



GEM4D DOCUMENTATION

Abandonment Bund (DMP 1997)

User Manual

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This manual shows you how to draw the zone of instability and the abandonment bund around an open pit with GEM4D, following the Western Australian 1997 guideline, and how to check the answer.

Regulatory scope. This tool implements the *generic* construction of the Western Australian guideline "Safety Bund Walls Around Abandoned Open Pit Mines" (1997), referred to in GEM4D as **DMP 1997**. The guideline's generic criteria assume **no major unfavourably oriented geological structures**, sound wall conditions and no nearby public infrastructure. Where any of these does not hold, the guideline requires a **site-specific geotechnical study**. This tool does not replace one, and every summary box says so. Check the current version of the guideline and any conditions attached to your tenement, and have the result reviewed by a competent geotechnical engineer.

How to use this manual

If you want to...	Read
Know what the tool produces	Chapter 1
Get a first result quickly	Chapter 2 — Quick start
Prepare the meshes and fill in the dialog	Chapters 3 and 4
Run it, read the results and check them	Chapters 5–7
Understand the construction behind the answer	Part 2 (Chapters 8–15)
Fix a problem or look up a term	Part 3 (Chapters 16–17)

Part 1 — Using the tool

1. What the tool does

Calc ► **Abandonment bund (DMP 1997)** draws the guideline's construction around an open pit. **Calc** is the Σ button on the scene toolbar; its tooltip starts *Calc*:

It produces four objects:

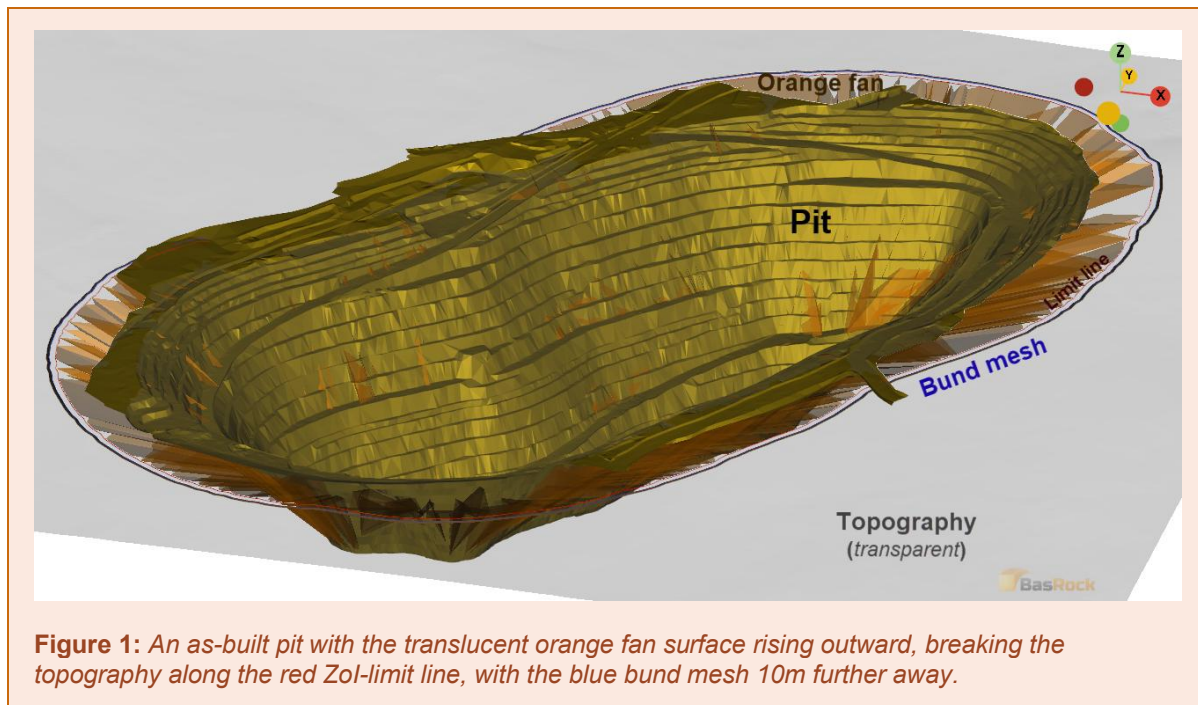
1. the **fan surface** — the projection lines that govern the answer, as a surface you can look at and check;
2. the **Zol limit line** — where those lines meet the natural ground, which is the outer limit of the zone of instability (Zol);
3. the **bund line** — the Zol limit moved outward by a standoff, and kept at least a set distance from the pit crest;
4. the **3D bund wall** — a solid wall of your chosen height and base width, with its pit-side toe on the bund line.

The tool slices the pit horizontally at many elevations. From each slice it projects lines outward and upward at the design angle: 45° in fresh rock by default, and optionally a flatter angle through weathered rock. Where a line meets the natural ground, it *daylights*. At each point around the crest, the line that reaches furthest from the crest governs. Part 2 explains the construction.

The results are ordinary GEM4D objects. You can save them to DXF, measure them and hand them on.

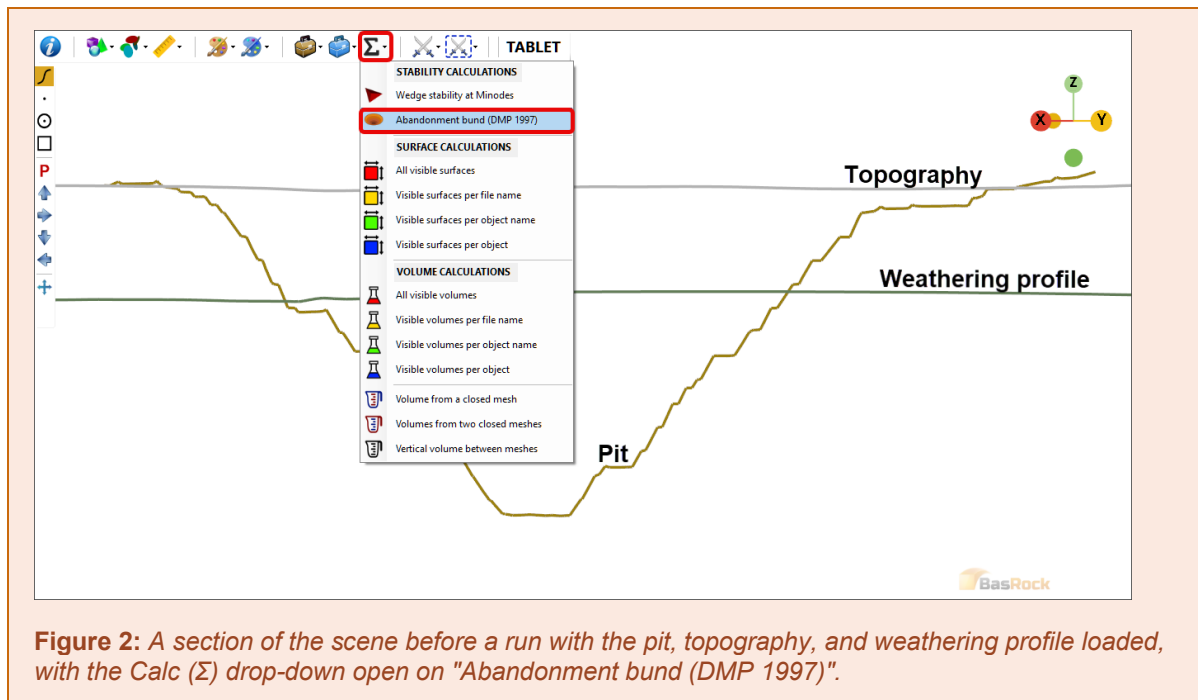
Typical questions it answers:

- *Where does the instability zone daylight around a pit whose depth, wall angle and relief all vary?*
- *Which bench actually drives the answer on each side of the pit?*
- *Where does the bund go, and how long is it?*



2. Quick start

1. Load the pit surface and the natural topography as **two separate meshes**. The topography must reach well beyond the pit. Turn clipping off.
2. Click **Calc** (Σ) ► **Abandonment bund (DMP 1997)**.
3. In the mesh-role table, tick the pit surface in the **Pit** column and the topography in the **TOPO** column. On a first run every visible mesh starts ticked as TOPO; ticking **Pit** on the pit's row clears its TOPO tick.
4. **Sections from / to** follows the pit. Set **every** to about half your bench height.
5. Keep the other defaults: 45°, the suggested line spacing, no weathering, 10 m standoffs and all four outputs ticked. Click **Calculate**.
6. Watch the progress bar in the status bar. **Esc** cancels.
7. A Save dialog asks for a DXF file name for the outputs. Cancelling it discards them.
8. Read the summary box (Chapter 6). Then hide the topography and look at the fan surface (§5.2).
9. Halve the section interval and run again, then halve the line spacing. The Zol limit should barely move (§7.1).



3. Before you run: the inputs

Input	Role column	What it is
Pit surface	Pit	An as-built or design surface of the excavation. The horizontal slices are cut from it. Required, unless you use a Toe string.
Natural topography	TOPO	The ground the projection lines daylight against. Always required. It must extend well beyond the expected reach.
Toe string (optional)	Toe	Any loaded object with polylines, such as a DXF string or a Surpac STR. Used as the source outline instead of slicing the pit.
Crest string (optional)	Crest	A surveyed crest string to measure "furthest from the crest" against. Without one, GEM4D uses the widest slice (§12.1).
Base of weathering (optional)	BOCO	The modelled contact surface, for mesh-defined weathering (§4.4). A constant contact RL needs no mesh.

Three rules:

- **The pit and the topography must be separate meshes.** The projection lines are cast against the TOPO surface only. A combined as-built used for both would stop every line on the pit wall. The dialog lets each mesh play only one role.
- **A combined as-built is fine as the Pit**, as long as a separate topography is ticked as TOPO. GEM4D drops the terrain contours a combined surface adds to each slice (§14.1).
- **Clipping must be off.** Clipped fragments would misrepresent the pit, so the tool refuses to run in clipping mode.

4. The settings dialog

Abandonment Bund (DMP 1997)

Mesh roles (Pit supplies the section; Toe replaces it with a drawn string)

Mesh: Object name	Cells	Pit	TOPO	BOCO	Toe	Crest
1_Pit	15,582	☒	☐	☐	☐	☐
2_Topography	6,452	☐	☒	☐	☐	☐
4_Weathering_dropped	4,023	☐	☐	☒	☐	☐

Source sections through the pit shell

Sections from: to: every: m (mine RL)

Ticked Pit meshes span RL 862.8 to 1226.21 — the current range and interval give 11 section(s).

Projection (unweathered rock)

Projection angle: ° from horizontal Line spacing: m

Weathering (flatter projection through the weathered profile)

☐ None — unweathered rock throughout Weathered angle: °

☐ Constant contact RL: m (mine RL) — fresh below, weathered above

☒ Contact surface mesh — tick it in the BOCO column above (fresh below the surface)

Output lines

Standoff outside Zol: m beyond the daylight line (DMP 1997: at least 10 m)

Crest standoff: m min clearance from the crest (DMP 1997: 10 m; 0 = off)

Simplify tolerance: m — removes the station sawtooth (0 keeps every point)

Smoothing radius: m min. concave radius — outward only (0 = off)

Outputs (inserted as Create objects)

☒ Fan surface ☒ Zol limit line ☒ Bund line

☒ 3D bund wall height: m (≥ 2 m) base width: m (≥ 5 m base)

DMP 1997 generic criteria — assumes no major unfavourably oriented geological structures. Site-specific study required near public infrastructure or where wall conditions were poor.

Cancel Calculate

Figure 3: The Abandonment Bund (DMP 1997) dialog with the mesh-role table populated, a section range and interval entered, and all four output checkboxes ticked.

The dialog has six groups, top to bottom: the mesh roles, **Source sections through the pit shell**, **Projection (unweathered rock)**, **Weathering**, **Output lines** and **Outputs (inserted as Create objects)**. A note at the bottom repeats the guideline's scope. **Calculate** runs the tool.

Every setting is remembered for the rest of the session.

4.1 Mesh roles

One row per loaded mesh. The columns are **Mesh: Object name**, **Cells**, then the five roles **Pit**, **TOPO**, **BOCO**, **Toe** and **Crest** (Chapter 3).

- **One role per mesh.** Ticking a role clears any other tick on that row.
- **Several meshes can share a role.** They are pooled into one surface.
- **BOCO drives the weathering option.** Ticking a mesh in BOCO selects **Contact surface mesh** (§4.4). Removing the last BOCO tick sets weathering back to **None**.
- **Ticking a Toe string turns slicing off.** The section-range row greys out, and the fan starts from the string's own polylines, at their own elevations.

Roles are remembered for the session and re-applied by object name the next time you open the dialog. Objects with the same name each take one remembered row, in order. On a **first** run only the TOPO column is pre-ticked, for every visible mesh. Every other role is a deliberate choice: pre-ticking Pit from visibility would quietly flag natural terrain whenever the topography is visible too.

4.2 Source sections through the pit shell

Control	Range	Notes
Sections from: / to:	±100 000 m (mine RL)	The elevation range to slice. The top of the range is always cut, whatever the interval leaves over.
every:	0.1–500 m	The vertical interval between slices.
<i>(hint line)</i>	—	<i>"Ticked Pit meshes span RL ... to ... — the current range and interval give N section(s)."</i>

Until you change them, the range follows the ticked Pit meshes from bottom to top, and the interval is a tenth of that span.

Choosing the range and interval:

- **Bottom.** The deepest point of a pit is often a **sump**, not a working level. Starting below it costs nothing: its projection simply loses, or flies off and never lands. To keep it out of the picture, start the range above its lip.
- **Top.** Set it at or near the crest. Without a Crest string, the crest reference is the widest slice (§12.1), which can only be as high as you slice.
- **Interval.** The interval decides which benches are seen. An interval much larger than the bench height can step over the toe that governs. Start at about half the bench height (or a tenth of the wall height), then halve it and confirm the Zol limit stops moving (§7.1). Up to 2 000 sections are allowed. All of them are cut in a single pass over the pit mesh, so a fine interval costs projection lines, not cutting time.

Setting the top equal to the bottom gives exactly one slice. If the range lies entirely outside the ticked Pit meshes, GEM4D asks before going ahead.

4.3 Projection (unweathered rock)

Control	Range	Default	Notes
Projection angle	5–89°	45°	Measured from horizontal. The guideline's generic value for fresh rock .
Line spacing	0.25–100 m	suggested	How far apart the projection lines sit along each outline.

The suggested spacing is about 1/400 of the plan width of the visible meshes, rounded up to the next 0.5 m. A scene 4 km across gets 10 m.

Line spacing sets the resolution of the whole answer twice over. It sets how densely each slice is fanned, and it is also the size of the crest stations that decide which projection governs (§12.2). It is the main cost driver: halving it doubles the lines per slice, and the number of slices multiplies that again. Start with the suggestion, then halve it and confirm the Zol limit stops moving.

Above about **500 000** projection lines, GEM4D gives the count and the memory it will need, and asks before starting. Above **2 000 000** it declines and asks you to coarsen the spacing or the interval. Both are guards against a mistyped setting, not limits on how fine the analysis can be.

Corners are always fanned finely, whatever the spacing. The arc across a corner is stepped at most 5° at a time, so a right-angle corner gets 17 lines of its own. The straight pieces on either side add one each at the ends of the arc.

4.4 Weathering

Control	Range	Default	Notes
None — unweathered rock throughout	—	selected	The single-angle construction.
Constant contact RL	±100 000 m (mine RL)	0	One horizontal contact for the whole site. Fresh rock below it, weathered above.
Contact surface mesh	—	—	The base of weathering is the mesh (or meshes) ticked in BOCO .
Weathered angle	1–89°	25°	The flatter projection angle through the weathered profile. Refused if it is steeper than the projection angle.

The weathered angle is greyed out while **None** is selected, and the RL box is greyed out unless **Constant contact RL** is selected. Chapter 11 describes what the lines do at the contact.

- **Constant contact RL** is the blanket assumption. Use it when the depth of weathering is known only regionally, or to bracket the answer. A contact at or above the highest topography cannot affect any line; the run is made without weathering and the summary says so. A contact below the whole slice range makes every line weathered from the start.
- **While Constant contact RL is selected, a translucent tan plane shows the contact in the scene.** It follows the RL box as you edit it, so you can set the contact against the walls rather than by number. It disappears when you choose another option or close the dialog. A run with a constant contact also **inserts the plane as a mesh named BOCOPlane** with the other outputs, so the assumption travels with the deliverable.
- **Contact surface mesh** follows your geological model. A projection line whose start point has **no contact surface** vertically above or below it is taken as **fresh rock**, and counted in the summary. GEM4D never assumes weathering where none is modelled. If the count matters, extend the contact model, or use a constant RL as the conservative blanket case.

- **The weathered angle extends the reach a long way.** At 25°, a line moves about 2.1 m outward for every metre it climbs, against 1 m at 45°. Expect the Zol limit to move out wherever weathered ground overlies the walls.

4.5 Output lines

Control	Range	Default	What it does
Standoff outside Zol	0–200 m	10 m	Distance from the Zol limit to the bund's pit-side toe (DMP: at least 10 m). At 0, the bund line is drawn on the Zol limit itself, still subject to the crest standoff.
Crest standoff	0–200 m	10 m	The guideline's second rule: the bund "in any case" at least this far, in plan, from the pit crest. 0 turns the rule off (§13.2).
Simplify tolerance	0–20 m	1 m	Removes the small sawtooth from both lines without moving them more than this distance. 0 keeps every point (§12.3).
Smoothing radius	0–200 m	50 m	The smallest concave radius the Zol limit may have. Smoothing only ever moves the line outward. 0 turns it off (§12.3).

4.6 Outputs (inserted as Create objects)

All four are ticked by default. Untick what you do not need.

Checkbox	Object name	What it is
Fan surface	BundFan	A translucent orange surface swept by the governing lines only, one sheet per continuous stretch of crest they govern. It carries the raw daylight positions. Tick it every time you check an answer.
Zol limit line	ZoILimit	A red closed ring on the governing daylight positions, lifted 0.3 m so it shows above the topography. One DXF polyline per ring.
Bund line	BundLine	A blue closed ring at the standoff beyond the Zol limit, draped on the topography and lifted the same 0.3 m. One DXF polyline per ring.
3D bund wall	BundWall	A brown solid wall with a triangular cross-section, its pit-side toe on the bund line (§13.3). One object for all rings.

The wall row has two boxes: **height** (0.5–20 m, default 2 m, labelled *m* ($\geq 2\text{ m}$)) and **base width** (1–50 m, default 5 m, labelled *m* ($\geq 5\text{ m base}$)). The labels show the guideline's minimums. The boxes are greyed out unless **3D bund wall** is ticked. A base narrower than twice the height gives side slopes steeper than 45°, steeper than dumped fill can stand. GEM4D asks before building such a wall rather than refusing it, because a keyed or reinforced bund is your decision.

The wall follows the bund alignment even when **Bund line** is unticked, so the crest rule still applies to it.

A run with **Constant contact RL** weathering also inserts the contact plane, BOCOPlane (§4.4). It has no checkbox of its own.

5. Running and viewing the results

5.1 Running

After you click **Calculate**:

1. The progress bar in the status bar fills as GEM4D cuts the sections, fans them, prepares the topography for ray-casting, projects the lines, selects the governing ones and builds the bund. The phase names go to GEM4D_diag.log.

2. **Esc** cancels at any time. Nothing is created (*"Abandonment bund calculation cancelled — nothing was created."*).
3. A Save dialog asks for a DXF file name. All ticked outputs go into that one file. Cancelling the dialog discards them (*"Saving was cancelled and the created objects deleted"*).
4. The summary box opens (Chapter 6).

The projection lines are cast in parallel across your processor cores. The cost is roughly $\text{slices} \times \text{lines per slice} \times \text{the cost of one line against the topography}$, so a fine interval and a fine spacing multiply.

5.2 Look at the fan first

Hide the topography and view the fan surface obliquely. In one look you can confirm that:

- it rises **outward**, away from the pit, everywhere;
- corners fan smoothly instead of leaving wedges;
- the line origins step from bench to bench where the governing slice changes. That stepping is the guideline's Figure 2B behaviour (Chapter 10), made visible.

Then show the topography again. The fan disappears into the ground, and the red Zol limit line marks exactly where it breaks through.

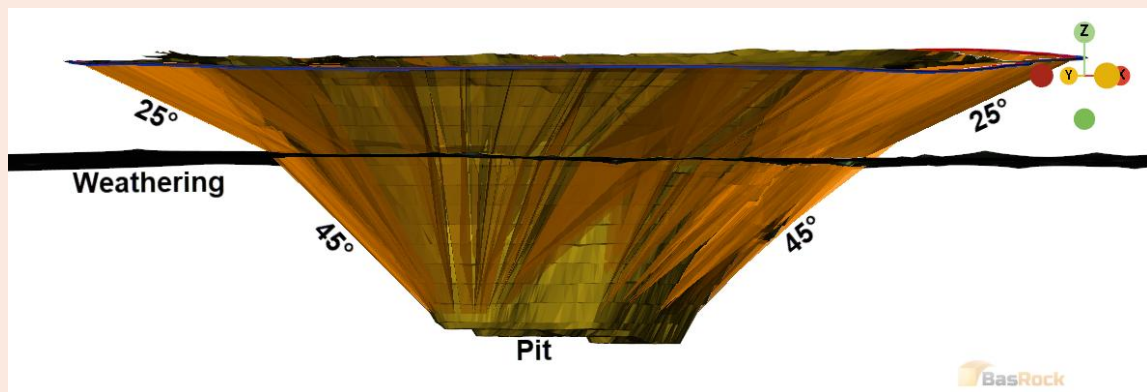


Figure 4: The governing fan surface with the topography hidden, showing the line origins stepping between benches around the pit.

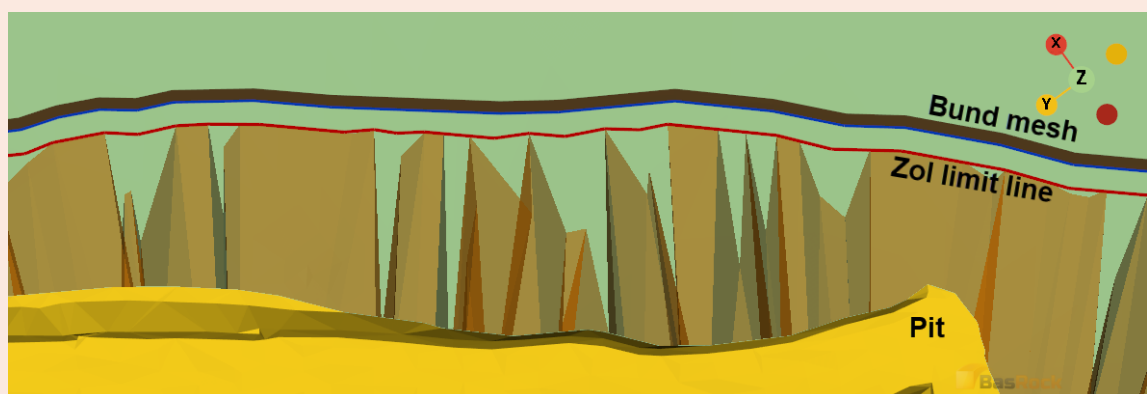


Figure 5: A plan view with the Zol limit line and the bund line together, showing the constant standoff band between them. The red (Zol) and blue (bund) lines are 10m apart, and the bund mesh built start at the blue bund line.

6. The summary box

The summary box opens after every run, headed *Abandonment bund construction complete*. It lists only counts and lengths; the full detail of each run goes to GEM4D_diag.log. The lines below appear in the order the box shows them. A line in *italics* appears only when it applies.

Line	Meaning
Source:	The sections that cut the pit, their range and interval (or <i>drawn outline</i> for a Toe string), the total outline length and the line spacing.
Section loops ignored: <i>N</i> open fragment(s), <i>M</i> topographic high(s)	Loops cut from the Pit mesh that are not excavation (§14.1). A large <i>M</i> means the Pit mesh covers a lot of ground beyond the crest. That is harmless; it tells you the mesh is a combined as-built.
Measured from the ...	The crest reference used: the <i>widest section ring</i> (<i>RL ...</i>), the <i>ticked crest string</i> , or, in a Toe-string run with no Crest ticked, the <i>drawn outline</i> (<i>no Crest ticked</i>). A reported <i>RL</i> far below your range top means the higher slices never form complete rings, usually on a pit in sloping terrain. Consider a surveyed crest string (§12.1).
Daylight: <i>N</i> of <i>M</i> lines (<i>K</i> trimmed on the medial axis)	How many projection lines met the ground. Trimmed lines are normal wherever an outline has inward corners (Chapter 9).
Governing: <i>N</i> station(s) drawn from <i>X</i> of <i>Y</i> section(s), reaching <i>A</i> to <i>B</i> m out	How much of the crest got an answer, how many slices contributed one, and the range of horizontal reach. If <i>X</i> is 1, one bench governs everywhere and a coarser interval would have done. If <i>X</i> is most of <i>Y</i> , the interval is earning its keep.
Zol limit: <i>L</i> m in <i>R</i> closed ring(s)	The total length of the Zol limit. One ring per crest loop; a single pit gives one.
<i>No line reached the ground — nothing daylighted, so there is no limit line.</i>	Replaces the three lines above when no projection met the topography. The topography does not reach the fan, or TOPO is ticked on the wrong mesh.
<i>Smoothed at a <i>R</i> m minimum concave radius — outward only, deepest sealed notch <i>X</i> m</i>	The smoothing (§12.3) ran at radius <i>R</i> . <i>X</i> is the deepest notch it sealed: the furthest any measured point now lies <i>inside</i> the smoothed line. A ring the smoothing could not process is left as measured and counted.
Bund line: <i>L</i> m at <i>S</i> m beyond the limit	The bund-line length and the standoff used. Shown when Bund line is ticked.
<i>Wall toe alignment: <i>L</i> m at <i>S</i> m beyond the limit (Bund line output not ticked)</i>	Shown instead of the bund-line line when the wall is ticked but the bund line is not. The alignment is still computed, so the crest rule still applies.
Crest rule: ...	Shown whenever the bund line or the wall is ticked. Either <i>N bund point(s) pushed out to the <i>C</i> m crest clearance (<i>K</i> added on the arcs)</i> ; or <i>the bund line already clears the crest by <i>C</i> m everywhere</i> ; or <i>OFF (crest standoff 0)</i> , so a disabled rule is never mistaken for a passed one. <i>N could not reach clearance</i> flags ground that cannot hold a compliant bund (§13.2). With the bund line unticked, the line speaks of the <i>wall toe</i> .

Line	Meaning
Bund wall: H m high on a W m base, pit-side toe on the bund line	The wall was built with these dimensions. A bracketed count of wall points that <i>had no ground beneath them</i> means the base ran past the edge of the topography; those points kept the nearest landed elevation. If it reads not built — the half-base-width offset swallowed every bund ring , the rings are smaller than the wall base.
N projection(s) daylighted INSIDE the crest and were discarded	These lines rose through the ground surface while still over the excavation, so they undermine nothing beyond the crest. Expected, often in large numbers, when the topography spans the pit opening, as a regional DTM does. Only lines that clear the crest can govern.
Interpolated across N station(s) where nothing daylighted, longest run X m	The ring is closed by interpolation where no line landed (§12.2). A short run is housekeeping. A long one is a stretch where the answer is not measured, and is worth a look.
Clean-up: N crest loop(s) ignored ...; M self-crossing(s) removed; K bund point(s) had no ground beneath them and took a neighbour's elevation	Three counts on one line: crest loops dropped for not enclosing the pit, folds untangled from the rings, and bund points with no topography beneath them. The line appears only when one of the counts is not zero.
Warning: untangling removed more than a tenth of N ring(s)	The crest reference is probably not a clean pit outline, so the stations are ordered badly. Check the fan and consider a surveyed crest string.
Note: the crest-enclosure check matched no loop ... all crest candidates were kept	Expected on a single-slice or Toe-string run , where the crest reference is the source outline. Nothing is wrong.
N of M lines never met the ground	Expected: these are the projections arrested inside the pit (Chapter 10). Act only if it is <i>most</i> of them, which means the topography does not reach far enough.
Note: the outward side of N open outline(s) was taken from their own direction	No Pit mesh was ticked to probe against (§14.5). Check that the fan points the way you expect.
Weathering: N of the M daylighted line(s) kink at the contact; K met the ground in weathered material	How much weathering changed the answer. If both counts are 0, the contact never mattered.
N line(s) started outside the contact surface's coverage and were taken as fresh rock	Contact-mesh weathering only (§4.4). Extend the contact model if the count matters.
N line(s) hit the 8-kink guard	The contact surface runs along those lines, so they crossed it more than eight times. From the eighth kink on they keep their material. Rare; look at the fan crease there if it matters.
Objects created: N.	How many output objects were inserted. Instead it reads <i>Objects: cancelled at the save dialog — nothing inserted</i> if you cancelled the save, or <i>Objects: none created (nothing to draw from these sections)</i> when there was nothing to draw.
Projection angle: ...	The angle used, <i>from horizontal (unweathered rock throughout)</i> ; with weathering, <i>Projection angles: ... in fresh rock, ... in the weathered profile, kinked at the contact RL or the contact surface</i> . If a constant contact lay at or above the highest ground, a note says the weathered angle never engaged.
Note: DMP 1997 generic criteria assume ...	The guideline's scope, repeated on every run.

7. Checking the answer

7.1 Refine, twice

Run once at the suggested spacing and your interval. Then **halve the section interval** and confirm the Zol limit barely moves. If it jumps, the interval was stepping over the governing bench. Then **halve the line spacing** and confirm the same. Refine whichever one moved until the line is stable.

7.2 The analytic check

Worth doing once, so that you trust the tool:

1. Build a simple conical or pyramidal pit with a flat floor at a known RL.
2. Load a **flat** topography a known height h above that floor.
3. Slice at the floor only (bottom = top = floor RL), angle **45°**, both standoffs 0.

The Zol limit must sit exactly h metres out from the floor outline, all the way round, and h metres above it. At 60° it must sit $h / \tan 60^\circ = 0.577 h$ out.

With weathering: add a constant contact RL a known height w above the floor ($0 < w < h$) and a weathered angle of 25°. The limit must now sit exactly $w + (h - w) / \tan 25^\circ$ out: the 45° rise to the contact, then the flatter climb. The fan shows a clean circular crease at the contact elevation. Put the contact below the floor and the answer becomes $h / \tan 25^\circ$. Put it above the topography and it returns to h .

The same cases are pinned by GEM4D's unit tests.

Part 2 — How it works

8. The DMP 1997 rule, in section

Draw a section through the pit. From the toe of the wall, project a line upward and outward at **45°** through unweathered rock, the guideline's generic value. Where that line meets the natural surface is the outer limit of the ground that could be undermined as the abandoned walls ravel and regress. The bund's pit-side toe stands at least **10 m** beyond that point, and at least 10 m from the crest. The bund itself is at least **2 m** high and **5 m** wide at the base.

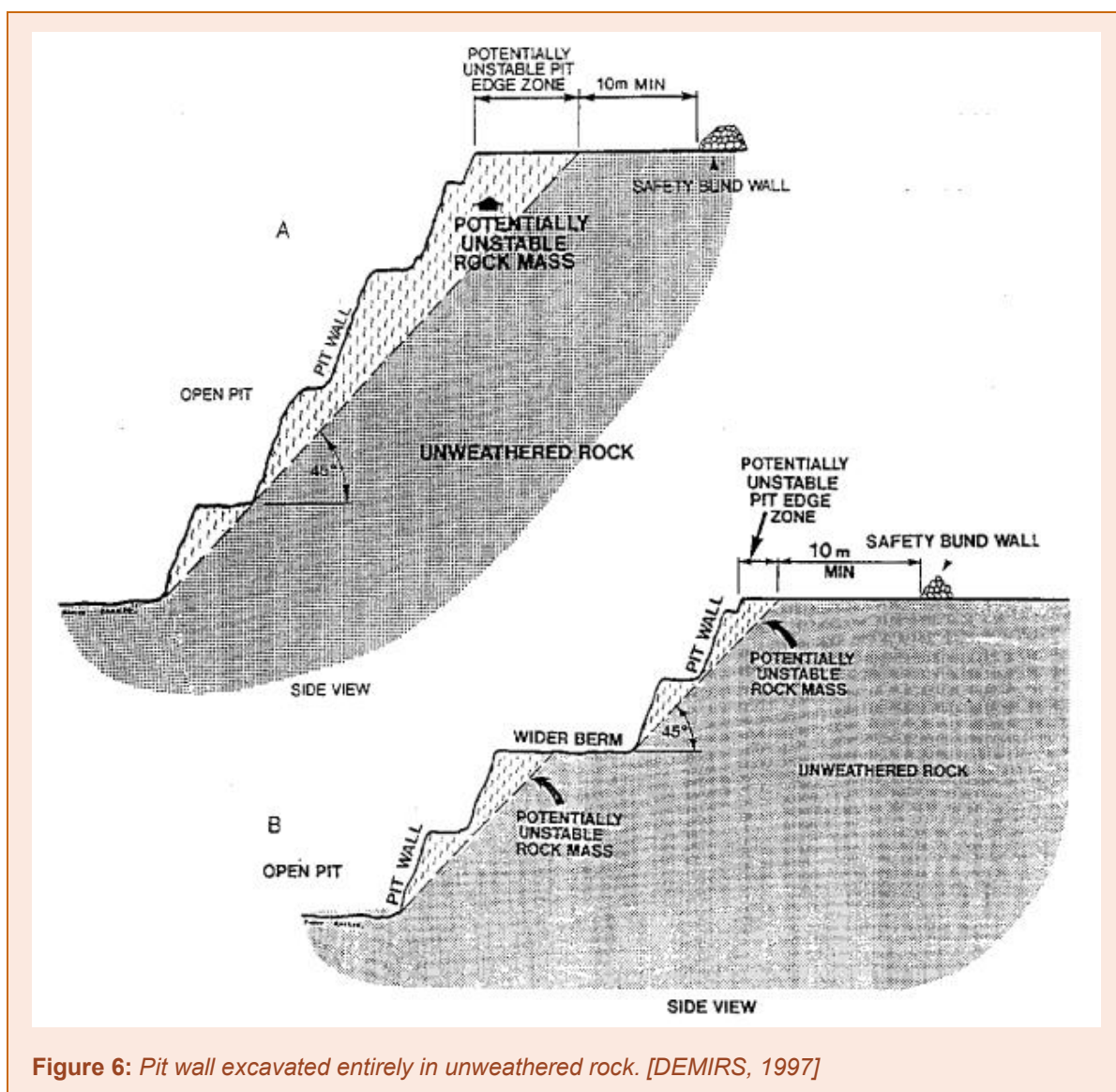


Figure 6: Pit wall excavated entirely in unweathered rock. [DEMIRS, 1997]

9. From a section to a fan

A pit is not one section. GEM4D takes the closed outline the pit makes at a chosen elevation and repeats the section construction **all the way around it**. Every straight piece of the outline sends out lines tilted outward, away from the void, at right angles to the piece. Together those lines form a surface: the **fan**.

Doing it this way, rather than on a handful of hand-picked sections, has two benefits:

- the answer is **continuous** around the pit, with no interpolation between sections and no missed re-entrant;
- the answer is **visible**. The fan is a real mesh. If it points the wrong way, or stops somewhere odd, you see it at once.

Corners. A fan of lines at right angles to the outline does not obviously know what to do at a corner. GEM4D does not guess; the answer follows from what the fan is. Its elevation at any point in plan is

$$\text{fan elevation} = \text{slice elevation} + \tan(\text{angle}) \times (\text{horizontal distance to the outline})$$

That gives a single value everywhere outside the outline, with three consequences:

Where	What you get	Why
Along a straight piece	The tilted plane you would draw by hand.	The nearest point of the outline is straight across.
At an outward (convex) corner	A cone around the corner : the fan opens out in an arc.	For a range of directions, the corner point itself is the nearest part of the outline.
At an inward (reflex) corner	The two sheets stop on the line that bisects the corner .	Each point is claimed by the nearer piece. The two sheets reach the bisector at the same height, so they meet exactly, with no gap and no crossing.

The same rule handles a narrow neck between two arms of an outline, with no special case. The line that stops at a bisector is reported as *trimmed on the medial axis* in the summary. Every inward corner also sends one line straight up its bisector, so that a smoothly curving inward stretch of wall is sampled too.

Within one slice, the daylight line therefore cannot cross itself. Folds can still appear once the slices are combined into one ring; §12.3 explains how they are removed.

Slices never trim each other. The bench above sits only a berm-width outside the bench below. If the slices competed geometrically, every line from the lower bench would be cut off after half a berm. Each slice is an independent construction, and the selection in Chapter 10 decides between them.

10. Many sections: the guideline's Figure 2B

Project 45° from the very bottom of a pit whose overall wall is *flatter* than 45°, or that has a wide berm, and the line leaves the rock and passes into the void. That projection is **arrested**: it daylights on the pit face itself, and the ground beyond the pit is not undermined by that toe at all. The real driver is the toe of a face **higher up**.

The guideline covers this case in its Figure 2B. GEM4D generalises it: it slices the pit at many elevations, fans every slice, and at each place around the pit keeps the projection that reaches furthest out.

The arrested projections need no special detection. Every line is cast against the **topography only**. A line that leaves the excavation into the void keeps climbing, never comes down and never offers a candidate. The upper slice wins by default.

11. Weathering: the contact kink

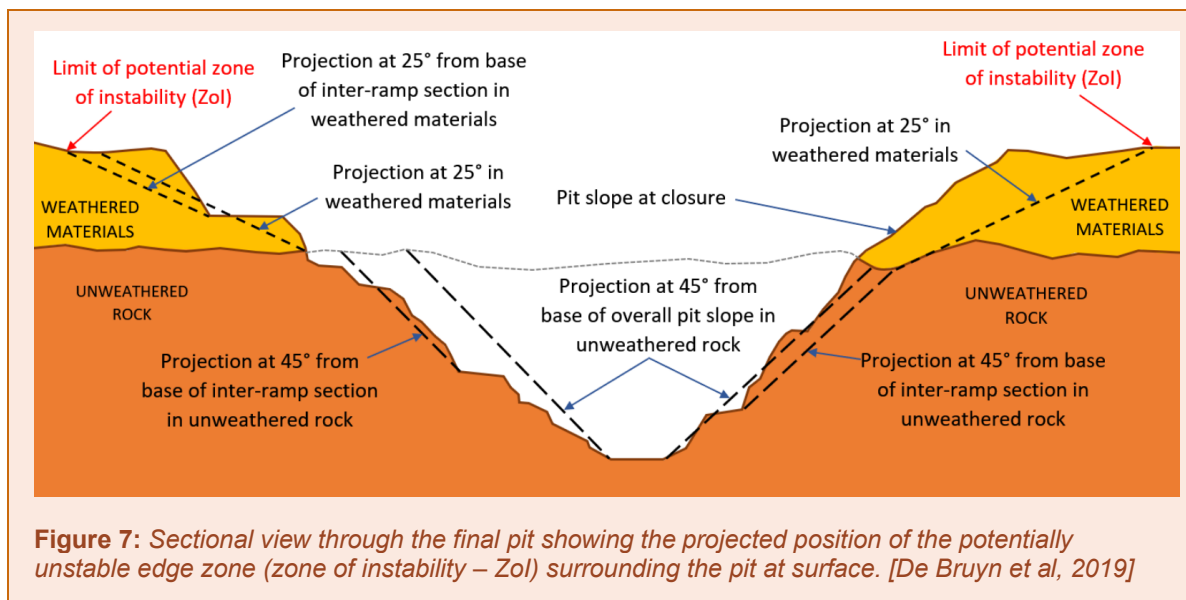
Weathered rock does not stand at 45°. The guideline projects at the fresh-rock angle only **below the base of weathering**. Above the contact, the projection continues at a **flatter angle**; GEM4D defaults to 25°. So the section line **kinks where it crosses the contact**, and the zone of instability reaches further out wherever weathered ground overlies the pit.

GEM4D draws exactly that, line by line:

- A line rises at the fresh angle until it crosses the contact, then continues at the weathered angle until it daylights.
- A line that starts in weathered ground (a slice above the contact) rises at the weathered angle from the start.
- A line that daylights before reaching the contact never kinks.
- If an undulating contact surface crosses a line more than once, the line kinks at every crossing, steepening back to the fresh angle where it re-enters fresh rock.

With a contact surface mesh, each line's starting material comes from a vertical probe: above the contact is weathered, below is fresh. The line then kinks at its **exact** crossings with the surface, with no gridding in between.

Weathering bends the lines only vertically. Everything that works in plan is unchanged: the corner trimming, the slice competition, the crest stations, the rings and the smoothing. On the fan surface the kink shows as a visible **crease**, so the two-angle construction stays inspectable. Every governing line is still the section an engineer would draw by hand through that point of the pit.



12. From projections to the Zol limit line

12.1 The crest reference

"Furthest from the crest" needs a crest. If you tick a **Crest** string, GEM4D uses it; that also lets you measure against a crest above or outside your slice range.

Otherwise the crest reference is the slice whose rings enclose the **largest plan area**. A pit widens towards the rim, so the widest ring is the highest *complete* outline. The summary reports the RL it came from.

It is deliberately **not** the topmost slice. On a pit in sloping terrain the rim RL varies, and the slices just below the high side of the rim survive only as small fragments, because the outline has already opened into the hillside on the low side. A fragment as the crest ruins the selection: the daylight points crowd onto a short stretch of stations, the inside-the-crest test stops working, and the limit line comes out as long chords across the pit. At a coarse interval the two choices usually agree; a fine interval exposes the difference.

The crest is used for three things: ordering the stations, deciding which way the bund standoff pushes, and measuring the crest standoff (§13.2). It never positions a point of the answer. It does not enter the projection either, and so the crest rule works with **no surveyed crest at all**: the widest slice comes from the same pit mesh as everything else.

A crest loop is used only if it holds the pit, that is, if it encloses or runs along a source outline. Other loops are dropped and counted on the summary's *Clean-up* line.

12.2 One point per crest station

GEM4D divides the crest into **stations**, one per line spacing. Every daylight point is assigned to the station of its nearest point on the crest, and at each station the projection that reaches **furthest from the crest** governs.

- A line that daylights **inside** the crest has risen through the ground while still over the excavation. It is arrested and discarded, and counted in the summary.
- Each station contributes exactly one point to the Zol limit: the **measured** daylight position of its governing line. So the limit comes out as one closed ring per crest loop, and fragments, gaps and forks cannot occur.
- A station where nothing daylighted takes a distance interpolated from its neighbours along the crest, so that the ring closes. The summary reports how many stations were interpolated and the longest run.

12.3 Cleaning up the limit line

Three steps tidy each ring, in this order:

1. **Untangling**. Combining slices can leave a small fold in a ring. GEM4D removes the enclosed loop and counts it on the *Clean-up* line.
2. **Smoothing** (the **Smoothing radius**). GEM4D rolls a disc of this radius around the *outside* of the ring and keeps the boundary the disc can touch. Inward notches narrower than twice the radius are sealed by smooth arcs. The line only ever moves **outward**, gaining margin and never giving any up. Wherever the line was already smoother than the radius it stays exactly where it was, and outward reaches, which are measured projections, are kept. Physically, the radius is the smallest concave radius an earthworks alignment can follow anyway. The summary reports the deepest notch that was sealed.
3. **Simplifying** (the **Simplify tolerance**). Because "furthest wins" is decided separately at each station, a corner projection reaching a metre further than its neighbours pulls out a small tooth. Douglas–Peucker simplification removes these teeth while guaranteeing that the line never moves more than the tolerance from the measured one. It also cuts the number of vertices substantially, which keeps the DXF light. At 0, every station is kept.

Every point on the finished Zol limit is still a measured daylight position, apart from interpolated stations and the arcs added by smoothing. The clean-up decides which points are used and in what order. The fan surface keeps every raw daylight position for audit.

13. The bund line and the wall

13.1 The standoff

The bund line is the cleaned Zol limit offset outward by the **Standoff outside Zol**, with rounded arcs at outward corners. It inherits the smoothing of the limit line. It is then untangled and simplified like the limit, and draped on the topography. A bund point with no topography beneath it takes a neighbour's elevation, so that the ring still closes, and is counted on the *Clean-up* line.

13.2 The crest rule

The guideline also requires the bund to be "in any case" at least 10 m, in plan, from the pit crest. This matters where the projection construction produces the least: walls flatter than the projection angle arrest every line inside the pit, and a shallow pit daylights just past the crest. In both cases the Zol limit hugs, or never leaves, the crest.

Wherever the bund line comes nearer than the **Crest standoff** to the crest reference, or strays inside it, that stretch is pushed straight out from the crest to exactly the clearance. Points are added around

crest corners so that the line between pushed points cannot dip back inside. Everything already clear is left where the projection put it.

- **The Zol limit line is never moved.** It is the measured answer; only the bund line is subject to the rule.
- **With the default 10 m standoff outside the Zol, the rule only engages on those starved stretches.** Wherever the zone encloses the crest, 10 m beyond the zone is already 10 m beyond the crest.
- **Some ground cannot hold a compliant bund,** for example a corridor between two crest loops narrower than twice the clearance. The summary then reports *could not reach clearance* rather than pretending. Those stretches need an engineering decision, not a longer offset.

13.3 The 3D bund wall

The bund line is the wall's pit-side toe, not its centre. Both standoffs are clearances to the bund's **nearest part**, its inner toe. A wall centred on the line would quietly give back half a base width of every clearance. So the wall's centre-line is the bund line offset **outward** by half the base width, with the same rounded corners, and the inner edge of the base runs along the bund line. The outer toe therefore reaches the standoff **plus one base width** beyond the Zol limit. The bund line in your DXF is the edge of the earthworks.

How the wall is built. At every point of the centre-line the wall has three edges: the **crest of the wall** at the local ground elevation plus the wall height, and the two **base edges** at half the base width on either side, each seated at **its own** ground elevation. The wall therefore follows undulating topography instead of floating or digging in. Ground elevations come from vertical ray-casts against the TOPO surface. Corners are mitred and limited at sharp turns so that the wall cannot flare out. Closed rings join seamlessly, open ends are capped, and the underside is closed, so the wall is a solid and reports a volume in CAD.

14. How the surfaces are used

14.1 The Pit mesh

The Pit meshes are pooled and cut by a horizontal plane at each section elevation. The cut segments are joined into ordered outlines.

Not every loop a section cuts is pit. A combined as-built that extends past the crest, as most survey pickups do, also yields contours of the surrounding ground at high sections: ridges, knolls and lines running off the edge of the survey. GEM4D keeps a section loop only when it is **closed** and the excavation rises towards its **outside**, which is what a contour of a depression does and a contour of a high does not. The summary counts both kinds of dropped loop.

14.2 The TOPO mesh

The TOPO meshes are pooled into one surface for ray-casting. Each projection line takes its **first** intersection with it as its daylight point. Nothing else is ever daylighted against.

14.3 The BOCO mesh

With mesh-defined weathering, the BOCO meshes are pooled into their own ray-casting surface (Chapter 11).

14.4 Toe and Crest strings

The object's line segments are joined into ordered polylines and used as they are, at their own elevations.

14.5 Which way is outward

GEM4D does not rely on how an outline happens to be wound. It probes the **pit surface** a short step to either side of the outline and takes the side where the pit is **higher**, because the pit rises towards the crest. Many samples along the outline vote, and the majority decides, so noise on a cut outline cannot flip individual lines.

Where nothing can be probed, the outline's own winding is used. That is reliable for a closed loop; for an open string it is not, and the summary says when it had to be used.

15. Assumptions and limitations

1. **Generic criteria only.** The guideline's angles assume no major unfavourably oriented structures, sound walls and no nearby public infrastructure. Adverse structure, poor ground or a sensitive receptor requires a site-specific study.
2. **Geometry only.** No groundwater, rock-mass strength, seismicity, time dependence or dynamic loading. The construction is a geometric projection rule, as the guideline intends.
3. **Two materials at most.** Fresh rock and one weathered profile with one flatter angle. A layered profile, such as transported cover over saprolite over saprock with an angle each, is not modelled. To bracket it, use the flattest applicable angle and the shallowest applicable contact.
4. **The interval sets which benches are seen.** A toe that falls between two slices cannot govern. Refine the interval until the answer stops moving.
5. **Ground rising steeply beyond the crest.** An arrested projection normally never lands. If the topography beyond the crest rises *more steeply than the projection angle*, such a line can come back down and land further out than it deserves. The error is conservative. With weathering on, the relevant angle is the **weathered** one (25° by default), which makes this more common than at 45°.
6. **One point per crest station.** The answer is resolved at the line spacing along the crest. Where the crest has a deep re-entrant, the Zol limit is much longer than the crest it is measured against, and the result is smoothed a little.
7. **First hit wins.** Each line takes its first intersection with the topography; overhanging ground is not modelled.
8. **The crest rule is only as good as the crest reference.** The clearance is measured against the ticked crest string or the widest slice. If your section range stops well below the true crest, the clearance is measured from that lower outline. Set the range top at the crest, or tick a surveyed crest string.
9. **The wall is a uniform prism.** One height and one base width along the whole alignment, a triangular cross-section, and the height measured above the local centre-line ground. It is a design surface for visualisation, volume take-off and DXF hand-over, not an earthworks design: no compaction, key-in, drainage or material specification.
10. **Bunds only.** Signage, fencing and other abandonment obligations are outside this tool.
11. **No macro recording.** Bund runs cannot yet be recorded and replayed as macros.

Part 3 — Reference

16. Messages and troubleshooting

16.1 Before the dialog opens

Message or symptom	Cause and fix
"This function does not work in clipping mode"	Turn clipping off.

Message or symptom	Cause and fix
"Load the pit and topography meshes first ..."	No meshes are loaded.

16.2 When you click Calculate

Message	Cause and fix
"Tick at least one mesh in the TOPO column ..."	No topography is ticked.
"Tick at least one mesh as the Pit source ..."	No Pit mesh and no Toe string is ticked. On a first run only TOPO is pre-ticked, deliberately (§4.1).
"The weathered projection angle (...°) is steeper than the fresh-rock angle (...°)."	The weathered profile projects flatter, not steeper. The angles are swapped or mistyped.
"The Contact-mesh weathering option needs a mesh ticked in the BOCO column ..."	Tick the contact surface in BOCO, or use a constant contact RL.
"The top of the section range is below the bottom."	The from and to boxes are the wrong way round.
"The section range RL ... to ... lies outside the ticked Pit meshes ... Go ahead anyway?"	The range and the pit do not overlap, so nothing would be cut. Usually a typo in the range (§4.2).
"No outputs are ticked — the calculation would create nothing."	Tick at least one output (§4.6).
"A ... m high wall on a ... m base has side slopes steeper than 45° ... Go ahead anyway?"	The base is narrower than twice the height. Fine for a keyed or reinforced bund; widen the base for dumped fill.

16.3 During the run

Message	Cause and fix
"That range and interval give N sections, past the 2,000 guard."	Increase the interval. The guard catches a mistyped interval; it is not a resolution limit.
"No section between RL ... and RL ... cut the Pit mesh."	The range lies outside the pit. Compare it with the pit's RL range shown in the dialog.
"... m of source outline at ... m line spacing comes to about N projection lines. ... Go ahead?"	A heads-up above 500 000 lines, with the memory needed. Yes runs it, and Esc still cancels.
"... would need about N projection lines, past the 2,000,000 guard."	Coarsen the line spacing or the section interval.
"The Pit role has no usable mesh geometry." (also Ground, Contact) / "The Ground meshes have no geometry."	The object ticked for that role has no triangles: an empty or line-only object. Tick the actual surface.
"The object ticked in the Toe column holds no polylines ..." / "The object ticked as the Crest holds no polylines ..."	You ticked a surface, not a line object. Untick it to slice the Pit mesh, or to measure against the widest section ring.
"The crest reference holds no usable polyline after resampling ..."	The crest string's lines are shorter than one line spacing. Tick a longer crest string, or untick Crest.
"The source outlines are too short to fan."	The sections (or the Toe string) are shorter than one line spacing. Reduce the line spacing, or check that the Pit mesh is the one you meant.
"Abandonment bund calculation cancelled — nothing was created."	You pressed Esc.
"Abandonment bund calculation failed: ..."	An unexpected error; the text says what failed. Send it and GEM4D_diag.log to BasRock support.

16.4 Results that look wrong

Symptom	Cause and fix
Nearly all lines <i>"never met the ground"</i>	The topography does not reach far enough, or TOPO is ticked on the wrong mesh.
Most projections <i>"daylighted INSIDE the crest"</i>	The topography spans the pit opening. Nothing is wrong: only lines that clear the crest can govern.
A long interpolated run is reported	Lines ran off the edge of the topography along that stretch, so the ring is closed by interpolation there. Extend the topography.
The fan points the wrong way	No Pit mesh was ticked, and the outline's own winding was used (§14.5). Tick the Pit mesh.
The limit line reaches into the pit, or fans appear in odd places	Check the <i>Section loops ignored</i> line. A Pit mesh full of terrain contours can still place fans oddly; also check the <i>Measured from line</i> and consider a surveyed crest string.
<i>"Warning: untangling removed more than a tenth of N ring(s)"</i>	The crest reference is not a clean pit outline. Tick a surveyed crest string, or check the section range top.
Only 1 of N sections governed	One bench drives the whole pit, which is normal on a uniform wall. A coarser interval would run faster.
The limit line moves when the interval or spacing changes	Refine whichever one moved until it is stable (§7.1).
The limit line looks smoother than the measured points	That is the simplify tolerance and the smoothing (§12.3). Set both to 0 to see every station, or show the fan, whose rim is the raw daylight line.
Weathering on, but the summary shows 0 kinks	The contact never crosses a line between its start and its daylight point. Either the contact is below the pit (every line is weathered from the start) or above the topography (the run was made without weathering, and the summary says so).
Many lines <i>"started outside the contact surface's coverage"</i>	The contact mesh does not extend under the fan. Those lines ran as fresh rock. Extend the contact model, or use a constant RL.
No bund line, although the Zol limit exists	Bund line was unticked. With the wall ticked, the summary then reports a <i>Wall toe alignment</i> instead.
The wall floats or digs in along a stretch	The wall's base ran past the edge of the topography; see the wall-point count on the <i>Bund wall</i> line. Extend the topography.
Nothing happens for a long time	Watch the progress bar; Esc cancels. A fine interval with a fine spacing is the usual cause.

17. Glossary

Term	Meaning
Arrested projection	A projection line that passes into the void of the pit and so never meets the topography. It cannot govern.
BOCO	Base of complete oxidation: the base of the weathered profile, used as the weathering contact. Also the dialog's contact-surface column.
BOCOPlane	The constant-RL contact, inserted as a mesh with the outputs of a constant-RL run.
Crest reference	The outline "furthest from the crest" is measured against: a ticked Crest string, or the widest slice (§12.1).

Term	Meaning
Daylight	The point where a projection line meets the topography.
Fan surface	The surface formed by the projection lines from one slice. The output BundFan shows the governing lines only.
Governing line	At a crest station, the projection that reaches furthest from the crest.
Interval	The vertical distance between slices (every).
Line spacing	The distance between projection lines along an outline, and the size of a crest station.
Medial axis	The line along which two parts of an outline are equally near. Projection lines stop there (<i>trimmed on the medial axis</i>).
Mine RL	Elevation in the mine's own coordinate system, as entered in the dialog.
Section (slice)	The outline the pit makes at one horizontal elevation.
Standoff	The distance from the Zol limit to the bund's pit-side toe.
Station	One step of the crest, one line spacing long. Each station contributes one point to the Zol limit.
Toe	The base of a pit face. In the dialog, the Toe column takes a drawn outline in place of slicing.
TOPO	The natural topography, and the dialog column for it.
Zol	Zone of instability: the ground that could be undermined as the abandoned walls degrade. Its outer edge is the Zol limit.

18. References

Department of Industry and Resources [DEMIRS]. (1997). *Safety bund walls around abandoned open pit mines: Guideline (Document No. ZMA048HA)*. Government of Western Australia.
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