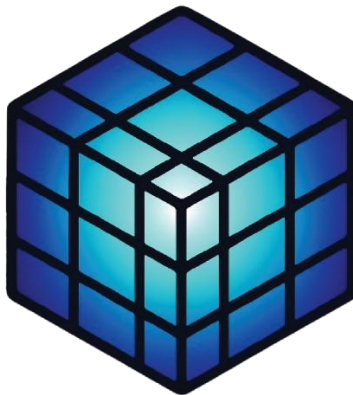


CSM 3D Suite – User guide

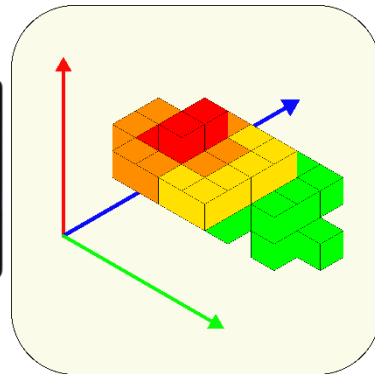


CSM 3D VIS™



CSM 3D

File Converter™



CSM

Interpolation

Studio™

By



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1. Introduction

CSM 3D Vis is a 3D visualization platform purpose-built for creating conceptual site models (CSMs). From the ground up, it was designed with two priorities above all else: ease of use and great visualization.

Conceptual site models exist on a spectrum. At one end, a CSM might be entirely conceptual, built using CSM 3D Vis's library of pre-built assets, with no external data required. At the other end, it might be fully data-driven, rendered from real site investigation results. CSM 3D Vis is designed to support anything in between, giving practitioners the flexibility to work at whatever level of data fidelity their project demands.

CSM 3D Vis is also designed to be a home for 3D assets built elsewhere. If your team has already developed models in CAD or other 3D software, CSM 3D Vis lets you bring those assets into their real-world site context, rather than leaving them isolated in the software they were built in.

CSM 3D Vis is also designed to be a home for 3D assets built elsewhere. If your team has already developed models in CAD or other 3D software, CSM 3D Vis lets you bring those assets into their real-world site context, rather than leaving them isolated in the software they were built in.

To support this, CSM 3D Vis works natively with the GLTF 2.0 format (also known as embedded GLTF), a widely supported open standard for 3D content. Converting your existing assets is handled by CSM 3D FileConverter™ (FC), our companion file conversion application included in the same subscription. CSM 3D FC™ accepts all major 3D file formats and converts them to GLTF, ready for import into CSM 3D Vis.

For soil and groundwater contamination modelling, our in-house interpolation tool is available as a standalone application, CSM Interpolation Studio™. It takes spatially distributed concentration data and generates 3D plumes ready for import into CSM 3D Vis. CSM Interpolation Studio™ is covered in detail in its own dedicated section.

2. 10-steps quick guide

The following is a condensed 10-step guide designed for users who are already familiar with CSM 3D Vis and want to get up and running quickly. For a detailed walkthrough of each function and workflow, refer to the full step-by-step guide in the sections that follow.

1. Open CSM 3D Vis and create a new project via Menu Bar > New Project
2. Import a terrain model via Import Terrain, applying scaling if required. If a draped basemap is needed, prepare outputs using the Image Extractor QGIS plugin and import as a draped DEM. If no terrain is available, add a Site Map using the corresponding tool in the left panel
3. Add built-in geological and site assets from the Asset Library in the right panel
4. Position, rotate, and scale assets using the tools in the left panel
5. Import any external 3D models (CAD, photogrammetry, etc.) via Import GLTF Library. Use CSM 3D FC™ to convert assets to GLTF 2.0 format if needed
6. Import concentration data via Import CSV to generate a 3D contamination plume, adjusting the Cut-off value as needed
7. Use Lighting Settings and Transparency to optimize the visual presentation of the scene
8. Annotate the model using the Pen Tool and attach reference images via Add Image
9. Save the project via Menu Bar > Save Project
10. Capture outputs using Screenshot

3. Basic Functions

The UI of CSM 3D Vis is very intuitive, and CSM 3D Vis' main functions are summarized in Figure 1.

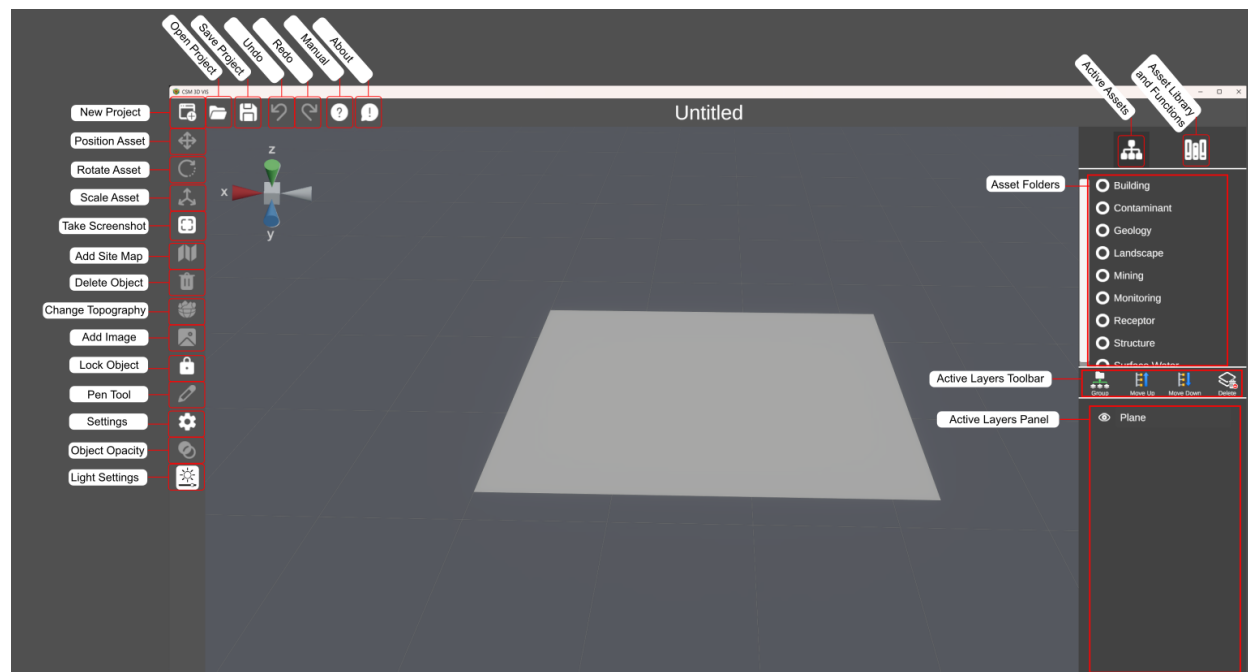


Figure 1 CSM 3D Vis basic functions

The left panel provides access to CSM 3D Vis's primary scene management tools.

- **Position Object** – Allows precise positioning of any asset within the scene. Objects can be moved along a single axis by dragging the corresponding arrow, or across a plane by selecting the area between two axes. Positioning can be performed manually or by entering values directly.
- **Rotate Object** – Functions on the same principle as Position Object. Objects can be rotated around any selected axis, either manually or through direct value input.
- **Scale Object** – Allows objects to be scaled along individual axes, using the same manual and input-based controls as the positioning and rotation tools.
- **Screenshot** – Captures the current scene at the highest resolution available.
- **Add Site Map** – Adds a 2D site map to the scene. Accepted formats include PNG, JPG, and TIFF.
- **Delete Object** – Removes a selected object from the scene.
- **Deform Geology** – Applies deformation to geological assets in the scene. Two deformation types are available 1) Hill and 2) Valley, selectable by clicking the corresponding label. The magnitude and spatial extent of the deformation are controlled by entering values in the Amount and Radius fields.

- **Add Image** – Attaches a reference image to a selected object in the scene. Once added, the image remains accessible through the same panel function.
- **Lock Object** – Locks an object in place, enabling specific tasks to be performed without inadvertently moving it.
- **Pen Tool** – Enables freehand drawing directly on the model, useful for annotating or highlighting specific features.
- **Lighting Settings** – Controls scene lighting across three parameters: intensity (via slider), background color, and light source position. The light source can be repositioned along multiple axes to optimize illumination for any viewing angle.
- **Transparency** – Adjusts the transparency of any selected object in the scene (imported assets, TIFs/DEMs, Geology assets, etc). Increasing transparency makes objects progressively more see-through, allowing interior features and underlying elements to become visible.

The top panel serves as CSM 3D Vis's main menu bar, providing access to project management and general application functions:

- **New Project** – Creates a new project. Note that clicking this will immediately clear the current scene.
- **Open Project** – Opens an existing project file (.json).
- **Save Project** – Saves the current project as it appears in the canvas.
- **Undo** – Reverses the last action. Also accessible via the **Ctrl + Z** keyboard shortcut.
- **Redo** – Reapplies the most recently undone action.
- **Manual** – Opens the online manual (this document).
- **About** – Opens the CSM 3D Vis software page.

The right panel has two entries, 1) Active assets and 2) Asset library.

The Active Assets entry displays all assets currently loaded in the scene, organized into the Asset Folder and the Active Objects panel

The Asset Folder functions as a category filter. Selecting a category, such as Geology, narrows the Active Objects panel to show only assets belonging to that category, making it easier to manage complex scenes with many layers.

Selected objects are highlighted with a green outline both in the Active Objects panel and directly in the canvas. Hiding an asset is possible by clicking on the eye icon next to the selected asset.

The Asset Library contains all built-in 3D assets included with CSM 3D Vis. Assets are imported into the scene by clicking on them directly. Once in the scene, they can be repositioned, rotated,

and scaled using the corresponding tools in the left panel. Assets imported from the Asset library will be added top the **active objects** panel **under active assets**.

Scene lighting is fully adjustable. Light intensity and temperature are controlled through sliders, and the light color can be changed to suit the scene. The angle and direction of the light are set with the dedicated gizmo, which lets you reposition the light directly in the scene to get the best illumination for the viewing angle. The scene background can still be changed to a color of your choice.

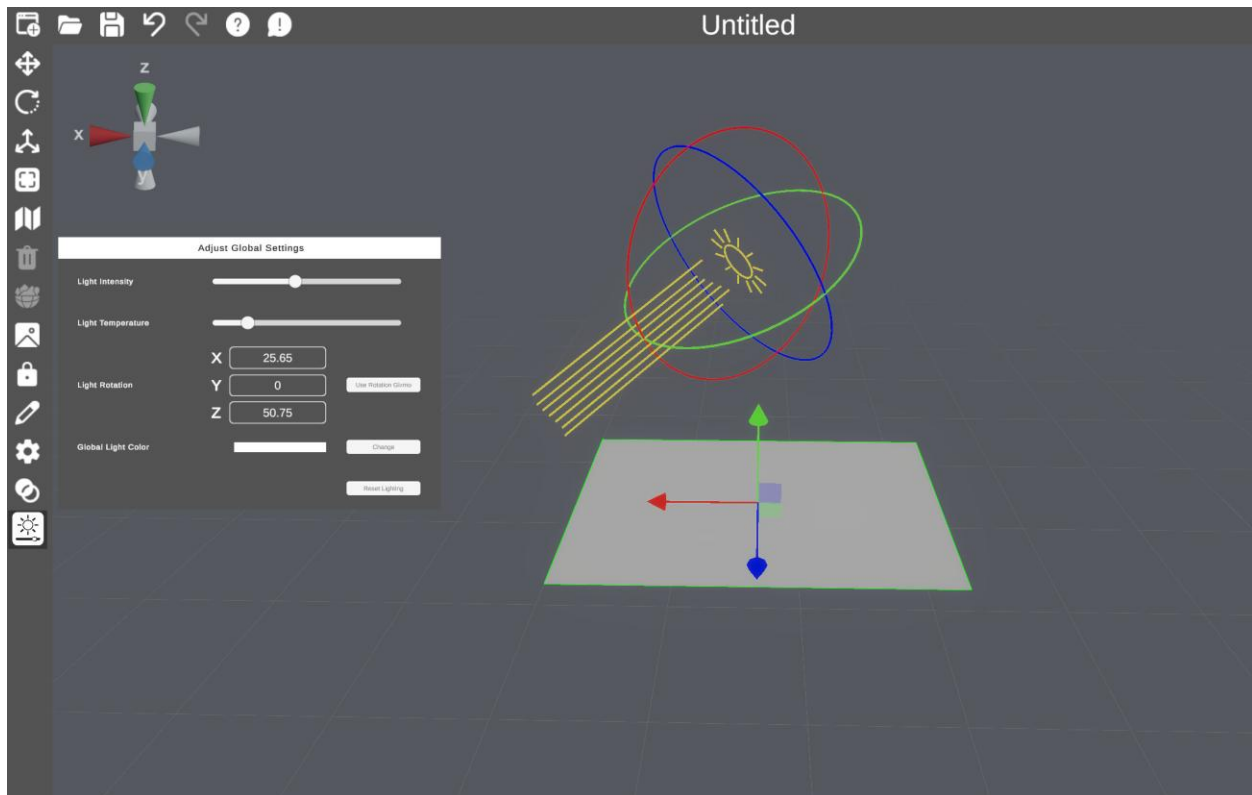


Figure 2 Light settings panel.

Assets in the hierarchy panel can be organized into groups. A group can be created in two ways: by selecting multiple assets in the hierarchy panel and clicking the Group function in the toolbar, or by creating an empty group and dragging assets into it. As with individual assets, groups can be renamed by selecting them and pressing F2. Groups also have their own eye icon, so toggling a group's visibility hides or shows every asset inside it at once, which saves a lot of clicking in scenes with many layers.

The order of assets in the hierarchy can be changed using the Move Up and Move Down functions in the hierarchy toolbar, the strip of controls containing Group, Move Up, Move Down, and Delete. The order is saved with the project and preserved between sessions.

4. Advanced functions

CSM 3D Vis contains two types of advanced functions. One type that is available directly through CSM 3D Vis, and others that are available through our sidecar app CSM 3D FC.

4.1. Built-in advanced functions

CSM 3D Vis offers 3 built-in advanced functions: 1) Import Terrain, 2) Import CSV, 3) Import GLTF Lib (Figure 3).

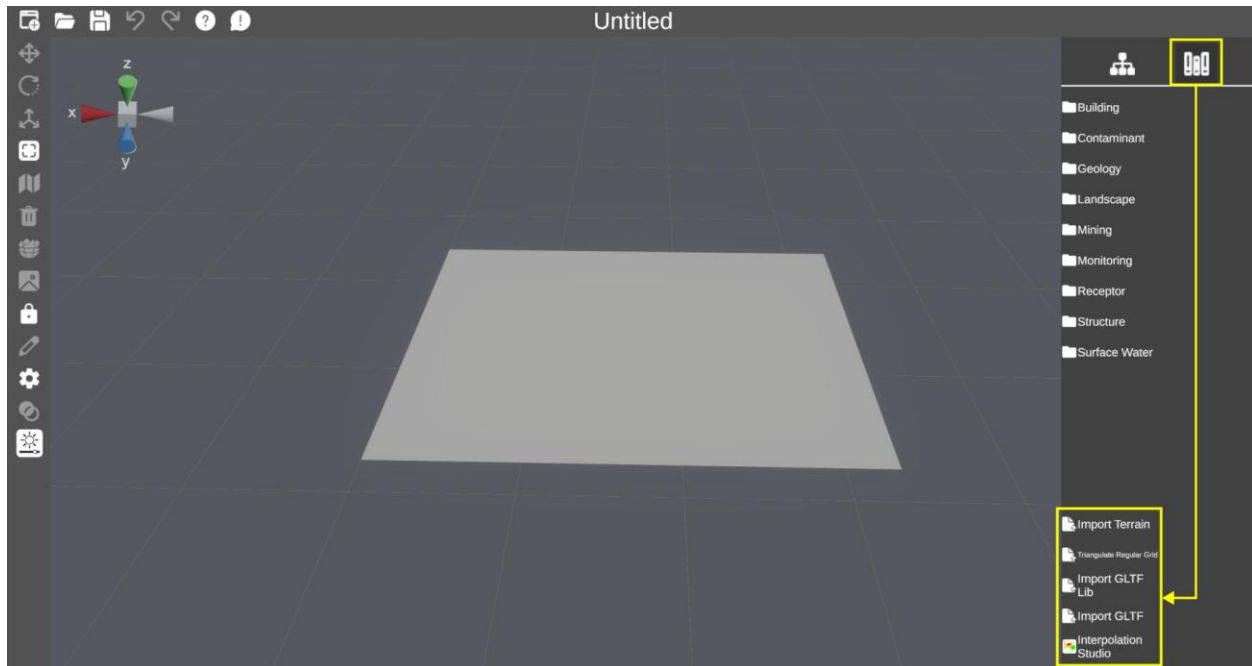


Figure 3 Built-in advanced functions

4.1.1. Import Terrain Function

The Import Terrain function supports any digital elevation model (DEM) in TIF format, whether a surface model or a geological model (Figure 4).

Scaling – When importing, the model can be scaled using the function-specific X/Y and elevation fields. Leaving both fields empty, or entering a value of 1, imports the model at its original size. Entering 0.1 in both fields scales the model to 10% of its original size uniformly across all directions, preserving vertical proportions. Entering different values for X/Y and elevation allows vertical exaggeration; for example, scaling X/Y to 0.1 and elevation to 0.2 produces a model at 10% of its original horizontal extent with 2x vertical exaggeration.

Importing a DEM Without Imagery – To import a plain DEM with no basemap, navigate to Import Terrain, browse to the TIF file, apply scaling if required, and import.

Importing a Draped DEM A terrain model can also be imported with a basemap draped over it, providing spatial reference for the site. This requires a specific folder and file naming convention:

- The DEM file should be named **[name].tif**
- A subfolder containing the drape imagery must be placed in the same directory and named **[name]_Textures**
- The texture file must be in PNG format and named **Tile__0__0** (with two underscores between each segment)

Usually, it is advised to use TIFF.tif for the DEM and TIFF_Textures for the texture folder (Example in Figure 4.1). To simplify the preparation of draped DEMs, **a dedicated QGIS plugin is available**. It can be downloaded for free directly from within QGIS via **Menu Bar > Manage and Install Plugins > All**, then searching for **Image Extractor**.

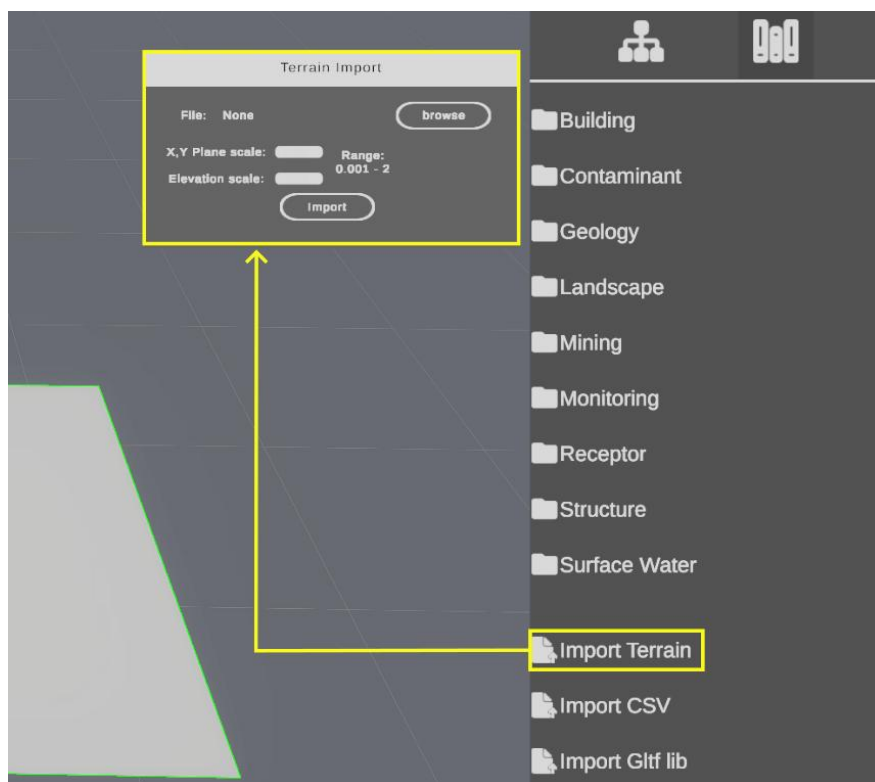


Figure 4 Import terrain function, and function-specific options

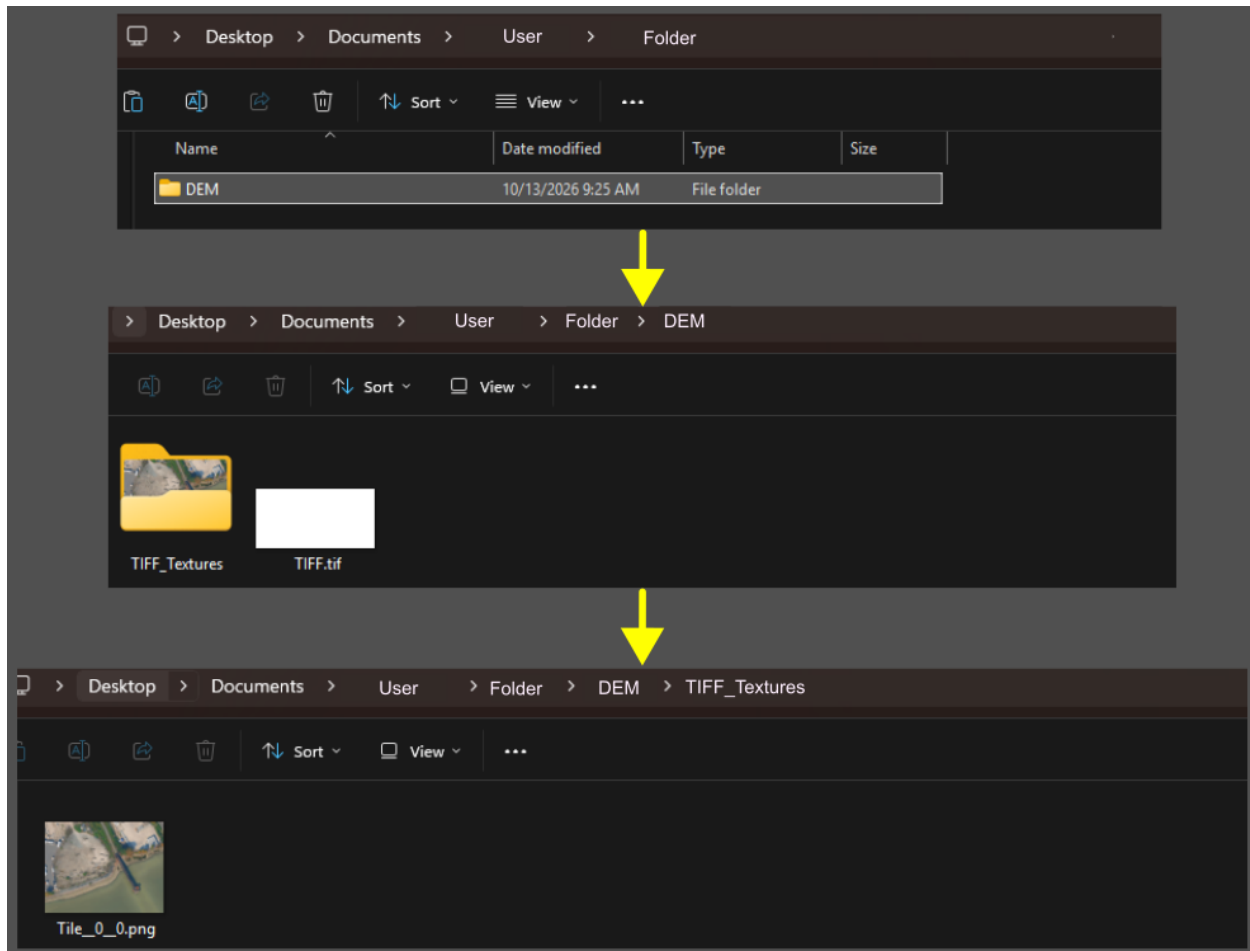


Figure 4.1 Example for folder structure for importing draped DEMs into CSM 3D Vis

4.1.2. Image extractor – QGIS Plugin

Image Extractor is a QGIS plugin developed by Geocentric Environmental Inc. that automates the preparation of basemap and DEM outputs for texture draping workflows in CSM 3D Vis.

The plugin clips a basemap (such as Google Satellite) and a DEM raster to a user-defined area of interest (AOI), producing two georeferenced outputs that share identical spatial extents. This ensures clean alignment when the terrain and imagery are imported together into CSM 3D Vis, with no skirt artifacts along the edges.

Inputs:

- Basemap layer (raster)
- DEM layer (raster)
- Cropping Extent layer (vector polygon)
- Output folder and file name

- Output CRS – WGS84 (EPSG:4326) is recommended for broadest compatibility
- Cropping Layer CRS – the CRS of the vector layer used for cropping
- Basemap CRS – the CRS of the basemap imagery (Google Satellite is typically Web Mercator, EPSG:3857)

Outputs:

- **Tile__0__0.png** – masked and cropped basemap image
- **[Output Name].tif** – DEM clipped to the matching extent (we recommend naming this file *TIFF* for consistency with the expected import structure)

These files are ready to be imported as a draped terrain directly in CSM 3D Vis.

Important Notes

1. **Use only square or rectangular cropping extents.** CSM 3D Vis does not support irregular polygon shapes – non-rectangular extents will produce skirt artifacts along the terrain edges.
2. **Turn off any layers you do not want captured in the basemap** before running the plugin. Everything currently visible on the QGIS canvas will be rendered into the output image.
3. **Zoom to the full extent of your Cropping Extent layer** in the QGIS canvas before running the plugin. This ensures the basemap is rendered at the highest possible resolution.
4. **Turn off the DEM layer** before running the plugin. Because the DEM typically sits above the background imagery in the layer panel, leaving it visible will cause it to be rendered into the basemap image.

4.1.3. Triangulate Regular Grid

The Triangulate Regular Grid function provides a simple, built-in interpolation tool for generating 3D concentration plumes directly within CSM 3D Vis. From a structured CSV input, it produces a colored 3D volume representing the spatial distribution of a contaminant or parameter of interest across the site. Visualization is cell-based – the concentration field is divided into a voxel grid, and each cell is displayed as a solid colored block. Cells above the Cut-off threshold are shown; cells below are hidden.

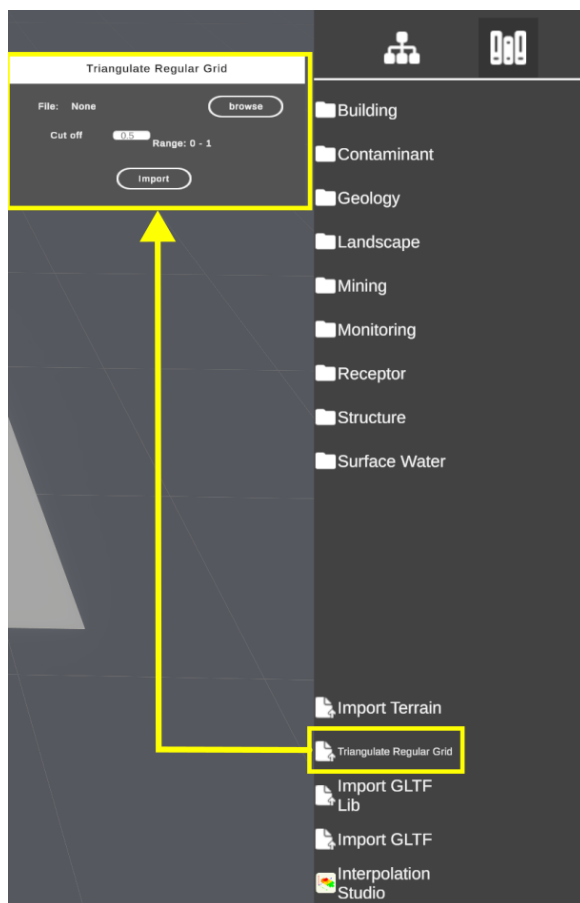


Figure 5 Import CSV function and function-specific options

CSV Format – The input file must be formatted with the following four columns, in order:

Column	Description
X	Longitude
Y	Latitude
Z	Depth
C	Concentration

Like in the example below:

	A	B	C	D
1	X	Y	Z	C
2	130	20	-10	10.24
3	130	60	-10	10.24
4	130	20	-2	10.27
5	130	60	-2	10.27
6	180	10	-6	10.49
7	180	70	-6	10.49

The format must be respected exactly, otherwise the software will not be able to perform the triangulation.

Cut-off – The Cut-off value sets a minimum concentration threshold for the interpolation. Any data points with a C value below the specified threshold are excluded from the output volume. A Cut-off of 0 includes all data points, producing the full extent of the interpolated plume. Increasing the Cut-off progressively removes lower-concentration zones, leaving only the higher-concentration core visible in the scene. Setting the Cut-off too high relative to the dataset's concentration range will produce no output.

Output – Once imported, the function generates a colored 3D volume in the scene, visually representing the interpolated concentration distribution across the defined X, Y, and Z extent. An example is visible in Figure 6.

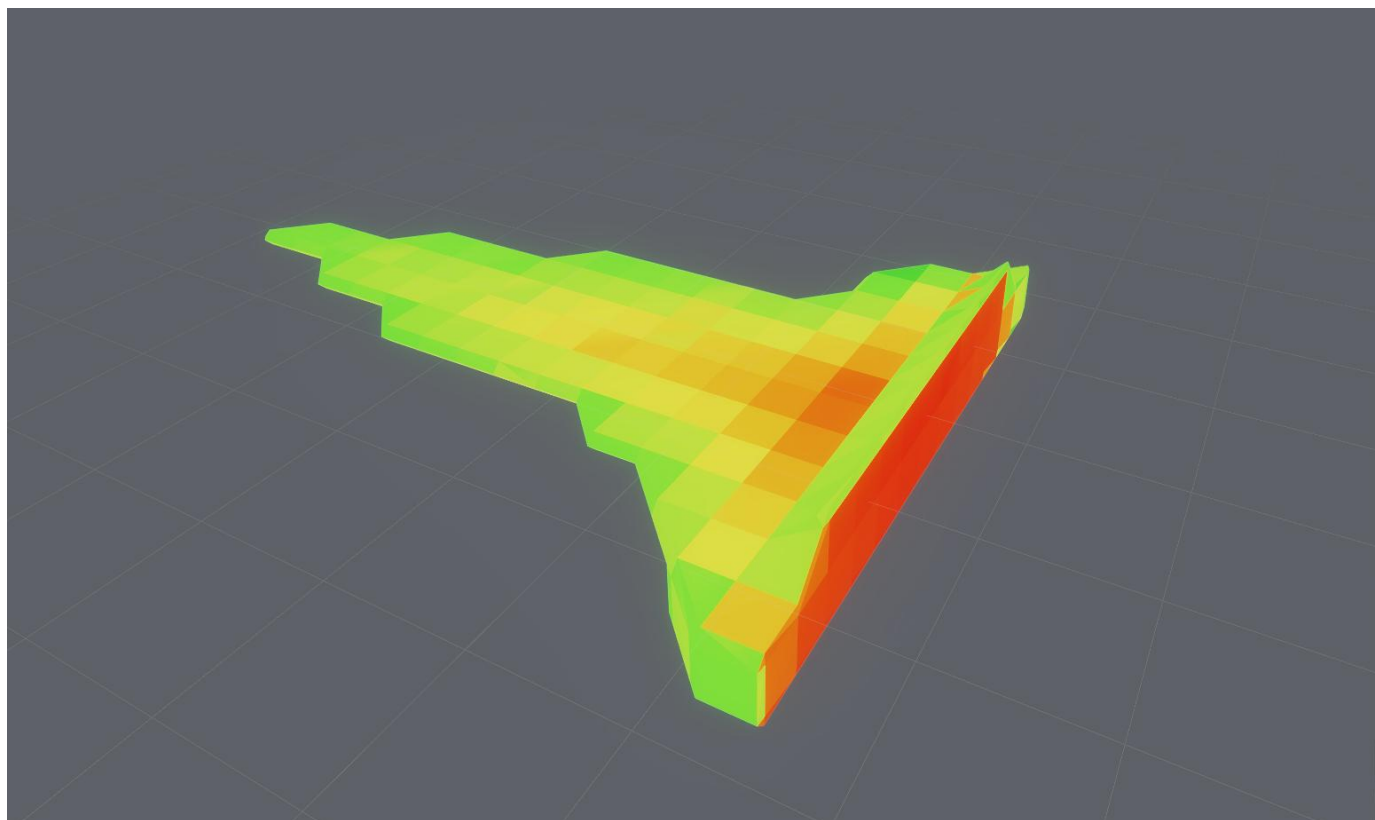


Figure 6 Example output from a regular grid CSV.

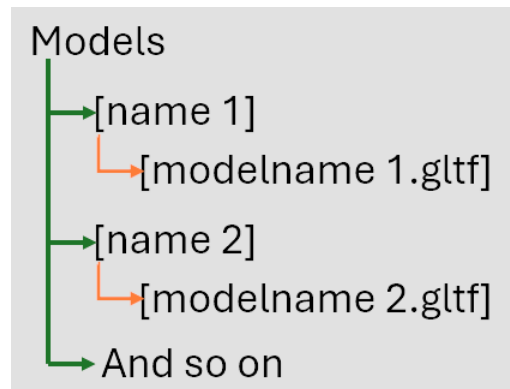
4.1.4. Import GLTF Library and Single GLTFs

Import GLTF Library (Figure 7) is one of CSM 3D Vis's primary advanced functions and the main point of integration with external 3D software, including CSM 3D FC. It allows any GLTF 2.0

(embedded) asset to be brought into the scene, from photogrammetric models to purpose-built 3D assets such as vehicles, machinery, buildings, or site infrastructure.

Clicking Import GLTF Library opens a file browser popup. Navigate to the folder containing your models and select it to import.

Folder Structure – While not strictly enforced, the following folder structure is strongly recommended. Some models may not appear correctly without it:



A root folder named Models should contain one subfolder per asset, with each subfolder holding a single GLTF (2.0 embedded) file.

Finding Assets – A wide range of GLTF-compatible assets are available online, from free to paid. A curated list of recommended sources is being compiled; in the meantime, assets can be found at [Sketchfab](#).

Converting Existing Assets – If existing assets are in other formats, such as OBJ, DXF, or Shapefile (SHP or zSHP), they can be converted to GLTF using CSM 3D FC™. This is covered in detail in the dedicated CSM 3D FC section.

The new “Import GLTF” supports single GLTF files in addition to libraries. Imported GLTFs will appear in the Imported GLTF folder under Assets Library and Functions, where they can be added to the scene like any other built-in asset. Imported libraries now appear as individual import entries rather than being compiled into one, which means each model in a library can be handled

separately. Libraries that are no longer needed in the model, such as outdated models, can be deleted.

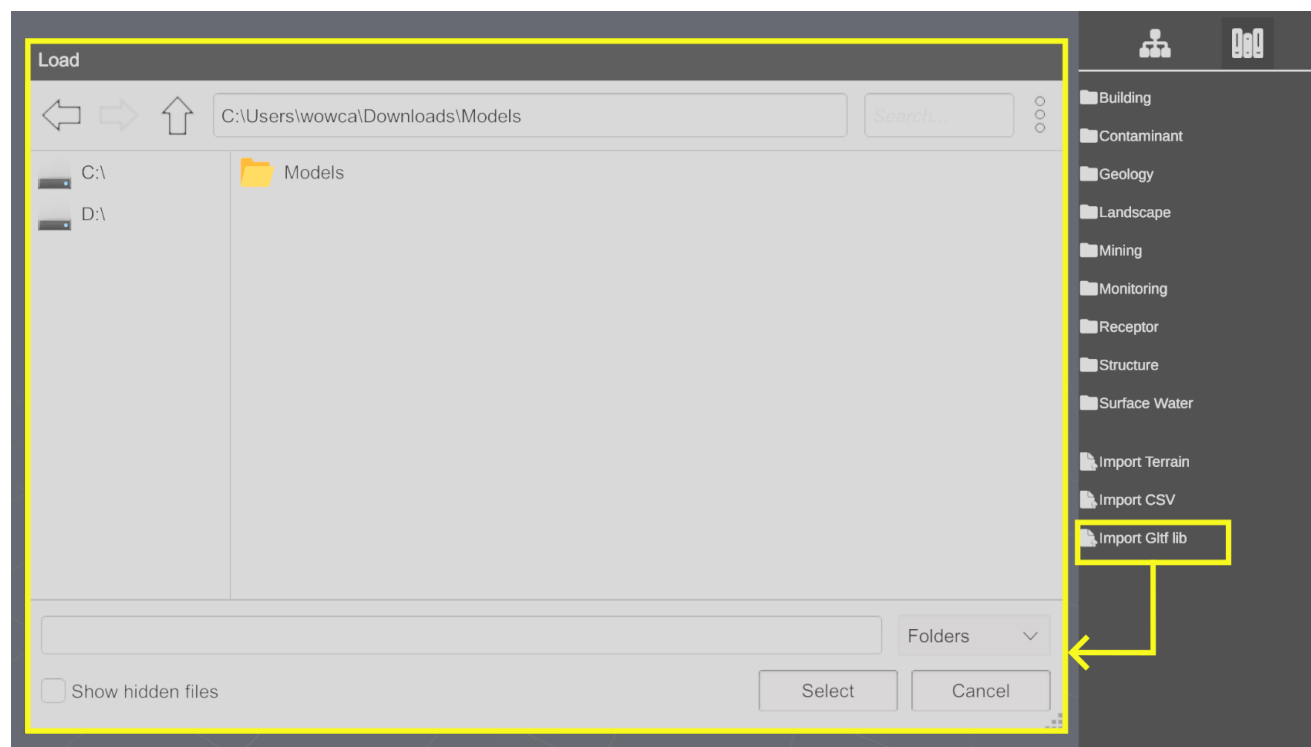


Figure 7 Import GLTF Library function

5. CSM 3D File Converter™

CSM 3D FC™ is the companion application to CSM 3D Vis, handling file format conversions and data interpolation. Like CSM 3D Vis™, it was built with ease of use as a guiding principle, however, as with any specialized software, its tools require parameterization. The degree of parameterization varies considerably depending on the operation: some conversions involve minimal setup, while others, such as the interpolation tool, require more extensive parameterization and a solid understanding of the input dataset.

Each tool within CSM 3D FC™ is covered in its own dedicated section.

5.1. Conversion – 3DSHP (or zSHP) to GLTF

This function converts 2D or 3D polygon shapefiles (for example, pit benches or excavation outlines) into interactive 3D models that can be viewed in PyVista or exported as GLTF files for use in CSM 3D Vis. It reads the shapefile geometry, recenters and scales the model, and can either

display filled bench surfaces or just the bench-edge rings. When ring export is selected, the tool can also thicken the edges into tubes to make them more visible in 3D.

Parameters:

- **save gltf:** should be checked – Exports the current view to a .GLTF file. Leave unchecked if you only want on-screen preview.
- **export rings:** should be checked – Outputs only the bench-edge rings (wireframe). Uncheck to export filled bench surfaces.
- **apply scaling:** Uniformly scales the geometry before viewing/export. If scaling is not necessary, leave unchecked.
- **scale factor:** Multiplier used when scaling is enabled (e.g., 0.1 to shrink to 10%, 1 means unscaled).
- **recenter xy:** should be checked – Recenters the model so X,Y = (0,0) for easier viewing and import into CSM 3D FC.
- **apply ring tube:** should be checked – Thickens ring polylines into tubes so edges are visible.
- **ring radius:** Tube radius (post-scaling). Increase for thicker edge tubes. I.e. 1.

5.2. Conversion – DXF to OBJ

This function converts a DXF into an OBJ mesh with optional recentering and uniform scaling. You can filter or prepare geometry (explode blocks, merge by layer, weld vertices), and quickly preview the result in a PyVista window before saving.

Parameters:

- **apply scaling:** should be checked if you need unit conversion or size normalization. Uniformly scales all vertices before export.
- **scale factor:** Multiplier used when scaling is enabled. Example: 0.1 = 10% size, 2.0 = 200%.
- **recenter xy:** should be checked to move the model so X,Y are centered to (0,0). Helpful for clean imports into other tools.
- **explode blocks:** Leave unchecked by default. If enabled, block references would be exploded into their component geometry.
- **merge by layer:** Leave unchecked by default. Conceptually groups or merges geometry per DXF layer.

- **triangulate**: should be checked. Ensures faces are triangles, maximizing compatibility with 3D apps and slicers.
- **weld vertices**: Leave unchecked unless you see cracks or duplicated edges. When enabled, close vertices are snapped together to remove seams and tiny gaps.
- **weld threshold**: Distance tolerance used when welding is on. Vertices closer than this value are merged. Start small (for example 0.001) and increase carefully.
- **enable preview**: should be checked. Opens a quick 3D preview so you can inspect scaling, centering, and mesh quality before writing the OBJ.

5.3. Conversion – OBJ to GLTF

This function converts .OBJ files into embedded GLTF files for easy visualization or integration into 3D applications. It supports both single-file and batch (folder) processing, ideal for exporting models from major 3D geological and modeling software. The tool allows users to uniformly scale and recenter meshes, apply random or custom colors, and choose between wireframe (edge-tube) or full mesh exports. All conversions run off-screen (no GUI), producing lightweight, double-sided GLTFs that are ready for viewing or further use in game engines, 3D viewers, or web-based platforms.

Parameters:

- **bulk conversion**: can be left unchecked unless you want to process a whole folder. When enabled, input_path should be a folder; all .OBJ files inside (recursively) will be converted to .GLTF in output_path (folder).
- **apply scaling**: should be checked if you need to uniformly resize geometry by scale factor.
- **scale factor**: numeric multiplier for size (e.g., 0.1 = 10% size, 2.0 = 200%).
- **recenter xyz**: should be checked to center the mesh at the origin on all axes (useful for engines expecting models around (0,0,0)).
- **use random color**: should be checked to assign a random flat color per mesh (ignored if “use custom color” is also enabled).
- **use custom color**: should be checked to force a specific color. Accepts “#RRGGBB”, “r,g,b”, “r g b”, (r,g,b), or named colors; 0–255 or 0–1 values are supported. Uncheck “use random color” when using this.
- **custom color**: the color value to apply when “use custom color” is enabled (formats above).
- **save gltf**: should be checked – writes the GLTF file(s) to the output path (embedded buffers, double-sided materials).

- **wireframe:** should be checked to export edge-tube wireframes (lightweight structural look). Leave unchecked to export the full mesh surface.

5.4. Conversion – (2D)SHP to GLTF

This function converts 2D shapefiles (LineString, MultiLineString, Polygon, MultiPolygon) into a single embedded .GLTF. The script reprojects to a target CRS that works with CSM 3D Vis, recenters to the origin, applies a uniform scale, and exports either outline lines or 3D tubes following the geometry of the shapefile. Inputs must be planar 2D features; Z is not required. Good for turning site boundaries, benches, or linework into GLTF layers.

Parameters:

- **Scale factor:** uniform multiplier applied after recentering. Use values like 0.1 to shrink or 10 to enlarge. Helps match engine or scene units.
- **USE OUTLINE MODE:** Should be checked – to export clean line outlines. Uncheck to generate cylindrical tubes along lines for a thicker, 3D look.
- **Tube radius:** radius of tubes when outline mode is off. Units follow your projected CRS then the scale factor. Increase for thicker tubes.
- **Radial segments:** number of sides used to build each tube circle. Higher values look smoother but increase file size.
- **Tube color (RGBA):** color for tubes as a 4-value list [R,G,B,A] where each channel is 0–1. Example: [255,125,0,1] is opaque orange.
- **Outline thickness:** line width hint for outline mode. GLTF core ignores line width, so most viewers treat lines as 1-pixel. Keep for future pipelines that respect thickness.
- **Outline color (RGBA):** color for outlines as a 4-value list [R,G,B,A] where each channel is 0–1. Example: [0,0,0,1] is opaque black, which is what we recommend.

5.5. Function – Image to GLTF

This function creates a textured, centered plane from an image and exports a single-file embedded .GLTF. The plane matches the image aspect ratio by default, or an explicit size if provided. Supports optional uniform scaling, UV flips, opacity, double-sided rendering, and an unlit material for consistent look across engines. Inputs accepted: PNG, JPG/JPEG, and most formats readable by Pillow. Outputs: embedded .GLTF.

Parameters:

- **save gltf**: should be checked – writes the embedded .GLTF to the output path.
- **apply scaling**: should be checked if you want to uniformly resize the plane by scale factor.
- **scale factor**: numeric multiplier for size. Example: 0.1 = 10% size, 2.0 = 200%.
- **plane size x**: optional explicit width for the plane. If only X is set, Y is computed to preserve image aspect.
- **plane size y**: optional explicit height for the plane. If only Y is set, X is computed to preserve image aspect.
- **flip x**: leave unchecked unless your texture is mirrored horizontally. Flips the U coordinate.
- **flip y**: leave unchecked unless your engine treats V upside-down. Flips the V coordinate.
- **opacity**: 0 to 1. Controls material alpha. Values < 1 enable alpha blending. 1 is recommended.
- **double sided**: should be checked – renders the plane from both sides to avoid backface culling issues.
- **unity compatible export**: should be checked – forces unlit material settings and sane PBR values for consistent sprites/decals in Unity.

5.6. Function – Synthetic Borehole Placer

This function is still in beta.

This function allows the user to manually add synthetic boreholes (control points) directly onto a map by clicking on the displayed dataset. It loads an existing XYZC CSV file and displays borehole locations colored by concentration thresholds. Users can add (left click) and remove (right click) synthetic points interactively, and the final XY coordinates are saved to a new CSV upon closing the pop-up window. The Z value is automatically assigned based on the average borehole depth from the input dataset. These synthetic boreholes can then be used as additional control points in the main plume generation workflow (CSV to GLTF) to improve interpolation accuracy and fill data gaps. Concentration (C) is assigned in the main plume generation workflow. Alternatively, concentrations can be added manually by editing the output CSV file.

Parameters:

- **backend**: Matplotlib engine for the interactive window (e.g., Qt5Agg, TkAgg). Change this if your display can't open the plot.
- **show plot**: should be checked – Opens the interactive map so you can click to place synthetic boreholes.
- **borehole radius**: Marker size for existing boreholes on the map (larger = bigger dots).

- color by threshold: should be checked – Colors boreholes red/green based on the cutoff value.
- threshold for color: Concentration cutoff used to set borehole color (above = red, below = green).
- color above threshold: Color used when a borehole's max C exceeds the cutoff (e.g., red).
- color below threshold: Color used when a borehole's max C is at/below the cutoff (e.g., green).
- apply_scaling: leave unchecked – This tool only picks XY locations; scaling can be handled in CSM 3D Vis.
- scale factor: do not fill – Ignored here. Only relevant if scaling is enabled in the main pipeline.

6. CSM Interpolation Studio™

CSM Interpolation Studio™ is an embedded application within the CSM 3D Vis, dedicated to soil and groundwater contamination modelling. It lives under the Asset Library and Functions menu. Previously bundled within CSM 3D FC™, it has been decoupled into its own application to better reflect the complexity and scope of the tool.

CSM Interpolation Studio™ takes spatially distributed concentration data and interpolates it across a 3D grid, generating colored plume models ready for import into CSM 3D Vis™. Like the rest of the CSM Suite, it was built with ease of use as a guiding principle, however, producing accurate and meaningful results requires familiarity with the input dataset and a basic understanding of interpolation methods. The tool's parameters are covered in detail in the sections that follow.

6.1. Soil and Groundwater impact interpolation

This function is still in beta.

The interpolation tool is currently the most advanced component of the CSM 3D Suite. It takes spatially distributed concentration data from a CSV file, interpolates it across a 3D grid, and exports the result as a GLTF file ready for import into CSM 3D Vis™. The output is a colored 3D plume – a volumetric representation of contaminant distribution in the subsurface – with optional borehole visualization overlaid on the model.

The tool supports two plume types: soil and groundwater. Groundwater mode uses well screen intervals to constrain the vertical extent of the interpolation, while soil mode works directly from XYZ point data.

Internally, the tool performs the following steps in sequence:

- Reads and validates the input CSV, removing invalid or zero-concentration values and applying optional outlier handling
- Applies log transformation to the concentration data (optional but recommended for datasets with high concentration variability)
- Optionally loads synthetic control points from a secondary CSV, which can be used to guide the interpolation in areas of sparse data
- Builds a 3D interpolation grid spanning the spatial extent of the dataset, with optional downward extension for proper plume closure at the base
- Interpolates concentration values across the grid using one of five available methods: RBF, Radius-limited RBF, IDW, Griddata, or Kriging
- Applies post-processing including vertical closure at the plume base, optional Gaussian or median smoothing, and optional sparse data masking
- Generates isosurfaces – concentration shells at defined levels – and renders them in an interactive 3D viewer
- Exports the result to GLTF, with baked per-vertex colors, transparency, and double-sided geometry ready for CSM 3D Vis™

Optional outputs include shapefiles of horizontal concentration contours at user-defined depth slices, and a volume report quantifying the subsurface volume above each concentration threshold.

6.2. Interface Overview

CSM Interpolator Studio™ is a GUI application organized into three tabs: Main, Advanced, and Export. Parameters are configured through the interface and the tool is executed by clicking the Run button. Output is displayed in the terminal panel at the bottom of the window.

- **Main tab** – Core inputs, plume settings, interpolation method, and visualization options. Must be reviewed for every run.
- **Advanced tab** – Outlier handling, Z-floor closure, post-processing smoothing, and performance settings. Defaults are suitable for most datasets.
- **Export tab** – GLTF export, volume calculations, and shapefile export options.

6.2.1. Main Tab Parameters

The Main tab covers the core inputs, outputs, and fundamental decisions that govern how the interpolation is performed. These should be reviewed and updated for every new dataset.

Input / Output

Parameter	Default	Description
Input CSV	—	Path to the input dataset. Browse using the ‘...’ button. For groundwater mode, required columns are: ID, X, Y, SCREEN_TOP, SCREEN_BOTTOM, C. For soil mode: X, Y, Z, C. All Z values must be negative (depth below surface).
Output File	—	Path and filename for the GLTF export. Always use a .gltf extension for compatibility with CSM 3D Vis™.
Use Synthetic Control Points	Unchecked	Enables loading of a secondary CSV containing synthetic control points to guide the interpolation in areas of sparse data. When checked, a file path field appears.
Synthetic CSV	—	Path to the synthetic control points CSV. Accepts three formats: X, Y, Z (direct 3D locations); X, Y only (tool generates vertical boreholes); or X, Y, Z_top, Z_bottom (borehole interval definitions).

Plume Settings

Parameter	Default	Description
Groundwater Plume Mode	Unchecked	Switches between groundwater and soil mode. When checked, the tool reads SCREEN_TOP and SCREEN_BOTTOM columns to calculate Z midpoints and constrain the vertical extent of the interpolation. When unchecked, Z values are read directly from the dataset.
Apply Threshold	Unchecked	When checked, only concentrations at or above the threshold value are rendered, suppressing the low-concentration fringe of the plume.
Threshold Value	0.01	The concentration cutoff used for visualization, borehole color coding, and volume calculations. This value should

Parameter	Default	Description
		be set based on the dataset and the concentration range of interest — for example, a regulatory guideline value or a site-specific screening level.
Log Transform Data	Unchecked	Applies a $\log_{10}$ transformation to concentration values before interpolation. Strongly recommended for environmental datasets where concentrations span several orders of magnitude.
Apply Scaling	Unchecked	When checked, all coordinates are multiplied by the scale factor before interpolation. Occasionally necessary when working with large real-world coordinates that cause numerical instability.
Scale Factor	0.1	The multiplier applied to all coordinates when Apply Scaling is checked. A value of 0.1 reduces coordinates to 10% of their original size. Note: this affects the spatial scale of the exported GLTF.

Interpolation

Parameter	Default	Description
Method	RBF	The interpolation algorithm. Options: 1) RBF – Radial Basis Function. Good general-purpose choice. It is usually our default choice; 2) RBF Radius – Radius-limited RBF. Good for sparse datasets. 3) Griddata – Fastest; 4) IDW; 5) Kriging – Most statistically rigorous. Slowest. Requires variogram setup; 6) Regular Grid – For regularly spaced grid inputs
Grid Resolution	40	Number of grid cells along each axis (X, Y, Z). Higher values produce more detailed plumes but increase processing time. Recommended range: 30–60.
Smoothing Factor	0.01	RBF and RBF Radius only. Controls how closely the interpolation follows raw data points. 0 = exact fit through all points. The response is quasi-logarithmic,

Parameter	Default	Description
		meaning small changes near zero produce large differences in output, while changes at higher values have smaller impact. For example, the difference between 0.001 and 0.01 will be clearly visible in the plume, while the difference between 0.1 and 0.4 will be negligible. Typical working range: 0.001–0.1.
Max Radius	20.0	RBF Radius only. Maximum search distance (in coordinate units, typically metres) within which data points contribute to each grid point. Decrease to prevent over-extrapolation; increase if the plume appears patchy.
Min Neighbors	4	RBF Radius only. Minimum number of data points required within Max Radius for RBF to be performed. If fewer are found, the fallback strategy is used.
Fallback Value	Mean	RBF Radius only. Strategy when fewer than Min Neighbors points are within range. Options: Nearest (closest point value) or Mean (average of available neighbors).
K Neighbors	6	IDW only. Number of nearest data points used per grid point. Higher values (e.g. 12) produce smoother results; lower values (e.g. 3) preserve more local variability.

Interpolation – Kriging Settings

The following parameters appear when Kriging is selected as the interpolation method.

Parameter	Default	Description
Auto-select Best Variogram Model	Unchecked	When checked, the tool automatically tests all variogram models and selects the best-fitting one based on the empirical variogram. Recommended for users unfamiliar with geostatistics. This might cause the software to become unresponsive for a short while. Please leave computing.

Parameter	Default	Description
Variogram Model	—	The model describing spatial correlation in the data. Options: Gaussian, Spherical, Exponential, Linear, Power, Hole-Effect. Only shown when Auto-select is unchecked.
Number of Lags	6	Number of lag intervals used when fitting the variogram. Default 6. Increasing (e.g. 10–12) captures correlation at greater distances but may become unstable with sparse data.
Auto-fit Variogram Parameters	Checked	When checked, sill, range, and nugget are fitted automatically from the data. When unchecked, manual parameter fields appear.
Sill	—	Manual variogram parameter. The plateau value of the variogram, representing total variance. Shown for Gaussian, Spherical, Exponential, and Hole-Effect models.
Range	—	Manual variogram parameter. The distance at which spatial correlation effectively reaches zero, in the same units as the coordinate system (typically metres).
Nugget	—	Manual variogram parameter. Represents measurement error or small-scale variability at zero distance.
Slope	—	Linear model only. The rate of increase of the variogram with distance.
Scale	—	Power model only. Scaling factor for the variogram.
Exponent	—	Power model only. Controls the curvature of the variogram. Range: 0.01–10.

Visualization

Parameter	Default	Description
Colormap	Jet	Color scheme for representing concentration. Jet produces the familiar blue-to-red spectrum. Other

Parameter	Default	Description
		options: Turbo, Viridis, Plasma, Inferno, Magma, Coolwarm.
Show Boreholes	Checked	Displays borehole cylinders in the viewer. Requires an ID column in the input CSV to group readings by borehole.
Borehole Color	Black	Default color of borehole cylinders when Color by Threshold is unchecked.
Show Borehole IDs	Unchecked	Displays borehole ID labels in the viewer purely for visualization purposes. Labels are not part of the export.
ID Label Color	Black	Color of borehole ID labels. Shown when Show Borehole IDs is checked.
Color by Threshold	Checked	Colors boreholes red or green based on whether their peak concentration exceeds the threshold value.
Color Above Threshold	Red	Borehole color for readings above the threshold. Shown when Color by Threshold is checked.
Color Below Threshold	Green	Borehole color for readings below the threshold. Shown when Color by Threshold is checked.
Borehole Radius	0.5	Display radius of borehole cylinders in coordinate units (typically metres). Increase for visibility in large scenes.
Borehole Opacity	1	The opacity of borehole cylinders can be adjusted between 0.1 and 1.0 for visualization purposes, but exported cylinders are always output as fully opaque bodies.
Delete Surfaces	Unchecked	When checked, specific isosurface levels can be excluded from the viewer and export. In most cases the tool generates 6 surfaces, indexed 1 to 6 from lowest to highest concentration. This is useful for isolating specific concentration shells, for example, deleting surfaces 2 through 6 leaves only the outermost isosurface, while

Parameter	Default	Description
		deleting surfaces 1 and 2 removes the low-concentration isosurfaces to reveal interior detail.
Surfaces to Delete	—	Numer-based list of isosurface indices to exclude, entered as comma-separated values (e.g. 1, 2). Shown when Delete Surfaces is checked.

6.2.2. Advanced Tab Parameters

The Advanced tab provides finer control over specific aspects of the pipeline. Most parameters can be left at their defaults for a first run and adjusted iteratively as needed.

Outlier Handling

Parameter	Default	Description
Method	None	How extreme concentration values are detected and handled before interpolation. Options: 1) None – no handling; 2) IQR – interquartile range; 3) Z-Score – standard deviations from mean; 4) Percentile – clip to defined percentile bounds.
Cap Outliers	Checked	When checked, outliers are capped at the boundary value (data point kept, concentration clipped). When unchecked, outlier rows are removed entirely. Recommended to leave checked to preserve spatial coverage.
IQR Multiplier	2.0	IQR only. Sensitivity of outlier detection. Lower values (e.g. 1.5) flag more values; higher values (e.g. 3.0) are more conservative. Example: $Q1=1$, $Q3=5$, $IQR=4$, multiplier=2 Lower bound: $1 - (4 \times 2) = -7$ Upper bound: $5 + (4 \times 2) = 13$

Parameter	Default	Description
Z-Score Threshold	3.5	<p>Z-Score only. Number of standard deviations beyond which a value is flagged.</p> <p>Example: mean=2, std=3, threshold=3.5</p> <p>Lower bound: $2 - (3.5 \times 3) = -8.5$</p> <p>Upper bound: $2 + (3.5 \times 3) = 12.5$</p>
Lower Percentile	5	Percentile only. Lower clip bound. Default 5 clips the bottom 5% of values. Increase for more aggressive clipping.
Upper Percentile	95	Percentile only. Upper clip bound. Default 95 clips the top 5% of values. Decrease for more aggressive clipping.

Z-Floor Closure

These parameters only apply when Enable Z-Floor Closure is checked. Z-floor closure extends the interpolation grid below the deepest data point and applies a decay function that closes the plume at its base, preventing it from appearing to extend indefinitely downward. Recommended for soil plumes. Not required for groundwater mode, which is already bounded by screen extents.

Parameter	Default	Description
Enable Z-Floor Closure	Unchecked	Enables Z-floor closure. When Groundwater Plume Mode is toggled in the Main tab, this is also toggled automatically in the advanced tab.
Method	Decay	Closure approach: 1) Decay – concentrations gradually taper to zero below the deepest data point. Produces the most natural-looking base. Recommended; 2) Extend – everything below the deepest point is immediately set to the target value. More abrupt.
Extension %	5.0	How far below the deepest data point the grid extends, as a percentage of the total data Z range. Example: if data spans 20m vertically, a value of 5.0 extends the grid

Parameter	Default	Description
		1m below the deepest point. Increase if the plume base still looks open.
Decay Rate	2.0	Controls how steeply concentrations drop within the closure zone. 1.0 = linear decay 2.0 = quadratic (faster drop near base) 0.5 = slower, more gradual taper
Bowl Strength	1.0	Adds a bowl-shaped taper toward the lateral edges of the plume at depth, producing a more natural rounded base. 0.0 = flat (no bowl) 0.3 = subtle 0.5 = moderate 0.8 = pronounced 1.0 = maximum curvature

Post-Processing

These filters are applied to the interpolated grid after interpolation to reduce blocky or jagged artifacts.

Parameter	Default	Description
Gaussian Smoothing	Unchecked	Applies a Gaussian blur to the concentration grid to reduce blockiness.
Sigma	2.0	Gaussian smoothing kernel size in grid cells: 1.0 – light, preserves most detail; 2.0 – moderate, reduces most blockiness (default); 4.0 – heavy, plume edges become very soft; fine detail is lost
Median Filter	Unchecked	Applies a median filter before Gaussian smoothing. Useful for removing isolated concentration spikes.
Kernel Size	3	Median filter window size: 3 (default) — removes single-cell spikes 5 — removes larger spike clusters; may also smooth real concentration peaks

Performance

Parameter	Default	Description
Auto-optimize Large Datasets	Checked	When enabled, automatically switches to faster settings (Griddata interpolation, lower grid resolution, no volume rendering) if the dataset exceeds the threshold. This can be unchecked for no auto-optimization
Threshold (points)	50000	The number of data points above which auto-optimization is triggered.

6.3. Export Tab Parameters**3D Model Export (GLTF)**

Parameter	Default	Description
Export GLTF Model	Unchecked	When checked, the GLTF file is written to disk after the interactive viewer closes. When unchecked, the viewer runs without saving.
Solid Bands	Unchecked	Changes export geometry from hollow isosurface shells to solid filled volumes between concentration levels. Produces a more opaque, layered appearance in CSM 3D Vis™.

Volume Calculations

Parameter	Default	Description
Calculate Volumes	Unchecked	When checked, calculates the subsurface volume above each isosurface level and above the defined threshold. Volumes are estimated by counting the number of grid cells with concentration values above each level and multiplying by the volume of a single cell; accuracy therefore increases with grid resolution. Results are printed to the terminal, but can also be exported.

Parameter	Default	Description
Export Volume Report (CSV)	Unchecked	Saves volume calculation results to CSV files. Requires Calculate Volumes to be checked. When checked, an output directory field appears.
Output Dir	—	Directory where volume report CSV files will be saved.

Plume Levels Export (SHPs)

Parameter	Default	Description
Export Shapefiles	Unchecked	Exports horizontal concentration contours as shapefiles at defined depth slices, ready for use in QGIS.
Output Dir	—	Directory where shapefile outputs will be saved.
Z Levels	—	Depths at which horizontal slices are exported, as comma-separated negative values in metres. Example: -0.1, -1, -3, -5, -8, -10. Leave blank to let the tool select slices automatically.