Braid Burn Flood Storage Reservoirs

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SYNOPSIS The recently completed Braid Burn Flood Prevention Scheme (£43m) incorporates two inner city emergency flood storage reservoirs, constructed to protect the eastern parts of the city from flood waters in the Braid Burn which runs from the Pentland Hills to discharge into the Firth of Forth.

The paper briefly describes the two flood storage reservoirs built as a major part of the project. The sites of the two flood storage reservoirs at Inch Park and Peffermill Playing Fields are important inner city recreational parks and University playing fields. When full the reservoirs are up to 3.5m deep. The reservoirs constructed within the city are bounded by nursing homes, a biscuit factory, sports pavilions and private houses, some within 5m of the reservoir walls. The paper describes the development of design which reviewed the extreme wind conditions over the two ponds, the extreme wave conditions and the wave induced forces on the buildings. Advice was obtained from HR Wallingford who provided a report on the problems of extreme wind speeds occurring simultaneously with the rare periods of high flooding.

INTRODUCTION

The Braid Burn is over 18km long and drains the southern and eastern part of the city of Edinburgh from its source in the Pentland Hills to Portobello where it discharges into the Firth of Forth. The headwaters contain three small reservoirs; Torduff, Clubbiedean, and Bonaly. Due to the catchment area being 80% urban in nature, the burn is very responsive to rainfall events. During periods of heavy rainfall the burn swells rapidly in size and water level can increase substantially in only a few hours. Over the last 16 years the burn has flooded significantly on five occasions, causing major distress and disruption to residents and businesses and many millions of pounds worth of damage. The main cause of flooding on the Braid Burn was the lack of the capacity of the watercourse and the number of structures crossing the burn or through which the burn passes. From the hydraulic

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model the critical storm duration for Inch Park occurs in a relatively short period, only 22.5 hours.

After the severe flooding which occurred in April 2000 the City of Edinburgh Council (the Council) arranged for feasibility studies to be carried out to mitigate flooding, leading to the appointment of AECOM in 2002 as designers for the scheme and subsequently for construction supervision. The main construction contract started in 2007 and was completed on schedule in 2010, despite one major flood event during the construction period.

The scheme is designed to protect over 900 homes and businesses against a 1 in 200 year flood event, with an additional allowance for predicted climate change. The project has also been used as a great opportunity to substantially benefit wildlife in the city by restoring sections of the river corridor. A variety of protected species live in and around the burn including European protected otters and bats, along with dippers, kingfishers, trout, bullhead and heron. The burn runs through a highly urbanised section of the city and provides a vital corridor for wildlife linking several habitats and providing a corridor for wildlife to travel.

This paper describes the development of design of the two major Flood Storage Reservoirs, built on the University playing fields and on a recreational public park providing a combined flood capacity in the region of 220,000m³ (Inch Park Flood Storage Reservoir - 120,000m³ capacity and Peffermill Playing Fields Flood Storage Reservoir - 100,000m³).

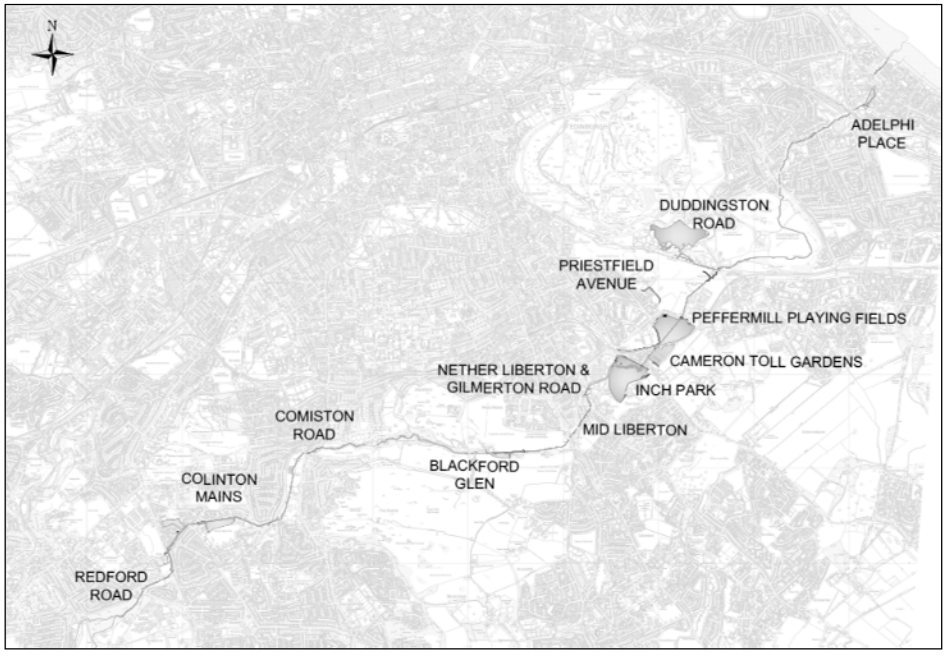

Figure 1. Edinburgh City Plan Showing Location of Main Areas of Flood Prevention Work

The scheme uses as much of the natural flood plain as possible, utilising areas where flood water can overspill from the burn without affecting properties or infrastructure. The Council required that the controls for flood discharge should not require user intervention or attendance by operatives during floods. Fish passage should also be unimpeded. The design of the scheme also took into account the effects of climate change.

INCHPARK FLOOD STORAGE RESERVOIR.

Inch Park is a Council-owned inner city public park. It was originally part of a landscaped estate parkland built in 1617 associated with Inch House, which is now used by the Council as a Community Centre.

The flood storage reservoir was created by construction of a piled wall primarily designed to contain flood waters and to contain the peak flood during flood conditions up to a depth of 3.5m. Before the piling works to the walls could commence a range of utility diversions were required, in particular old medium pressure gas mains and old sewers which had to be replaced due to clashes with the line of the new sheet piled flood walls. Future development of the Edinburgh Tram System was planned to run from the city centre to the new hospital along the eastern edge of the flood storage reservoir, requiring adjustment of the wall alignment to allow space for a future tram line, and redesign of the wall to take the full impact of a derailed tram against the 'dry' face. The overflow embankment contains a spillway designed to take a Probable Maximum Flood inflow for this Category A reservoir (PMF Summer 42.6m³/s; 1 in 10,000 year flood 21.3m³/s).

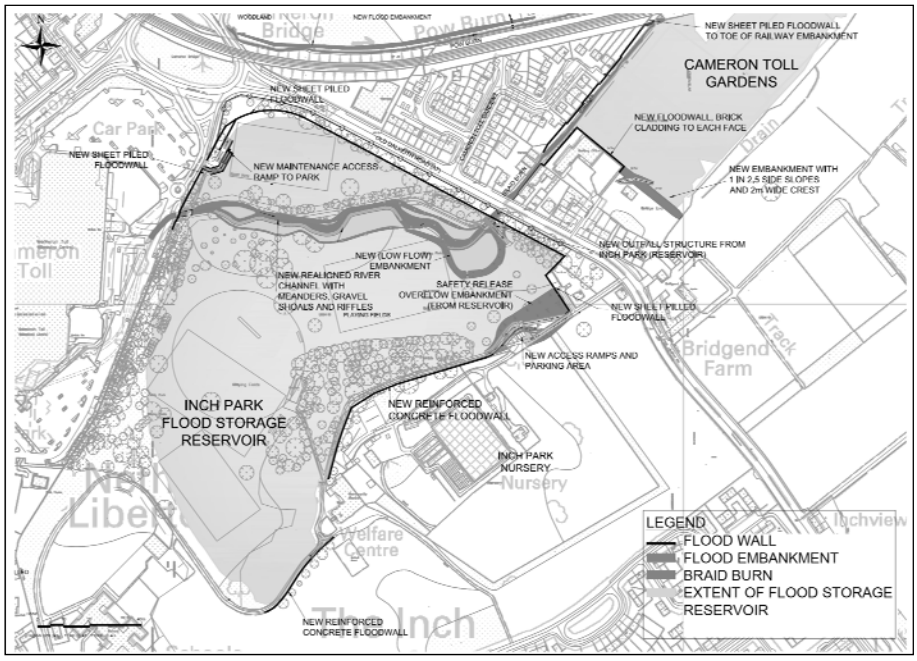

Figure 2. Inch Park Flood Storage Reservoir – Plan

The original Burn was contained within a straight concrete and brick channel. The opportunity was taken to restore meanders to this section of the Burn which was developed as a two stage flooding regime. The replacement of the brick and concrete channels by sinuous meanders and gently sloping low flood embankments provided soft engineered flood defences designed to work with the natural processes of the burn rather than impose on them through hard engineering. For a five year event, flood water will only inundate the small area of low bunded waterway within the park. Once flows increase, the bunds will be overtopped and gradually flood the remainder of the park. Once the impounded flood level drops water will re-enter the burn waterway and enable the park to dry out.

The Braid Burn enters the reservoir site via a twin box-section concrete culvert located under the car park of Cameron Toll Shopping Centre. These culverts (one 2.4m wide and one 2.1m wide, both 1.5m high) control the inflow into the reservoir. The outflow from the reservoir is formed by two old semi-circular masonry arch culverts that are located below Old Dalkeith Road. These culverts are 2.6m wide by 1.1m tall and surcharge at a flow of about 5m³/s (water level of 45.75mOD at the inlets). The limited discharge capacity of the culverts determines when the storage volume within the reservoir will start to be utilised, and the water storage levels for any flood event. Many of the floods will be of a short duration and utilise only a small part of the available storage capacity.

Figure 3. Inch Park Flood Storage Reservoir from the Outlet Structure

DESIGN OF IMPOUNDING STRUCTURE AT INCH PARK

The dam comprises a mixture of sheet-pile impounding walls, lower reinforced concrete cantilever walls and earth-fill embankments. A 540m sheet-pile wall with natural stone cladding replaces the old boundary wall, with the alignment adjusted to allow for a future tramway. To fulfil planning requirements the wall cladding was to be similar in appearance to the old wall. Masonry was recovered from the removed sections of wall, was redressed and re-used for the new cladding. The wall height varied from 1.16m to 2.68m. The overflow is located on the right bank to the eastern corner of the reservoir. It is an earth-fill dam with a fixed crest length of 43m, a crest level of 47.68mOD and it discharges to another area of the Park and downstream across Old Dalkeith Road. The surface of the embankment is reinforced with a geotextile membrane to protect against scour, with grasscrete protection on the downstream slope.

A baffle was installed on the upstream slope of the spillway to reduce storage losses due to wave slop overtopping the overflow weir.

OUTLET STRUCTURE

The existing culverts under Old Dalkieth Road are retained and form the controlled outlet discharge from the reservoir. The culverts are extended on their upstream side by twin box section culverts with debris screens on the upstream face. These are the only outlets to the reservoir. The screens are provided to reduce the risk of blockages of the culverts. Access for clearing and cleaning the screens is incorporated in the access bridge as part of the outlet structure.

Operation of the reservoir is wholly dependent on the restriction to the flood flows presented by the Old Dalkeith Road culverts. There is no scour outlet or other means to empty the reservoir, nor for controlling the outlet flow.

Figure 4. Inch Park Flood Storage Reservoir Outlet Structure

PEFFERMILL PLAYING FIELDS FLOOD STORAGE RESERVOIR

The Braid Burn enters the lower storage reservoir at Cameron Toll gardens through the twin culverts at Old Dalkeith Road at the outlet to the Inch Park reservoir discussed above. This site is primarily the University's playing fields, split by a railway embankment which has a culvert for the Braid Burn and an underpass between the playing fields. The reservoir is formed by approximately 1,200m of earth-fill embankment and 400m of brick faced reinforced concrete cantilever walling, constructed along the perimeter boundary between the playing fields and residential and business premises. A section of the floodwall adjacent to the neighbouring Nairns Biscuit factory incorporates glass panels in the flood wall as a planning requirement to provide natural light into the factory offices which are close to the new wall.

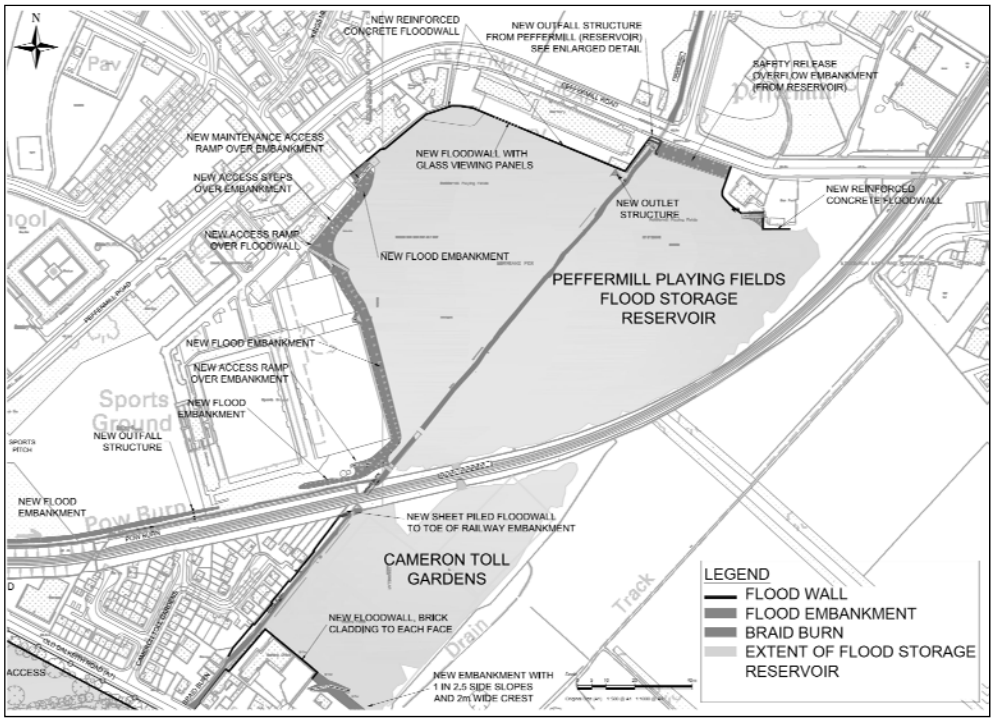

Figure 5. Peffermill Playing Fields Flood Storage Reservoir – Plan

IMPOUNDING EMBANKMENT AND WALLS

The embankment is of earth-fill construction with grass covered slopes and crest. The maximum slope for the embankment is 1 in 3 on the river side and 1 in 2.5 on the landward side with a 2m wide crest. Vehicle access ramps and steps are provided over the embankment at a number of locations to provide access for maintenance equipment.

The impounding walls are of reinforced concrete cantilever construction, varying in height from 0.7m to 2.7m and are brick clad to meet planning requirements.

The overflow is situated on the right bank at the north east corner of the reservoir. It is an earth-fill embankment with a fixed crest 63m long, 2m to 3m wide and a weir level of 44.50mOD.

A timber baffle is installed on the upstream slope of the overflow embankment to reduce storage losses from wave slop overtopping. The use of geotextile reinforced grass in both spillways with good grass cover gave enhanced erosion resistance at both reservoirs.

WAVE ACTION IN FLOOD STORAGE RESERVOIRS

Both flood storage reservoirs are within urban areas of Edinburgh. During flood conditions, the two reservoirs will allow waves to be generated which could affect the windows of nearby buildings, either through wave-induced overtopping or wave impact forces. Preliminary calculations and experience from marine works highlighted the potential risks to people and property. Advice was obtained from HR Wallingford, who reviewed extreme wind conditions over the two ponds; extreme wave conditions at three locations in both ponds; wave-induced overtopping at three locations in each pond and wave-induced forces on buildings at two locations for return periods of 200, 1000, and 10,000 years.

Basic wind speed over land, for a one hour duration 50-year return period for Edinburgh is 24m/s. Adjustments for return periods of 200, 1000, and 10,000 years are 1.10, 1.22, and 1.39. For the wind speeds and pond sizes involved, the peak wind speed would have to be sustained for only two to five minutes for waves to reach their maximum height. The appropriate adjustment for two to five minutes would be 1.11. Wind speeds are higher over water than over land, because of the lower surface roughness. For the distance of 200m the adjustment factor is 1.03. Accumulating all the above factors yields wind speeds of 30.2m/s, 33.5m/s and 38.1m/s for return periods of 200, 1000 and 10,000 years respectively.

For Inch Park the overtopping calculations indicated one location where damage to vehicles or pedestrians would occur (close to the Sharpdale Loan/ Old Dalkieth Road junction). The potential risk here would be to vehicles passing 5m behind the wall and to flood water possibly not being drained away fast enough from the road junction. At other locations at the east of the reservoir adjacent to the overflow structure there is no building within 10m and no likelihood of pedestrians or vehicles close by.

For Peffermill Playing Fields the calculations indicated potential damage to buildings and a danger to pedestrians within 3m of the floodwalls during a 200 year return period event. Parkview Nursing Home and Cameron Park Nursing Home are very close to the rear of the flood wall, together with Nairns biscuit factory and sports pavilions at the playing fields. The forces/pressures for a 1 in 200 year event indicated severe potential risks if

heavy overtopping occurred, with damage to any parked vehicles nearby and potential injury to pedestrians and residents of the nursing homes. Damage to the proposed new tram system planned to run along Old Dalkeith Road could occur restricting the use of the trams during such rare extreme events. Drainage from behind the walls required to be increased to deal with more water than just that caused by rainfall. Larger return periods showed structural damage to the glazing at both the nursing homes. A more realistic estimate at more frequent return periods of 2, 10 and 100 years gave a 20%-30% reduction in wind speed which might occur simultaneously with the reduction in predicted wave height and overtopping damage. Waves of 0.20m, 0.26m and 0.31m respectively were predicted for these return periods. Adjustments were made to deal with the above, and the additional drainage was provided.

Figure 6. Peffermill Playing Fields Flood Storage Reservoir

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REFERENCES

HR Wallingford, (2004).*Braid Burn Flood Prevention Scheme*; Technical Note TN01