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Control of reservoir water levels during construction when existing scour facilities are not available

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SYNOPSIS Whilst working on existing scour and draw-off systems it is not unusual to have to install temporary works in order to maintain specified drawdown levels, supply to water treatment works and compensation flows to the downstream watercourse. This paper investigates the many ways of achieving the required controls and reviews the potential costs and pitfalls associated with each of the identified options from schemes that Mott MacDonald Bentley (MMB) has undertaken.

Based upon multiple examples of projects undertaken, the paper presents temporary pumping, siphons and associated priming and control, learnings realised and solutions implemented to resolve commissioning issues. All works were undertaken on statutory impounding reservoirs and as such have been planned and undertaken with the supervision of an All Reservoirs Panel Engineer.

MMB planned and undertook the following works:

- Level control – Pant Yr Eos Reservoir
- Level control - Upper Carno Reservoir
- Compensation and augmented river flows - Usk Reservoir
- Compensation flows – Gouthwaite Reservoir
- Level control – Cwmtillery Reservoir
- Additional drawdown capacity – Castell Nos Reservoir

This paper summarises the methodology behind each of the installations, reviews the scale of costs for purchase, hire and maintenance, strengths and weaknesses for each of the installations and lessons learned for future projects.

INTRODUCTION

Many of the projects MMB has completed in recent years have required the need for water level control outside of the usual operation of draw-off valves and natural draw downs. Water quality, existing valve condition, operating restrictions and other works on-going can all affect the ability to use existing installations. The preference from an affordability point of view is to maximise the use of existing assets where appropriate and minimise use of temporary pumping and power generation as this is expensive in terms of both cost and carbon.

Managing Risks for Dams and Reservoirs

Key questions to ask when planning works are amongst others:

- Can the inflows be diverted?
- What duration are the planned works expected to take?
- What magnitude of flows are required?
- Are there any supply or compensation flow requirements?
- How critical is the supply or compensation?
- Are there any restrictions on discharge to the receiving watercourse?
- What are the options, which are most cost beneficial, or more reliable?

PANT YR EOS RESERVOIR

Pant yr Eos is a 597,000m^3 volume reservoir, with an embankment dam of 27m in height and crest length of 280m with a direct catchment of just over 1km^2 located near Newport, south Wales. In order to undertake upgrade works to the drawoff system in 2018, reservoir level control was required. At Pant yr Eos, single gate valves within the reservoir body control flow into a wet well shaft, from which flows are piped through the tunnel under the downstream shoulder, to the downstream watercourse. In order to complete works on the original drawoff facilities, it was necessary to lower the reservoir to an acceptable level. A by-wash channel was available and suitable for use during the construction works, and as such, it was possible to divert the majority of the incoming flows. The remaining flows amounted to circa 30 l/s which was required to be pumped due to lift (>20m) and water quality. Pumps were deployed using floating pontoons (Figure 1) to ensure water quality was maintained throughout the works and flows discharged to the downstream watercourse via the existing bywash channels. A single duty pump was utilised to keep costs lower, with the water level within the reservoir allowed to rise and fall between set levels which enabled works to progress unhindered. For more project details, see parallel paper by Cornelius and McAree (2024).

Figure 1. Pumping arrangement adjacent to Pant yr Eos dam. Right-hand bywash visible in the background

UPPER CARNO RESERVOIR

The dam at Upper Carno is a 14m high, 270m long Pennine-type embankment with a central puddle clay core. The reservoir has a volume of 0.34Mm³, a surface area of 0.063km², an operational Top Water Level (TWL) of 444.54mAOD and a total direct and indirect catchment area of 5.1km². Works were undertaken to many aspects of Upper Carno; for further details please see parallel paper by Swetman et al (2024).

A number of approaches were applied at Upper Carno and modified as the project progressed through distinct stages. Initially, the existing by-wash channel was cleared of vegetation and its use reinstated. This enabled diversion of the majority of flows received from one of the two stream inlets, directing flows to the head of the existing spillway (Figure 2).

The second inlet was controlled using duty / standby pumps, again pumping direct to the head of the spillway. A siphon system was reviewed for this element, however this was not hydraulically feasible. The pumping of the inlet was sized to control up to Q_{10} flows, with any flow above this retained in the reservoir basin and dealt with via siphons as the need arose.

Figure 2. Upper Carno – Arial image of Upper Carno drawn down with pumps and siphons shown to left hand side (Google Earth – modified)

Informed by ongoing studies by MMB, and while undertaking a Section 10 inspection under the Reservoirs Act 1975, the Inspecting Engineer instigated a need to control water levels within the reservoir to a minimum of 3m below Top Water Level (TWL) until all works had been completed.

To achieve the water level control with limited or no availability for use of the scour system over a prolonged two-year period, duty / assist siphons were also installed using Bauer pipes with ductile iron fittings. Siphons were feasible for durations of the scheme as their hydraulic operation could maintain the flow required and were operated when required. Given the duration of installation, the system was cost beneficial to purchase the materials and install siphons when compared with other means, including pumping. The materials were transferred to the Client upon completion of the works for their future use.

The siphon was pump-primed and designed to operate from 6m below TWL, with flow rates of up to 350l/s (175l/s each pipe) discharging to the spillway (Figure 4). For the majority of the construction period only one siphon was utilised and trimmed daily to maintain a balance with inlet flows. During storm conditions the second pipe was put into service and left running until the storm had abated or levels had reduced to normal. Initial commissioning showed some air ingress; however, this was solved by first using sealant on each of the Bauer joints and later, wrapping joints with plastic wrap.

The siphon was in place for approximately two years and required little maintenance, following commissioning, for the duration of the project. A small centrifugal pump was purchased to allow priming of the siphon (Figure 3). The use of a siphon here saved the need to pump up to 350l/s continuously for two years, providing a significant saving in terms of both cost and carbon.

Figure 3. Upper Carno siphon priming point

Figure 4. Upper Carno siphon discharge point.
Note flows from By-wash channel

USK RESERVOIR

Usk Reservoir is formed by an earth embankment dam, which completed constructed in 1955 with an approximate capacity of 12,268,000m^3. The dam is 480m in length, with a maximum height of 31m, and supplies raw water to Bryngwyn Water Treatment Works as well as providing compensation water to the River Usk, which is classified as a Special Area of Conservation (SAC) and a Site of Special Scientific Interest (SSSI). MMB was appointed to primarily replace the aged pipework within the dam tunnel due to its condition, while secondly maximising the drawdown capability through this tunnel.

To enable the replacement of the tunnel pipework, flows were required to be maintained by other means to the downstream watercourse for river regulation and downstream abstraction. A temporary solution was required to be designed to maintain compensation flows for the planned 18-month construction period. In addition, the possibility of needing to augment flows to the River Usk meant capacity of up to 50 MLD had to be catered for at all times of the year.

With no bywash available, the solution adopted at Usk was to use a twin pump-primed siphon system installed from the reservoir basin to the spillway's stilling basin (Figure 5). Each siphon consisted of 280m long, 400mm OD HDPE butt-fused welded pipework, with ductile iron fittings. The siphon was designed to operate down to 4m below top water level, which was typical for Usk Reservoir during the summer, as the water level fluctuates. The system used a pump to prime the siphon, and the pump could also be used in the event that the siphon loses prime to discharge the minimum compensation requirement. As the compensation was mandatory and to environmentally sensitive areas, a back-up system was installed in the event of a prolonged drawdown, with the added capacity of floating electric submersible pumps to add additional flows. The duration of installation was such that the siphon system was cost beneficial to purchase the materials and install siphons and back-up pump pipelines when compared with other means, including pumping. The materials were transferred to the Client upon completion of the works for their future use. The back-up pumps were hired from a pump supplier given their limited use.

As flows to the receiving watercourse were critical a duty / standby installation was installed so that should something untoward happen to the operating siphon a second pipe would be immediately available. Flow monitoring was installed with an automated alarm system activated should flows stop for any reason. A 24 hour call out was instigated with a view to returning flows as soon as possible, or within 2hrs after a notification. Upon installation, both pipes were pressure tested as for any permanent pipework. A battery-operated flow meter was installed to give a daily record of flows discharged. For the majority of time, flows were routinely discharged via the siphon methodology (Figure 6). The siphon operated successfully down to TWL-4m as designed, although auxiliary pumping was utilised to maintain flows to the River Usk following a prolonged dry spell in September 2021.

The siphon upstream leg was installed by Edwards Diving Services (EDS), with the crest and downstream sections, testing, commissioning and operation by MMB. The siphon was found to be reliable, and throughout the construction phase, saved approximately 260,000 litres of diesel, and 700 tonnes of CO_2, when compared to over-pumping.

Figure 5. Usk Reservoir siphon and over pumping intakes

Figure 6. Usk Reservoir siphon outfall

CWMTILLERY RESERVOIR

Cwmtillery reservoir is formed by a 15m high, 150m long earth embankment dam. The reservoir has a 148,000m^3 storage volume, 41,000m^2 surface area and a 2.83km^2 catchment area. The reservoir is situated north of Newport, South Wales. The reservoir's primary use is to supply the water treatment works (WTW) adjacent to the dam. In 2022, investigation works were undertaken into the spillway by MMB where the reservoir water level was required to be controlled. The existing drawoff arrangement has a combined scour and supply main and as such it was not possible to feed both raw water supply to the WTW and drawdown the reservoir using the scour at the same time.

With no bywash available, the decision was made for twin, pump-primed siphons to be installed to maintain water levels around 2m below top water level as investigations were undertaken in the spillway. The priming pipework from Upper Carno was re-used and installed within the spillway (Figure 7), however the number of bends within the spillway meant it was easier to deploy flexible wire armoured flanged pipework to complete the installation rather than utilising the previously deployed Bauer pipework for the siphons length.

Figure 7. Cwmtillery Reservoir – Siphon priming installation

The duration of was long enough to balance the cost with pump installation along with the cost saving of re-utilising some pipework from Upper Carno siphons. However, the installation was also short enough duration such that it was cost beneficial to hire the wire armoured flanged pipework from a pump supplier. The siphon upstream leg was installed by Edwards Diving Services (EDS), with the crest and downstream sections, testing, commissioning and operation by MMB.

The siphon operated well and needed little intervention other than trimming of flows following installation. Flow rates of up to 350l/s were routinely discharged with no pumping required, again saving on fuel costs and associated carbon.

GOUTHWAITE RESERVOIR

Gouthwaite impounds the River Nidd in North Yorkshire, by a composite dam. The dam is of masonry faced cyclopean concrete to the left-hand side (170m long, 15m high) and an earth embankment (165m, 12m high) to the right-hand side of the valley. The reservoir has a volume of 7.11Mm^3, a surface area of 134,000m^2 and a catchment area of 115.5km^2. The primary function of the reservoir is to provide riparian flow and flood protection to the downstream watercourse.

During the installation of permanent siphon pipework in 2023, it was necessary to close the existing scour valves due to water quality risks associated with silt bed movements. A floating pump arrangement was installed to provide compensation flows of up to 720l/s for the relatively short duration of the project. A duty/standby pumping arrangement was installed with power provided from duty/standby generators situated on the dam crest. The need to discharge substantial flows, potentially at water levels greater than 5m depth, coupled with the short downstream discharge pipe meant a siphon was less suitable and pumps more reliable for the statutory discharge required.

Figure 8. Gouthwaite Reservoir – Pumping pipework arrangement

CASTELL NOS RESERVOIR

Castell Nos reservoir is formed by a 100m wide, 12m high earth embankment dam. The reservoir has a volume of 91,000m³, a surface area of 20,000m² and a catchment area of approx. 8km².

To supplement the existing draw-down facilities (scour and siphon) with a cost beneficial solution, two additional HPPE siphons were installed over the spillway crest. To augment the flow required, twin siphons were installed, with the pipework of 400mm OD HDPE butt-fuse welded pipework, with ductile iron fittings. The siphon crest and downstream sections, testing, commissioning were by MMB. The upstream legs were installed in the reservoir basin utilising divers (Edwards Diving Services), who were also used along the spillway edge where it was secured into position with pipe straps. Issues with silt within the reservoir basin prevented commissioning initially. The silt was removed and the non-return valves placed such that silt would not affect their operation. Priming for this siphon is from an adjacent supply main which can be utilised with careful valving. This siphon now forms part of the permanent works and is routinely tested with all other reservoir safety critical valves.

Figure 9. Castell Nos – Twin siphons installed

CONCLUSIONS

Where water levels need to be controlled, it is always best to use existing assets to their full potential ahead of employing costly temporary measures. Where durations are short, pumping flows up to 300l/s may typically be suitable. For medium-term projects it may be decided to install a system utilising hired in pipework. For longer-term installations it may be beneficial to purchase the pipework, which may help guard the against cost over-runs and provide a usable asset that can be reused multiple times. Siphons typically only generally operate to approximately 6m below TWL and have a limited hydraulic flow range when compared with pumps. The commissioning and operation of siphons may require more management; however if used in an appropriate manner they can provide a reliable and cost-beneficial solution. If the discharge flow is of a critical nature it may be prudent to have a duty-stand by arrangement with pumps available.

The use of siphons should be encouraged where appropriate as they are typically cheaper to install and operate than over pumping, with the added benefit of removing fuel from site which can pose an environmental risk. Additionally, carbon savings can soon add up with a saving of around 2.6kg CO_2 for every 1 litre of diesel saved.

An understanding of the underwater topography and of the presence of silt and debris will assist in planning works. Good quality bathymetric, diver and ROV (remotely operated vehicle) surveys can prevent issues during installation and commissioning.

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