Underfall Yard MEICA Inspection Report

24 May 2019

Bristol City Council

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1 Introduction

1.1 Terms

- MEICA Mechanical, Electrical, Instrumentation, Control and Automation
- HPU Hydraulic Power Unit

1.2 Description of structure

The Underfall Yard assets are used to manage the water level in the Floating Harbour. Figure 1 shows the arrangement of the assets. The location of the two Underfall Yard sluice rooms and the Harbour Master office are shown in Figure 2. There are four culverts which connect Underfall Yard to the Floating Harbour and to the New Cut. The third culvert is at a lower level than the others. Historically, culverts one, two, and four have been used for maintaining the harbour level and culvert three, the "deep sluice", has been used for discharging dredged silt.

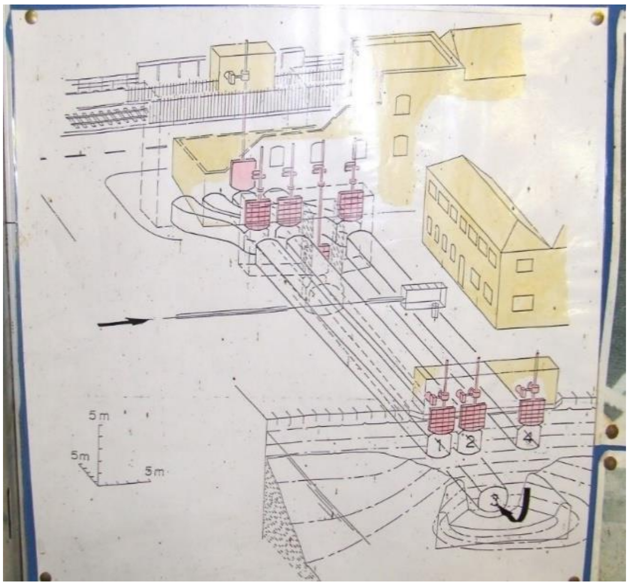
The four main sluice gates are located at the New Cut side of the culverts below the Underfall Yard building. It is understood that the gates were replaced in 1995 with spheroidal graphite iron like-for-like gates. The seal of the main sluice gates is formed when the gate is pressed against the wall by the water pressure on the harbour side. Here the gate is said to be in a "seated" position. When the water pressure on the New Cut side of the river is greater, the gates are pushed away from the wall and they are said to be in an "unseated position". This occurs when the harbour is tide locked.

At the harbour side there are four emergency gates; gates 1, 2 and 4 are sluice gates and gate 3 is a blanking plate.

The four main sluice gates are operated by Rotork electric actuators. The main sluice gate actuators 1 and 2 were manufactured in 2009. The main sluice gate actuators 3 and 4 were manufactured in 1971. On the harbour side emergency sluice gates 1 and 2 are operated by a vertical action oil hydraulic cylinder. The HPU operates with one Duty pump which uses an 11kW motor. The emergency plate (sluice gate 3) however is operated using a chain block system, and emergency sluice gate 4 is operated by a hydraulic power unit and cylinder which is currently disconnected.

There is also an external sluice gate, located at the River Side, which was inaccessible and not covered within the scope of this survey.

Figure 1: Arrangement of the Assets at Underfall Yard



Source: Mott MacDonald survey, April 2019

Figure 2: Underfall Yard Location

Source: Bing Maps

2 Description of Site Investigation

The Inspections of Underfall Yard were undertaken on Wednesday 10th April 2019, and Wednesday 17th April 2019. The results of the survey may be found in the document: *WS1718-MEICA-SURV ISSUE B01 Underfall Yard Survey Results*.

The following assets were examined:

- 4 main Sluice Gates including 4 Rotork electrical actuators
- main sluice gate control panel
- 4 emergency sluice gates and HPU
- SCADA station

The methodology of the inspection and its associated risks may be found in the method statement *WS1718-MEICA-RAMS-ISSUE B01 Underfall Yard MEICA Inspection Method Statement*.

The inspections were visual and tactile examinations. Their objective was to gather data on the following (during or after analysis of the information gathered on the site visit):

- Whether there has been any significant deterioration of the structural strength of the gates and the operability of the MEICA equipment.
- The significance of any identified defects (i.e. are they critical for the assets operations?)
- The overall condition of the asset.
- Future maintenance activities which may be necessary for the structures.
- The global structural integrity relative to actual loads on the structure, considering observed damage or deterioration.
- An estimate of the remaining useful life of the structures.
- Order-of-magnitude estimates of probable costs for rehabilitation works.

The structural integrity of the gates could not be reliably evaluated, because thickness readings could not be taken. The reason for this was the ultrasonic thickness measurement tool could not take reliable measurements of the gates as they were made of cast iron.

3 Underfall Yard

3.1 Main Sluice Gates

Figure 3 shows the main sluice room in the Underfall Yard building. Varying levels of corrosion and marine growth were found on the main sluice gates during the inspection.

Figure 3: Underfall Yard Main Sluice Room

Source: MML Site visit 17th April 2019

3.1.1 Sluice Gate 1

Some minor corrosion was found at the top of the actuator rising stem of sluice gate one. This is shown in Figure 4. Some marine growth and zebra mussels were found at the base of the stem. This is shown in Figure 5. A significant amount of zebra mussels was found on the gates which increased towards the centre of the gate as shown in Figure 6.

Varying amounts of surface degradation was found on all gates. All bolts, rivets, and nuts appeared to be in good condition.

Figure 4: Corrosion on actuator rising stem - main sluice gate 1

Source: MML Site visit 17th April 2019

Figure 5: Zebra mussels and corrosion on actuator rising stem base - main sluice gate 1

Source: MML Site visit 17th April 2019

Figure 6: Corrosion and zebra mussels - main sluice gate 1

Source: MML Site visit 17th April 2019

3.1.2 Sluice Gate 2

Significant amounts of zebra mussels and marine growth were found on the main sluice gate no.2, which increased towards the centre of the gate as shown in Figure 7. Patches of surface corrosion were found at the bottom of all gate's flanges (Figure 8). All rivets, nuts and bolts were intact.

The guides appeared to have corroded to an undetermined depth; this is shown in Figure 9. The parts of the bronze seal on the side of the gate, which could be seen, were in good condition. A redundant corroded pole, which ran to the top of the chamber, is shown in Figure 10.

The actuator rising stem for the main sluice no.2 appears to be deflected. The operators informed the surveyors that the gate is over-driven in its closed position, which has resulted in the deflection of the stem Some corrosion was also found on the actuator rising stem of sluice gate no.2. (Figure 11).

Figure 7: Corrosion and zebra mussels – main sluice gate 2

Source: MML Site visit 17th April 2019

Figure 8: Moderate corrosion on the bottom flange - main sluice gate 2

Source: MML Site visit 17th April 2019

Figure 9: Corroded gate and guide – main sluice gate 2

Source: MML Site visit 17th April 2019

Figure 10: Corroded pole – main sluice gate 2

Source: MML Site visit 17th April 2019

Figure 11 Corrosion at base of rising stem – main sluice gate 2

Source: MML Site visit 17th April 2019

3.1.3 Sluice Gate 3

No structural defects were found on the actuator shaft for main sluice gate no.3, however some surface corrosion was present on the shaft. The redundant poles behind the sluice gate were severely corroded and covered in hard silt. They may be seen in Figure 12. There were significant amounts of hard and soft silt lodged in the corners of the sluice gate compartments which increased towards the bottom of the gate. This may be seen in Figure 13. The gate was also covered in a large amount of marine growth and was significantly corroded in some areas. The condition of the gate may be seen in Figure 14.

A significant amount of corrosion was also found on the sluice gate guides as shown in Figure 15. The issues found on main sluice gate three may be due to the gate being operated infrequently. This is because emergency plate 3 is neither sealed nor operational, meaning that the culverts and chamber will eventually fill to the level of the Floating Harbour.

Figure 12: Corrosion on redundant poles– main sluice gate 3

Source: MML Site visit 17th April 2019

Figure 13: Siltation on gate – main sluice gate 3

Source: MML Site visit 17th April 2019

Figure 14: Condition of gate – main sluice gate 3

Source: MML Site visit 17th April 2019

Figure 15: Corrosion on guides– main sluice gate 3

Source: MML Site visit 17th April 2019

3.1.4 Sluice Gate 4

The redundant poles behind main sluice gate 4 were heavily corroded. The base of the actuator shaft was also corroded. They may be seen in Figure 16 and Figure 17 respectively. Hard silt deposits were found in the corner compartments of sluice gate 4. Otherwise the gate appeared to be in good condition.

Figure 16: Severely corroded pole – main sluice gate four

Source: MML Site visit 17th April 2019

Figure 17: Actuator shaft base - main sluice gate f4

Source: MML Site visit 17th April 2019

3.2 Emergency Sluice Gates

3.2.1 Sluice Gate 1

The sections of the structure surrounding emergency sluice gate 1 appeared to be in good condition. Below the water the diver found all the fixings were intact. Large amounts of marine growth, zebra mussels, and corrosion were found on the far left, far right and centre row compartments. A gap was found in the bronze seal, behind the gate, on either side of the HPU shaft; the total size was 750 mm. There was some moderate corrosion found in the top left compartment and on the flanges of the gate. A large amount of marine growth was also found on the bottom left compartment. As mentioned earlier a thickness reading could not be taken due to the material of the gate.

3.2.2 Sluice Gate 2

The side seal of emergency sluice gate 2 was covered in marine growth, so it could not be examined. Heavy marine growth was also found on the centre of the gate. The bronze seal was also discontinued and peeling off at the back of the gate.

3.2.3 Sluice Gate 3

Emergency blanking plate 3 was found to be hanging on an open hook with nothing preventing it from falling forwards. A gap of approximately 20mm was measured behind it and on the sides of the plate. A heavy amount of marine growth was found on the top right of the plate. The diver also reported that a concrete funnel like structure was found in front of the plate. A large possibly wooden beam, approximately 3m high and 500mm thick, was found obstructing the gate on the right-hand side. Finally, the plate handle was broken.

3.2.4 Sluice Gate 4

Emergency sluice gate 4 was covered in a large amount of marine growth. The seal was in good condition. Some debris was found on top of the sluice gate. Again, the issues with this gate may be due to its infrequency of operation; because it is not connected to the HPU.

4 Mechanical Inspection

4.1 Equipment Surveyed

A static inspection was undertaken on the following:

- emergency sluice HPU
- HPU shafts.
- emergency plate 3 chain block
- 4 Rotork electrical Actuators

4.2 Condition

4.2.1 Static

The main sluice gate Rotork actuators appeared to be in good condition, no defects were found apart from the bending of the rising stem of main sluice gate 2, which was mentioned in section 3.1. Actuator 4 also appeared to have seen little use in some time. It is worth noting that limited support and spares are available from the manufacturer for the "A-series" actuators (3 and 4) due to their age and obsolescence.

Figure 18: Actuator one – main sluice gate one

Source: MML Site visit 17th April 2019

Figure 19: Actuator two – main sluice gate two

Source: MML Site visit 17th April 2019

Figure 20: Actuator three – main sluice gate three

Source: MML Site visit 17th April 2019

Figure 21: Actuator four – main sluice gate four

Source: MML Site visit 17th April 2019

The HPU for the emergency sluices appeared to be in good condition. No functional defects were found although it was not connected to sluice gate 4 which was mentioned earlier. Various items were found around the area which should be cleared. Some debris was also found in the bund of the HPU which should be cleaned.

The support bar holding emergency blanking plate 3 appears to be permanently deformed under the sustained load. The Safe Working Load SWL was shown at the back and appears to be 5 tonnes for the chain block and 3 tonnes for the support bar this may be seen in Figure 22 and Figure 23. The bar showed signs of bending and failure may occur unexpectedly. No evidence was found that the lifting equipment had undergone a thorough examination under, the Lifting Operations and Lifting Equipment Regulations 1998, (LOLER) in a long time. The chain block itself appears to be in good condition. However, there is an open hook attached to the gate which is not secure, and there are no guide grooves on the wall of blanking plate 3, so there is nothing preventing the gate from detaching.

Figure 22: Chain block – emergency plate three

Source: MML Site visit 10th April 2019

Figure 23: Back of Chain block – emergency plate three

Source: MML Site visit 10th April 2019

4.2.2 Operational

Main sluices 1,2 and 3 were observed during operation. Main sluices 1 and 3 were operated without any issues. An observation regarding the deflection of main sluice 2 was earlier discussed, believed to be attributed to the over-driving of the gate.

Main sluice gate 3 was operated for a short time due to a large amount of leakage at the corresponding emergency blanking plate. Main sluice gate actuator 4 was not operated. This was because the risk of being unable to close the gate was identified due to the large build-up of silt which could have dislodged and prevented the gate from resealing. It is recommended that the culvert is scoured when emergency sluice gate four is connected to an HPU.

Main sluice gate 4 was not operated at the time of the inspection. As the emergency sluice 4 is not operational, there is an operator concern that lifting the main sluice would dislodge the silt in the culvert and prevent the main sluice from sealing, thus compromising the resilience of the Floating Harbour.

5 Electrical Inspection

5.1 Equipment Surveyed

The inspection survey covered the main sluices room, the emergency sluices room and the Harbour Master office yard.

The following assets were examined:

- level display
- SCADA station
- cables and cable glands
- level measuring instruments
- level instrument panel
- telemetry outstation panel
- radio communications station
- telemetry marshalling panel
- electrical distribution panels
- actuator isolators
- earthing lugs
- cable tray
- emergency sluice HPU
- emergency blanking plate 3 chain block system
- main sluice controls
- main sluice gate control panel
- HPU control panels
- isolator switch

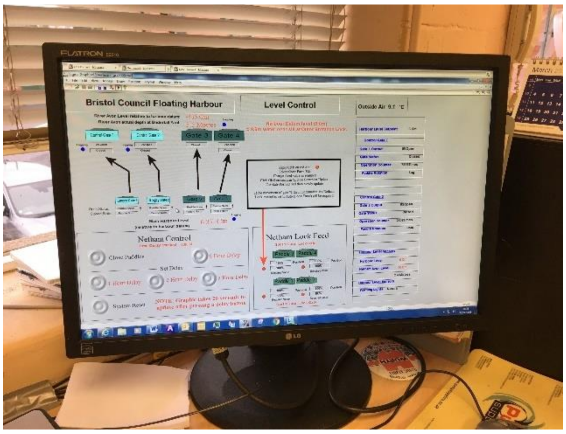
5.2 Limit Switch Condition

5.2.1 Static

Figure 24: Levels display panel

Source: MML Site visit 10th April 2019

Figure 25: Harbour Master office SCADA station



Source: MML Site visit 10th April 2019

The Harbour Master office has a panel with the level displays for the harbour float level and the River Avon level as shown in Figure 24. Following conversations with the operators on site it is understood that the habour level displayed is measured in *cm* above ordnance datum (±cm AOD) and the river level is also measured in *cm* above ordnance datum (±cm AOD). The third level display indicates the level set point that sets the harbour's level in *cm* above or below the river's level according to the principles of harbour level control operation.

It was also understood that the operator has the facility to select the harbour level set point from the computer based SCADA station in the office as shown in Figure 25 above. Note that the exact principle of harbour level control is not fully understanable due to the limitatons of the readily available review material.

Figure 26 below shows the harbour's level measuring instrument which is a pressure transducer guided through a PVC tube and located in the harbour master's yard next to the parking area. Figure 27 shows a panel where the instrument cable is wired to. It is believed to house the instrument controller. Access to the panel could not be obtained at the time of visit.

Figure 26: Harbour's level measuring instrument

Source: MML Site visit 10th April 2019

Figure 27: Harbour's level instrument panel

Source: MML Site visit 10th April 2019

Within the main sluices room there are four sluices driven by electrical Rotork actuators and the associated electrical panels for the control and monitoring of the sluices as well as Telemetry panels for the interface to the Harbour Master office and the Entrance lock operations station.

Actuators no.3 and no.4 are of the older version (manufactured in 1971) than actuators no.1 and no.2 (manufactured in 2009). It is recommended that the actuators no.3 and no.4 are replaced with newer actuator models to ensure serviceability and reliability of operation in future.

From the historical information the control principle of the main sluices is as follows:

- The normal harbour operating water level is 6.2m AOD +100mm. The harbour level set point is selected via a dial located on the main sluices control panel.
- If the harbour water level rises above the selected set-point level, then sluice no 1 opens in pre-programmed steps to allow water out of the harbour into the river.
- If the harbour water level keeps increasing, then the sluice gate opens further until the opened position limit switch is reached and stops. The system then waits and monitors the levels.
- When sluice no1 has reached its fully open position, then the sluice no2 opens in pre-programmed steps until it is fully open.
- When the harbour water level starts to drop then sluice no2 starts to close first.
- If the harbour water level drops below the pre-set level, both sluice gates close to stop water flowing out of the harbour into the river.
- Sluices no.1 and no.2 are set up as duty standby and the controller changes their rotation so that each sluice operates in similar working hours.

Figure 28 below shows the main sluice gate control panel which controls and monitors the operation of the main sluices. The panel also provides indication of the emergency sluices status and the power supply to them. There is a level display for the harbour level displayed measured in cm above the level of the river Avon. The dial is used to manually set the setpoint for the level of the harbour above or below the river level according to the principle of harbour level control.

The main sluices control panel has signs of physical wear. The dial switch which controls the level of the harbour has a padlocked cover which is easily accessible with just a pin as the cover does not close firmly. This could trigger unwanted harbour levels when the area is accessed by unauthorised personnel. Signs should have been posted on the entrance to warn for authorised personnel access only. The lock should also be removed, and a new cover should be placed over the dial switch. The panel has a level display socket which is not used and covered with a piece of tape, therefore this could possibly reduce the ingress protection level of the panel. Additionally, not all indication LEDs are functional.

As part of the Telemetry and communications scheme there is a Seprol S250 Telemetry outstation unit and a radio communications station as shown in Figure 29 and Figure 30 respectively. It is noted that the details regarding the Telemetry system and communications network could not be obtained due to limitations of readily available material on site.

Figure 28: Main sluices main control panel

Source: MML Site visit 10th April 2019

Figure 29: Telemetry outstation

Source: MML Site visit 10th April 2019

Figure 30: Radio communications station

Source: MML Site visit 10th April 2019

Figure 31: Telemetry marshalling panel

Source: MML Site visit 10th April 2019

In various locations there are cable installations within the electrical and instrumentation cubicles that was not done in a neat manner, following good installation practice. Lengths of cable were left untidy and not securely fixed. Examples can be seen in Figure 30, Figure 31, and Figure 34. This increases the possibility of the cables being damaged during any intrusive work therefore the installation should be revisited and rectified.

Moderate corrosion on some electrical panels was noted. In future the corrosion could affect the operation and integrity of the internal components and cabling. It is recommended that remedial works are carried out on these panels to prevent further corrosion or the other option is to replace these panels.

Figure 32: Corrosion on electrical distribution panels

Source: MML Site visit 10th April 2019

Figure 33: Corrosion on electrical distribution panels

Source: MML Site visit 10th April 2019

Figure 34: Corrosion on actuators isolators

Source: MML Site visit 10th April 2019

Figure 35: Corrosion on actuators isolators

Source: MML Site visit 10th April 2019

Figure 36: Actuator No.2 cable glands

Source: MML Site visit 10th April 2019

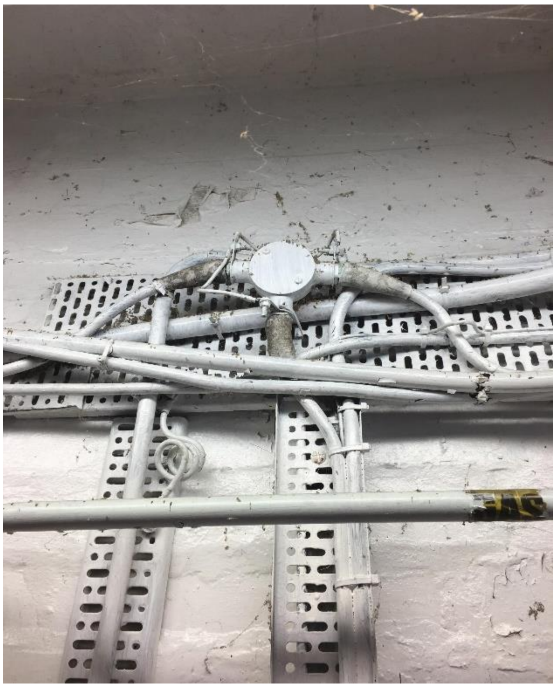
Figure 37: Actuator No.1 with cable glands

Source: MML Site visit 10th April 2019

Figure 34 and Figure 35 above show the actuator isolators, and Figure 36 and Figure 37 show the cable termination and glands on the sluice actuators number 2 and number 1 respectively. There are two glands which appear to be a modified installation not appropriately sized for the cable termination and covered with a piece of green and yellow insulation tape to provide insulation and cable fixing. It is recommended that these cable glands should be replaced with appropriately sized glands to ensure secure cable termination at the actuators.

There are cables and earthing lugs covered in paint as shown in Figure 38 following cable installation. This is not considered to be good practice as it will possibly cover any cable insulation defects and make them difficult to detect. Also, the painting of the cable terminals could reduce the cable conductance. In Figure 38 it can be seen that some parts of the cable conduits are deteriorated and should be restored locally to enhance the conduit protection.

Figure 38: Painted cables and earthing lugs



Source: MML Site visit 10th April 2019

The building housing the emergency sluices in Figure 39 is in Underfall Yard adjacent to the parking area. This building houses the control panel for the operation of the HPU and the sluices, the HPU and electrical distribution panels.

Figure 39: Emergency sluices building

Source: MML Site visit 10th April 2019

Figure 40: Emergency sluices control panel

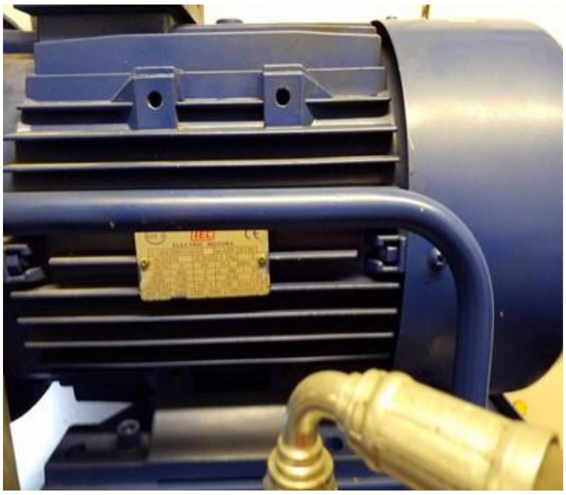
Source: MML Site visit 10th April 2019

The HPU unit and the motor shown in Figure 41 and Figure 42 are in good condition and the associated cables appear in good condition with regards to the cable terminations and insulation.

Figure 41: Emergency sluices HPU

Source: MML Site visit 10th April 2019

Figure 42: HPU motor



Source: MML Site visit 10th April 2019

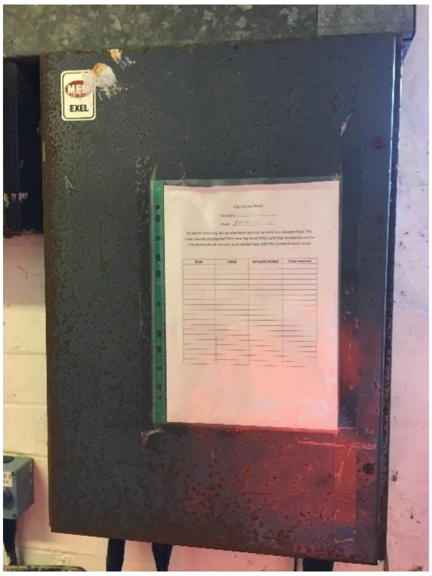
The electrical isolator and the distribution panel within Underfall Yard shown in Figure 43 and Figure 44 are both fairly corroded. In future this could possibly have a negative impact on the normal operation and integrity of the internal components and cabling. therefore these panels need to be replaced.

Additionally, the bracket which supports the sluice gate number one limit switches are heavily corroded, as can be seen from Figure 45, and needs to be replaced to ensure secure support of the switches in the future.

Figure 43: Corroded local isolator

Source: MML Site visit 10th April 2019

Figure 44: Corroded electrical distribution panel



Source: MML Site visit 10th April 2019

Figure 45: Corroded Limit switch bracket

Source: MML Site visit 10th April 2019

Figure 46: Limit switch cabling

Source: MML Site visit 10th April 2019

Examples of unsupported cables can be seen in Figure 47 where the cables of the limit switches are not securely fixed on the wallside via cable trunking. All unsupported cable installations should be rectified utilising appropriate cabe trunking to provide cable protection.

Figure 48 shows a cable trunking which is not supported and securely fixed on the wallside with cables hanging and exposed. Dirt covering the opening for the cable through the floor at the cable trunking was obstructing to observe whether the opening has been sealed with the appropriate foam sealant to prevent vermin intrusion. However it appears that the sealant was not applied. This shall be further investigated and sealant to be applied in case it was not done previously.

Figure 49 shows a free earthing lug not fixed in place. It is not confirmed where the earthing lug was connected to; however, a free earthing lug could compromise the installation bonding and personnel safety. Therefore, it shall be checked whether it forms parts of an active circuit and reconnected back in place as required.

Figure 47: Unsupported cables

Source: MML Site visit 10th April 2019

Figure 48: Unsupported cable trunking

Source: MML Site visit 10th April 2019

Figure 49: Broken earthing lug

Source: MML Site visit 10th April 2019

On several sections of cable tray, shown in figures Figure 50 and Figure 51 it appears that there is no earth bonding conductors between the cable tray sections. Additional bonding may be required to provide an equipotential bonding system. This shall be further investigated and any installation required to be by a competent electrical subcontractor. Installation and the continuity tests shall be in accordance to the BS7671 wiring regulations.

Figure 50: Cable trays

Source: MML Site visit 10th April 2019

Figure 51: Cable trays

Source: MML Site visit 10th April 2019

5.2.2 Operational

No issues were identified in the operation of the sluice gates other than those highlighted in section 4.2.2, which concern the mechanical operation.

6 Risks associated with failure

The main mechanical risks are most likely to cause the failure of the assets are:

- the deflected shaft of main sluice gate 2
- the corroded guides of the main sluice gates
- the severely corroded poles behind main sluice gates 1, 2 and 4.
- the broken seals on emergency sluice gates 1 and 2
- the open hook and circular section lifting beam supporting blanking plate 3
- emergency sluice gate 4

If the above are left unrectified these are the likely risks which may occur. The deflected shaft may buckle leading to an inability to close the gate. The corroded guides would also increase the difficulty of operation and reduce the load bearing capacity of the gates becoming another possible cause of a structural failure. Worse yet the guides could be damaged which meaning the gates could not be operated. The severely corroded poles could collapse and cause damage to the gate. The broken seals could increase the volume of leakage leading to increased wear, a lower load bearing capacity of the gates and eventual damage. Emergency blanking plate 3 can easily become dislodged, increasing the hydrostatic load on main sluice gate 3 and damaging the asset if a better system is not put in place. It is also a statutory obligation to ensure that the lifting arrangements for the plate comply with LOLER. Finally, emergency sluice gate 4 should be connected to a hydraulic actuation system to allow it to be operated. This will in turn allow main sluice gate 4 to be operated and reduce the burden and wear placed on emergency sluice gates 1 and 2.

The main electrical risks identified are:

- **Panel corrosion:** There are several electrical panels which show moderate to fair corrosion. In the long term this could possibly have a negative impact on the normal operation and integrity of the earthing system and internal components therefore these panels need to be rectified or replaced.
- **Unsupported cables:** In several locations there are cable installations which are not securely clipped or installed on a cable trunking system and this potentially could lead to cable damaging when any nearby activities happen. These installations should be rectified to follow good installation practice and ensure the security of the cables.
- **Earthing and bonding:** It has been highlighted that some cable tray installations have no equipotential bonding, and this may give rise to a potential electricity hazard. This shall be further investigated by a suitably qualified electrician and rectified. There was an occasion of a free earthing conductor located at the installation in the emergency sluice room which needs to be investigated and if is still in use shall be rectified. Inspection and test methods shall be in accordance to the BS7671 wiring regulations.

7 Recommendations

7.1 Mechanical Recommendations

To ensure the sluice gates meet their design life it is recommended that they are regularly maintained. Maintenance plans for the equipment would typically involve:

- Regular minor maintenance (approximately every six months).
  - Inspection of the gates recording the material condition and the level of biological growth and degradation making sure no damage has occurred.
  - Operation of all moving parts making sure they function correctly.
  - Operation of the hydraulic power unit and seek for any lack of pressure or leakage in the system.
  - Reporting of any excessive or wide spread leakages if any and remedial measures should be carried out.
- Regular major maintenance (annually).
  - Repair or replacement of any small maintenance free components.
  - Lubrication of the moving parts like the HPU shafts and gear boxes.
  - Checking of tightness of all coupling bolts of gear box and line shaft. If required, they may be tightened.
  - All debris, sediments and any foreign material shall be cleared off the sluice gates and their frames.
- Repair or replacement of maintenance free components for example bearings, hydraulic fluid lines, etc. (Approximately every five to seven years).
  - Checking for condition of painting of all components and remove rust or marine growth wherever noticed and repaint after proper cleaning as per painting schedule.
- Replacement of major mechanical components for example hydraulic cylinders, hydraulic oil, etc. (Approximately every ten years).
  - Replace hydraulic oil and components, as per manufacturer recommendation and painting schedule.

It is also recommended that all emergency sluice gates are transitioned to a hydraulic actuation system.

7.2 Electrical Recommendations

- As described in detail in section 5.2.1 the main sluice gate control panel has signs of physical wear and needs to be repaired. The dial level switch cover, functional LEDs which are not functional and seal slots which are not in use all need to be repaired or replaced.
- Panels with moderate to fair corrosion should be scheduled for replacement to ensure secure operation in the long term.
- Replacement of main sluice gate actuators 3 and 4 to ensure future reliability.
- Warning signs to be installed on the entrances of both the emergency sluices room and main sluices room to warn for authorised personnel access only.
- Lock to be removed and dial switch cover to be replaced.

- Bad practice installation of cables which have been identified need to be revisited and rectified to follow good installation practice and cable protection, including cable installations within the electrical and instrumentation cubicles.
- Provision of an enclosure to store the relevant electrical installation drawings. Further investigation into Telemetry and communications system to establish the as built system in use which could not be obtained due to limitations of readily available material on site.
- Cable glands on actuators which are not appropriately sized should be replaced with appropriately sized glands to ensure secure cable termination.
- Painted over cable terminations and equipotential bonding should be inspected and tested in accordance to the procedures by BS7671 wiring regulation to ensure conductors integrity and good continuity of electrical path.
- Painted cable conduits should be further inspected for physical wear and restored where damage is detected in the appropriate manner to ensure cable good cable insulation.
- Frequent inspection schedules to be set in place for the installation inspection in terms of good cable insulation, security and integrity.
- Replacement of heavily rusted limit switch brackets.
- Apply appropriate foam sealant in through floor openings for cables as required.
- Provision of additional equipotential bonding as required following further investigation on cable tray sections which are bonded in between them. Carry out inspection on free earthing conductors and fix in place. Installation and tests shall be carried by a competent electrical sub-contractor.
- Frequent inspection schedules to be set in place for the inspection of the limit switches installation in terms of good cable terminations, corroded terminals and lugs, secure fixing, integrity and good condition of support brackets. Any defects found should be scheduled for replacement.

7.3 Useful Life of Structure

Assuming the sluice gates were replaced in 1995 they should have a design life of at least 50 years. Therefore, a reasonable estimate of their remaining operational life would be approximately 10-26 more years depending on the frequency of their use and the level of maintenance given. However, the guides are far older and will require immediate investigation and possible replacement.

The HPU is expected to operate for approximately 25 years from its installation date which is currently unknown. However, various components within the HPU would require changing, after a shorter period, as part of their regular maintenance of the HPU. Section 7.1 gives more details of this.

The Rotork actuators have a design life of approximately 15- 20 years assuming actuators one and two were installed in 2009 they are expected to have an operational life of 5 - 15 years depending on number of uses and the level of maintenance given. The older actuators operating main sluice 3 and 4 should be immediately investigated to confirm they are still operational.

7.4 Additional Future Maintenance

It is recommended that the wear on the guides is monitored and recorded regularly. Monitoring of any water leakage is also recommended. This will allow more predictive, as opposed to reactive, asset management strategies.

8 Cost of Works

8.1 Repairs and Replacements

The recommended repairs and replacements with some associated costs include:

- Blast cleaning of the corroded surfaces to preparation grade Sa 2.5 as specified in ISO 8501-1:2007 (order of magnitude £10k).
- Replacement of all main sluice gate guides (order of magnitude £300k).
- Application of a corrosion protection system selected in accordance with BS EN ISO 12944-5:2007(order of magnitude £5k).
- Cleaning of marine growth and investigation of seals on the side of the gates (order of magnitude £3k).
- Scouring of silt in main sluice chamber (order of magnitude £3k, if done by divers).
- Thorough examination of chain block and beam (order of magnitude £500)
- Redesign and installation of certified lifting arrangements for emergency blanking plate 3 (order of magnitude £10k)
- Removal of debris obstructing emergency blanking plate 3.
- Upgrade of emergency blanking plate 3 and emergency sluice gate 4 to allow hydraulic actuation (order of magnitude £10k)
- Investigation and removal of debris obstructing sluice gate 3 (order of magnitude £10k).
- Investigation of main sluice gate actuators 3 and 4 (order of magnitude £2k)
- Replacement of emergency sluice gate 1 and 2 bronze sealing (order of magnitude £100k).
- Adjustment of main sluice gate 2 Rotork actuator (order of magnitude £1k).Main sluices control panel repairs to ensure security, ingress protection and functionality (order of magnitude £300)
- Rearrange unsupported cables to provide protection by means of burying them or mounting on cable trays (order of magnitude £3k)
- Replacement of corroded panels including installation (order of magnitude £10k)
- Installation of warning signs to BS EN ISO 7010:2012+ A5:2015 (order of magnitude £300)
- Replacement of cable glands on actuators and the corroded brackets for the limit switches (order of magnitude £500)
- Investigation into operation of main sluice actuators no.3 and no.4 (order of magnitude £2k)
- Inspection and installation work of electrical subcontractor on the equipotential bonding and electrical tests as per BS7671 wiring regulations (order of magnitude £5k)

8.2 Cost of Upgrades to Required Standards

The equipment is relatively recent and does not require upgrading.

8.3 Cost Benefit Analysis

8.3.1 Make no changes

- Cost – No cost.
- Benefit- with the current condition of the gates and equipment, failure of the Underfall assets are likely. This is due to the risks highlighted in the section 5.2.2. This is not an option as there

are several issues which must be addressed immediately. For example, LOLER compliance of the lifting accessories for emergency blanking plate 3 is a statutory obligation. However, this has not been met.

8.3.2 Repair Significant Defects

This option involves the replacement of the deflected actuator shaft of main sluice gate 2; the replacement of the corroded main sluice gate guides; the replacement of all critically corroded poles in the main sluice gate chambers; a redesign and replacement of the lifting accessories for emergency plate 3, to a more permanent solution, to ensure compliance with LOLER; a the removal of the debris in front of emergency plate 3; the connection of the emergency sluice gate 4 to the HPU; and an investigation into the operation of main sluice gate actuators 3 and 4.

- The priority works recommended from an electrical perspective are the replacing of the main sluices actuators no.3 and no.4; the inspection of the existing equipotential bonding systems due to corrosion and paint on cable lugs and testing; an investigation of the requirements for additional equipotential bonding; and the repairs or replacements of the corroded electrical panels and isolators. Cost – order of magnitude £400k.
- Benefit- These repairs and replacements would enable the Underfall Yard assets to continue operating for another 10-15 years, given appropriate maintenance regime is applied.

8.3.3 Repair all Defects

This option involves completing all recommended repairs and replacements.

- Cost – Order of magnitude £500k.
- Benefit- Ensures the gates are kept in good condition and will likely reach the end of their specified design life, and may surpass it, assuming future maintenance is undertaken.

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