Challenges in Underground Mine Planning:

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Doreen Thomas
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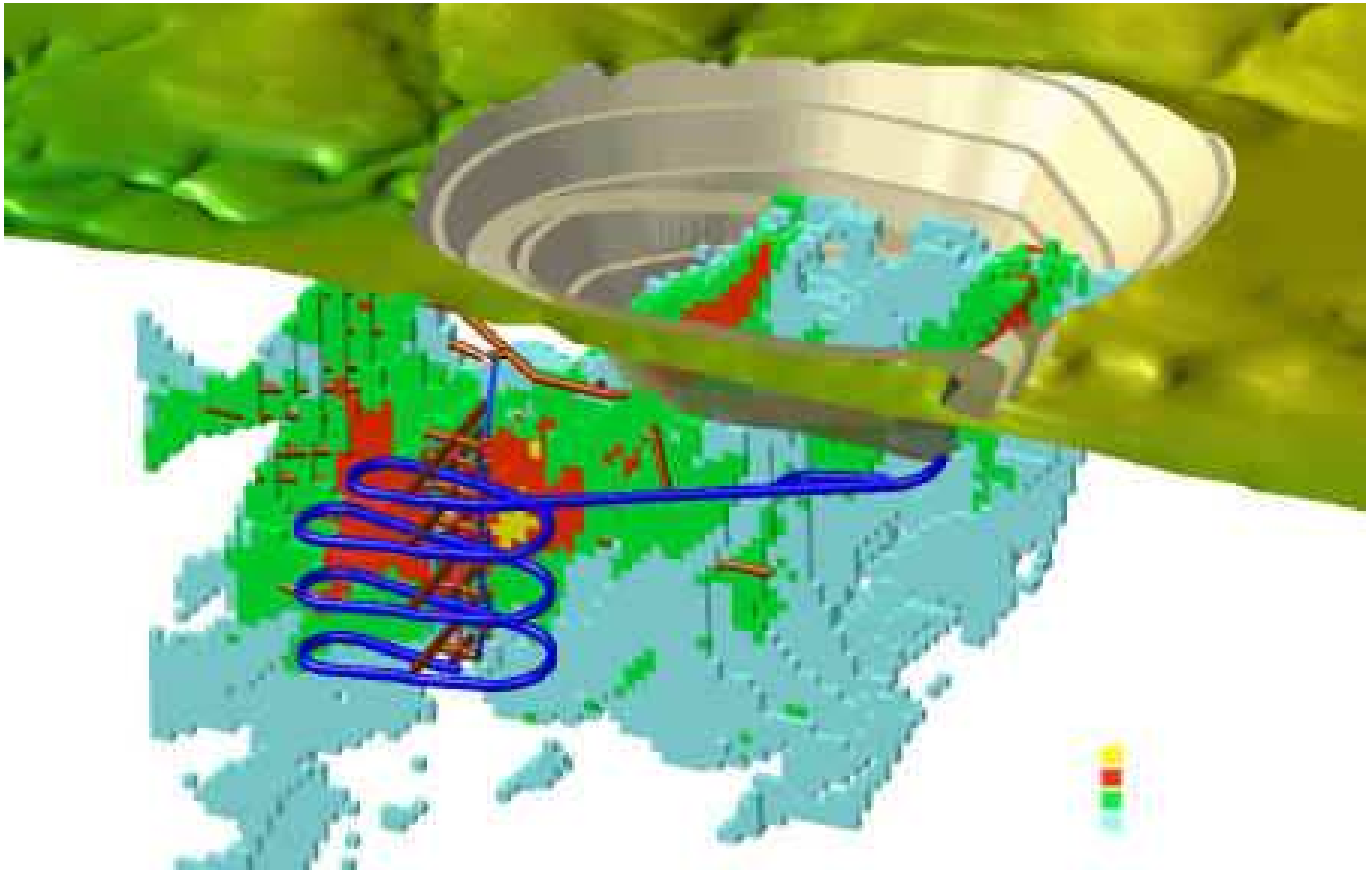
BAM November 2012

Underground Mine Planning - Challenges for Optimisation



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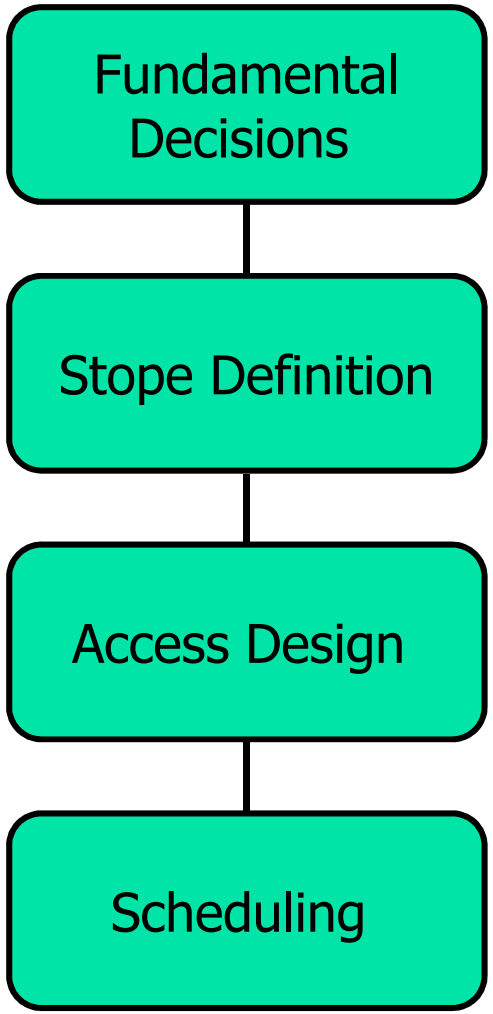
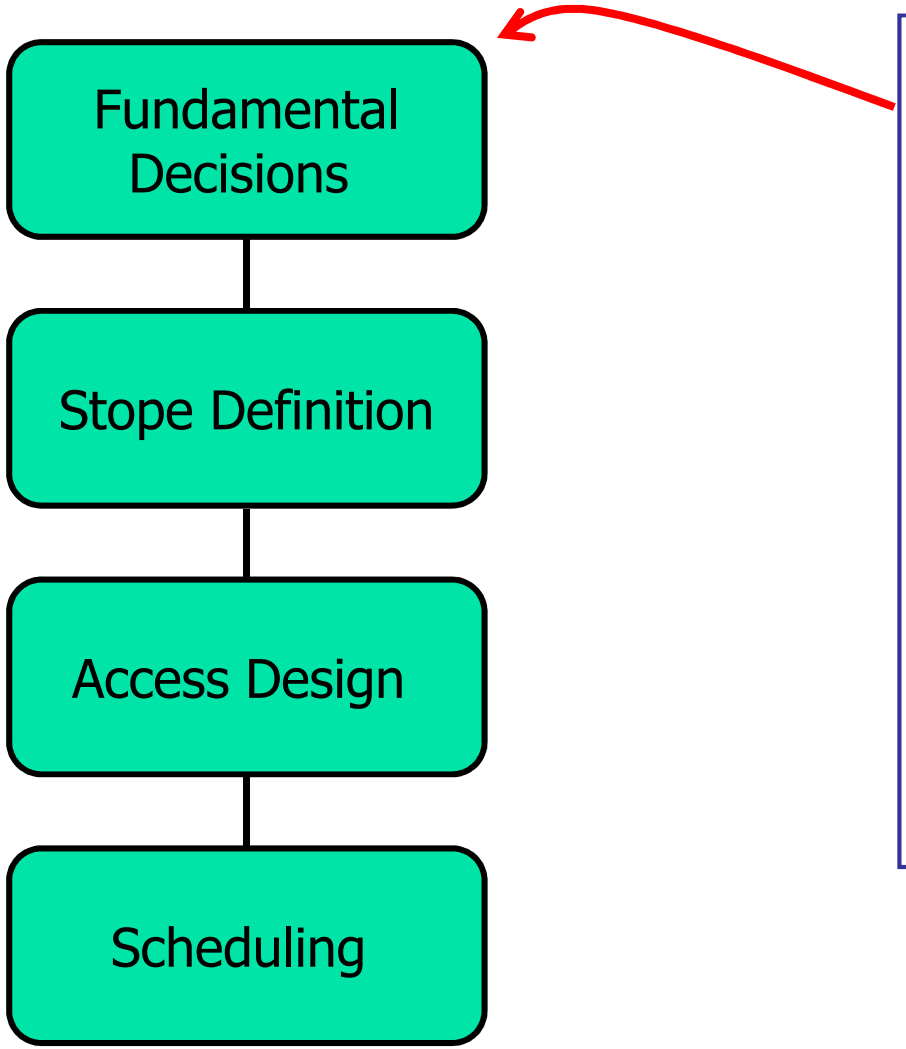
Strategic Optimisation



Strategic Optimisation

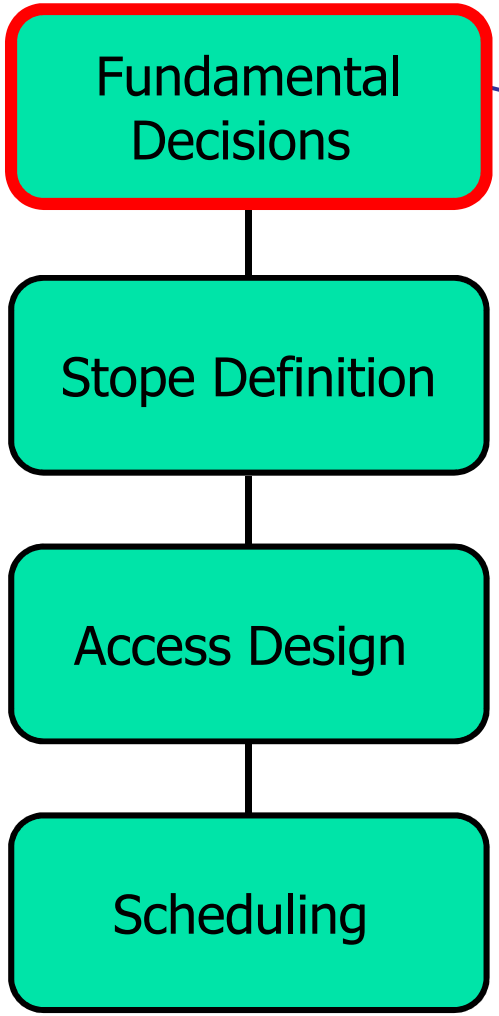


Inputs:

- Block Model
- Financial Model
- Infrastructure and production costs
- Geotechnical Data

etc…

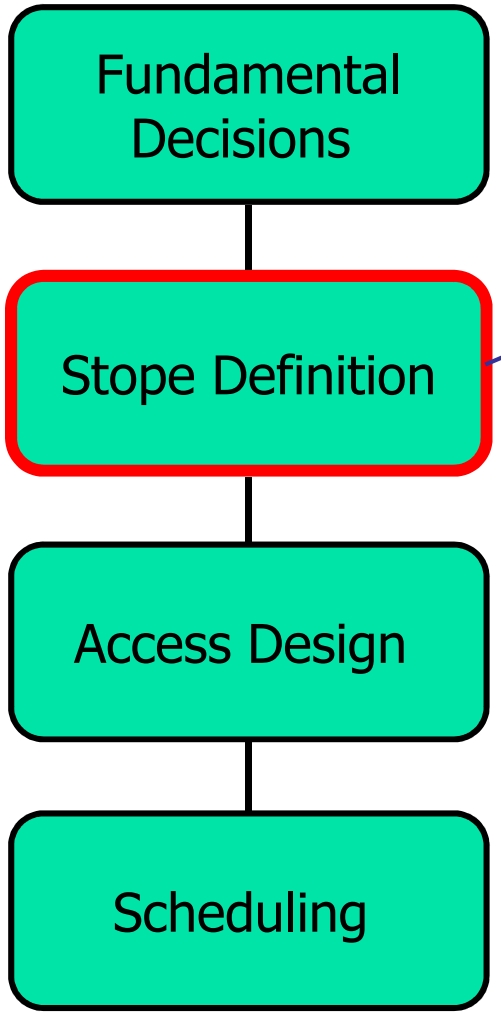
Strategic Optimisation



- Cut-off grade/s
- Mining method/s
- Bench heights
- Properties of the Mill

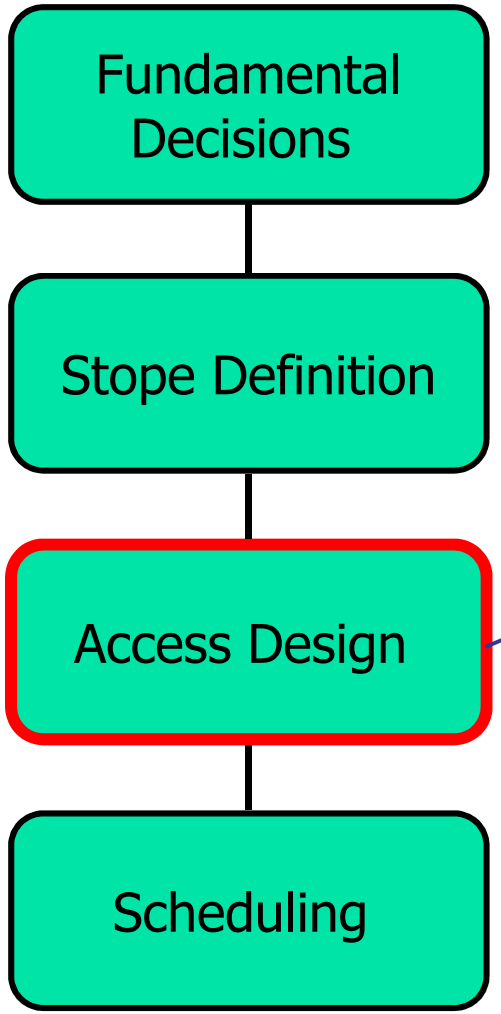
etc…

Strategic Optimisation



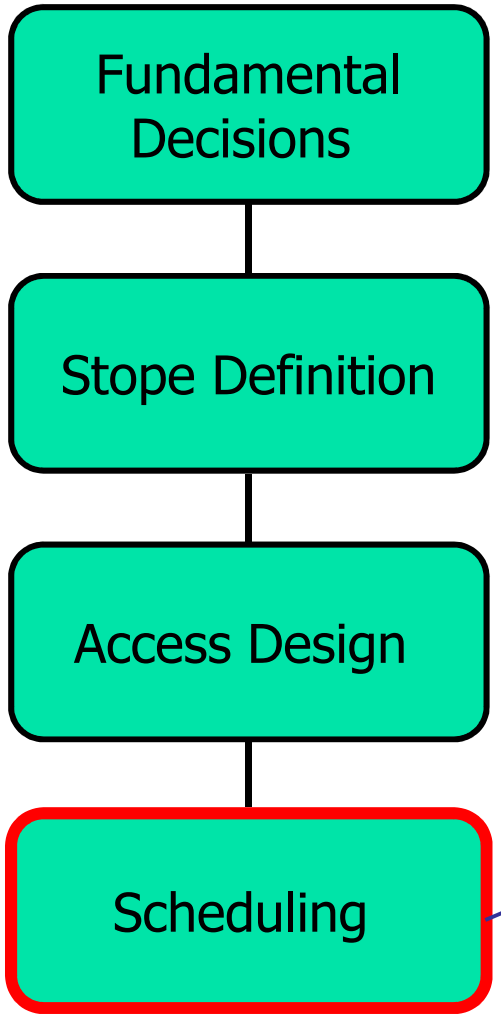
- Orebodies and orebody envelopes
- Determination of Bench RLs
- Placement of amalgamated or simplified stopes.

Strategic Optimisation



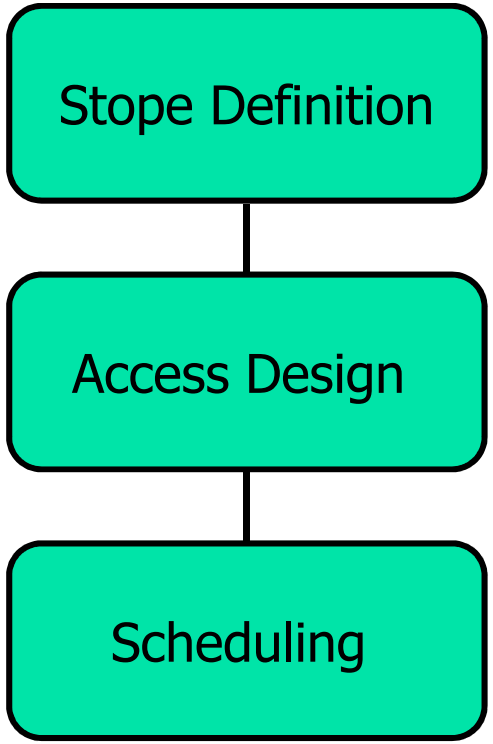
- Decisions on declines vs. shaft
- Templates for level layouts
- Topology of access network (with relaxation of some physical and geotechnical constraints).

Strategic Optimisation



- High level schedules (a month or year at a time)

Tactical Optimisation



Tactical Optimisation

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Stope Definition

Access Design

Scheduling

- Determination of all stopes, allowing for complex stope shapes.
- Stopes meet physical design constraints
- Geotechnical requirements and constraints addressed.

Tactical Optimisation

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- Detailed layout of the mine access network.
- Physical and geotechnical constraints taken into account

Scheduling

Tactical Optimisation

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Access Design

- Detailed layout of the mine access network.
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Scheduling

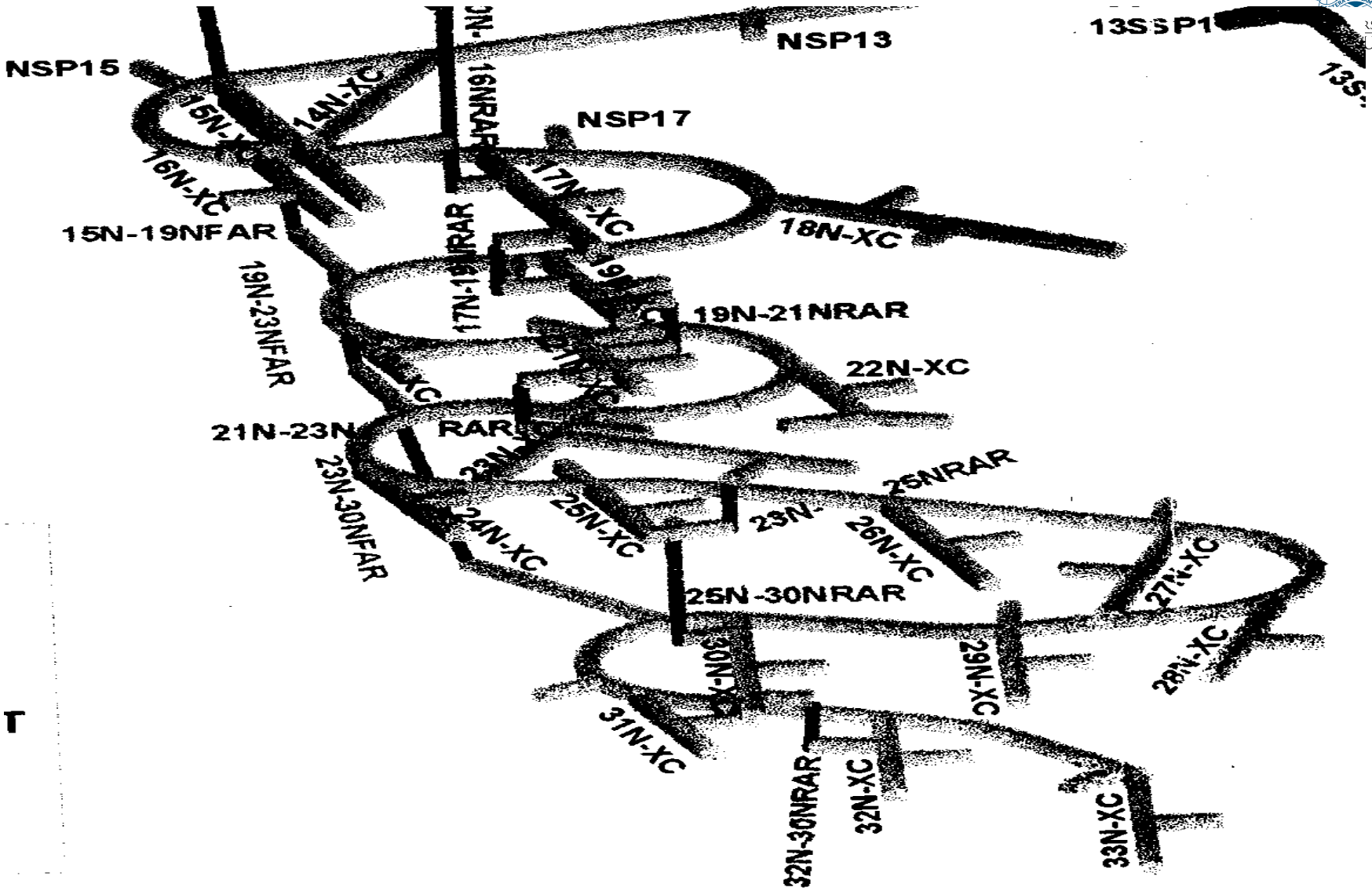
- More Detailed scheduling over shorter time periods

Challenges in this approach

- Information about the ore zone, ground conditions, financials etc changes throughout the planning process. Key decisions need to be locked in only when sufficient data is available, to ensure that value is not lost.
- The production schedule is dependent on an accurate evaluation of the geotechnical constraints on mining sequences. Adequate ventilation can also be a limitation on production.

Challenges in this approach

- Optimisation techniques are applied separately at each stage of the process – design of stopes, access and scheduling. Integration can only be obtained by iteration, producing a large number of strategic designs and then a more detailed analysis of the best ones.
- Further efficiency may be obtained e.g using the access design which gives the highest value schedule rather than least cost, or determining which stopes are uneconomic, due to access cost of outliers from the main ore zone.


NSP15
NSP13
NSP17
14N-XC
16N-XC
15N-19NFAR
19N-23NFAR
17N-XC
18N-XC
19N-21NRAR
22N-XC
21N-23N
23N-30NFAR
24N-XC
25N-XC
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26N-XC
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31N-XC
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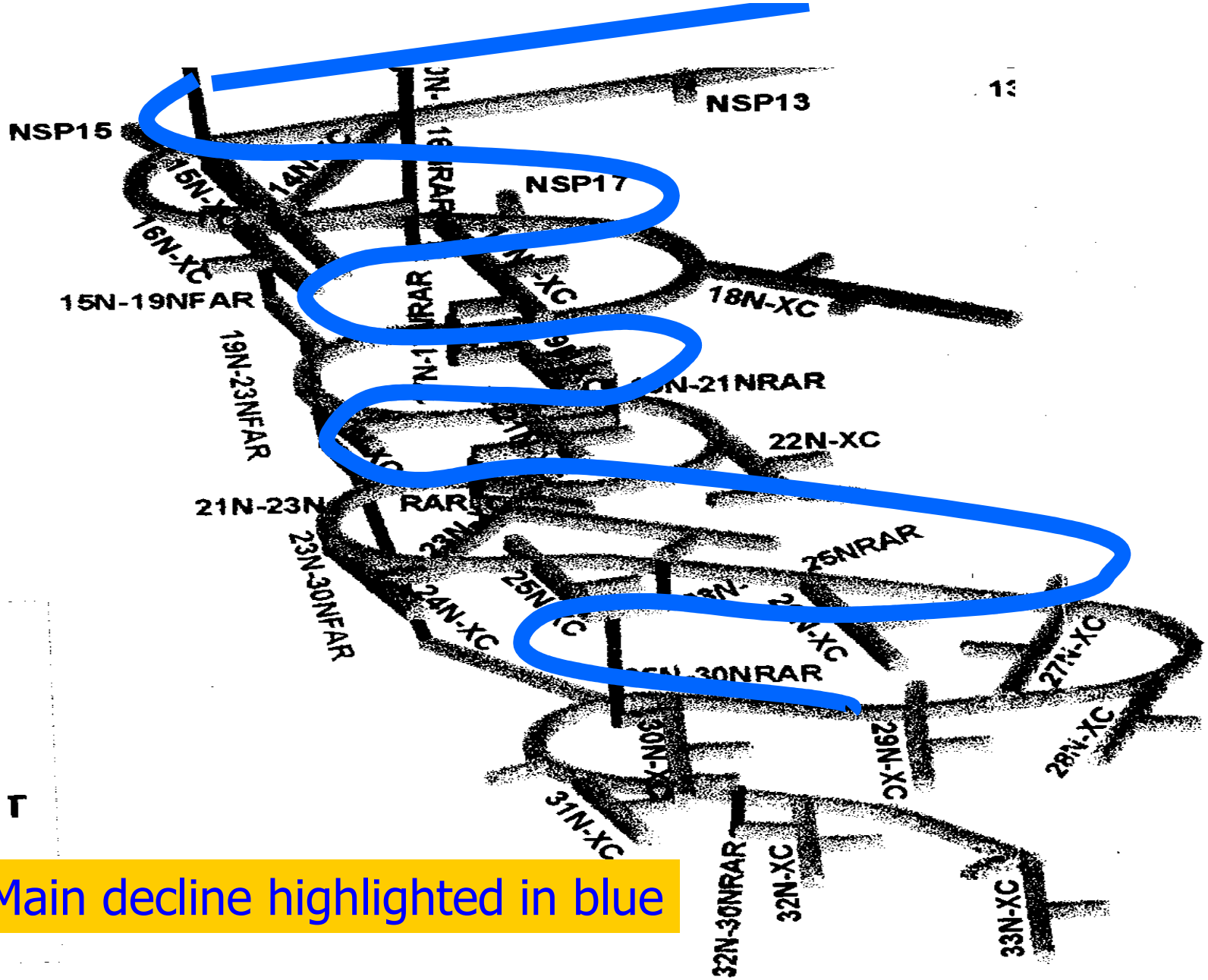
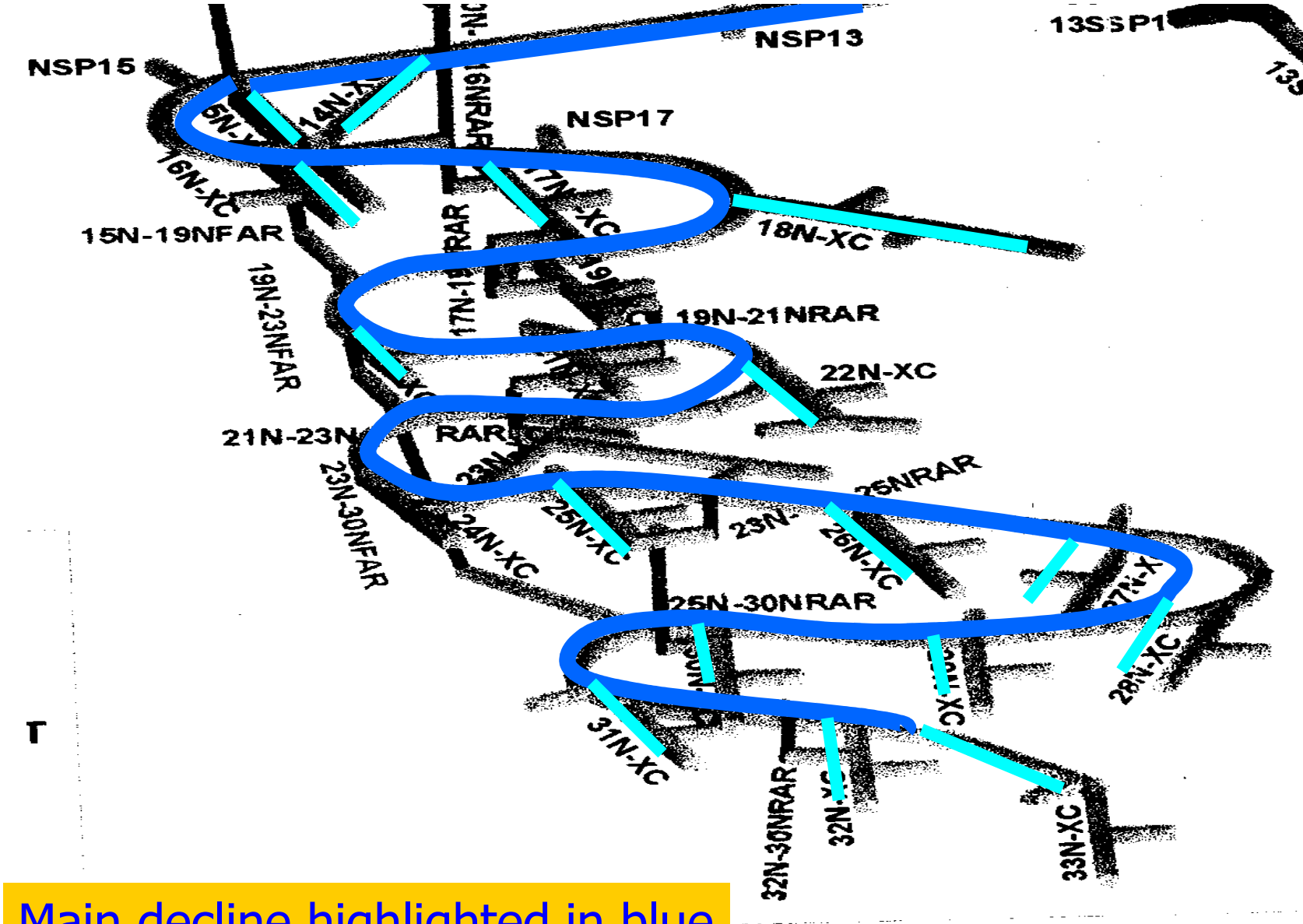
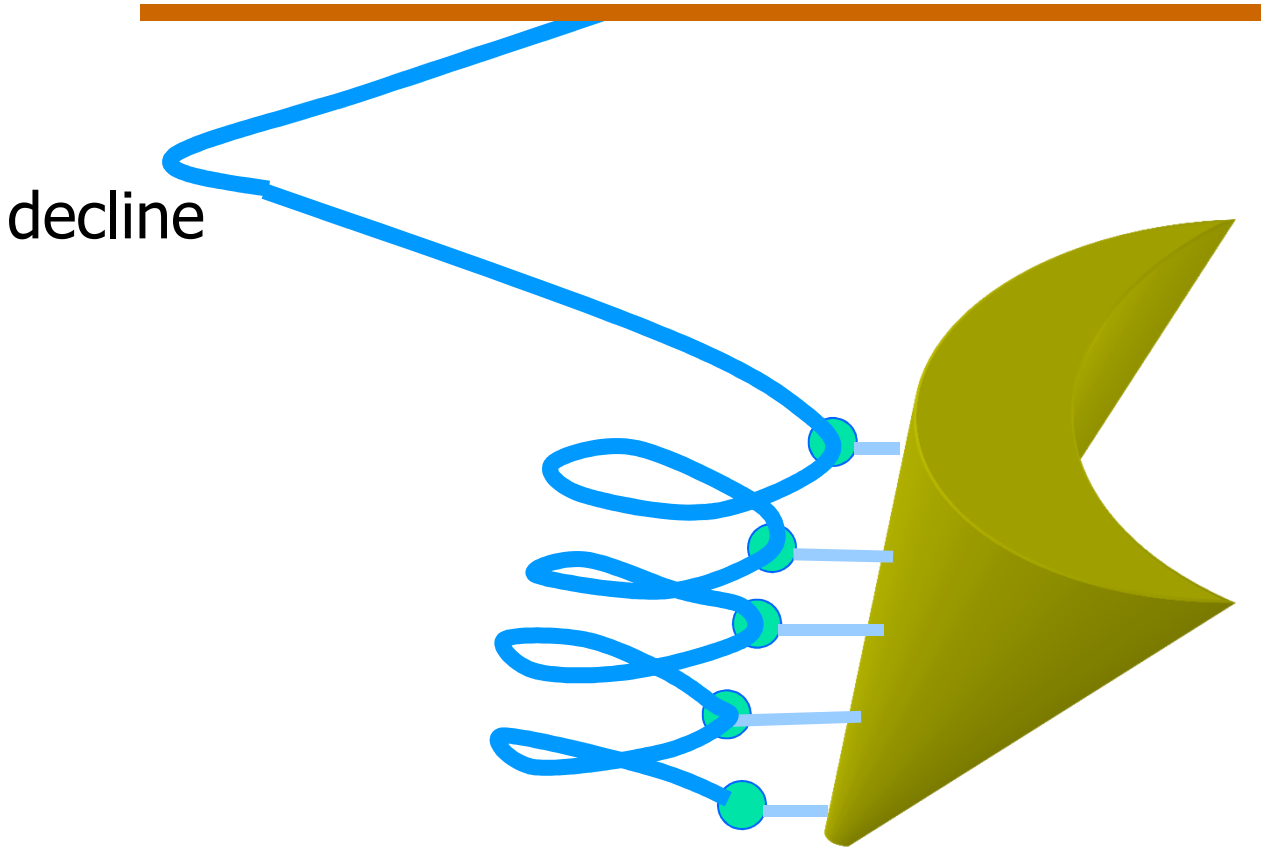


Main decline highlighted in blue



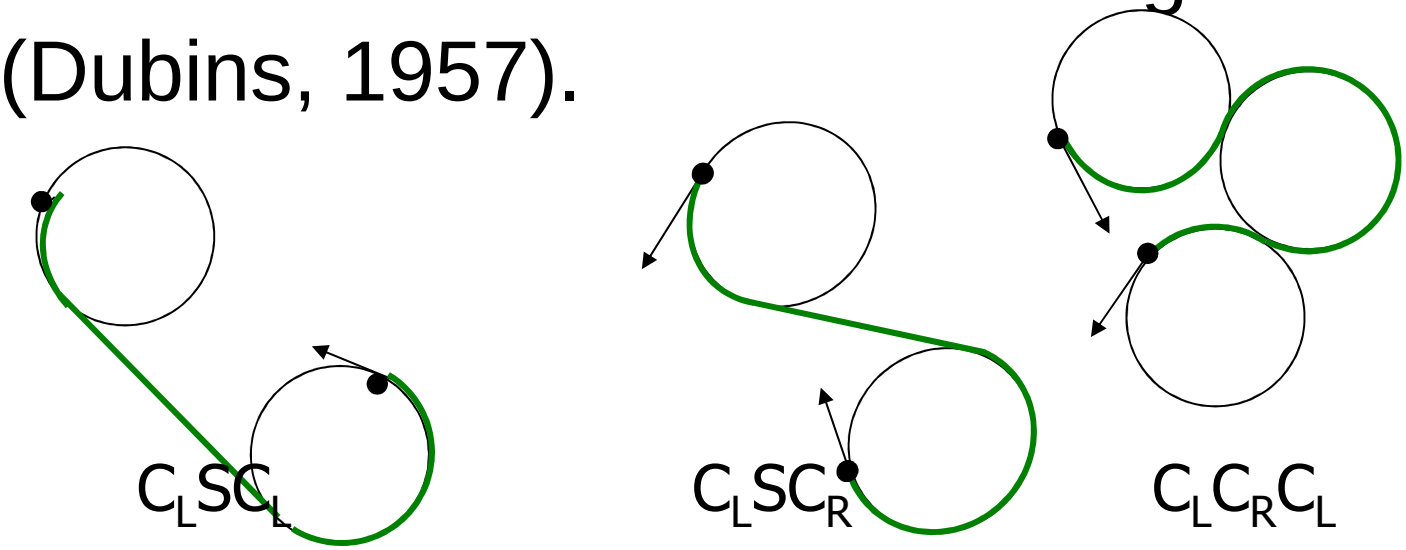
Main decline highlighted in blue
Crosscuts shown in light blue

A decline is a path navigable by mine equipment –e.g. trucks, boggers, drills - which services underground draw & access points

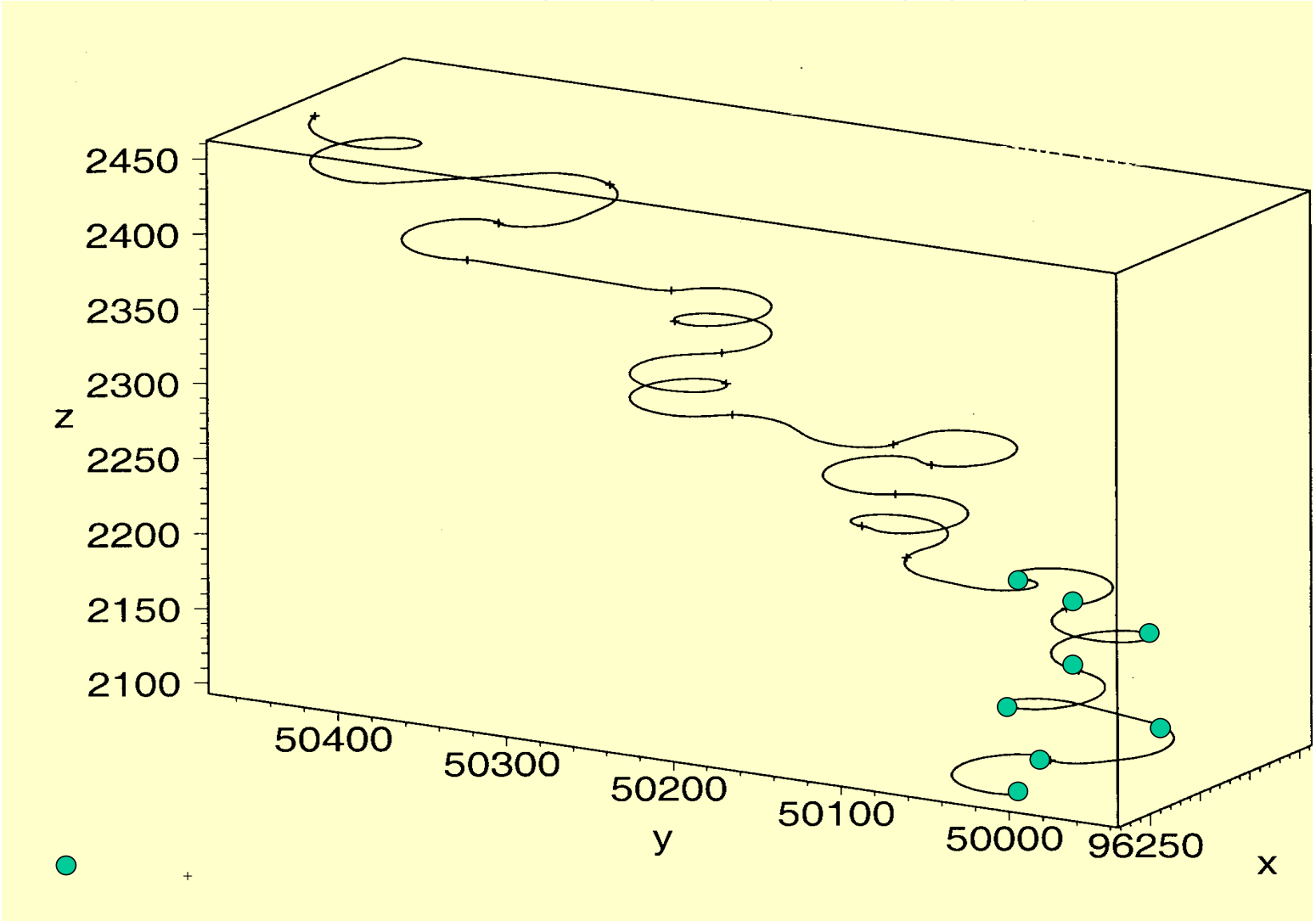


Turning circle constrained paths

- Minimum length, smooth, curvature-constrained paths between directed points in the plane have the forms CSC and CCC, where C corresponds to an arc of a circle with radius *r* and S to a line segment (Dubins, 1957).

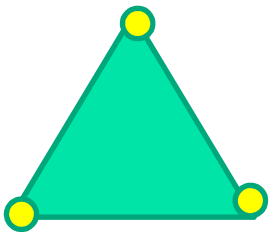


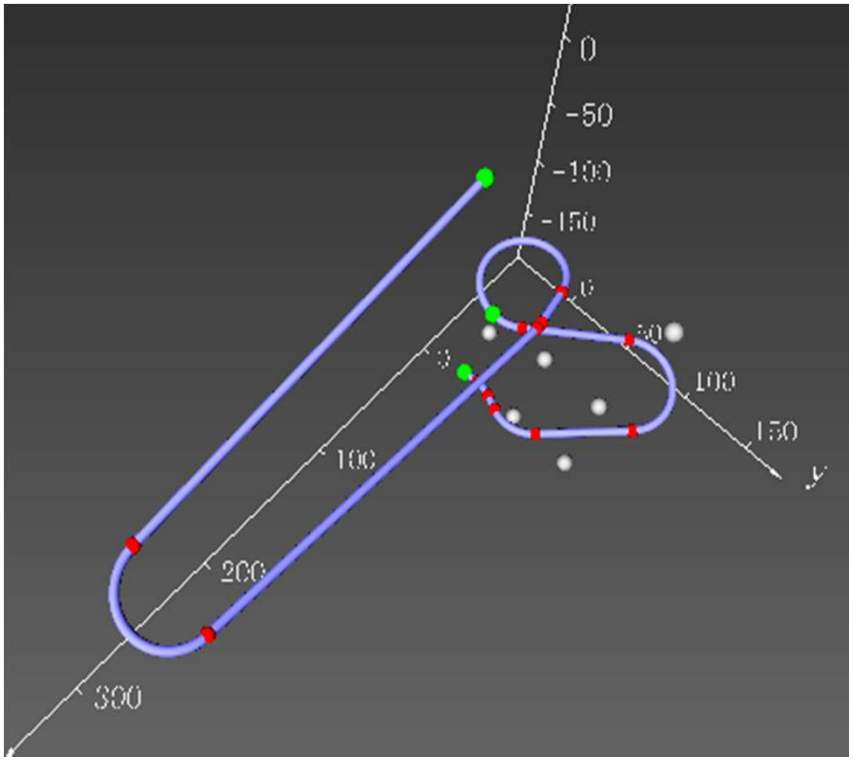
Extended to gradient constrained 3d paths - no crosscuts solution

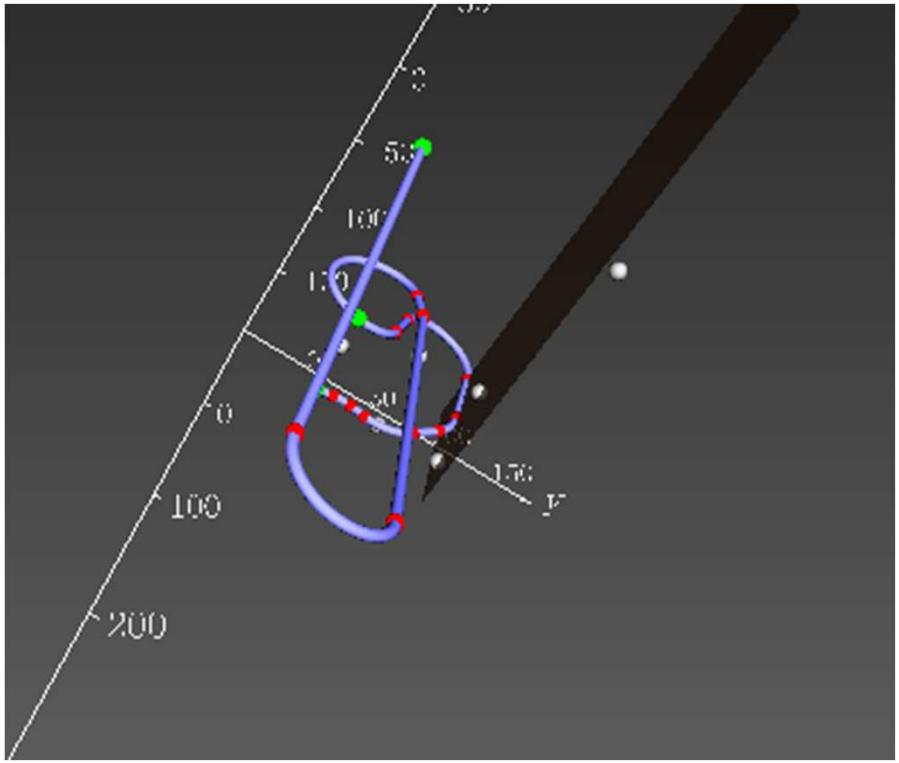


Decline Optimisation Tool (DOT) - scope & data set

- Objective
  - minimise development cost + haulage cost
- Operational Constraints
  - Maximum gradient m for decline
  - Radius r of minimum turning circle
  - Development cost ($/m)
  - Haulage cost ($/tonne.km)
- Target points
  - Group identifier, x, y, z, bearing at target, tolerance, tonnage, point label , crosscut length
- Barrier file via triangulations
  - Indexed set of co-ordinates of triangles & triangulated barriers represented by ordered triples of the indexed vertices



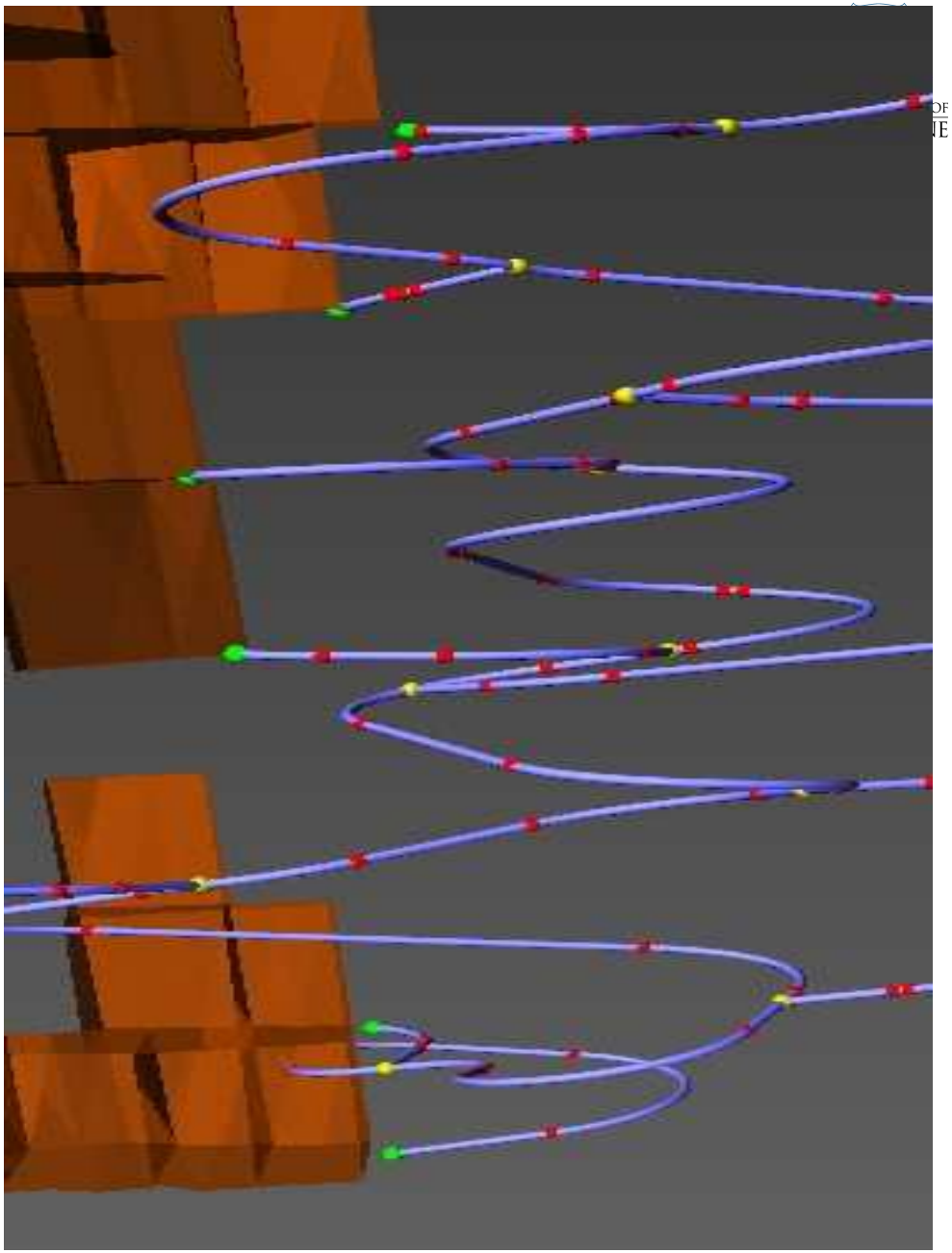


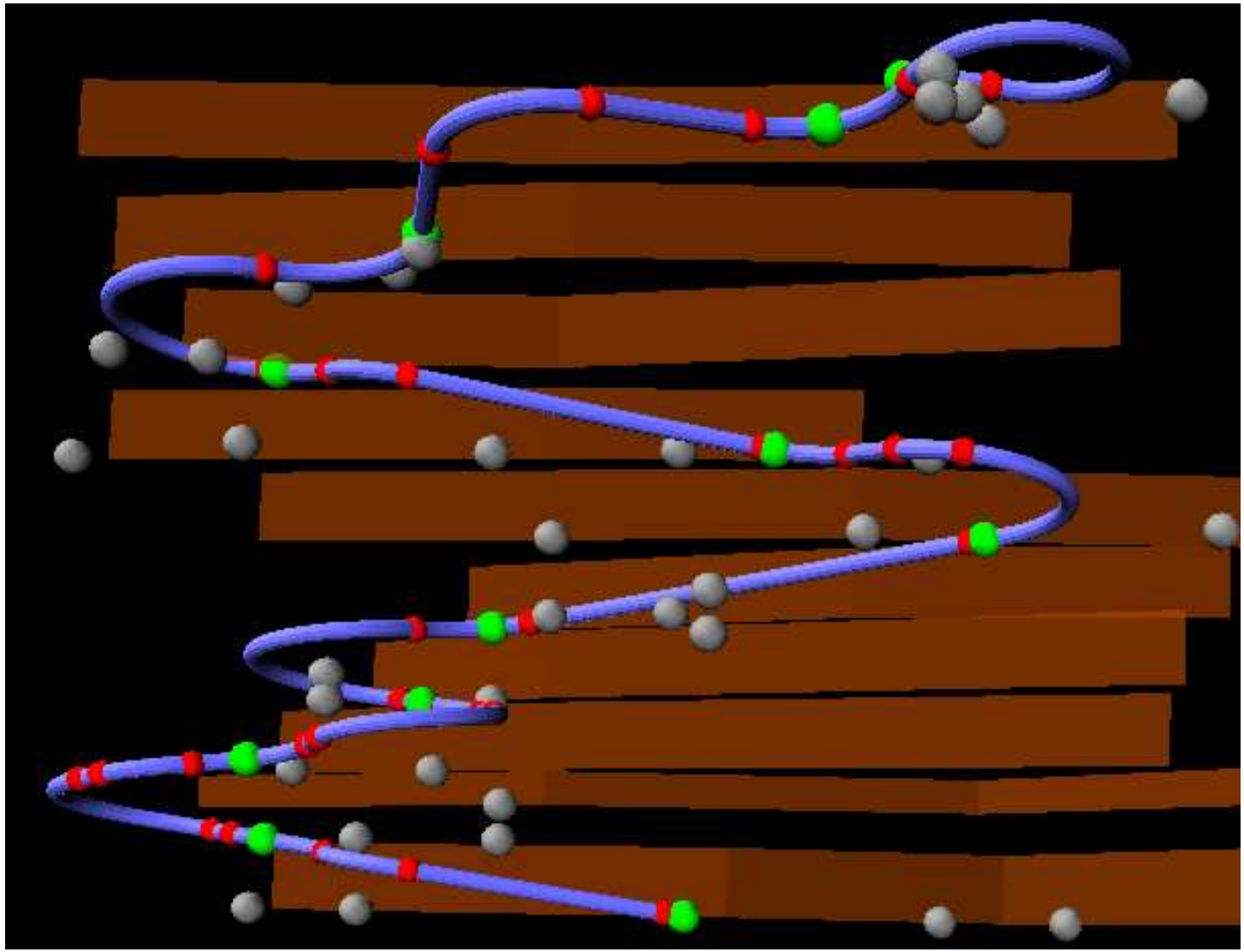


DOT optimal decline
With no barriers

DOT decline for the same target set but with a barrier

A snapshot of an optimal decline generated by DOT-decline optimisation tool

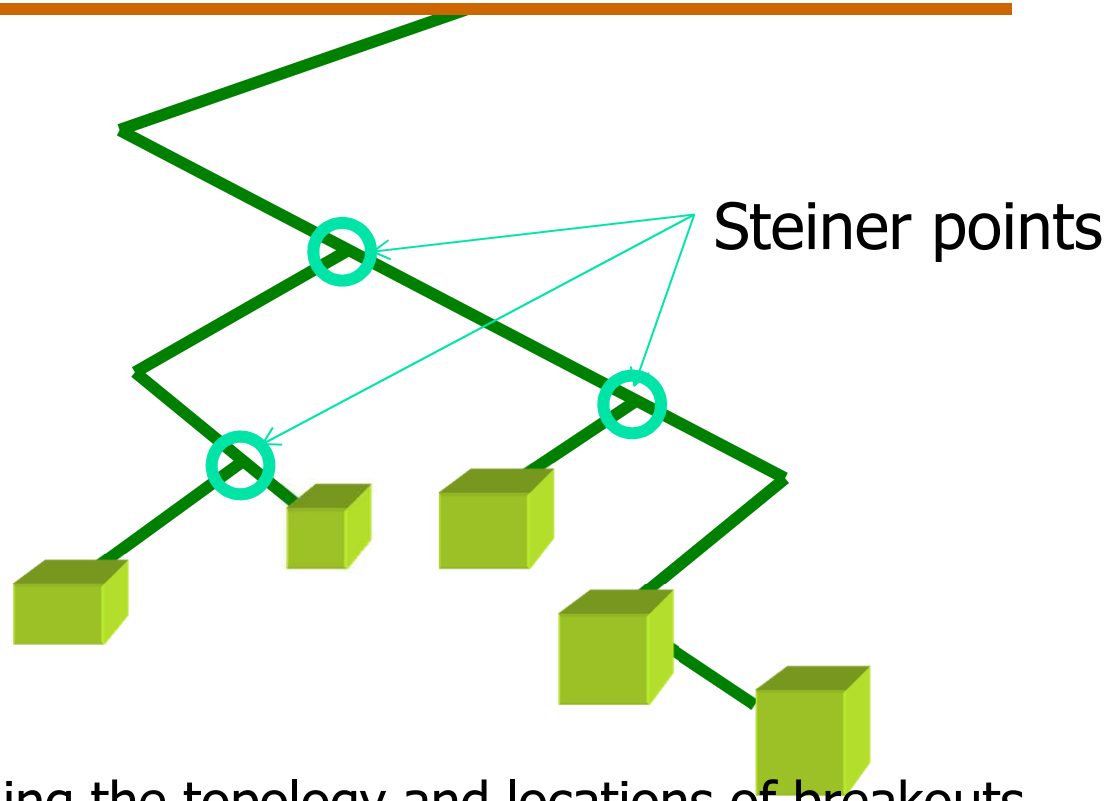




So far we have seen examples where the decline is a path
-but in general a decline is a branching structure

Nodes correspond to access points and surface portal

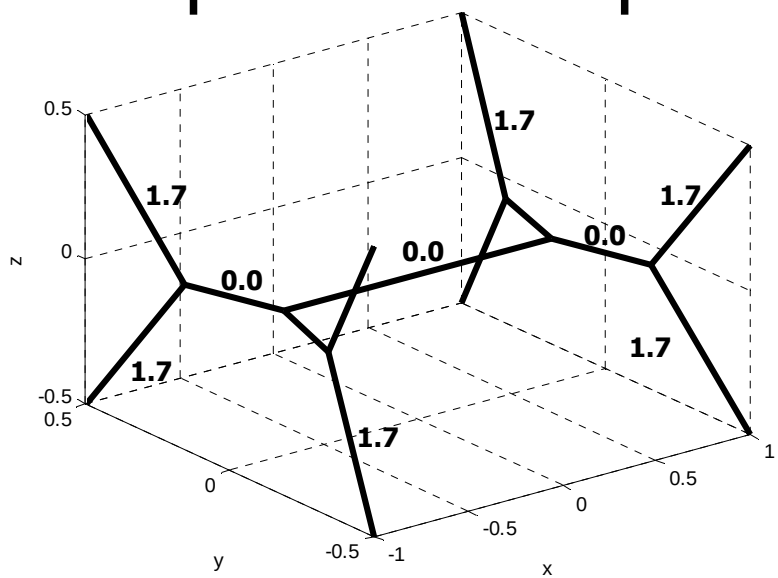
Links correspond to centreline of decline



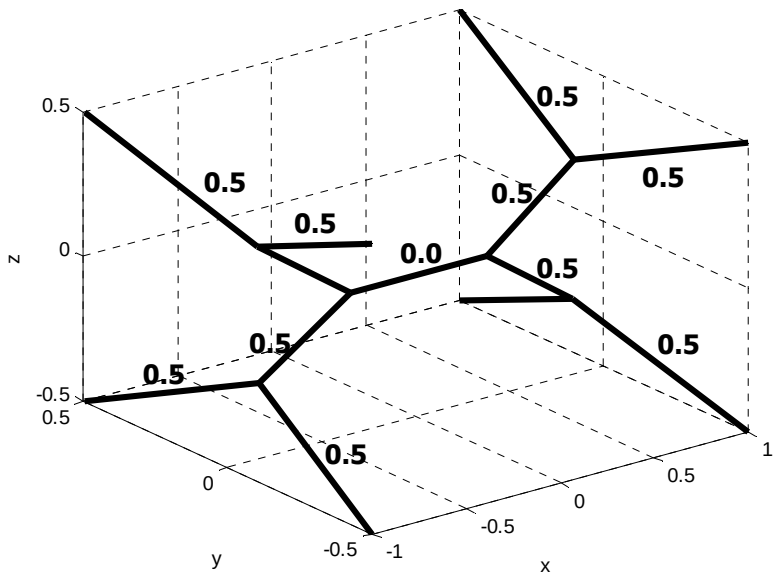
Finding the topology and locations of breakouts (steiner points) in a tree decline layout – this is an NP hard combinatorial problem

Minimum gradient-constrained trees

Understanding the geometry of these minimum networks, has enabled us to find good approximate solutions to this optimisation problem

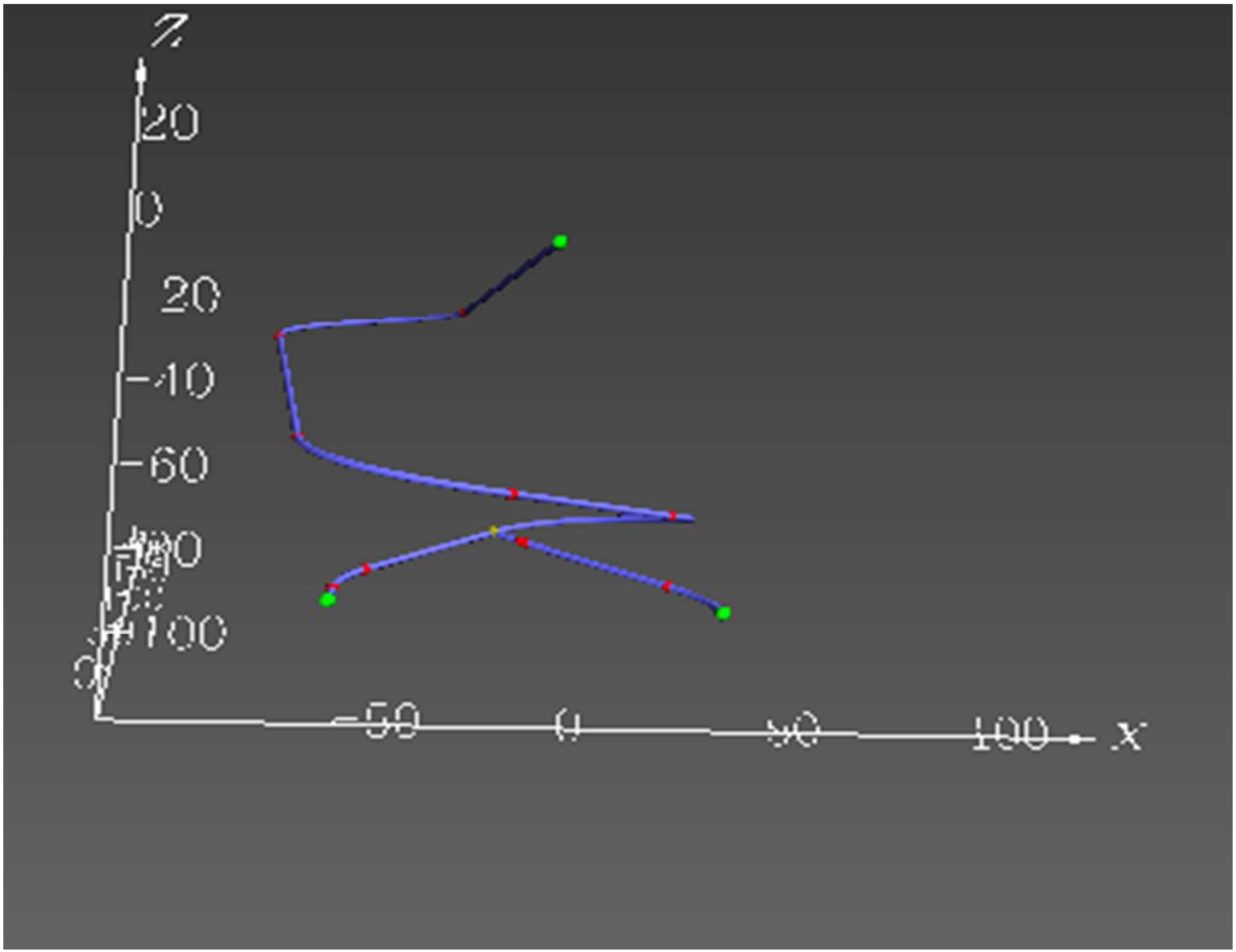


Not gradient-constrained

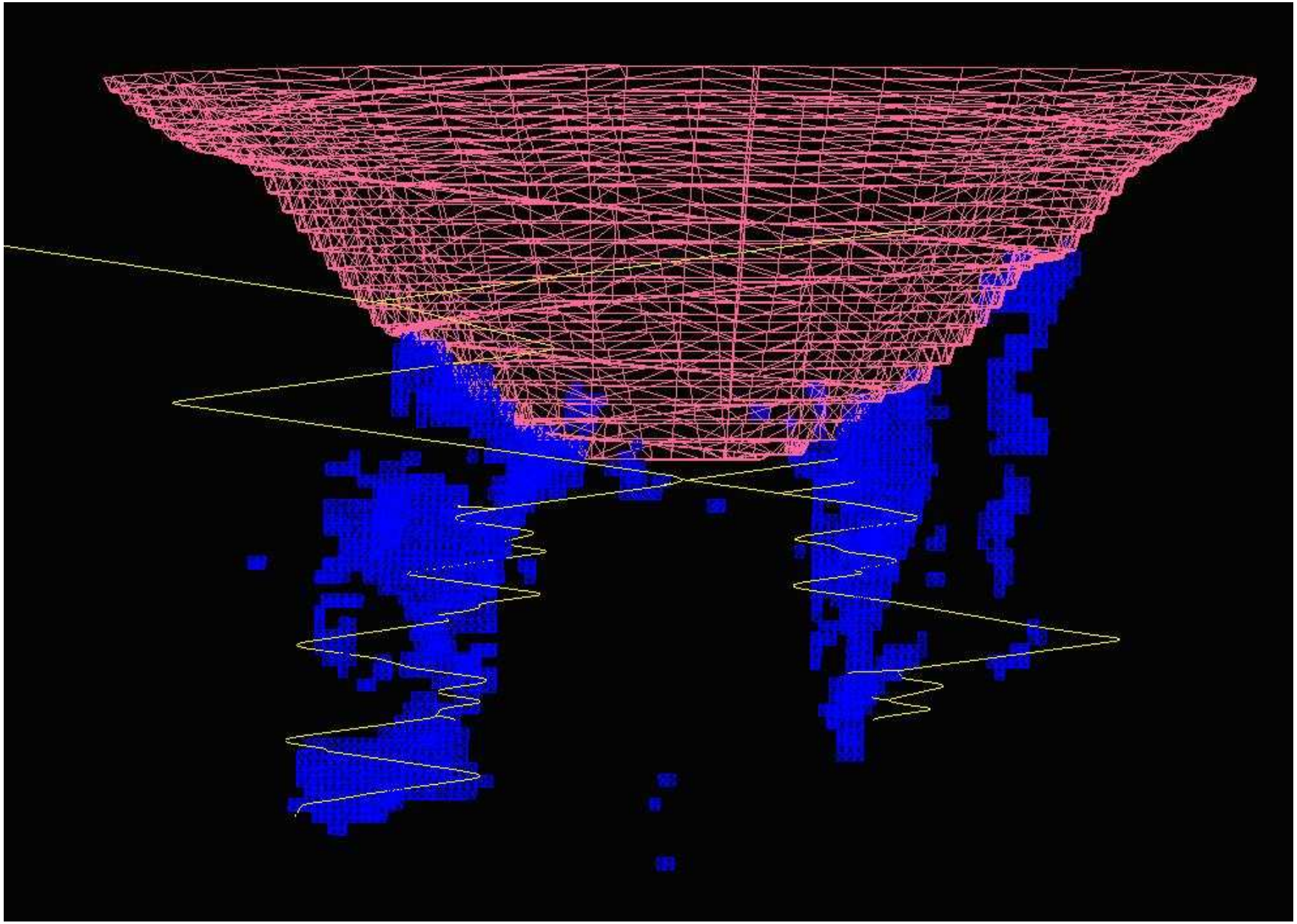


Gradient-constrained

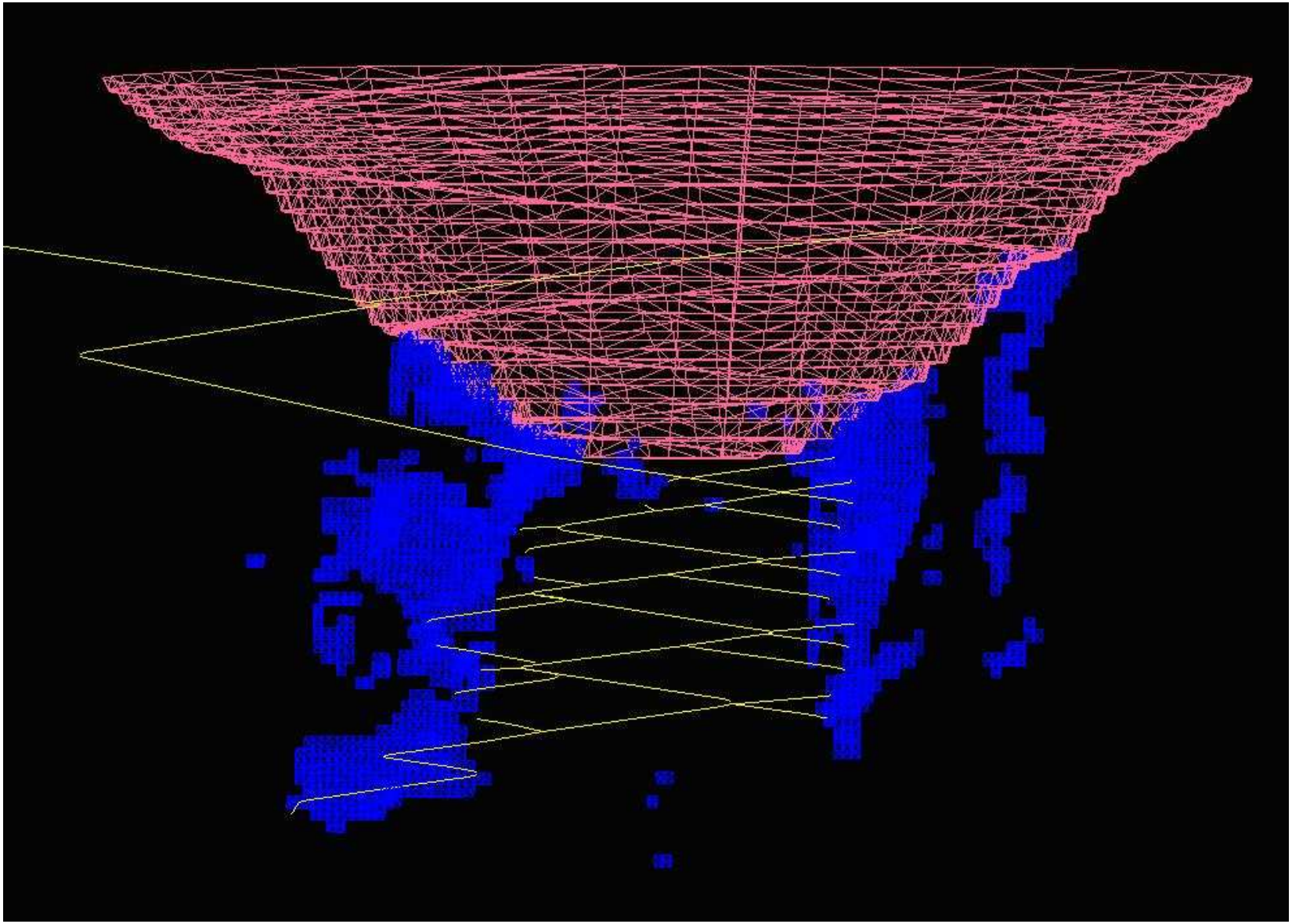
DOT generated tree network with optimal breakout



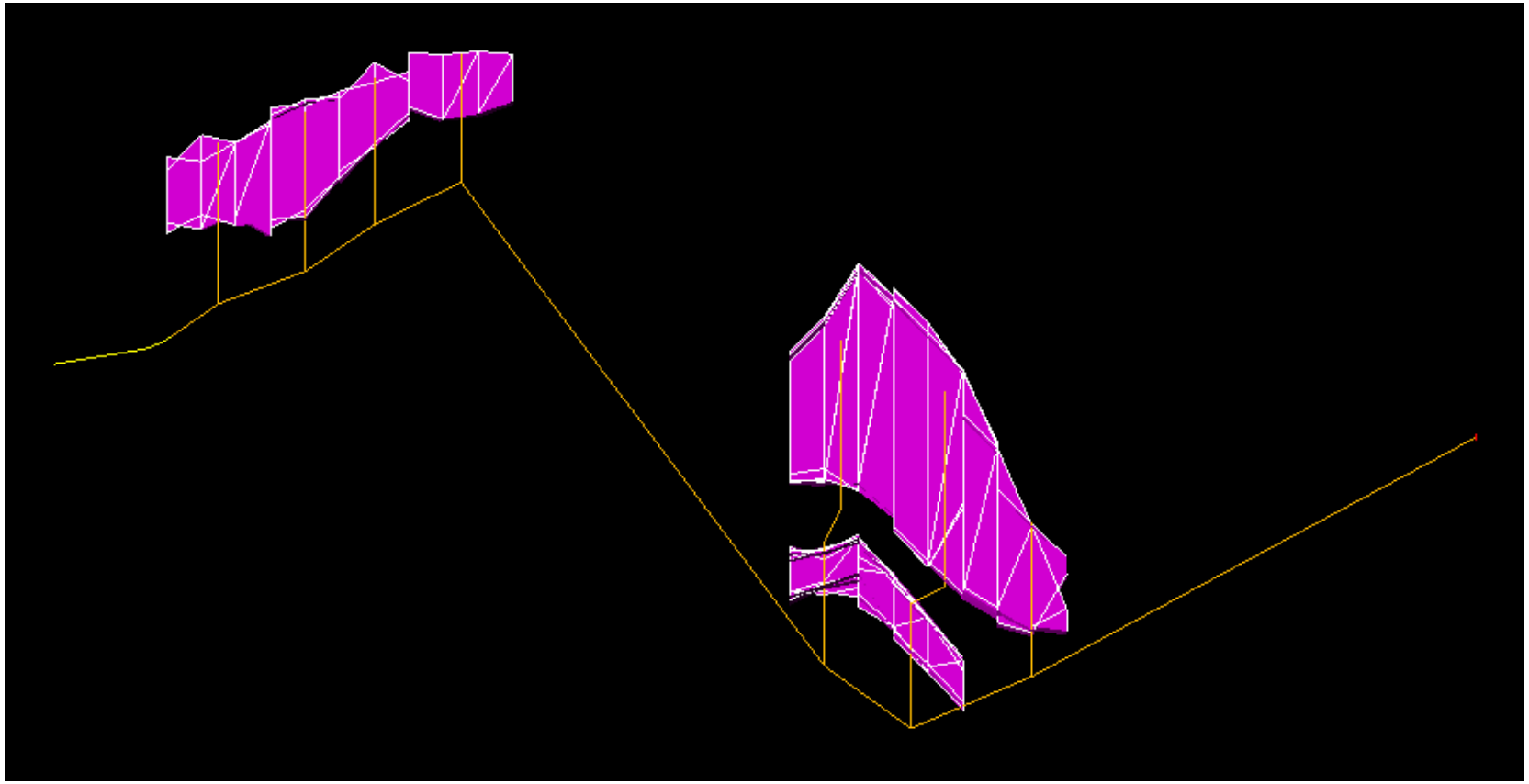
Twin decline development



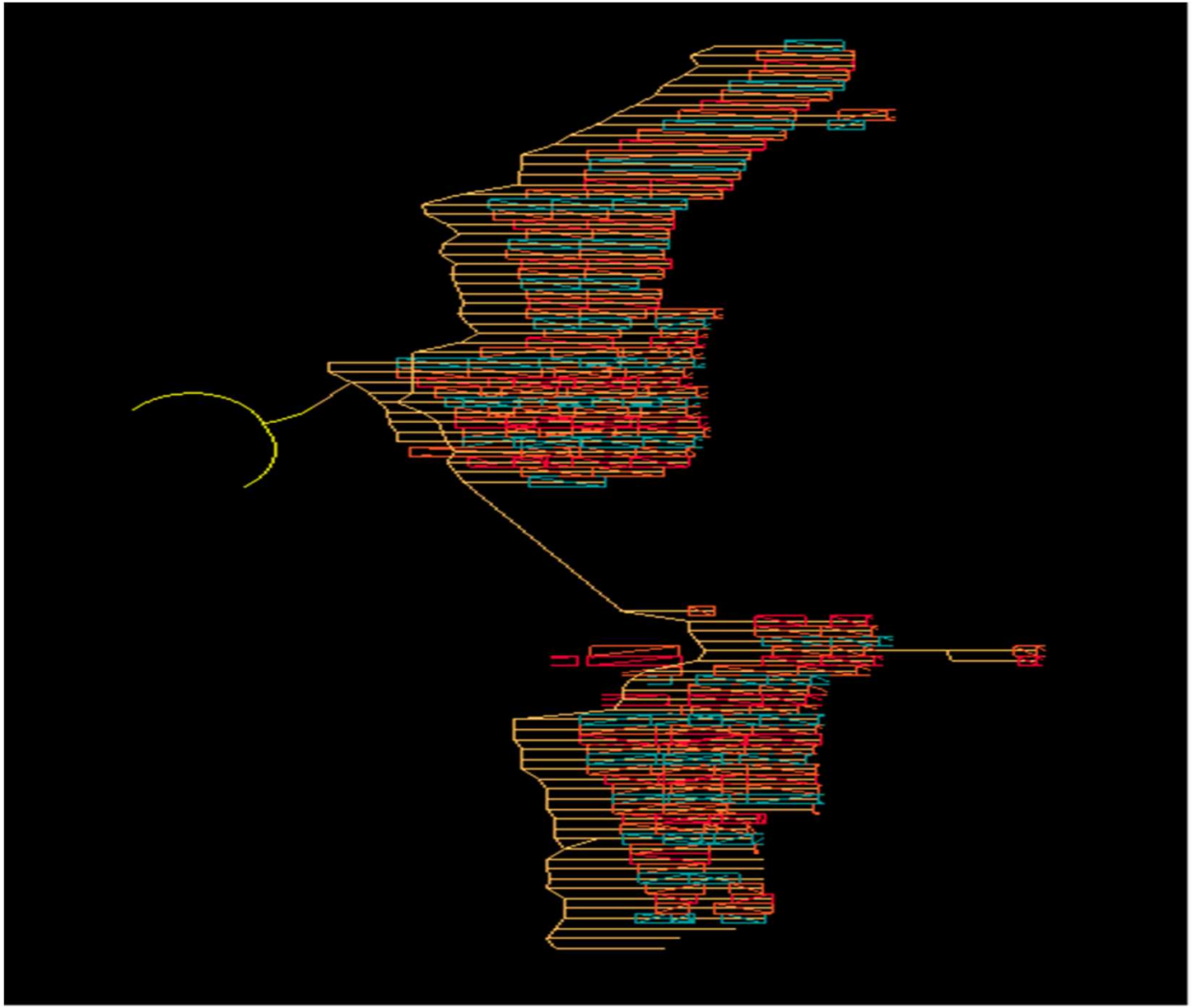
Nominated single decline development



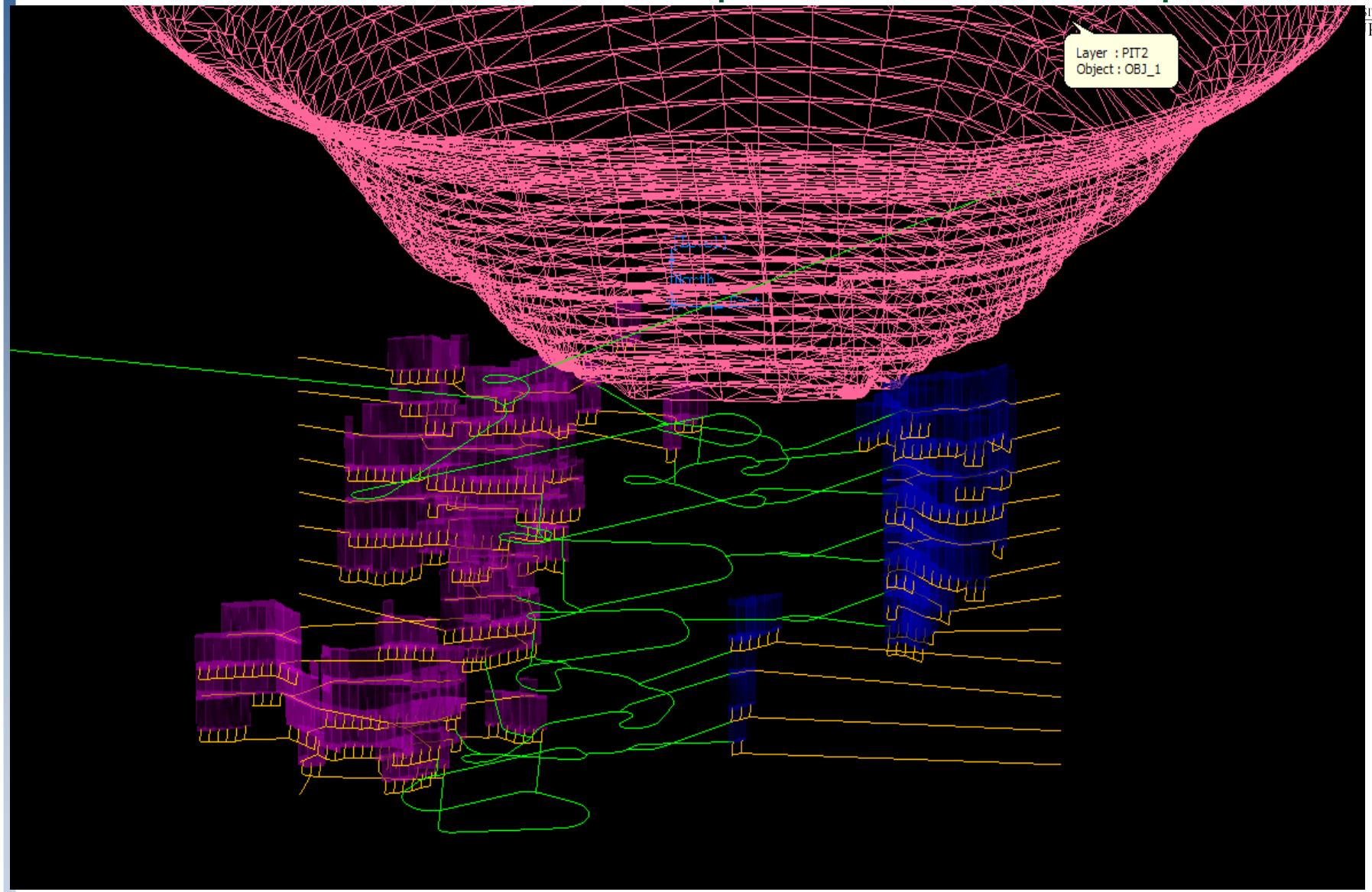
PUNO level design



Using PUNO to find optimal layout of a level development



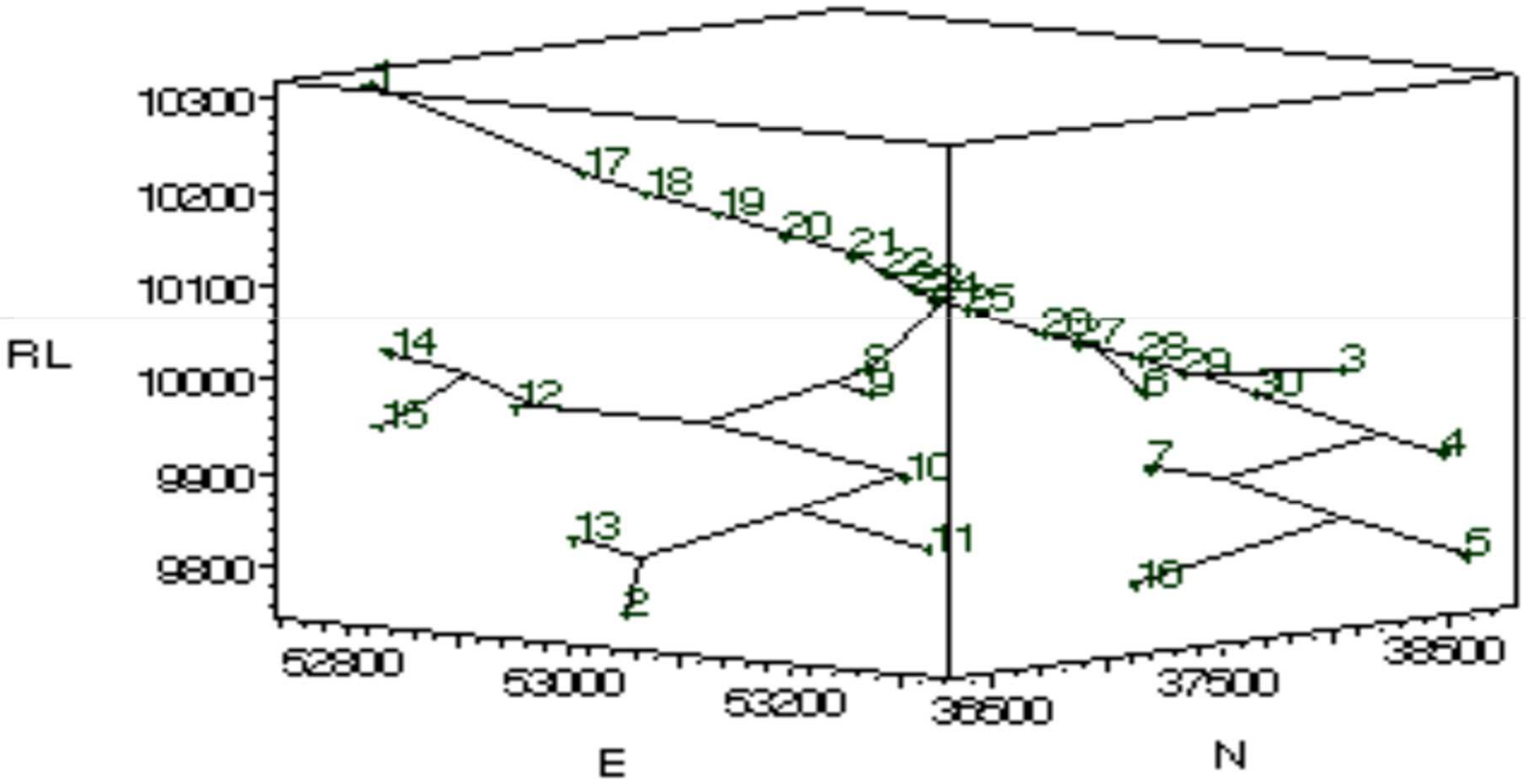
DOT and PUNO combined for optimal access development



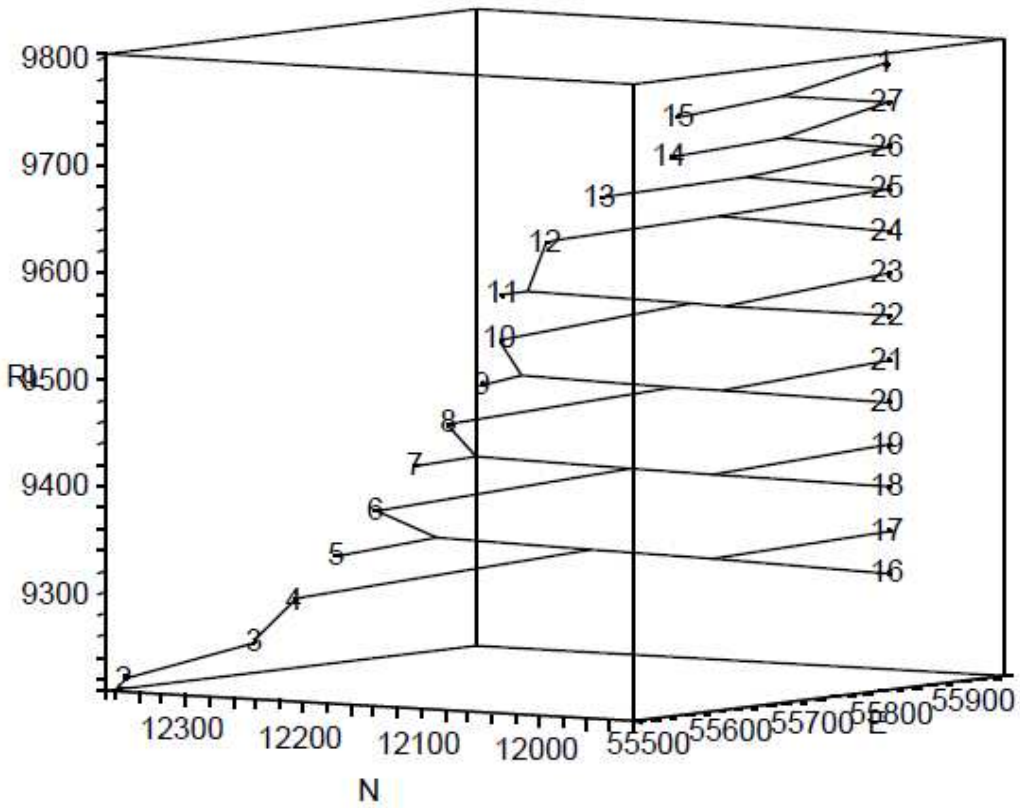
Mineoptima software tools under development

- UNO
  - A strategic planning tool which finds the best tree structure for an underground mine development
- UMOID
  - Underground Mine Optimal Infrastructure Designer incorporates ventilation and escape way development into the DOT like optimisation of declines
- Optimal declines in heterogeneous conditions e.g. bad ground
- Optimising infill drilling programs

UNO - Underground Network Optimiser
An example of UNO designing the template for an optimal decline layout



Using **UNO** for an optimal strategic decline layout of Prominent Hill



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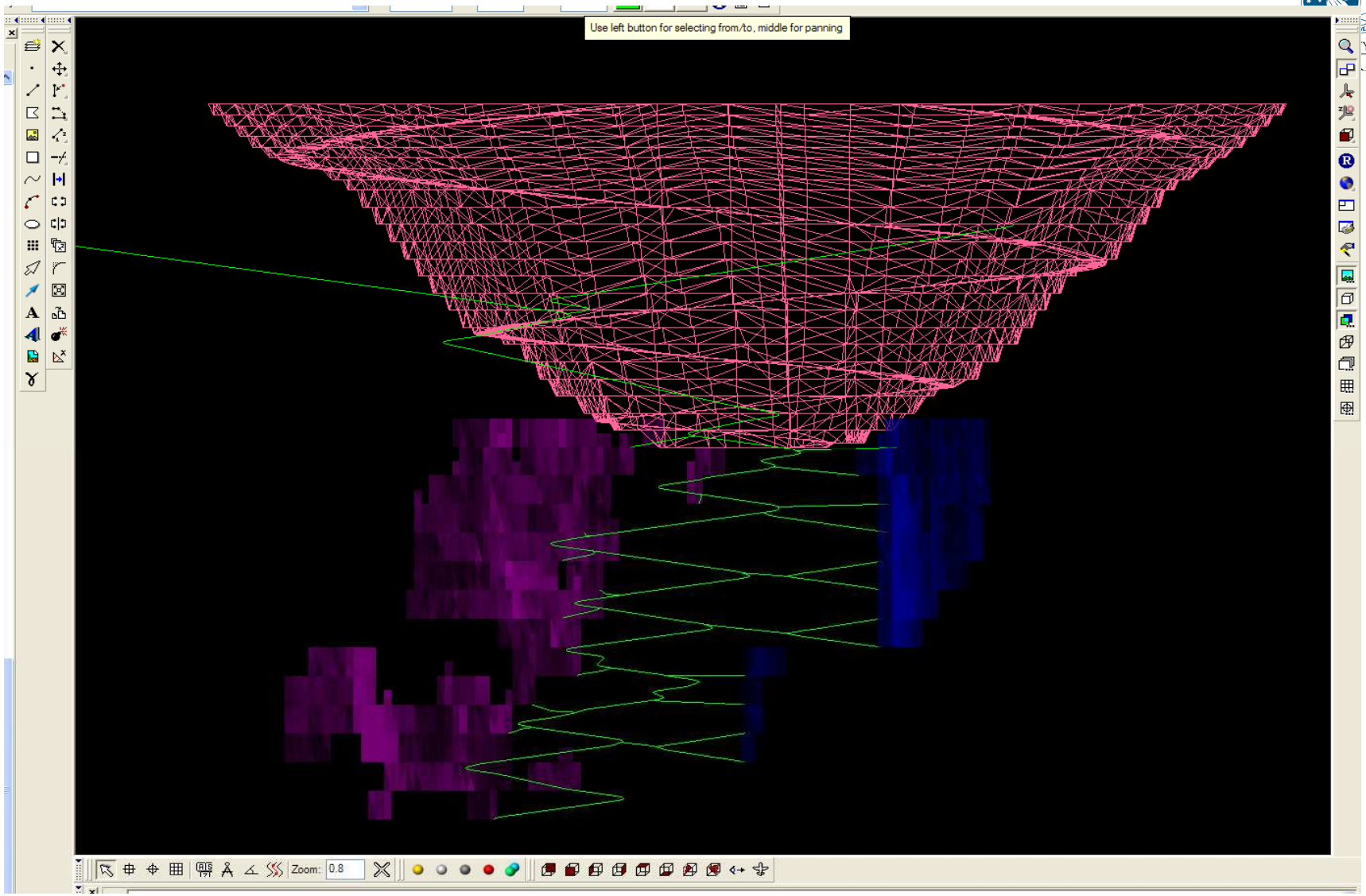
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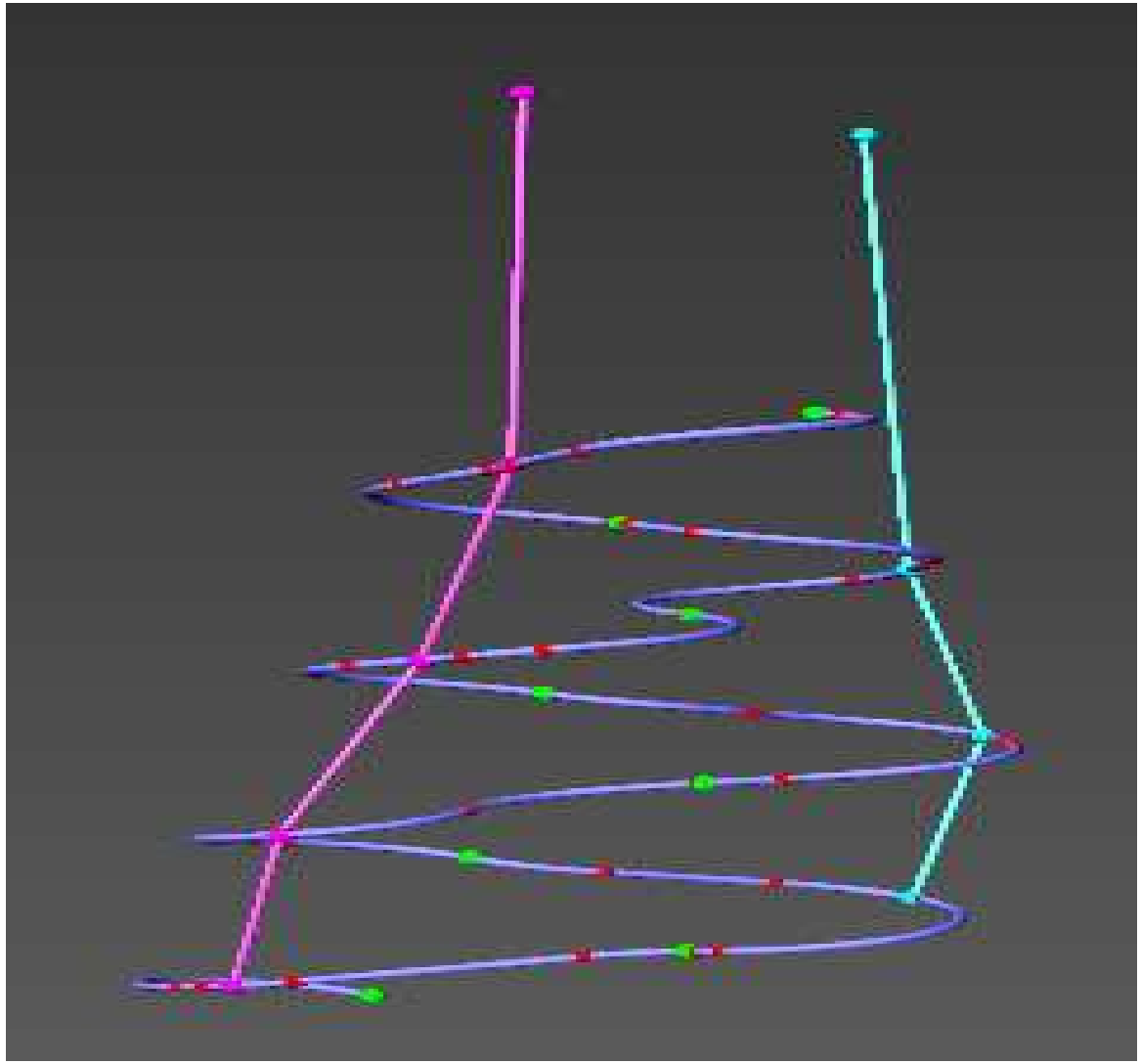
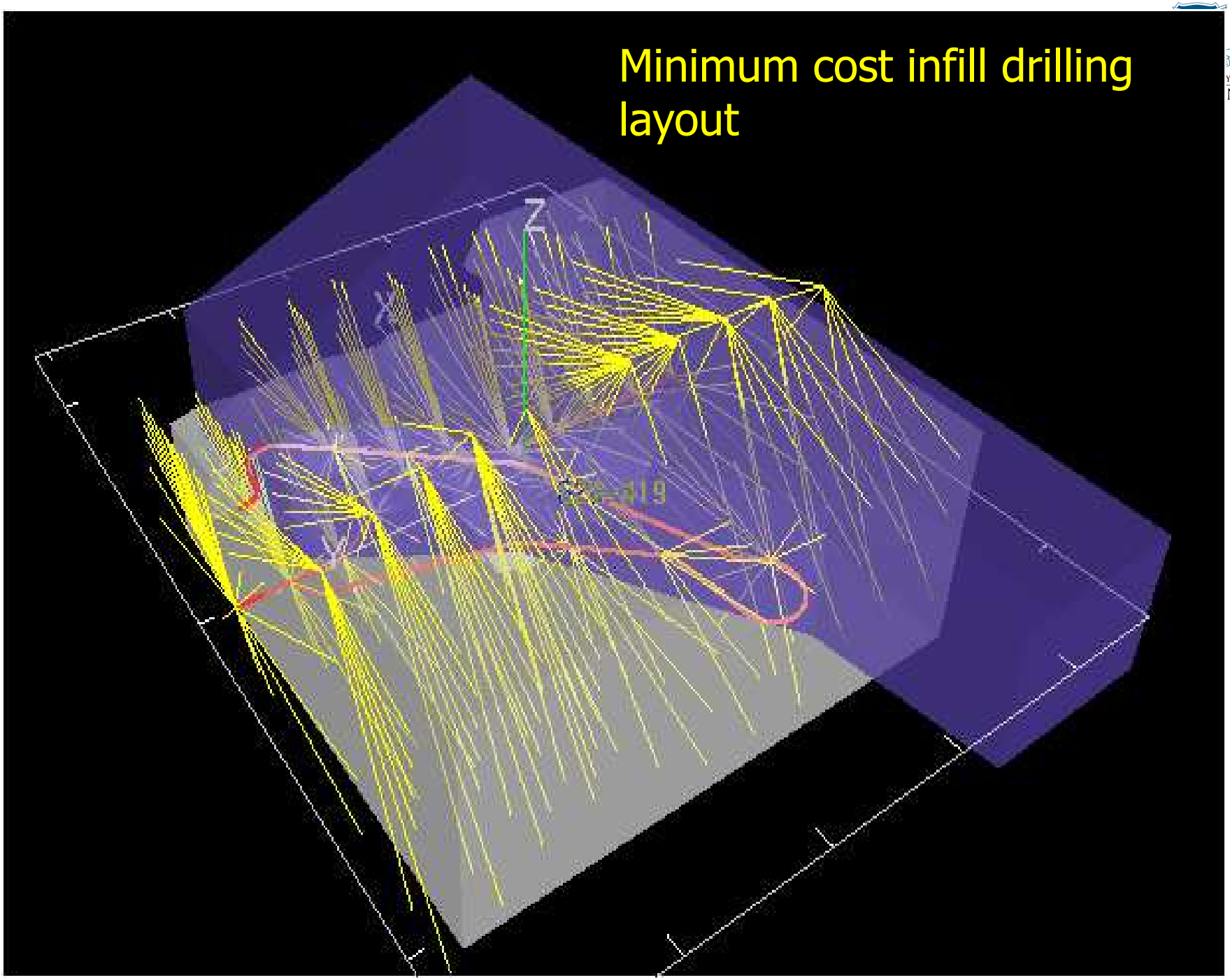
Zoom: 0.8

UMOID - Underground Mine Optimal Infrastructure Designer



Minimum cost infill drilling layout



PRIMO project

- Aim was to integrate software tools which will allow rapid design of an underground mine
  - Optimal layout of stopes (Chris Alford's StopeOpt)
  - Optimal Access (DOT, PUNO)
  - Optimal scheduling (SOT)

Current projects 1

PhD student Kash,

- Determine the access network which maximizes production revenue minus development cost, discounted by the time taken to complete tasks.
- A family of linked equations has been found, so that iteration appears to converge to the maximum value.

Current projects 2

- Drilling equipment (jumbo) is expensive for both development and ore extraction.
- Develop a scheduling algorithm for an optimal sequence of tasks for the jumbo.
- Determine when to operate a second jumbo.
- Combine the two projects into a decision tool for access design and scheduling at a tactical level.

Mineoptima

Mineoptima is a spin off from the University of Melbourne to achieve commercialisation of our software. The access design software DOT and PUNO, for networks of declines and level layout infrastructure around the ore zone, respectively, will be released through Maptek early next year.

See www.mineoptima.com.au for more details