WinCan

WinCan Europe Ltd
Unit 10, Woking Business Park, Albert Drive, Woking, GU21 5JY
Tel: 01483 762222

WinCan Advice Note

WAN002 – Inclination

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1. Introduction

This advice note intends to describe details of acceptable inclination reporting in drains and sewers as described in the Svenkst Vatten P91 (Swedish Water SV-P91) sewer construction control documentation, previously known as VAV-P50.

2. General Information

The intention of sewer CCTV inclination measurements should not normally be to attempt to ascertain the level of an inaccessible end of a sewer pipe, although this is possible. An example may be a highway gully connecting to a carrier pipe under the carriageway at a connector node, where the upstream height (AOD[1]) can be measured but the downstream end is inaccessible for height measurements. In such cases, the accuracy of any calculated result should be treated with caution.

When using inclination enabled equipment, the output is design to indicate how the pipe behaves at the points between the ends of the pipe. So, we may know very accurately what the height (AOD) of the pipe is at both of its ends and this may demonstrate that the pipe has the correct or a suitable gradient, but the inclination report shows us how the line of the pipe behaves between these points.

[1] AOD: Above Ordinary Datum (usually, sea level)

The SV-P91 standard sets limits for the acceptable deviation of the sewer from the theoretical 'straight line' between each end of the pipe.

Many CCTV sewer inspection cameras have inclinometers built-in, and WinCan VX includes the features required to record the data stream from the inclinometer and also has tools for printing and reporting the captured data in accordance with SV-P91 and WinCan's own reporting style.

The data coming from the CCTV camera back to the control PC can be affected by many things including dirt or debris in the pipe and tension on the camera cable, so in order to get the best results, it is recommended that the pipe be well cleaned before an inclination test, and that the inclination run be carried out in reverse as the camera is driven back to the insertion point.

So, the CCTV operator would carry out a regular CCTV inspection going forwards, where they can pause, pan, tilt, zoom, take photos, and make observation etc, and then activate the inclinometer data stream and drive the camera at a steady and constant pace back towards the CCTV rig. This works best with an auto-wind cable drum since the inclination measurement points are distance triggered and a manual drum may make this data stream irregular.

There is little point in measuring the gradients of rising or pumping mains against this technique.

3. Assessment Criteria

This section (3) and the following sections (4, 5 and 6) are taken directly from SV-P91.

The test length of sewer is assessed with respect to the horizontal length of the piped asset and the vertical deviation from the control profile level.

The control profile is defined as a straight line between the pipe invert connection points at the nodes at each end of the sewer length.

The values of maximum allowable deviations from the control profile are given in Table 1. These are the amounts by which the inclination can deviate from the control profile in either direction, up or down. The deviations are calculated using a combination of the pipe diameter and the calculated gradient (in permille ‰) between the two ends of the sewer length.

From the deviations measured by the inclinometer, a measurement accuracy of 10mm shall be deducted before the tolerance class is determined in accordance with Table 1.

4. Tolerance Classes

There must be no backfall for a pipe to have an acceptable inclination, regardless of the tolerance class achieved. Where backfalls occur, the self-cleaning ability of the asset is seriously reduced.

The angular change of direction at a joint in the pipe must not be greater than that for which the joint was designed.

The maximum allowable deviations with respect to tolerance classes are:

Direct Gradient (‰)	Pipe Diameter (d_i mm)	Tolerance Class (± mm)			
		A	B	C	D
< 6	$d_i \leq 225$	≤ 35	≤ 55	≤ 75	> 75
	$225 < d_i \leq 400$	≤ 40	≤ 60	≤ 80	> 80
	$d_i > 400$	≤ 45	≤ 65	≤ 85	> 85
≥ 6 and ≤ 20	$d_i \leq 225$	≤ 40	≤ 60	≤ 80	> 80
	$225 < d_i \leq 400$	≤ 45	≤ 65	≤ 85	> 85
	$d_i > 400$	≤ 50	≤ 70	≤ 90	> 90
> 20	$d_i \leq 225$	≤ 45	≤ 65	≤ 85	> 85
	$225 < d_i \leq 400$	≤ 50	≤ 70	≤ 90	> 90
	$d_i > 400$	≤ 55	≤ 75	≤ 95	> 95

Table 1: Maximum acceptable deviations by gradient and pipe diameter.

$$Direct\ Gradient = \frac{(h_{US} - h_{DS}) \times 1000}{l}$$

Where:

- h_{US} = the height above ordinary datum of the upstream end of the sewer in metres,
- h_{DS} = the height above ordinary datum of the downstream end of the sewer in metres,
- l = the length of the inclination test run in metres, and
- ‰ = permille (i.e. per thousand equal parts).

5. Test Methodology

There are 3 test methods; A, B and C where the level of control and the probable accuracy of the results can be indicated.

Method A:
The operator must calibrate and certify all measuring equipment at the start of each shift. This includes GIS equipment and CCTV equipment measuring tools including distance readers. The operator must make sure the pipe is clean and empty and the operator must make sure the heights given are correct. By indicating a 'Method A' test in the inspection data, the operator is indicating that all measurements are correct and accurate at the point of the test.

Method B:
The operator must calibrate and certify that their equipment and that all data from their equipment shows correctly. There is no responsibility for the pipe to be cleaned or to test that the heights measured are accurate where they have been provided by others.

Method C:
There is no requirement for calibration or cleaning and the inclination test results are taken as read.

6. Accuracy of Data Collection

The measurement method used to measure the heights and lengths shall have a measurement accuracy not less than ± 10mm in height and 10mm per 100m along its length. If other requirements for measuring accuracy are set, these must be stated in the technical specification.

The inclination height and length measuring devices should be accompanied by service calibration certificates valid at the time of the inspection as defined by the manufacturer. The measuring devices shall be able to be ground-calibrated at the point of inspection.

When reporting the results for each test length, any factors that may have influenced the results of the test must be included as inspection comments in the data.

The pipe length between the nodes shall not generally be less than 5m. If measurements for other specified pipe lengths are required, this must be stated in the technical specification for the job.

CCTV inspection should always be performed before the test to assess if cleaning is required. Cleaning should be carried out as required to ensure accurate test results.

The levels (AOD) of the start and end points of the pipe shall be measured at the time of the test when carrying out a ‘Method A’ test.

If the test result shows deviations exceeding the requirement for acceptable tolerance classes for the pipe, the contractor will be given the opportunity to repeat the measurement once before the final test report is agreed with the engineer.

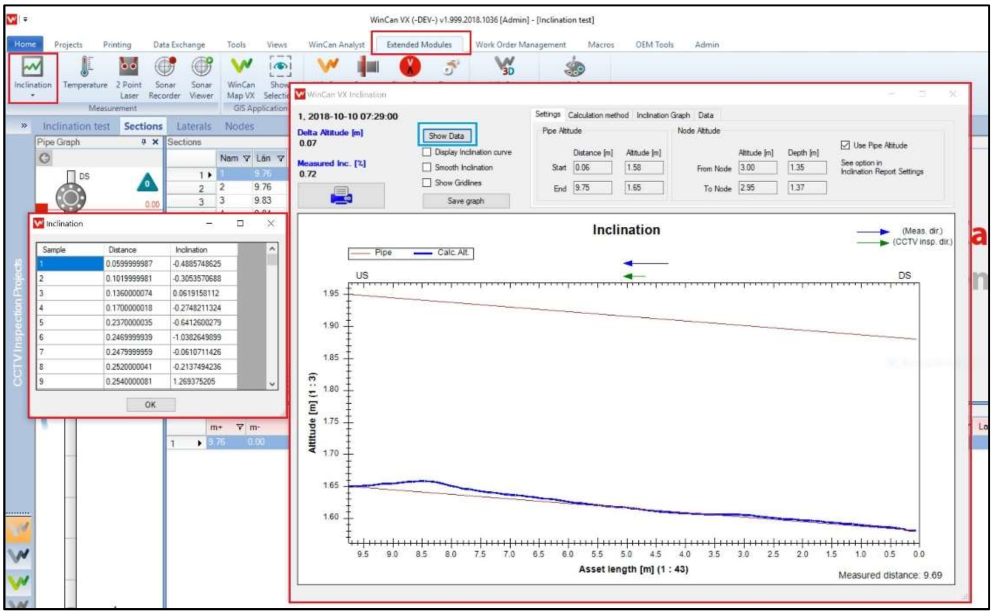
In order to reduce measurement errors, only the difference in height between the ends of the pipe section should be used, regardless of any standing water levels observed in the sewer section.

7. Reporting

Inclination data captured in WinCan VX can be reviewed and presented in two ways. One is via a per-inspection viewer and the other is via the standard print manager to PDF file.

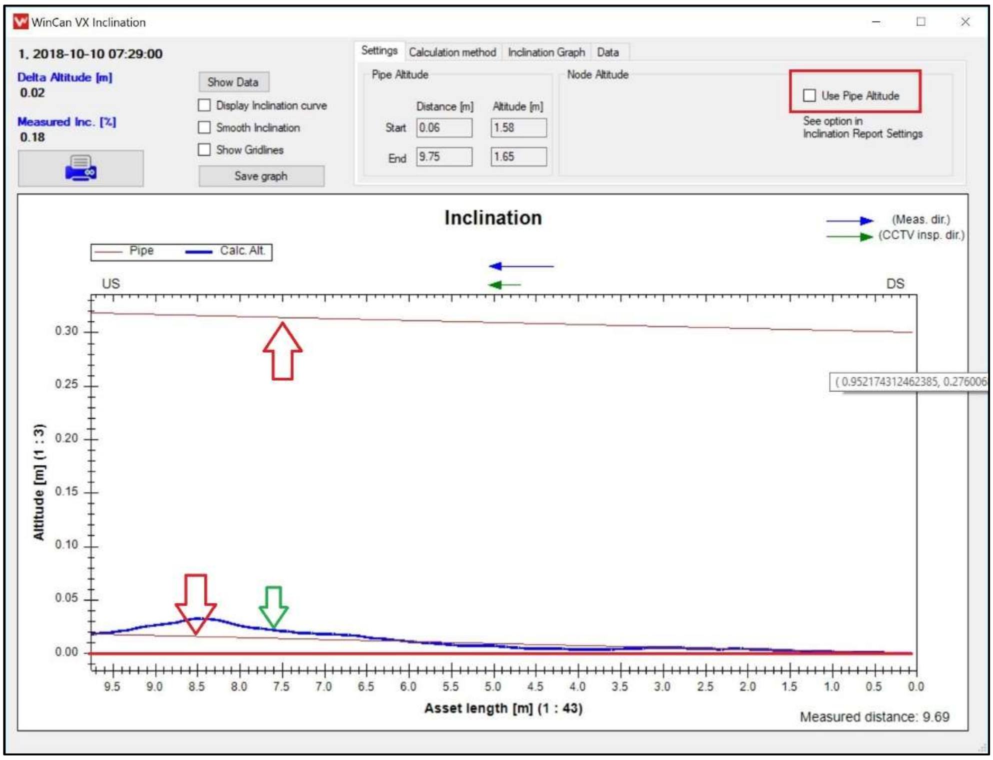
Some customers in some global territories prefer to output all of the inclination tests with in a project at a specified scale for consistency. This feature can be accessed when printing a project report, where a single output scale can be applied to all graphs in the project.

The inclination viewer can be accessed from the Extended Modules ribbon bar in WinCan VX:



From, here we can use the 'Show Data' button to see the data points that have been collected during the inclination test. These are useful for verifying the direction and measurement values contained in the data set.

If we consider the inclination panel itself in more detail, the standard output looks like this:



In this standard graph, we see the top and bottom (invert and crown) of the pipe indicated by the sloping brown straight lines and the blue curve is the inclination data recorded during the test.

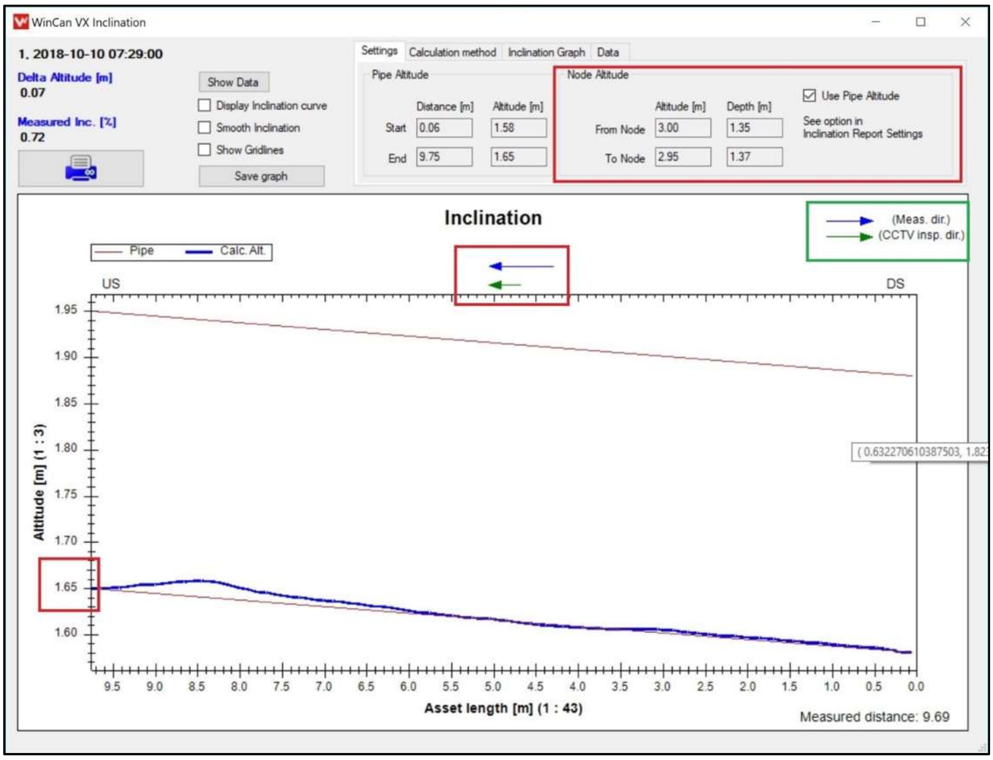
The green and blue arrows at the top of the chart indicate the inspection direction (green) and the inclination test direction (blue). It must be remembered that these two directions are mutually exclusive and should never be considered as the same thing.

In the sample above, the inclination tests has been completed from the downstream end of the pipe and with the camera driving forwards, so the test starts on the right hand side of the page at a height of zero (see the red line to the scale on the left hand side of the graph), and then rises to a final value of about 0.02m over a distance of 9.7m at the left hand side of the graph.

The chart shows a pipe that is flowing downhill from the upstream end (always on the left-hand side of the chart) to the downstream end of the asset (always on the right-hand side of the chart) and has been designed this way so that it is intuitive, regardless of the CCTV inspection direction or the inclination test direction.

Charts of this style are generally considered to be rudimentary, in that the actual delta height (Δh height difference from one end or the other) is likely to be inaccurate due to wear and poor calibration of the CCTV equipment. It has been identified that even minor items like a small amount of camera wheel wear or debris clogged to the wheels can have a significant effect on the data logged by the inspection system.

Much better charts can be created when we have accurate heights above sea level for the upstream and downstream ends of the pipe as measured by GIS equipment. These levels can be entered into the pipe section header, and can then be activated in the inclination report by checking the 'Use Pipe Altitude' button on the top right-hand side of panel, like this:

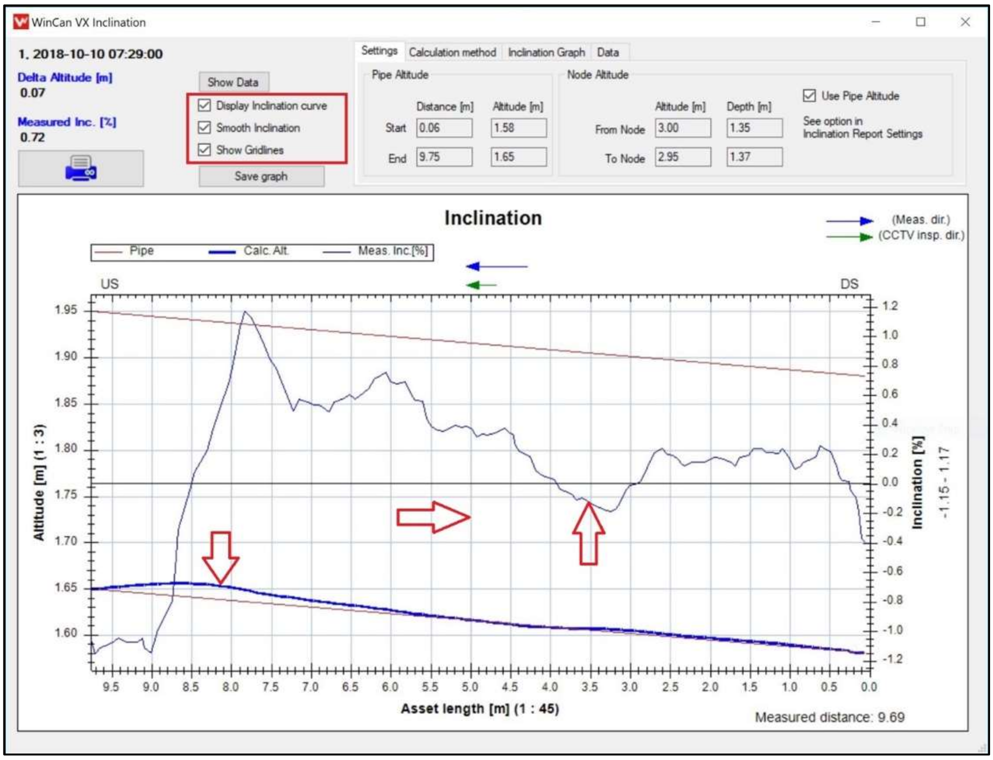


Now, we see that the upstream end of the pipe is at 1.65m above sea level, and the downstream end of the pipe is at 1.58m above sea level as can be seen from the left-hand altitude value and the right-hand altitude value.

Since we have some confidence that these values are correct as measured, the inclination dataset can be stretched or compressed as required to fit between these values. The result is that the chart is showing the pipe at its actual heights at each end, and the inclination now shows us accurately the shape of the pipe between these two points.

The above chart is based on the same data as the previous chart, as are all of the examples included here.

We have some checkbox options on the top-left hand side of the inclination panel which can turn some additional useful features on and off on the graph, like this:

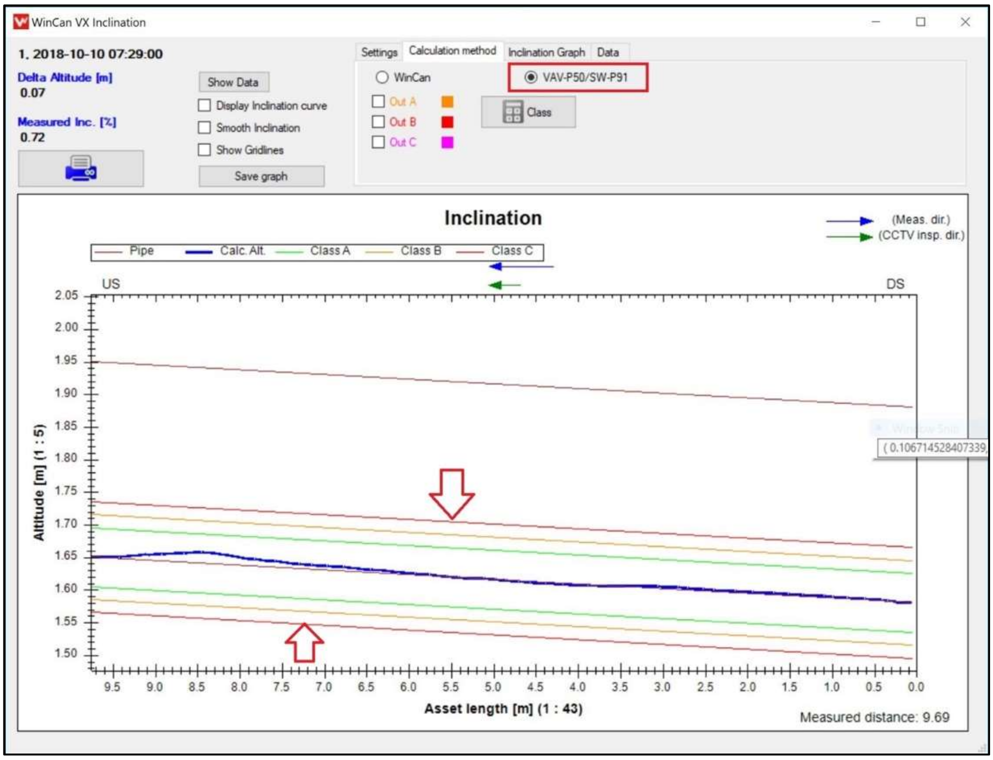


- **Display Inclination Curve** – turns on the graph of the actual data values recorded by the system during the test. Note that there is now a new scale on the right-hand side of the chart showing the inclination scale in %. Remember that when the crawler is dead level, the inclination value is zero, when it is heading uphill, the value is positive and when it is heading downhill, the values are negative. This is a difficult graph to comprehend, but it can be very useful for expert who wish to trouble-shoot their data.
- **Smooth Inclination** – simply smooths out the blue curve on the graph to a higher level than it is already. This can improve the visual output and should be considered only as an aesthetic fix.

- **Show Gridlines** – turns on the graph paper lines which can help to make reading the values from the graph scales easier.

The next level of output that we can apply is the Swedish SV-P91 grading thresholds as described earlier. These are the 3 pairs of coloured tramlines based on the lookup table from the pipe diameter and measured inclination GIS values. When this graph is printed to PDF, the Class A, B and C values will be printed on the chart. When the blue line steps outside of these tramlines, it can be highlighted a different colour by checking the Out A, Out B and Out C boxes.

As can be clearly seen, the three pairs of tramlines are parallel to (and straddle) the brown straight line that represents the theoretical 'perfect' line of the pipe between the given altitudes and the order of measurement of these guides is in mm ranging from 35mm to 95mm:



The SV-P91 class grading system is considered globally to be an excellent standard, and we would suggest that this be used in the absence of any other regional specified standard.

8. Conclusion

Many contractors in the UK already have CCTV crawler camera systems with inclinometers built-in and they also use WinCan VX. So, they already have all of the hardware and software that they need to produce these reports. That, when combined with the fact that the time taken on site to add this to an existing CCTV inspection is usually nil, and the fact that this can really develop a contractor's opportunity to secure further work makes the addition of this information a powerful and cost-effective addition to their deliverable's portfolio.

9. Definitions

- Invert level – the height of an asset or part of an asset above a datum (AOD). This term should not be used to describe the depth of a pipe or a node below the cover level.
- Invert depth – the depth of an asset or part of an asset measured down from the cover level.
- Cover level – the height of the cover of a node asset above a datum (AOD).

10. References

- Swedish Water P91 (Svenskt Vatten P91)

11. Author

- Steve Peregrine Beng Hons, Senior Technical Manager, WinCan Europe Ltd and CD Lab.