MODELLING LARGE DETENTION TANKS

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1. INTRODUCTION

Detention Tanks (frequently referred to as Storage Tanks) are nowadays frequent features of sewer systems with a high proportion of hydraulic upgrading schemes or environmental improvement schemes completed in the past decade including a detention tank.

The modelling of detention tanks has improved significantly since the early days of modelling. In those earlier days it was necessary to use several ‘fixes’ so that tanks could be modelled. Even with these ‘fixes’ the results needed to be treated with some caution. With current modelling packages it is no longer necessary to use special Tank records and the ‘fixes’ are no longer required, but it is still necessary for a modeller to understand what is happening within the model and to treat the results accordingly.

This user note discusses the alternative ways in which detention tanks can be modelled and considers the advantages and disadvantages of each. Critical storm durations and sedimentation processes are also discussed.

2. TYPES OF DETENTION TANKS

The frequently used types of detention tanks are:-

- Tank Sewers (with various cross-sections but most commonly circular);
- Insitu Tanks (normally rectangular and constructed of reinforced concrete);
- Shafts;
- Ponds (either wet or dry).

These tanks can either be on-line or off-line but most commonly Tank Sewers and Ponds are on-line and Insitu Tanks and Shafts are off-line.

3. CONTROL DEVICES

The most frequently used types of control device are:-

- Orifice Plates;
- Weirs;
- Vortex Controls (Hydrobrakes);
- Variable Penstocks;
- Pumps;
- Motorised Devices (penstocks, gate valves etc).

Most of these devices control discharges in a direct relationship with the in depth of water upstream (in free discharge conditions) (see WaPUG User Notes No 1, 2, 14 and 27); it is only with Active Control systems that the discharges become independent of water level in the tank (see WaPUG User Note No 32).

4. MODELLING ALTERNATIVES

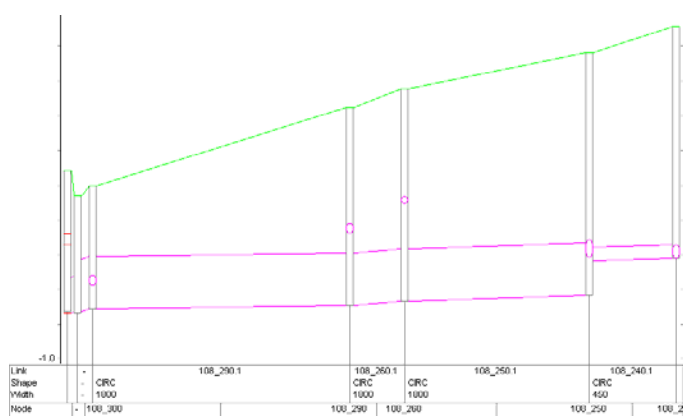
There are 3 principal alternatives for the modelling of detention:-

- Conduits;
- Nodes;
- Ponds.

4.1 Conduits

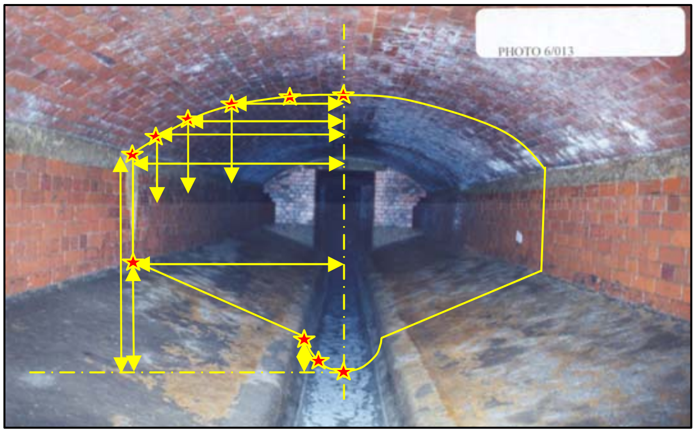
This is the most frequently used method for modelling Tank Sewers and has a significant advantage over other methods as the Modeller simply has to include the sewers and manholes in the model without having to specifically re-arrange any of the physical features of the sewerage network.

In early models the storage in Tank Sewers could only be modelled by means of the “Level Pool Effect” which required the ‘Tank Sewer’ to be modelled as a single length of pipe with an ‘On-Line Tank at the downstream end. This frequently required a number of ‘fixes’ to bring all of the incoming sewers to the head of the tank sewer with adjustments made to invert levels in order for this to work. Many models built originally in these early models still retain these modelling techniques and it is important to consider whether these can now be removed and re-modelled in more modern software packages.



In most modern packages, it is possible to satisfactorily model tank sewers with a series of pipes as illustrated to the right with intermediate nodes and with branch sewers. The control devices used in Tank Sewers are located at the downstream end and are usually governed by the water level (or depth) at that location. These can be simply modelled without any adjustments or fixes being necessary apart from normal headlosses.

It is now possible for almost any cross section of a conduit to be modelled with several points defined for each shape type in a separate ‘shape’ file. The cross-sections do not always need to be symmetrical. The diagram on the left shows the cross section of a 185 m long tank superimposed with the modelled cross section.



Modelling of Tank Sewers as 'Conduits' also has another significant advantage. The results replay facilities enable a modeller to easily view the water levels along the length of the tank and appreciate how close to ground level they reach and whether the tank is surcharged or not.

However there are some aspects of modelling tanks as conduits which the modeller should be aware of:

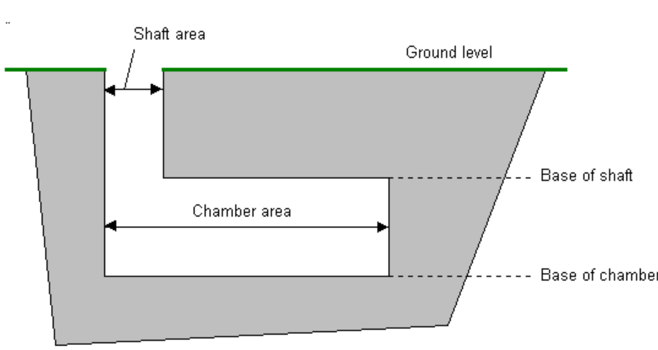
- Low flow conditions in large conduits, can sometimes cause model instabilities. To overcome this, an artificial base flow is often introduced. The base flow is usually equivalent to about 5% of the conduit height. The artificial base flow does not affect volume computations as it is removed within the boundary conditions. However when viewing a results replay on a longitudinal section the depth due to the artificial base flow is often shown.

- In some software the modelling of any conduit includes a "Preismann Slot" extending from the conduit soffit to ground level. This enables a constant series of open channel flow equations to be used and provides a steady transition between un-surcharged and surcharged pipe conditions. The width of the slot is usually taken as around 2% of the conduit width and in the case of tank sewer at significant depths the volume of the slot can become significant. This can be overcome by reducing the modelled diameter (not recommended) or reducing the plan areas of the nodes (preferred), but such measures should only be undertaken after a careful analysis of the local conditions.

It is recommended that tank sewers are modelled using the 'Conduit' technique

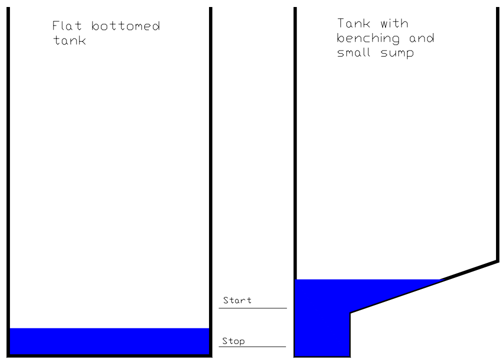
4.2 NODE

The on-line documentation in software often recommends that storage tanks are modelled as 'Nodes' with adjustments made to the plan areas for the manhole and shaft sections of the node. The plan areas used in this context should not be confused with those at normal manholes when the lower portion of the manhole will have a far smaller plan area (ref 1).



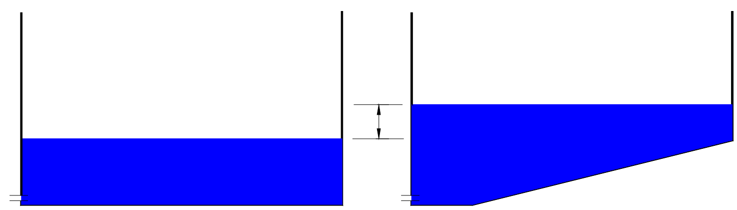
Modelling of tanks as 'Nodes' is very simple but it is important to note that the tanks when modelled this way have a flat bottom and the invert level of the control device must be above the bottom (10mm is frequently used). However it is very unusual for a large detention tank to have a flat bottom as there is either side benching or a sloping floor to try and reduce siltation in the tank. The physical layout of large detention tanks therefore means that the depths of water at the outlet control are far greater than that in a modelled tank with a flat bottom. In small tanks this is probably not a problem but in large tanks it can produce serious problems with major inaccuracies in tank water levels and tank discharges.

These problems are illustrated in the sketches below. The first sketch shows the arrangement of a tank with a pump as the control. The left hand diagram shows a flat bottomed tank whilst the right hand one shows the arrangement with benching. For the same volume of water in the tank it can be seen that the water level in the flat bottomed tank is far lower and that the pump has not started.



The other sketches show a tank with a flat bottom and with a sloping floor. Again for the same volume of water stored it can be seen that the water levels are far lower in the flat bottomed tank which would result in far lower discharges from the tank and possibly lower water levels throughout the tank operating range leading to overflow weirs being set at the wrong level.

Many people try and overcome these problems by reducing the plan area of the tank, taking an average floor level or making adjustments to the control device. Whilst these maybe considered acceptable with small tanks they should not be attempted with large tanks where the consequences (financial, operational or environmental) could be severe.



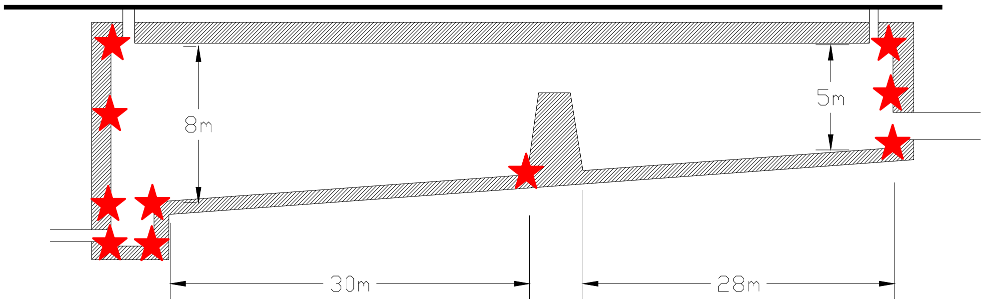
Therefore the modelling of large detention tanks as simple 'Nodes' is <u>not recommended</u>

4.3 PONDS

The term 'Ponds' in this context is perhaps mis-leading but is used because in several packages they are referred to as Ponds, it is really variable plan section storage. The technique can be used for any tank whether covered or open.

For a covered tank a rainfall profile is not specified and for an open tank (or pond) a rainfall profile is specified. Some programs treat an open pond as an impervious surface so it is important that rainfall profiles are not inadvertently added for large covered tanks.

The advantage of this technique is that any shape of tank or pond can be modelled whether it has a flat floor, sloping floors, sumps, dividing walls etc. Several pairs of figures can be given for each pond with the first figure being the level and the second figure being the plan area at that level. In-between the different stages or levels the areas are interpolated. The different stages or levels do not need to be at uniform increments.



The sketch above shows the layout of a large detention tank which was recently modelled. The tank has an overall volume of 7,753m^3 in four compartments with a sloping floor and a small sump area at the main outlet. This tank was modelled as a covered pond (i.e. rainfall profile=0) with the following stages:

When this is compared with a flat bottomed tank the difference that this modelling technique makes can easily be appreciated.

It is recommended that large detention tanks are modelled using the 'Pond' technique

Stage Level	***Plan Area***
2.410 mOD	25 m^2
3.175 mOD	25 m^2
3.600 mOD	1664 m^2
3.900 mOD	2794 m^2
4.5 mOD	2794 m^2
6.5 mOD	2794 m^2
8.3 mOD	2794 m^2
The stars on the above diagram illustrate the locations of the different stages.	

5. MODELLING CONTROL DEVICES

The modelling of the flow control device at a tank is equally as important as the choice of tank modelling technique because both of these must achieve the correct water levels in the tank in all conditions. In almost all cases the discharges are a function of the water depth and therefore if the water depth is wrong because of the tank configuration not being modelled correctly the discharges will be wrong (probably by a greater extent).

If Tank Sewers are modelled as 'Conduits' and other tanks are modelled as 'Ponds' the modelling of the flow control devices becomes very easy as the physical installation is included in the model without any adjustment (e.g. a 150 mm dia orifice will be modelled as a 150 mm dia orifice).

Further information on modelling various types of control can be found in WaPUG User Notes No 1, 2, and 27.

6. WATER QUALITY MODELLING

The Water Quality Modelling modules in current software packages will model surface (and pollutant) washoff from the catchment, sediment deposition or erosion in the sewerage network, dissolved pollutant transport through the sewerage network and hence pollutant loads (dissolved and attached to sediment) at the various outfalls or overflows in a network. Sediment deposition and erosion modelling is only usually carried out in the conduits. There is no sediment deposition onto the floors of nodes or ponds included in the program because at the moment the nodes are considered as being the locations at which all incoming flows and local inflows are thoroughly mixed before being transported along the outgoing conduits.

Modelling of the sedimentation processes in large detention tanks is a very complex matter and is beyond the scope of this usernote, which aims simply to summarise the current state of the art. It is, however, understood that much active research is underway on these aspects with the intention that before too long the sedimentation in tanks will be fully modelled.

7. CRITICAL STORM DURATIONS AND SUCCESSIVE STORMS

When any detention storage is added to a sewer system the characteristics of the system will alter significantly. The critical storm duration for the portions of the network upstream of the storage may well not alter and therefore flooding assessment can usually be based on the previous storm durations. However, for the tank itself and any downstream portions the critical storm duration (giving the worst flooding or surcharge) will probably be extended from the usual 60 or 90 minute storms to several hours. In these circumstances it is also important to consider the effects of successive storms as the tank may not be fully emptied before the next storm comes along. The Annual Time Series rainfall data is based on 1 hour dry period between storm events and this was adequate before detention tanks became a common feature.

When designing new tanks or analysing the performance of existing tanks it is recommended that a study is undertaken on the effects of repeat storms for tanks with a drain down time in excess of 60 minutes. In some cases it may be necessary to use rainfall time series to study this effect.

When considering critical storm durations it is important that this is based on sensible criteria such as surcharge levels (i.e. the number of properties with Restricted Toilet Use (RTU)) rather than the more conventional flooding criteria as the tank is likely to have cured the flooding problems.

8. RECOMMENDATIONS

The increasing power and sophistication of modelling software over the years has meant that the models nowadays are becoming a exact copy of the physical sewerage networks. It is no longer necessary to make ‘fudges’ and ‘fixes’ and carry out endless stability checks in order to get satisfactory (and sensible) results. The modelling of detention tanks is no exception to this and we should now include in the model what is actually (or will be) in the ground.

It is therefore recommended that:-

- ***For "Tank Sewers" the manholes and pipelines forming the tank are modelled exactly as manholes and conduits;***

- ***Only very simple small tanks are modelled as "nodes"***

- ***For all other "Tanks" they are modelled as 'Ponds';***

9. REFERENCES

1. Allitt R, *Simulating High Return Period Storms*. WaPUG Spring Meeting May 1998.

AMENDMENTS

Ver	Description	Date
1.	First Published	May 2002
2.	Editorial Amendments	March 2009