Softree Optimal for RoadEng Tutorial

Version 10

Softree Technical Systems Inc.

Document Version – September 2, 2022

Trade Marks

Contents

1. Getting Started

Installation

The tutorial files referred to in the following examples can be installed from Softree's Support web site:

- Go to the *Support-Documentation Updates* page on Softree's web site: https://support.softree.com/product-updates/Documentation-Tutorials.
- Once *SoftreeTutorials.exe* has been successfully downloaded.
- *Double-click* on the file to begin installation.

During the installation you will be prompted to select which content to install, we recommend installing all the available tutorial options.

Documents

The tutorial files (data sets) will be installed in the folder below by default:

C:\Users\Public\Documents\softree\TrainingV10\SoftreeOptimal

We will refer to this folder as <SoftreeOptimal> in the examples below. It is possible to change this folder at install time; you can also copy it to a new location afterwards if you wish.

Recommendation: To make accessing files easier as you work through the tutorial, we suggest pinning the <SoftreeOptimal> folder to your Quick Access menu. To do so, open Windows Explorer, navigate to the folder, right-click on the folder, select "Pin to Quick Access". This will now make the folder available on the left-hand side of Windows Explorer.

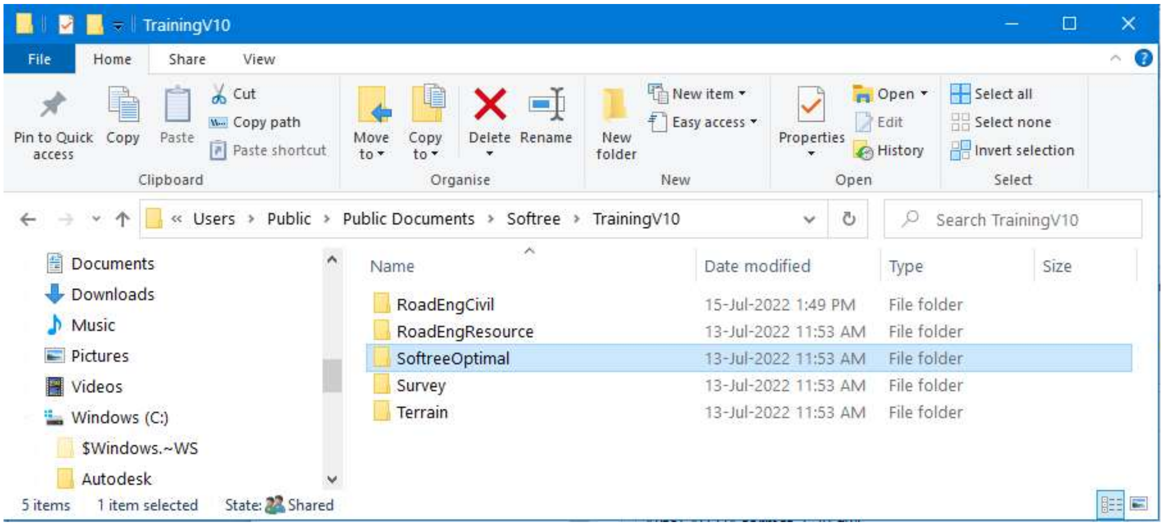


Figure 1-1: File Location in Windows Explorer

Don't Save Files (in most cases)

Most of the following examples end with the phrase: "... do not save changes". If you modify the tutorial files, they will no longer work with the steps in the exercise; this will prevent you, or someone else, coming back and doing the exercise again. If the files do get modified, you can always delete and re-install the tutorial files.

Function Groups

The vertical alignment optimization functionality included with *Softree Optimal* is <u>not</u> permitted in *demonstration mode*. Unlike other Softree tutorials, you will not be able to complete some of these tutorials without a *Softree Optimal* software license.

Defaults and Layouts

The setup and layout files for SoftreeOptimal are stored the folder below by default:

C:\ProgramData\Softree\SoftreeOptimal

It is possible to change this folder, so we will refer to it as <Defaults and Layouts> in the examples below. A folder containing training specific files has also been added to this location:

<Defaults and Layouts>\

Tutorial Units

Most examples in this tutorial are in Imperial units (feet). To correctly follow the examples, ensure Imperial (feet) units are enabled in the *Module* | *Setup* dialogue box.

Conventions

- The following conventions are used throughout the manual:
    - Menu functions are delimited by a line "|". File|Open means to click on *File* in the menu bar and then select *Open* from the drop-down menu.
    - Dialogue box control (like buttons) and heading names are *italicized*.
    - The symbols "< >" contain keyboard functions. For example, < shift-enter> means: hold down the *Shift* key and press the *Enter* key.
    - File names and path names are **bold.**

Screen Layout Facts

Screen layouts are small files that save display options. Many of the examples in this training manual include a step to retrieve a screen layout; retrieving a screen layout will changes multiple view options in one quick step.

The *screen layout* drop-down control can be found in the Standard toolbar in all modules (Figure 1-2 : Accessing Screen Layouts below).

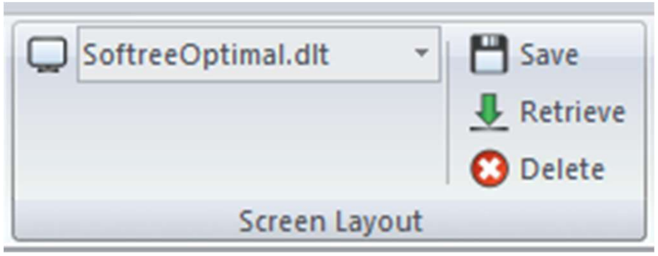


Figure 1-2 : Accessing Screen Layouts

With the drop-down expanded, you can:

- <Right-click> on a screen layout in the *Screen Layouts* tool bar item to:
  - Change *Properties*
  - *Delete*
  - *Copy*
  - *Save*

- <Right-click> on a folder (*Softree* or *Custom*) in the *Screen Layouts* tool bar item to:
  - Change properties (only the *Custom* folder can be changed here)
  - Paste a screen layout that was recently copied
  - Save new layout (define name and description)

The *Custom* folder is often defined on a network drive so that the layouts are accessible to all users.

- The *Save screen layout* button allows you to save a screen layout anywhere but only those in the *Custom* or *Softree* folders will appear in the *Screen Layouts* tool bar.

- The *Retrieve screen layout* button allows you to open a screen layout file anywhere including those in the *Custom*, *Training* or *Softree* folders.

- The *Delete screen layout* button opens up the screen layout folder where you can select multiple layouts to delete.

- You can change the *Softree* folder from the menu *Module* | *Setup, Install* tab. Do not do this unless you understand the consequences; more than just screen layouts are stored in this folder. The most common change is to put *Settings and Layouts* into your *Documents* folder (private to one user only).

2. Functional Overview

Softree Optimal Concepts

Softree Optimal is an add-on for RoadEng. It requires a license of Softree Optimal.

Softree Optimal provides automated and semi-automated functions to determine the lowest cost vertical alignment based on curvature, cross section configuration, and horizontal alignment. It accounts for excavation, embankment, and material movement costs. *Softree Optimal* produces a true optimal solution (guarantee of optimality) and will accommodate detailed design specification. These features allow it to be applied at any stage of the design process. *Softree Optimal* can also be used to evaluate existing designs.

Optimization requires an original ground terrain. The designer controls cross section templates, alignment location and curves. It provides real time feedback of volumes, mass haul, road footprint, cross sections, grades, etc.

Softree Optimal can also export designed surfaces back to the other design programs (Civil 3D®, 12D® Model, Bentley Open Roads).

Disclaimer

Softree Optimal is a tool to assist road designers and planners. It is not a substitute for knowledge in the subject area. Individuals using it need to have a sound understanding of road design and understand the limitations of this technology.

Although earthwork optimization may save time and help the designer identify economic solutions, there is no guarantee that the results will be practical or meet the project design criteria. It is up to the designer/engineer to ensure the suitability of the design.

3. Design Time Cost Reporting

Cost reporting and feedback is useful at all stages of design (preliminary, detailed and construction estimation).

Design Time Cost Reporting is the ability to accurately evaluate the cost of a particular design interactively before it is complete. *RoadEng* (no Softree Optimal license required) provides interactive and automated feedback to report earthwork costs. This functionality is extremely useful for manual design and is a prerequisite for optimization.

Earthwork cost calculations are based on material excavation, embankment, movement and borrow/waste locations.

It is worth noting, that excavation and embankment costs are generally straightforward to calculate manually but movement costs are much more difficult. The complete cost model will be discussed in greater detail further in this document.

Design Time Costing Example

In addition to being a very useful function for road design, cost calculation is a prerequisite to alignment optimization; the optimizer minimizes the cost. In this example, we will use design time costing with a hand-designed road alignment.

Project Explorer Panel

First let's look at the *Project Explorer Panel*.

1. Open the RoadEng Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/Hart Rd.dsnx. Press *Open*.
3. Arrange your screen to look like the figure below. You may need to arrange your visible windows by selecting the *View* | *Tile Vertically*.
4. You will need to *Recalculate Range & Re-Cost*: select *Recalculate Range* from the *Home* ribbon tab. Check the *Re-Cost* box, press *OK*.

Your screen should now look similar to the one below:

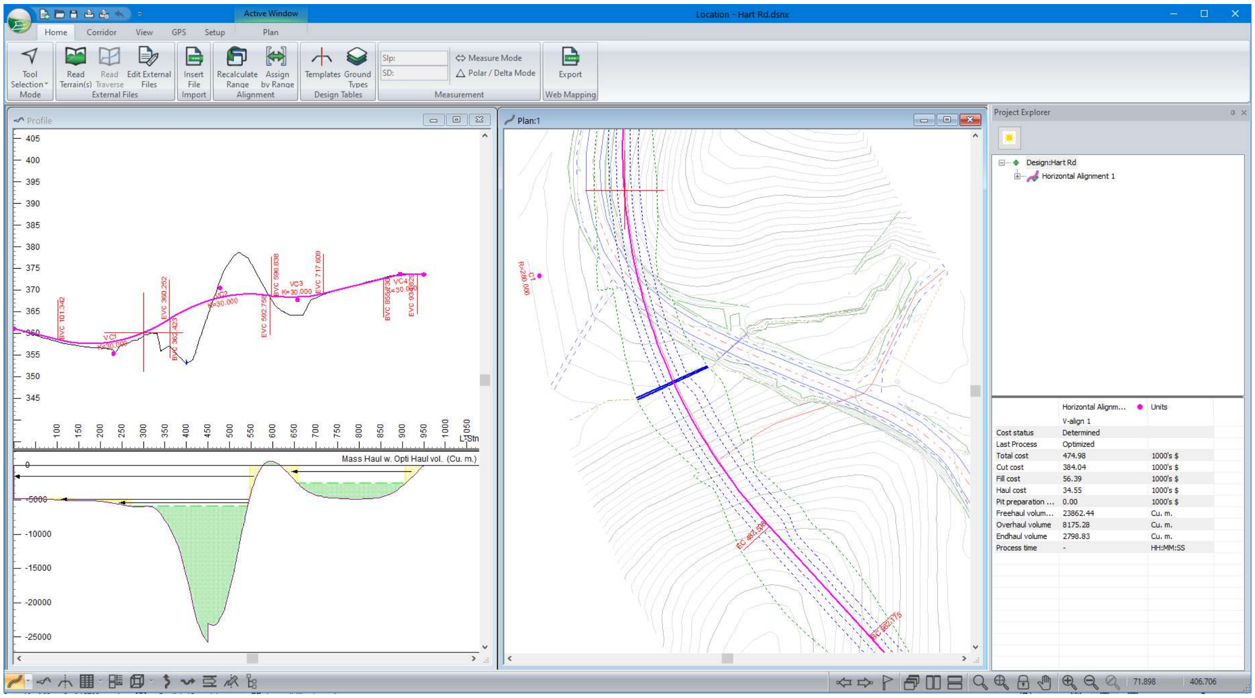


Figure 3-1: Softree Optimal with Alignment Properties Panel

The Alignment properties panel was created to do the following:

- Manage multiple vertical alignments.
- Define parameters required for design time costing and vertical alignment optimization.
- Report cost and other information related to design time costing and vertical alignment optimization.

Alignment(s) Tree

The top part of the panel is a list of horizontal alignments, and their vertical alignments; for this example, there is only one vertical alignment called *V-Align 1: Hand Design*.

5. Click the ⊞ buttons next to the alignment names to open the tree (as shown in the figure below).

The tree control displays parameters that are used for cost calculations and alignment optimization. The parameters relating to cost calculations are briefly outlined below.

- **Costs** include the unit costs for cut, fill and haul.
- **Pits** can be used to borrow and waste materials.
- **Sidecast** is used to waste material alongside the road.

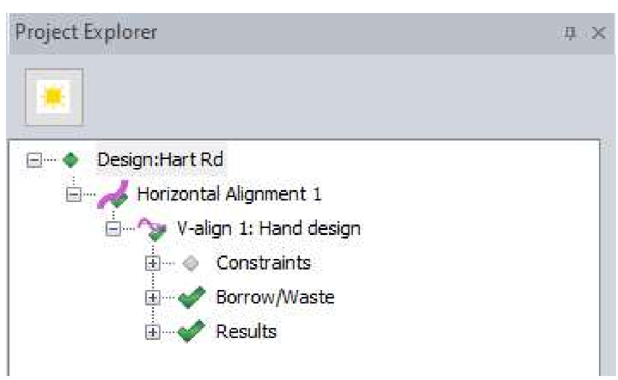


Figure 3-2: Alignment Tree Control

Information Area

The bottom part of the panel is the reporting area. It displays information about the selected alignment such as volumes and costs.

The contents and order of this list is configurable. Right click and *Choose fields to report* or press the button at the bottom of the panel.

The size of the information area can be changed. Click on the top of the information area to activate a slider to re-size the panel.

	Horizontal Alignm...	Units
	V-align 1	
Cost status	Determined	
Last Process	Optimized	
Total cost	474.98	1000's $
Cut cost	384.04	1000's $
Fill cost	56.39	1000's $
Haul cost	34.55	1000's $
Pit preparation cost	0.00	1000's $
Freehaul volume (Total)	23862.44	Cu. m.
Overhaul volume	8175.28	Cu. m.
Endhaul volume	2798.83	Cu. m.
Process time	-	HH:MM:SS

Figure 3-3: Reporting Area

Cost Reporting

Now let's use the *Design Time Costing* features. The next steps will demonstrate the change in cost when the vertical and horizontal alignments are moved.

> **Note:** It is assumed the reader is familiar with interactive design using RoadEng®; however, even if you haven't used RoadEng® before, you can probably follow along by reading the detailed instruction steps (a, b, c, ...).

6. In the Profile Window, change the vertical alignment slightly:
   a. Right click and change to the *Add/Edit IP* tool (or select *Home* | *Tool Selection* | *Add/Edit IP*).
   b. Move your mouse over a VIP (indicated by the magenta circle symbol); note that the mouse cursor changes to a box.
   c. Click the mouse to capture the IP.
   d. Move the point slightly and left click to re-anchor the point.

> **Note**: The information list is displayed grey after design modifications cause the costs and other items to be *out of date*.

7. *Re-Calculate* the alignment as before.

Note that the costs are different. Now to streamline this procedure:

8. In the *Project Explorer* tree, right-click *V-align 1* and select *Re-Cost.*

The *Calculate Costs* dialogue box will appear as shown below.

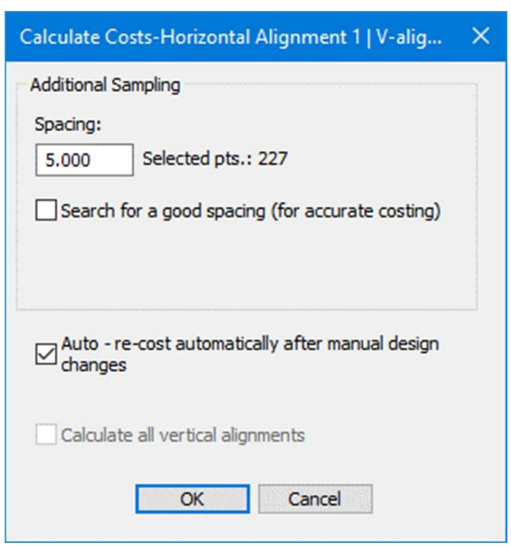


Figure 3-4: Calculate Costs dialogue box.

9. Set the *Auto* checkbox; then press *OK*.

Now your design will automatically re-calculate the cost any time it is changed. This is only sensible for short alignments where re-cost doesn't take too long.

10. In the Plan window, capture and move an IP slightly and observe the updated cost.
    a. Move your mouse over an IP; note that the mouse cursor changes to a box ⌜⌟.
    b. Click the mouse to capture the IP.
    c. Move the point slightly and left click to re-anchor the point.

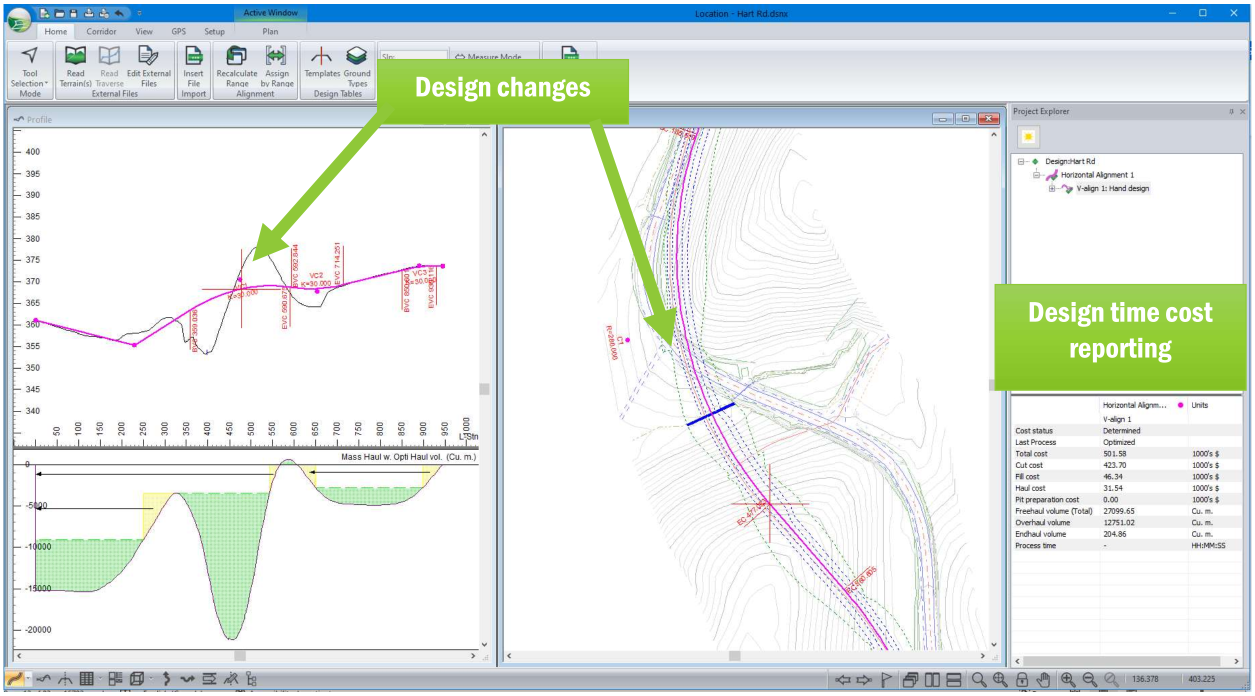


Figure 3-5: Design Time Cost Reporting

> Note: If *Auto* is checked (Figure 3-6), the cost will automatically update each time the alignment is changed. In some situations, this will noticeably slow recalculation.

Cost Parameters

The earthwork cost values reported in the steps above are dependent on the volumes and types of materials excavated and embanked. Softree Optimal allows you to specify what material layers are found in the ground and what materials you are using for subgrade fill. To calculate costs, you also need to provide cut/fill cost for each material and generic haul cost information.

> Note: This document uses $ for currency. You can change the currency symbol by selecting menu *Setup* tab and choosing the *Units* tab.

11. *Right-click* on V-Align 1, select *Vertical Options…*. This will open the *Vertical Optimization Options* dialogue and then click on the *Unit Costs* tab.

The *Ground Types* dialogue box will appear as shown in the figure below.

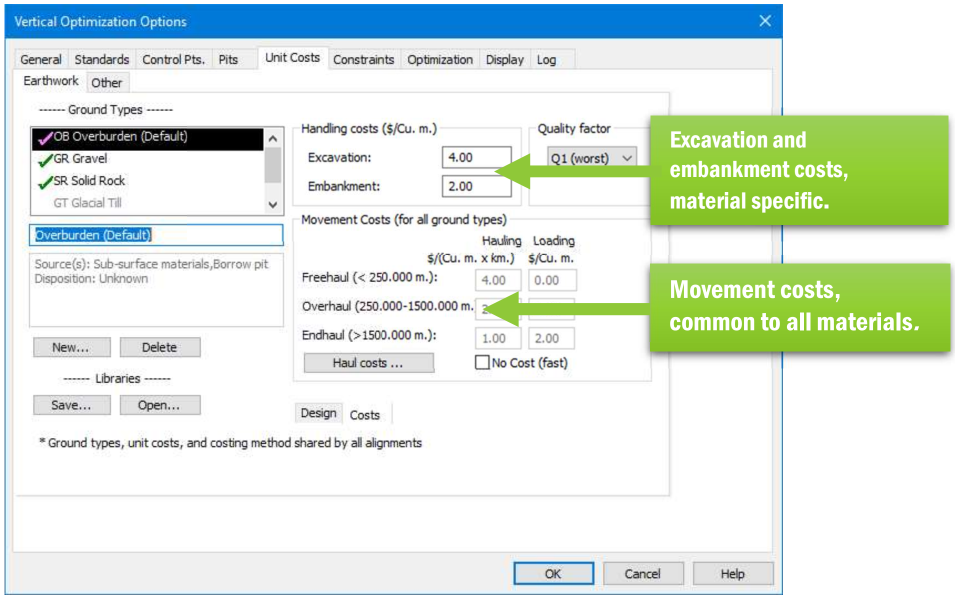


Figure 3-6: Cost Parameters

Handling Costs

The *Excavation* and *Embankment* (Cut/Fill) costs are dependent on material type. Unit costs are entered in $ per Cu. m (or $ per Cu. Yd.).

Quality Factor

Used to control fill operations. When fill material of a given quality is specified, any material with the same or *higher* quality can be used as fill.

Movement Costs (for all ground types)

Are common to all material types. There are up to 3 haul categories (*Freehaul*, *Overhaul*, and *Endhaul*); this allows you to model up to 3 different types earth moving equipment (for example bulldozer, scraper and truck/excavator) the distance for each type of haul depends on the *Hauling* and *Loading* costs.

Haul Costs button allows you to modify these values (also see note below).

- *Hauling Cost* (cost to move material) has units of $ per (Cu. m x km) or $ per (Cu. Yd. x mi).
- *Loading Cost* (cost to load material prior to moving) has units of $ per Cu. m or $ per Cu. Yd.

Movement Costs Simplified

When the *simplified* check box is set, your options are reduced. You need only specify a loading cost (zero is OK) and a haul cost which is applied to haul longer than a specified Freehaul distance.

Note: For alignment optimization, costs don't need to be exact. The ratio between the costs is what determines the optimal alignment (i.e. the ratio between cut, fill and haul costs). If the total $ cost is not absolutely precise, it can still be used to compare different alignments and options.

You can save your ground table, including costs, to a small file (.GDX extension) for use in future optimizations (*Save/Open Libraries* buttons).

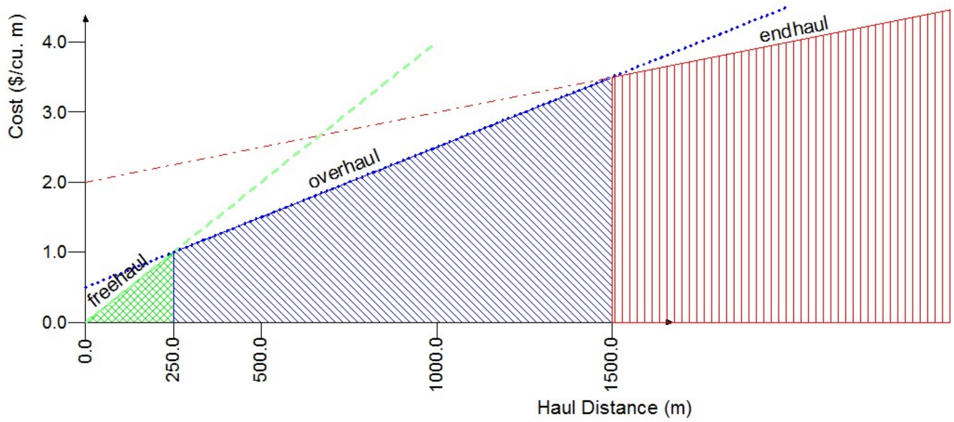


Figure 3-7: Movement Costs by Class

The graph above shows how the transition distances of 250m and 1500m are calculated in the example.

Movement costs are assumed to be linear with distance; this agrees well with empirical haul equipment productivity data. The haul distance where it becomes cheaper to switch from *Freehaul* to *Overhaul* or from *Overhaul* to *Endhaul* depends on the intersection of the linear cost graph (see figure above).

The *Ground Types* dialogue contains information that is common to RoadEng®. It can be accessed from the Alignment Panel using the *Options* button; it can also be accessed from the *Edit* |*Edit Ground Types* menu.

The volume for each distance category is reported in the Alignment Panel as *Freehaul*, *Overhaul* and *Endhaul*.

Optimal Haul

If you have spent any time thinking about the problem of costing road earthworks, you know that calculating the haul cost is not trivial; especially if you have multiple borrow/waste pits and different materials in the ground along the road corridor. Before reporting the haul cost, *Softree Optimal* solves an optimization problem to determine the lowest cost haul specification that balances material.

12. Press *Cancel* to exit the *Options* dialogue.

Section Sampling and Accurate Costing

Cost calculations are dependent on the spacing of sampled cross sections; if the spacing is too large (there are too few cross sections calculated) then the volumes will be inaccurate. Softree Optimal, RoadEng® (and other civil software) calculate volumes by sampling cross sections so you should be familiar with the concept of accuracy increasing with sampling frequency.

Ideally, you would like to obtain a cost for any given alignment that would not be affected by the choice of the sections. *Softree Optimal* provides a procedure that helps determine an appropriate section spacing to determine an accurate cost.

Next let's experiment and see how section spacing affects the cost calculation.

13. In the *Project Explorer* tree:
    a. Right-click *V-align 1*
    b. Select *Re-Cost.* This will open the *Calculate Costs* dialogue box,
    c. Type 10 in the *Spacing* edit box.
    d. Press the *OK* button to re-calcuate costs.

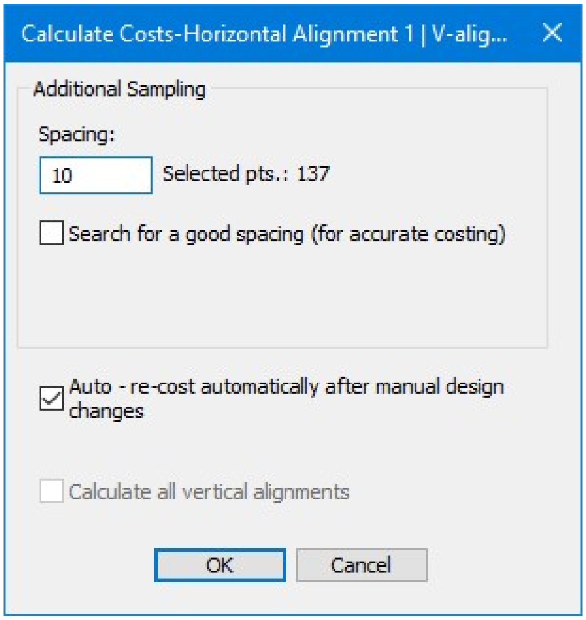


Figure 3-8: The Re-Cost Dialogue Box

Note the calculated cost values in the information area.

14. Repeat the *Calculate Costs* operation for spacing values of 5, 2, and 1.

The example results are shown in the table below (these will vary depending on the design changes you made in steps 6 and 10):

Spacing	Total Cost	Cut Cost	Fill Cost	Haulage Cost
10	*473.95*	*383.19*	*56.36*	*34.40*
5	*474.98*	*384.04*	*56.39*	*34.56*
2	*475.12*	*384.13*	*56.37*	*34.62*
1	*475.14*	*384.15*	*56.37*	*34.63*

Table 3-1: Costs as a Function of the Sample Spacing (example)

Observe that the costs vary (in this case very slightly) with the spacing. This means that the spacing we have chosen is already fine enough. Also, note that each calculation took a little longer than the previous.

Softree Optimal has automated the procedure for finding a fine enough spacing for accurate costing; it will automatically find a reasonable spacing so that the costs are unlikely to change by more than 1% when adding more cross sections. This procedure will be referred to as *accurate costing*.

15. In the *Project Explorer* tree, right-click *V-align 1* and select *Re-Cost* button again. Check *Search for a good spacing (for accurate costing)*. Press the *OK* button.

Location returns with the following message:

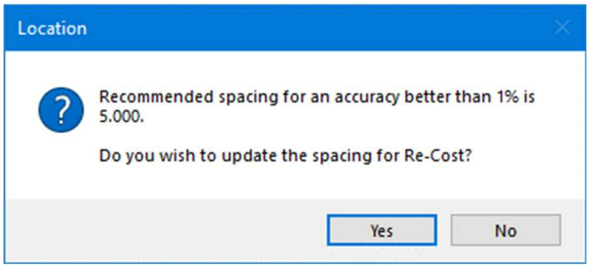


Figure 3-9: Recommended Spacing

Location suggests using 5.0 for the spacing.

16. Choose *Yes* to close the message and set the sample spacing.

17. Select *Re-cost from V-Align 1* to view the dialog box one more time.

The *sample spacing* has been set to the new value.

18. Continue to the next example, or press *Cancel,* then *Home* button | *Exit*. Do not save changes.

Note: It is suggested that you perform an accurate costing at the start of every project.

External Material Movement Example

Material Movement Types

While calculating a cost for your alignment, the software is also generating an optimal haul specification. Because you can specify borrow and waste pits, there are two types of haul available:

- *Internal* haul moves material from excavation in the road construction area to embankment also in the road construction area.
- *External* haul is earthwork which either starts or ends up in pit (outside the road construction area).

All material movement is classified as either *Freehaul*, *Overhaul* or *Endhaul* depending on the haul distance. External material movement includes the following types of movement:

Borrow / Waste	Material movement from/to user defined pits.
Sidecast	Excess cut material disposed of along the alignment.
Overflow / Underflow	This movement is used only when all other options to balance volumes have been exhausted. The *Overflow/Underflow* pit is located at the beginning of the alignment.

> Note:
>
> a) The software must account for all material of each type. The sum of all Internal and External Material must be zero for all material types (cut and fill have opposite signs).
>
> b) If you want to internally balance a road, remove all *Borrow* and *Waste* pits. If it is geometrically possible (without violating constraints), the road will be balanced internally (material movements will be restricted to the road construction area). If a significant volume ends up in *Overflow / Underflow*, it indicates a balance can't be made without importing or exporting material.

In this example, we consider the most common applications of external material movement. In the first part, we will look at overflow/underflow reporting and how to configure the reporting area in the *Project Explorer Panel*. In the second section, we will examine side-cast and how to add range-based constraints.

1. If you are starting here, open the Location Module. If you are continuing from the previous start at step 4.
2. *File* button | *Open*. Select <SoftreeOptimal>/Hart Rd.dsnx. Press *Open*.
3. Arrange your screen as before, to look like the Figure 3-2. You may need to arrange your visible windows by selecting the *View* tab | *Tile Vertically*. Ensure re-cost is set to *Auto* as per step 8 above.
4. <Right-click> on vertical alignment in the *Project Explorer Panel*, select *Vertical Options…*
    a. Select the *Pits* tab.
    b. Select *Pit2: Borrow variable Stn: 0.000*.

The *Pits* dialogue (below) is used to create and configure borrow and waste sites for volume handling. We will discuss the options briefly before we continue the exercise.

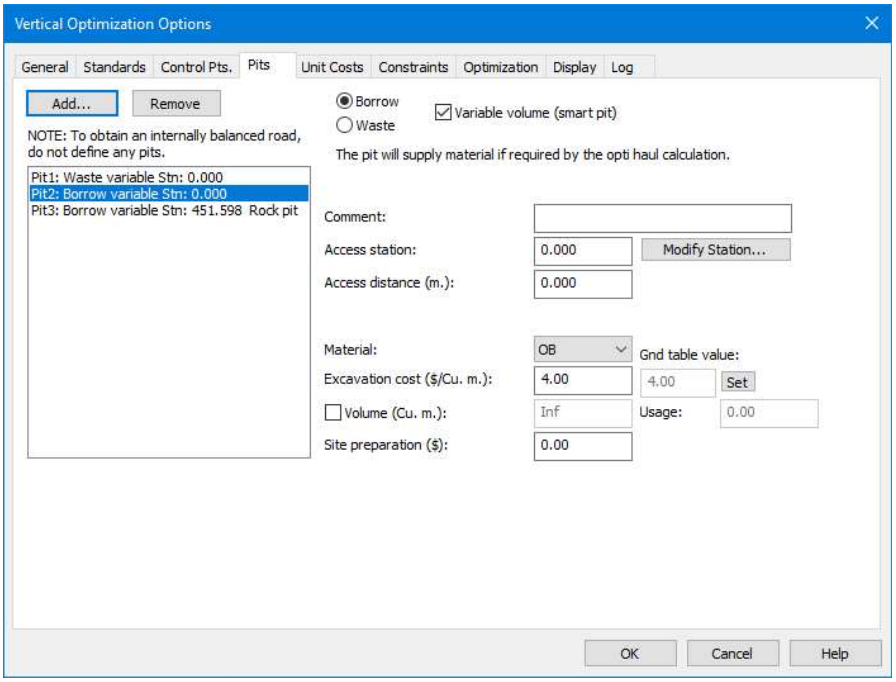


Figure 3-10: Pits Tab in the Optimization Options Dialogue Box

The controls at the top of the dialogue box allow you to specify four types of pit:

Borrow (variable)	Material can be extracted from the pit if necessary.
Borrow (not variable)	The quantity specified <u>must</u> be removed from the pit.
Waste (variable)	Material can be dumped in this pit if necessary.
Waste (not variable)	The quantity specified <u>must</u> be placed in the pit: *stockpile*.

Note: We sometimes refer to variable pits as *smart pits*. And pits that are not variable can be referred to as *fixed* pits or *stockpiles*.

In earlier versions of RoadEng, there was no such thing as a variable pit; when you open older documents, borrow/waste assignments will be converted to fixed pits.

A brief description of the other pit attributes follows.

Access station - location on the alignment from which the pit is accessed.

Access Distance - from access station to the borrow/waste site (sometimes called *dead-haul* distance).

Comment – for tracking purposes (optional).

Waste quality – The minimum material quality required (non-variable only).

Material - available (borrow pit only).

Excavation $ - Cost to excavate (borrow pit only).

Capacity limit - Maximum volume of borrow or waste (*variable* only).

Volume - Exact amount of borrow or waste (non-*variable* only).

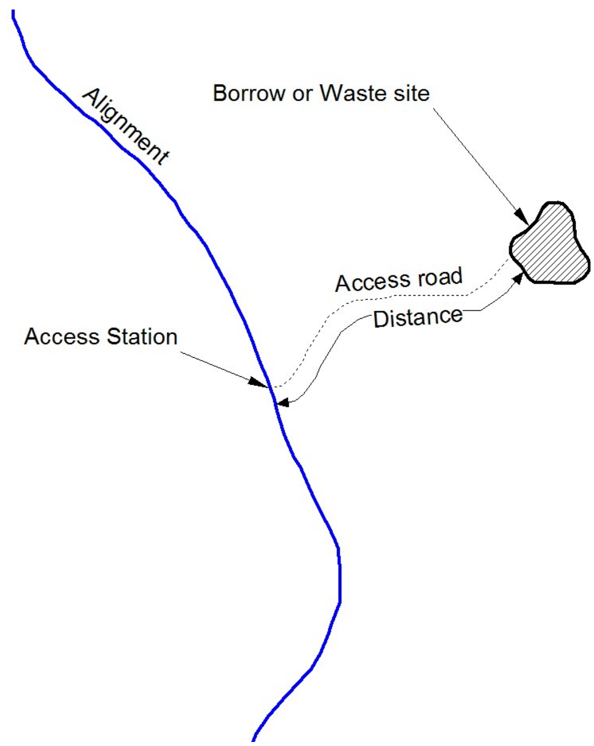


Figure 3-11: Pit Attributes

Overflow and Underflow

In this design, material is balanced by use of both borrow and waste pits. The quantities can be displayed in output reports and in the Optimal Haul diagram (discussed later).

Let's see what happens when we remove the only waste pit:

a. Select *Pit-1 (Waste variable)* then press the *Remove* button.

b. Press *OK*, to close the *Options* dialogue box.

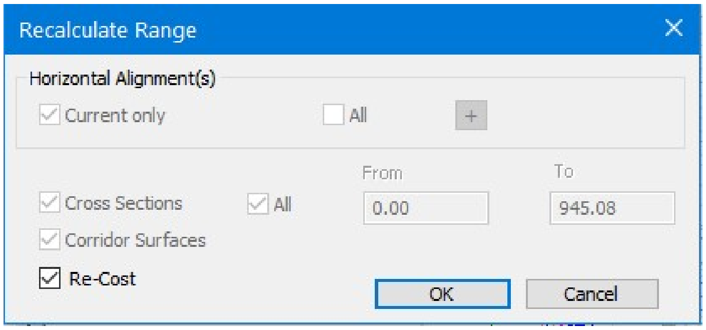


Figure 3-12: Re-Calculate Range Dialogue Box

c. Press *OK* to Recalculate Range, with *All* for the *Station Range* (entire design) checked.

Now let's update the costs explicitly (*Recalculate Range*, above, can do this also, but it doesn't report warnings).

5. Right-click on an alignment, select the *Re-Cost* option in the *Project Explorer Panel* to open the *Calculate Costs* dialogue box.

6. Press the *OK* button inside the dialogue box. When the Log for Cost Calculation dialogue box comes up. Expand the tree by pressing the *plus* buttons.

Because it was impossible to balance materials, you will be presented with the log shown below. The Log shows an overflow of 4,861 cu. m. of excavated material.

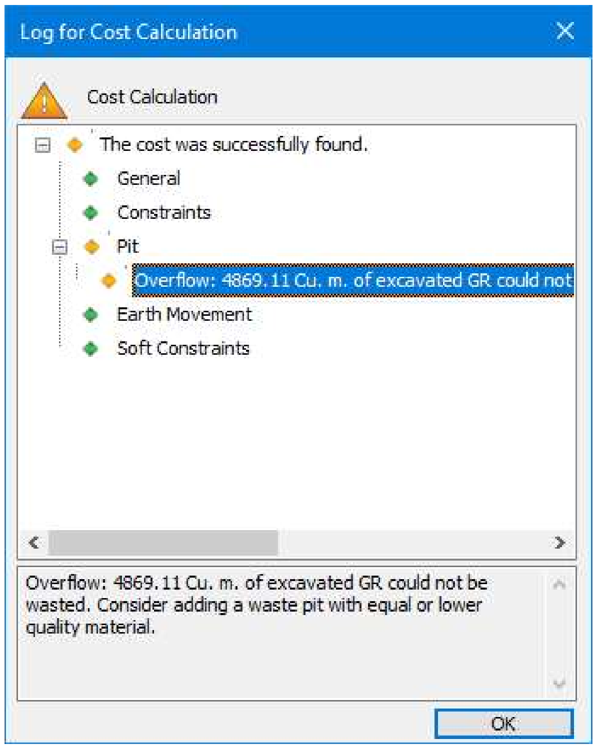


Figure 3-13: *Log for Cost Calculation* Information

7. Add *Overflow* and *Underflow* to the displayed items:

    a. Right-click in the reporting area and choose menu *Set Report Fields* to open the *Optimization Data Report* dialogue box.

    b. Open the *Volume* branch in the *Available* list the select and *Add* both *Overflow* and *Underflow* to the *Selected* list (as in the figure below).

    c. Press *OK* to close and save changes.

The information area (shown below right) now displays these values whenever they are available.

8. Press *OK* to close the log.

Note: The most recent log text is always available in the *Log* tab of the *Vertical Optimization Options* dialogue box.

Configuring the Alignment Panel Reporting Area

Overflow/Underflow information can also be displayed in the configurable reporting area.

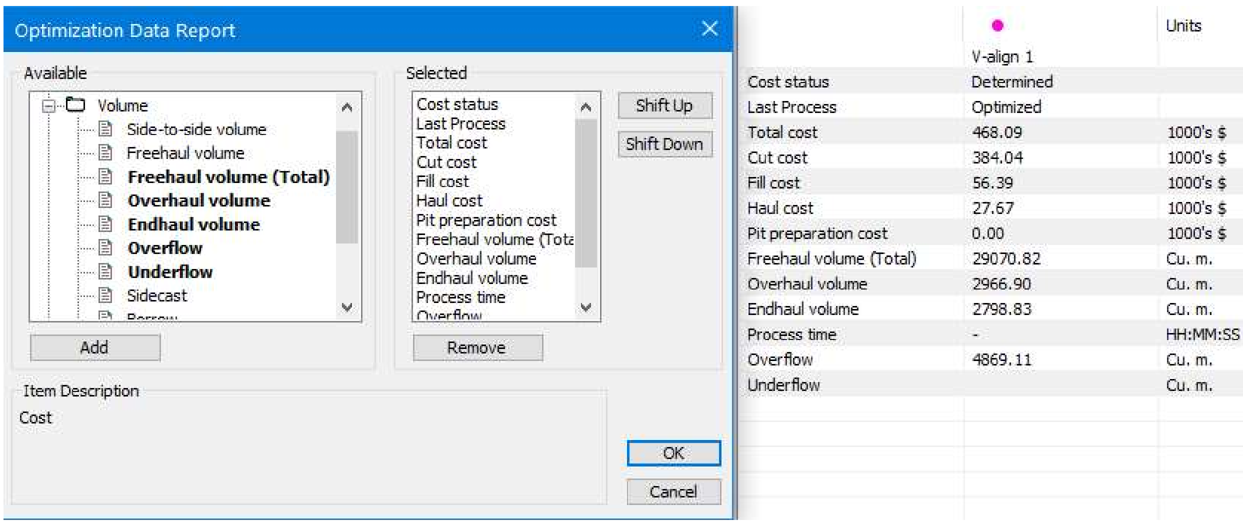
9. Add *Overflow* and *Underflow* to the displayed items:

   a. Click on the *Options* button at the top of the panel (or right click in the reporting area and choose menu *Choose fields to report*) to open the *Optimization Data Report* dialogue box.

   b. Open the *Volume* branch in the *Available* list the select and *Add* both *Overflow* and *Underflow* to the *Selected* list (as in the figure below).

   c. Press *OK* to close and save changes.

The information area (shown below right) now displays these values whenever they are available.

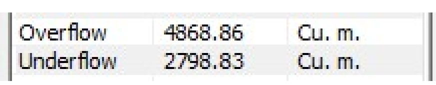


	V-align 1	Units
Cost status	Determined	
Last Process	Optimized	
Total cost	468.09	1000's $
Cut cost	384.04	1000's $
Fill cost	56.39	1000's $
Haul cost	27.67	1000's $
Pit preparation cost	0.00	1000's $
Freehaul volume (Total)	29070.82	Cu. m.
Overhaul volume	2966.90	Cu. m.
Endhaul volume	2798.83	Cu. m.
Process time	-	HH:MM:SS
Overflow	4869.11	Cu. m.
Underflow		Cu. m.

Figure 3-14: Configuring the Information Area to Show *Overflow/Underflow Values*

The *Overflow* field in the reporting area indicates an excess of material; this is because there is no waste pit available. This is referred to as *Overflow* to distinguish it from ordinary pit waste. When necessary, an *overflow* pit is created at the start of the alignment. Note that the cost is the same because the waste pit we removed (previous steps, above) was also located at the start of the alignment.

10. Next, use the same procedure to remove *Pit-2 (Borrow variable) Rock Pit* and then *Re-cost*.



Overflow	4868.86	Cu. m.
Underflow	2798.83	Cu. m.

Figure 3-15: After Rock Borrow Pit Removal, *Underflow* is No Longer Zero

The *Underflow* field in the Reporting Area now indicates a shortage of material. This is referred to as *Underflow* to distinguish it from ordinary borrow. When necessary, an *underflow* pit is created at the start of the alignment. Note that the cost is different now for two reasons:

- Haul costs are different because the *underflow* pit is not at the same location as the original borrow pit.
- Excavation costs are also different. The cost of material from the *underflow* pit is determined from the ground type table ($20.00/cu. m); the original borrow pit had an explicit unit cost of $6.00/cu. m.

You may have also noticed that the Mass Haul diagram changed during this process.

> Note: *Overflow* and *Underflow* is not shown in the Mass Haul diagram.

Finally, there is a small change in the *Overflow* volume (and totals); this is caused by a slightly different sample set used in the optimal haul calculation. When there was a pit located at station 450, there were also a pair of automatic report points at stations 449.9 and 450.1; these report points have been removed and the volume is slightly different.

Material Quality Application

At first glance this may seem strange; how can there be an excess and a shortage at the same time? If you look carefully at the design, you will see that the designer has specified SR (rock) fill for a portion of the road (menu *Edit* | *Assign Parameters by Range*, *Fill Types* tab). However, most of the material being excavated along the alignment is GR (as defined in the *Sub-Horizons* tab of the same dialog box). Because GR has a lower *quality* than SR (as defined in our *Ground Types* table, see Figure 3-7: Cost Parameters), it cannot be substituted for the required SR fill.

In summary, we are short of rock fill, but we have an excess of gravel excavated from the roadway.

Sidecast of Material

Sidecast provides an alternative to using a waste pit; material is discarded along the corridor beside the road.

11. Open the *Vertical Options* dialogue box, select the *Constraints* tab, and then the *Sidecast* tab.

We have an excess of about 5000 Cu. m of material; the length of the alignment is 950m; this works out to about 5 Cu. m/m. If we could discard this much material along the side of the constructed road, we would no longer have to haul material to a waste pit.

12. Setup for *Sidecast*, as shown in the figure below:

    a) Check the *Active* checkbox.

    b) Enter a *Linear sidecast* of 5.0.

    c) Leave the station range as is (“..” to “..” represents the whole road). But note that you can define station ranges if desired.

    d) Press *Add/Edit* (warning – it is easy to forget this step!).

    e) *OK* to close *Vertical Optimization Options* dialogue box.

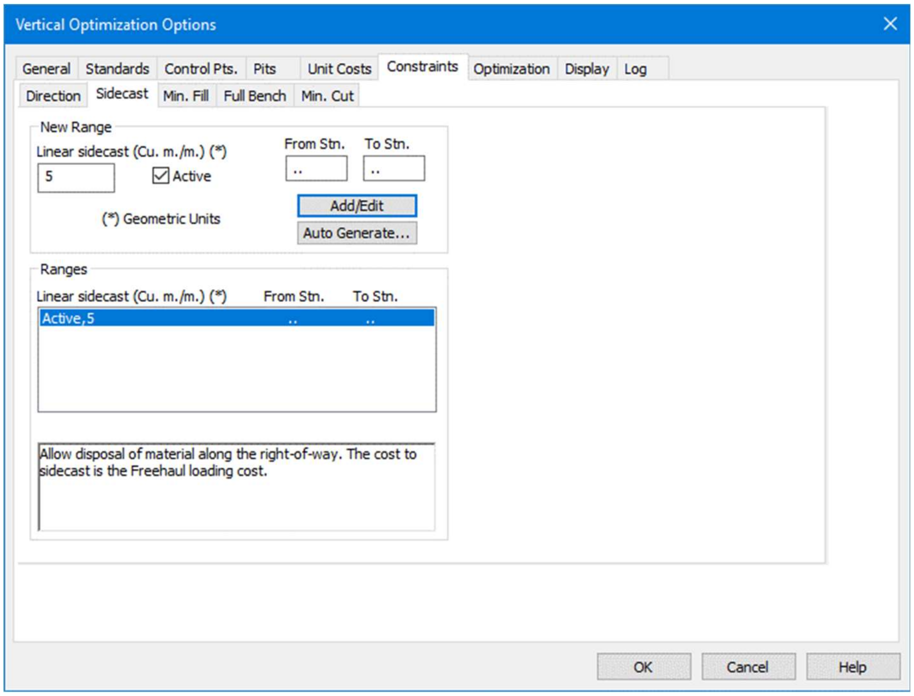


Figure 3-16 – Sidecast Constraints

13. *Re-Cost* the design.

The overflow volume has changed, *Softree Optimal* returns with an overflow of 2166 Cu. m.

14. Use the procedure described in step 9 above to add *Sidecast* volume to the reported items.

Overflow	2166.12	Cu. m.
Underflow	2798.83	Cu. m.
Sidecast	2702.75	Cu. m.

Figure 3-17: Sidecast Volume Displayed in the Reporting Area

Why is the *Sidecast* so much smaller than what we calculated? *Sidecast* is only practical where excavation is occurring so the actual station range where sidecast is occurring is less than then length of the alignment. We need to choose a value bigger than 5.0 to get rid of all of our excess cut.

15. Repeat the steps above using a *Linear sidecast* of 10.0. Then *Re-Cost.*

Observe that the volume of overflow has been reduced significantly. Similar to pit volumes, sidecast quantities can be displayed in output reports and in the Optimal Haul diagram.

16. *File* | *Exit.* Do not save changes.

4. Vertical Alignment Optimization

Alignment design is a fundamental part of any corridor engineering project. The alignment position directly affects the cost of the project. *Softree Optimal* can be used to create new designs or refine and verify existing designs.

Three-dimensional alignment design is a complicated geometric problem. In addition to standards such as design speed curvatures and maximum grade, engineers must contend with a variety of conditions and restrictions such as right of way, utilities and crossing grades. These constraints often make the alignment problem even more challenging.

Softree Optimal can quickly calculate the earthwork cost of any alignment (see previous exercises); in mathematical optimization terminology, this is called the Cost Function. To optimize a vertical alignment, *Softree Optimal* minimizes the cost function over all possible alignments. Your job as an engineer/designer is to constrain *Softree Optimal* to reasonable alignments.

Vertical alignment optimization is based on the following parameters and constraints:

- Earthwork Costs - Excavation, embankment and haul costs (see previous section).
- Pit Locations - Waste and borrow locations and associated costs (see previous section).
- Design Standards - Maximum curvature (minimum K values), minimum and maximum grades.
- Control Points - Elevation and grade constraints:
  - Terminating Conditions - Starting and ending elevations and grades.
  - Control Points - Defined station, elevation points (intersections, driveways, etc.).
- Special Constraints:
  - Cut or fill depth constraints – for example minimum fill requirements in wet areas.
  - Preferred direction for earth movement.
  - Full Bench Cut requirement.

Softree Optimal allows you to create multiple vertical alignments in one document. This lets you to try different constraints and scenarios. To work with and compare multiple horizontal alignments, it is necessary to create multiple documents (DSN files); in this event, it is sometimes convenient to open two instances of the Location module.

An optimal vertical alignment is based on all the current design settings, e.g. horizontal alignment, sub-surface layers, template assignments, ground types, etc.

> Note (for those familiar with RoadEng®): Vertical optimization is not recommended if you have *fixed sections* defined. A change in vertical position may produce unwanted results on a fixed section. Fixing sections (if desired) can be done later once both the horizontal and vertical alignments are finalized.

Creating a New Optimized Alignment

In the following example, you will create a new optimized alignment and set up the associated standards, constraints and control points.

1. Open the Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/Hart Rd.dsnx. Press *Open*.
3. Arrange your screen as before, to look like the Figure 3-2. You may need to arrange your visible windows by selecting the *View* tab | *Tile Vertically*. Ensure re-cost is set to *Auto* as per steps in Chapter 3 above.

It is possible to optimize the current alignment. However, in this example, we will create a new vertical alignment so that we can compare it with our initial alignment after optimization.

4. In the *Corridor* tab, press the *Add* button, select *Add Vertical Alignment* to open the *Vertical Optimization Options* dialogue box shown below.

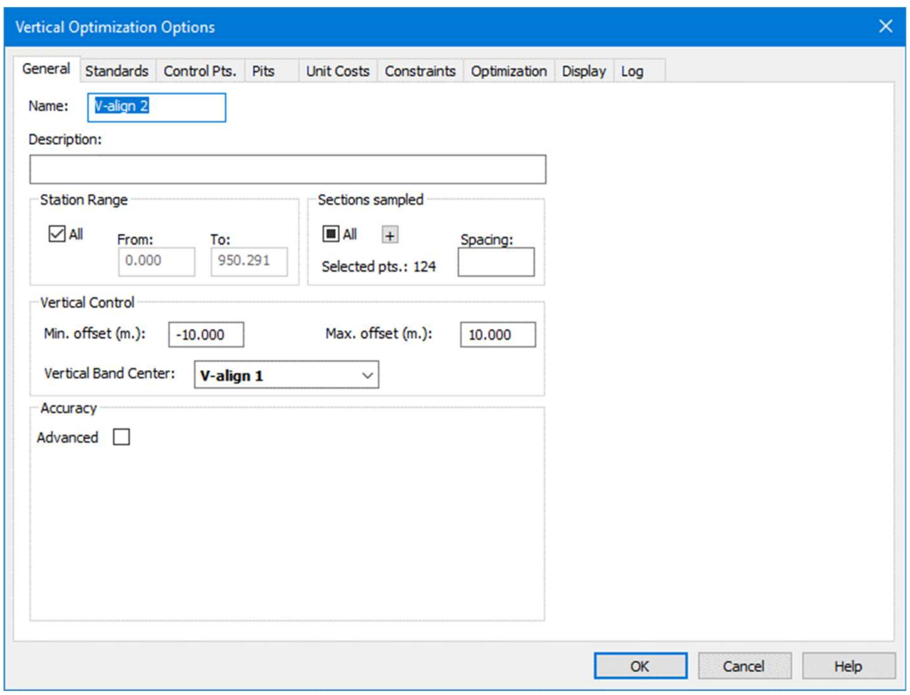


Figure 4-1: Starting a New Alignment

A *New* optimized alignment copies options from the selected alignment. In this case, the *Pits* (see previous exercise) will be set up already. The *Costs* are shared by all vertical alignments (see previous exercise for details).

In the next few steps, we will examine options that control the vertical alignment optimization that have not been discussed above.

General Options

The *General* tab in the *Vertical Optimization Options* dialogue box allows you to control the station range, section spacing and vertical accuracy.

Name - Name of the alignment object here (maximum 15 characters).

Description – Optional description of the alignment here.

Station Range - This area allows you to select the range of sections to be considered.

Note: ".." in *From* is the beginning of the alignment, similarly a ".." in the *To* field is the end of the alignment.

Sections sampled - This area allows you to choose the section points to be included in the optimization. Clicking on the  button will allow you to choose specific point types using the *Point Type Selection* dialogue and *Report Point Properties*. The *Selected points* specifies how many cross sections will be calculated.

Equal spaced sections defined by the *Spacing* field will be added to those defined by the *Point Type Selection* dialogue.

Note: The larger the number of sections, the more accurate the optimization and the longer the process will take.

Vertical Control - This section allows the user to control the vertical extents (upper and lower bounds) and accuracy of the optimization in the vertical direction.

> *Min. and Max. Offset* - These offsets are measured relative to the current vertical alignment (L-line). If there is no vertical alignment, then the offsets are measured from ground.

Accuracy Advanced – Set this checkbox to display the accuracy slider. This control allows the user to select the horizontal and vertical accuracy (from low to high).

Note: The higher the accuracy the more accurate the optimization and the longer the process will take. However, the resolution time is more dependent on the number of sections.

Figure 4-2: *General Options* Dialogue Box Fields

5. Enter the parameters as shown in Figure 4-3, below.

    a. Change the *Name* to "Trial 1" and *Description* to "K=30".

    b. In the *Sections* area, uncheck *All* and enter 5.0 in the *Spacing* field. Type <tab> to move to the next field – this will update the point count.

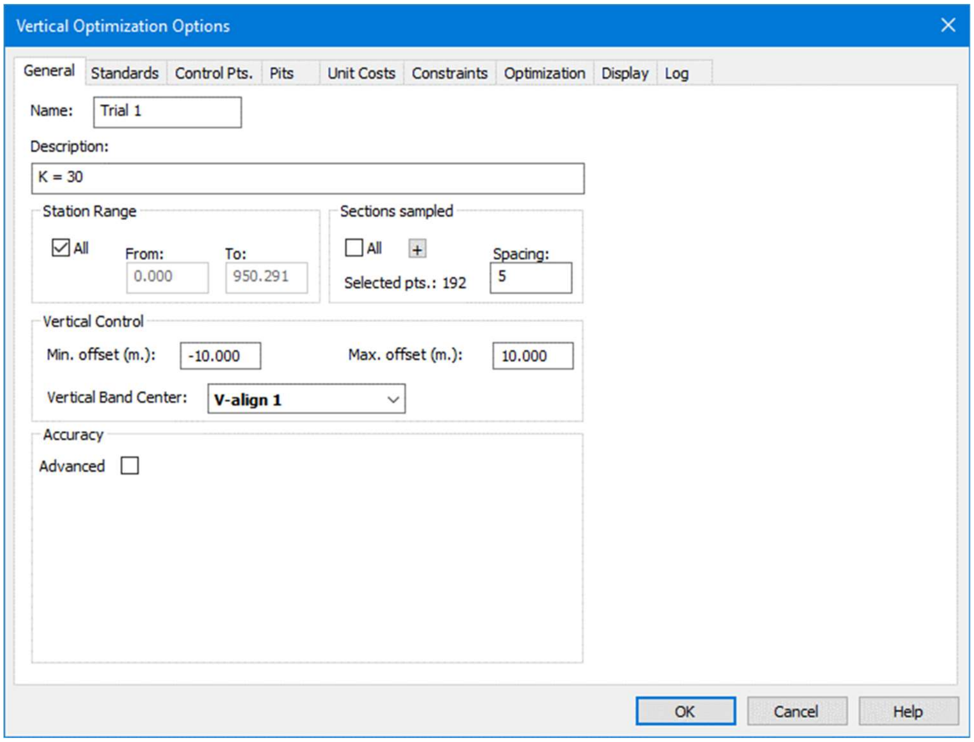


Figure 4-3: *Vertical Optimization Options* General Options

5.0 m is the value suggested by the accurate costing procedure (previous exercise); now you should see 192 *selected* cross sections to be calculated.

c. We will keep the 10.0 m vertical *offsets*.

Standards Tab

Softree Optimal allows you to control grades and vertical curvatures.

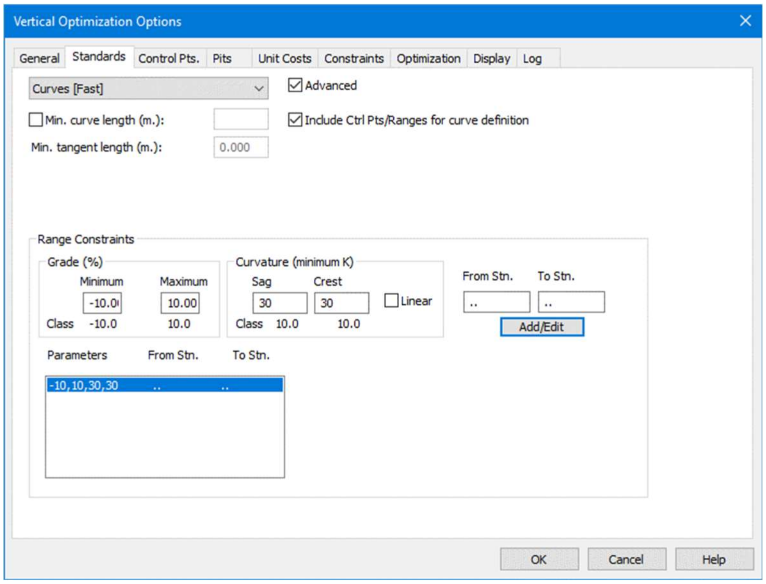
6. Click on the *Standards* tab.

In this first trial, we will use the default *Curves [Fast] Alignment Specification*. This will generate short vertical curves with no tangents between them. As the name suggests, this will solve quickly; we will examine other options later.

7. Enter the parameters as shown in Figura 4-4 below:

   a. In the *Curvature* area enter minimum *K* values of 30 for both *Sag* and *Crest*.

   b. Press *Add/Edit* (note: the values appear in the *Parameters* list only after you do this).



Grade % - Enter the minimum and maximum grade values in %.

Curvature (K) - This area allows you to set curvature constraints.

Linear - If selected, the alignment will be constrained to be a straight line (no vertical curve) over the selected range.

Sag, Crest. - If not linear, the alignment will be constrained to be greater than the specified K values over the selected range.

Figure 4-4: *Standards Tab*, for Curve and Grade Constraints

You have now applied the default grades (+/-10%, extracted from the *Road Class Parameters*) and K=30 (design speed of approximately 80 km/h) to the entire alignment. It is possible, however, to divide the alignment into intervals and set different Grade/K constraints for each interval.

Note: ".." in *From Stn.* is the beginning of the alignment, similarly ".." in the *To Stn.* field is the end of the alignment.

Control Points Tab

8. Click on the *Control Pts*. tab.

Control points allow you to set the elevation and/or grade at specific points along the alignment. In this example (a road re-alignment) it is important that the start and end of the alignment match the existing road. The human engineered alignment provided meets this requirement, so you only need to tell the optimizer to match the existing alignment at each end.

9. Define a control point at the start of the alignment:

   a. Press the *Add* button at the bottom of the screen to add a new control point.

   b. Select *Start of alignment* and press *OK*.

The *Elevation* (361.057m) has been automatically extracted from the existing alignment.

   c. Check *Enable Grade control*.

   d. Then, press the *Get from Alignment* button to match the initial grade (-2.49%).

This will add a control point, forcing the optimized alignment to match the existing vertical alignment at station 0.0.

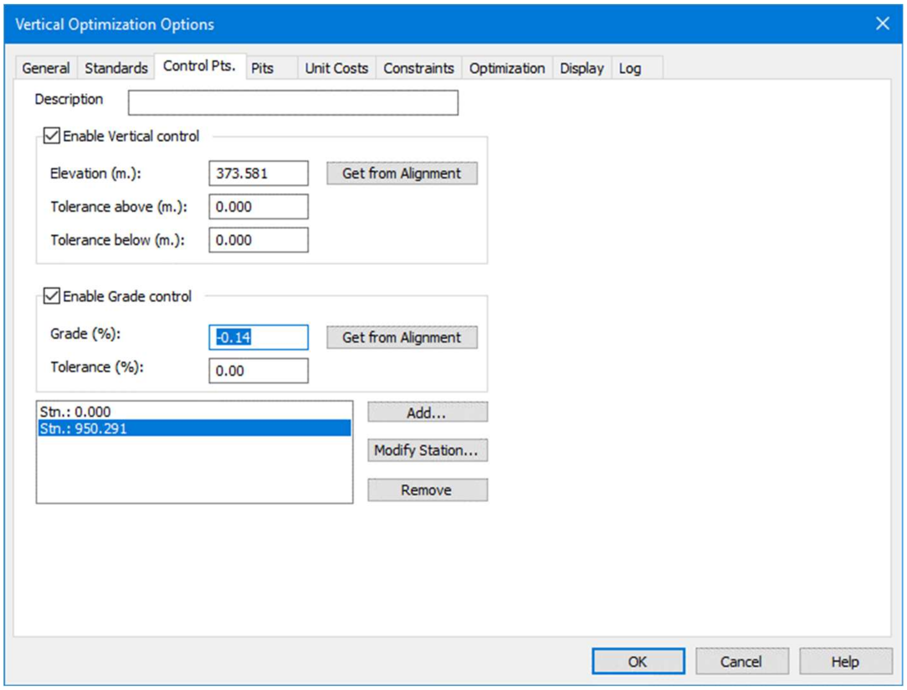


Figure 4-5: *Control Points*

10. Similarly, define a control point at the end of the alignment (see figure above).

> Note: There is a *Tolerance* field available for both vertical and horizontal control points. If possible, looser tolerances allow the optimizer more freedom to minimize costs. For example, a culvert may require a minimum cover depth, but higher alignments are OK; alignment will never drop below *Elevation – Tolerance*.

Pits, Costs and Constraints

Pits and *Costs* have already been defined (see previous exercises) and we will not be using the *Constraints* in this exercise.

11. Press the *OK* button at the bottom to exit the *Vertical Optimization Options* dialogue.

You will see the new alignment at the top of the list as shown in the figure below:

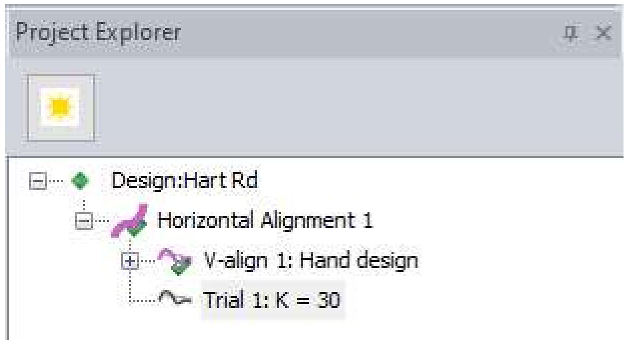


Figure 4-6 - *Alignment Options*

Display of the Vertical Band

We have constrained the alignment vertically using control points; we have also constrained the offset from the current alignment to be less than 10.0m. You can display these constraints graphically:

12. Maximize the Profile window

13. Display the *vertical band* in the profile window:

    a. In the *Project Explorer*, click the ⊞ button beside our new **Trial 1** alignment to expand the tree.

    b. Select the *Constraints* branch.

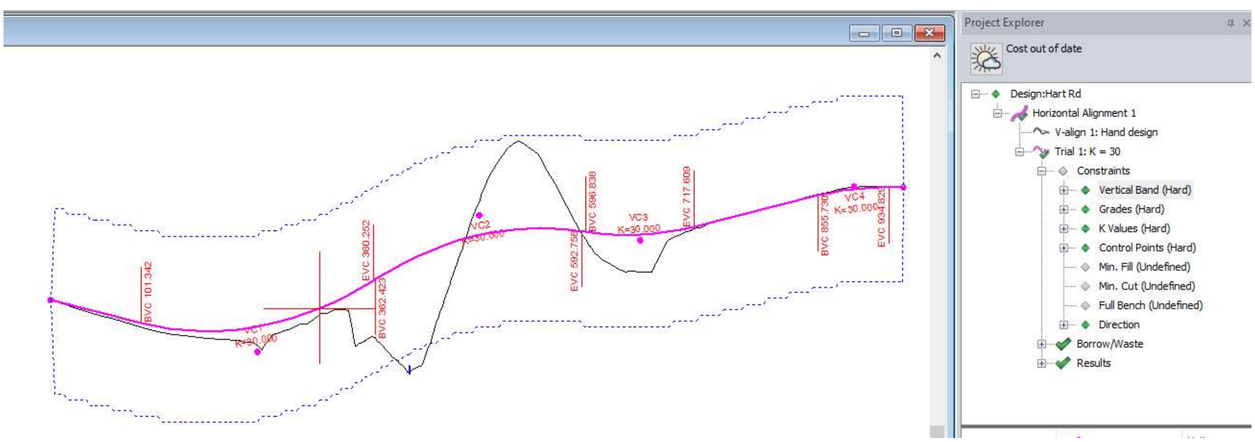


Figure 4-7: *Graphical Display* of the Vertical Band

Calculation of the Optimal Vertical Alignment

Now that the options have been defined, you can calculate an optimal vertical alignment.

14. With Trial 1 selected, right-click, select *Vertical Optimization*, press the *Process* button.

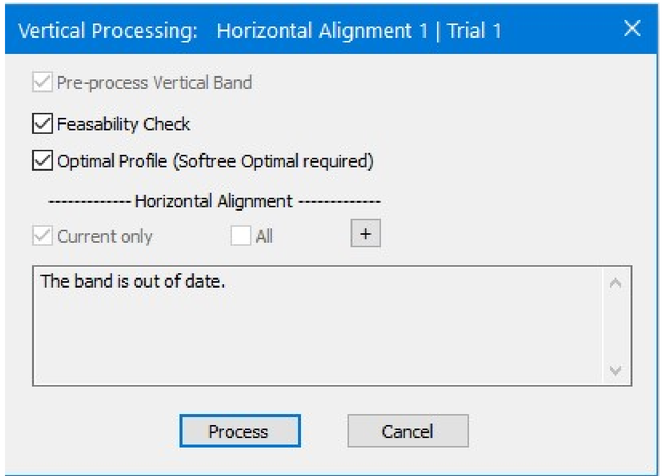


Figure 4-8: *Process Control* Dialogue Box

You will be prompted with the *Process Control* dialogue. This dialogue allows you to review the specifications you have entered for the road by selecting items in the tree control. It also gives you a choice of four actions:

- *Pre-Process*: this process calculates all the necessary cross-sections. It is a pre-requisite to Optimal Profile and Quick Profile, but can also be done on its own.
- *Feasibility Check*: check that the constraints are geometrically feasible same as above except that cross sections inside the vertical extents are calculated (pre-process) to determine the true *vertical band* (sections that fall off the surface model are discarded).
- *Optimal Profile*: generate a vertical alignment with minimum cost. Cross sections inside the vertical extents must be calculated (pre-process) first. A valid Softree Optimal license is required to use this functionality.

For larger projects, the *Optimal Profile* process can take a long time to complete, even the *pre-process* calculation of cross sections can be time consuming. To avoid wasting time, it is worth doing a *Quick Feasibility* test first.

15. Choose the *Feasibility check* action. Press the *Process* button.

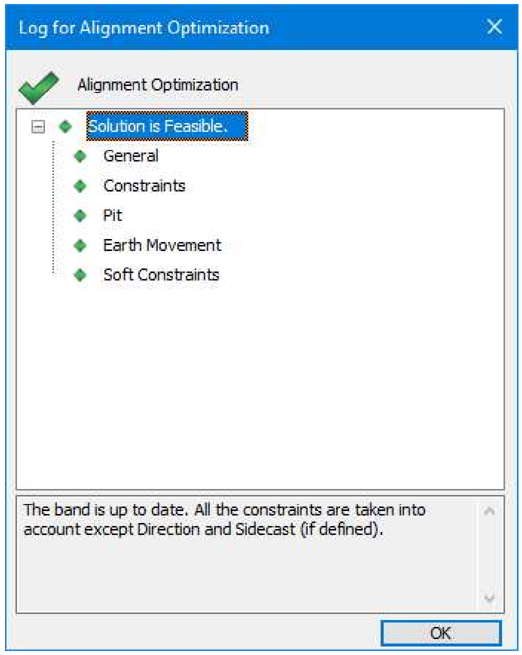


Figure 4-9: *A Vertical Alignment* Matching Your Specifications is Possible

Note: If a feasibility test fails, it is usually because a vertical alignment with specified grades and curvatures will not fit within the *vertical band* you have defined by the current alignment and the vertical extents.

16. Repeat the step above, but this time choose the *Optimal Profile* action. Press *Process*.

At the end of the optimization, a dialogue box appears summarizing the status of the optimization. This information can also be accessed later through the *Log* tab in the *Vertical Optimization Options* dialogue box.

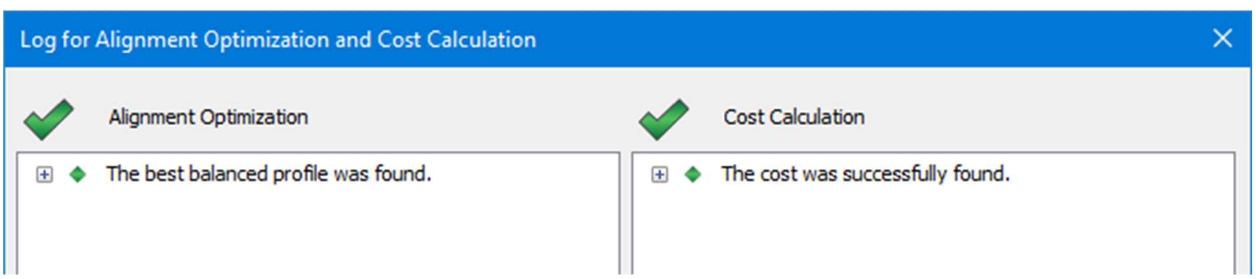


Figure 4-10: *Final Log, Errors and Warnings* Will Be Reported Here

Optimization is a three-step process:

- *Pre-process* (calculation cross sections at sampled stations)
- *Alignment optimization* (using the settings defined above)
- *Cost calculation* (using the *spacing* set in the *Re-Cost* dialogue box)

> **Note:** The *Alignment optimization* always takes longer than *Cost Calculation,* so it is often wise to use a larger spacing (select fewer points) for this step.
>
> You will receive a warning if the *Cost calculation* is using fewer points than the *Alignment optimization.*

17. Press *OK* to close the log.

18. Right-click on *Trial 1* in the *Project Explorer*, select *Compare with current*.

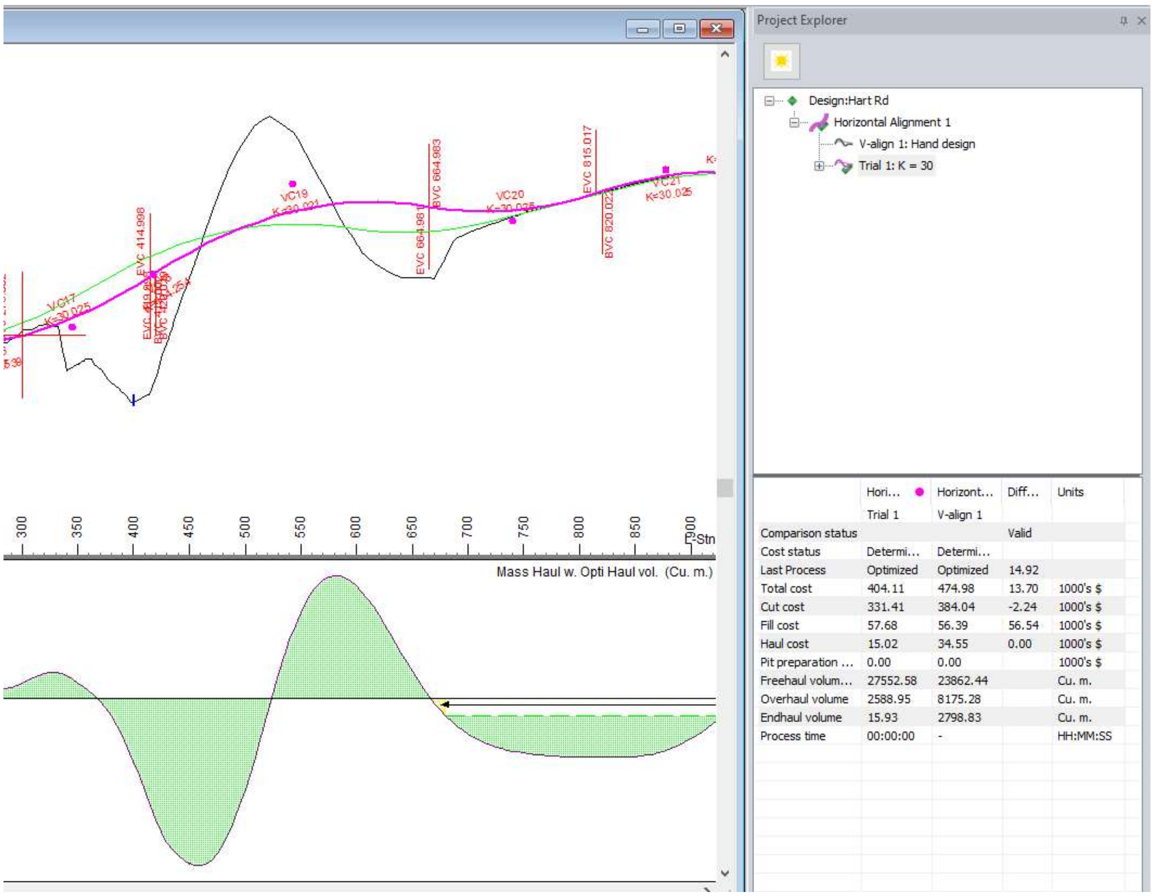


Figure 4-11: *Optimized Results*

Note that the selected optimal alignment is blue in this example (you can change the color and line-type in the options *Display* tab). Notice the optimized alignment total cost is now $404,000 compared to $475,000 in the original design. This represents a cost reduction of approximately 15%.

> **Note**: The *Mass Haul* graph at the bottom of the window applies to the *current alignment* not the new optimized alignment. Press the *Set Current* button to see all the properties of the new optimized alignment.

17. *File* | *Exit*. Do not save changes.

Evaluating Different Scenarios

Softree Optimal makes it easy to compare various alignments with different design constraints. We will now create another alignment for a higher standard of road (K = 70) and compare it with the alignment created in the example above.

1. Open the Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd optimal.dsnx**. Press *Open*.
3. If it is not already shown, press the *Project Explorer* button in the bottom navigation toolbar to open the *Project Explorer Panel* (or select *View* tab | *New Window* | *Alignment Properties*).

This is the design you should have at the end of the previous exercise; Profile labels have been turned off however (to re-enable, right-click, *Profile Options* menu, *Labels*).

4. Create a new vertical alignment and modify the curve constraints:
    a. Right-click on *Trial 1* to select it the *Alignment(s)* list (this is the alignment with the options we want to copy)
    b. Press the *New* button | *vertical alignment.*
    c. In the *General* tab, change the *Description* to "K=70".
    d. In the *Standards* tab, change minimum *Sag* and *Crest K* to 70, press *Add/Edit* to update the range.
    e. Press *OK* to save the new optimization parameters.
5. Find a new optimized alignment:
    a. Right-click on the alignment, select *Vertical Optimization*
    b. The *Optimal Profile* action should already be selected.
    c. Press *Process*. This process will take a few minutes.
    d. When complete, press *OK* to close the *log*.
6. To visualize the two optimized alignments together:
    a. Right-click on *Trial 2*:, select *Set Current* to set *Trial 2* as the current alignment.
    b. Select *Trial 1* in the *Alignment(s)* list*,* right-click *Re-Cost* to update *Trial 1*.
    c. Right-click on *Trial 1* again, select *Compare with current*

Now the information list (under the buttons) has extra columns to show *two* alignments and the differences between them.

> Note: The *Compare with current* option displays the *selected* alignment (high-lighted in list) and the *current* alignment (green dot). If you select the current alignment, it just shows the same data twice.

7. If necessary, adjust the *Project Explorer Panel* width and the column widths (with your mouse) to show the information more clearly as shown in the figure below.

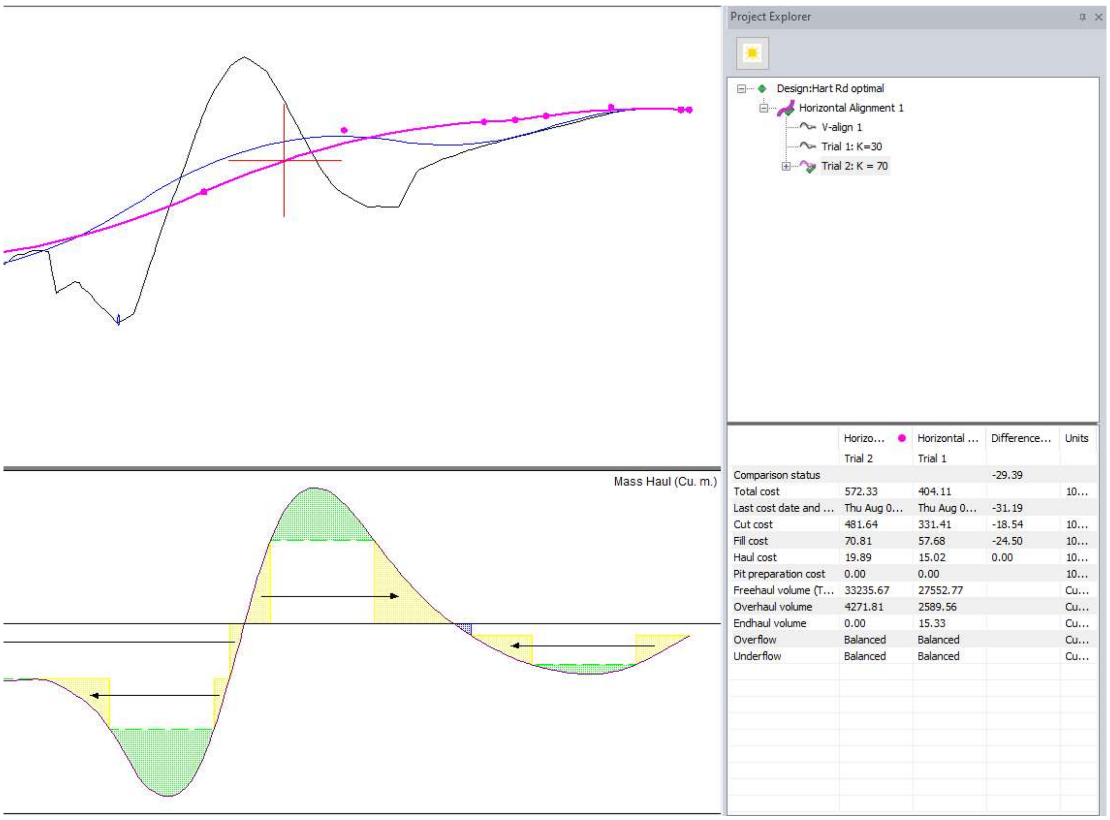


Figure 4-12: Optimized Results with K = 70 (magenta solid – current) and K = 30 (blue)

The figure above shows the two alignments. As expected, *Trial 2* with K=70 is more expensive than *Trial 1* with K=30.

8. Select each of the three alignments and notice the behavior of the Profile display and the information list in the *Project Explorer Panel*.

9. *File* button | *Exit*. Do not save changes.

Reviewing Multiple Vertical Alignments

The previous example demonstrated how to create an additional optimal alignment; we also set the new alignment current and compared it with the previous iteration. In this exercise, we will examine many of the options available for evaluating multiple vertical alignments.

The Current Alignment

The current alignment is the one that can be edited with the Location module alignment design tools. It is also the alignment that is displayed in the various windows (Section, Mass Haul, Data, etc.). Only the current alignment can be exported to external file formats (such as LandXML) for import into third party road design software.

The *Set Current* button in the optimizer panel sets the *selected* optimal alignment to the current alignment. The following example illustrates the process.

1. Open the Location Module.

2. *File* | *Open*. Select <SoftreeOptimal>/Hart Rd optimal.dsnx. Press *Open*.

3. In the *Project Explorer Panel*, expand (+) to see the vertical alignments, set *Trial 1* current by selecting it, right click, *Set Current*

> Note: the profile window now shows *Trial 1* in solid magenta while all other graphics have been washed out (faded). The Mass Haul graphic is also washed out and displays **** not currently selected **** in the top right corner.

The cross sections and volumes will be updated automatically. When complete, *Trial 1* will be the current alignment and will be shown in the profile window.

The Selected Alignment

4. To visualize the two alignments together, select *Trial 1: K=30*.

In the *Alignment(s)* list, the selected alignment is high-lighted.

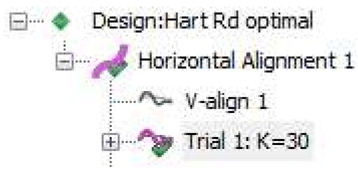


Figure 4-13: The Selected Alignment is High-Lighted

The selected alignment is shown in the Profile window alongside the V-align 1. The color and linetype are configurable.

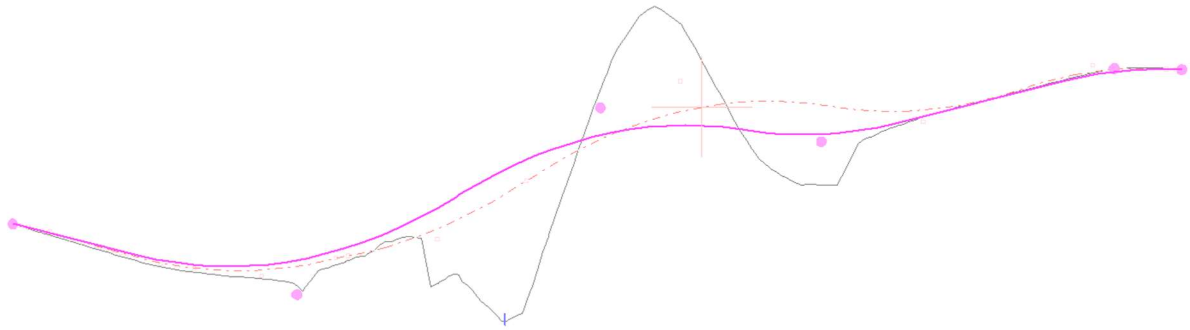


Figure 4-14: *Selected Alignment* Alongside the V-align 1

5. Change the color of *V-align 1:*

   a. Right-click on V-align 1, select *Vertical Options*

   b. Select the *Display* tab.

   c. Select the *Display Always*

   d. Press the *Format…* button. Choose a new color.

   e. Press *OK* twice to exit.

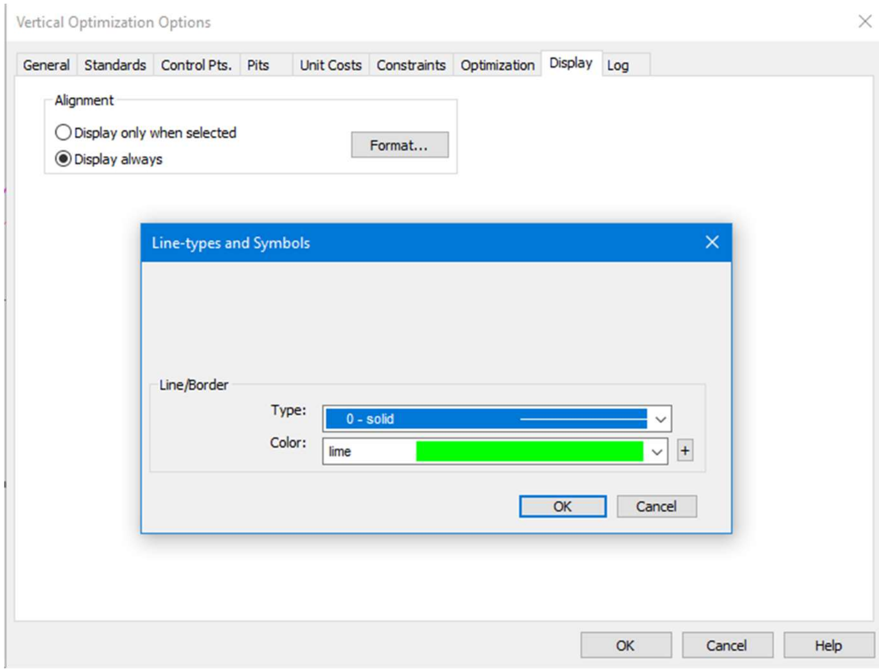


Figure 4-15: Profile *Display Options* for the Selected Alignment

> *Note*: When selected, an alignment will always appear in magenta.

6. Click on the other alignment, *Trial 1*, to see the impact of the display format change.

The Alignments Tree List

As we have seen above, the selected alignment is displayed in the Profile window. It is also possible to display other selected alignment information graphically.

7. In the *Alignments* list in the *Project Explorer Panel*, press the ⊞ button beside *Trial 1* to expand the tree.

8. Select the *Constraints* item.

Now the Profile window will show the *vertical band*, this is the elevation range where the optimizer can generate a profile (see *Vertical Control* in the *Options*, *General* tab). Note also, the control points at the ends of the alignment.

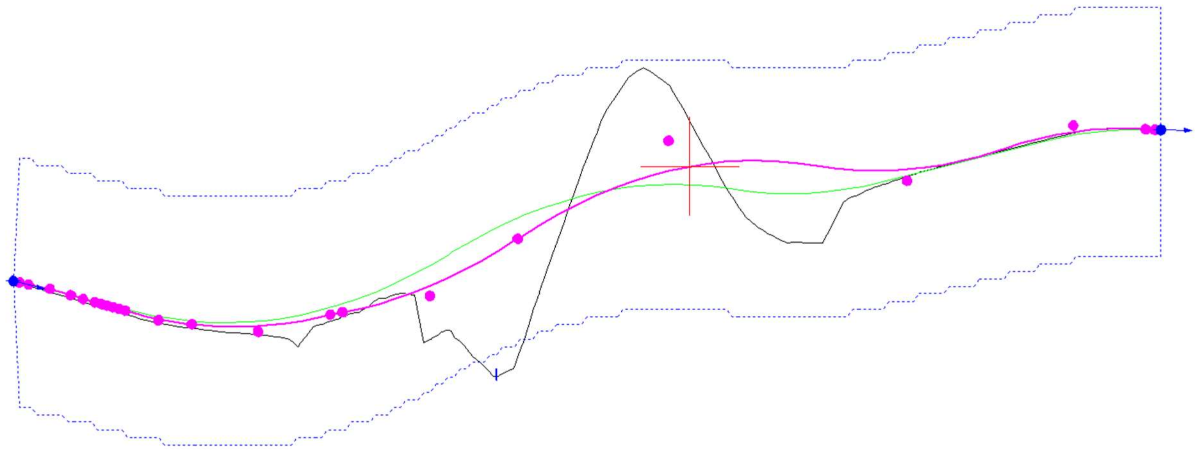


Figure 4-16: Profile Window *Showing Constraints* for The Selected Alignment

Explore the tree and see what other graphics can be displayed.

9. *File* | *Close*. Do not save changes.

5. Working with Curves

Controlling Curves

When the default (fastest) method is used for optimization (*Options* | *Standards* tab, *Curves [Fast]*), *Softree Optimal* often produces multiple short, adjacent curves (no tangent separating curves). This will be difficult to edit if you wish to make changes, it may also fail to conform to some design standards.

Softree Optimal has several alternatives that can be set in the options *Standards* tab.

Types of Curves

There are five vertical alignment types generated by *Softree Optimal*:

- *Polyline*: No curves; vertical alignment is a series of tangents. You can control the minimum tangent length and the maximum grade break between tangents.
- *Curves [Fast]*: Curves can be adjacent (back-to-back). You can control minimum curve length and curvature (K values).
- *Curves and tangents [Slow]*: Similar to above, except a tangent is inserted between curves. The minimum tangent length is the same as the minimum curve length.
- *Variable curves and tangents [Slowest]*: Similar to above, except that the minimum curve and tangent lengths are not required to be equal and curve location is more flexible.
- *User Defined*: Curves and/or VIPs (Vertical Intersection Points) defined in the current alignment are preserved. Optimal can only move existing VIPs up and down without changing curve length.

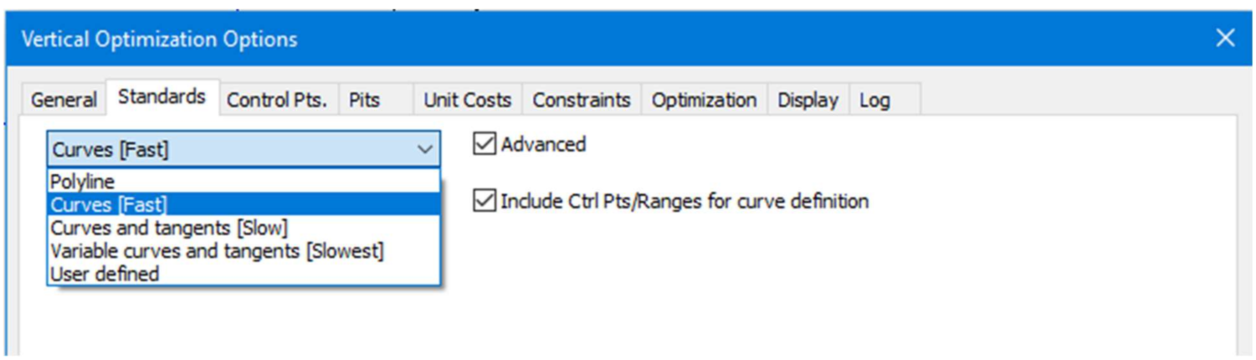


Figure 5-1: Types of Curves

What Type of Curve Should I Use?

The *Polyline* type is often used for low volume resource roads where geometric curves are not required. Like *Curves [Fast]*, this optimization is relatively quick.

Curves [Fast] (back-to-back curves) is the quickest curve type for *Softree Optimal* to solve. For this reason, we recommend that you start with this curve type while you are still experimenting with constraints and other options. If you have not yet finalized your horizontal alignment, use this curve type to quickly generate a feasible solution and cost estimate for each possible horizontal alignment.

> Note: *Curves [Fast]* is a good starting point for many workflows; it will give you a qualitative profile and the lowest possible cost. Keep this alignment and use it as a base line for comparison to future iterations.

The next two curve types are often used towards the end of the design cycle to generate a final vertical alignment. Because curves are separated by tangents, it is also easier to modify curves manually after optimization.

Variable curves and tangents [Slowest] is more flexible than *Curves and tangents [Slow]*. You can define the minimum tangent length to be different from the minimum curve length (if required by standards). In addition, *Softree Optimal* has more freedom to choose where to start or end a curve (see curve *base length* below); this can lead to a more cost-effective design.

Finally, *User defined* allows you to take an alignment and optimize the cost by changing only the elevation of the existing VIPs. We see this as a kind of hybrid human/machine process where the designer chooses the location of the curves and tangents and *Softree Optimal* fine tunes the elevations to get minimum cost.

Back-to-Back Curves

Curves [Fast]

This first example will look at the *Curves [Fast]* option (back to back curves with no tangents) used in the previous example, but with a well-defined curve length.

1. Open the Location module.
2. *File | Open*. Select <SoftreeOptimal>/**Hart Rd optimal.dsnx**. Press *Open*.
3. Make a copy of *Trial 1* and modify the *Standards*:
    a. In the *Alignments* list, select *Trial 1*, right click, *New Vertical Alignment*
    b. Change the *Description* to "K=30, L=50".
    c. Select the *Standards* tab and set the *Minimum Curve Length* to 50.

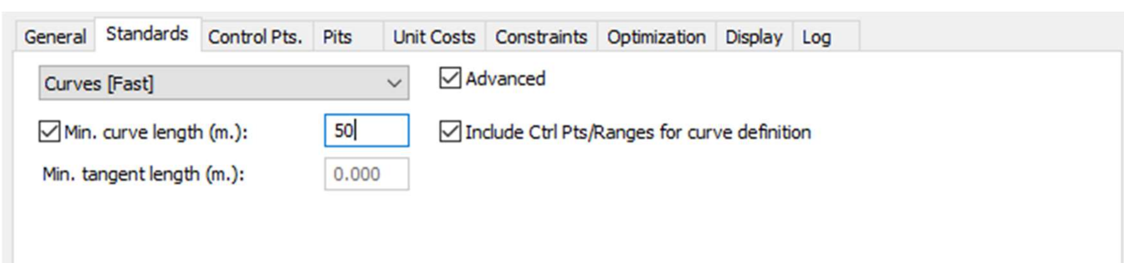


Figure 5-2: *Options, Standards* tab with Minimum Curve Length Defined

    d. Press *OK* to close the modified options (nothing else should be changed).

If *Minimum Curve Length* is not checked (the default), a curve or tangent will be created between all sampled section points (defined in the *Options dialog, General* tab, *Sections* area). Adjacent curves with the same K factor will be combined so the actual number of curves is much smaller than the number of points.

If *Minimum curve length* is checked, you need to enter a curve length that is *longer* than the point spacing. In this case, most curve (or tangent) lengths will be greater than or equal to this value – the length of road is divided up into equal length segments. However, if *Include Ctrl Pts/Ranges for curve definition* is checked, then some curves may be shorter than the minimum because of the requirement to put a segment boundary on these special points. In this example, the control points are at the ends and the grade and curvature constraints are constant along the alignment, so this check box will have no effect.

> Note: You will be notified of a conflict, if base curve length is less than the point spacing defined in the *General* tab.

4. Do a feasibility check:

    a. Right click on the new *Trial 2* alignment and select *Vertical Optimization,* only select *Feasibility Check*. Press *Process*.

    b. The alignment is feasible. Press *OK* to close the *Log* message.

> Note: You will avoid a lot of waiting around for Pre-Process and Optimization calculations on impossible designs if you get in the habit of checking feasibility first. Many of the examples do not include this step for brevity.

5. Optimize the *Trial 2* alignment:

    a. Right click on the *Trial 2* alignment and select *Vertical Optimization*.

    b. The *Optimal Profile* action should be selected (if it is disabled your *Softree Optimal* function group is not enabled).

    c. Press *Process* (and wait for the calculations to conclude).

    d. Press *OK* to close the *Log* report.

6. Compare *Trial 2* and *Trial 1*:

    a. (*Trial 2* should still be selected) right-click, *Set Current*

    b. Select *Trial 1* and *Re-Cost* if necessary.

    c. Right click, *Compare with current* check box

These solutions are very similar; the total cost difference is just over 1% and the selected *Trial 1* profile (solid line) is almost coincident with the current *Trial 2* profile (dash dot).

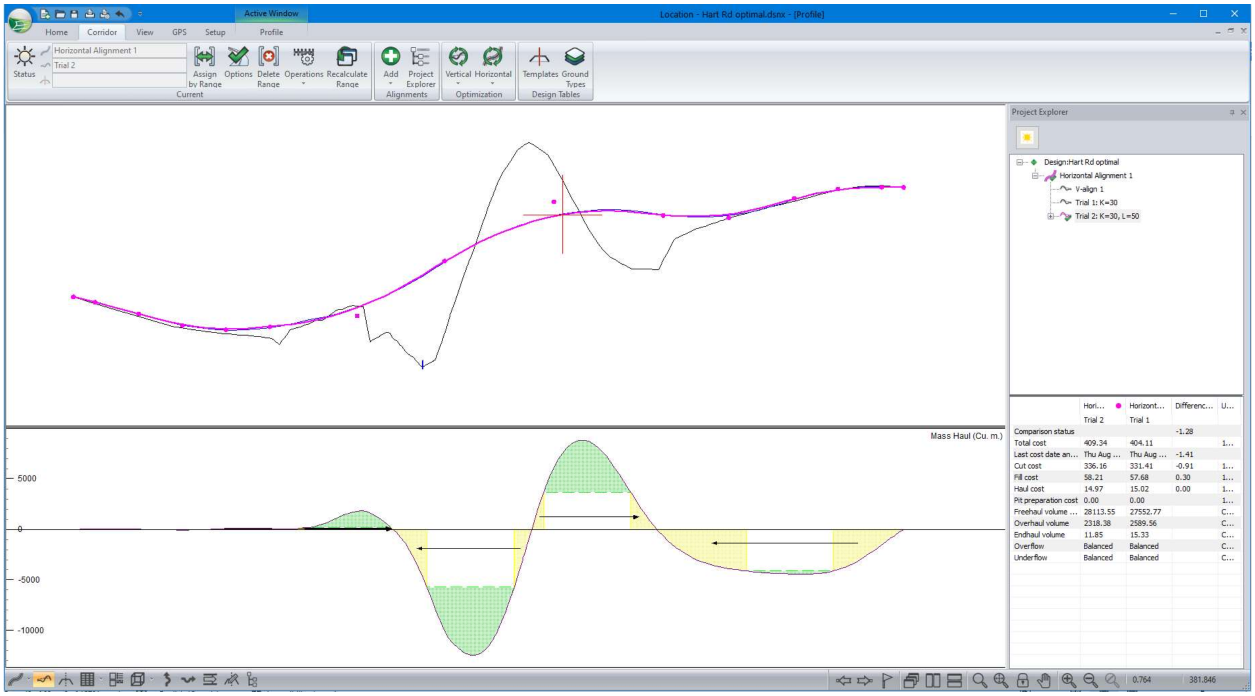


Figure 5-3: Comparing the Small Difference Between Alignments Generated with Short Back-to-Back Curves and 50m Back to Back Curves

The curves generated by Optimal are displayed in the Profile window (although we haven't displayed all the applicable labels). Curve information can also be viewed in a data window.

7. *View* | *New Window* | Select *Data* from dropdown or press the *Data* window shortcut from the bottom navigation toolbar.

We will need to configure the reporting columns.

8. Right-click, select *Data Options…*.

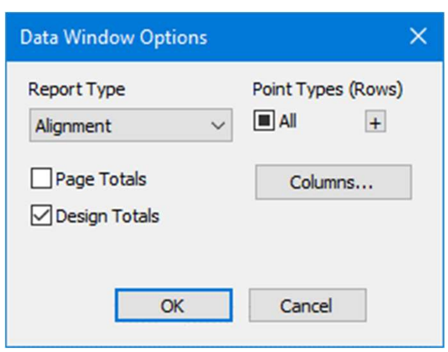


Figure 5-4 : Data Window Options

9. Press the + for Point Types (Rows)

10. Deselect all Point Types Selected. Double click on *BVC/EVC Points*. It should now have a check mark next to it. Press *OK* to close.

11. Select *Columns…*, add:

- L-Stn (*L-Line* folder)
- Grade (*L-Line* folder)
- K (*Curves* folder)
- HD (*L-Line* folder)

L-Stn m.	Grade %	K	HD m.
0.002			
49.998	p -2.6	-301.545	49.996
50.002	-2.7		0.004
99.998	p -2.6	5123.239	49.996
100.002	-2.6		0.004
149.998	p -1.8	30.000	49.996
150.002	-1.0		0.004
199.998	p -0.2	30.679	49.996
200.002	0.7		0.004
249.998	p 1.0	80.901	49.996
250.002	1.3		0.004
399.998	p 3.8	30.002	149.996
400.002	6.3		0.004
449.998	p 5.8	-58.179	49.996
450.002	5.4		0.004
649.998	p 2.1	-30.002	199.996
650.002	-1.3		0.004
699.998	p -0.8	56.237	49.996
700.002	-0.4		0.004
799.998	p 1.3	30.001	99.996
800.002	3.0		0.004
849.998	p 2.5	-59.440	49.996
850.002	2.1		0.004
899.998	p 1.3	-30.000	49.996
900.002	0.5		0.004
950.289	p 0.2	-83.165	50.287
Cum. Tot.			

Figure 5-5: Curves Generated Using Back to Back Curve with Minimum Length Set to 50m

Notice that most of the curves are 50m in length (almost – a small tangent has been inserted between curves to accommodate the Location module's data structure). Some curve lengths are multiples of the shortest (consecutive curves with the same K factor have been combined). The last tangent/curve length (0.294m in this case) is less than the minimum to deal with the fact that the total alignment length is not a multiple of 50m.

12. Select *Trial 1* and push the *Set Current* button.

Notice that now you see many more curves in the Data window. Many are roughly 5.0m; this is the sample spacing we chose.

13. *File* | *Close*. Do not save changes.

Curves with Tangents

In this section, we will examine the two curve types that include tangents between vertical curves.

1. Open the Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd curves.dsnx**. Press *Open*.

The current alignment when you open this project is *Trial 2*, the 50m back-to-back curves vertical alignment created in the previous exercise.

Trial 3 and *Trial 4* have been created for you and optimized to save you time. The process used to create these alignments is very similar to the previous exercise and you should have no problem doing this for yourself at the end of this exercise.

Curves and tangents [Slow]

3. Set *Trial 3* current, with *Trial 2* in the Profile background:
    c. Select *Trial 3*.
    d. Right click, *Set Current*.
    e. Select *Trial 2*.

This alignment was created with the *Curves and tangents [Slow]* curve type. As you can see in the figure below, there are fewer curves. Also, note that the there is little elevation difference from *Trial 2* (back-to-back curves); therefore, it is reasonable to use the quick, back to back solution as a first iteration and cost estimate.

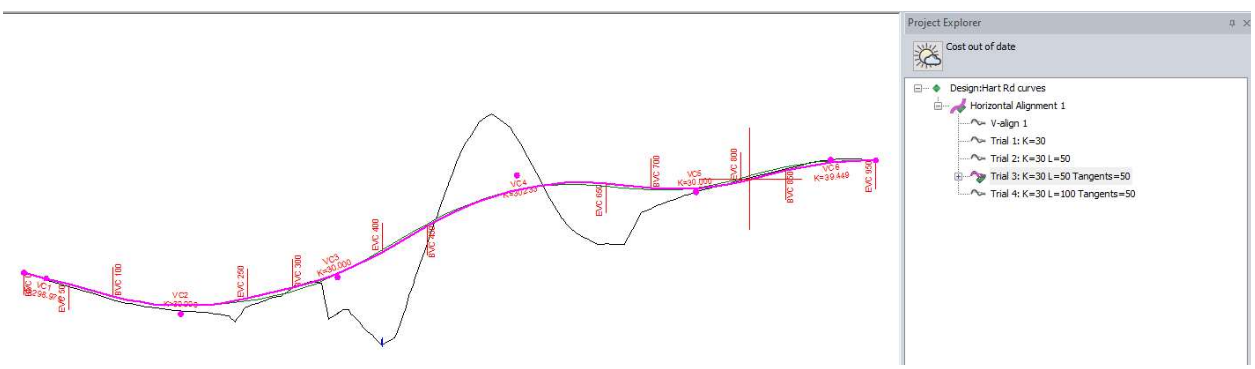


Figure 5-6: *Profile Window* Showing Both Trial 2 (solid line) and Trial 3 (dash dot line)

4. Open the *Standards* options for *Trial 3*
    a. Select *Trial 3* then right click the Vertical *Options*
    b. Select the *Standards* tab.

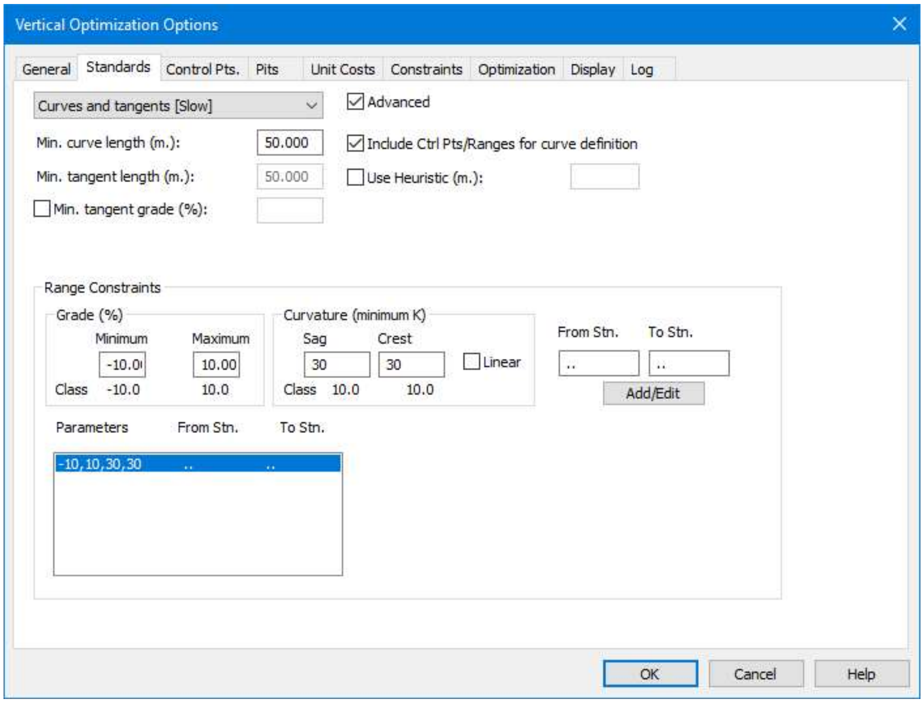


Figure 5-7: Curves and Tangents [Slow] Options

Note that the *Min. tangent length* is equal to the *Min. curve length,* but not editable.

5. *Cancel* to close Options.

Variable Curves and Tangents [Slowest]

6. Set *Trial 4* current, with *Trial 2* in the Profile background

   a. Select *Trial 4*

   b. Right click, *Set Current*.

   c. Select *Trial 2*.

This alignment was created with the *Variable curves and tangents [Slowest]* curve type. There are fewer curves still, but it is still a close match to *Trial 2*.

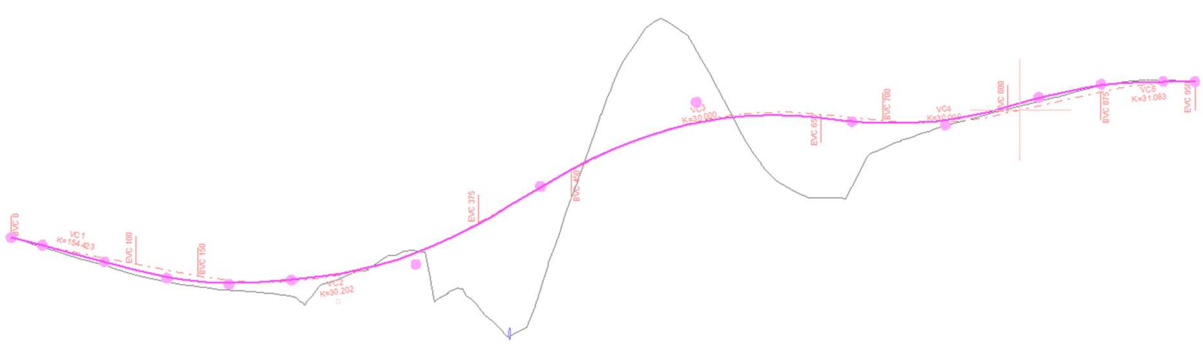


Figure 5-8: Profile Window Showing Trial 4, 100m Curves and 50m Tangents

7. Open the Vertical Options | Standards tab for Trial 4.

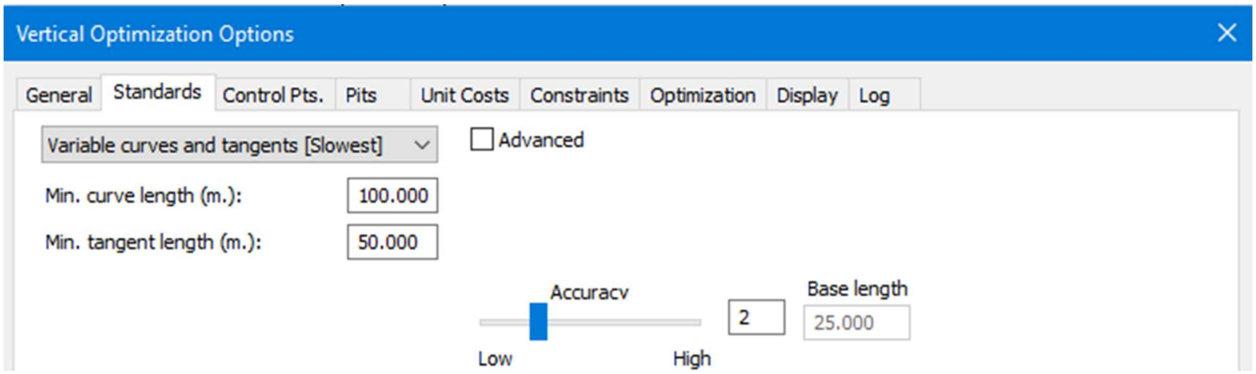


Figure 5-9: Variable Curves and Tangents [Slowest] Options

Note that the *Min. tangent length* is not equal to the *Min. curve length* and you can change it. Also, note the new value called *Base length*.

For this type of curve, *Softree Optimal* divides the road into segments of *Base length*. Curves will start or end on segment boundaries; tangents and curves will be multiples of *Base length* greater than or equal to the minimum values specified. In this example, the second curve starts at station 150 and ends at station 375; this curve would not be possible in *Trial 2* or *Trial 3*.

Base length is calculated from the minimum curve and tangent lengths and your choice of *Accuracy*. If *Base Length* is too small (less than your sample spacing), you will generate a conflict:

8. Try a very small base length:

   a. Set *Min. tangent length* to 20.0m.

   b. Slide the *Accuracy* up to *high* (5).

   c. Press the *Conflict* button that appears in the lower left of the Options dialogue box.

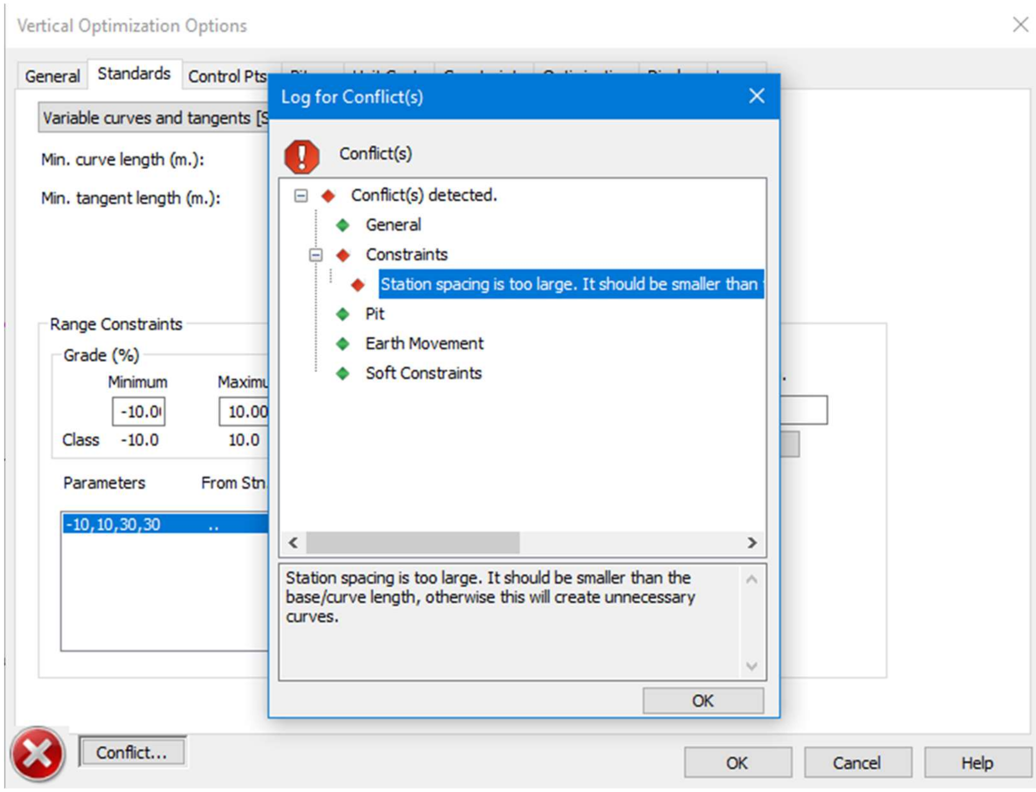


Figure 5-10: Conflict Caused by Curve Base Length Shorter than Sample Spacing

d. Press *OK* to close the conflict log.

Note: Many conflicting constraints and specification will be detected automatically and reported in the conflict log. For example, defining a Control Pt. with a required grade greater than your Standards maximum will generate a conflict.

9. Try entering a few different parameters and see what you get.

In summary, by making the *Base length* smaller (higher *Accuracy*), you can make the curves more granular and therefore more flexible. While this provides the best alignment solution of all the curve types, it is also the slowest.

10. Press *Cancel* to exit the dialogue.

The information list has been set up to show the optimization time (*Alignment process time*).

Item	5) Trial 4	Units
Total cost	419.15	1000's $
Cut cost	343.58	1000's $
Fill cost	60.22	1000's $
Haul cost	15.35	1000's $
Pit preparation cost	0.00	1000's $
Freehaul volume (…	29452.01	Cu. m.
Overhaul volume	2014.33	Cu. m.
Endhaul volume	3.69	Cu. m.
Last alignment dat…	Wed Sep 06 …	
Process time	54.326	seconds

Figure 5-11: *Optimization Time* (Alignment Process Time) May Be Added to the Information List

11. Select the alignments one at a time and watch *Alignment process time* in the list.

The times for the three optimizations, *on the author's laptop*, are shown below:

Trial 2	Curves [Fast]	3.52	seconds
Trial 3	Curves and tangents [Slow]	24.79	seconds
Trial 4	Variable curves and tangents [Slowest]	54.33	Seconds

Table 5-1: Comparison of Optimization Times for Different Curve Types

Note that these times do not include the pre-process time which is roughly constant at 30 seconds for all three.

Note: it is possible to create a large problem that will take days to solve or that will cause the solver to run out of memory.

At this point you may want to try re-optimizing to see how long your computer takes. You may also want to experiment with some of the curve parameters we have discussed.

12. *File* | *Exit*. Do not save changes.

6. The Optimal Haul

When *Softree Optimal* calculates the cost of an alignment, it determines the lowest cost prescription (or recipe) for moving material. We call this the *Optimal Haul* (or sometimes *OptiHaul*). The *Optimal Haul* is a detailed description of how material is moved along the alignment, and from/to borrow/waste pits.

Mass Haul Diagram

The *Mass Haul* diagram is a traditional and valuable tool for road design. Some of the quantities calculated with the *Optimal Haul* are automatically included in the mass haul diagram.

1. Open the Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd optimal.dsnx.** Press *Open*.

Pits Display

The current alignment, *V-align 1*, has several pits defined. These pits were used during the calculation of *Optimal Haul* (calculated automatically on open) and the mass haul diagram shows these quantities as vertical lines in the graphic.

3. In the *Project Explorer* panel, expand the tree for *V-Align 1* and select the *Pits* branch. As shown below:

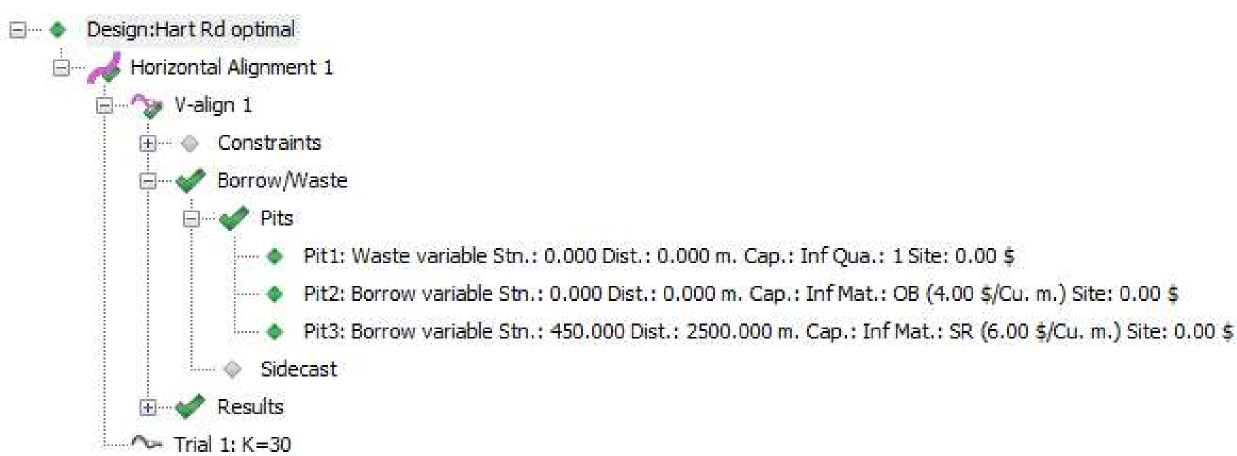


Figure 6-1: Pits Display

This will display the pit locations in the Profile window.

- denotes a waste pit.
- denotes a borrow pit.
- denotes both a waste and borrow pit.

4. Turn on the axis labels in the Profile window (optional)

a. Right click in the Profile window and select menu *Profile Options*.

b. Set the *Grid* check box (lower left).

c. Press *OK* to close *Profile Window Options*.

Your screen should look similar to the figure below. (You may need to *Re-Cost* if Mass Haul is out of date)

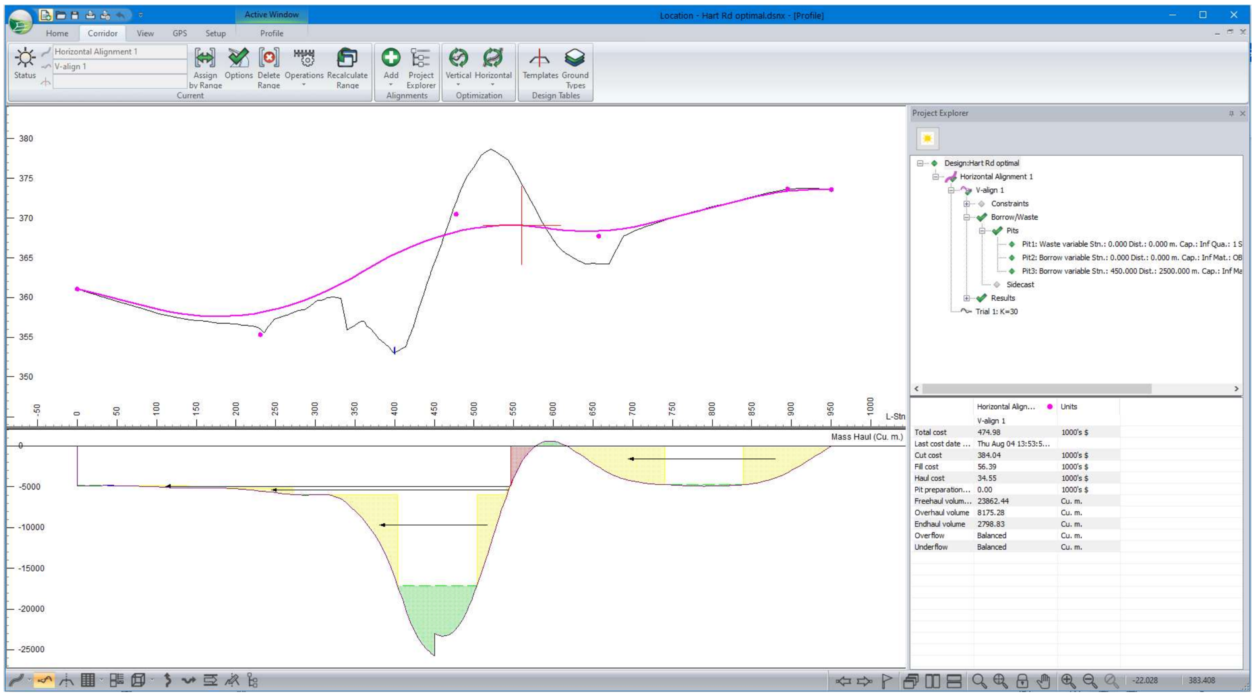


Figure 6-2: Assigned Pits Shown in Profile and Mass Haul

5. Right-click *Vertical Options…* and select the *Pits* tab.

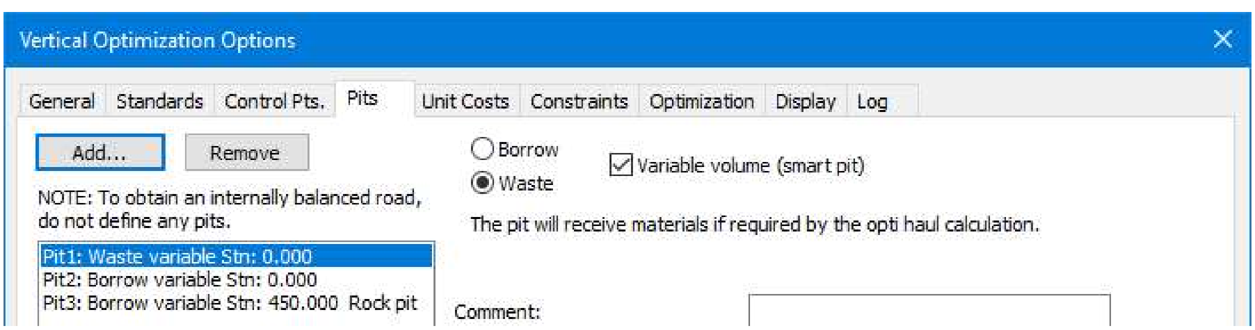


Figure 6-3: Pits for the Selected Alignment

We looked at this design in Chapter 4 and found that we were short of rock (SR) but had an excess of GR. The waste pit at station 0.0 is taking the excess GR, while the borrow pit at station 450.0 is providing the SR. The mass haul diagram reflects these two volume insertions.

6. Press *Cancel* to close the options dialog box.

Optimal Haul Diagram

The *Mass Haul* diagram does not fully expose the optimal movement prescription. It does not provide a detailed schedule of earth movement between stations and it does not handle the concept of material quality introduced in the case of multiple materials. The *Optimal Haul* diagram addresses these two deficiencies.

The *Optimal Haul* diagram illustrates material movement as determined by Softree Optimal.

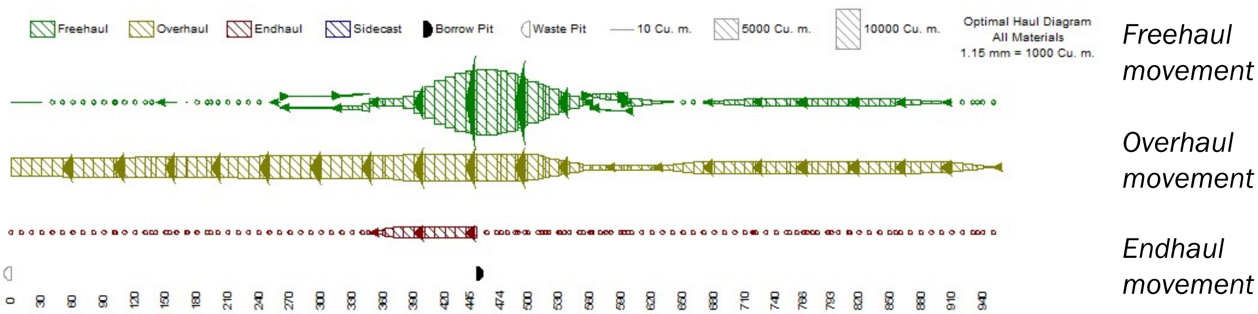


Figure 6-4: Optimal Haul Diagram

Optimal Haul Diagram Properties

- A left arrow indicates that material is moved towards the beginning of the alignment, or decreasing station number. A right arrow indicates that material is moved towards the end of the alignment, or increasing station number.
- The height of an arrow indicates how much material is being moved. By hovering over the arrows, it is possible to get the exact volumes involved. If the height of an arrow decreases from a section to the next one, this means that material has been unloaded for fill. Conversely, if the height of an arrow increases from a section to the next one, this means that material has been loaded from cut.
- There are at most three flow lines, one for *Freehaul*, one for *Overhaul*, and one for *Endhaul.* By hovering the mouse over the legends Freehaul, Overhaul, and Endhaul, it is possible to get the total volumes for each. These volumes should be equal to the values displayed in the reporting area or the Alignments panel.
- Below the Endhaul line, pits are displayed with half circles. Half right black circles represent borrow pits; half left white circles represent waste pits. For underflow and overflow, the color red is used. By hovering over the half circles, it is possible to get the volumes borrowed or wasted. By hovering over the legends *Borrow Pit* and *Waste Pit*, it is possible to get the total volumes borrowed or wasted.

Optimal Haul Diagram Example

Your screen should now display a profile and mass haul diagram.

7. Add the Optimal Haul sub-window to the Profile window.

    a. Right click in the *Profile* Window and select menu *Profile Options.*

b. Under *Sub-Windows* (right hand side) press the *Select* button to display a list of available profile sub-windows.

c. Select *Opt. Haul* and press *Add*.

Opt. Haul will be moved from *Available* to *Selected*.

d. Press *OK* to close the selection dialogue box.

e. Press *OK* again to close Profile options.

The Optimal Haul diagram now appears below the Mass Haul diagram similar to the figure below.

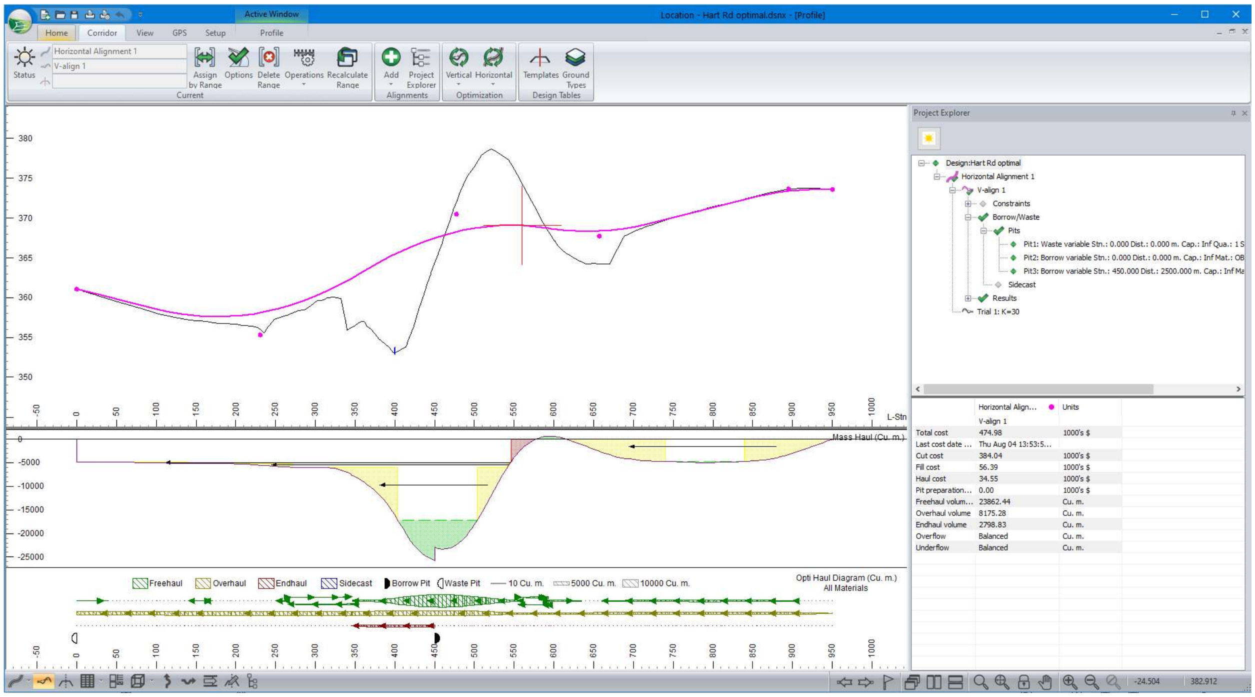


Figure 6-5: *Optimal Haul Diagram* All Materials Selected

8. Make the Optimal Haul diagram a little bigger:

a. Right click on the Optimal Haul diagram sub-window and choose menu *Optimal Haul Options.*

b. Set *Height* to 20 (as in the figure below); note the other controls available.

c. Press *OK* to accept and exit.

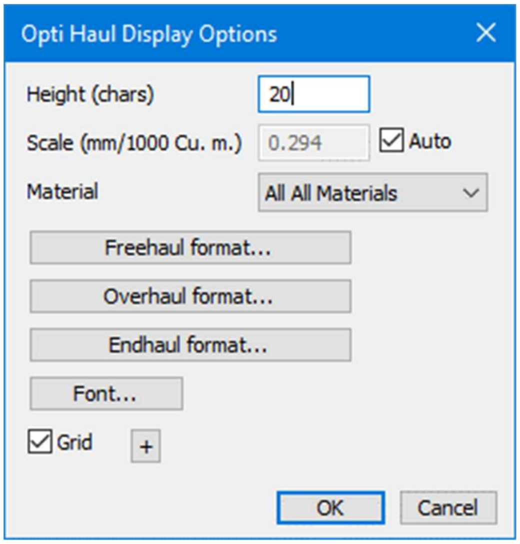


Figure 6-6: Optimal Haul Options

d. Click and drag the divider bar up to make more room for the sub-windows (if necessary).

Now let's look at some of the information available in this sub-window. First of all, you can see qualitatively where and how much material is moving. While this is similar to the Mass Haul diagram in this example, this not always the case.

You might have noticed that there is material being extracted from the pit at station 450.0 and moved a small distance along the road to the left. This is shown as *Endhaul* movement because the pit is located 2500m (dead haul distance) from the road alignment.

9. Hover tips in the Optimal Haul diagram display volumes:

    a. Hover the mouse over the *Freehaul* legend item to display materials and volumes.

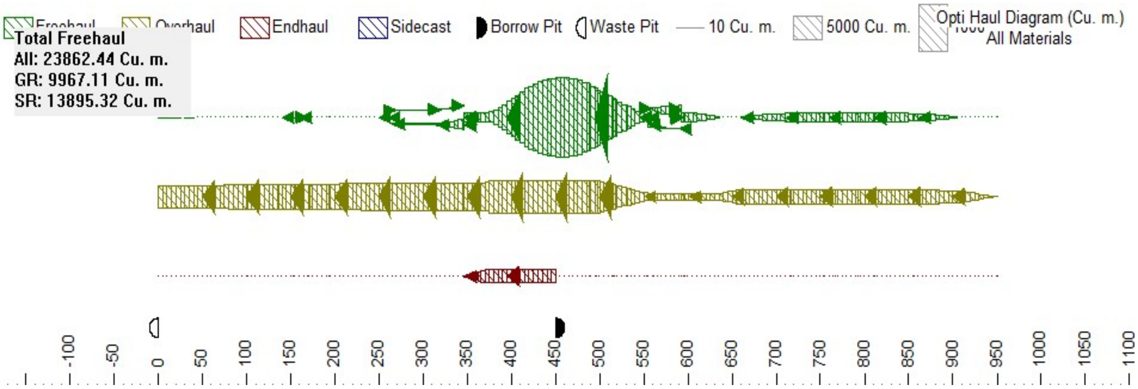


Figure 6-7: *Legend Hover Tip (Tooltip)* Displays the Total Volume of Material Moved

    b. Similarly, hover over the other legend items to see total *Overhaul*, *Endhaul*, *Sidecast*, *Borrow* and *Waste*.

    c. Hover over a movement arrow in the body of the diagram to see the volume of material moved past that station.

d. Finally, hover over the Borrow ◗ and Waste ◖ pits to see their respective quantities.

So far, we have been displaying all material in one graphic. In the next few steps, we will choose to display movement for only one material.

10. Display only gravel in the Optimal Haul diagram:

    a. Right click on the Optimal Haul diagram sub-window and choose menu *Opti Haul Options.*

    b. Choose *GR Gravel* in the *Material* list.

    c. Press *OK* to exit.

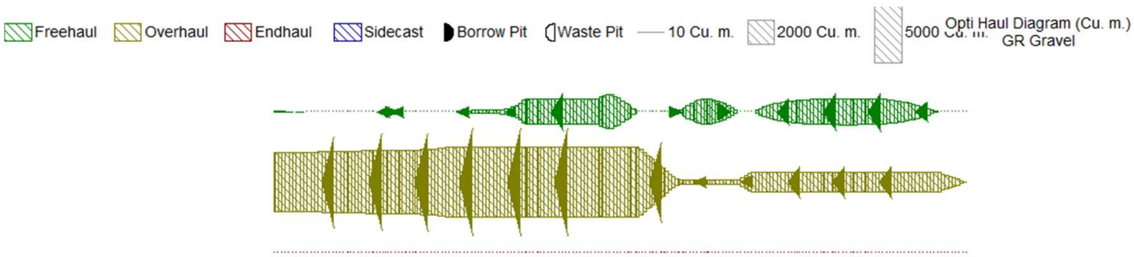


Figure 6-8: *Optimal Haul Diagram* for Gravel Only (GR)

Now the volumes reported are for gravel only. Observe that the borrow pit at station 450.0 is no longer visible; this pit is a rock (SR) pit.

11. *File* | *Exit*. Do not save changes.

Optimal Haul Export

The Optimal Haul graphic (previous exercise) and hover tips (tooltips) are useful while you are designing but you will also need to generate numeric reports. The following example will export all the information contained in the Optimal Haul diagram into a spreadsheet.

1. Open the Location module.
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd optimal haul.dsnx.** Press *Open*.
3. Expand to find *V-Align 1*, right click, *Re-Cost.*
4. Export the Optimal Haul data:

    a. Right click in the Optimal Haul diagram window and choose menu *Copy Opt Haul to Clipboard*. (Alternately, use menu *File* | *Save As* to save a *Opti Haul (*.csv*) file).

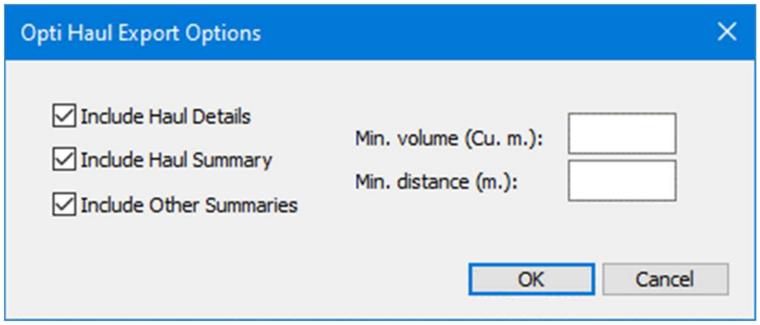


Figure 6-9: Optimal Haul Export Options

b. When prompted with the *Optimal Haul Export Options* dialogue box, select all three options as in the dialogue above.

    a. *Other Summaries* include:

        i. *Cost summary,*
        ii. *Volume summary,*
        iii. *Pit summary,*
        iv. *Movement summary.*

    b. *Haul Details* include:

        i. *Movement details,*
        ii. *Pit details.*

    c. *Haul Summary* include*:*

        i. *Detailed movement summary.*

c. Press *OK* to continue.

5. Open a spreadsheet program (such as Microsoft Excel) and *paste*.

The first few rows of the spreadsheet contain summary information. This is slightly more detailed than the information area of the alignment panel.

Cost Summary

Cost summary					
	Haul	Cut	Fill	Pit Opening	Attributes
Total	34551.89	384040.47	56386.42	0	0
GR	13717.69	68376.73	24450.16		
SR	20834.2	315663.74	31936.27		

Table 6-1: Optimal Haul Output Excerpt: *Cost Summary*

The total costs are available in the information area of the alignment panel; however, this table breaks the costs down by material. *Site Preparation* cost is the sum for all opened pits.

Volume Summary

Volume summary							
	Cut	Borrow	Underflow	Fill	Waste	Overflow	Sidecast
GR	17094.18	0	0	-12225.08	-4869.11	0	0
SR	14943.54	2798.83	0	-17742.37	0	0	0
OB	0	0	0	0	0	0	0

Table 6-2: Optimal Haul Output Excerpt: *Volume Summary*

This table reports all the categories of material sources (positive) and uses or disposal (negative). The sum of each of the materials is zero; this indicates conservation of mass.

- Cut: excavation from the road-bed.
- Borrow: material from a user defined pit.
- Underflow: material from a system defined pit of last resort.
- Fill: embankment in the road-bed.
- Waste: disposal to a user defined pit.
- Overflow: disposal to a system defined pit of last resort.
- Sidecast: disposal along the road corridor directly opposite to the excavation (not a pit).

Pit Summary

Pit summary			
	Pit1	Pit2	Pit3
Station number	0	0	450
Distance	0	0	2500
GR	-4869.11	0	0
SR	0	0	2798.83
OB	0	0	0

Table 6-3: Optimal Haul Output Excerpt: *Pit Summary*

This table contains total volumes of material extracted from pits (positive) and deposited into pits (negative). If you would like to see how the material was moved to/from the pit, scroll down to the *Pit details* section at the bottom of the spreadsheet.

Movement Summary

Movement summary						
	Cut	Pit Load	Station Unload (movement)	Pit Unload	Same Station Unload (no movement)	Sidecast (no movement)
GR	17094.18	0	-9180.25	-4869.11	-3044.82	0
SR	14943.54	2798.83	-17742.37	0	0	0
OB	0	0	0	0	0	0

Table 6-4: Optimal Haul Output Excerpt: *Movement Summary*

This table reports total volumes of material moved. Rather than define all possible movement types (pit to road, road to road, road to sidecast, etc.) we define load (positive) and unload (negative). Material is handled by earthmoving equipment; the equipment *loads* material, moves it somewhere, and *unloads* it.

Again, the sum of each of the rows is zero.

A Movement Model

In the spreadsheet follows the detailed movement information for stations (*Movement details* section) and pits (*Pit details* section). To understand this section (and the movement summary above), consider material movement as a series of six conveyor belts which move material forwards and backwards as below:

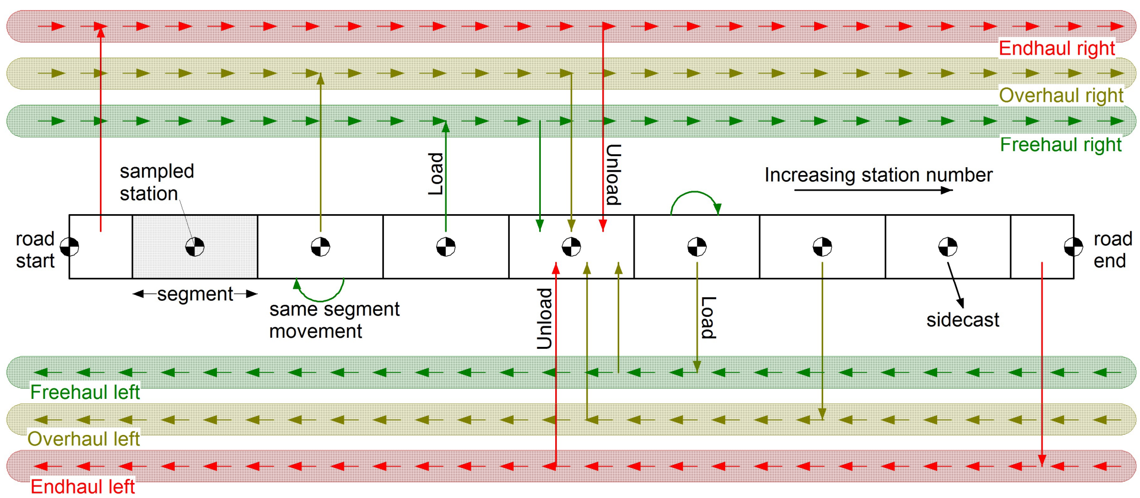


Figure 6-10: Schematic of *Material Movement* via Conveyor Belts

The *Freehaul* conveyors handle short hauls (perhaps representing bulldozers); the *Overhaul* conveyors handle medium hauls (perhaps representing scrapers); the *Endhaul* conveyors handle long hauls (perhaps representing trucks and shovels).

The optimal haul calculation works from cross-sectional *areas* at sampled stations; to generate *volumes*, it creates a *segment* for each sampled station.

Internal Movement

The schematic above includes material movements within the road corridor (we call this *internal* movement). Material excavated within a segment can be:

- Placed in the *same segment* (zero distance).
- Sidecast (zero distance).
- *Loaded* to one of the six conveyors.

The conveyor used depends on the distance and the direction the material needs to travel. Embanked material must be *unloaded* from a conveyor or come from the same segment.

External Movement

The schematic does not include external movement, but it is not hard to imagine:

- Borrow pits can *load* material to a conveyor.
- Waste pits can *unload* material from a conveyor.

Multiple Material and Balance

All excavated material (from pit or road-bed) must be placed somewhere (to road-bed, pit or sidecast); the quantities must balance. This is true for each of the materials individually.

Detailed Movement Summary

The spreadsheet finishes by a detailed movement summary, which compounds the information contained in the movement model, in a more usable format.

Detailed movement summary									
Material	Vol moved	Cut Stn1	Cut Stn2	Fill Stn1	Fill Stn2	Distance	Type	Direction	Comment
GR	3.07	30	35	35	45	6.715	Freehaul	Push	
GR	1.25	165	170.806	170.806	175	5	Freehaul	Push	
GR	2047.65	555	595	595	640	52.565	Freehaul	Push	
GR	0.13	0	0.1	0	0	0	Freehaul	Push	Mvt to Pit:
GR	2076.09	785	905	655	785	185	Freehaul	Pull	
GR	735.74	485.605	496.887	445	455	44.999	Freehaul	Pull	
GR	1701.45	459.517	485.605	300	346.114	147.353	Freehaul	Pull	
GR	294.58	455	459.517	246.31	285	203.127	Freehaul	Pull	
GR	9.97	285	300	245	246.31	44.901	Freehaul	Pull	
GR	6.3	150	165	136.024	150	15.672	Freehaul	Pull	
GR	46.05	0	25	0	0	14.04	Freehaul	Pull	Mvt to Pit:
GR	1405.03	914.632	950	635	660	283.784	Overhaul	Pull	
GR	382.63	905	914.632	197.761	245	681.311	Overhaul	Pull	
GR	218.34	552.547	555	170.806	197.761	355.198	Overhaul	Pull	
GR	298.14	549.196	552.547	35	140	458.068	Overhaul	Pull	
GR	4822.93	495	549.196	0	0	524.652	Overhaul	Pull	Mvt to Pit:
SR	90.65	265	325	346.114	350	49.567	Freehaul	Push	
SR	13804.67	460	592.758	370	445.032	114.364	Freehaul	Pull	
SR	1048.21	855	950	365	375	540.655	Overhaul	Pull	
SR	2798.83	450	450	346.114	370	2588.923	Endhaul	Pull	Mvt from I

Table 6-5: Optimal Haul Output Excerpt: *Detailed Movement Summary*

> Note: The detailed movement summary is presented with same format as the Mass Haul balance items (Right click on the Mass Haul diagram and select *Copy Mass Haul balance items to Clipboard*).

6. *File* | *Exit*. Do not save changes.

7. Smart Pits

This example illustrates two key pit properties:

- Pits can now have a *variable volume*.
- Pits have a *site preparation* cost.

1. Open the *Location module*.
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd optimal haul.dsnx.** Press *Open*.
3. Expand to find *V-Align 1*, right click, *Re-Cost.*

You may have noticed that the Mass Haul is balanced. This is because the pits are defined as *variable*.

4. View the pit properties for the current alignment:
   a. With *V-align 1* still selected, press the *Vertical Options* button and select the *Pits* tab.

Notice that all three pits are set as *variable volume (smart pits*).

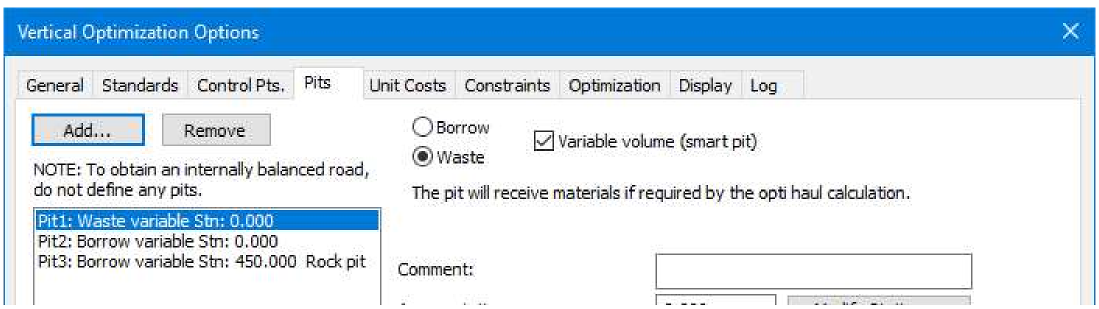


Figure 7-1: *Pits* for the Selected Alignment

   b. Press *Cancel* to close options.

> **Note**: You can also access the *Pits* dialogue box from menu *Edit* | *Assign Parameters by Range*.

5. Make a small change to the vertical alignment:
   a. Right click in the profile window and change to the *Add/Edit IP* tool.
   b. Move your mouse over a VIP ● (indicated by the magenta circle symbol); note that the mouse cursor changes to a box ⌜⌟.
   c. Click the mouse to capture the IP.
   d. Move the point slightly and left click to re-anchor the point.

Your Mass Haul is no longer balanced; *Softree Optimal* automatically updates volumes, but it doesn't re-calculate the Optimal Haul (that option is turned off in this example).

6. *Re-Cost* the current alignment

Notice that the Mass Haul is again balanced; the pit volumes have been updated to balance (see below).

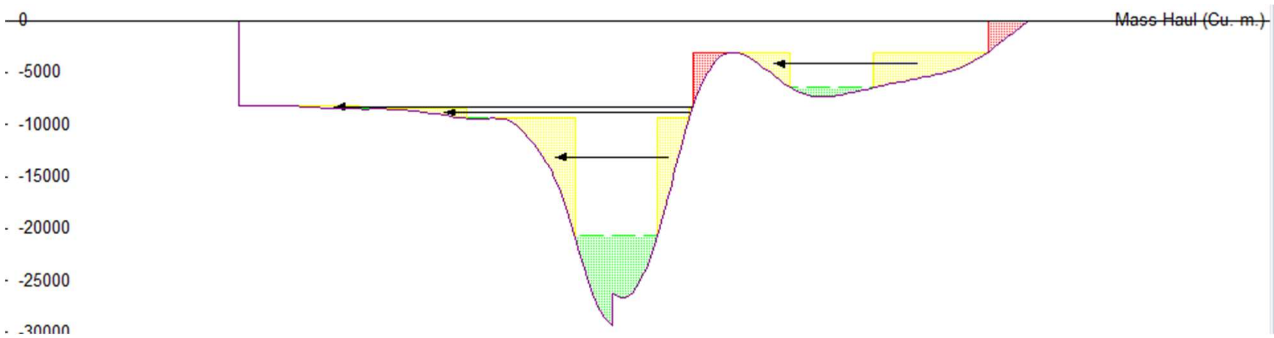


Figure 7-2: *Balanced Mass Haul*

7. *File* | *Exit*. Do not save changes.

Smart Pits, Continued

Softree Optimal can also decide which pit should be used if there is a choice.

1. Open the *Location module*
2. *File* | *Open*. Select <SoftreeOptimal>/**Hart Rd optimal haul.dsnx.** Press *Open*.
3. Expand to find *V-Align 1*, right click, *Re-Cost.*

At this point, *Pit-1* is being used for all waste as there are no alternatives.

Figure 7-3: *Waste Pit* Usage at Station 0.0 Only

4. Add variable waste pits at stations 500 and 900:

a. Make sure that *V-align 1* is still selected.

b. Right click , *Vertical Options* and select the *Pits* tab.

c. Press the *Add* button in the *Pits* dialogue box.

d. Enter station 500 in the *Pit Access Station* dialogue box, press *OK* to accept and close.

e. Make sure that *Waste* and *Variable volume* are set (figure below).

f. Repeat to create another variable waste pit at station 900.

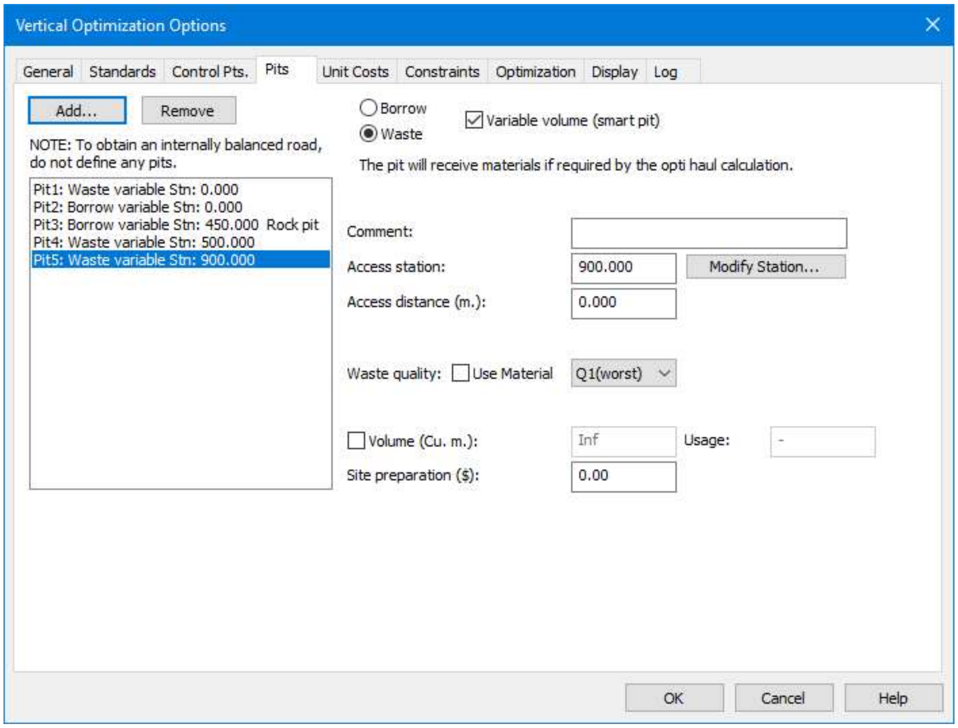


Figure 7-4: New Waste *Pits Added*

Notice that the *Waste quality* is Q1 (worst); this means that any material can be accepted by this pit. *Capacity* is set to inf (infinite); you can optionally limit the size of the pit by setting this property. *Site preparation* cost is set to zero by default.

g. Press *OK* to close the options dialogue box.

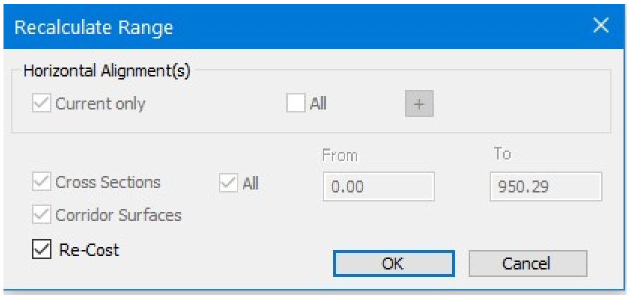


Figure 7-5: *Recalculate Range* Dialogue Box with The Re-Cost Option Set

h. Set the *Re-Cost* check box when prompted with the *Recalculate Range* dialogue box.

i. Press *OK* to recalculate and update the Optimal Haul.

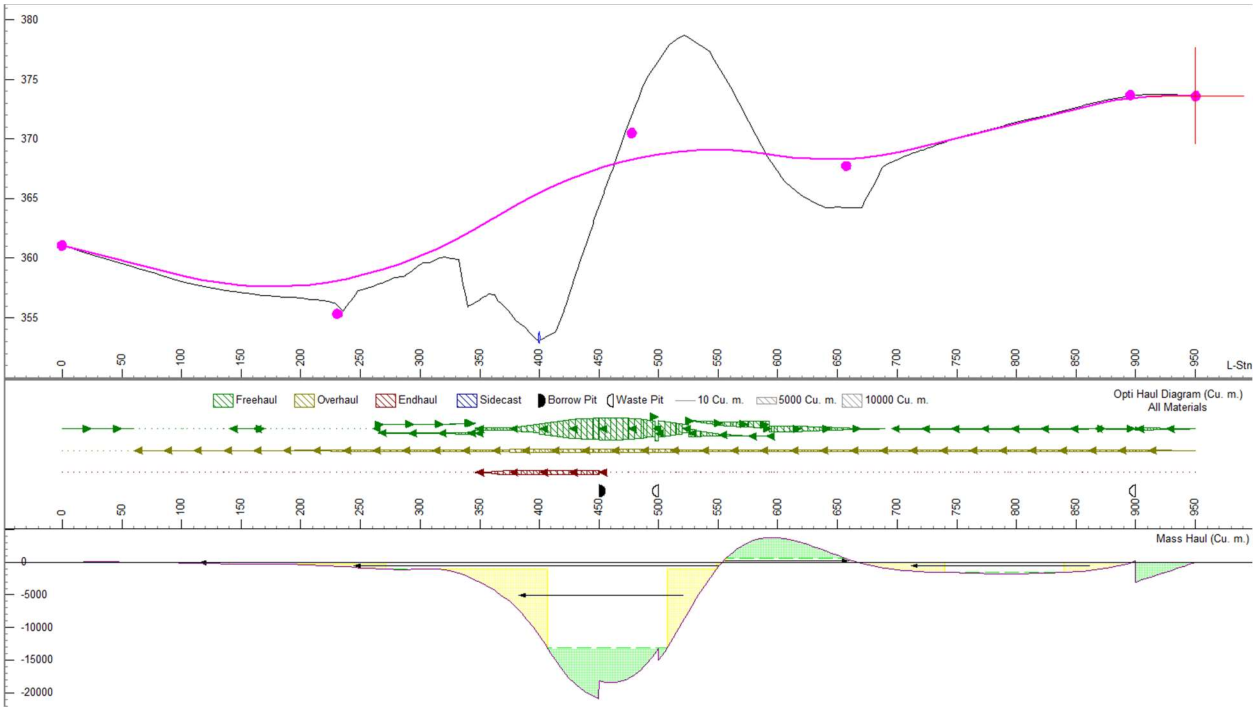


Figure 7-6: *Waste Pit Usage* at Stations 500 and 900.

Our new pits are both being used and *Pit 1* at station 0 pit is not; this reduces the haul cost.

Now let's add site preparation cost and see how the optimal haul calculation is impacted.

5. Right click on V-Align 1, select *Vertical Options*. Select the *Pits* tab.
6. Select Pit 4: waste variable, enter 10,000 as the site preparation $.
7. Enter the same site preparation $ for Pit 1 and Pit 5.
8. Press OK to accept the change as shown in the figure below:

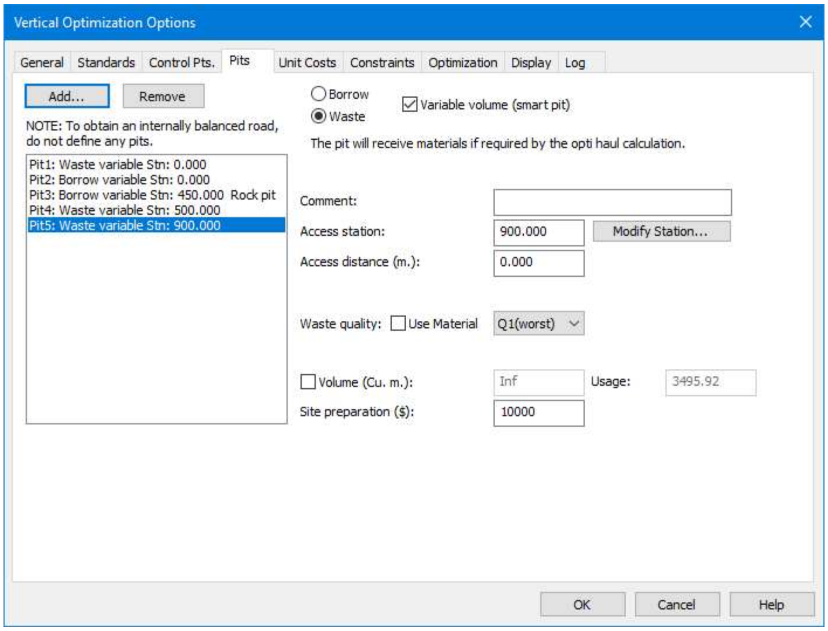


Figure 7-7: Adding Site Preparation Cost

9. When prompted to *Recalculate Range*, select *OK*.

Notice that the only waste pit being used now is the one at station 900; the optimal haul calculation has determined that, in this case, the extra hauling cost is less than the *Site preparation* cost of opening two pits.

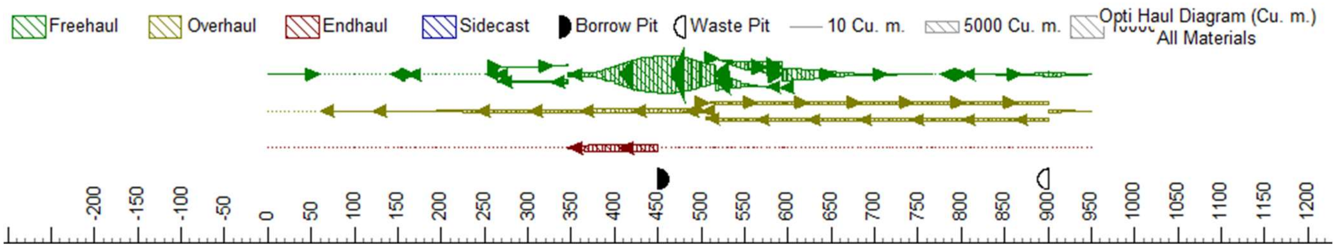


Figure 7-8: Updated Opti-Haul Showing Pit Usage

10. *File* | *Exit*. Do not save changes.

8. Optimization Strategies

Infeasible Problems

It is easy to unknowingly constrain the vertical alignment so that it is infeasible. This is a difficult problem to diagnose in general, but several tools are provided to help you.

Conflict detection

At the interface level, *Softree Optimal* checks in real-time for basic constraint compatibility. For example, it will check whether a control point lies within the user defined vertical band or not. When a conflict is detected, a *Conflict* button appears at the bottom left of the *Vertical Optimization Options* dialogue box; press this button for a description of the conflict.

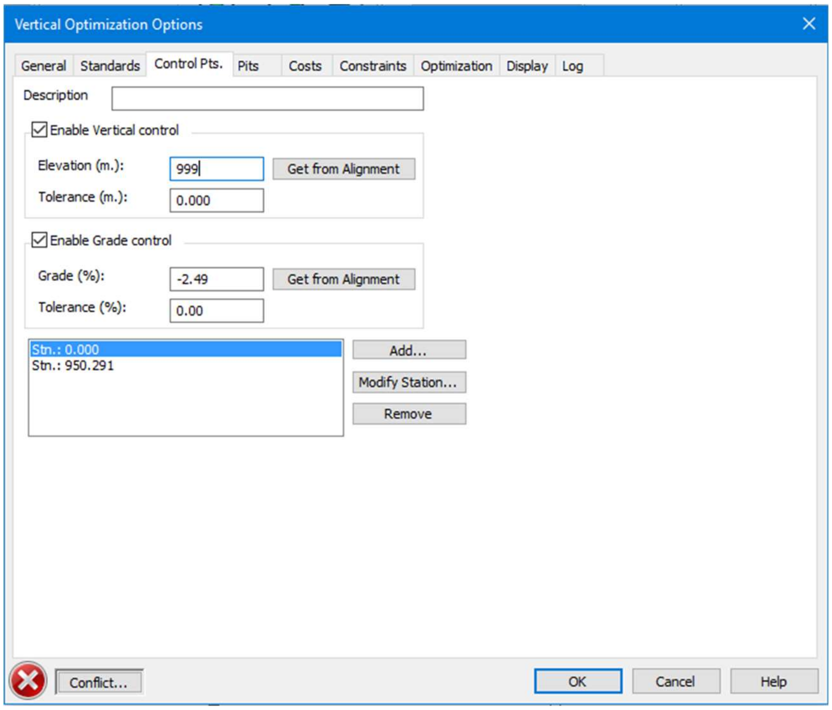


Figure 8-1: Conflict Detected

Note: If there is a conflict, any optimization will fail. So, conflicts must be addressed.

Feasibility Tests

When you press the *Process* button, you are given the option to run *a Feasibility* check.

- If the band is up to date or *Pre-Process* is selected, then *Feasibility* considers all the geometric constraints provided by the user and will determine whether there is at least one alignment that satisfies all these constraints.

> **Note**: If *Feasibility* fails, the *Optimal Profile* will also fail.

- If the band is out of date, then *Feasibility* only considers:
  - *Standards*,
  - *Control Pts*., if applicable,
  - *Min. Cut*, if applicable,
  - *Min. Fill*, if applicable,
  - The vertical band is simply calculated from vertical offsets (*Options*, *General* tab) and the selected alignment (*Options*, *General* tab, *Vertical Band Center* list).

> **Note**: In this case, it is possible that *Feasibility* succeeds, and *Optimal Profile* fails. This is because not all the constraints are considered (for example, *Hor. ROW*) and the band is larger. The advantage of this test is that it is faster as it does not require *Pre-Process.*

If you run a *Feasibility check* immediately after you define each constraint, it will be clear which constraint caused infeasibility.

Softening

If your alignment is infeasible, you need to relax one or more constraints. *Softening* a constraint is a quick way to do this without having to change any of the constraint parameters. *Softening* only applies to geometric constraints so it does not apply to the *Direction* and *Sidecast* constraints.

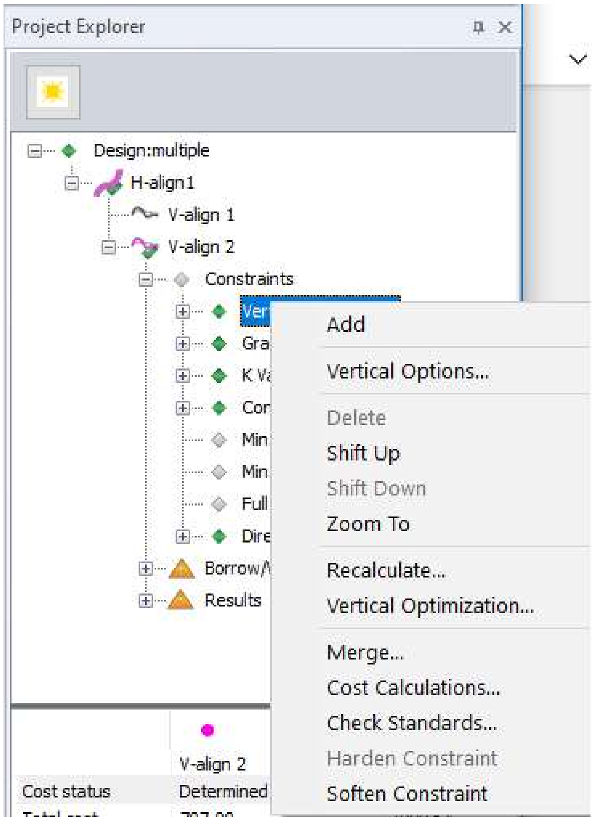


Figure 8-2: *Alignment Panel* tree context Menu Includes Softening and Hardening of Constraints

The idea behind *softening* is to allow a constraint to be violated wherever it cannot be enforced, and then report the information. For example, the ground may be too steep for your desired maximum grades. If you *Process* to find an *Optimal Profile* with softened grades, the optimization log will report wherever the desired maximum grade was exceeded.

> Note: The alignment found with a softened constraint should not be considered optimal.

Vertical Band

Optimization is restricted to a *Vertical Band* (or corridor) around the ground line or selected alignment (*Options*, *General* tab, *Vertical Band Center* list). The Vertical Band is defined by the two vertical offsets set in the *Options* | *General Tab* | *Vertical Control*.

To display the vertical band, select the alignment in the *Alignment(s)* list. Expand the *Tree Control* and select *Vertical Band.* The band will appear in the profile window.

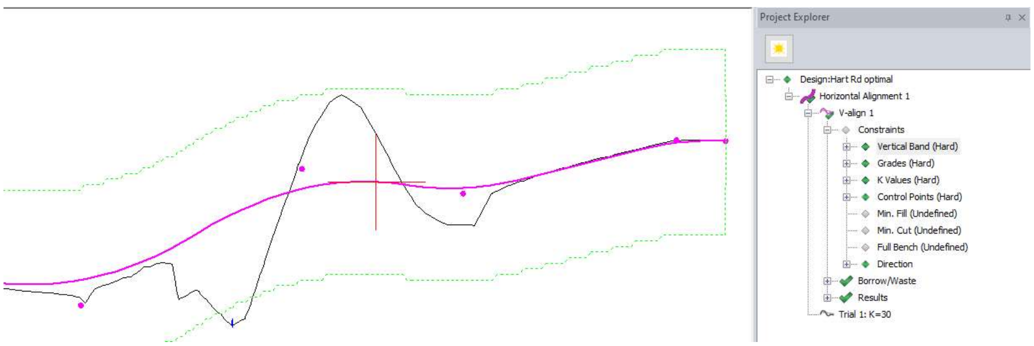


Figure 8-3: The *Vertical Band* is Visible When Selected

When *Constraints* is selected in the tree control the vertical band is modified by all constraints. In the figure below, a *Min. Fill* constraint and *Control Pts.* are constricting the vertical band.

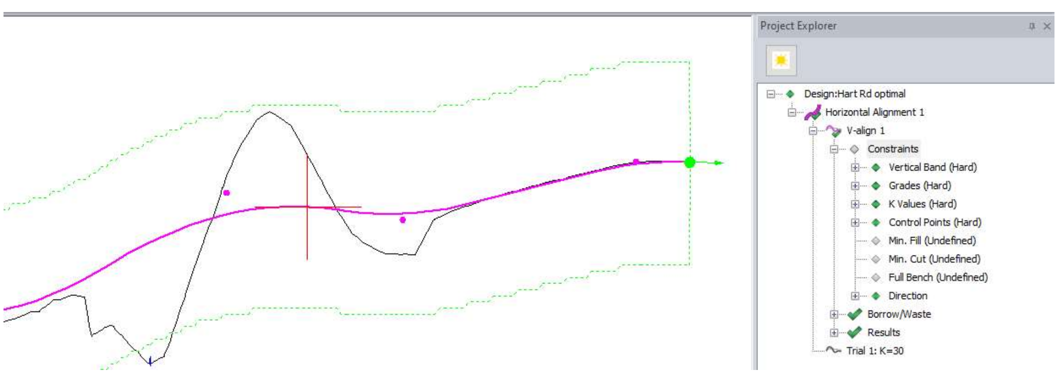


Figure 8-4: The Vertical Band is Visible when Constraints are Selected

There is another subtler way that the vertical band can be restricted. If the underlying surface doesn't extend far enough horizontally, the cross section may have slope errors (the cut or fill slope does not catch the surface). In such case, potential alignment elevations that generate slope errors are removed from the vertical band, resulting in a smaller “true” vertical band. The “true” vertical band is the one being displayed whenever available. *Optimal Profile* will *Pre-Process* all cross sections to check for slope errors.

> Note: *Full bench, Hor. ROW, and Vert. ROW* can only be visualized with the "true" vertical band.
>
> Note: If the "true" vertical band pinches out, you may need to extend the surface model.
>
> Note: After a successful alignment optimization, the optimal solution must be within the vertical band. If your optimized alignment is touching the vertical band, then the solution is being constrained; there is probably a cheaper solution available if you move the initial alignment or increase the depth of the band.

Speed and Accuracy Considerations

Optimization can take a long time. It is not difficult to generate problems which take hours (or even days -- yes really!). Unfortunately, there is no way to know in advance how long a specific problem will take.

Here are some recommendations:

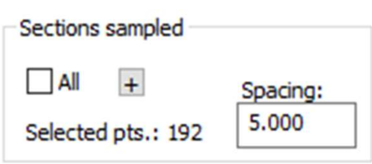
Recommendation 1: Start by using *Curves [Fast]* (or *Polyline*).

In the *Vertical Options Standards* tab, start by using *Curves [Fast] (or Polyline*). This will generate the lowest cost alignment possible for a given set of constraints; use this cost and the profile as your baseline for evaluating future alignments. If satisfied with the alignment and a solution has been found, create a *New* alignment then switch to *Curves and tangents [Slow]* or *Variables curves and tangents [Slowest].* These two algorithms will take longer to solve.

Recommendation 2: Set the Spacing to *Auto*

For accuracy purposes, the user should set the ***Spacing* to the recommended *Auto*** calculated spacing. Such a choice might yield a very large number of sections. In that case, you have two options:

- Clear the *All* check box in *Sections Sampled* and possibly increase the *Spacing*. This will speed thing up but reduce accuracy.



- Divide your alignment into pieces; see image below.

Recommendation 3: *Cancel* and Accept the *Current, Best Solution*

Once the alignment is being optimized (after *Pre-Process*), a dialogue box appears displaying the *Optimality gap*. The *Optimality gap* is defined as the best improvement that can be made over the current solution. (Note that this is an upper bound; in fact, the current solution may already be the optimal solution.) **Rather than wait for the optimality, when the optimality gap reaches zero, you may cancel at any time to accept the *current best solution*.** So, if you cancel the process at 5%, the cost of the alignment obtained will be within 5% of optimal cost. Often, the time it takes to find a solution with a small *Optimality gap* is much less than the time to reach optimality.

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