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Introduction

The modelling of attenuation ponds, infiltration basins, swales, channels and embankments has always been a problem when trying to use programs like InfoWorks during the design phase of options to alleviate flooding. During the preliminary design stage, it is possible to use a simplified approach such as using storage nodes, mesh zones and porous walls to determine storage volumes required. However, during the detailed design phase, these simplified approaches are no longer adequate, with the various design stipulations that commonly need to be adhered to.

This paper will examine how these issues were overcome for a flood alleviation scheme for a project at Filey where a scheme was required in order to deal with pluvial runoff from surrounding areas.

Background

On the 18th July 2007, 82mm of rain fell in 90 minutes in Filey, a small coastal town in North Yorkshire. Due to the town being situated in a depression, significant overland flow from the surrounding arable fields occurred. This resulted in flooding of over 200 residential properties and a school, and caused severe erosion and scour to St Martin's Ravine, which is the main drainage outlet for the town and route to the beach, causing it to be closed for a year for re-stabilisation.

As a result of this event, a scheme comprising of a series of channels, embankments and ponds was developed to intercept these overland flows and protect the town from flooding. Richard Allitt Associates acted as a sub-consultant to Royal HaskoningDHV who was responsible for the detailed design and implementation of the scheme.

Current Practice

The current practice when incorporating 3D structures into a model is to use a simplified approach of mesh zones, river reaches and porous walls (Figure 1). This method is ideal during the initial design phase, as it allows for testing of the scheme to be undertaken, a preferred option to be selected from this and approximate storage volumes to be determined.

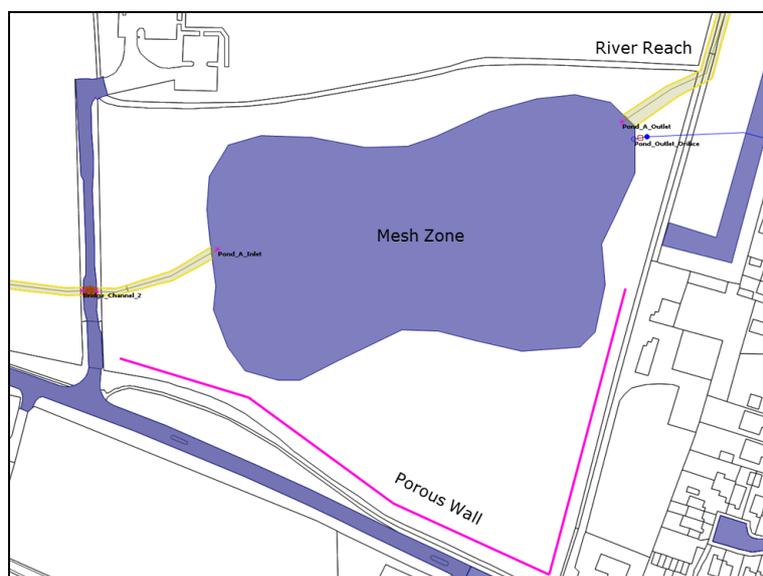


Figure 1- 3D structures modelled as mesh zones, porous walls and river reaches

During the detailed design stage, there are normally specific design criteria to adhere to, such as a maximum gradient on all slopes and a minimum distance from buildings. Many schemes also need to achieve a balance in the earthworks so that there would be no net import or export of material for budget and environmental purposes. The current modelling practices do not help scheme designers determine the true scale and volumes of the proposed structures, as they are often modelled with vertical sides so do not spatially represent the actual extent of the structure with slopes.

In addition, an important aspect of publically funded flood defence schemes is the approval from a variety of different stakeholders. As many of these stakeholders are non-technical, it is important that the visualisations of schemes are easily understood. This is often not achieved with the most common method of modelling 3D features as storage nodes and mesh zones, as these are only easily understood by modellers and can be misinterpreted by others. This is therefore where the incorporation of 3D features into the DTM becomes important.

As a result of these concerns, a decision was taken during the detailed design phase for Filey to incorporate the 3D structures directly into the DTM. This can be achieved by using two different techniques using the Global Mapper program and 3D AutoCAD.

Building 3D structures in the DTM using Global Mapper

The first technique involves using the tools within Global Mapper, a raster and vector GIS program, to manipulate the DTM to include the 3D structures.

The program enables the user to define a polygon (the crest of an embankment or the base of a pond) with a uniform level, which the program will then project upwards or downwards at the specified ground slope to meet the existing ground level. In the case of a large balancing pond with side slopes of 1 in 4 in a field with a general slope of 1 in 10, this ability to work in 3 dimensions is absolutely essential.

The process of adding a storage area into the DTM is shown in Figures 2-6. This example is showing the creation of a storage area which included an embankment on the southern side of the structure and some excavation within the pond area.

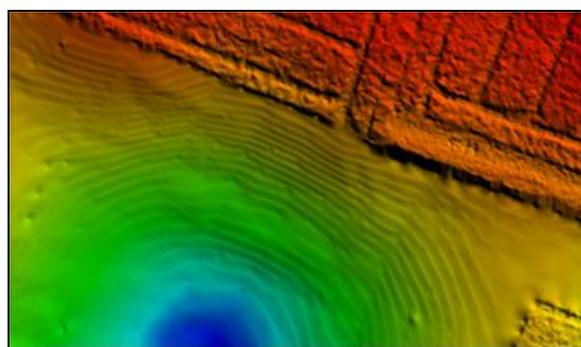


Figure 2 – Original DTM

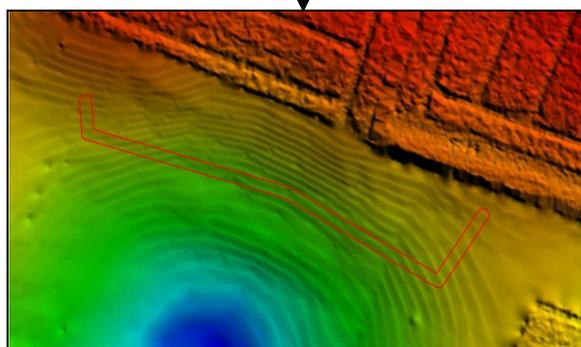


Figure 3 - Extent and crest level of embankment



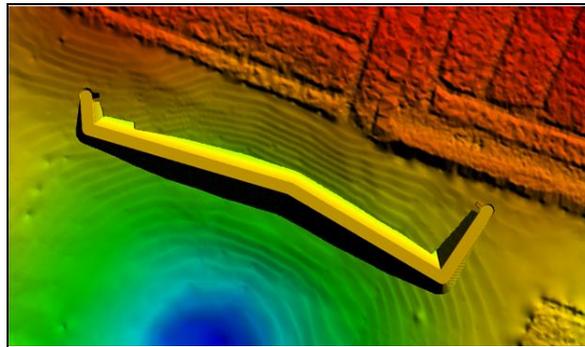


Figure 4 - Extruded embankment with 1 in 4 slope

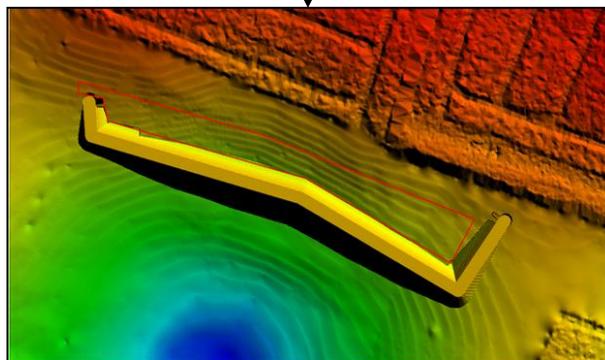


Figure 5 - Extent of storage area base

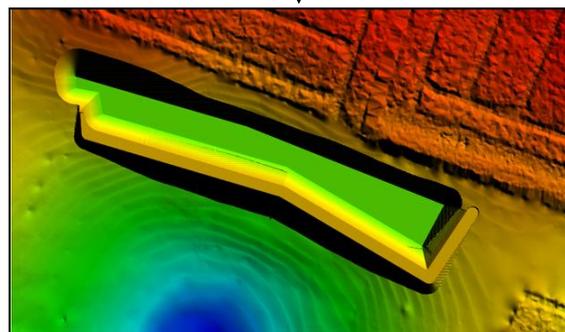


Figure 6 – Final storage area

This method allowed for rapid prototyping of various iterations of the proposed storage pond areas, as adding the 3D structure to the DTM took less than 10 minutes. It is possible to quickly adjust both the depth of storage areas and the height of the embankment. The updated DTM can then be used in InfoWorks using both the terrain sensitive meshing function and break lines around the top of the embankment or pond so that the pond or embankment is fully represented in the 2D mesh and can be used for simulations.

Whilst this method works well for embankments with a constant crest level, if the embankment needs to be at differing heights, or the base of a storage area needs to slope towards the outlet, this is more difficult and time consuming to achieve. The recent addition of mesh level zones to the Infoworks ICM package (which was not available during the detailed design phase of the Filey project) allows varying elevations to be modelled.

Additionally, swales and channels, which by their nature have reasonably uniform cross-sections and a longitudinal slope are currently difficult to build into a DTM. These features are currently best modelled within the Infoworks ICM package, defining them initially as an open trapezoidal channel and then convert into a 1D watercourse channel. Once the bank lines are built, the swale or channel is able to intercept overland flows and route them within the channel.

Building 3D structures in the DTM using 3D AutoCAD

The most common program used for creating engineering drawings for scheme design and subsequent construction drawings is 3D AutoCAD. It is therefore useful to be able to bring these designs directly into the DTM, which can be achieved by again using Global Mapper.

A section of the existing DTM is extracted covering a larger extent than just the proposed 3D structure. A buffer region (width dependent upon data resolution) is generated around the extent of the AutoCAD drawing forming a donut polygon. Regular XYZ points were generated to match the data resolution within the buffer region, ensuring that the AutoCAD generated contours merge correctly with the existing DTM levels without steps, pits or peaks. The contours exported from 3D AutoCAD were then combined with the XYZ buffer points, adding in break lines or points where necessary to ensure that the resulting surface is free from artefacts once interpolated. The interpolated surface is then clipped to the buffered boundary to eliminate any effects the interpolation has had around the outside of the pond due to Global Mapper interpolating the data using the convex hull principle where points are interpolated using a triangulation method.

The process of adding a storage area into the DTM using a 3D AutoCAD drawing is shown in Figures 7-11. This example is showing the integration of the largest storage pond designed in Filey into the DTM.

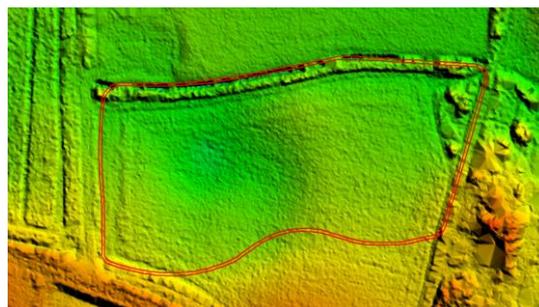


Figure 7 – Extent of proposed storage area with 2m buffer

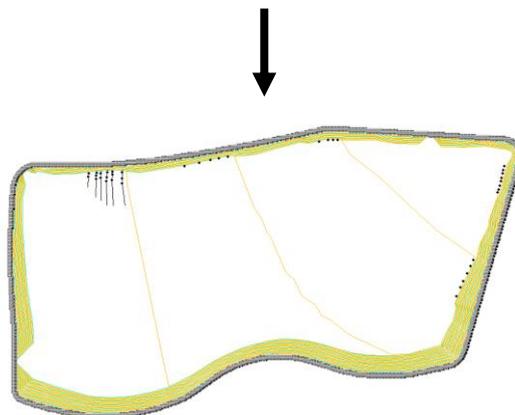
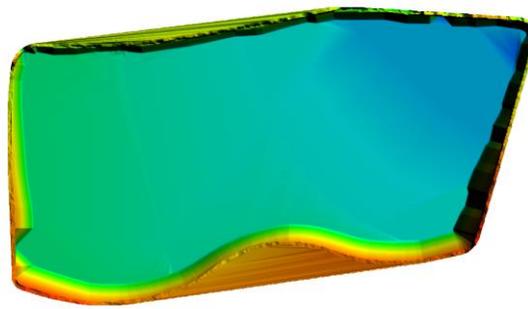


Figure 8 – Contours added into Global Mapper and combined with XYZ points.





*Figure 9 – Interpolated surface created from points and contours.
Note interpolation artefacts (particularly on southern bank due to convex hull)*

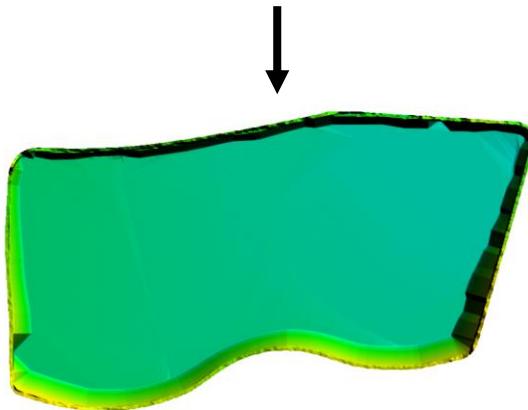


Figure 10 – Interpolated storage area clipped to buffered storage pond polygon.

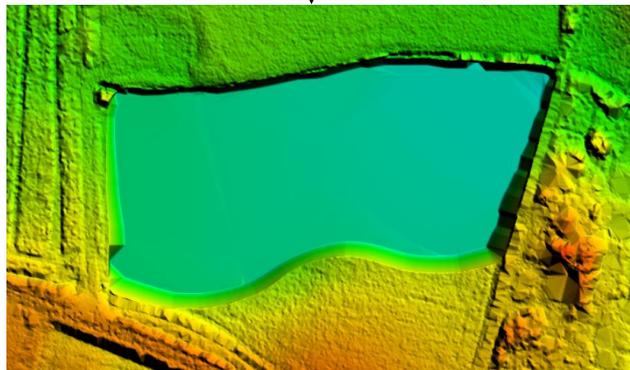


Figure 11 – Storage area merged within the existing DTM.

The major advantage of incorporating the 3D AutoCAD drawing into the DTM is that the model is directly testing the same scheme drawing which will also be used during the construction process. This means that there is less risk of work duplication and mistakes due to misinterpretation or using different data sources and formats.

The limitation of modelling 3D features within the DTM is the resolution of the elevation data. For Filey, the DTM was improved by incorporating a topographical survey and up-sampling the output resolution of the output DTM to ensure that these areas of higher detail were incorporated before the detailed design was undertaken, thus minimising this effect.



Conclusion

Whilst using approximation techniques such as storage nodes and mesh zones is appropriate at the preliminary stages of the design, accurate modelling of 3D structures within the DTM is essential when developing the detailed design.

Having a DTM that accurately represents the final scheme within the available space is far easier to visualise for both the stakeholders and the general public. DTMs, represented as a raster grid are easily used for outputs for other purposes such as watershed analysis, fly-through animations, or public consultation visualisations. These outputs are not possible to be created with the design built within the modelling software without considerable work converting the outputs, or remaking the final scheme in the appropriate software from scratch. With the current drive of working in partnership and the inherent visual nature of modelling, it seems logical that the next step in modelling is to directly detail design schemes by adding them directly into the DTM.

Acknowledgements:

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