and low water levels at the lake at present.

9.2.5 In terms of mitigation measures, methods appraised include installing wind breakers, using chemical evapo-retardents or installing floating covers, such as 'shade balls' or photovoltaic panels. Taking into account the function and setting of the lake, none of these options are deemed appropriate. Furthermore, using alternative water sources (e.g. mains supply) may help to maintain lake water levels in dry periods, but required volumes would be large and depending on the source may be costly and restricted in times of drought. Hence, mitigation measures are not considered to be feasible.

9.3 Infiltration

9.3.1 Infiltration is a process in which water percolates through subsoils, via pores and fissures, to the groundwater table. Infiltration is typically associated with granular subsoils that yield higher soakage rates, such as gravels and sands, but it also naturally occurs in subsoils comprising fine particles, such as silts and clays, though these characteristically yield lower soakage rates. For unlined water bodies, such as lakes and reservoirs, infiltration typically occurs at side and base areas that interface with subsoils.

9.3.2 In Section 8.3, the effects of infiltration losses on the lake water storage volumes were hypothetically tested. The results indicated that average monthly infiltration volume losses were approximately up to 4% of the lake storage volume. This scale of losses is deemed relatively low.

9.3.3 Given the information in Section 6.1, it is possible the lake has not been wholly lined and the masonry walls and mortar joints may be porous, so

there is a chance the base and sides interface with natural subsoils comprising clay, and thus some degree of infiltration may occur at present.

9.3.4 Therefore, infiltration losses are considered to have a low impact on water loss and low water levels at the lake at present.

9.3.5 In terms of mitigation measures, methods appraised include installation of an impermeable liner, such as plastic sheets, bentonite clay or concrete; this is considered possible for the lake's base but not the sides as it may be difficult to implement and affect the character of the wall when water levels are low. While lining the lake's base is considered possible, it will not be as effective without treating the sides, thus benefit is considered negligible for relatively high cost. Hence, mitigation measures are not considered to be feasible.

9.4 Seepage Losses

9.4.1 Seepage is a process in which liquid flows through something, such as a porous material or holes. In the context of water bodies, such as dams and reservoirs, seepage occurs as impounded water seeks the path of least resistance through the structure. Unlike the process of infiltration, seepage flow typically reemerges downstream at a surface level, such as via a new spring-like feature or contributing baseflow to a watercourse¹⁵.

9.4.2 Seepage loss flow rates may vary over time because of changes to the structure of a lake, dam or reservoir. Changes may include retaining wall failure that creates a flow path, or changes to soil structure characteristics, such as due to prolonged flow via a band of porous strata, tree root growth or sub-surface animal burrows. While seepage results in water loss from a water body, the process itself can cause erosion which can result in destabilisation of embankments and retaining structures and may eventually result in failure, particularly for dams and reservoirs.

9.4.3 As per Section 5.2, during site reconnaissance, some observed defects indicate a high likelihood of localised seepage occurring at the lake at

¹⁵ Association of State Dam Safety Officials (ASDSO) (2023). Seepage Through Earthen Dams. Available at <https://damsafety.org/dam-owners/seepage-through-earth-dams> (Accessed: September 2023)

present. Firstly, water was observed flowing underneath the spillway to an adjacent ditch, from the lake direction. Secondly, several trees were observed growing through the lake wall and in these places localised sections of wall appeared to have been displaced, thus potentially creating a route through which lake water may seep.

- 9.4.4 Due to the complex nature of seepage, it is not possible to quantify its potential effect on water loss and the lake water levels. However, based on observations, the effects of seepage on water loss are likely to be relatively low given defects are small and localised and due to the scale of the lake. Nevertheless, the defects should be prioritised for repair primarily to maintain the structure of the lake and avoid failure; it may be that an additional benefit to remedial works might be a reduction in seepage losses.
- 9.4.5 Therefore, seepage losses are considered to have a low impact on water loss and low water levels at the lake at present.
- 9.4.6 In terms of mitigation measures, it is critical to identify the potential seepage mechanisms before undertaking any measures to ensure works are appropriate and effective. As per Section 5.2, defects were observed during site reconnaissance and these should be prioritised for repair primarily to maintain the structure of the lake and avoid failure but may also help reduce seepage losses. Hence, mitigation measures are considered to be feasible.

9.5 Outlet Configurations

- 9.5.1 Outlet configurations has been used as a term to describe the features designed to convey controlled water flows to another location. On-line outlets are assumed to correspond with features that typically convey flows regularly and under normal operating conditions, while off-line outlets are assumed to correspond with features that seldom convey flows and usually only during extreme circumstances. Outlets from water storage features, such as lakes and reservoirs, are typically sized and positioned to maximise water storage over a long period of time while also maintaining some level of baseflow downstream and mitigating against overtopping and failure.

- 9.5.2 As per Section 6.3, the lake has two known outlets. The on-line outlet corresponds with a pipe weir and the off-line outlet corresponds with a spillway. Both outlets are set at a relatively high, with on- an off-line outlet crest levels set at approximately 0.33m and 0.21m below lowest top-of-bank/wall level respectively. Given the lake's maximum storage depth is up to 1.8m at the southern and eastern edge, the outlet configurations are well arranged to minimise outflows and prioritise the lake's water retention capability; this is demonstrated in Table 1 where an estimated circa 9,000 cubic metres of water storage capacity is available below lowest outlet crest level and lake base.
- 9.5.3 Therefore, outlet configurations are considered to have a negligible impact on water loss and low water levels at the lake at present.
- 9.5.4 In terms of mitigation measures, methods appraised include reducing the number of outlets, reducing outlet size, and elevating the outlets. The lake has one on-line and one off-line outlet and both are required to maintain normal function and provide exceedance relief, and these are set at a high level and are relatively proportional in size compared to the lake, thus it is not deemed beneficial to alter the existing outlets. Hence, mitigation measures are not considered to be feasible.

9.6 Catchment Leakage

- 9.6.1 For the purposes of this report, catchment leakage has been used as a collective term to describe factors that may have a significant bearing on the catchment's ability to generate runoff, such as nature of precipitation, vegetation coverage, urban development coverage, groundwater recharge, and water abstraction. Only some factors have been explored in this section.
- 9.6.2 Urban development cover comprises areas of impermeable surfaces and vegetated cover comprises areas of permeable surfaces, which typically yield higher and lower runoff flows and volumes respectively during storms. Hence, the types and distribution of surface coverage affects catchment runoff characteristics. A comparison of historic mapping (1888-1913, OS Six Inch) and present-day mapping (2023) indicates that catchment cover has

remained largely unchanged over the circa 120-year period, bar a very small increase of urbanisation at the northern edge at Red Hill, Rowlands Castle.

- 9.6.3 Therefore, since catchment coverage composition has hardly changed, the factor is considered to have a negligible impact on water loss and low water levels at the lake at present.
- 9.6.4 The nature of precipitation (e.g. rainfall) greatly influences catchment runoff flows and volumes. For example, long duration low intensity storms tend to generate low peak flows but high runoff volumes, whereas short duration high intensity storms tend to generate high peak flows but low runoff volumes; typically winter and summer storm profiles correspond with the former and latter respectively. As per Sections 7.3 and 7.4, rainfall data indicates that typically more rainfall falls in the winter than in the summer, and UKCP18 data indicates that winters will likely become wetter and summers will become drier in the future. This means the lake will likely receive more water in the winter and less water in the summer, thus leading to more obvious seasonal variations in lake water levels. But, while seasonal precipitation patterns may become more pronounced, the annual rainfall volume yield is unlikely to vary significantly. Notwithstanding, weather data from 2022 suggests the projected impacts of climate change may be being felt at present and thus are already impacting the lake to some degree.
- 9.6.5 Therefore, the nature of precipitation is considered to have a moderate impact on water loss and low water levels at the lake at present.
- 9.6.6 In terms of mitigation measures, options are limited due the catchment's scale and complex nature of individual factors. Some measures were appraised including altering catchment coverage and using alternative water sources to supplement inflows. Changing surface coverage on a catchment level is likely to be prohibited by land ownership constraints and national and local planning policies. Using alternative water sources (e.g. mains supply) may help to maintain lake water levels in dry periods, but required volumes would be large and depending on the source may be costly and restricted in

times of drought. These measures are not deemed appropriate or achievable. Hence, mitigation measures are not considered to be feasible.

9.7 Catchment Initial Losses

- 9.7.1 For the purposes of this report, catchment initial losses have been used as a collective term to describe factors that may have a significant bearing on net runoff flows and volumes generated by the catchment, such as interception, infiltration, transpiration, and evapotranspiration.
- 9.7.2 Initial loss represents the amount of rainfall required to fall on the catchment surface before measurable runoff is generated. Initial losses may be influenced by various factors including vegetation coverage, soil types and climate characteristics.
- 9.7.3 Some factors associated with catchment leakage and catchment initial losses are linked and thus are not mutually exclusive in certain instances. Hence, for this study, it was not deemed appropriate to explore initial losses in detail, and thus the scale of impact has been appraised at a high level.
- 9.7.4 According to Kellagher¹⁶, around 50% of rainfall events in the UK yield less than 5mm and cause no measurable runoff from greenfield (undeveloped) areas into receiving waters; this indicates several key things: firstly, catchment initial losses likely correspond to approximately 5mm; secondly, around half of annual rainfall events in the UK are very small; and thirdly, around half of annual rainfall events actually generate measurable runoff within a catchment. Hence, relatively undeveloped catchments are much less likely to generate measurable runoff throughout a year than more developed catchments due to initial losses.
- 9.7.5 As per Section 7.1, it is worth bearing in mind that currently the lake's catchment consists of approximately 90% vegetation coverage and thus is predominantly undeveloped. This means that it is likely that effects of initial losses may have a noticeable impact on runoff generation for around half of the annual rainfall events and thus affect water levels at the lake.

¹⁶ Kellagher, R. (2013). Rainfall runoff management for developments, Report SCS030219, Environment Agency, Bristol, UK (ISBN: 978-1-84911-309-0).

- 9.7.6 Therefore, catchment initial losses are considered to have a moderate impact on water loss and low water levels at the lake at present.
- 9.7.7 In this instance, mitigation measures for catchment leakage and initial losses are considered to be similar, hence for appraisal refer to Paragraph 9.6.6.

10 Findings and recommendations

10.1 Findings

10.1.1 Based on the information set out in Section 9, findings from the appraisal of causes of water loss and possible scale of impact on low water levels at the lake are summarised below in Table 5.

Table 5 – Summary of causes of water loss and scale of impact on the lake's water levels

Item	Causes of water loss	Scale of impact on lake water levels
i	Evaporation from water surfaces	High
ii	Infiltration	Low
iii	Seepage	Low
iv	Outlet configurations	Negligible
v	Catchment leakage	Moderate
vi	Catchment initial losses	Moderate

10.1.2 Out of the explored potential causes of water loss in Table 5, items i to iv directly relate to the lake feature itself, whereas items v and vi relate to the lake's catchment characteristics.

10.1.3 Evaporation from water surfaces (item i) is considered to have a high impact on water loss and low water levels at the lake. Mitigation methods appraised are not deemed appropriate taking into account the function and setting of the lake, thus mitigation measures are not considered to be feasible. Since the scale of impact is deemed to be high, using alternative water sources (e.g. mains supply) could be considered to help maintain lake water levels in dry periods, but the required volumes would be large and may be costly to implement, thus while this approach may be possible it is not recommended. Hence, there is no perceived benefit in considering this factor any further.

10.1.4 Infiltration (item ii) is considered to have a low impact on water loss and low water levels at the lake. Mitigation methods appraised may not be wholly effective and benefits are considered negligible for relatively high cost, thus mitigation measures are not considered to be feasible. Hence, there is no perceived benefit in considering this factor any further.

10.1.5 Seepage (item iii) is considered to have a low impact on water loss and low water levels at the lake. Defects were observed during site reconnaissance

and should be prioritised for repair primarily to maintain the structure of the lake and avoid failure but may also help reduce seepage losses. Hence, there is perceived benefit in considering this factor further; refer to the recommendations.

10.1.6 Outlet configurations (item iv) are considered to have a negligible impact on water loss and low water levels at the lake. Mitigation measures appraised indicate it is not deemed beneficial to alter the existing outlets, thus mitigation measures are not considered to be feasible. Hence, there is no perceived benefit in considering this factor any further.

10.1.7 Catchment leakage and initial losses (items v and vi) are considered to have a moderate impact on water loss and low water levels at the lake. In both instances mitigation measures options are limited due the catchment's scale and complex nature of individual factors. Mitigation measures appraised are not deemed appropriate or achievable. Hence, there is no perceived benefit in considering these factors any further.

10.2 Recommendations

10.2.1 Based on the findings, it is recommended that remedial works are carried out to address observed defects at the lake to maintain the structure and avoid failure while also possibly reducing seepage losses, thus helping to address water loss and low water level issues at the lake.

10.2.2 In addition, the following actions are recommended to retain the lake and associated watercourses in good condition, albeit not specifically addressing water loss issues at the lake:

- i. Undertake remedial works in the watercourse channel downstream of the lake, local to 300mm diameter outlet pipe, to remove the formed plunge pool. Also, introduce erosion control measures to mitigate such features occurring in future.
- ii. Clear debris (e.g. bricks and branches) from the watercourse channel downstream of the lake, and ensure regular ongoing vegetation management is undertaken in the near vicinity to mitigate accumulation of debris.

Appendix A – Topographical Survey

Appendix B – Photographs

1) Watercourse immediately upstream and north-east of the lake [Report Section 5.2, a)]



2) Watercourse immediately upstream and north of the lake [Report Section 5.2, b)]



3) Watercourse immediately upstream and north-west of the lake (west of Chinese Bridge) [Report Section 5.2, c)]



4) Chamber on watercourse immediately upstream and north-west of the lake [Report Section 5.2, c)]



5) Land drainage outfalls on the western side of the lake [Report Section 5.2, d)]



6) Manhole chamber containing the lake's on-line outlet [Report Section 5.2, e)]



7) On-line outlet pipe weir approximately 0.33m below cover level [Report Section 5.2, e)]



8) 300mm diameter pipe outlet into downstream watercourse, south of lake [Report Section 5.2, f)]



9) 300mm diameter pipe outlet into downstream watercourse, south of lake [Report Section 5.2, f and g)]



10) Lake's downstream watercourse channel with evidence of scour and debris [Report Section 5.2, g)]



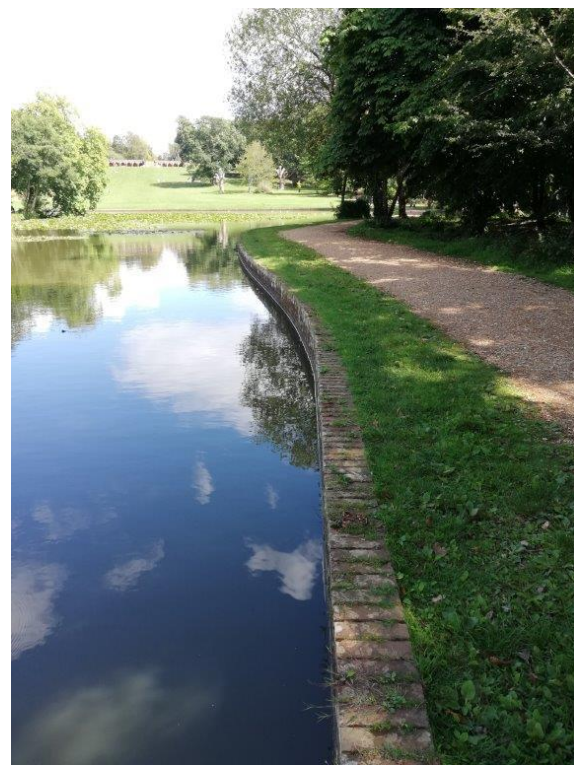
11) Off-line outlet spillway [Report Section 5.2, i)]



12) Small ditch channel adjacent the off-line outlet (i.e. spillway) [Report Section 5.2, j)]



13) Masonry wall running along part of the lake's perimeter [Report Section 5.2, k)]



14) Example of tree stumps growing through masonry wall around the lake's perimeter [Report Section 5.2, k)]



15) Channel from 'Well House' to north-east watercourse upstream of the lake [Report Section 5.2, l)]



16) 'Well House' chamber structure [Report Section 5.2, l)]



17) Spring-like feature in the field north-west of the lake [Report Section 5.2, m)]



18) Water flows and iron staining local to spring-like feature [Report Section 5.2, m)]

