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Post-calculation checks of GSI3D Models V2

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Post-calculation checks of GSI3D Models V2

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Front cover

Cross-sections from the Central Glasgow Model showing a before and after example of cross-section remediation.

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Summary

This report describes methods for identifying, checking and remediating issues in GSI3D models post calculation using cross-sections and exported surface and thickness grids. These checks are to ensure that the outputted geometry of geological units bear a true resemblance to the lateral and depth extents of those units correlated in GSI3D.

The cross-section checks and issues include:

- Missing envelopes or cross-section correlations geometries
- Lack of correlation nodes on cross-section lines
- Wrongly attributed correlation lines in cross-section
- Lack of constraint at envelope boundaries

The surface and thickness grid checks and issue include:

- Bulls-eyes from anomalous correlation points
- Holes in the top and base calculated surface
- Surface crossovers
- Unnatural artefacts in modelled surfaces from cross-sections

1 Introduction

An important part of the model checking process is done in post calculation. This allows you to see whether the 2D and 3D distribution of geological has been calculated correctly. This is very important when making volumetric calculations and assessing the distribution of these units. Please refer to the GSI3D 2011 manual (Mathers *et al* 2011) for related information regarding the checking of models.

All of the cross-sections in section 2 have been generated from calculating the model and looking at the synthetic outputs from the calculation. The snapping functionality has now made some of these problems easier to avoid but for older models or models that pre-date this functionality the following checks should be made to improve the calculation of the model and the surface triangulation, and the resulting surfaces generated.

Before checking the model, you must calculate it by doing the following: ***Calculate – NonFaulted – Calculate All units from Sections and envelopes***

Once the model has been calculated do the following to view the 'calculated' or synthetic output of each of the existing sections: ***Right click in the Cross-section window – Window Properties – Click off Polygons under Correlated section rendering – Click On Polygons for Synthetic section rendering*** (**Figure 1**).

The next stage is to **go through every cross-section** to see if any of the calculated units are missing/have a spiked triangulation or have a peculiar geometry compared to the original correlation lines. In the following pages there are examples of the kinds of issues to look for in post calculation and how to remediate these to improve the calculation of the units.

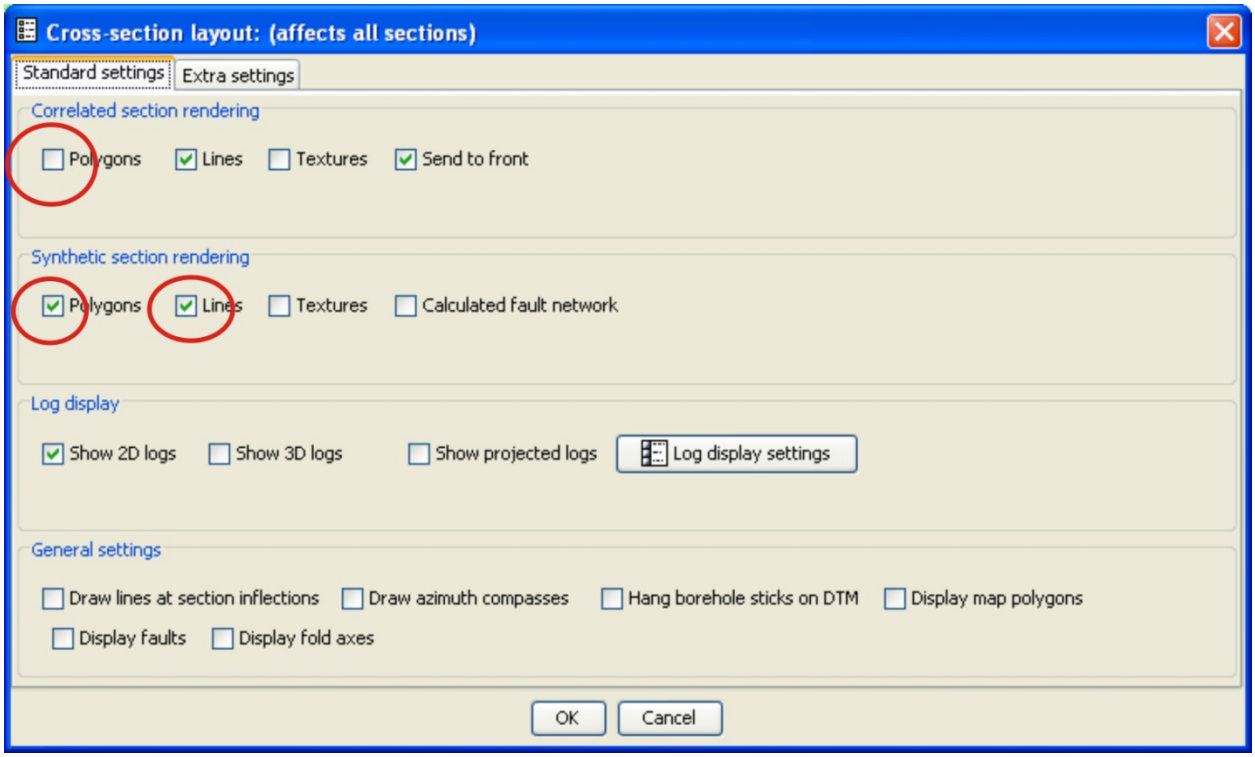

Figure 1 – Setup for checking calculated sections in cross-section

2 Post-calculation checks and remediation for cross-sections

2.1 GENERAL CALCULATION ISSUES

Check the calculation does not take overly long or does not finish – occasionally this can be seen if the certain units are not calculated or take a very long time to calculate (successful calculation indicated by aterisk * in top left corner of geological unit and a pop-up box indicating the calculation has finished). **Figure 2** indicates where the calculation progress can be monitored.

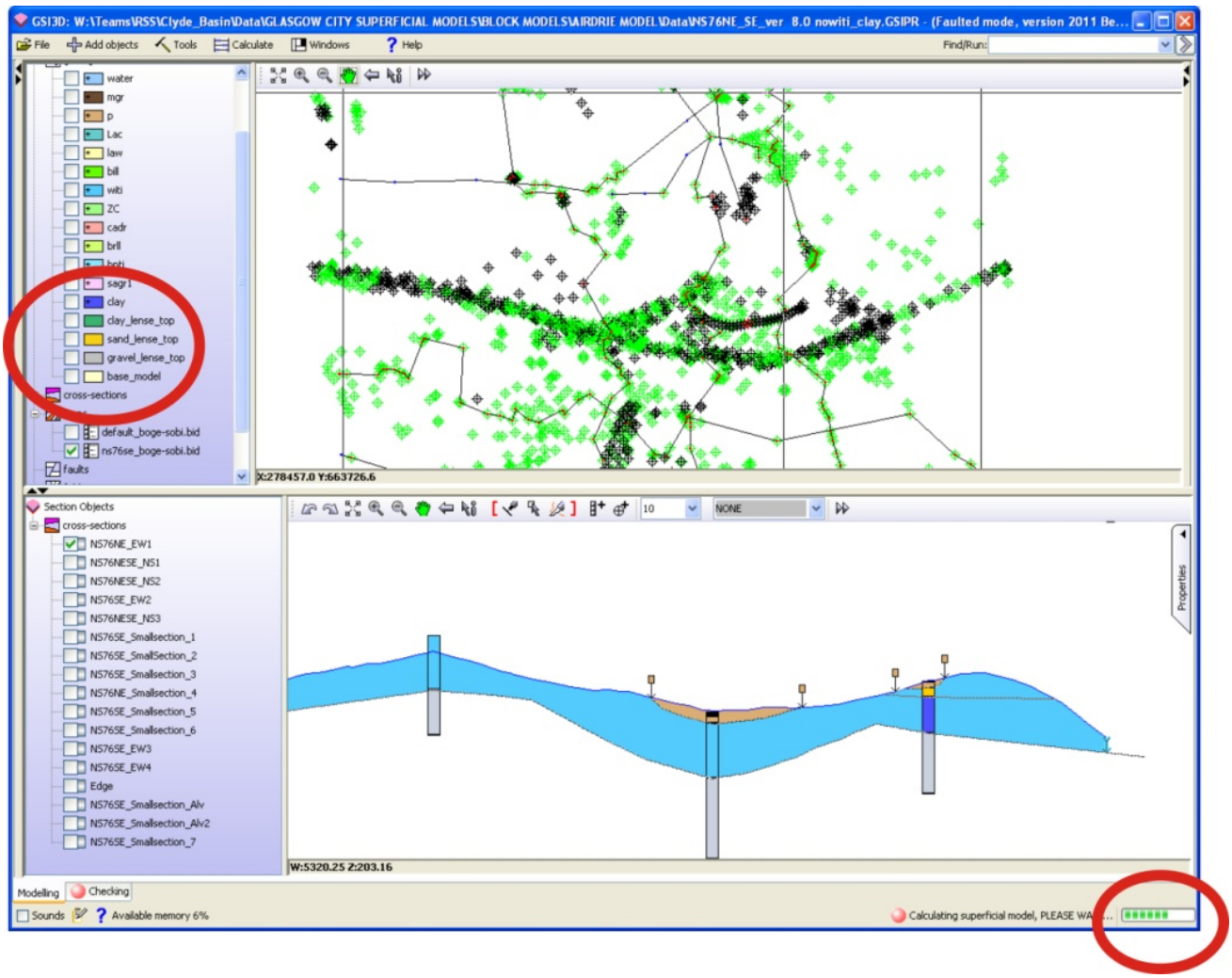

Figure 2 - Calculation Progress Monitoring

A number of factors could contribute to the unsuccessful calculation of a model. These include:

- Wrongly attributed units in the ID GVS column (e.g. the numbering order has been corrupted or is no longer sequential)
- Java Memory runs out (Check Java console for an indication of this). This could be due to large DTM sizes (generally those above 10mb) or large image sizes within the project (those above 2mb)

2.2 WRONGLY ATTRIBUTED LINES AND MISSING ENVELOPES

If when viewing the calculated cross-section, the correlation line exists but does not appear to be forming a calculated unit in cross-section then it is probably one of the factors below:

- The correlation line could be unattributed with anything from the GVS list and will appear to be attributed with **NN** (no name) or wrongly named as in **Figure 3**. Please re-name the line as applicable from the GVS
- The correlation line could be wrongly attributed from the list in the GVS and therefore not match the envelope defining its 2D distribution. Please re-name as applicable
- The envelope for the correlated line could be missing as in **Figure 4**. Please draw the necessary envelope required to match the correlation line in the cross-section

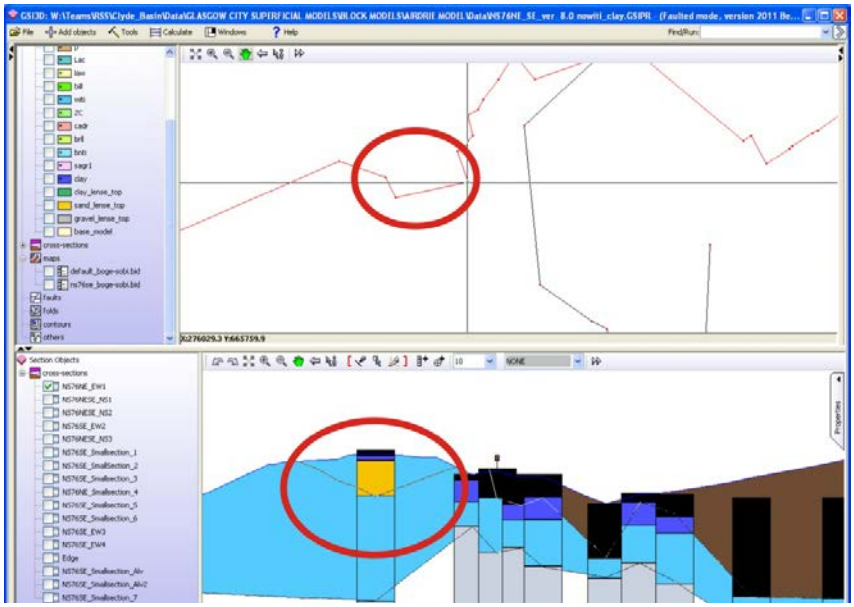

Figure 3 - Wrongly named Correlation Lines

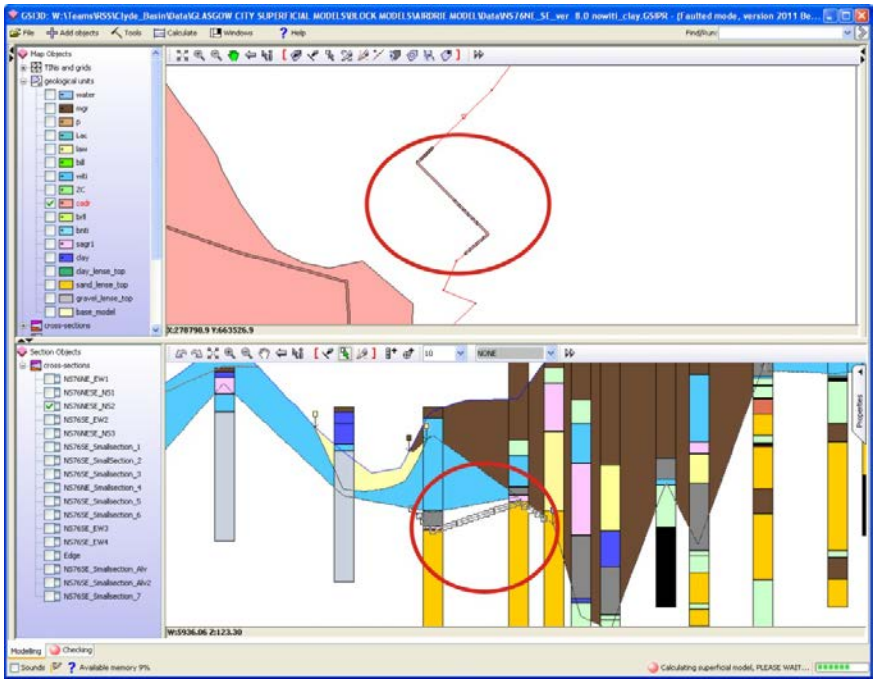

Figure 4 - Missing envelopes for correlated lines

2.3 ENVELOPES NOT FULLY EXTENDED

For each of the units the cross-section correlations must be covered by an envelope for it to calculate and form a surface. **Figure 5** shows an example where the geological unit has not been calculated to its full extent on the cross-section. Where this occurs, envelopes must be extended to cover the extent of the correlation on cross-section or the cross-section must be investigated to see if the correlation should actually exist there.

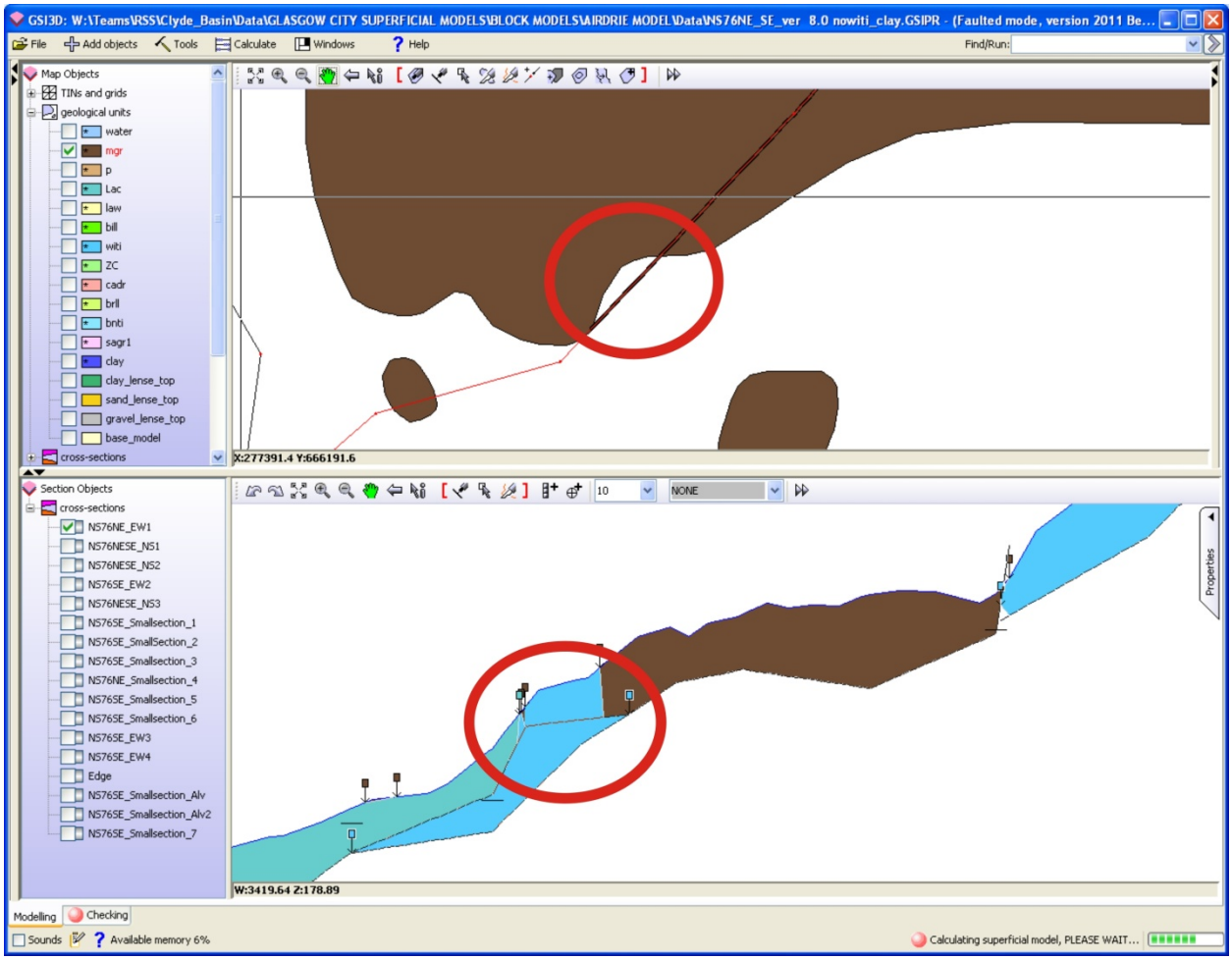

Figure 5 - Cross-section envelope missing full extent of envelope

2.4 LENSE ISSUES

Lenses must have a base and top correlated in cross-section for the calculation. Only the Top lense needs to exist in the list of the geological units and have the envelopes drawn for it. A reason why a lense will not calculate is because the correlation lines are not tightly linked together in cross-section (i.e. the area in which the top lense line meets the base lense line). The envelope for the lense must also be tightly wrapped around the cross-section correlations. The snapping functions in GSI3D do not exist at present for snapping lense to cross-sections to lense outcrops so this must be done eye.

If the lense still does not calculate please check the GVS to make sure the top has a negative ID and the base a positive ID with the same number (e.g. Top Silt lense = -450, base silt lense = 450)

Below is an example of a calculated model section showing a lense that hasn't been calculated correctly (**Figure 6**) and the areas in the map window and cross-section window to check the tightness of the correlation lines.

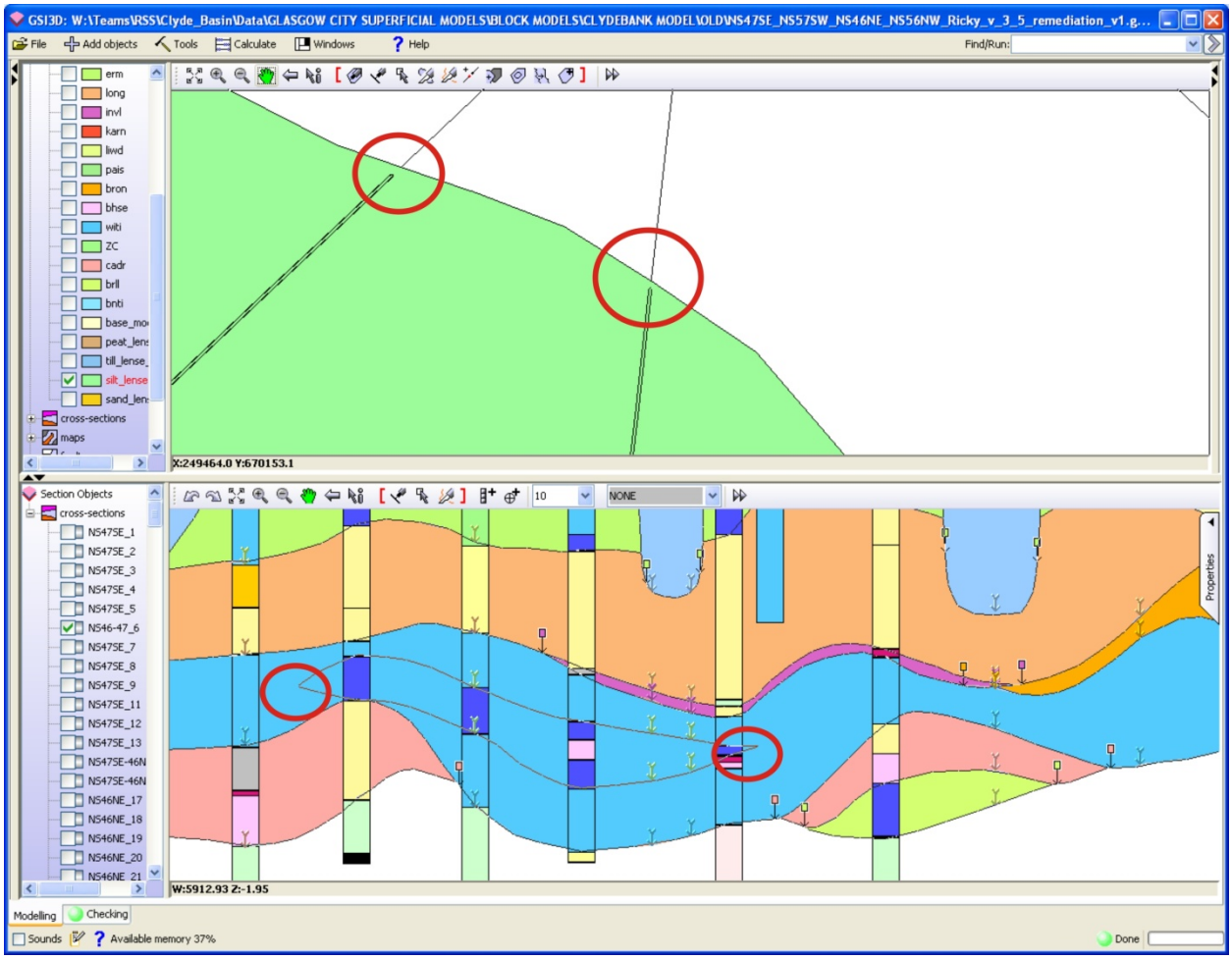

Figure 6 - Incorrectly calculated lenses

2.5 MISSING ENVELOPE EXTENSIONS

A common error that occurs is where the envelope has not been extended far enough to the end of where it has been correlated in cross-section. **Figure 7** shows an example where the blue (water) envelope needs to be extended so the unit is calculated to its correct extent. This can be remediated by simply extending the envelope over the area of correlated section or changing the extent of the correlation in section

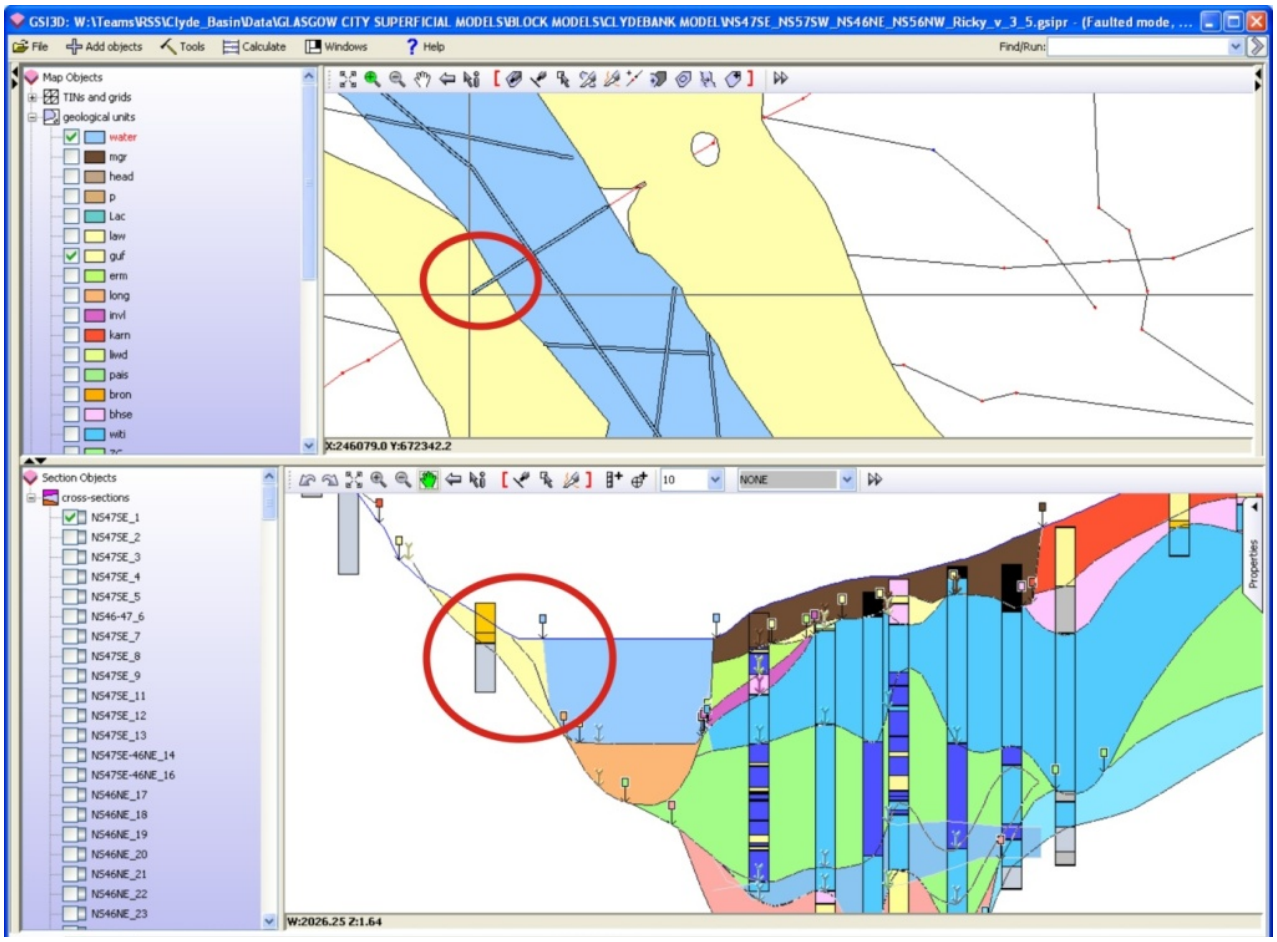

Figure 7 - Envelope extensions needed

2.6 MISSING CORRELATION LINES ON SECTION OR MISSING 'HOLES' IN THE ENVELOPE

In some of the cross-sections, the geological unit may appear to be incorrectly calculated or have an incorrect geometry due to a correlation line not actually existing for that unit in cross-section but where an envelope does exist for that unit. The reasons for this include:

- Missing 'holes' in the envelope where the correlation has stopped mid-way through the section but the envelope still exists over this area **Figure 8**
- An envelope has been extended too far beyond the end of the section as in **Figure 9**
- The correlation needs to be added to the cross-section where the envelope exists in that area **Figure 8 and 9**

To remediate this issue, the surrounding geological data must be assessed and that is why either of these scenarios could exist as seen in figures below**.**

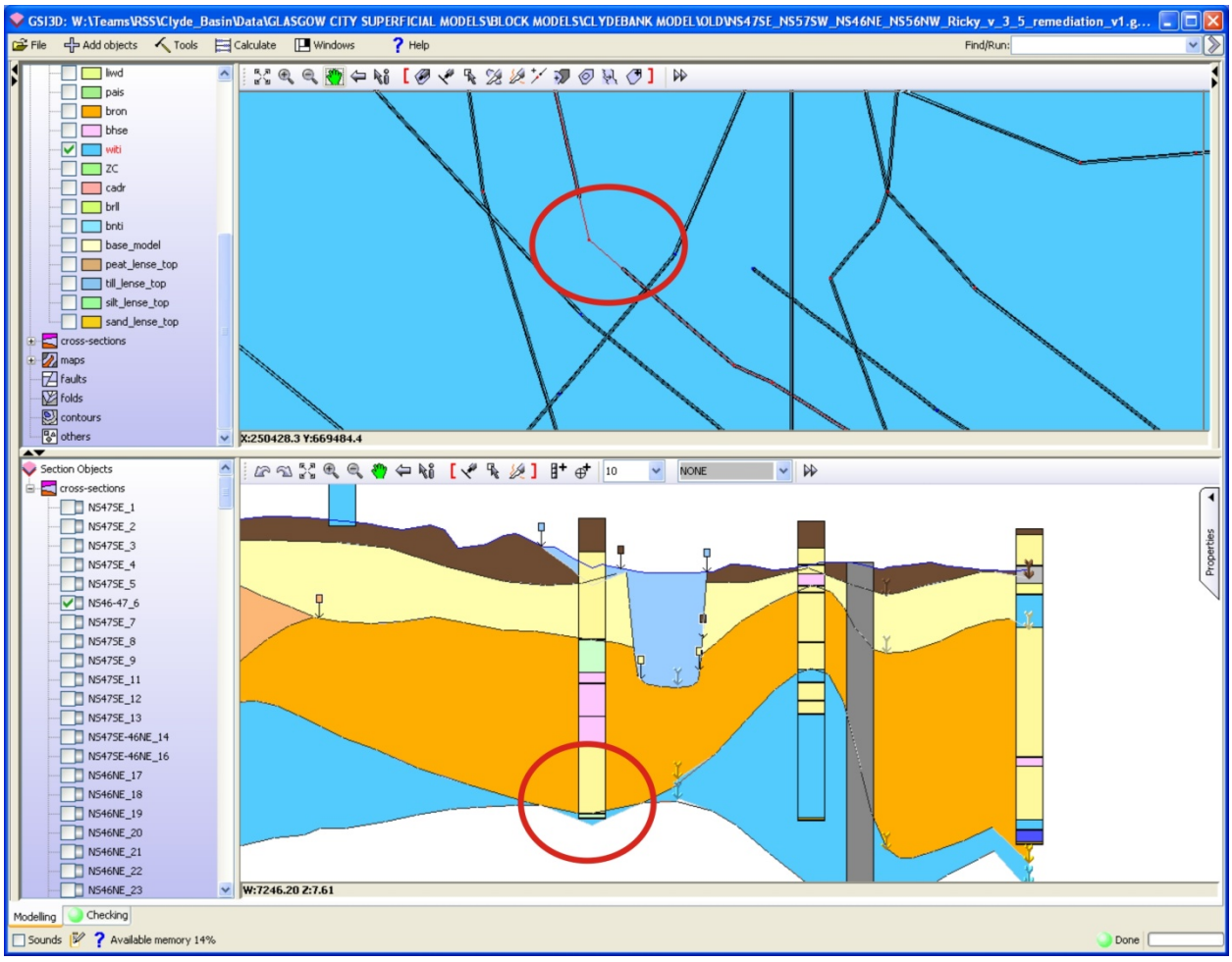

Figure 8 - Missing hole in envelope

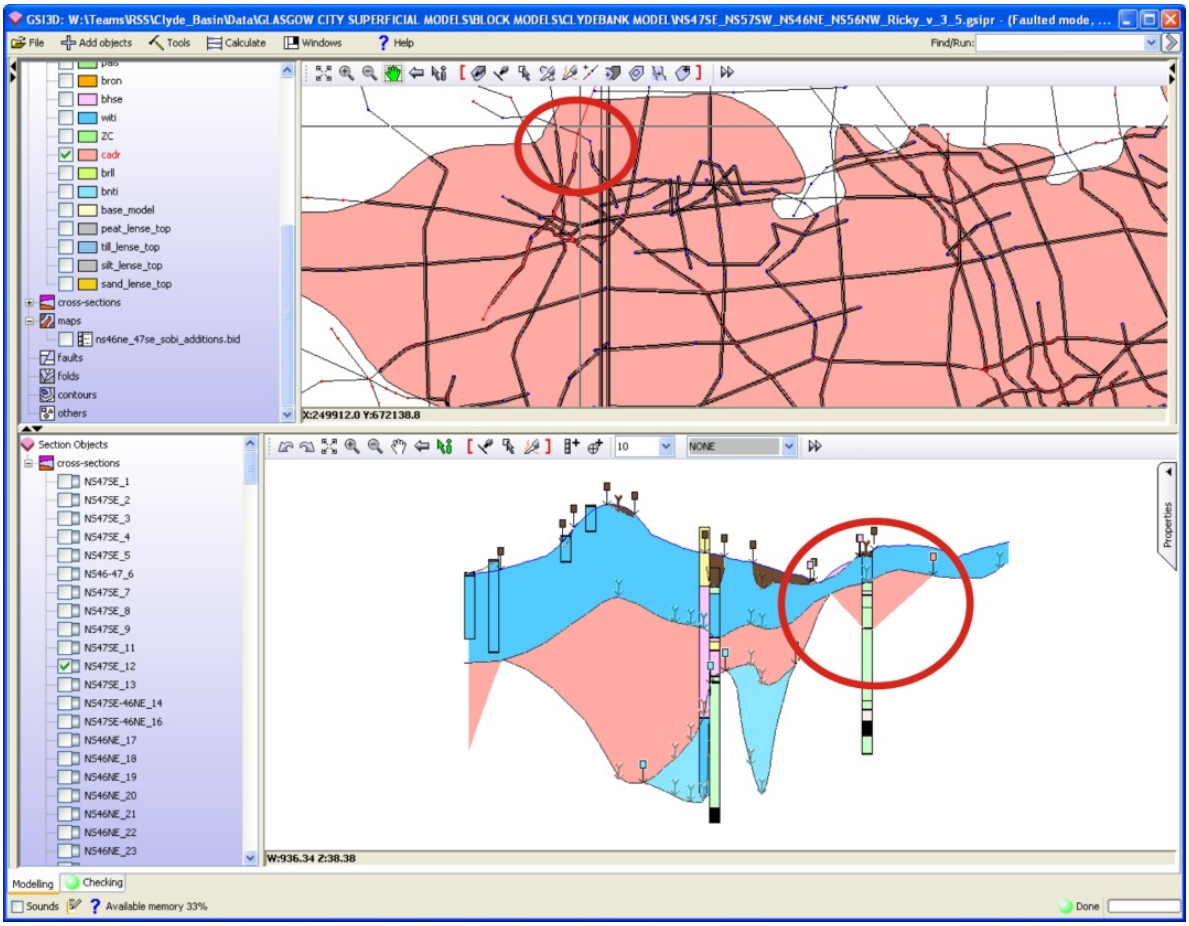

Figure 9 - Envelope or cross-section correlation needs editing

2.7 LACK OF NODES ADDED TO CORRELATED LINES

A common problem with thinner geological units (e.g. head, alluvium) is where there are not enough nodes on the cross-section correlation for the triangulation to calculate a full distribution of the unit. This will be shown in cross-section as ‘spiked’ triangular projections where the unit should be flat and continuous (**Figure 10**).

This can be remediated by adding nodes on the correlation line at the base of the spike/triangle where it spikes upwards as shown by the arrows in **Figure 10**. There is a *Densify Line* tool in GSI3D that can help you fix this quickly but this should be used with care as it makes future editing cumbersome and calculations take longer.

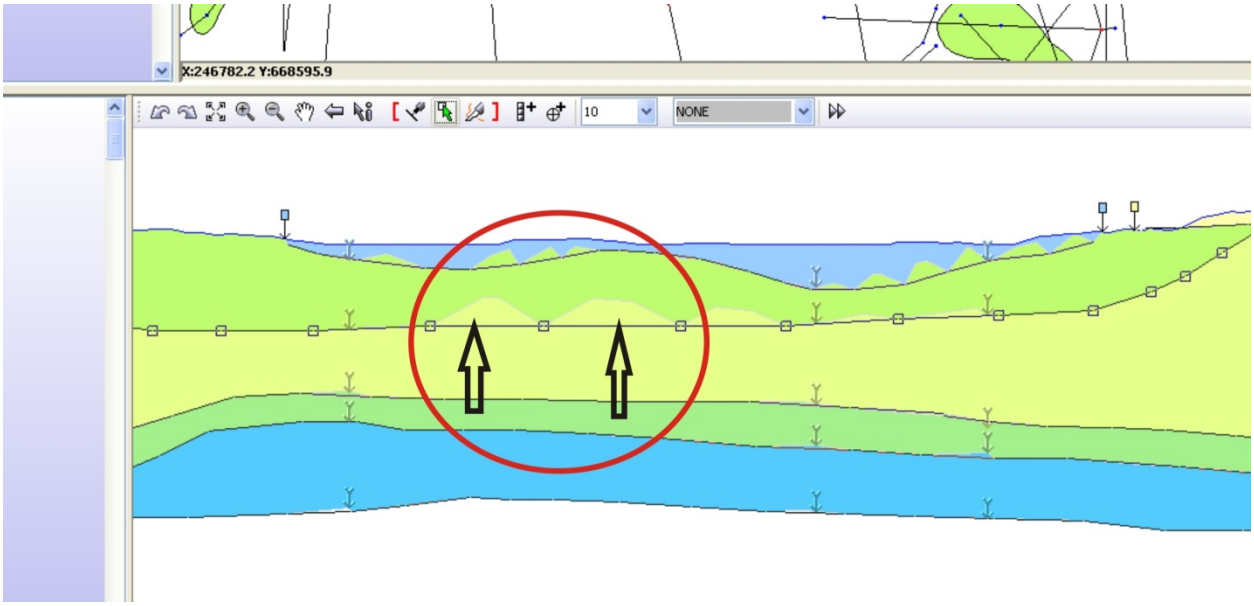

Figure 10 - Adding nodes to improve triangulation

Further testing of the model the model triangulation can be achieved by creating new sections in the model and viewing the synthetic outputs. This will help indicate where 'Helper' sections might need adding, or where the calculation is poorly constrained.

3 Surface and thickness grid checks

An important post calculation check is to generate a grid inspection of the top and base surfaces and the thickness (isopach) maps generated from exports produced from modelling software such as GSI3D and GOCAD®. Areas of extreme high or low values in the thickness of the unit or where there are isolated areas of extreme thickness or thinness of a unit (bulls-eyes) could indicate errors in the correlation or poorly calculated areas (Section 3.2). In some cases these could be true representations of the changing thickness of a unit. In all of these cases, it would be necessary to go back to the original model to check if the data corroborates the top and base anomalies and thickness grids produced.

Likewise, by assessing the top and base unit grids it is possible to identify unit areas which may or may not have calculated to their full extents so they appear as holes in the surface grids (Section 3.3).

Surface crossovers can occur for example if the model is poorly constrained, where there are many thin geological units, or the surfaces undulate steeply across the area. By assessing the thickness grids produced, negative values can indicate where these crossovers occur (Section 3.4).

Some other unnatural features may appear from assessing grids, such as the influence of bounding sections between model areas, sometimes known as docking sections. These can unnaturally influence the depths recorded which appear as a linear feature (Section 3.5).

In the following sections, there are examples of how to produce these outputs, and identify these potential errors in the model.

3.1 METHODOLOGY - GRID EXPORT AND IMPORT FOR ANALYSIS

The following steps show how to export grids from a GSI3D project, convert them to ESRI grids and then change their symbology classification to help identify any potential anomalies in the surfaces or thicknesses of the unit. Please note – this will only work for superficial calculated projects in GSI3D but please check if the grids have already been exported before proceeding.

1. Open the GSI3D and calculate the model. Use the **Calculate all units from sections and envelopes** (**Figure 11**). The other option actually creates holes in the model where a surface is poorly constrained and results in a calculation above the DTM.

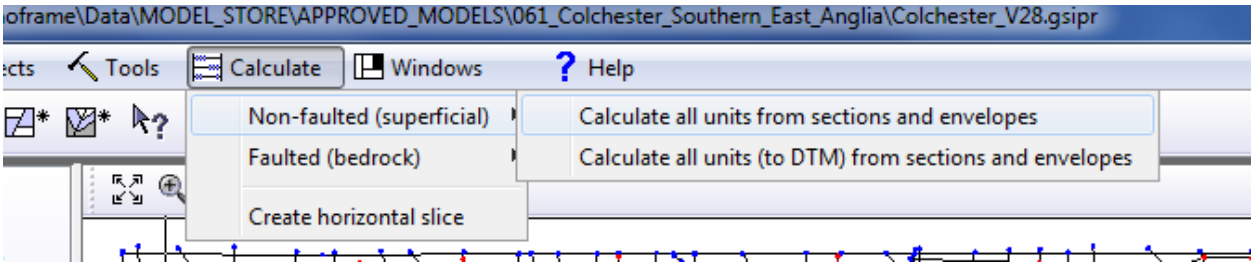

Figure 11 Calculating a GSI3D Model

2. Once the model has finished calculating, export the grids by right clicking on **Geological Units in the Map Window TOC – Import and Export – Export all as grids** (**Figure 12**).

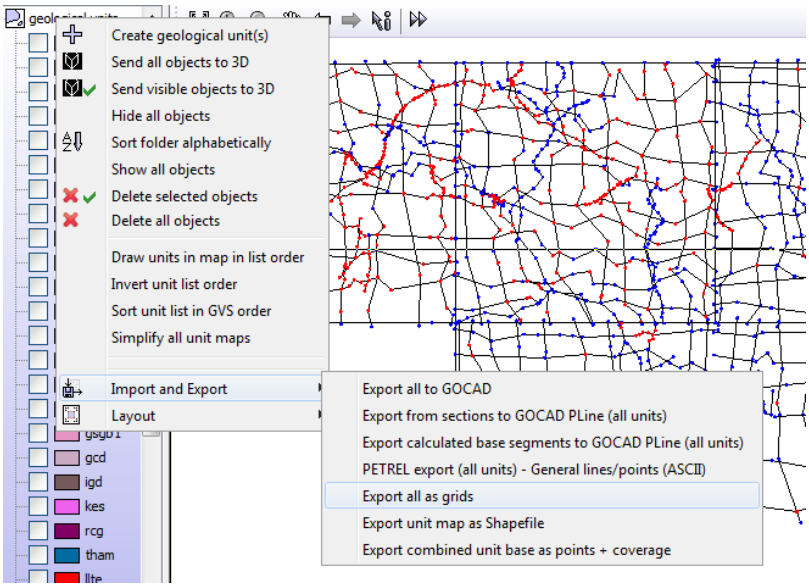

Figure 12 Exporting grid unit tops, bases and thicknesses from a GSI3D model

3. The following dialogue will appear. The default grid extent can be kept the same as this gives the full model area. The cell size must be changed to something more suitable depending on the resolution of the DTM and model, such as 25 m or 50 m for superficial models. Even at this cell size, some units may appear patchy such as the thin sinuous units like Alluvium or Head for example. See section 3.3 for more details on checking these units. Select a folder to save the grids to and press OK. (**Figure 13**).

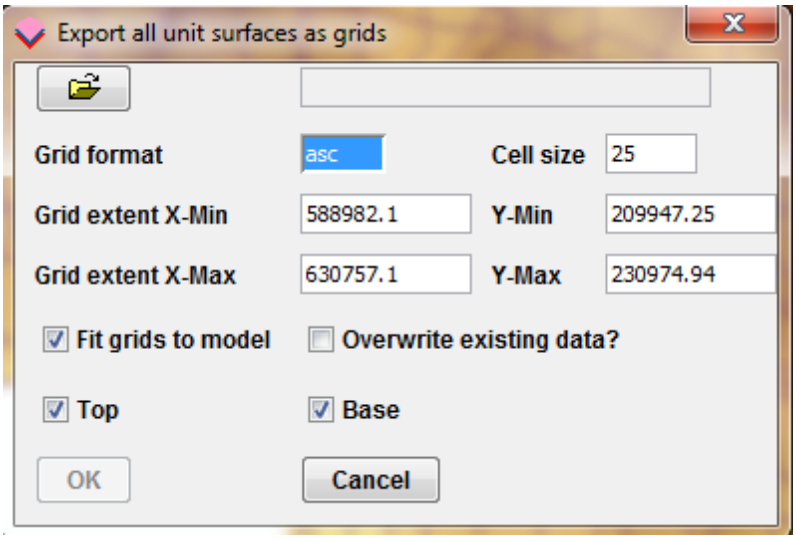

Figure 13 Grid export options

4. These grids will appear as ASCII grids (.asc) in the folder specified. There should be three files for each unit, a base surface (_B), a top surface (_T), and a thickness calculated from the top and base surfaces (_TH). These can be loaded directly into ArcGIS, however it might be necessary to convert them to ESRI grids if to re-classify them using the classified symbology options (See step 5).

5. The ESRI ArcGIS GSI3D toolbar can be used to do a bulk conversion of the ASCII grids to ESRI grids (Please note - When converting to ESRI grid, any files names of more than 13 characters will not be converted as there is a file name restriction size for ESRI grids – **Figure 14**)

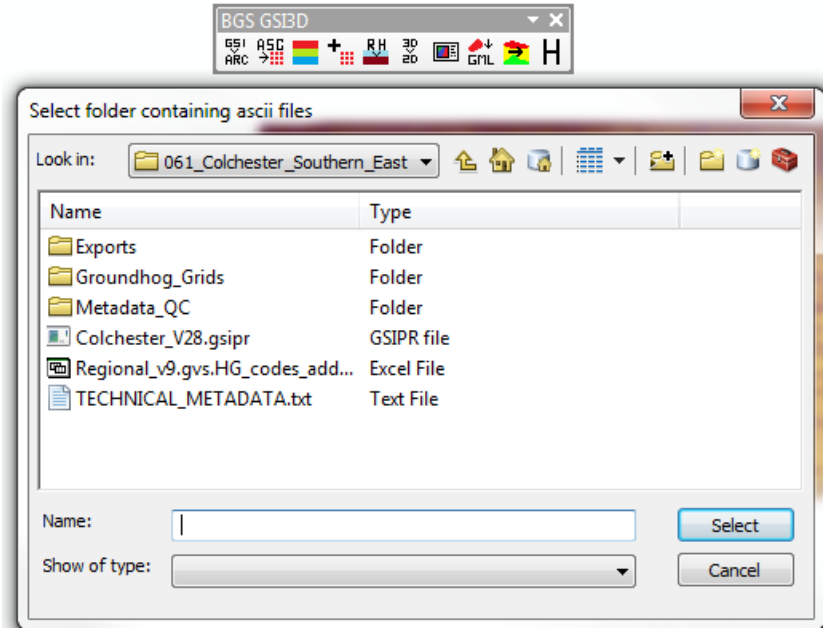

Figure 14 Bulk conversion of ASCII grid to ESRI grids

6. The ESRI grids can be imported directly into ArcGIS. To help identify any potential anomalies, the colour ramp for the ESRI grid can be altered as shown in the example below (**Figure 15**) or re-classified to identify extreme values (**Figure 16**). To edit the colour ramp, either double left click directly onto the colour ramp and choose a suitable colour ramp to visualise the gridded surface or right click on the grid object – Properties - Symbology and change the colour ramp to something suitable to identify features easily (**Figure 15**).

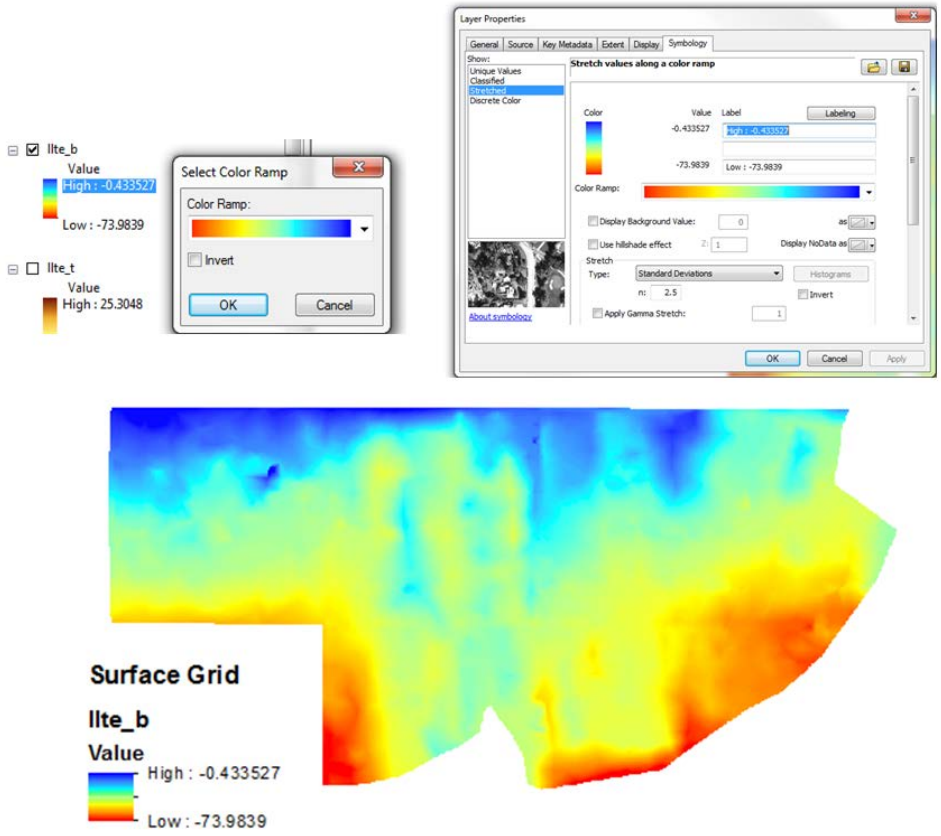

Figure 15 Colour ramping grid data

7. By re-classifying the data colour ramp into partitions, it is possible to identify extreme values, or values that should not occur such as negative thickness values. In the example below, the **Break Values** have been adjusted for the thickness grid data of the Top Lias to the ground surface. Therefore anything below zero is coloured up as black and can be indentified easily within the map view (**Figure 16**).

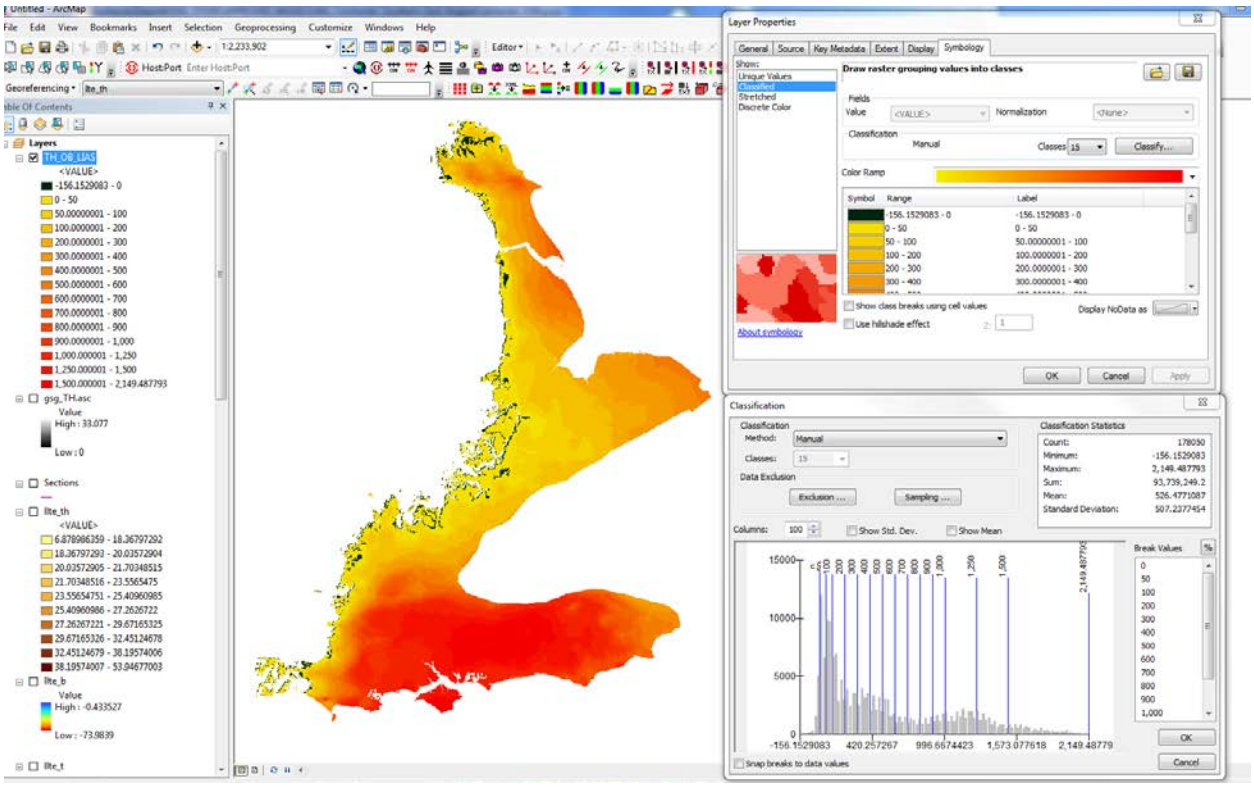

Figure 16 Re-classifying data using break values

8. An additional export from the GSI3D project which can increase the speed in which to identify any anomalous data are the GSIPR exports using the ArcGIS toolbar. . This tool exports the sections, boreholes and envelopes as shapefiles. These can be added to the ArcGIS project and by using the boreholes and sections overlain onto the grid exports, potential anomalies within the GSI3D data can be identified quickly (**Figure 17**).

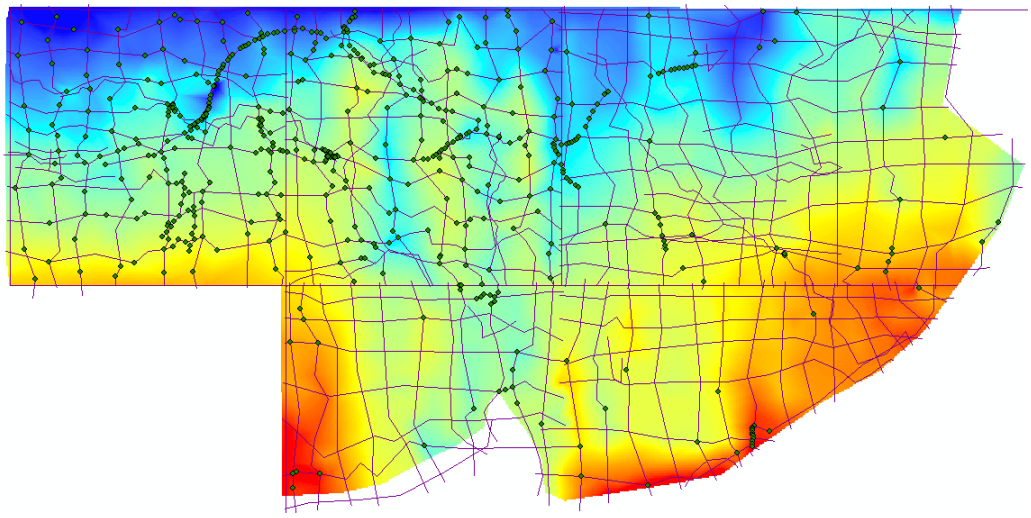

Figure 17 Grid (with colour ramp), section and borehole locations

3.2 CHECKING GRID EXPORTS FOR BULLS-EYES

Bulls-eyes in surfaces or thickness grids indicate sharply changing gradients in isolated areas. These might be natural features such as scour hollows (Royse et al., 2008) into which there are terrace gravel infills into the upper bedrock surface which commonly occur in London, or dissolution hollows where material may have collapsed and fallen into hollows into rocks that are susceptible to dissolution. Faulting in bedrock surfaces may show sharp undulations in the top and base surfaces, however, the thickness of that unit should remain quite consistent between these faults. These are just a few examples where these types of artefacts reflect natural variations in the geological structure.

However, in some instances these might be artefacts caused from a poor calculation of the surface, mistakes in the interpretation or a lack of data. Below is an example of a potential bulls-eye highlighted in red (**Figure 18**)

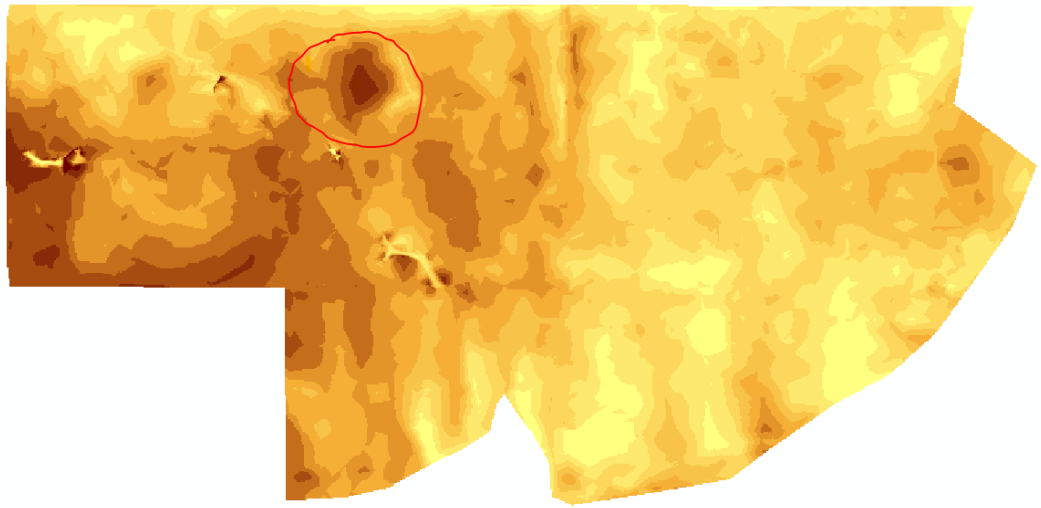

Figure 18 Bulls-eye identification

By overlaying the sections and boreholes, the potential problem areas can be identified and

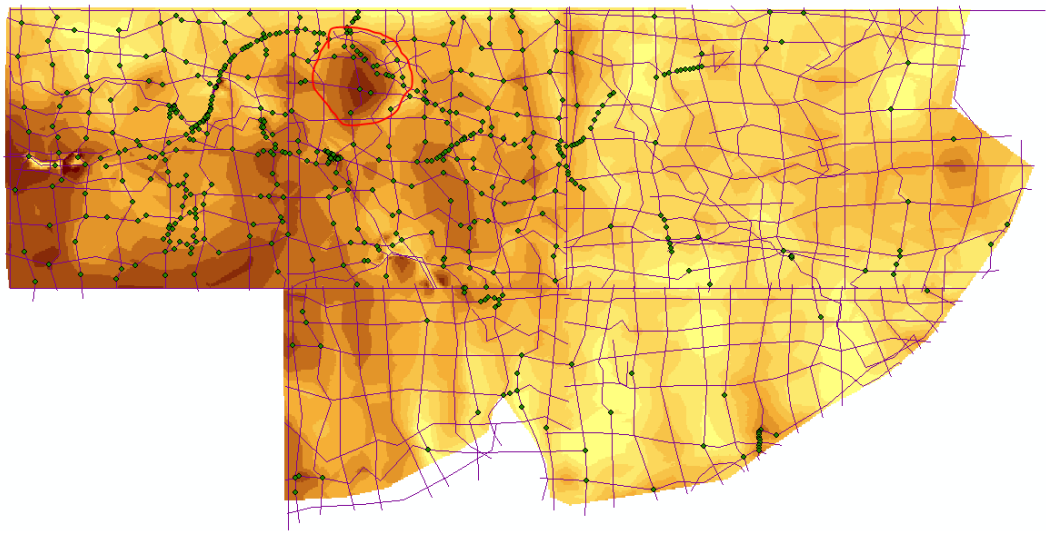

Figure 19 Bull-eye identification with sections and boreholes

investigated in GSI3D (**Figure 19**)

In this case, there are two sections that go straight through the middle of the bulls-eye and there is a borehole at the intersection of these sections. This can be recorded as a potential area of the

model to check, in this case the borehole and intersecting cross-sections. Alternatively, the area may occur between cross-section and boreholes which may indicate a lack of data constraint in that area.

In all cases it will be necessary to go back and check the original model.

3.3 CHECKING TOP AND BASE SURFACES FOR HOLES

By exporting the grids, it is sometimes possible to identify areas where the calculation of that unit does not truly represent the whole extent of that unit both laterally and at depth. This could occur in any unit but is most likely to happen in thin sinuous units such as Alluvium or Head. For example, in Figure 20, the Alluvial envelope shows the extent of the unit as taken from the geological map. The 2nd image in this figure shows the gridded output of the base surface for the alluvial unit.

Figure 20 Missing parts or holes in model grid exports (Alluvium)

Reasons for this could include:

- Poorly constrained by cross-sections in the GSI3D model
- The resolution of the grid (cell size) is not fine enough to truly represent that unit
- Other units such as Artificial Ground that usually lies above the alluvium may have cut the unit out through human actions. This may account for some of the missing unit in the calculated grid. (**Figure 21**)

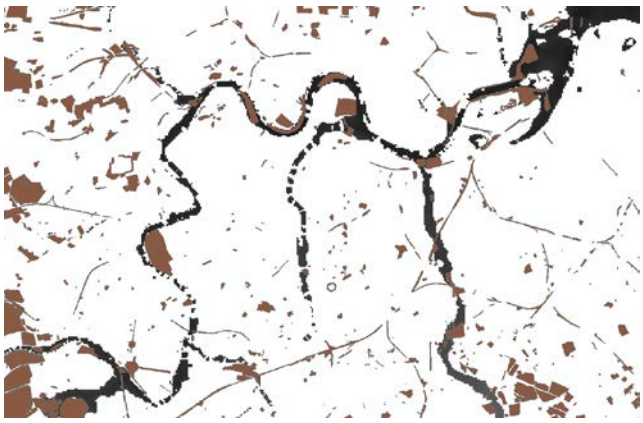

Figure 21 Artificial Ground (brown) with gridded base Alluvium unit (black)

3.4 CHECKING FOR SURFACE CROSSOVERS – NEGATIVE THICKNESSES

As shown in **Figure 16** in Section 3.1, negative thicknesses can occur where there are surface to surface crossovers or where a calculated surface occurs above the DTM (more commonly found in GOCAD regional models). They are unlikely to be found in the GSI3D derived grid exports because of the nature of the calculation. However, they are found in GOCAD derived grid exports, particularly close to subcrop and outcrops where the unit thins.

3.5 ARTEFACTS FROM CROSS-SECTION BASED MODELLING

Occasionally, features can appear in surfaces generated from modelling software which are not natural features but are artefacts of where sections have been drawn or anomalous points in the dataset have been used, such as an incorrect borehole level. Point data will often appear as bulls-eyes (please refer to section 3.2). The other common artefact from GSI3D (or other section drawn 3D geological models), are linear features that are corresponding to the line of section (**Figure 22**). This is partly due to the method used in GSI3D which is a direct interpolation of the correlation points which means that the surface is not smoothed as in other 3D modelling software. In **Figure 23**, the section location corresponds to the unnatural artefact in the surface generated (a docking section between two model areas that have been modelled at different times).

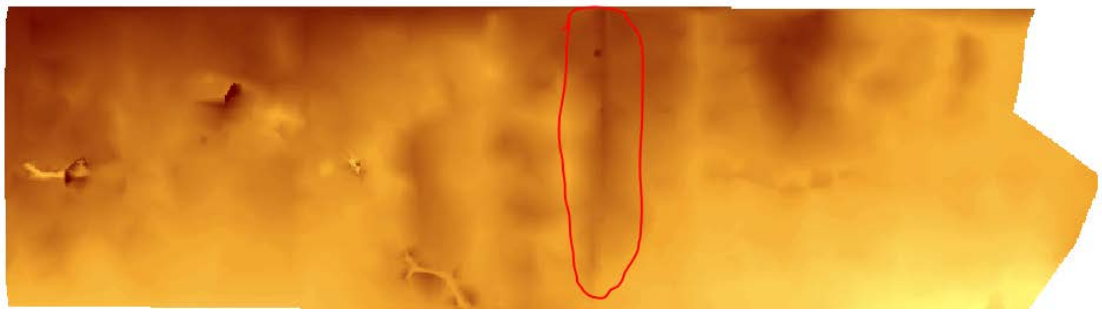

Figure 22 Linear artefact in model surface

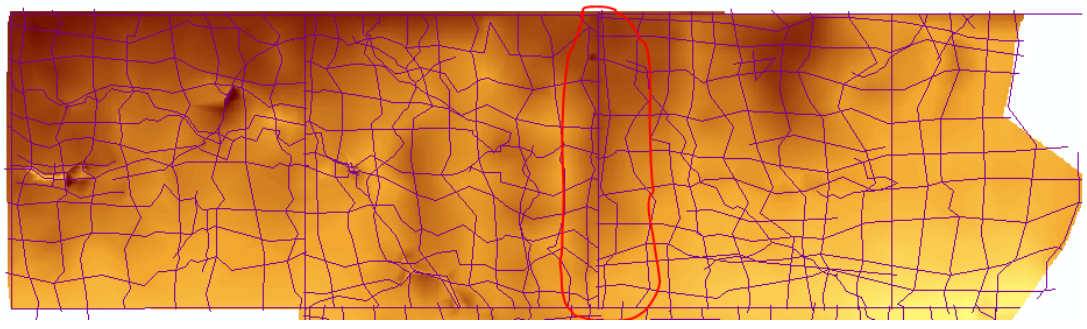

Figure 23 Linear feature with cross-sections

3.6 SUGGESTED ALTERNATIVE CHECKS

Contours are a useful method for identifying structures in bedrock, especially areas of faulting or folding for top or base surfaces. Contours could also be used to identify anomalous data where areas of the model steepen or thicken/thin unnaturally.

For GOCAD/SKUA generated models it is possible to check the thickness of a unit within the software by using the **Distance to Surface** function which enables the user to map the distance (thickness) as a property for the surface of interest. This also identifies any potential crossovers between surfaces.

Glossary

Envelope	Defined here as the extent of a geological deposit in plan view (2D): forming a distribution map of the particular unit, a presence – absence map. May include an area of outcrop, subcrop or a combination of both
Grid	An exported surface or thickness as a gridded object with a specified cell size
GSI3D	The Geological Surveying and Investigation in 3-D software and methodology
Helper	A sections used to constrain the calculation in areas of few sections or thin units such as Alluvium or Head.
Section	Defined here as a vertical x, z plane attributed with correlation lines
Surface	Base or top of a geological unit exported as a grid or TIN
TIN	Triangular Irregular Network. GSI3D exports TINs in Indexed Triangle Mesh format (VRML97).
Triangulation	A form of interpolation (Delauney) that uses TINS in GSI3D to form the base and top surfaces of a unit
Unit	A geological unit is a particular geological deposit that has been identified and mapped out during a GSI3D project. A unit is defined by its basal surface in sections and an envelope of its lateral extent. The top of the unit is back calculated during calculation of the model stack

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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