Reservoir Inspection Report

Lisvane Reservoir

Prepared for

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By

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Disclaimer

This document has been prepared in good faith based on data collected by Abyss Solutions Pty. Ltd. during the inspection of Lisvane Reservoir on January 21-22, 2019. The information contained herein, is to the best knowledge of Abyss Solutions Pty. Ltd. complete and accurate.

Confidentiality

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1 Document Details

1.1 Document History

Date	Version	Description
08.02.2019	1.1	First Draft

Executive Summary

Traditional asset inspections through the use of divers and dewatering are highly disruptive, unsafe, costly and often deliver sub-optimal quality information. This creates a major disincentive for establishing accurate and complete asset records of older infrastructure, where information for effective asset management decision making is often lacking.

Abyss Solutions was hence engaged by Welsh Water to demonstrate an alternative approach to inspecting and documenting the condition of underwater assets that avoids these limitations. Abyss Solutions' underwater remotely operated vehicle (ROV) equipped with high-fidelity visual and acoustic imaging systems was used to conduct a baseline survey of Lisvane Reservoir.

The survey involved (1) deploying the ROV from the southern bank of the reservoir, (2) locating and inspecting the scour outlet, (3) locating and inspecting the embankment inlet, (4) identifying and inspecting any other features of interest including the embankment inlet and (5) processing the data offsite to produce a visual record of the inspection, the internal configuration of the reservoir and a condition assessment.

The key findings of the inspection are summarised in the table below.

Table 1 - Outcomes of the high fidelity ROV inspection of Lisvane Reservoir

Reservoir Element	Apriori Information	Inspection Findings
Scour Outlet	- Location unknown - Whether above/below silt line unknown - Appearance/configuration unknown	- Outlet located at north-east of reservoir - Box shaped screen found over outlet - Silt level found to be below screen - Screen largely intact - Fractured bar and debris lodged on southern face of screen
Embankment Inlet	- Location unknown - Appearance/configuration unknown	- Inlet located at southern bank of reservoir - Consists of a 2.5m(W) x 5.2m(H) concrete headwall - Headwall braced with I-beams embedded in concrete - Concrete, I-beam and their interfaces found intact
Embankment Inlet Channel	- Existence of channel unknown	- Channel extending from embankment inlet identified - Channel extends 40m from inlet

1 Introduction

Welsh Water has indicated to Abyss Solutions that it lacks accurate and readily accessible documentation and condition information for a number of its older underwater assets. This information is critical for responsive, reliable and cost-effective asset management decision making. However, the limitations of traditional inspections, such as dewatering or divers, create a major disincentive for collecting this information. Dewatering is highly disruptive and costly while diver inspections can be dangerous, resource intensive and often deliver sub-optimal quality data.

Abyss Solutions was engaged by Welsh Water to demonstrate an alternative approach to collecting this information that avoids the limitations of traditional inspections. Abyss Solutions' underwater remotely operated vehicle (ROV) equipped with high-fidelity visual and acoustic imaging systems was used to conduct a baseline survey of Lisvane Reservoir. The information collected was used to establish the configuration of the asset as well as the condition of its key features.

2 Asset Information

The general details of the reservoir are summarised below.

Table 2 - General details of Lisvane Reservoir

Basic

Reservoir name - Lisvane Reservoir
Location - ST 18920 82113
Location grid reference - 51°31'43.5"N 3°10'23.3"W
Year built - 1886

Capacity

Volumetric capacity - 363,636 m³
Contents - Raw water
Dimensions - Max. length 407m, max. width 238m, wall height 10m
Water level - 8m

Construction

Type - Earth fill embankment dam with clay core
Key features -
- *Scour outlet:* Covered by screen - 1.2m (L) x 1.2m (W) x 0.6m (H) at floor
- *Active Inlet:* Not surveyed
- *Embankment Inlet:* Concrete headwall 2.5m (W) x 5.2m(H) with ~40m channel

Access

Access road - Unnamed pedestrian path off Rhyd-Y-Penau Rd
Gates and fence - Timber fencing with locked gates
Parking - Parking at end of pedestrian access path

3 Inspection Details

The inspection was conducted using Abyss Solutions' underwater remotely operated vehicle (ROV) equipped with high-fidelity imaging and sonar systems. The ROV was deployed near the centre of the southern embankment of the reservoir. The ROV was navigated in a systematic pattern to locate the key features such as the scour outlet, embankment inlet and inlet channel using the onboard sonar. Once a feature had been located a close visual inspection was undertaken with high-fidelity imagery collected.

Following data collection, the imagery was subject to Abyss Solutions' algorithmic enhancement pipeline. The enhancements improved both colour and detail representation whilst avoiding distortion of features within the imagery.

4 Inspection Findings

The general outcomes of the inspection are presented in Section 4.1 with examples of the high-fidelity imagery collected shown in Section 4.2. The overall condition of the surveyed portion of the reservoir is reported in Section 4.3. A detailed condition assessment of the key features of the reservoir is presented in Section 4.4.

4.1 Inspection Outcomes

The key outcomes of the inspections are summarised in Table 3.

Table 3 - Outcomes of the high fidelity ROV inspection of Lisvane Reservoir

Reservoir Element	Apriori Information	Inspection Findings
Scour Outlet	- Location unknown - Whether above/below silt line unknown - Appearance/configuration unknown	- Outlet located at north-east of reservoir - Box shaped screen found over outlet - Silt level found to be below screen - Screen largely intact - Fractured bar and debris lodged on southern face of screen
Embankment Inlet	- Location unknown - Appearance/configuration unknown	- Inlet located at southern bank of reservoir - Consists of a 2.5m(W) x 5.2m(H) concrete headwall - Headwall braced with I-beams embedded in concrete - Concrete, I-beam and their interfaces found intact
Embankment Inlet Channel	- Existence of channel unknown	- Channel extending from embankment inlet identified - Channel extends 40m from inlet

4.2 High-fidelity imagery

A comparison of the imagery obtained using Abyss Solutions' imaging system and subject to post-processing with the ROV navigation camera imagery is presented in Figure 1. The latter represents the quality that can be achieved using standard underwater cameras and which is obtained by divers and standard ROVs. The high-fidelity imagery presents superior detail and colour information than that captured by the navigation camera, to enable improved condition assessment.

(a) **(b)**

Figure 1 Comparison of the imagery obtained using Abyss Solutions' imaging system and subject to post-processing (a) with the ROV navigation camera imagery (b) of the Lisvane Reservoir scour outlet screen.

4.3 Reservoir Condition

The condition of the inspected portion of the reservoir and its key elements was established using the criteria in Table 4. Overall the reservoir was found to be in an **adequate** condition. Moderate deficiencies, including a fractured bar and lodged debris on the scour outlet screen were noted. However, the reservoir appeared to be functioning as designed.

Table 4 - Condition grading criteria used in this report

1. Excellent	- No defficiancies noted
2. Good	- Minor deficiencies noted. Element functioning as designed.
3. Adequate	- Moderate deficiencies noted. Element functioning as designed.
4. Poor	- Major deficiencies noted. Element requires repair to continue functioning as designed.
5. Awful	- Repair or preplacement required immediately. Item no longer functions as designed.

4.4 Condition of Reservoir Elements

Three elements of the reservoir were inspected as part of the survey by Abyss Solutions. These included (a) the scour outlet, (b) embankment inlet and (c) embankment inlet channel. The condition of each of the elements was established in accordance with the criteria in Table 4.

(a) Scour Outlet

What is believed to be the original scour outlet of the dam was located at the north-east of the reservoir. A rectangular screen with 4 open sides and horizontal penetrations was found over the outlet. The screen was largely intact with the silt level below the bottom of the screen. A fractured bar was observed at the southern face of the screen. Debris was lodged against the southern and top faces. All other faces of the screen appear to be intact and free of obstructions.

The scour outlet was judged to be in adequate condition based on the moderate deficiencies (fractured bar & debris) identified. Nevertheless, the outlet appeared to be functioning as designed. Imagery of the outlet screen is presented in Figures 2-06. Inspection video footage of the outlet and a visual 3D model are presented in Figure 7 and Figure 8, respectively.

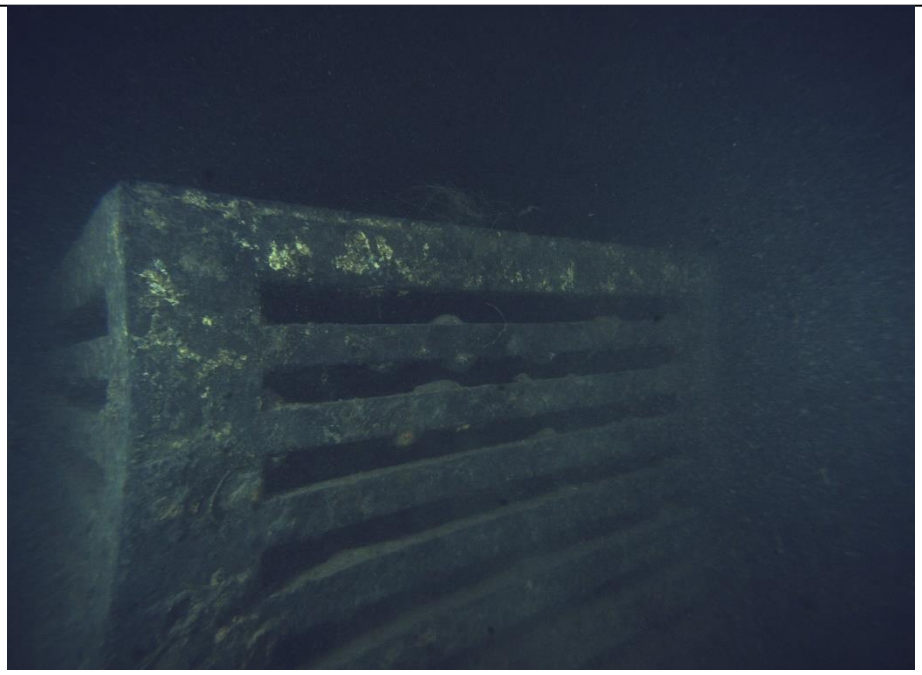


Figure 2 - North face of scour outlet screen appears to be intact, above the silt level and free of obstructions.

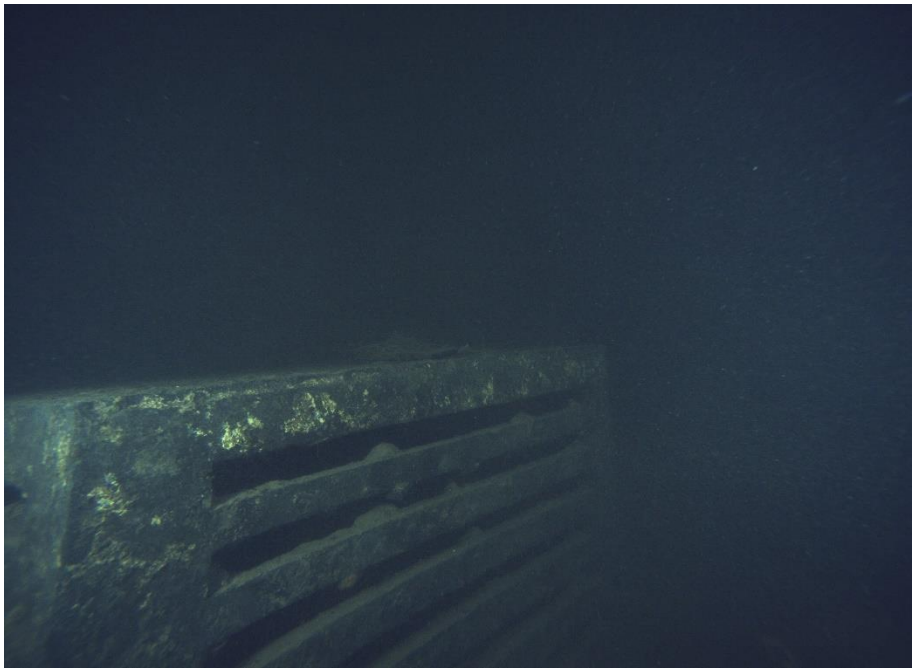


Figure 3 - East face of scour outlet screen appears to be intact, above the silt level and free of obstructions.

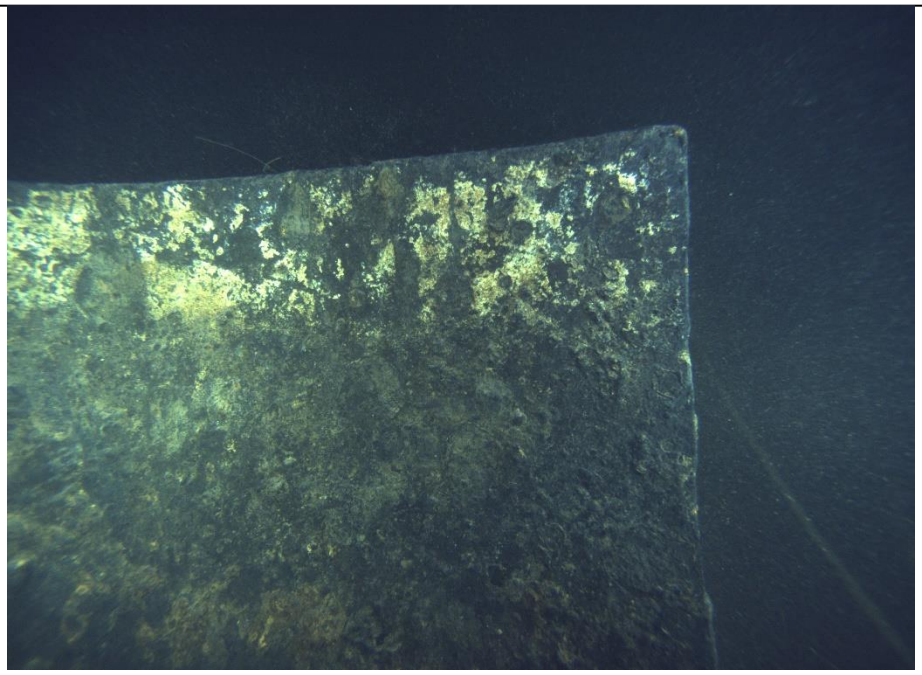


Figure 4 - West face of scour outlet screen is completely solid and appears to be intact.

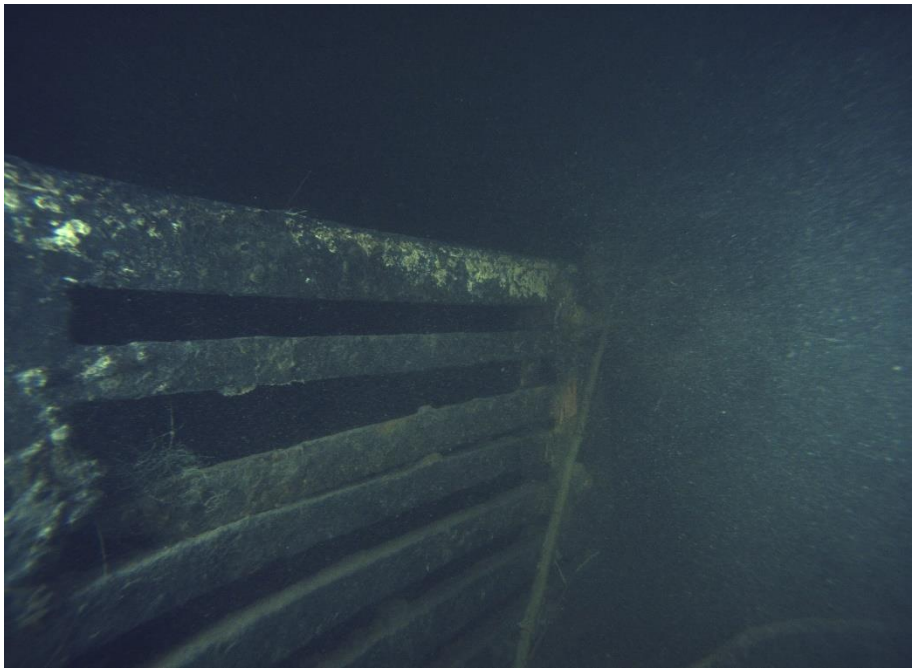


Figure 5 - South face of scour outlet screen presents a fractured bar and debris lodge against it. The silt level appears to be below the screen.

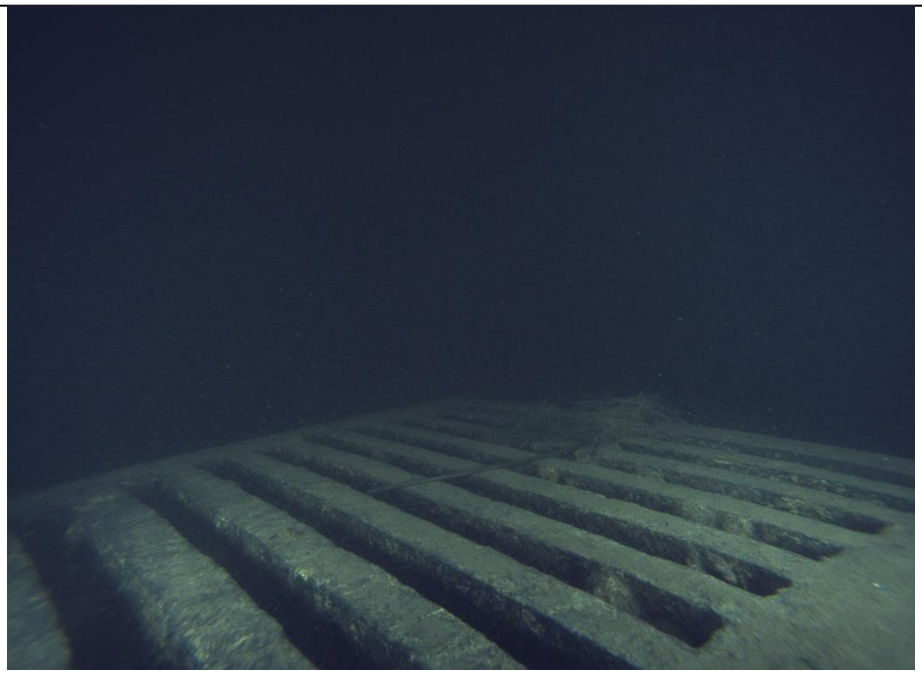


Figure 6 - Top face of scour outlet screen presents minor debris lodge against it. The silt level appears to be below the screen.

Figure 7 - Inspection video of scour outlet screen (click here or on the image above to launch).

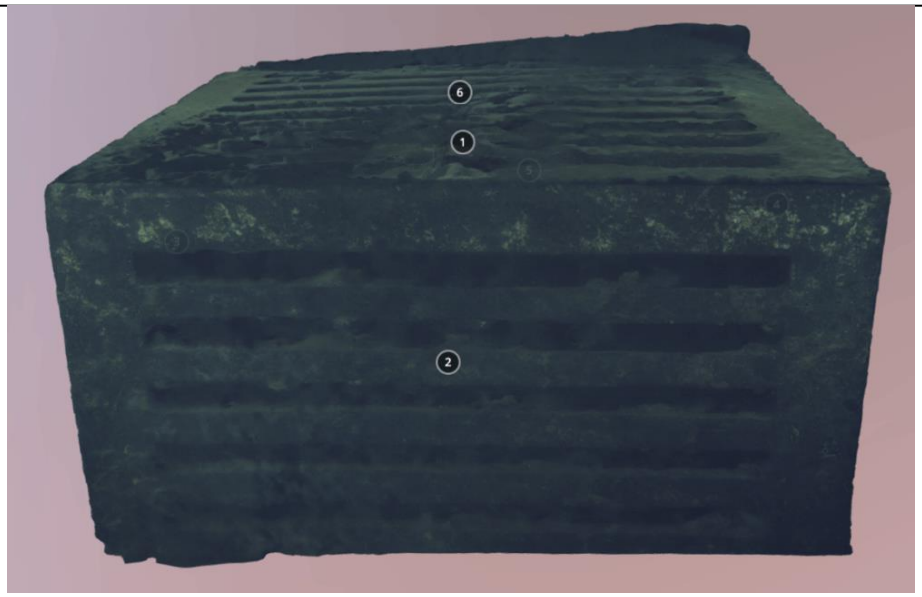


Figure 8 - Visual 3D model of scour outlet screen (click here or on the image above to launch).

(b) Embankment Inlet

The embankment inlet was located along the southern embankment of the reservoir. The inlet consisted of a semi-circular concrete headwall with an embedded I-beam brace. The headwall was found to be 5.2m high and 2.9m wide.

The concrete headwall was found to be intact with no signs of spalling or major concrete damage. The I-beam bracing was intact. Examination of the I-beam to headwall interface reveals that the I-beam was embedded within the concrete wall. The interface appears free of major spalling. The I-beam and headwall were covered in thick fouling.

The inlet was judged to be in good condition based on the minor deterioration of the asset. The inlet appeared to be functioning as designed. Imagery of the inlet is presented in Figures 09-12. Inspection video footage of the inlet is presented in Figure 13. Visual 3D models of the concrete headwall and the interface between the I-beam brace and headwall are presented in Figure 14 and Figure 15, respectively.

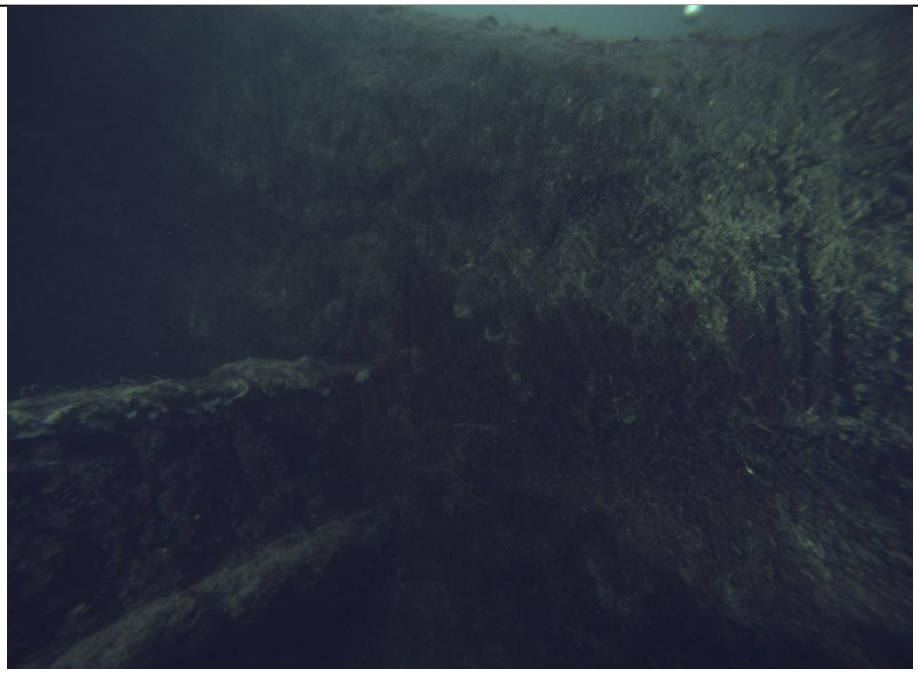


Figure 9 - Close up of interface between I-beam and concrete headwall of inlet. The I-beam appears to be embedded within the concrete. The interface is free of major spalling.

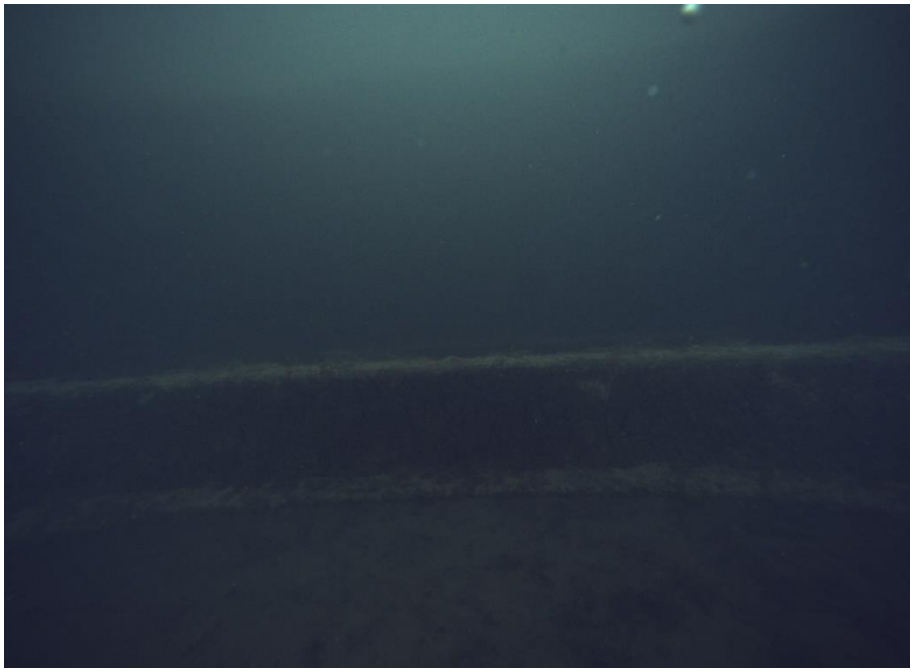


Figure 10 - I-beam brace across the inlet headwall. The I-beam appears to be intact and covered in thick fouling.

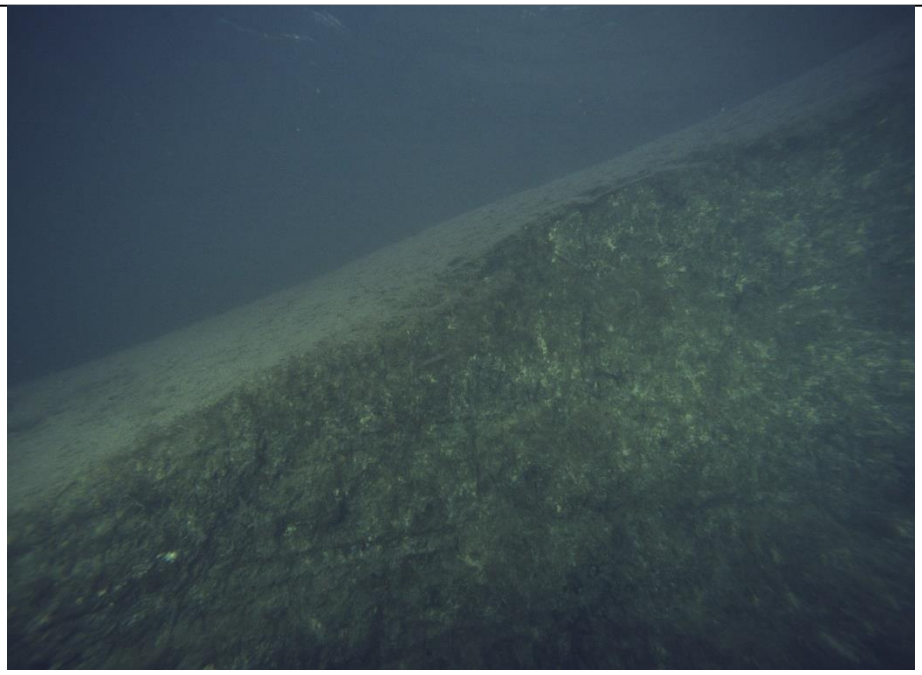


Figure 11 - Eastern end of inlet concrete headwall. The headwall appears intact with no signs of major spalling or concrete damage. The concrete is covered in thick fouling.

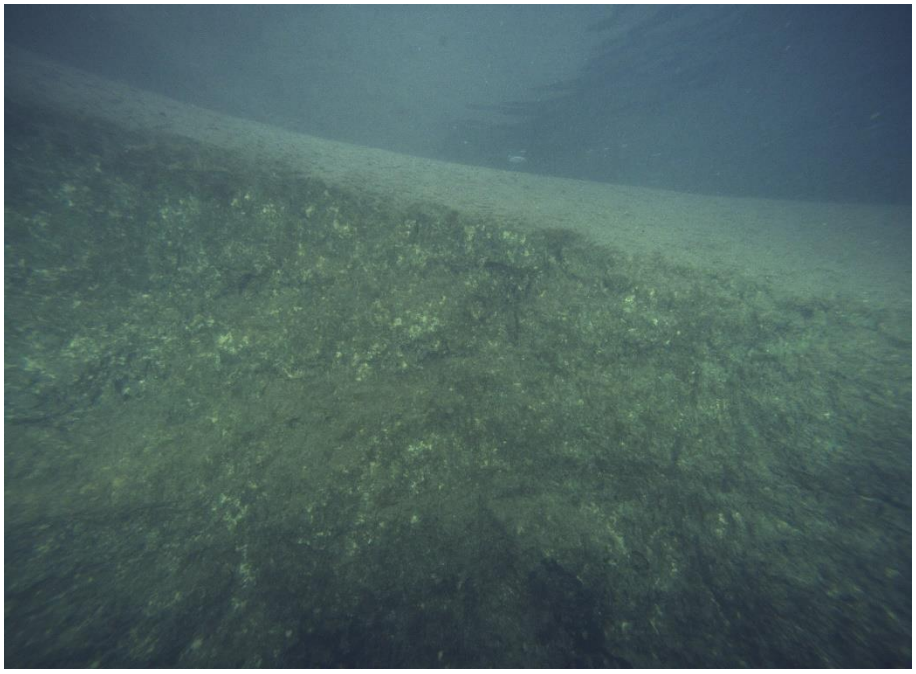


Figure 12 - Western end of inlet concrete headwall. The headwall appears intact with no signs of major spalling or concrete damage. The concrete is covered in thick fouling.

Figure 13 - Inspection video of embankment inlet (click here or on the image above to launch).

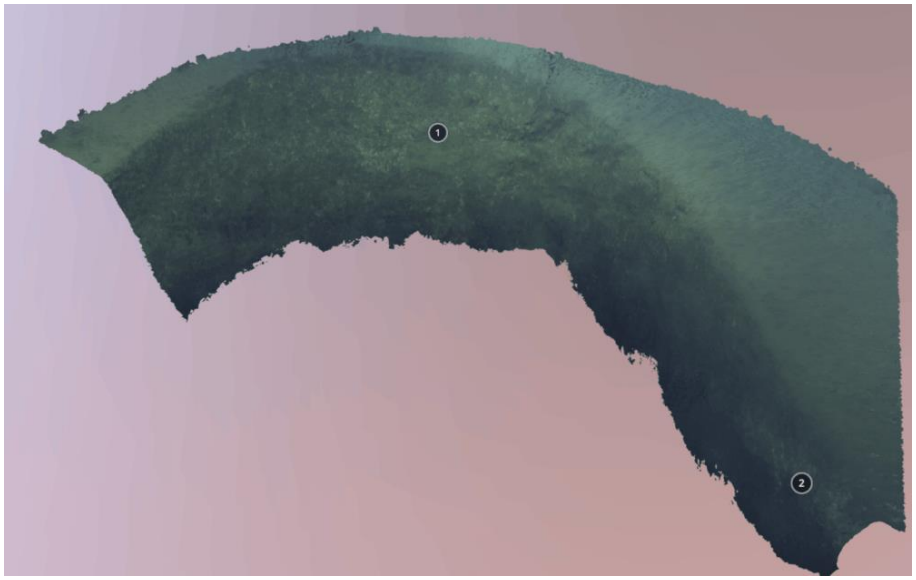


Figure 14 - Visual 3D model of embankment inlet headwall (click here or on the image above to launch).

Figure 15 - Visual 3D model of embankment inlet headwall (click here or on the image above to launch).

(c) Embankment Inlet Channel

What is believed to be a channel extending from the embankment inlet was identified at floor level using a sonar scan. The channel extended approximately 50m from the inlet. The channel gradually disappears into the reservoir floor at its end.

The channel appeared well defined in the sonar imagery indicating that it is largely intact and not completely silted. The channel was judged to be in good condition. A sonar image and video of the channel are presented in Figure 14 and Figure 15, respectively.

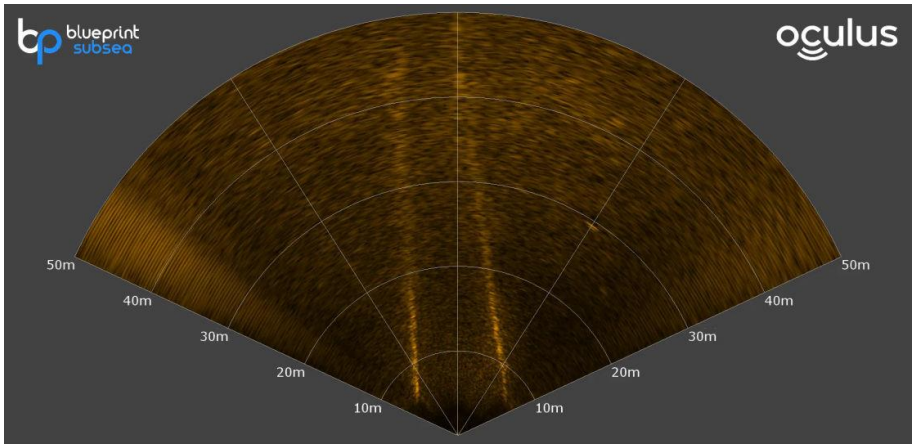


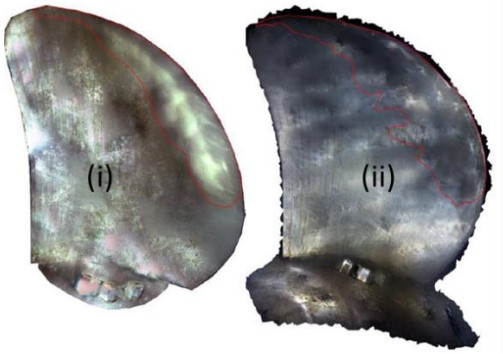
Figure 16 - Sonar image of embankment inlet channel.

Figure 17 - Sonar inspection video of the embankment inlet channel (click here or on the image above to launch).

4.5 Temporal Comparison of Asset Condition

The data collected as part of this survey can be used to track changes in the condition of key elements of the reservoir during successive inspections. However, given this inspection is the first of its kind and no comparable legacy data is available, this cannot be demonstrated as part of this trial.

Nevertheless, an example of fault evolution tracking for another application, the shipping industry, is shown Figure 18. The deterioration of asset condition can be quantified between successive inspections to better schedule maintenance for cost and disruption reduction.



Blade	Fault	Increase in affected surface area
1/SIM003-2	Pitted surface	8.7%

Figure 18 - Pitting corrosion highlighted on 3D models of a propeller blade between successive inspections. The change in affected surface area is estimated between the (i) first and (ii) second inspections.

5 Asset Configuration

The following 3D and 2D plans show the internal configuration of the reservoir. The plans were produced using data from the inspection. Approximate dimensions have been included based on onsite measurements. Click on the 3D plan in Figure 19 for an expanded and interactive view.

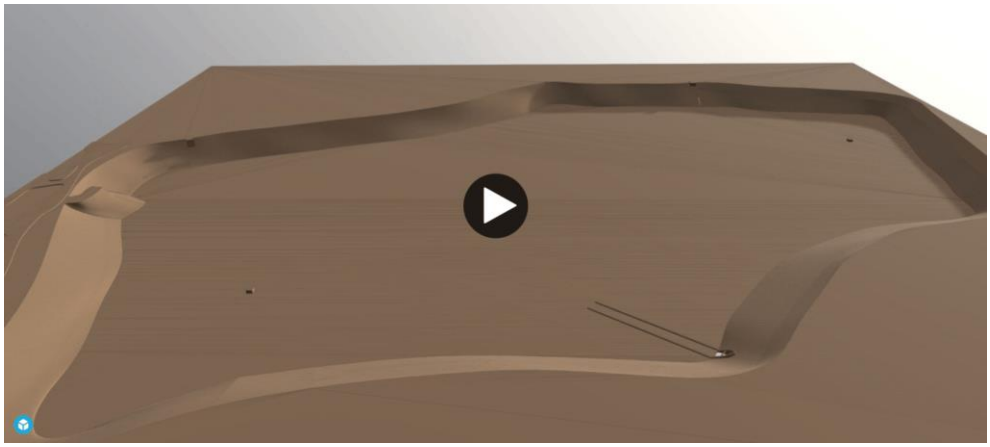


Figure 19 3D plan of reservoir configuration. **Click here or on the image above for an expanded and interactive view.**

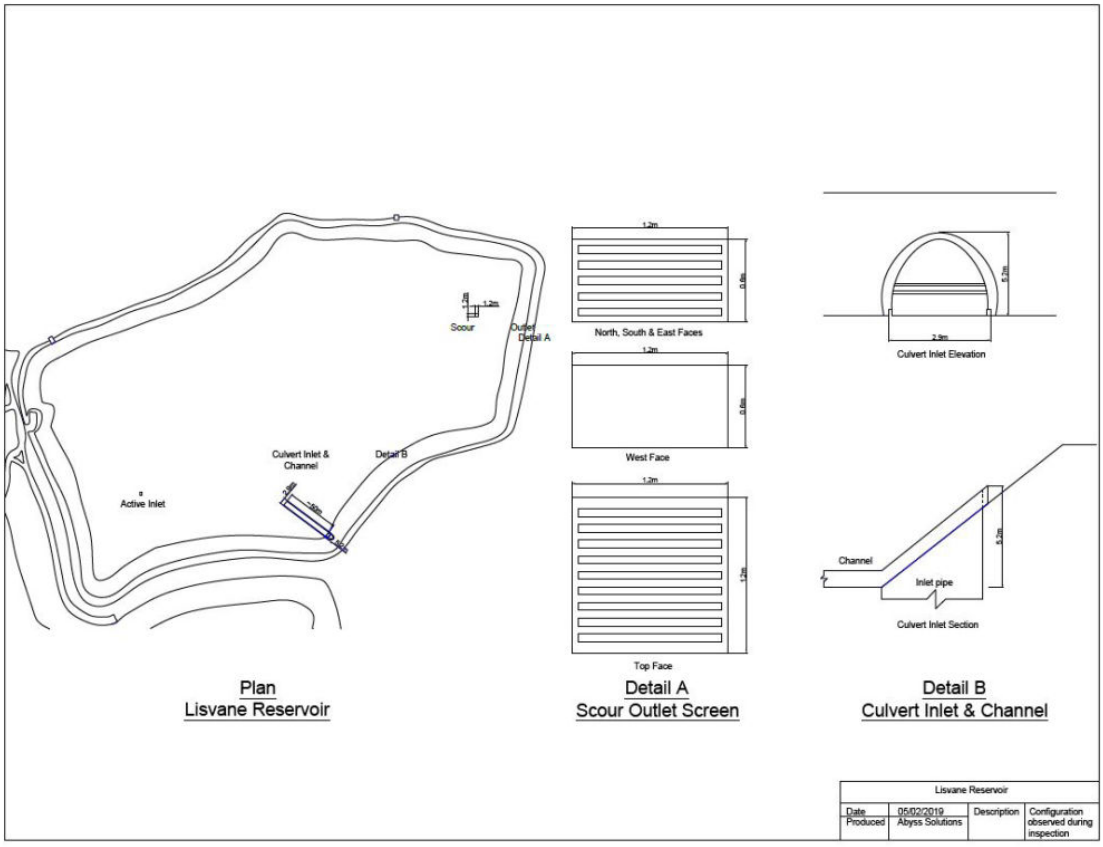


Figure 20 2D plan of reservoir configuration.

6 Conclusion

Abyss Solutions demonstrated an alternative approach to inspecting and documenting the condition of underwater assets that avoids the disruption, safety risks and quality issues of traditional diver and dewatering inspections. Abyss Solutions' underwater remotely operated vehicle (ROV) equipped with high-fidelity visual and acoustic imaging systems was used to conduct a baseline survey of Lisvane Reservoir. Abyss Solutions produced a visual record of the inspection, the internal configuration of the reservoir and a condition assessment of key features. The inspection and analysis work revealed:

- The location of the original scour outlet of the dam for which the location was previously unknown.
- The silt level was below the scour outlet that the outlet remains functional.
- The condition and configuration of the scour outlet.
- The location of the embankment inlet, its configuration and condition.
- The presence of a previously unknown channel attached to the embankment inlet and its condition.

Based on the outcomes of this trial, Abyss Solutions recommends implementing the approach to underwater inspections presented herein as part of Welsh Water's routine inspection program. The ability to collect high quality underwater asset and condition information as well as document the state and configuration of assets with minimal operational disruption, safety risks and resources will lead to better and more frequent condition assessment, cost-effective maintenance and enable temporal tracking of fault evolution and asset condition.