Wanstead Park Ponds
Flood Study

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1 Introduction

1.1 Purpose of Study

Wanstead Park contains four reservoirs in cascade which are classified as large raised reservoirs under the provisions of the Reservoirs Act 1975. These are:

- Shoulder of Mutton Pond (Category C),
- Heronry Pond (Category C),
- Perch Pond (Category C) and
- Ornamental Water (Category D).

The meaning of the categorisation will be explained in later sections.

These reservoirs have not been subject to a flood study since the introduction of the current standards as set out in the 4th Edition of "Floods and Reservoir Safety" (FRS4) or the release of the FEH 2013 rainfall depth model.

1.2 Location

The lakes are located in Wanstead Park in in the London Borough of Redbridge, as shown in *Figure 1 and* Figure 2*.*

Wanstead Park is in the middle of a heavily built up area of London. The River Roding runs down the north east boundary of the Park and Ornamental Water is in the flood plain of the Roding. "The Basin" is also a reservoir under the Act but is in separate ownership and is considered to have no net effect on the flood safety of the downstream reservoirs.

For clarity the 'Basin' is situated on the golf club to the west of the chain and was inspected by myself recently. It appears to be fed by an urban drainage system to the northwest and there are two small piped feeds into the reservoir. As a result, the catchment to the north of the A12 and indeed Overton Drive as shown.

1.3 Classification of the Reservoirs

The reservoirs are classified as 'High Risk' by the EA. This definition is such that a high risk reservoir must be considered so if*, 'in the event of an uncontrolled release of water from the reservoir, human life could be endangered'* (Clause 2C(i) of the Reservoirs Act 1975 as modified by the Flood and Water Management Act 2010).

The designation of High Risk involving the situation where human life could be 'endangered' applies if:

- the likely loss of life is greater or equal to one;
- the rate of flow is greater than or equal to 3 m^3/s per metres (this is when structural damage is likely to occur);
- there is a significant population at risk of flooding to say more than 200 people or 20 businesses within the downstream flood plan;
- it also includes where infrastructure could lead to direct loss of life which could include destruction or flooding of road and rail infrastructure.

The designation High Risk or Low Risk in England merely defines whether the reservoir is subject to the legislation or not. High Risk reservoirs are subject to the legislation and Low Risk reservoirs are not. This classification is at the moment for reservoirs which hold more than 25,000 cubic metres of water above the level of the natural ground.

So, Michael Pitt's report after the 2007 floods led to suggestions to modify the Reservoirs Act 1975 and provision is made in the Flood and Management Act, 2010 to bring about amendments.

One of the amendments, which has been adopted by Wales (who has the same legislation) is the reduction in qualifying capacity to 10,000 cubic metres. The English Government is still considering this matter but at the moment is unlikely to bring in the 10,000 capacity criteria, and so 25,000 cubic metres exists.

Another suggestion was for cascades of reservoirs, such as that at Wanstead, where the capacity considered would be the total volume of water in the cascade – so you could have a situation where the volume of an individual reservoir means that the reservoir is not subject to the Reservoirs Act 1975 but because of the domino effect the total volume is more than 25,000 cubic metres (or 10,000 cubic metres if brough in) – where one dam fails and that causes the next dam downstream to fail and so on.

Once subject to the Act each reservoir is considered by the Inspecting Engineer during his 10 yearly inspection and what the consequence of failure would be.

The higher the consequence of failure then the plan is protected against larger and larger flood events. Where the failure would result in the loss of 10 or more lives then the dam has to be able to pass the most extreme event possible – the Probable Maximum Flood (PMF) – without the dam failing i.e. reducing the probability of a failure due to a flood to a very small number. The PMF has a return period of about 1 in 400,000 years.

As the consequence of failure reduces then one is able to spend less money to pass a lesser flood. However, the adoption of a lesser flood at a particular site does not mean that the flood event will be exceeded at that site and cause failure of the dam.

In some cases, owners of dams decide to provide a higher degree of protection for a number of reasons. This could include an understanding that the marginal cost of providing higher protection is not very much, or the organisation does not want to suffer any reputational loss should a dam fail.

The classification with regard to floods is as follows:

Dam Category	Consequence of failure	Safety Check Flood Flood inflow	Design Flood Flood Inflow
A	Where a breach could endanger lives in a community	PMF	10,000 year flood
B	Where a breach (i) could endanger lives not in a community, or (ii) could result in extensive damage	10,000 year flood	1,000 year flood
C	Where a breach would post negligible risk to life and cause limited damage	1,000 year flood	150 year flood
D	Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage would be caused	150 year flood	150 year flood

- **Design flood** - is the inflow that must be discharged under normal conditions with a safety margin provided by an accepted freeboard limit. This means that the water level in the reservoir rises but does not reach the top of the dam and start flowing over it. For an earthfill dam this could result in a situation where erosion of the downstream face takes place which if it continues could cause failure of the dam.
- **Safety Check flood** – the inflow beyond which the safety of the dam cannot be assured. This means water goes over the dam and overtopping is likely to occur and cause damage to the dam and it could fail as a result.

Thus, to try to prevent a failure of any earthfill dam due to floods one would design to the highest standard – the Probable Maximum Flood.

1.4 Key Catchment Characteristics

	Perch Pond (gross catchment)	Ornamental Water (gross catchment)
NGR (for FEH-Web Service catchment)	TQ 41900 87150	TQ 41500 88050
Catchment Area from FEH-Web Service (km^2)	0.855	1.4725
SAAR (mm)	602	601
SPRHOST (%)	22.66	24.26

1.5 Key Lake Characteristics

	Shoulder of Mutton Pond	Heronry Pond	Perch Pond	Ornamental Water
Water area from 2019 survey (m^2)	10,488	31,379	21,566	51,338
Water area shown by OS mapping	11,366	23,465	19,518	65,021
Previous estimates of water area	N/A	35,600 (Wren Group)	22,000 (Record sheet))	55,700 (Record Sheet)
Overflow level from 2019 survey (m OD)	14.20 (IL of 225mm pipe)	12.65 (sill in front of piped outlet)	11.425 (sill in front of piped outlet)	6.66 (sill in front of piped outlet)
Minimum crest elevation of Dam (m OD)	14.50 (2019 survey)	13.82 (2019 Survey & 0.5m LiDAR)	11.94 (2019 survey)	6.73 (0.5m LiDAR; from "The Canal" to the overflow)

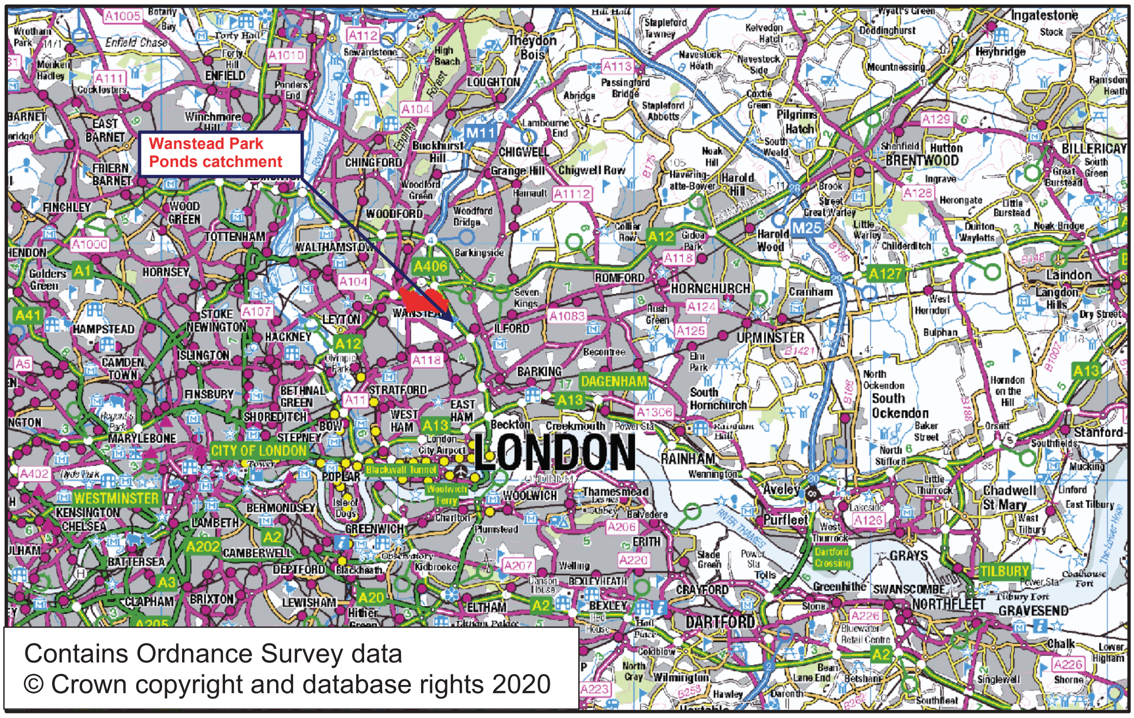

Figure 1 – Wanstead Park Ponds - Catchment Location

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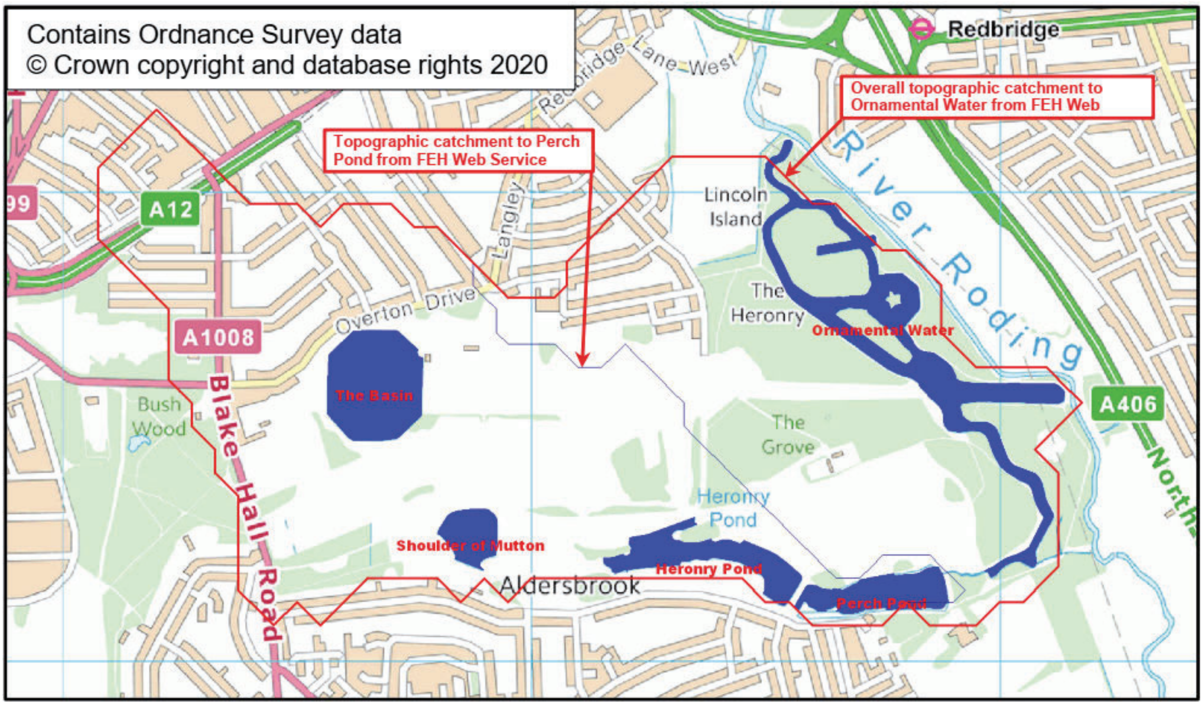

Figure 2 – Wanstead Park Ponds – Catchment Boundaries

2 Flood Assessment

2.1 Basis for Design Flood Inflow Calculations

The standard approach to spillway design flood estimation requires the use of topographic and hydrological parameters derived using the Flood Estimation Handbook (FEH) methodology as implemented in the FEH Web Service. This methodology makes use of a 100 metre resolution gridded ground model to define catchment areas, drainage paths and slopes.

The original UK Government guidelines for reservoir safety flood estimation combined the Flood Estimation Handbook (FEH) rainfall-runoff modelling technique with the rainfall depth assessment techniques previously proposed in the Flood Studies Report (FSR). This approach arose from observations that the rainfall figures, and corresponding flood flows, given by the FEH were sometimes considerably in excess of the FSR figures, particularly when considering events with return periods of some hundreds of years, upwards. The Probable Maximum Flood (PMF) was however still to be determined using the methodology set out in the FEH.

This approach has now been augmented by the "Flood Estimation Handbook Web Service", launched in 2015, which provides "FEH2013" rainfall depth estimates which are intended to replace both the original FEH rainfall depth estimates, now referred to as "FEH1999", and the FSR rainfall depth estimates. T-year floods (150 year, 1000 year and 10,000 year return periods) are now calculated following the FEH rainfall-runoff methodology but using the FEH2013 rainfall depth estimates.

2.2 Selection of Appropriate Flood Magnitudes

Table 2.1 of FRS4 indicates that a Category C dam should be able to accommodate a 150 year flood with no wave overtopping and pass a 1000 year flood safely. A Category D dam is required to be able to pass a 150 year flood safely. Acceptable overtopping rates are given in FRS4 together with a recommended assessment methodology.

Since publication of FRS4 in 2015, further guidance on wave overtopping flows has been published in the EurOTop manual, as set out in Figure 3. The most significant aspect of this update is that grassed embankments are deemed not to be at risk from overtopping flows when the significant wave height is less than 0.3 metres.

Table 3.1 Limits for wave overtopping for structural design of breakwaters, seawalls, dikes and dams		
Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Rubble mound breakwaters; $H_{m0} > 5$ m; no damage	1	2,000-3,000
Rubble mound breakwaters; $H_{m0} > 5$ m; rear side designed for wave overtopping	5-10	10,000-20,000
Grass covered crest and landward slope; maintained and closed grass cover; $H_{m0} = 1 - 3$ m	5	2,000-3,000
Grass covered crest and landward slope; not maintained grass cover, open spots, moss, bare patches; $H_{m0} = 0.5 - 3$ m	0.1	500
Grass covered crest and landward slope; $H_{m0} < 1$ m	5-10	500
Grass covered crest and landward slope; $H_{m0} < 0.3$ m	No limit	No limit

Figure 3 – Limits for wave overtopping from EurOTop 'Wave Overtopping of Sea Defences and Related Structures - Assessment Manual' – 2nd Edition (2016) Table 3.1

2.3 Catchment Area Allocation

The gross catchment to Ornamental Water, given by the FEH Web Service, is 1.4725 km^2 and is shown outlined in red in Figure 2. The equivalent catchment to Perch Pond is 0.855 km2 and the sub-catchment boundary is shown in black in Figure 2, whence the intermediate catchment between the two lakes is 0.6175 km^2.

On the same basis, the incremental area between Perch Pond and Heronry Pond is 0.045 km^2, the area between Heronry and Shoulder of Mutton ponds is 0.21 km^2 and the area upstream from Shoulder of Mutton is 0.60 km^2. It should be noted that the latter includes "The Basin" which is assumed to have no net effect on flood flows.

These areas have been reviewed against LiDAR elevation data and appear to be realistic, though the fringes of the catchment are significantly affected by urban development. The area is too flat for OS contours to be of use in defining catchment areas at this scale. It is considered that the Web Service areas are appropriate for reservoir safety flood calculations.

According to the S10 report for Ornamental Water, the 1984 record sheet stated that the catchment area of Ornamental Water was 2.61 km^2 of which 2.18 km^2 drained through Perch Pond, making the intermediate catchment between Perch Pond and Ornamental Water 0.43 km^2. The basis for those rather larger areas is not known but it is likely that a proportion of the, now urbanised, area to the south was originally seen as draining towards the Park; the reduction in gross catchment area relative to the earlier assessment is 1.1375 km^2.

From current OS mapping, the urban area immediately to the south of Wanstead Park is about 0.57 km^2. That area is essentially level and it is likely that a significant proportion of its surface water drainage could actually be directed towards the ponds. Despite this, the combination of flat gradients and continuous lines of houses across the possible flow routes is likely to make peak flood flows from the area relatively small. It would however be appropriate to take the potential for a flow component from this area into account when considering any possible works to the pond spillways. As an initial estimate of this effect, the gross catchment to Perch Pond has been increased by half this additional urban area to 1.140 km^2.

2.4 Flood Inflow Allocation

Following initial trial assessments, it was concluded that the most appropriate methodology would be to distribute the overall flood flows from the catchment to Perch Pond between the top three reservoirs in proportion to their direct catchment areas. The inflow to Ornamental Water is then the sum of the outflow from Perch Pond and flow from the Perch Pond to Ornamental Water intermediate catchment factored by area from the overall catchment to Ornamental Water flows.

2.5 Flood Routing Parameters

For the purposes of flood routing through a reservoir it is necessary to estimate the storage available above the overflow level and the hydraulic characteristics of the overflow arrangements.

The latest figures for the lake areas are set out in Section 1.5, above. There has been some variation in the areas quoted over time which may reflect siltation, weed growth and/or fluctuating retained water levels. For consistency, the areas given by the 2019 survey have been adopted for flood routing purposes, without allowance for increasing area with elevation.

For each pond, the dam crest has been treated as a weir with a conservative discharge coefficient of 1.4 and a profile based on a combination of ground survey and 0.5 metres LiDAR elevation data.

The Shoulder of Mutton overflow is modelled by treating the twin 225mm dia. overflow pipes as orifices. The other three pond overflows are all modelled as a weir flowed by a nominal storage connected to the next pond, or the downstream boundary, by an orifice representing the overflow pipe.

In the case of Ornamental Water, the downstream condition is initially modelled by an arbitrary fixed water elevation of 6.00 metres OD. This should ideally be replaced by water levels of an appropriate return period in the River Roding at that location, though it should be noted that Ornamental Water falls within the flood plain of the Roding and is likely to be entirely flooded from the Roding in a 100 year flood on that watercourse

2.6 Event Duration

Initial trials showed that the critical event duration varied substantially across the four lakes. The routing has therefore been carried out for a range of events of 3.5, 5.5, 7.5 and 10.5 hours in duration, based on a nominal lag for Shoulder of Mutton up to 4 hours for Heronry.

2.7 Flood Assessment and Routing Results

Shoulder of Mutton Pond	Event Duration	Rainfall Depth	Peak Flood Inflow from upstream lake	Peak Flood Inflow from direct (intermediate) catchment	Peak wave-free water level	Maximum rise above overflow level (14.20 mOD)	Maximum discharge from overflow	Maximum discharge over dam crest
Event:	hours	mm	m^3/s	m^3/s	m OD	m	m^3/s	m^3/s
10,000 year FEH2013 flood:	3.5	168	N/A	3.84	14.71	0.51	0.16	3.67
	5.5	185	N/A	3.67	14.71	0.51	0.16	3.51
	7.5	195	N/A	3.37	14.70	0.50	0.16	3.20
	10.5	203	N/A	2.91	14.69	0.49	0.16	2.75
1000 year FEH2013 flood:	3.5	121	N/A	2.50	14.67	0.47	0.15	2.34
	5.5	136	N/A	2.44	14.67	0.47	0.15	2.29
	7.5	145	N/A	2.26	14.66	0.46	0.15	2.10
	10.5	152	N/A	1.95	14.65	0.45	0.15	1.81
150 year FEH2013 flood:	3.5	83	N/A	1.54	14.63	0.41	0.14	1.39
	5.5	95	N/A	1.53	14.63	0.41	0.14	1.38
	7.5	102	N/A	1.43	14.63	0.41	0.14	1.28
	10.5	108	N/A	1.25	14.62	0.40	0.14	1.09

Figure 4 – Initial Flood Routing – Existing Conditions – Shoulder of Mutton Pond

Heronry Pond	Event Duration	Rainfall Depth	Peak Flood Inflow from upstream lake	Peak Flood Inflow from direct (intermediate) catchment	Peak wave-free water level	Maximum rise above weir level (12.65 mOD)	Maximum discharge from overflow	Maximum discharge over dam crest
Event:	hours	mm	m^3/s	m^3/s	m OD	m	m^3/s	m^3/s
10,000 year FEH2013 flood:	3.5	168	3.83	1.34	13.94	1.29	0.59	0.98
	5.5	185	3.67	1.29	13.97	1.32	0.60	1.98
	7.5	195	3.36	1.18	13.98	1.33	0.60	2.11
	10.5	203	2.91	1.02	13.97	1.32	0.60	1.94
1000 year FEH2013 flood:	3.5	121	2.49	0.87	13.49	0.84	0.45	0.0
	5.5	136	2.44	0.86	13.62	0.97	0.49	0.0
	7.5	145	2.25	0.79	13.67	1.02	0.51	0.0
	10.5	152	1.96	0.69	13.70	1.05	0.52	0.0
150 year FEH2013 flood:	3.5	83	1.53	0.54	13.13	0.48	0.31	0.0
	5.5	95	1.52	0.53	13.22	0.57	0.34	0.0
	7.5	102	1.42	0.50	13.26	0.59	0.36	0.0
	10.5	108	1.23	0.44	13.28	0.61	0.37	0.0

Figure 5 – Initial Flood Routing – Existing Conditions – Heronry Pond

Perch Pond	Event Duration	Rainfall Depth	Peak Flood Inflow from upstream lake	Peak Flood Inflow from direct (intermediate) catchment	Peak wave-free water level	Maximum rise above weir level (11.425 mOD)	Maximum discharge from overflow	Maximum discharge over dam crest
Event:	hours	mm	m^3/s	m^3/s	m OD	m	m^3/s	m^3/s
10,000 year FEH2013 flood:	3.5	168	1.57	0.28	11.65	0.23	1.21	0.00
	5.5	185	2.58	0.27	11.77	0.35	1.57	0.00
	7.5	195	2.71	0.25	11.82	0.40	1.61	0.00
	10.5	203	2.54	0.22	11.81	0.39	1.61	0.00
1000 year FEH2013 flood:	3.5	121	0.45	0.18	11.54	0.12	0.46	0.00
	5.5	136	0.49	0.18	11.55	0.13	0.51	0.00
	7.5	145	0.51	0.17	11.56	0.14	0.54	0.00
	10.5	152	0.52	0.15	11.56	0.14	0.55	0.00
150 year FEH2013 flood:	3.5	83	0.31	0.11	11.51	0.09	0.30	0.00
	5.5	95	0.34	0.11	11.52	0.10	0.34	0.00
	7.5	102	0.36	0.11	11.53	0.11	0.36	0.00
	10.5	108	0.37	0.09	11.53	0.11	0.38	0.00

Figure 6 – Initial Flood Routing – Existing Conditions – Perch Pond

Ornamental Water	Event Duration	Rainfall Depth	Peak Flood Inflow from upstream lake	Peak Flood Inflow from direct (intermediate) catchment	Peak wave-free water level	Maximum rise above weir level (6.66 mOD)	Maximum discharge from overflow	Maximum discharge over dam crest
Event:	hours	mm	m^3/s	m^3/s	m OD	m	m^3/s	m^3/s
10,000 year FEH2013 flood:	3.5	168	1.21	2.39	6.92	0.26	1.48	1.03
	5.5	185	1.57	2.41	6.94	0.28	1.50	1.58
	7.5	195	1.61	2.27	6.95	0.29	1.50	1.62
	10.5	203	1.61	2.03	6.94	0.28	1.50	1.48
1000 year FEH2013 flood:	3.5	121	0.46	1.55	6.86	0.20	1.10	0.34
	5.5	136	0.51	1.60	6.87	0.21	1.20	0.44
	7.5	145	0.54	1.52	6.88	0.22	1.21	0.45
	10.5	152	0.55	1.37	6.87	0.21	1.18	0.41
150 year FEH2013 flood:	3.5	83	0.30	0.95	6.81	0.15	0.68	0.08
	5.5	95	0.34	1.00	6.82	0.16	0.77	0.12
	7.5	102	0.36	0.96	6.82	0.16	0.80	0.14
	10.5	108	0.38	0.87	6.82	0.16	0.79	0.13

Figure 7 – Initial Flood Routing – Existing Conditions – Ornamental Water

3 Ornamental Water and EA Flood Information

3.1 EA Flood Zones and River Levels

Figure 8 shows the location of Ornamental Water relative to the Environment Agency's Flood Map for Planning (Rivers and Sea) Flood Zones 2 and 3, February 2020 release. It is clear that Ornamental Water falls entirely within Flood Zone 2 where flooding is expected, on average, once in 1000 years.

Flood elevations from the modelling used as the basis for the flood zones have been obtained from the EA and can be found in Appendix B to this report. Water levels for selected locations are also shown in Figure 8.

Comparison with the lake flood levels in Figure 7 shows that the maximum calculated level of 6.9 5metres OD in a10,000 year event is only 0.43 metres above the 1 in 100 flood level in the adjacent main river as estimated by the EA. Additionally, the 1000 year river levels are above the surveyed embankment levels for Ornamental Water.

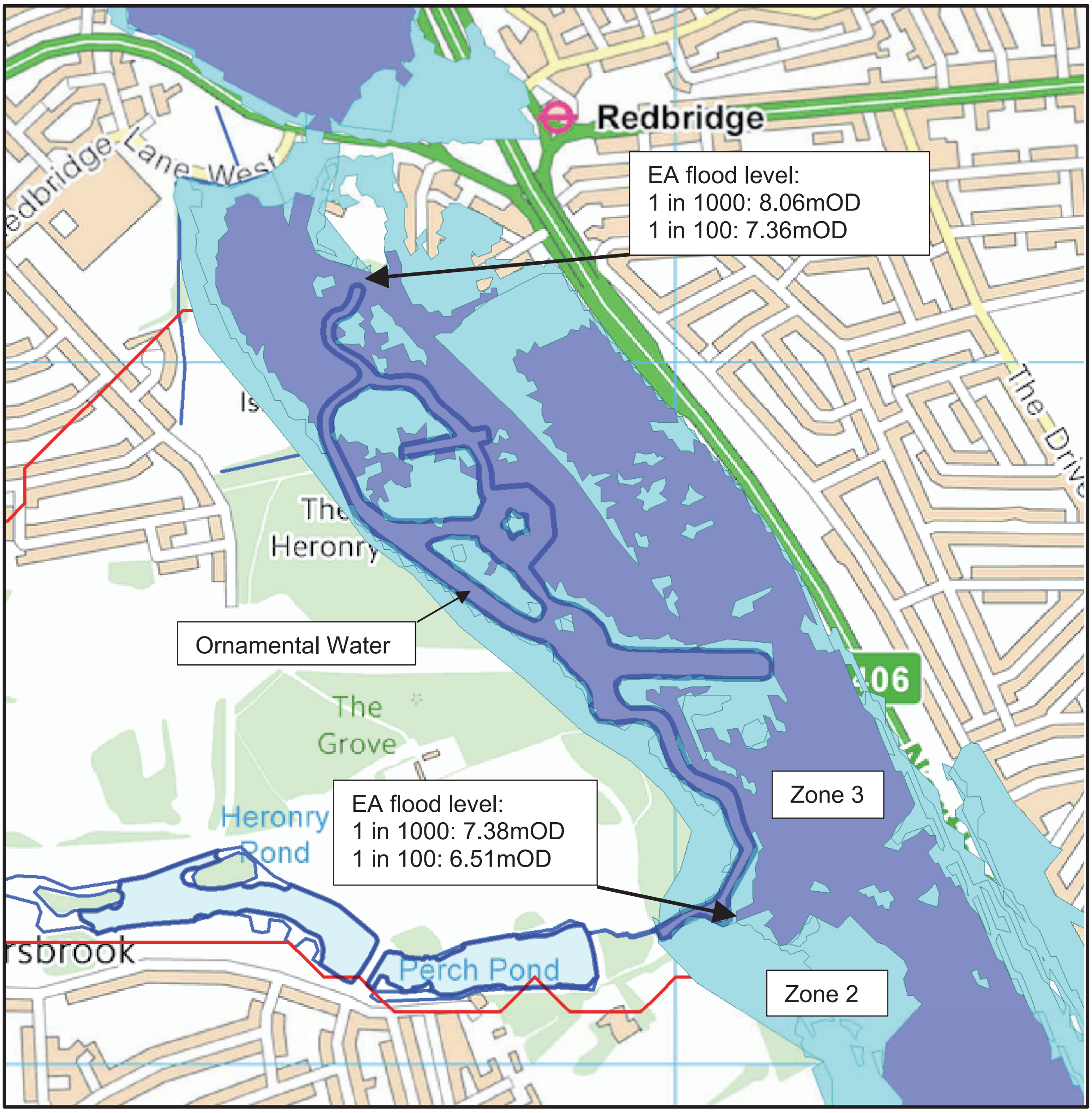

Figure 8 – Flood Zone Mapping and Ornamental Water

4 Conclusions

The results are taken in turn from the top of the cascade.

4.1 Shoulder of Mutton

One can see that, for the Shoulder of Mutton, which is a very low embankment at the top of the cascade, is overtopped during the 1000 year event by about 5.5 hrs with a maximum discharge of about 2.3 cumecs. This sort of flow could be easily accommodated over the long low embankment as long as the grass cover is good without any significant damage. The embankment is likely to withstand the safety check flood without failure, as long as the embankment crest is kept as level as possible and the grass cover is maintained and the grass cut short.

Works here should include some regulation of the crest at the left-hand end (when viewed looking downstream).

4.2 Heronry Pond

At Heronry Pond, the safety check flood causes the water level to rise but the 1,000 year event is retained within the embankment and no overtopping occurs and the still water flood event stays within the embankment crest.

Even in the 10,000 year event the embankment is only overtopped for 5 hrs or so by up to 2 cumecs. Again, an embankment of this size, with a level crest and a good grass cover might be damaged, but is not likely to fail. It would be necessary to try to keep the crest level, and to maintain a good grass cover on the downstream face.

Here works would include regulation of the crest and installation of a concrete edging beam to ‘control’ the flow. Grass improvement and some regrading of the downstream face would be beneficial.

4.3 Perch Pond

The next reservoir in the cascade has a significant surface area, albeit smaller than Heronry Pond, and a freeboard which is able to absorb the inflow from both the 1,000 and 10,000 year events.

Some benefit would be advised by regulating the crest, raising the crest at the right-hand end and installation of a concrete edging beam to again control the flow.

4.4 Ornamental Pond

Here there is significant overtopping in the 1,000 year and 10,000 year events. As a Category D dam, the safety check flood and design flood is the 150 year event, which fills the reservoir and causes a small degree of overtopping.

The interaction of the dam within the River Roding could mean that there is a greater risk of erosion from the Roding rather than from the dams above.

Thus, **I recommend a study be undertaken to understand the effect of the interaction of the River Roding and works which might be put into effect not only to protect the structure from failure of the dams or from flooding from the River Roding.**

4.5 Summary

My recommendation to safeguard the system of reservoirs, is to ensure that the levels of the embankment at the river are such that overtopping occurs only at the ‘overflow embankment’ and here the crest is regulated and the downstream face is ‘engineered’ with a reinforced grass system to provide some erosion resistance.

The City of London should consider these reservoirs as a formal cascade in which case it might be sensible to do elements of improving the resilience of dams on the cascade to cope with the larger floods and protect the reputation of the City.

5 Costings

A very rough estimation of costings are as follows (including preliminaries).

	Costings	Consideration as a cascade
Shoulder of Mutton	£40k	£40k
Heronry Pond	£60k	£150k
Perch Pond	£60k	£150k
Ornamental Pond	£80k	£120k
Total	£240k	£460k
Say	£250k	£500k

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