Integrated Urban Drainage Modelling Guide

Appendix E

Culvert Inspections

CIWEM Chartered Institution of Water and Environmental Management

E1. Introduction

It is increasingly essential that the extensive network of culverted watercourses across the United Kingdom are adequately maintained to help reduce the potentially devastating effects of failure or blockage.

If we are to maintain these critical assets, we must first determine both their structural and service condition to allow informed engineering decisions to be made and funding assessments to be made. This can only be achieved through the implementation of a strategic inspection programme.

This Appendix will go on to explain the inspection methods commonly used to inspect culverts as well as highlighting the many difficulties likely to be encountered along the way.

E2. What is a Culverted Watercourse ?

A culverted watercourse is a ***covered channel or pipe designed to prevent the obstruction of a watercourse or drainage path by an artificial construction or a covered channel, conduit or pipeline used to continue a watercourse or drainage path under an obstruction***.

Culverted watercourses were often constructed and extended over long periods of time as urbanisation expanded often resulting in a wide variety of construction methods, construction material types and even not insignificant cross sectional dimension changes.

It is this often random approach to construction that provides headaches to inspection professionals when the time inevitably comes to get an inside view of a culvert.

E3. Accessing the Culvert

Unlike the UK public sewer system, the network of culverts rarely follow streets but instead traverse large open areas of public and private land, woodland, farmland and frequently through multiple private gardens providing a substantial challenge for any inspection team tasked with completing an internal inspection.

Many culverted watercourses have only two points of access, depending on their length. These are the Inlet and the Outlet. Potentially there could be several hundred metres of culvert to inspect between these two points of access so it is essential that personnel and surveying equipment can reach these locations.

Depending on land ownership, which must be determined prior to commencement of any survey activity, it may be necessary to serve a land entry notice, however, permission to enter can often be obtained in a more informal manner by direct liaison/communication with the landowner or tenant.

Once permission to enter has been granted or land entry notice served, a pre-inspection visit is advisable. This visit will provide essential information about any access difficulties such as:

- Vehicular access possible or foot access only (4WD required)
- Ground conditions on approach to inlet/outlet
- Inlet/Outlet condition (water level/screens/grids/vegetation density/safe personnel entry)
- Assess area around inlet/outlet for presence or potential presence of any protected species such as native crayfish, water voles, great crested newts, nesting birds or bats.
- Assess area around inlet/outlet for presence of any invasive species such as Japanese Knotweed, Himalayan Balsam and Giant Hogweed. The latter can cause painful blistering from unprotected skin contact.
- Presence of overhead powerlines
- If cleaning is required to permit inspection, can large jetting plant reach the inlet/outlet
- Will track matting be necessary to protect the ground from vehicle damage
- Obtain sufficient information (including digital photographs) to enable a detailed Risk Assessment and Method Statement to be produced (RAMS).

There will inevitably be culverted watercourses that not only have an inlet and outlet but will have access chambers at intervals between. These are not always mapped and may only be revealed during the internal inspection, however, if the location of access chambers is known, each of these locations should also be visited and assessed.

The greater the frequency of points of access along the length of a culverted watercourse, the greater the chances are of achieving a successful inspection because the survey team are able to undertake overlap surveys where surveys have been abandoned due to an obstruction or sediment for instance.

E4. Culvert Construction

As previously mentioned in Section 2, culverted watercourses come in a wide variety of shapes and sizes. Some may be of recent construction, probably using concrete pipes, however, older culverts were often constructed using materials available at the time. A list of typical culvert construction types follows:

- Masonry (Stone) – often square or rectangular in cross section and randomly coursed with slab invert and soffit
- Brick – circular, egg or arch coursed with mortared joints
- Masonry/Brick mix – coursed or randomly coursed masonry side walls with brick arch soffit
- Concrete/Vitrified Clay pipe
- Concrete Box Culvert.

Culverts are rarely straight between inlet and outlet because they were usually laid along the original, often meandering, watercourse route which makes the task of inspection even more difficult as the inspection equipment has to negotiate potentially multiple changes in direction which in turn significantly increases the possibility of survey abandonment and, in the worst case, equipment becoming stuck within the culvert.

Culverted watercourses can be as small as 600mm (smaller is possible) and as large as several metres high and across which means that there is no single method of inspection to cover all eventualities.

Because culverted watercourses were often extended multiple times over a period of many years, the method of construction from section to section, as well as the cross sectional dimensions changed, again, introducing further hazards into the mix when attempting to achieve a successful survey.

E5. Culvert Service Condition

Trash screens, where fixed in place at culvert inlets, usually catch most large objects before they can be washed into a culvert, however, solids/fines suspended in the flowing water settle over time resulting in a build-up of sediment along the culvert invert which can prevent the progression of crawler mounted CCTV systems, often resulting in survey abandonment.

Because culverts are often difficult to get to, they are rarely cleaned internally to remove sediment build up as part of a planned maintenance programme. Trash screens, on the other hand, are usually cleared periodically to prevent flooding upstream of a culvert inlet.

Where trash screens do not exist, debris of all types, shapes and sizes can find its way into and along a culvert carried by heavy flows where it is then deposited in the invert.

Whilst large objects do not unduly affect the hydraulic performance of large culverts, they can have a very serious effect on the performance of smaller culverts, potentially resulting in total blockage, especially as, over time, smaller debris will collect around the large object.

Service condition plays a very significant role in the success or otherwise of an internal inspection and may dictate the method of inspection chosen. Culverts that are too small for man entry rely upon either a floating method of transporting the CCTV equipment through (subject to flow levels and velocities present at the time of inspection) or, more commonly, the use of a mechanically driven crawler mounted system.

Large objects (i.e. tree branches, large stones/bricks etc) will prevent a crawler from progressing and the survey will inevitably be abandoned at that point. If the abandonment is at a point where 90% of the inspection length has been reached then the survey would be deemed to have been successful, however, if the survey has been abandoned only a few metres from the start access point and that access point is the only identified or accessible one, then the survey would be deemed to have been unsuccessful.

It isn't only large objects that can cause abandonment, settled silt deposits, if sufficiently deep will also cause the crawler to lose traction because the crawler body will be sat on a bank of silt with all driven wheels spinning freely preventing any forward motion.

Service condition doesn't just include objects washed into the culvert from upstream but also includes, for instance, tree root ingress. Tree roots can access a culvert through the tiniest of cracks/fractures in their relentless search for water and nutrients. Once fine roots have reached the inside of a culvert they can then grow at a very rapid pace forming root masses that can eventually restrict the cross section of a culvert to such an extent that a CCTV system cannot get past. Mass roots can even block a culvert completely.

Removing objects/debris/roots from culverts to facilitate an internal inspection can be achieved using a variety of methods, however, most of these methods are vehicle based so restricted access to a culvert can mean that cleaning cannot easily be achieved.

High pressure water jetting is usually the method of choice, however, care must be exercised when using high pressure water equipment in culverts where poor structural condition is suspected. Some companies can provide remote hose reel systems where the large jetting machine is positioned away from the culvert access at the nearest hard standing area which is then connected to the remote hose reel (usually mounted on either a motorised tracked or dumper style chassis with a narrow footprint).

There are also trailer mounted jetting machines that can be towed using tractors or a JCB Fastrac as well as 8 wheel drive water recycling machines where restricted access width is not an issue.

E6. Inspection Techniques

Essentially, there are two primary types of culvert inspection, Man Entry and Non-Man Entry. The former involves confined space trained and suitably equipped personnel entering the culvert and walking along its length noting structural and service condition defects and taking still digital images or video as they proceed whilst the latter avoids the inherent risks associated with man entry by utilising CCTV equipment mounted on floats or a crawler controlled remotely by an operator at the survey unit.

E6.1 Man Entry Inspection Technique

If at all possible, primarily from a Health and Safety perspective, this method of inspection should be avoided, however, there will inevitably be instances where Man Entry will be the only suitable method to ensure successful completion of a culvert inspection.

Thorough documented assessment of potential risk and associated risk mitigation must be carried out prior to undertaking a Man Entry inspection including but not limited to emergency escape, which may include provision of a dedicated Rescue Team.

Reasons why Man Entry may be considered:
(advisable that the culvert height/diameter is equal to or greater than 1200mm)

- The size of the culvert to be inspected is too large for conventional CCTV survey equipment and illumination, either because the equipment is too small or the on-board illumination is insufficient to produce a satisfactory CCTV image
- It is not possible to reach the access locations by any other method than on foot.
- Debris is evident that would prevent progress of a crawler mounted CCTV system.
- There is a requirement to use physical methods as part of the inspection (i.e. check for loose mortar, take sediment samples etc)

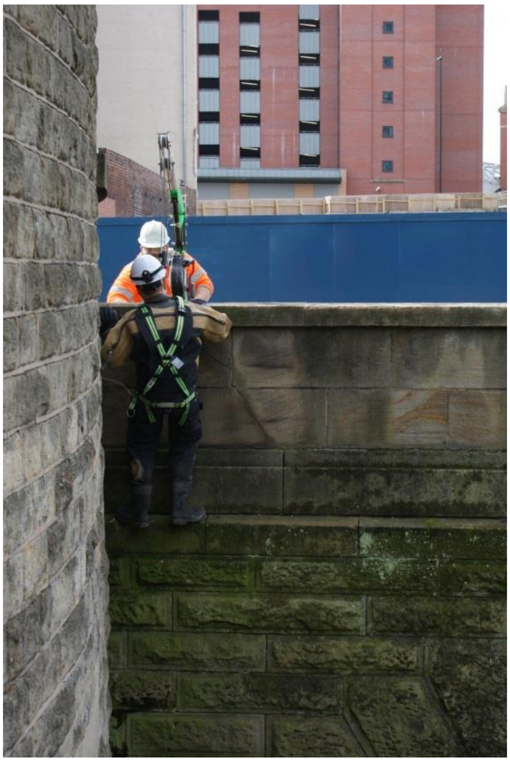
Where possible, it is advisable that Man Entry inspections should only be considered where there is more than one point of access/egress in case of emergency. If trash screens or safety grids are in place that prevent emergency egress, these must be temporarily removed for the duration of the inspection.

If it is critical that a culvert with a single point of access/egress is inspected by Man Entry method, depending on length and results of a thorough risk assessment, it may be necessary to include for provision of a dedicated Rescue Team.

The greatest risk related to Man Entry inspection of a culverted watercourse is from drowning or wash away caused by sudden inundation during a heavy rainfall event. Checking weather forecasts in advance of mobilisation to site is, therefore, critical as is the continued assessment of approaching rainfall using Rainfall Radar (several apps are available). It is important to remember that because some large culverts serve very large catchment areas, it is possible that the weather can be dry at the survey location but a heavy storm can occur many miles away causing water levels to creep up, slowly initially, but rapidly increase as the river/stream upstream gathers more run off.

Many large culverts in urban locations may only be accessed from street level at overbridges or side retaining walls where the culvert opens up. These present significant challenges for getting personnel and equipment safely down to the culvert entrance.

To mitigate the risk of a fall from height in such circumstances, a man ride hoist backed up with a secondary fall arrest system would be utilised. The most effective system upon which to mount the hoist/fall arrest is a Counterweight Davit Arm which can be positioned against the wall with its jib extended over. A series of 25kg counterweights are locked in position onto the frame of the davit arm device permitting personnel to safely descend, one by one, from street level to the stream bed.



E6.2 Non-Man Entry Inspection Technique

Because this technique uses remotely controlled equipment to inspect the culvert, the risks to personnel are significantly reduced. Confined space entry may still be required if access into the culvert is via a manhole chamber but any associated risks can be mitigated by following a routine NC2 entry procedure (Water UK National Classification for Confined Space Entry).

An NC2 entry procedure applies where the chamber allows a suitably trained operative vertical direct unobstructed access with continuous attachment to a man riding hoist or similar mechanical rescue device.

Where the above does not apply, alternative entry procedures must be considered.

There are a variety of methods available for the Non-Man Entry inspection of a culvert, all of which use a colour CCTV camera transmitting live video images via an umbilical cable to a screen in the CCTV Survey Unit.

All functions of the CCTV system can be controlled by the surveyor using a controller. If the camera is mounted on a crawler, the surveyor is able to control the following functions:

- Crawler forward/backward motion
- Crawler forward speed
- Crawler steering (if crawler has this function)
- CCTV focus (near to far)
- CCTV iris (open to closed)
- CCTV pan/rotate (if CCTV camera has this function)
- CCTV zoom (if CCTV camera has this function)
- CCTV elevator (to raise and lower camera position – if crawler has this function)
- Illumination (dim/brighten)

An integrated text generator allows important information about the culvert to be superimposed onto the monitor screen which is in turn recorded onto the video.

The CCTV system has a cable counter which measures the distance travelled in 0.1m increments. The reading from this counter is also superimposed onto the monitor/recording.

The structural and service condition of the culvert is assessed by the surveyor as the survey proceeds and reported in a coded format using the WRc Manual of Sewer Condition Classification (BS EN 13508-2:2003+A1:2011).

Video footage is recorded digitally, in a variety of formats, including MPEG1, MPEG2 and MPEG4.

Most “standard” CCTV crawler systems are capable of inspecting culverts up to 1200mm high/diameter although with certain adaptations good results can be achieved in culverts up to 1800mm high/diameter.

Larger culverts will necessitate the utilisation of larger, heavier and more powerful crawlers teamed with powerful LED lighting arrays.

It is worth noting that where crawler systems are to be used in non circular culverts, the ability to be able to steer the crawler becomes more critical as the crawler may wander off the centre line and will at some stage come into contact with a side wall which will at best negatively affect forward progress but at worst, may result in the crawler overturning resulting in a difficult retrieval process depending on distance travelled for the point of access.

In culverts where water levels are high and submerged debris may affect a crawler’s progress, it may be possible, subject to flow velocities, to float a tow line from one end of the culvert to the other and then mount the CCTV system/lighting onto a float assembly. A portable capstan winch can then be used to pull the CCTV system forward in a controlled manner, stopping at defects as instructed by the surveyor using two way radio communication.

Pipe Profiling Sonar can also be added to provide information about the culvert below the water level which would not be visible by the CCTV camera. The Sonar scanner will show the shape of the culvert as well as the surface of any settled deposits allowing silt depths to be measured.

Pipe Profiling Sonar can be used in fully surcharged conditions to give a 360° view of the culvert structure, however, the resolution is not sufficiently high to identify minor structural defects such as cracks and fractures, especially in larger culverts. It is important to note that Sonar cannot "see" forwards and looks only to the side as it proceeds, therefore, there is always a risk that the system could strike an object or fall into an uncharted pit so extreme caution must always be used.

Finally, Laser Profiling technology is also available which can supplement a CCTV survey to provide highly accurate profile measurements that can be measured using system software allowing small changes in shape to be identified that may otherwise have gone unnoticed by the "human eye".

Repeat surveys can then be undertaken using this method allowing any dimensional changes to be determined allowing any ongoing deterioration to be identified and proactively monitored.

E7. New Inspection Techniques

The emergence of LiDAR survey techniques is slowly but surely revolutionising the inspection sector and it's only a matter of time before this amazing technology is used more frequently in the pipeline/culvert inspection market.

For large Man Entry culvert inspections (1800mm and greater) it is now feasible to use survey grade LiDAR mounted on a tripod producing millimetre accurate dense point clouds, which will allow future repeat surveys to detect even the smallest of changes in critical underground structures.