The reservoirs of the Holme Valley

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SYNOPSIS. The Holme Valley is situated in the Yorkshire Pennines south of Huddersfield and has a catchment of approximately 10km². A feature of this valley is the four reservoirs of Yateholme, Riding Wood, Ramsden and Brownhill which are known as the Holmbridge Group. These reservoirs were built over a period of 54 years from 1879 to 1932 and are a major source of raw water to the towns and cities of West Yorkshire. Over the last six years, the overflow systems of each reservoir have been upgraded following recommendations made during Statutory Inspections. Two of the reservoirs are also in the Peak District National Park, with a third situated on the boundary.

This paper outlines the history and hydrology of the valley, describes the works carried out on each reservoir and explains the differences in construction and design.

THE HOLME VALLEY

The Holme Valley extends from the picturesque village of Holmfirth to the town of Huddersfield some 12km to the north. At the southern end of this valley are the four reservoirs of Yateholme, Riding Wood, Ramsden and Brownhill, which are known as the Holmbridge reservoir group. These reservoirs are approx. 4km south of the village of Holmfirth just below the surrounding Pennine hills of Holme Moss and Black Hill which climb to heights of around 580m.

The reservoirs in the Holme Valley were built in the 19th and 20th century to serve the ever expanding populations and industry of West Yorkshire. The four reservoirs of the Holmbridge group were built by Batley Corporation Waterworks and paid for by public subscription from the local communities, of Heckmondwike, Staincliffe and Batley. Combined these reservoirs provide a reliable yield of approx. 12Ml/d.

Water treatment was originally provided immediately below Ramsden reservoir, but later relocated below Brownhill following the construction of the Brownhill reservoir in 1932. Treated water was stored downstream at Batley Corporation's large service reservoir at Staincliffe some 20km to the north east (just south of Leeds).

Dams: Engineering in a Social & Environmental Context. Thomas Telford, London, 2012

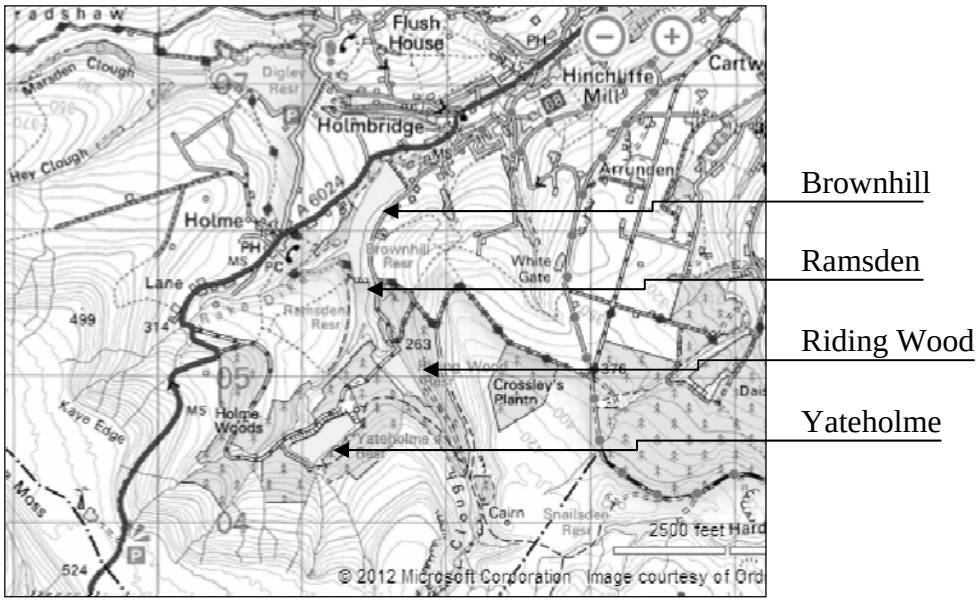

Figure 1 – Reservoir locations

Over the years the supply system has evolved considerably, principally under the ownership of Yorkshire Water, following the amalgamation of local water boards of Huddersfield, Calder and Batley (and others) in 1974.

Water treatment is now provided at a new treatment facility at Holmbridge for the entire valley, including the adjacent reservoirs of Bilberry and Digley. This treatment works has a capacity of 35Ml/d and water from here can be feed to most areas via the Yorkshire Water Grid.

RESERVOIR CONSTRUCTION

The reservoirs were built over a period of 54 years from 1878 to 1932 under the Batley Corporation Act of 1878. One of the original reservoirs was to be located adjacent Holme village but was never built, instead being replaced at a later date by the much larger Brownhill reservoir, 500m downstream. The consultant used for design and supervision of the construction of all the Holmebridge reservoirs was G H Hills of Manchester.

The table overleaf shows the contract periods and the original contracts awarded. In the case of both Ramsden and Brownhill, the works were completed by the Corporations direct labour force following disputes with the contractors.

Table 1. Construction Periods and Contracts

Reservoir	Construction Periods	Construction cost	Contractor
Yateholme	1872 to 1878	N/A	N/A
Riding Wood	1872 to 1878	N/A	N/A
Ramsden	1879 to 1883	£32,000	Crabtree Brothers
Brownhill	1924 to 1932	£640,000	Lehane, MacKenzie & Shand

Little remains of any original photos, with the exception of photos of the old railway system used during construction at Brownhill. This was used to bring the puddle clay from a site above Netherley Clough down to Brownhill. The following photo shows the impressive wooden trestle viaduct crossing over Rake Dike with the part completed Brownhill embankment in the distance.

Figure 2. Rake Dike trestle bridge above Brownhill

The geology of the valley consists of Namurian Millstone Grit Group. This comprises sandstone, from very fine grained to very course grained, which is interbedded with mudstones and siltstones. The regional dip of the geology is generally towards the north-east.

All four reservoirs are typical Pennine embankments with a narrow clay core and steep shoulders with zoned fill. Upstream shoulders are protected with stone pitching and grassed on the downstream side. All use concrete cutoff trenches dug deep in to the rock below. The photograph overleaf shows the type of detail used at the base of the clay core; a deep trapezoidal channel cast in to the top of the concrete cutoff trench.

The principle dimensions of the four reservoirs are as follows:-

Table 2. Reservoir capacities and levels

Reservoir	Capacity	TWL	Dam height
Yateholme	415,000m³	301.7mAOD	14m
Riding Wood	235,000m³	261.7mAOD	23m
Ramsden	394,000m³	235.0mAOD	21m
Brownhill	1,209,000m³	291.5mAOD	29m

Figure 3. Typical clay puddle to cut off trench detail of the period

The following section shows the typical construction:-

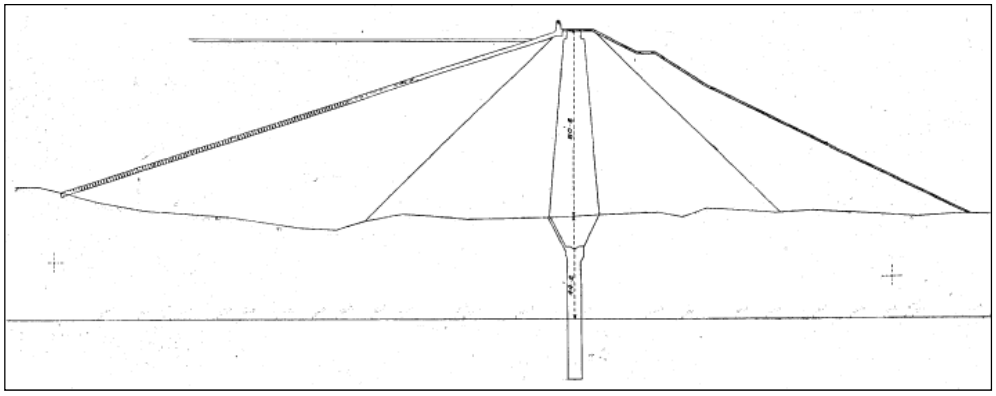

Figure 4. Cross section through Brownhill embankment

Yateholme sits at the head of the valley between Netherley Clough and Ramsden Clough. Yateholme is unique in the Holmbridge group in that it is perched on the side of the hillside above Netherley Clough, requiring a three sided embankment of considerable length. Riding Wood spans the steep sided valley of Ramsden Clough, adjacent to Yateholme reservoir at the head of the valley. Ramsden reservoir is situated downstream of both Yateholme and Riding Wood. Ramsden was built five years later and has similar features to Riding Wood. However following construction the reservoir was not brought in to service for nine years whilst leakage was reduced on the right hand abutment. This involved an additional cut-off trench on the right hand valley side at 90 degrees to the main trench and of considerable depth. Brownhill was built much later in 1932 and is the lowest reservoir in the sequence. The photo below shows excavation of the deep cutoff trench, below the newly constructed workers cottages.

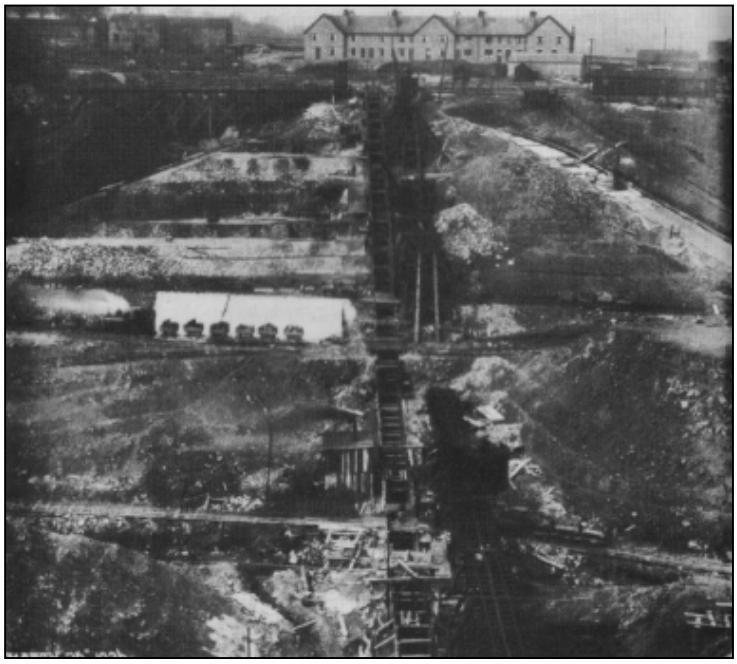

Figure 5. Photograph of Brownhill showing cut off trench construction

HISTORY OF MODIFICATIONS

In addition to the works carried out in recent years, each of the reservoirs has had a variety of modification works carried out since their original construction. At Yateholme modifications have been the widening of the weir and tumble bay in 1987 and renewal of the mitre drainage and valve tower access bridge in 1990. Riding Wood had clay core raising in 1930s and a new ogee weir installed in 1987. Ramsden had clay core raising and weir lengthening works in 1949 and again in 1991. Brownhill also had clay core and crest raising works in 1949 together with a widening of the tumblebay with the addition of a by-pass culvert. Both Ramsden and Brownhill have had wave wall improvements in the last 20 years.

HYDROLOGY

The catchment consists mainly of high moorland with some forested areas, characterized by steep slopes with thick beds of peat at the higher elevations. The steep gullies of Ramsden and Netherley Clough run from the hilltop to the reservoirs. The catchment totals some 9.70km², ranging height from 220mAOD at Brownhill to 580mAOD at Black Hill (with an average gradient of 80m per km). Annual rainfall is in the order of 1500mm to 1700mm per year in this part of the Pennines.

Flood studies have been carried out at various times over the last 30 years, the latest by MMB (April 2007) and Rust Consulting Services (July 1996).

Table 3. Reservoirs and catchment areas

Reservoir	Direct Catchment (km²)	Total Catchment (km²)
Yateholme	1.15	N/A
Riding Wood	2.31	N/A
Ramsden	3.16	6.62
Brownhill	3.08	9.70

The recent calculation of the runoff hydrographs using the FEH catchment descriptors and the FEH time to peak of the unit hydrograph has produced very similar results to the previous FSR methods.

Routing these storm flows through the individual reservoirs, gives the following spillway discharges and the expected flood rises:

Table 4. Reservoir flood rises and storm flows

Reservoir	Flood rise (m)	PMF (m³/s)
Yateholme	1.12	26.5
Riding Wood	1.30	41
Ramsden	2.80	112
Brownhill	3.66	153

Although these flood rises can be accommodated by the existing weirs and wave walls, the latest flood study did highlight potential restrictions downstream of the tumblebays that could cause the weirs to drown at the higher flows. To determine this each of the four spillways were physically modelled by CRM of Bolton, to confirm the capacity and to optimise velocities and flow patterns for the required improvements.

RECENT SAFETY WORKS

The recent programme of improvement works commenced in 2005, in a new Yorkshire Water Asset Management Period (AMP4 - 2005-2010). The design & build contract was awarded to Mott MacDonald-Bentley (MMB) under a 'Target Cost' framework agreement. Ramsden and Riding Wood were completed under this framework. This was followed by a similar AMP5 framework contract albeit under a different 'risk' base target approach.

MMB is a joint venture partnership set up between Mott MacDonald and J N Bentley of Skipton to deliver design & build solutions. Site works are carried out by J N Bentley as Principal Contractor.

Ramsden Spillway Works – 2008-2009

Improvements to Ramsden were required following the Section 10 Inspection by Martin Airey in November 2006. Following model testing, there were concerns regarding the ability of the existing spillway channel to adequately pass the PMF flow of 112m³/s. Due to difficult access to the left hand side of the embankment, it was decided to provide a new primary spillway on the right hand mitre. The existing spillway was retained to

enable the bywash system to continue operation. The design philosophy was to limit the flood rise using a long crump weir, which discharged in to a steep shallow tumblebay, thus avoiding a deep dig into the hillside and any crest raising works. The tumblebay utilised the velocity from the weir to direct the supercritical flow under the crest bridge at minimum depth. The penalty for this approach was the slightly higher walls to contain the cross waves further downstream. Flows then accelerate towards the end of the spillway at velocities approaching 18m/s. Due to the limited space at the base of the chute, a ski jump was provided to discharge the flows high into the air before falling in to Brownhill reservoir below.

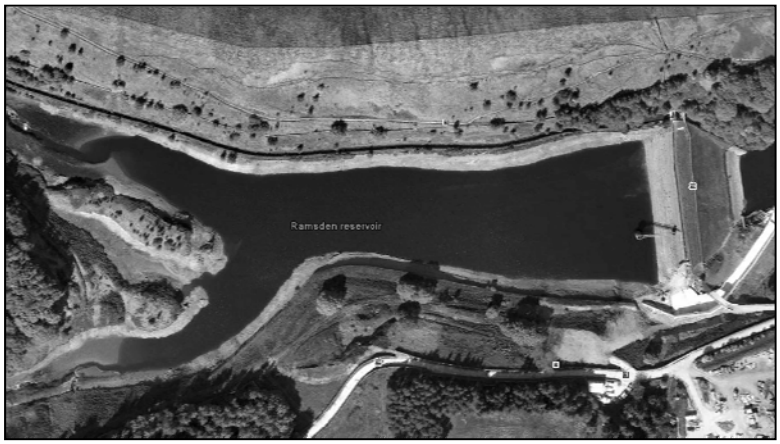

Figure 6. Aerial view of Ramsden reservoir

Work commenced on site in March 2008 at the lower end of the spillway. The underlying rock was exposed and cleaned off prior to the installation of shear pins to prevent any sliding and bind the underlying sandstone blocks together. Additional pins where also used at the end of the spillway where the ground fell steeply into Brownhill reservoir. Even with the channel pushed as far as possible in to the hillside the left hand side wall was not entirely founded on the original concrete cut-off trench as anticipated. The cut-off in this area had to be raised and the clay\wall nib extended.

Figure 8. Ramsden crest bridge

Figure 9. Ramsden Ski Jump

As expected, the concrete cut-off trench turned through 90 degrees under the slab forming a solid foundation for two edges of the spillway slab. However the leading edge of the weir was left some 5m above the rock head. A large concrete pillar 4m in diameter was constructed down to rock head to support this edge. The slab edge thickness was also increased and heavily reinforced to support the weir between the pillar and the concrete cut off.

Following completion the concrete walls were stained to tone down the brightness of the new plain concrete walls.

Construction was substantially complete by March 2009. Total cost of the works was £2.9m

Riding Wood Spillway Works – 2009-2010

Improvements to Riding Wood were required following the Section 10 Inspection by Martin Airey in December 2006. Following model testing, there were concerns regarding the existing spillway channel to adequately pass the PMF flow of 41m³/s. Due to difficult access to the right hand mitre of the embankment, and the close proximity of the old reservoir keeper's property, it was decided to provide a new primary spillway on the left hand valley side. The existing spillway was retained to enable the bywash system to continue operation. As was the case at Ramsden, the existing spillway was left in operation whilst the new spillway was constructed on the opposite side of the embankment. Access was available across the crest on the public highway, and the land adjacent to the mitre was relatively flat. This aided both construction of the new spillway and site compound. This area of flat land was chosen to site the weir and tumblebay as the valley sides adjacent to the embankment were extremely steep.

Figure 10. Aerial view of Riding Wood reservoir

An efficient ogee weir 23m long was designed to minimize flood rise and pass the flow in to a wide sub-critical tumble bay. A long shallow sloping chute passes under the crest bridge, gently accelerating the flow away from the embankment. This continues to the Section 10(6) limit; where flows are deemed to be an acceptable distance away and the embankment and the

integrity of the dam is no longer compromised. From here the gradient steepened quickly to 1 in 4 where the flow accelerated rapidly to 20m/s and discharged into a plunge pool adjacent to Ramsden reservoir. Localised clay core raising works were also needed on a short section of the crest.

Works commenced in April 2009, with the removal of trees and excavation of the main channel. The works were sequenced to maintain the embankment until the majority of the new channel, up to the Section 10(6) point, was in place. Once this was completed, the highway was closed for a period of sixteen months and the embankment breached to construct the tumble bay and connecting section of the spillway. One major difference to the works at Ramsden was the fact that the entire works at Riding Wood are within the Peak District National Park. A higher standard of finishing was required, comprising patterned concrete walls and sandstone wall copings. The pattern used was not a standard pattern but was taken from a latex impression of the existing spillway wall and stained. The crest road bridge was built in mass concrete using a 'flexiarch' former made by Macrete Ltd, and clad in local stone. This bridge manufacturer's design for the standard panel walls was modified to suit the planning requirement to incorporate real stone spandrel walls.

Figure 11. Riding Wood Flexi-arch bridge

Figure 12. Completed works at Riding Wood

The stilling basin was situated some 24m below the main chute on the edge of Ramsden reservoir. A simple stepped mass concrete design was chosen to suit the restricted access and steeper valley sides. This was founded on a thick reinforced concrete base slab founded on the bedrock.

The works were completed by August 2010 at a final outturn cost of £3.8m

Brownhill Spillway Works – 2010-2011

Brownhill is the lowest reservoir in the cascade and as such has the highest storm flows. The weir and wave wall were adequate for these flows, so the design philosophy was to improve spillway efficiency by retaining the existing tumblebay floor level and increasing capacity by widening and raising of the walls downstream of the embankment. This meant the flow accelerated quickly through the tumblebay enabling the works to be relatively shallow at the expense of wall raising downstream to accommodate cross waves. Given the length and gradient of Brownhill the flows accelerated further to over 23m/s. The low flows are stilled by a small weir on the end of the channels, but high flows are not stilled until the downstream river water level increases and floods the end of the spillway. A substantial end wall diverts the flows through 45 degrees back in to the natural water course.

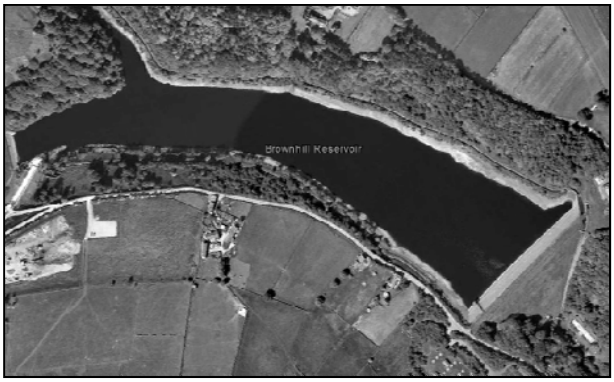

Figure 13. Aerial view of Brownhill reservoir

Works commenced in March 2011 with the construction of the upper channel and tumblebay. A drawdown of 10.5m was maintained in Brownhill throughout the works, together with drawdowns in the upper reservoirs to give 1 in 100 year protection.

Access to the site was restricted and a new track had to be cut through woods from the site compound adjacent the A6024. A steep track was also cut into the hillside parallel the spillway. Only limited access was afforded from the opposite side of the valley. The formation was sandstone as expected under both the tumblebay and upper channel. The channel mid-section was built on top of the existing slab whilst retaining the right hand wall to aid flood protection.

To prevent flotation in the tumblebay and sliding on the steep sections 32mm diameter anchors were drilled 4m into the bed rock. Although outside the Peak District National Park Boundary, the proximity of local houses meant a similar standard of finish to the completed Riding Wood project was required.

Figure 14 –Widened Brownhill tumblebay

Concrete Formliner was initially proposed for the full length of the spillway but after investigation an artificial stone cladding was used in the tumblebay, where velocities were relatively low.

On the lower spillway the straight, sections were better suited for a formlined pattern. These constant height sections also meant that pre-cast concrete could be used. The basic panels were developed from those used in the Withens Clough project, manufactured by Carlow, but formlined patterns were added for Brownhill. With careful design of the panel lengths and infill joint widths, the infill joints were also cast with a matching pattern.

Figure 15 – Precast concrete infill joint

Works were substantially completed by December 2011 and landscaping in the spring of 2012, at a total cost of £3.7m.

Yateholme Spillway Works – 2012

Yateholme has the smallest catchment and hence lowest PMF of 26.5m³/s but even so the existing channel and weir required improvements to minimise flood rise and direct the flow past the embankment toe. Due to the long crest at Yateholme (600m) various weir options were investigated to enable any crest works to be eliminated. This involved the widening of the weir with a corresponding increase in the tumblebay. Part of the existing tumblebay base was retained together with the right hand wall. A new left hand wall directed the flow through 90 degrees down a new widened channel constructed on top of the existing base slab. The side walls were constructed with pre-cast concrete units with a patterned finish similar to those used at Brownhill. The original stone copings were then re-used. Sliding and flotation are not an issue due to the shallow gradient and narrow channel design. The works terminated at the highway bridge at the toe of the embankment. The works commenced in February 2012 and are due for completion September 2012. The formation was a mix of sandstone and weak mudstones as expected, with isolated soft clay pockets which were removed. Concrete joints had the same formlined pattern finish as used at Brownhill.

Figure 16 - Aerial view of Yateholme reservoir

Figure 17 – Yateholme pre-cast concrete units being installed

A stilling structure was not constructed as after passing under a highway bridge the flow falls quickly into Netherley Clough, some 50m metres above Ramsden Reservoir, and is well away from the embankment.

Completion date is due August 2012. Costs are on target outturn of £1.3m.

SUMMARY

Working on these reservoirs over the last 6 years has been a privilege for the entire MMB team. It has enabled a unique insight in to some of the original constructions, development and history of the valley. It has also enabled the team to demonstrate some alternative methods of construction which have brought benefits both in terms of time savings and safety, whilst enabling the new works to complement the existing structures in the National Park Area.

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