Session 4

THE MECHANICAL SIDE OF DAM ENGINEERING

Spillway and Dam Gate Reliability – Harmonising the Approach to Mechanical and Electrical Systems? – R Digby

Incident management and repair of a ruptured scour main at Talybont dam caused by a pressure wave - T Williamson and A Warren

Recent Experiences in Design and Construction of Siphons to Supplement Reservoir Drawdown Capacity - N Kempton

Slaithwaite Reservoir Improvement Works - M Coombs and D Brown

Discussion

Spillway and Dam Protection Gate Reliability - are we heading towards Harmonising the approach to Mechanical and Electrical Systems ?

Presentation by:

R J Digby, KGAL Consulting Engineers Ltd, Poole, UK

Scope of Presentation

1. Set out the various approaches to Spillway and Dam Protection Gate Reliability currently being used
2. To show the direction of travel being adopted by ICOLD, which will likely become accepted practice in the near future

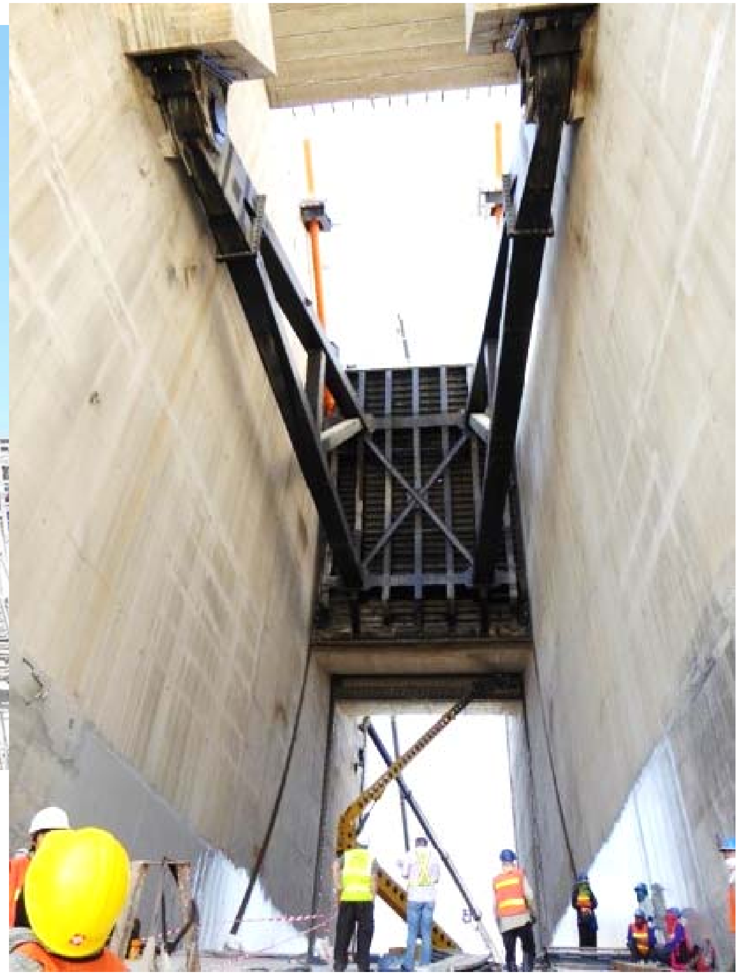
Key questions to be answered

- What is an acceptable risk to individuals and society ?
- Does this vary if:
  - Equipment is old or new ?
  - Equipment is in the developed or third world ?
- How does the hydro-mechanical equipment reliability relate to dam reliability overall ?
- How will this be transferred into contract specifications ?
- What are the implications for Inspecting and Supervising engineers ?

Where are we now – The Traditional Approach

- Redundancy + Contractors of “proven” experience = Reliability
- Number of spillway gates required + 1
- Gates generally procured through EPC “design and build” contract

Where are we now – International Standards



Where are we now – International Standards

Some new Risk-based standards (e.g. IEC 61508 & BS EN 62061) use the concept of Safety Integrity Level (SIL)

- SIL has four levels SIL 1 to SIL 4
- SIL 1 represents the lowest rating with a probability of failure on demand of 10^{-1}
- SIL 4 represents the highest rating with a probability of failure on demand of 10^{-4}

Recent focus on Probabilistic Failure Analysis

- Reliability from a probabilistic failure rate point of view
- Studies have been carried out by Scottish and Southern Energy in Scotland, by BC Hydro in Canada and by US Army Corps of Engineers in the USA
- This work has considered risk to lives in the event of various types of failure, the required level of reliability for those potential risks and the actual reliability levels delivered

Recent focus on Probabilistic Failure Analysis

- Individual Risk and Societal Risk
- Individual risk relates to the totality of risk relating to the dam
- Societal risk relates to each specific event that might occur
- For the individual, consider a level of risk (of death) and ensure that the risks from the dam do not exceed that

Recent focus on Probabilistic Failure Analysis

Figures for acceptable risk often used in developed societies:

- 10^{-3} where there is some control over the risk
- 10^{-4} for a minimum tolerable background risk
- 10^{-5} as a general rule
- 10^{-6} as an aspiration to be achieved “as low as reasonably practicable (ALARP)

Recent focus on Probabilistic Failure Analysis

Societal risk is usually quantified by:

- Assessing the Loss of Life (LOL) that would result from a dam failure due to an event
- Calculating the Population at Risk (PAR)
- Finding the Annualised Lives at Risk (ALR) = LOL/PAR

The values for societal risk are generally in the range 10^{-2} to 10^{-3}

Recent focus on Probabilistic Failure Analysis

- First need to analyse the consequences of failure (using Failure Modes and Fault Tree Analyses) and then determine how reliable the specified gate systems need to be
- Current ANCOLD advice recognises the higher costs of addressing existing dams versus designing new ones
- Accept the principle that acceptable risks for an existing dam can be up to ten times higher than for a new one

Recent focus on Probabilistic Failure Analysis

- How to quantify manual intervention ?
- In a one in ten thousand year event, how many people could be considered to have turned up for work on that fateful day ?
- The answer to this question could reasonably vary according to the circumstances of the dam

International Commission on Large Dams (ICOLD)

In 2014 ICOLD formed a technical committee for hydro-mechanical equipment in order to:

- Analyse current practices
- Develop guidelines

Currently developing a bulletin entitled "Best Practices for Achieving Reliability of Flood Discharge Gates"

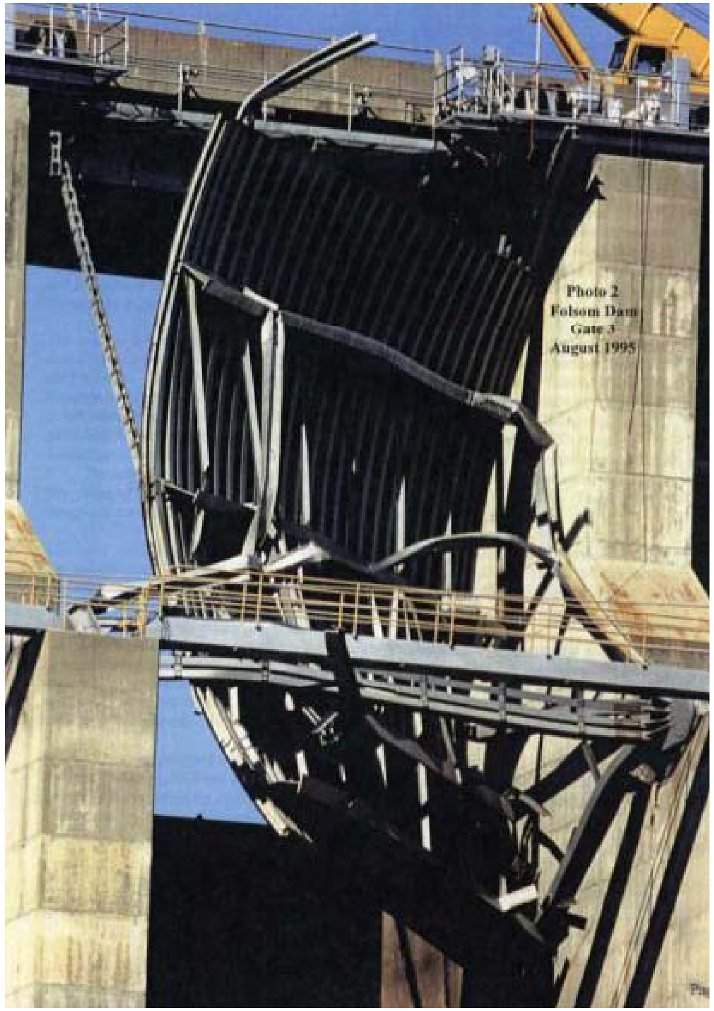
Incidents and Accidents

- Why reliability is an issue
- Dams have the ability to cause massive loss of life if they fail and there are a number of well-documented dam failures

Technology	Deaths per TWh Generated
Nuclear	0.04
Hydropower	1.4
Coal	60

Incidents and Accidents

- Anecdotal statistic that 30% of dam failures are due to the failure of the spillway to pass the required flow – not verified by ICOLD
- Some dam failures due to spillway inadequacies, which includes failure to open gates during a flood event
- Cases of deaths by drowning due to unexpected opening of discharge gates
- Common-cause failure modes making redundancy illusory



Health & Safety – An Engineers Responsibility

An engineer has duty of care

Needs to consider the risks associated with the use and misuse of the equipment under design and to:

- Remove "avoidable" risks
- Reduce "unavoidable" risks to be as low as reasonably practicable (ALARP)
- Protect from and manage those remaining risks
- Record risk assessment results so that all parties are aware of the risk that they own

How to procure Dam Protection Gates

It is proposed that the process for specifying gated spillways should be as follows:

1. Determine the various Hazards arising from one or more gate failure modes
2. Determine the consequences of such gate failure modes in terms of risk
3. Determine the reliability levels required of the gates and their associated systems

How to procure Dam Protection Gates

4. Design the gates and establish by analysis that the actual reliability levels of the gates and systems meet the requirements
5. Build, test, maintain
6. Re-examine the recorded hazard and risk analysis periodically as things change with time

How to procure Dam Protection Gates

- The full results of any previous hazard analysis and safety review should always be included within the specifiers systems specification.
- For Contractor design required to meet a reliability standard, the contract specification should clearly set out:

  - the standard to be attained
  - a requirement for the system designer to provide a numerical reliability study which shows that the standard will be attained

Reliability as a Journey not a Destination

Essential to document the hazard analysis process.

This fulfils two essential needs:

1. Clear evidence that a risk analysis has been undertaken and that the Engineers responsible have fulfilled their health and safety related duties
2. Enables others to re-visit the assessment later and update it in the light of changes, e.g. new hazards that have appeared or changes in the assessment such as increased population in the dam vicinity

Documentation should be updated every 5-10 years

Implications for Inspecting and Supervising Engineers

- No real direct impact on Inspecting and Supervising Engineers
- However, it is most likely that they will need specialist advice from reliability experts
- Need to undertake & continuously update studies for existing installations is likely to become a requirement

Conclusions

- The need for improved emphasis on reliability is demonstrated by the current “statistics” in respect of dam and gate failures and the known consequences of such events
- The civil engineering community has been taking a risk-based approach to acceptable levels of failure for some time - arguably the current European Machinery Directives also requires this approach.
- The predicted future requirements will logically build on these existing trends
- ICOLD is currently developing guidance for mechanical and electrical machinery systems that is likely to embrace the probabilistic approach that is already being adopted as best practice in a number of organisations

Conclusions

- The risk based approach helps to overcome the need for absolute rules by applying principles which can apply to all countries, since the risks associated with future maintenance and dependence on manual intervention can then be evaluated.
- Applies to the existing background risks to people who live in particular countries
- By adopting ongoing evaluation, reliability will be seen to be a journey rather than a destination. Inspecting and Supervising Engineers will become part of this process.
- Increasingly there will be encouragement to share lessons learned from failures.

Incident management and repair of a ruptured scour main at Talybont dam caused by a pressure wave

Tracey Williamson
Arup

Alan Warren
Mott MacDonald

Tracey will present:

- Facts about Talybont dam and the pipework arrangement
- Description of the incident
- Incident management
- Options & challenges
- The repair

Alan will present:

- The implications of the incident for reservoir safety
- His role in the incident as the QCE
- Post-incident analysis
- Lessons learnt

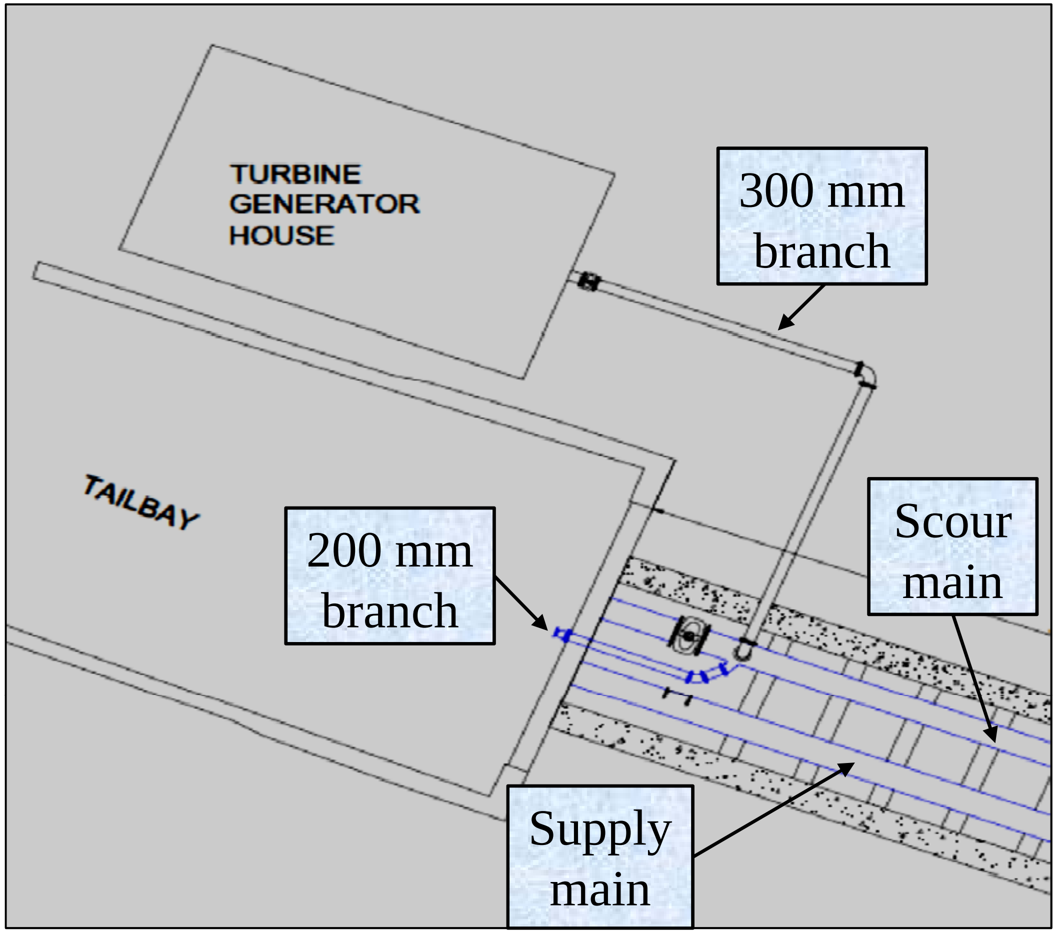
Talybont dam and reservoir location

Talybont dam and reservoir

View inside the tunnel

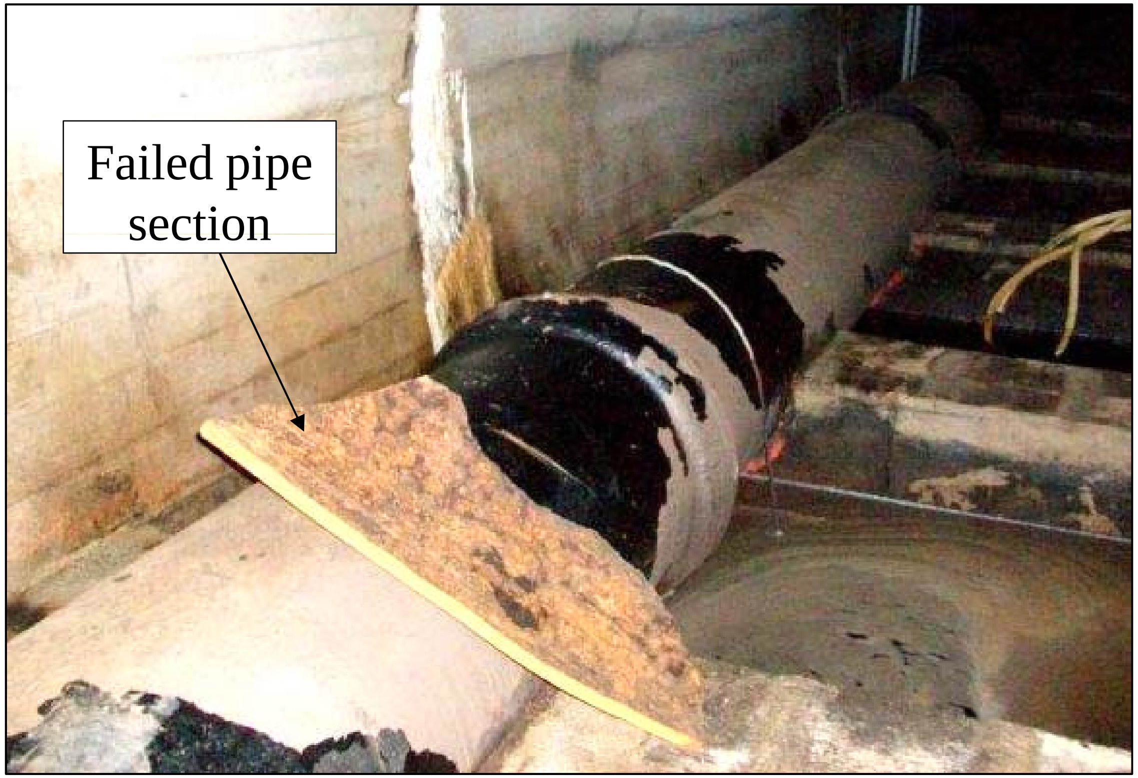
Pipework arrangement

- 635 mm diameter cast iron scour on the right
- 760 mm diameter steel supply main on the left
- 300 mm branch off the scour supplies a hydropower turbine
- 200mm bypass branch off the scour designed to automatically open if the turbine stops



The incident

- One evening in June 2015 the turbine inlet valve was operated to reduce flows
- The next day an operative saw water discharging from the tunnel



- The scour valve was closed as far as possible and flow from the tunnel reduced
- An inspection found a large section of the scour pipe had failed

Incident management

- Due to the risks to water supply and contractors, a ‘Gold Incident’ was declared
- A ‘Command Structure’ as used by UK emergency services was set up
  - ‘Gold’ located in Cardiff
  - ‘Silver’ near the site
  - ‘Bronze’ on site
- ‘Gold’ formulated the strategy and had overall control
- ‘Silver’ designed and managed the action plans
- ‘Bronze’ implemented the action plans
- Emergency services were not involved as there were no immediate impacts on the public

Incident management

- ‘Gold Commander’ – Director of Operations
- ‘Silver Commander’ – Head of Water Assets
- ‘Silver’ included the Dam Safety Manager, Designers and QCE
- ‘Bronze’ included the Contractor, Operators and Mines Rescue

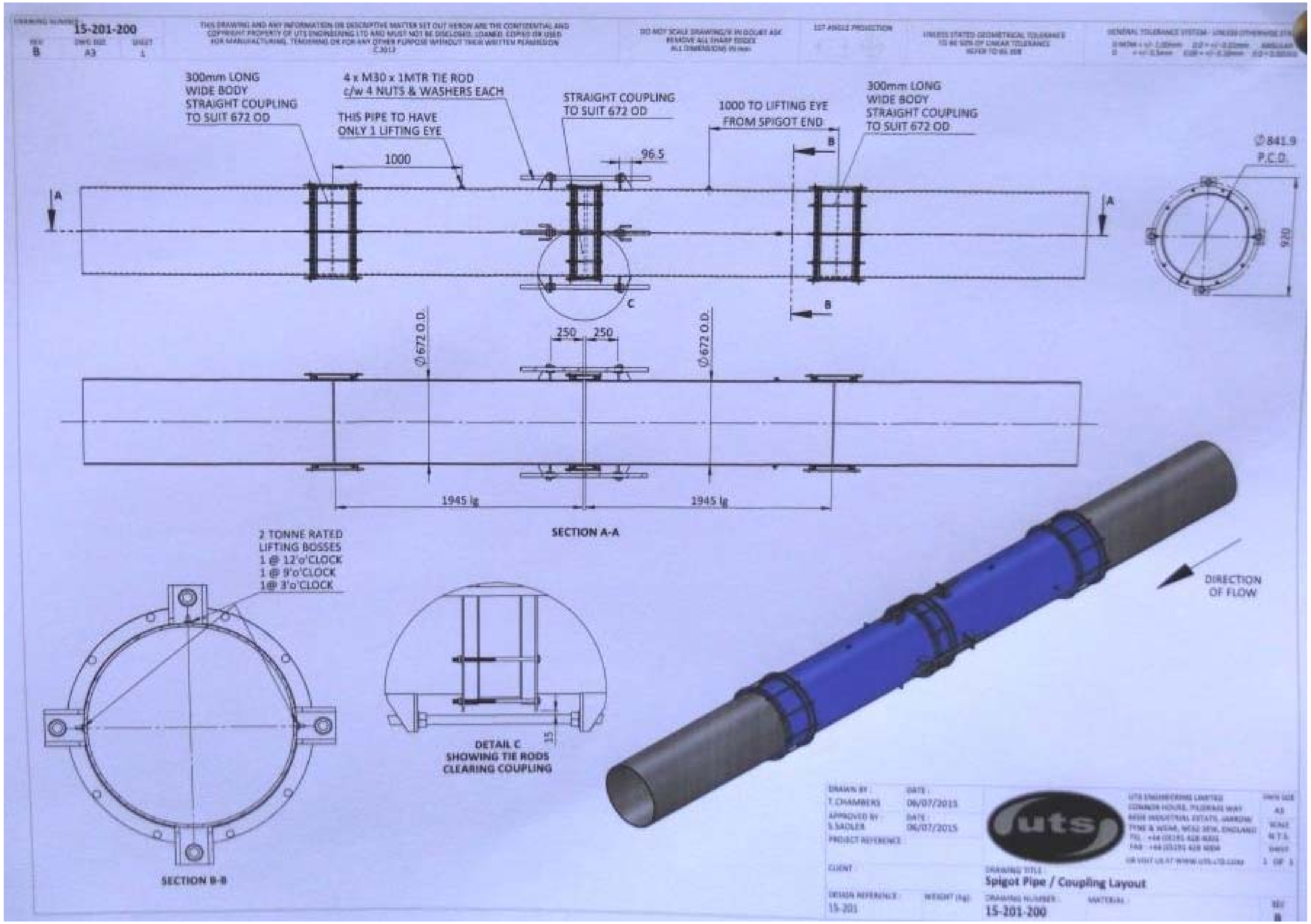
Challenges complicating the repair

- Single isolation only
- Valve stuck partially open, with a substantial flow passing through the main
- Pipes had spigot and socket joints
- Unknown condition of the rest of the pipework
- Supply-critical main was corroded and had weakened joints
- Manual handling issues
- Working in the confined spaces

Repair options

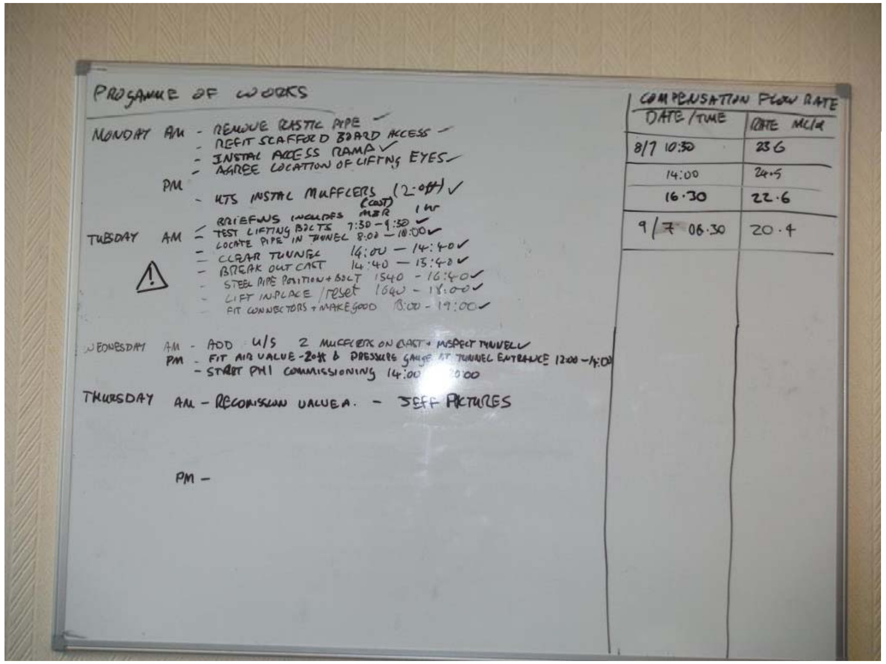
- Options to isolate the scour main were considered
  - Limpet dam on upstream end of tunnel
  - Freeze the scour main
  - Inflatable flow stop
- Lowest risk solution – repair pipe under existing flow conditions
- Steel pipe had to be used to prevent other complications:
  - Pipe size not available in plastic
  - Pipe support would need re-profiling whilst being hammered with flow
- However, this created manual handling concerns
  - Pipe manufactured to manageable lengths
  - Lifting points installed in the tunnel roof

Pipe repair


15-201-200
300mm LONG WIDE BODY STRAIGHT COUPLING TO SUIT 672 OD
4 x M30 x 1MTR TIE ROD c/w 4 NUTS & WASHERS EACH
THIS PIPE TO HAVE ONLY 1 LIFTING EYE
STRAIGHT COUPLING TO SUIT 672 OD
1000 TO LIFTING EYE FROM SPIGOT END
300mm LONG WIDE BODY STRAIGHT COUPLING TO SUIT 672 OD
1000
96.5
Ø 841.9 P.C.D.
920
Ø 672 O.D.
250
250
Ø 672 O.D.
1945 lg
1945 lg
SECTION A-A
2 TONNE RATED LIFTING BOSSES
1 @ 12'o'CLOCK
1 @ 9'o'CLOCK
1@ 3'o'CLOCK
SECTION B-B
DETAIL C SHOWING TIE RODS CLEARING COUPLING
DIRECTION OF FLOW
T.CHAMBERS
06/07/2015
S.SADLER
06/07/2015
uts
Spigot Pipe / Coupling Layout
15-201
15-201-200

Contingency planning

- Preparations and pipe manufacturing took a week
- Meanwhile detailed contingency planning undertaken:
  - Drawings pinned on the walls
  - Actions plans written on white boards with step by step instructions
  - ‘What if’ scenarios considered
  - Additional staff and materials brought on site
  - Briefings and ‘dry runs’ held



The repair

- Final briefing
- Materials and equipment checked
- New pipe sections rolled in
- Scour pipe cut
- Couplings and new pipe lifted in place
- The repair took 6 hours

Lifting the pipe into place

Success!

MOTT MACDONALD

Talybont Reservoir incident

Reservoir safety perspective

Alan Warren, Mott MacDonald

Dŵr Cymru Welsh Water

Was the reservoir at risk?

Performance indicators – early information

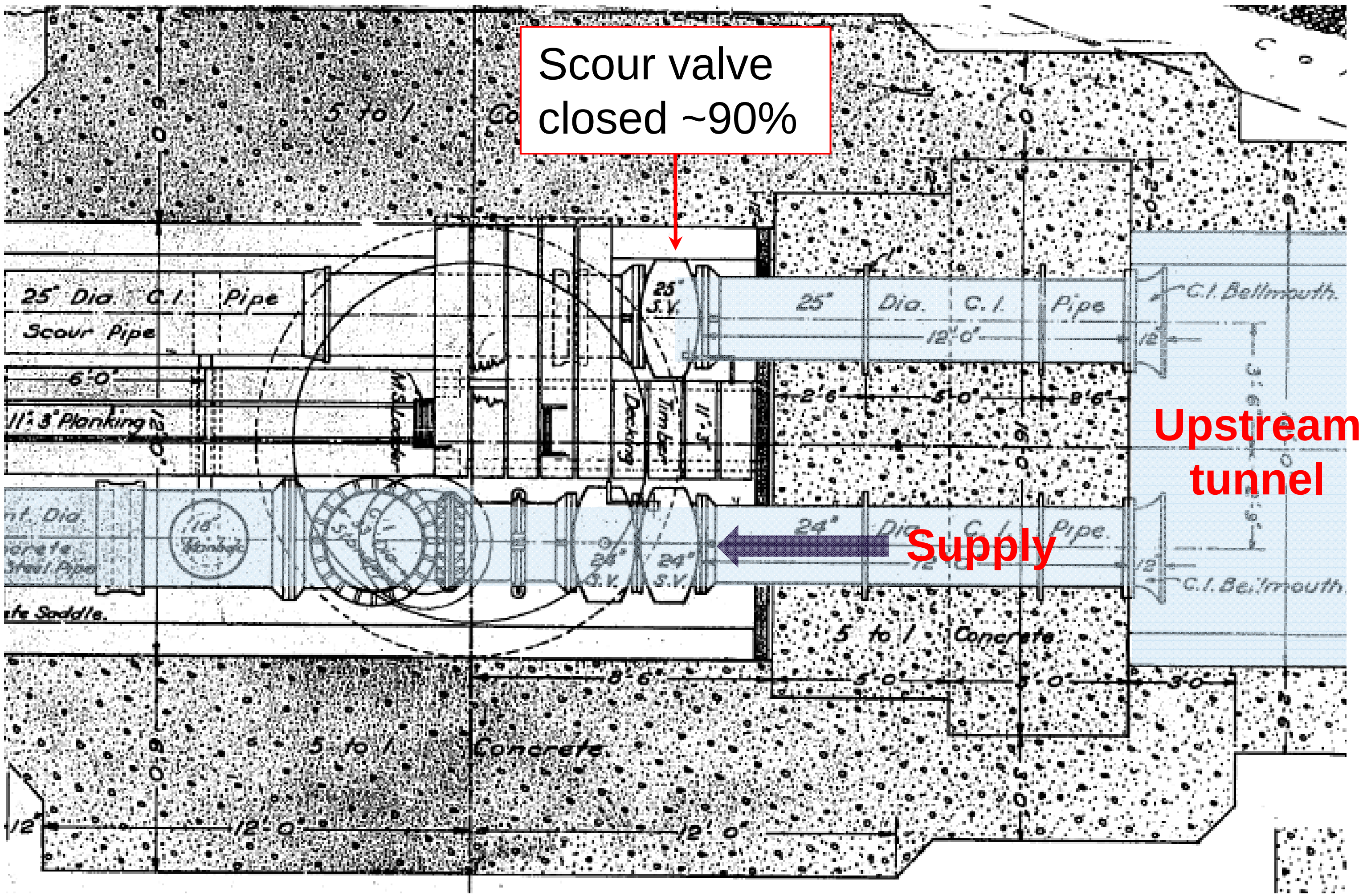
- No reported instability of the embankment
- No scour erosion of the downstream toe arising from the uncontrolled release of water
- No evidence of leakage from the embankment body
- No reported damage to the tunnel plug or tunnel lining
- No evidence that the core had been compromised by the incident.

QCE advice for incident management

QCE support was provided to:

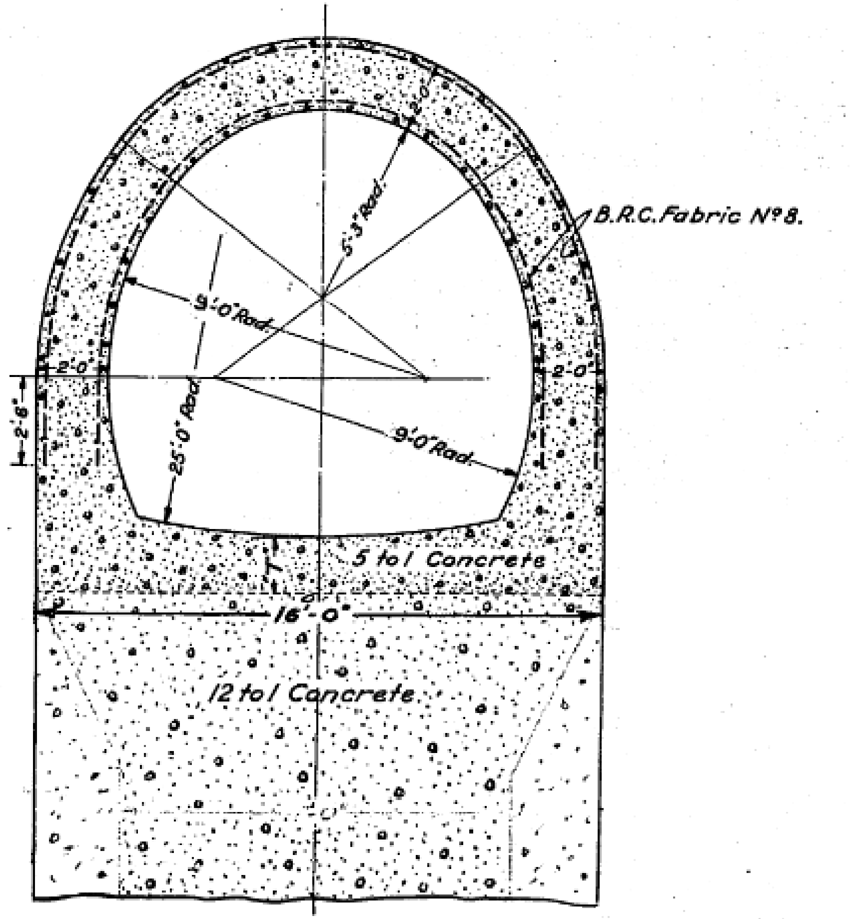
- Review dam safety implications of the incident
- Advise on alternative repair strategies
- Monitor any actions which could impact the condition of structures
- Assist in emergency planning (if required)

Plan on plug and pipework – no secondary isolation

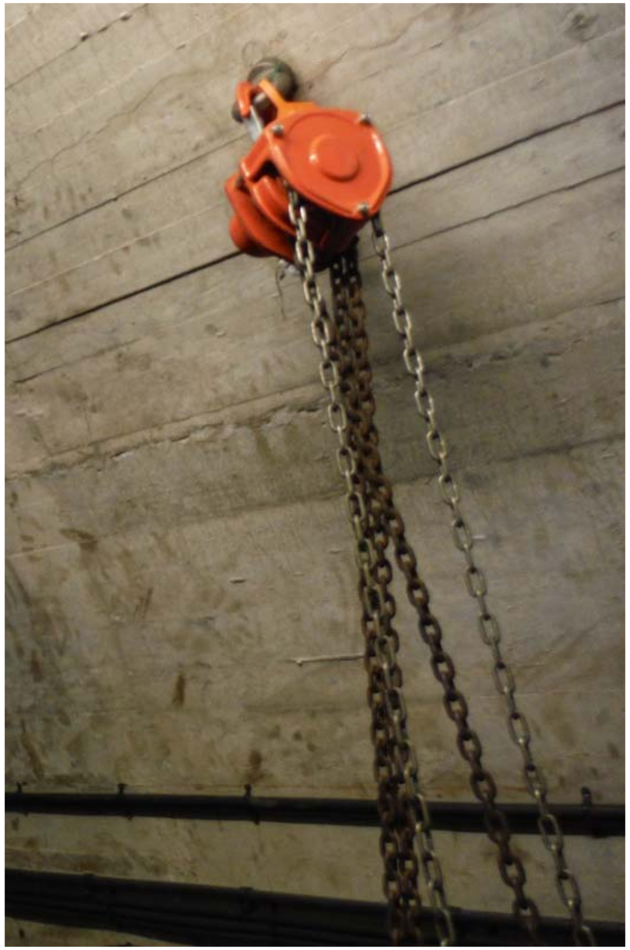


Risk of scour in downstream tunnel

- Tunnel was of relatively modern design: 600 mm thick mesh reinforced concrete roof
- Substantial thickness of mass concrete to the invert
- No risk of the scour pipe water eroding the tunnel



Lifting facilities



Access for investigations and remedial work

Investigations following the incident

Post-incident findings

- The records showed power reduced from 16kW to 4kW in one second
- Inconclusive whether the bypass valve opened before the turbine valve closed
- Evidence that the scour main had lifted off its supports
- Investigation of the failed cast iron sections indicated:
  - The material tensile strength was typical for cast iron
  - There was only a minor degree of surface corrosion
  - Fractures had been present for some time
- Pipe failure occurred due to multiple instances of turbine load rejection generating pressure waves and movement/stress of the scour main on its saddle supports.

Questions for managing pipework assets?

Are the assets being subjected to operational conditions which differ to the original design condition?

- Pressure transients from rapid valve operation
- Increased head through dam raising
- Changes in physical environment which could hamper inspection, accelerate corrosion, increase stresses

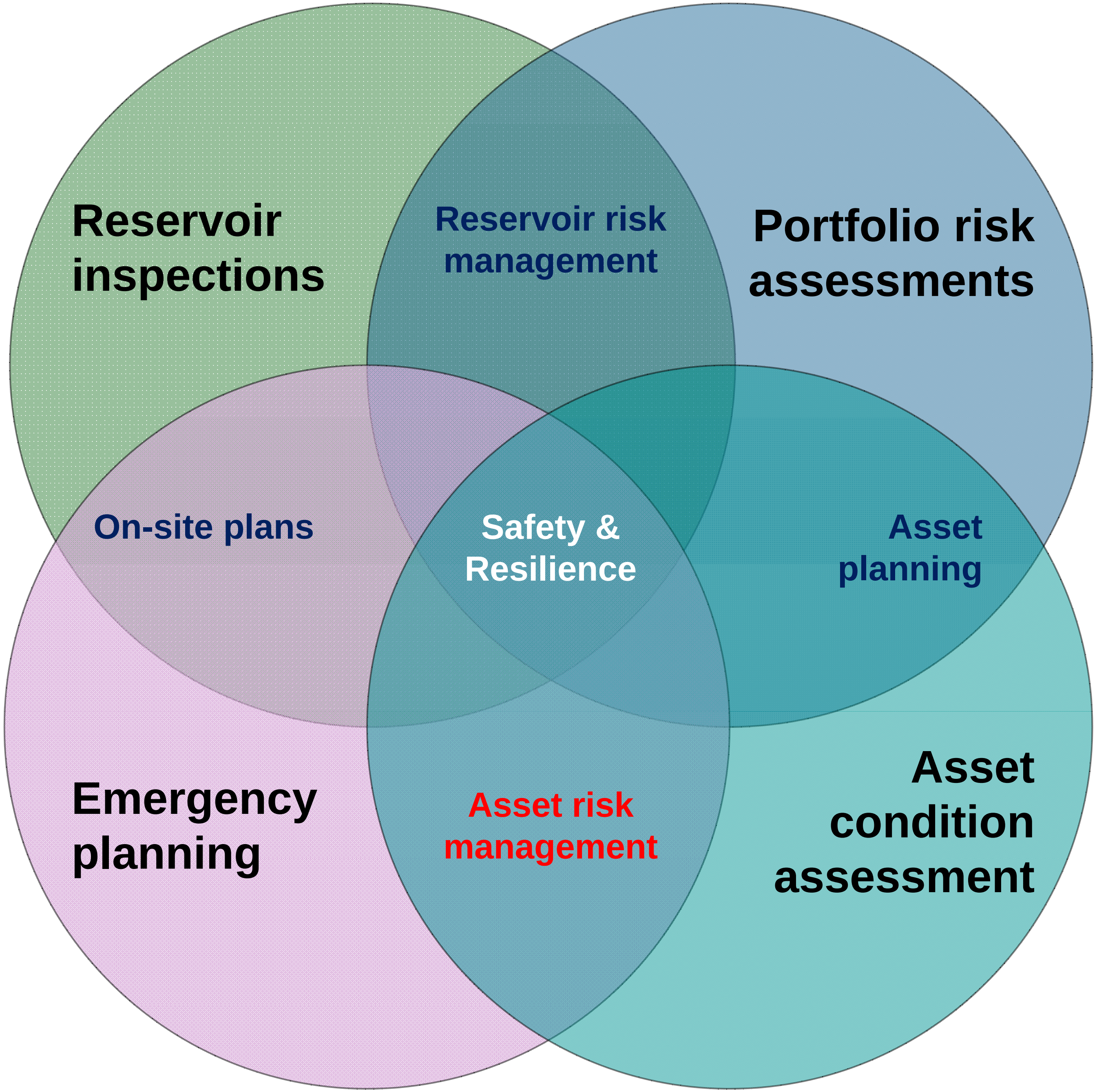
Do we REALLY know the current condition of assets?

- Visual inspections are only part of the solution
- Paint systems can protect but also conceal
- Non-destructive testing can help

What are the impacts of a pipe/valve failure on:

- Reservoir safety?
- Operational resilience?
- Staff safety in dealing with incidents?

Learning and moving forward


Reservoir inspections
Reservoir risk management
Portfolio risk assessments
On-site plans
Safety & Resilience
Asset planning
Emergency planning
Asset risk management
Asset condition assessment

Asset risk management study

DCWW are completing studies for all statutory impounding and non-impounding reservoirs to review and evaluate:

- Pipe and valve arrangement and general condition/operation
- Isolation of critical pipelines
- By-pass facilities
- Implications of incident management (access, safety)
- Physical constraints to condition assessment and repair work

MOTT MACDONALD

Acknowledgement is given to Welsh Water for their permission to share the learning from the Talybont reservoir incident

Thank you

Dŵr Cymru Welsh Water

Recent Experiences in the Design and Construction of Siphons

Supplementing Reservoir Drawdown Capacity

Presenter: Neil R Kempton

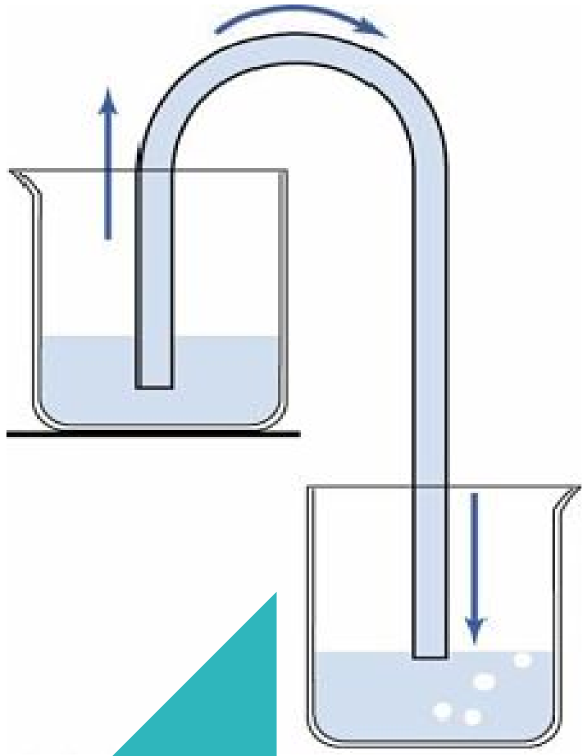
Introduction to Siphons

What is a siphon/syphon?

Definition:

- *A **tube** used to convey liquid **upwards** from a reservoir and then down to a lower level of its **own accord**.*

  – Oxford English Dictionary



Introduction to Siphons

How do they function?

Chain / Train analogy:

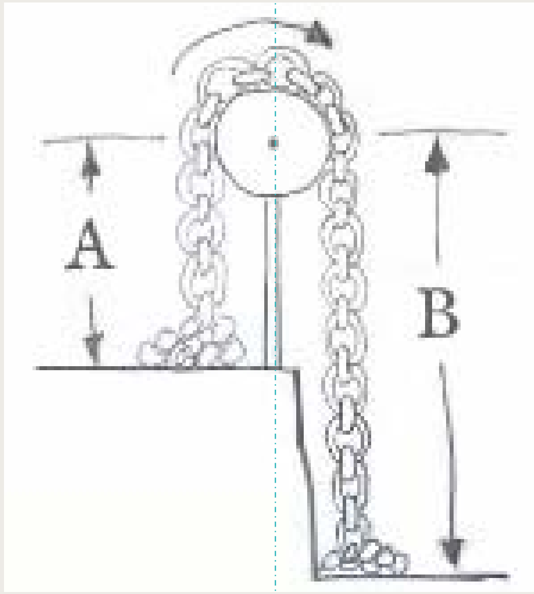
A siphon will flow continuously in the direction shown if:

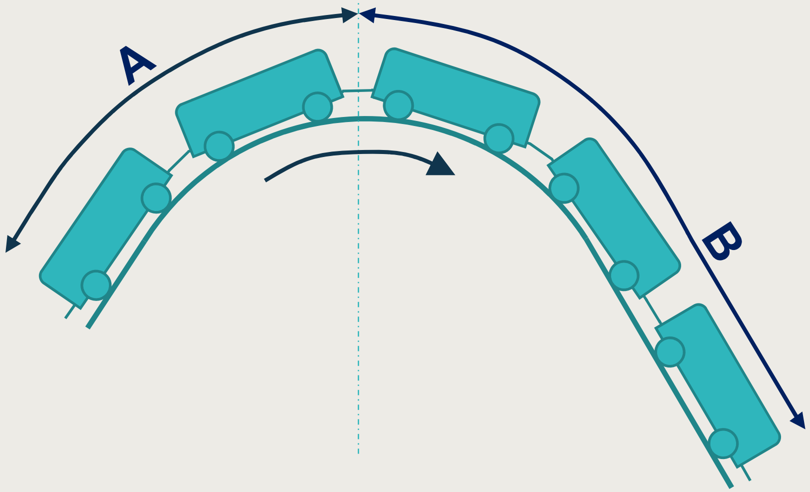
- Length B > Length A;
- Siphon is full of water ('primed');
- A constant supply of water;

Priming Methods

The siphon can be 'primed' in different ways:

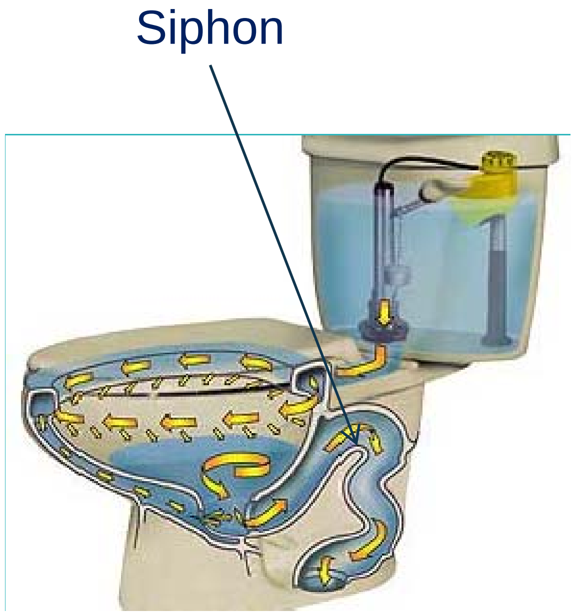
- Pumped
- Vacuum
- Self-priming





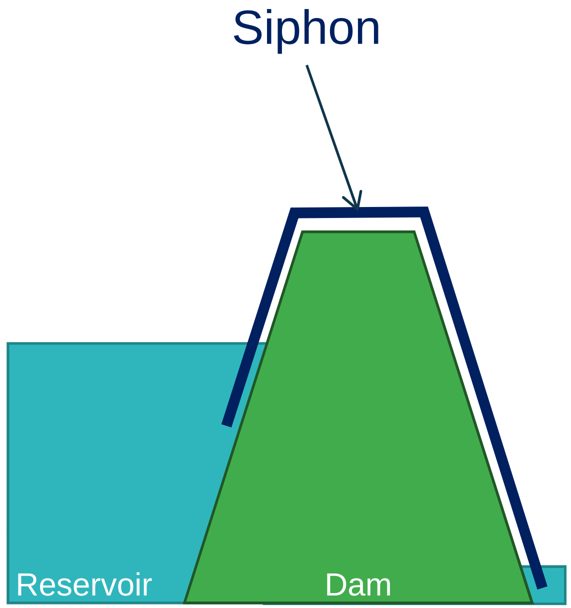
Introduction to Siphons

How are they used?



To flush a toilet.

‘Siphoning’ fuel from a car.

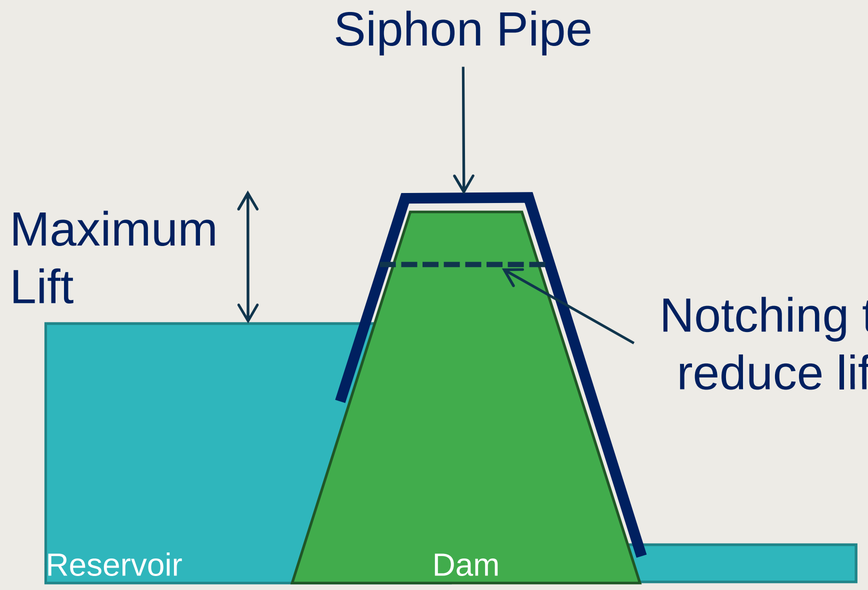


Drawing down a reservoir.

Introduction to Siphons

Maximum Lift

- Maximum theoretical lift = 10m.
- After head losses this is significantly reduced.
- Burying the siphon pipe through the dam crest reduces the lift.
- Normally capable of providing drawdown for top 5m.



Presentation

Keighley Moor Reservoir

YorkshireWater

Eccup Reservoir

YorkshireWater

Wessenden Old Reservoir

YorkshireWater

Warland Reservoir

United Utilities

Presentation Case Studies

Summary

	Peak Capacity	Pipe Diameter	Priming Method	Client
Keighley Moor Reservoir	0.5m³/s	500mm	Pumped	Yorkshire Water Services
Eccup Reservoir	8.0m³/s	1400mm	Vacuum	Yorkshire Water Services

Case Study 1
Keighley Moor Reservoir

Client: Yorkshire Water Services

Project
Keighley Moor Reservoir

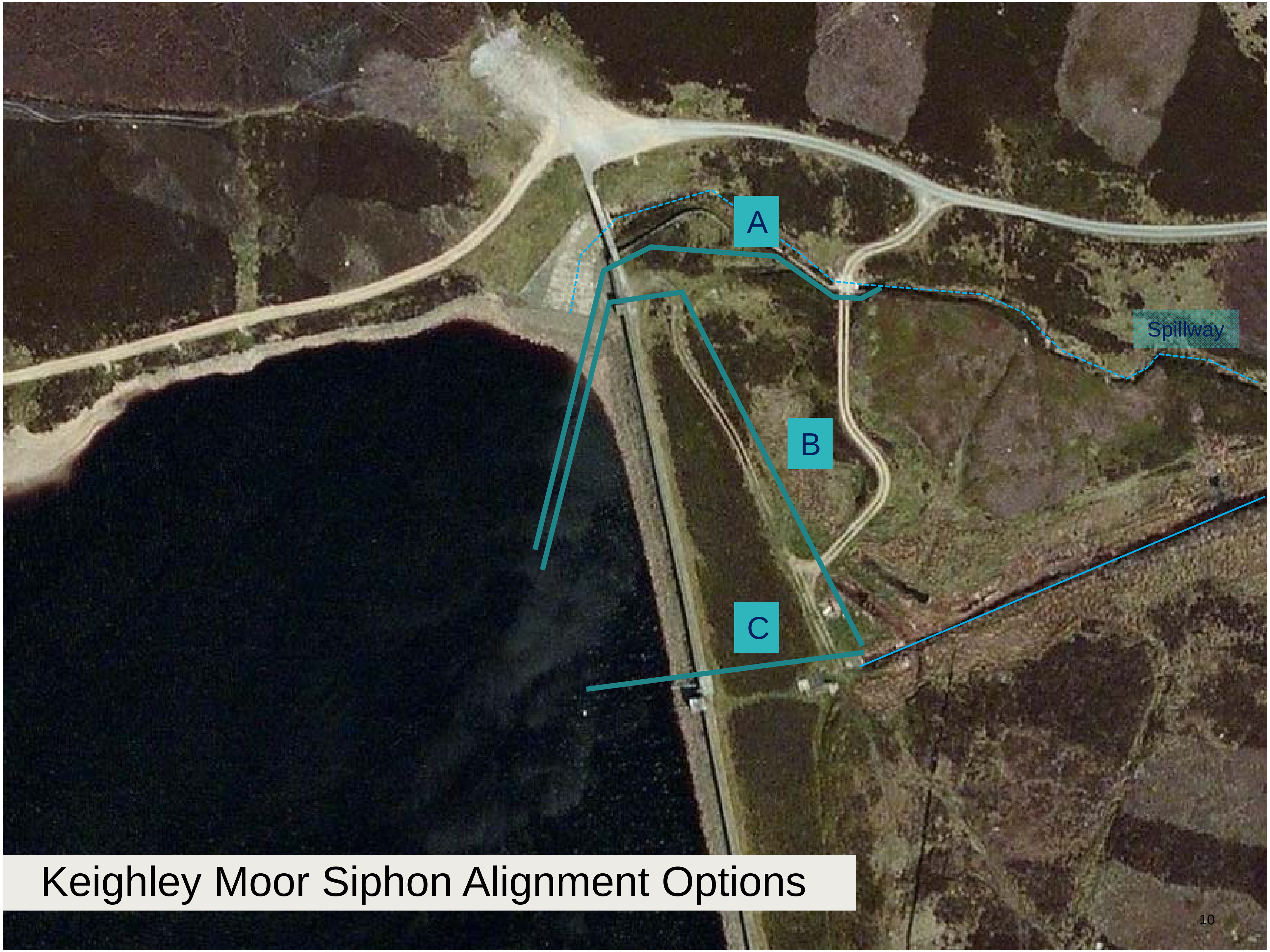
Client
Yorkshire Water Services

Location
West Yorkshire

Scour pipe Diameter
300mm

Peak Discharge (@TWL)
$0.34m^3/s$

Drawdown (@TWL)
0.44m / day



Keighley Moor Siphon Alignment Options

Upstream Valve

View of the non-return valve at inlet of siphon pipe during construction.

Priming Arrangement

View of the pumped priming arrangement during commissioning.

Siphon Supports

View of pipe supports on upstream leg of siphon.

Reservoir Drawdown

View of Keighley Moor Reservoir near the end of the construction phase.

Keighley Moor Commissioning

Case Study 2
Eccup Reservoir

Client: Yorkshire Water Services

Project
Eccup Reservoir

Client
Yorkshire Water Services

Location
West Yorkshire

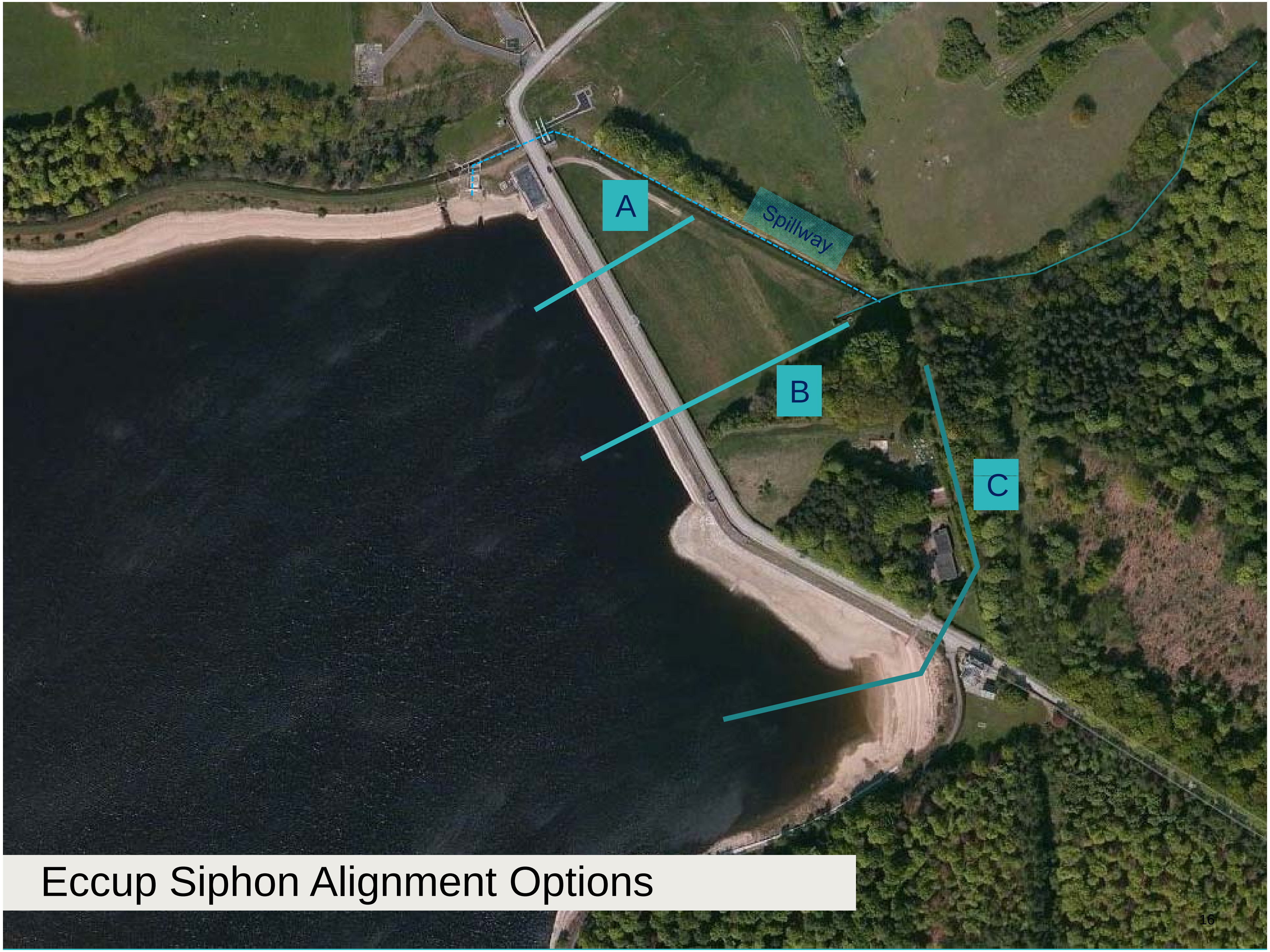
Scour pipe Diameter
535mm (21 inch)

Scour peak Discharge (@TWL)
1.2m^3/s (now plugged)

Supply pipe Diameter
1000mm (3 no.)

Supply peak Discharge (@TWL)
1.39m^3/s

Drawdown (@TWL)
0.3m / day



Eccup Siphon Alignment Options

Number of Pipes

View of downstream leg of siphon pipe, looking towards the crest and siphon control kiosk.

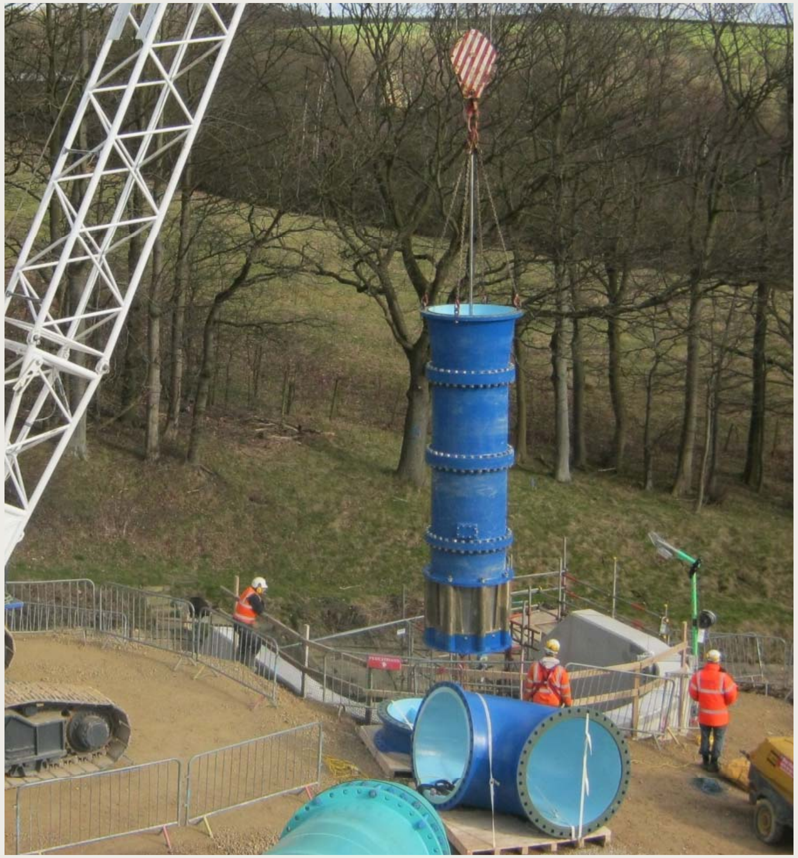
Priming Method

View of vacuum pump inside siphon control kiosk located at the siphon crest.

Upstream Valve

View of Gate Valve installed at upstream edge of dam crest.

Downstream Valve

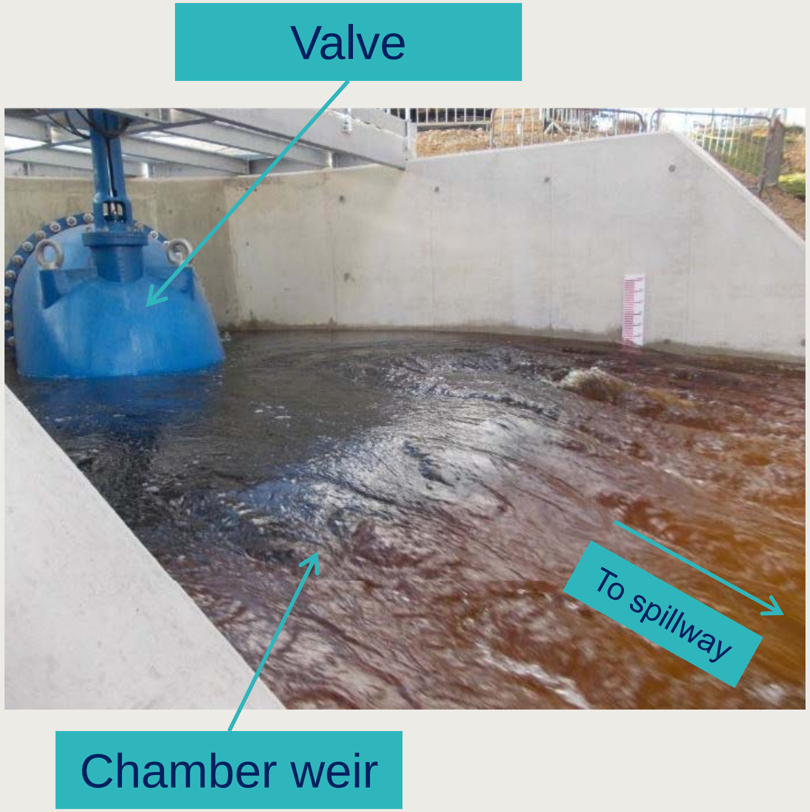


View of Submerged Discharge Valve being lifted into downstream circular chamber.

Submerged Discharge Valve

View of Submerged Discharge Valve in circular chamber.

Discharge Overflow



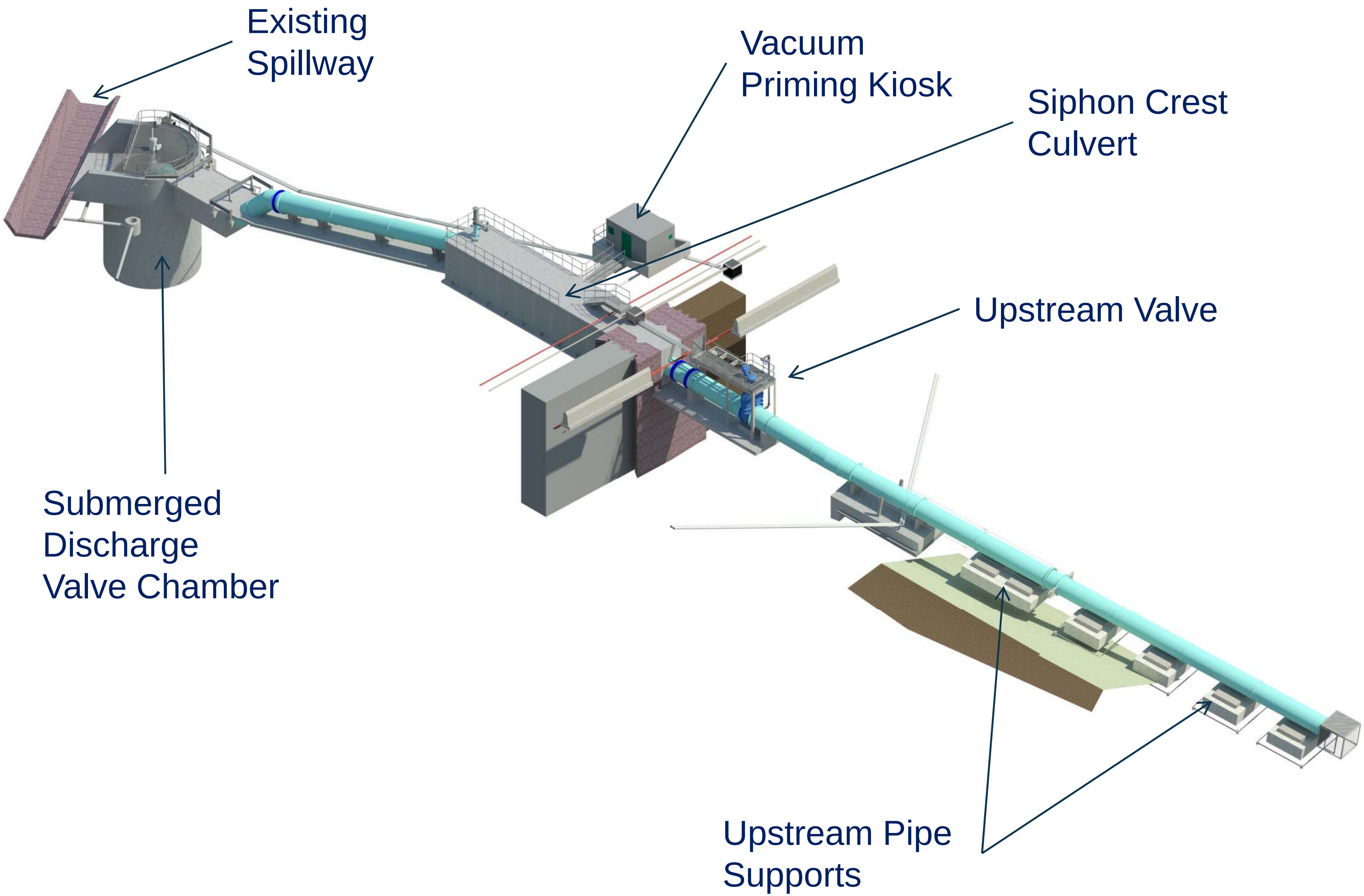
View of the downstream chamber connection into the existing spillway.

Upstream Pipe Supports

View of upstream supports during construction.

Sinking of Upstream Leg

View of upstream siphon pipe being located onto pipe supports.



Eccup Reservoir Siphon

Video of Eccup Commissioning

Summary

Siphons:

- Are a feasible solution to increase drawdown capacity;
- Applicable for a wide range of flows;
- Design is site specific;
- Require a collaborative and considered design process;
- Anticipated many more will be constructed.

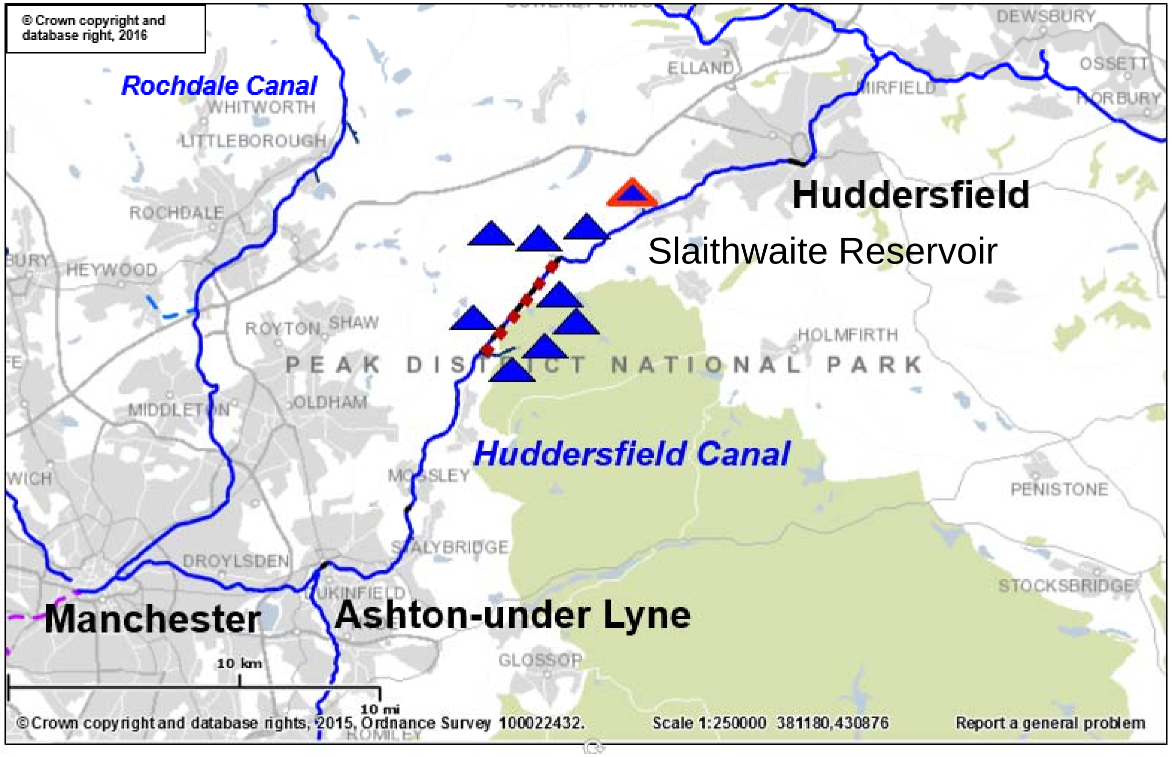
Thank you

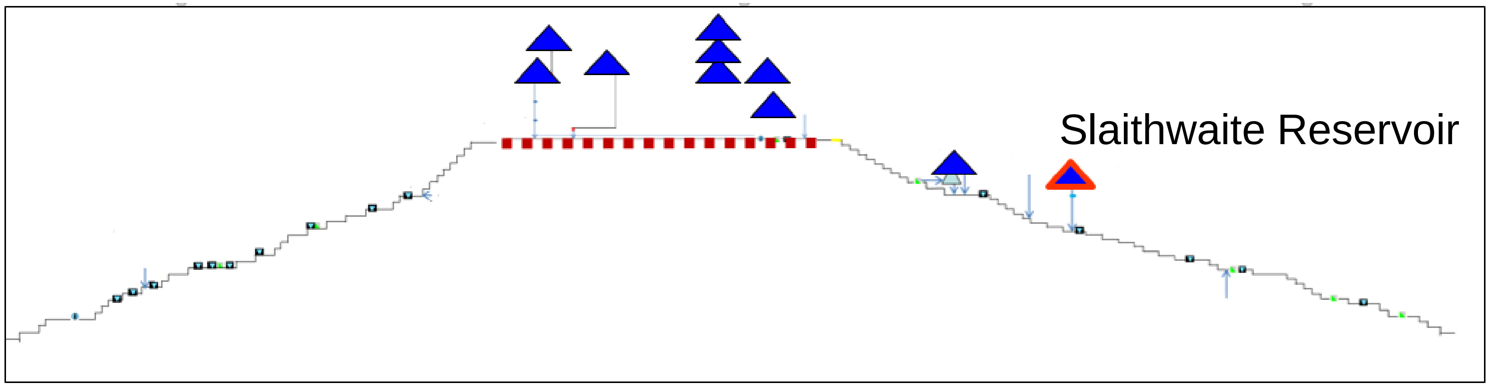
Thank you to Yorkshire Water Services and United Utilities Group for agreeing to share these experiences and to the co-authors of the paper for their contributions.

Slaithwaite Reservoir Improvement Works

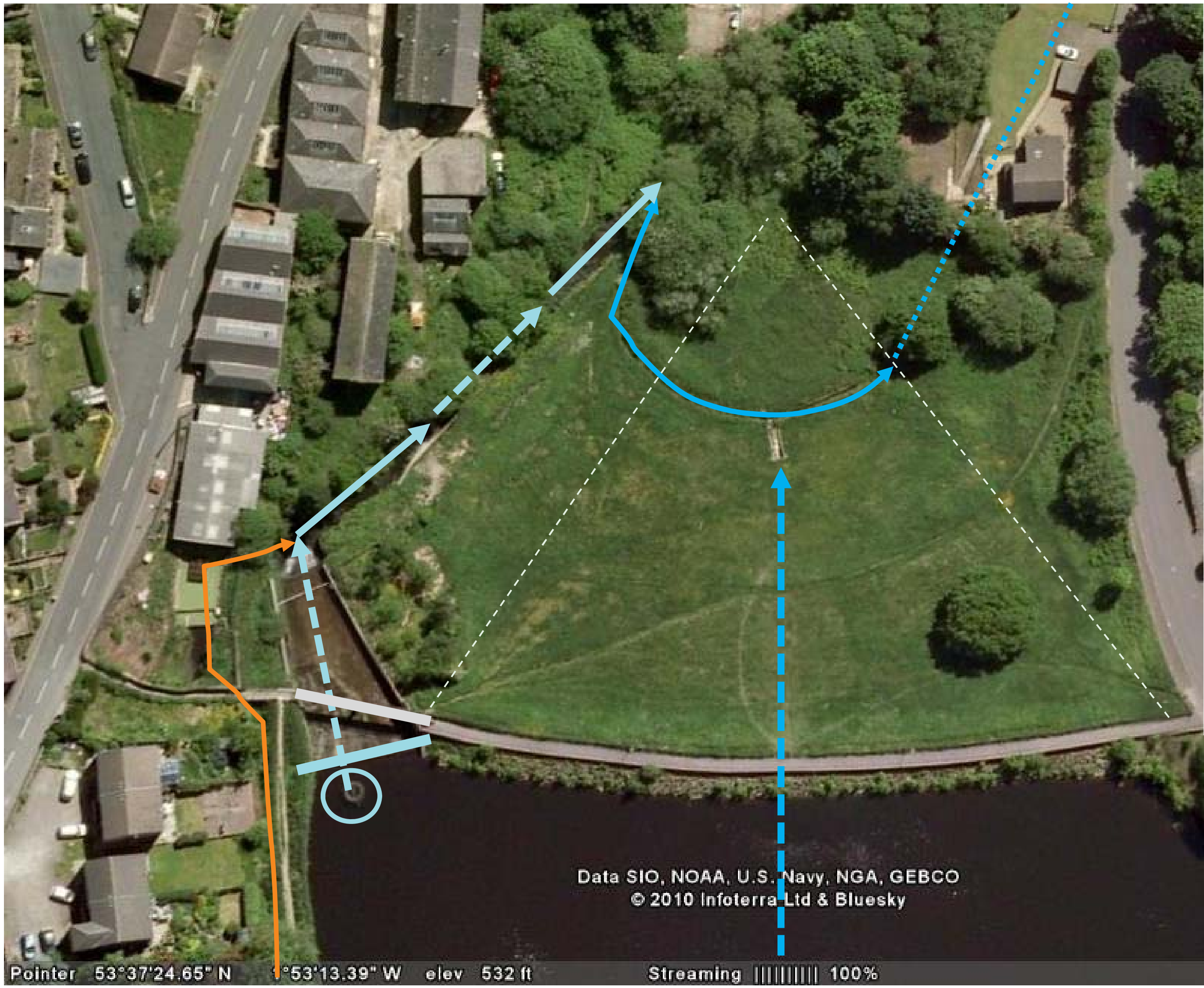
David Brown, Canal & River Trust
Matt Coombs, Arcadis Consulting (UK) Ltd

Slaithwaite Reservoir





Slaithwaite Reservoir



Challenges

Challenges

Works Planned

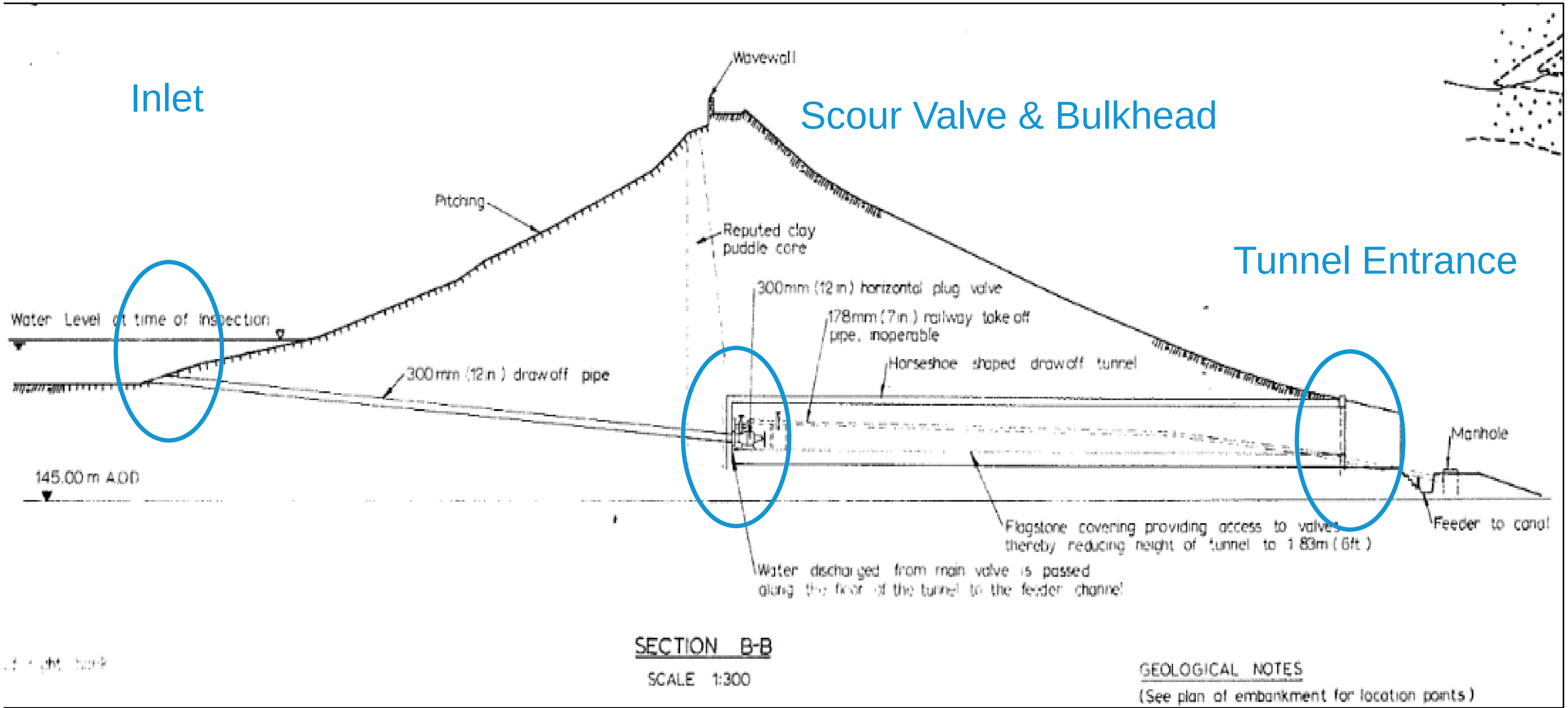
- Bellmouth penstock replacement
- Scour pipe replacement and extension
- Footbridge refurbishment
- Drop shaft and tunnel grouting
- French drain and v notch
- Spillway minor repairs

Phase 1 - Bellmouth Penstock

Bellmouth Penstock - Issues

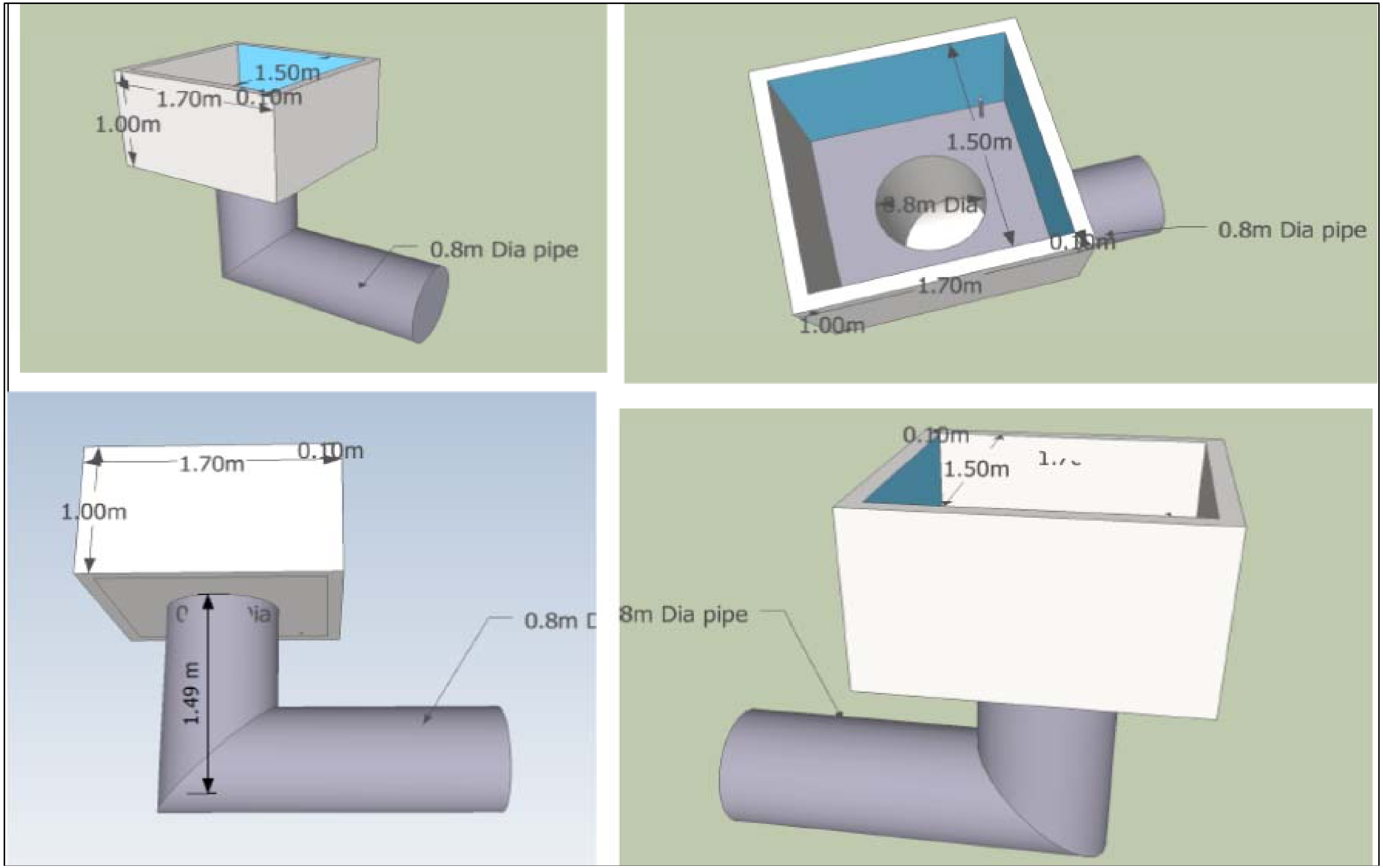
Bellmouth Penstock - Solution

Phase 2 - Scour Valve



Scour Valve - Issues

Scour Valve – Upstream Inlet

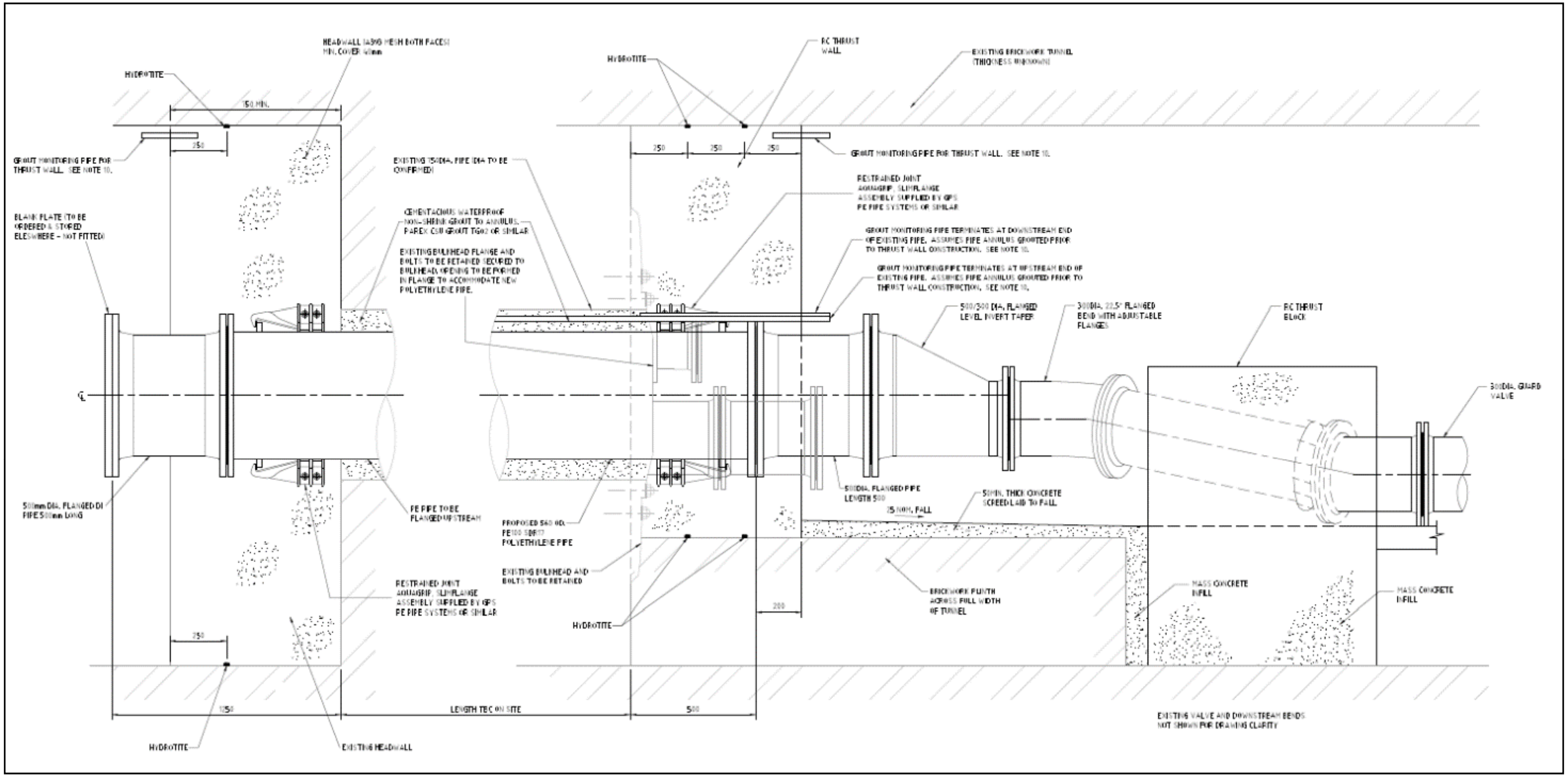


Slaithwaite Reservoir

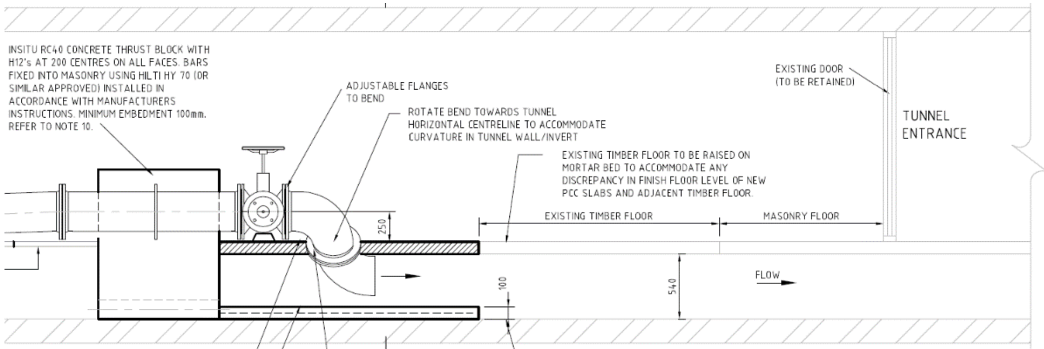
Scour Valve – Upstream Culvert

Scour Valve – Bulkhead

Scour Valve – Bulkhead



Scour Valve - Relocation



Other Works

Footbridge Refurbishment

Footbridge Refurbishment

Lessons and Conclusions

Lessons

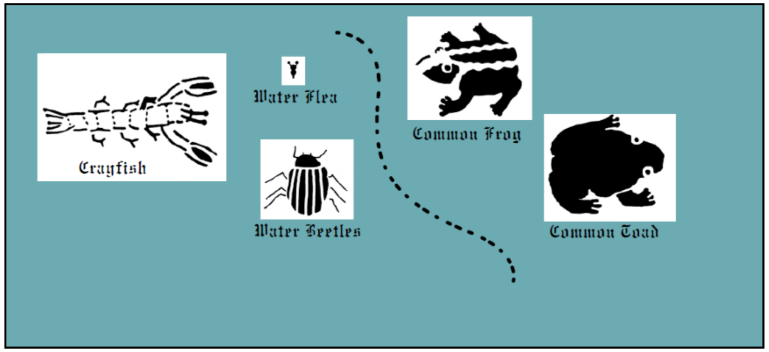
- Treat dive information with care
- Make sure you have contingency plan(s)
- Make sure the supplier of the remote operating system installs it

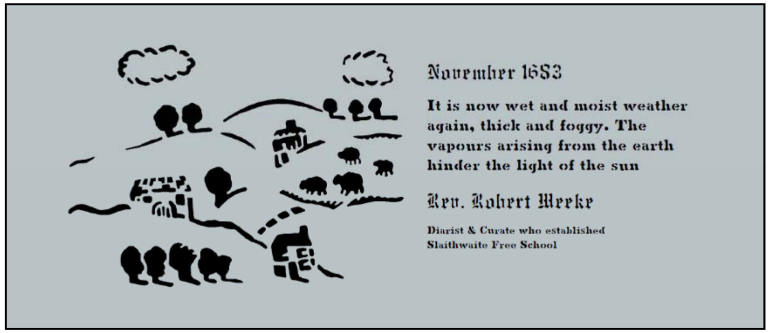
Specifically the works have provided:

- Safe operation of the Bellmouth penstock and scour valve
- Provision of a guard valve
- Upstream culvert restored and grille provided
- Leakage reduction and monitoring facility
- Engagement of local community via school competition

Involving the Community

Celebration event was arranged at the school - ‘I love Slaithwaite Reservoir’ T shirts



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Session Chair: Stuart King
Technical Reporter: Alasdair Couttie

Spillway and Dam gate reliability – Harmonising the Approach to Mechanical and Electrical Systems? (Grubb *et al,* p297 of the Proceedings)

Comment: Jonathan Hinks (HR Wallingford)
The paper by Ken Grubb and Russ Digby about spillway gates was very interesting. What they said about the incidents in South Eastern Norway echo what I have found in several countries. For example at five large dams in the Far East the main safety concerns centred around the spillway gates. I see that 50% of the incidents at the Norwegian Dams were associated with power failure at the gates. My own view is that there should always be a standby generator and that these should always be run on a weekly basis to check that they are available if the main source of power is out of action.

Question: Christine McCulloch, Oxford:
I wonder if you would talk me through the ethics of relating "Acceptable Risks" to "Background Risks" in developing countries?

Response: Russ Digby(KGal)
What we were trying to identify, which comes out more in the paper than the time I had for the presentation, was that risk comes in many different forms, some of it, as Jonathan was mentioning, relating to the actual machinery itself. Other aspects talk about relations to people and society and all we were trying to do is highlight the differences between the various aspects that might play a role and certainly different areas have different acceptable requirements and that is ultimately the point we were trying to make. Part of the Risk assessment is that if there were risks that people thought were reasonable in that vicinity they would be quite at liberty to take them into consideration in their modelling.

Incident Management and the repair of a ruptured scour Main at Talybont Dam caused by a pressure wave (Williamson & Warren, p307 of the Proceedings)

Question: Duncan Scott (SSE)
How concerned are you that the remaining cast iron pipe may suffer a similar failure mechanism (be it over-pressure or fatigue)? Were any special measures taken or difficulties encountered in achieving a good seal between the new VJ couplings and existing CI pipe ends?

Response: Alan Warren (MMB)
As I mentioned at the end there is a study going on for all the reservoirs within Welsh Water that includes Talybont, and Non Destructive Testing is to be done on the remainder of the scour main sections. From a visual point of view there were no signs of damage but there will be some ultrasonic testing to confirm there are no other cracks and yes they got a very good seal with the couplings.

Question: Socrates Metaxas (MOD Cyprus)
Again on the same topic the failure was caused by water hammer, what precautions have you taken for the water hammer failure not to be repeated? I was wondering that if the valve was leaking even after the repairs were completed whether you have considered the option of installing another valve to provide effective isolation in the future?

Response: Alan Warren (MMB)
The turbine has been taken off line. There is no intention to put it back online. Regarding the scour valve that was passing 10%; once we had done the repair and had downstream control, we were able to refill and re-pressure the scour pipe and with a little difficulty we were able to free the valve under balanced head conditions.

Air valves were fitted on the scour main to release the air when refilling the pipe section, but there was still a pocket of air, upstream of the last air valve, which was released through the scour valve gland when the scour valve was opened

Response: Tracey Williamson (Arup)
I will answer the second question first about the valves. Yes as part of the additional works that Welsh Water is planning they are looking at putting in secondary isolation, not just on that valve, but on all the valves in their dams.

Recent Experiences in Design and Construction of Siphons to Supplement Reservoir Drawdown Capacity (Kempton *et al,* p241 of the Proceedings)

Question: Peter Kite (Peter Kite Associates)
Take into account the effect on downstream property and infrastructure when determining the number of scour pipes and siphons. Immediately downstream of Eccup reservoir is Harewood Estates which is a Historic England Grade 1 Park and Garden. It was designed by Capability Brown with many unique water features including lakes, cascades bridges and waterfalls. The owners were greatly concerned on the effect of regular testing of an 8m^3/s scour siphon on their historic water features.

The original design allowed for two pipes which could discharge 4m^3/s each which model testing showed was acceptable. The single 8m^3/s pipe siphon can now only be tested with flow half of its capacity. Was the reason to change to a single pipe system purely one of cost?

A point for all to note when considering the design of scour systems is to take into account the size and number of pipes so each one can be tested to full capacity.

Response: Neil Kempton (MMB)
On the first point of a single pipe versus double, at the downstream end of a single pipe there is a submerged discharge valve. This is used to control the flow that can come out of the siphon - the video I showed was of the siphon flowing at 3.5 m^3/s, which is the flow that we commissioned the siphon pipe to (approximately half the maximum flow). As you know we had 20 to 30 people at various places downstream. As you mentioned we had completed modelling to estimate the flows and flood levels allowable in the downstream watercourse to avoid damage / flooding. During the commissioning process we finalised the operation system to be followed during the routine six-monthly testing, and there is an operation system in place for Yorkshire Water to operate it to the 3.5 m^3/s flow, and not to exceed that. Additionally an isolating valve was installed on the siphon so Yorkshire Water can isolate the siphon and operate the valves over their full range without releasing the full flow downstream.

The economics of the single pipe was of course a consideration with the selection. This choice does not increase the flows that are released downstream during routine testing, due to the inclusion of the submerged discharge valve. Yorkshire Water can operate the single pipe at half flow, which is the same flow as would have been released when testing the two single pipes, which you would operate at full flow, each one in turn, obviously not together; so you have the same control with the single pipe due to the inclusion of the discharge valve, it is actuated and you can tweak it to the exact flow required, so really it is more controlled than the 2 pipe option.

The only time it would be tested to its full operating capacity would be during a real incident. It could cause localised flooding downstream, but that would be better than a dam failure.

Question: Ranjit Seehra (Severn Trent Water)
What were the considerations when you determined the location of the outfall point for the siphons?

Response: Neil Kempton (MMB)
For any of the schemes it is determined by the maximum lift, like any gravity pipe or siphon pipe, the hydraulic profile from the reservoir level to the outlet point. If you lower the outlet point, the maximum lift may well be exceeded and that is dependent on the flow, diameter, fittings etc. There are many intricate parameters, including levels and flows, and the design process involves many spreadsheets and trialling different arrangements until you do not exceed the maximum sub-atmospheric pressure at the crest point.

Slaithwaite Reservoir Improvement Works (Coombs & Povey, p333 of the Proceedings)

Question: Stuart King (SSE)
Martin and David: The upstream culvert was blocked (silted up), so was it not blocking the outlet?

Response: Matt Coombs (Arcadis)
Where you had the original masonry tunnel, at some point, I don't know when, maybe there was a bit of an issue with silt at some point and somebody had put a bespoke timber shutter above it about 1.5m high and over time it had just simply silted up.

Question: Stuart King (SSE)
Are there modifications there?

Response: Matt Coombs (Arcadis)
It was not in the presentation, but what we have subsequently done it to is to put some shutters in and build up with concrete walls at either side, then put some inclined grills in to protect it from debris in the future. It is done in such a way that if it is 50% blinded or more it will still pass all the flow or more and the cofferdam has been left in place as well.

Can I make a point about not lining the pipes which I think has been over-looked, we ended up just lining the section through the core because the rest of the pipe was in excellent condition and it can always be lined later.