

CES500056

## The Handy Man's Guide To: Grading Optimization in Your Civil 3D Toolbox

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Morrison-Maierle

### Learning Objectives

- Discover what components are needed for the Grading Optimization program
- Learn how to create a design surface using the Grading Optimization program
- Learn how to successfully use the Grading Optimization program in your workflow
- Learn how to apply generative design parameters to use within the Grading Optimization program

### Description

In this class, we'll cover Civil 3D software and the new Grading Optimization program workflow. One of the most time-consuming tasks in Civil 3D is optimizing the design surface for your project. Using the new Grading Optimization program can greatly reduce the time you spend on this task. We'll walk through a basic site and demonstrate how to set up your Civil 3D design for the Grading Optimization program.

### Speaker

Creg Dieziger has over 31 years of experience in the civil engineering field and with Autodesk, Inc., products. He is a 7-time Inside the Factory (a.k.a. AutoCAD Civil 3D Gunslinger) member. He is a Sr. Civil Engineer Designer for Morrison-Maierle, which has over 200 users of Autodesk products. He also has been an adjunct at the Missoula College – University of Montana for 7 years. He has taught AutoCAD software, Survey software, and AutoCAD Civil 3D software. He is energetic and he loves speaking at Autodesk University. Basically, love teaching because he finds it a great way to give back but also to learn himself. His favorite quote is "The day I stopping learning is the day I die" Tommy Lasorda.

## Notes

## Introduction to Grading Optimization and its Components

Grading Optimization for Civil 3D (a.k.a. GO) is a tool intended to help with designing surface grading plans. It is an interactive way of using optimization constraints or optimization objectives to obtain a design surface.

### Optimization Constraints

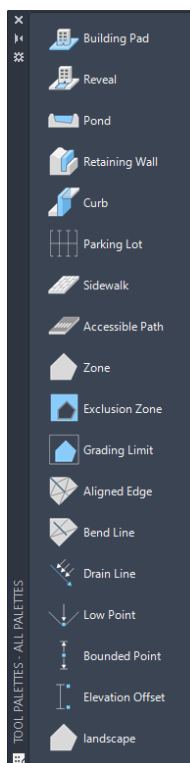
Optimization Constraints are surface restrictions such as spatial limits, slopes, grades and/or elevations.

### Optimization Objectives

Optimization Objectives are functions used to measure the feasibility of the surface. Things like terrain smoothness, balancing of cut and fill, and total earthwork volumes are considered Optimization Objectives. Feasibility usually entails aspects such as cost, constructability, or construction schedule.

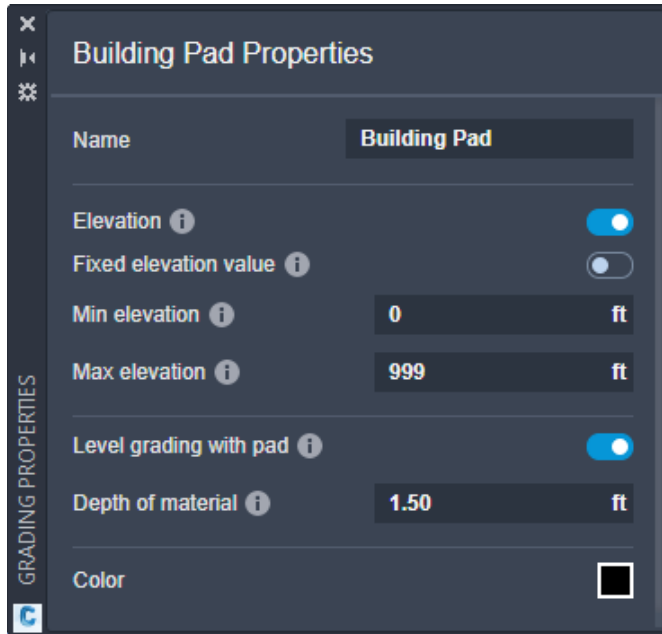
### Grading Optimization Grading Objects

Grading Optimization Grading Objects are objects that use optimization constraints and objectives to define how that object shall work. Grading objects include Building Pad, Reveal, Pond, Retaining Wall, Bounded Point, Aligned Edge, Bend Line, Low Point, Drain Line, Elevation Offset, Zone, Exclusion Zone, Parking Lot, Grading Limit, Sidewalk, Accessible Path, Curb, and other user-defined objects. . The Grading Objects Tool Palette is shown below.



## Building Pad

Building Pad grading object will flatten the area within the closed geometry and will adjust its elevation to meet the constraints and grading objectives of the project. The building pad grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.




Note:

- Must be closed geometry.
- The grade of the surface around the Building Pad may rise or fall sharply as an exposed or buried foundation wall would. Use Reveals to control the amount of foundation shown.
- The elevation from the Building Pad to the adjacent grades can be controlled with Elevation Offsets.

## Reveal

Reveal grading objects control the desired visibility of a building pad from the terrain surface to the top of the pad. Reveals are placed on the edges of building pads.



**Reveal Properties**

Name: **Reveal 1**

Fixed elevation value: ☐

Start elevation difference

Min difference: **3.50** ft

Max difference: **4.50** ft

End elevation difference

Same as start elevation: ☒

Min difference: **3.50** ft

Max difference: **4.50** ft

Length: **12.227** ft

Color: 

GRADING PROPERTIES

Note:

- Reveal can only be applied to existing building pad grading objects.
- Use Reveals to specify locations for common building elements such as loading docks, steps, stairways, and entryways.

## Pond

Pond grading objects represent the surface area and depth of a pond in a project. Pond objects allow for fine detail of slope constraint through dimensional parameters for their pond type; either dry, or wet. The pond grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.

×

⌵

⚙

Pond Properties

Name

Pond

Pond type ⓘ

☒ Dry pond ☐ Wet pond

Min storage volume ⓘ

30000 cu.ft

Max storage depth ⓘ

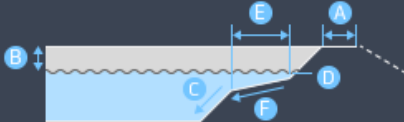
5 ft

Allow boundary change ⓘ

☒

Safety bench

☐



▼ Berm

A Berm width ⓘ

10 ft


B Freeboard ⓘ

1 ft

C Inside slope(H:1V) ⓘ

3:1

Color

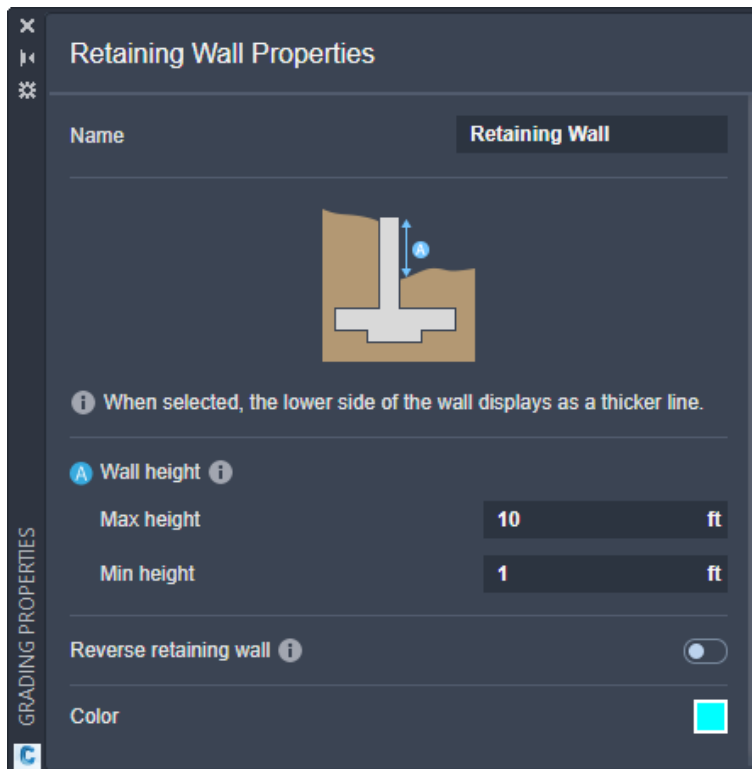


Note:

- Must be closed geometry.

## Retaining Wall

Retaining Wall grading object will break the terrain along the retaining wall geometry and step the terrain at a specified height and width. The retaining wall grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, and/or feature lines.



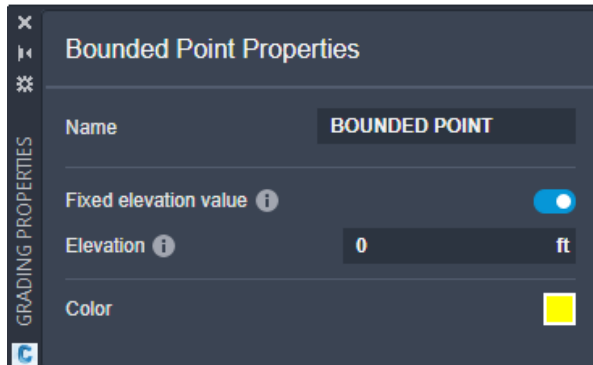
Note:

- Can be open or closed geometry. Open geometry creates a wall. Closed geometry creates islands.
- Closed geometry will need to be verified that the back of wall and front of wall on the desired side. If not, the direction of the wall can be reversed manually.
- Open geometry will step the wall up on one side, but the wall may need to be manually reversed. The side the wall steps on is based on the the direction of the line that was drawn.
- When the wall grading object is selected, the lower side of the wall **1** is the lighter thicker (shaded) displayed line and the darker thinner line is the upper side of the wall **2** as shown here.



## Bounded Point

Bounded Point is a grading object that creates an elevation constraint for a point along the a surface. The bounded point grading object optimization constraints can be applied to a C3D COGO point and/or AutoCAD point objects. Bounded Point is useful for points of entrance or exit such as a road or culvert for example. If a bounded point is placed within a zone it will affect the zone accordingly.

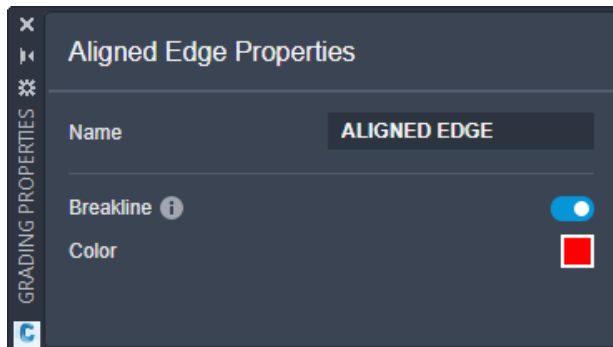


Notes:

- When the minimum and maximum elevation constraint property is equal the bounded point is then at a fixed elevation.
- While useful in defining specific elevations at a point it may be to high or to low to satisfy the slope constraints defined around it, and it will cause a conflict warning within GO.

## Aligned Edge

Aligned Edge grading objects are used to create breaklines in a design surface. The aligned edge grading object optimization constraints can be applied to a AutoCAD lines, arcs, 2D polylines, 3D Polyines and/or C3D feature lines. Aligned Edges are useful when a linear elevation with a consistent slope is needed such as wall locations and parking lot ridge lines. Aligned Edges do not need to be straight but can have curves and bends.



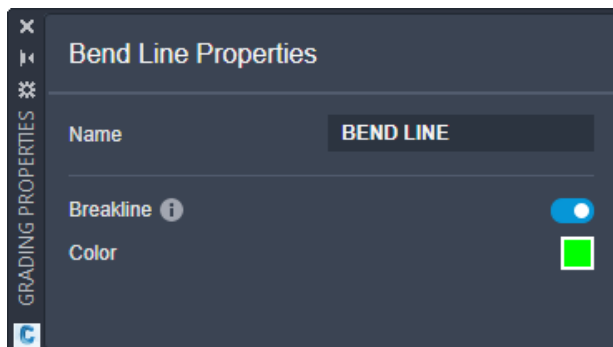
Notes:

- Enable the breakline property for consistent contour break. This is a recommended default setting almost all the time for Aligned Edge grading objects.
- Aligned edges can be placed on top of a Drain line grading object to create sharp contours.



## Bend Line

The Bend Line grading object attempts to relax the slope of surface triangles along a line. The line is not necessarily straight but can have corners or curves. During optimization, surface triangle edges that touch a Bend Line object will be set to a minimum slope of zero and a maximum slope of infinity. The Bend Line grading object optimization constraints can be applied to a AutoCAD lines, arcs, 2D polylines, 3D Polyines and/or C3D feature lines.

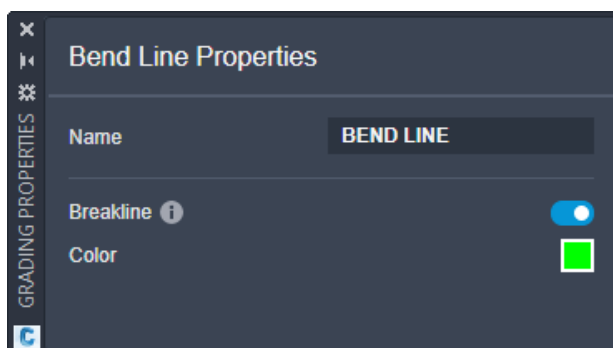


Note:

- Bend Lines are useful for areas where slope constraints can be relaxed to reduce earthwork.

## Low Points

Low Point is a grading object that is a drain element that controls the direction of of drainage to a surface to it. The low point grading object optimization constraints can be applied to a C3D COGO point and/or AutoCAD point objects. Multiple drain elements can exist in a model. The design surface triangles will slope to the **nearest** drain elements in GO. Design surface triangles in a zone with the exclusive drainage property applied will only point toward drain elements within the zone. Design surface triangles outside of the zone will not see these drain elements.

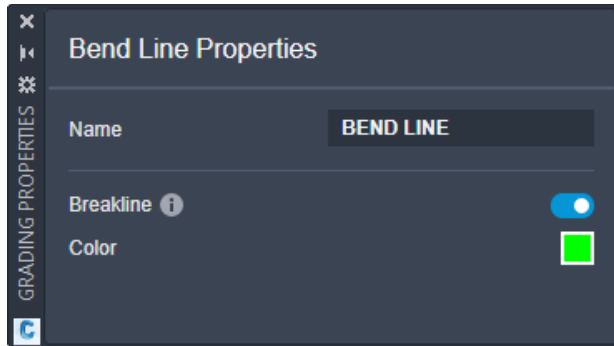


Note:

- A diamond shaped pattern can also be specified for the slope (instead of this default circular pattern) in the Low Point Properties Dialog.

## Drain Line

Drain Line grading objects are drain elements that control the slope direction of surface triangles. All triangles in a model will try to slope towards the closest drain line, unless overridden by the slope of an aligned surface zone. The Drain Line grading object optimization constraints can be applied to a AutoCAD lines, arcs, 2D polylines, 3D Polylines and/or C3D feature lines.

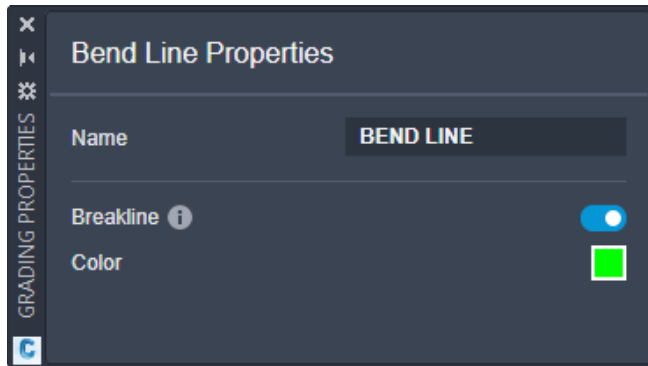


Note:

- The high point of a Drain Lines is defined by the start (or the first point drawn) of the line.
- Drain Lines must be open geometry and not form a closed loop.
- The optimization process for a Drain Line for a surface is that, the centroid of a surface triangle will incline towards the nearest point on the drain line. Whether it be the high point, low point or the line itself.
- Triangles in zones with the exclusive drainage property applied will only point toward Drain Line located within the zone. Triangles outside of the zone will not see these Drain Lines.

## Elevation Offset

Elevation Offset grading objects control the elevation difference between each end of a line segment. Use elevation offsets to constrain slope between grading objects and adjacent grades or other objects. The elevation offset grading object optimization constraints can be applied to a AutoCAD lines, arcs, 2D polylines, 3D Polylines and/or C3D feature lines.



Note:

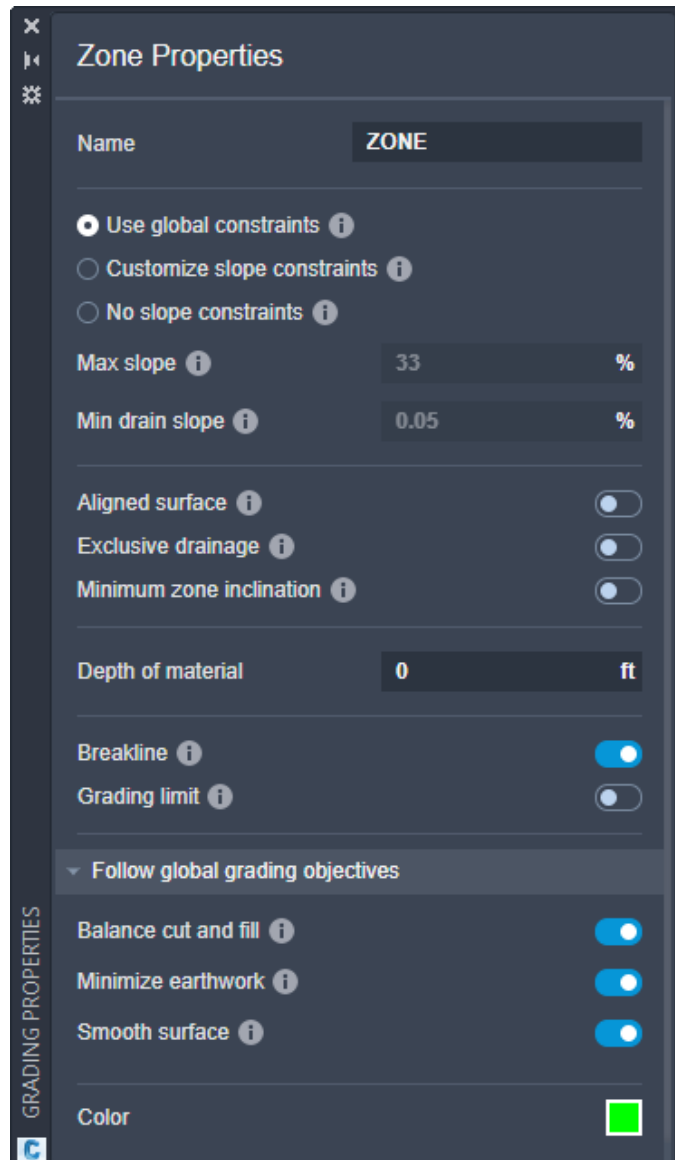
- Elevation Offset grading object can be constrain by a minimum and maximum elevation offset properties. This can be a range for the elevation difference or fixed at a specific elevation difference when the values are equal.
- The start of the line as drawn is the higher elevation and the end of the line is the lower elevation. A positive value for the elevation offset tries to keep the first point higher than the end of the segment by that positive value. A negative value would force the start point to be lower.
- When setting an elevation offset to one or more objects, the line must snap to the object geometry in the source drawing.

## Zone

Zone grading objects represent areas of a site that require specific grading considerations. Zones can contain and be influenced by other grading objects in regard to slope, elevation, and drainage. Zones are useful for paved surfaces, boundaries for grading projects, or even creating ramps. The zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.

Note:

- Must be a closed geometry.
- There are four common zones available as preconfigured objects in the Grading Object Tool Palette: Parking Lots, Sidewalks, Accessible Paths, and Grading Limits.
- Multiple zones are often used in an optimization project, so it is important to understand how they interact with each another. In the Grading Objects Browser, zones have optimization priority as they are listed from the top down.
- Leveraging the constraints available in the Zone Properties Dialog, zones for different features can be specified.



The image shows the 'Zone Properties' dialog box in a software application. The dialog has a title bar with standard window controls (close, maximize, minimize) and a 'Zone Properties' title. Below the title, there is a 'Name' field containing the text 'ZONE'. The main body of the dialog is divided into several sections. The first section contains three radio buttons: 'Use global constraints' (selected), 'Customize slope constraints', and 'No slope constraints'. Below these are two input fields: 'Max slope' with a value of '33' and a '%' symbol, and 'Min drain slope' with a value of '0.05' and a '%' symbol. The next section contains three toggle switches: 'Aligned surface' (checked), 'Exclusive drainage' (checked), and 'Minimum zone inclination' (checked). Below these is another input field: 'Depth of material' with a value of '0' and a 'ft' unit. The next section contains two toggle switches: 'Breakline' (checked) and 'Grading limit' (unchecked). Below these is a section titled 'Follow global grading objectives' which is expanded, showing three toggle switches: 'Balance cut and fill' (checked), 'Minimize earthwork' (checked), and 'Smooth surface' (checked). At the bottom, there is a 'Color' field with a small green square icon. On the left side of the dialog, there is a vertical label 'GRADING PROPERTIES' and a small 'G' icon at the bottom.

**Zone Properties**

Name: ZONE

☒ Use global constraints *i*

☐ Customize slope constraints *i*

☐ No slope constraints *i*

Max slope *i*: 33 %

Min drain slope *i*: 0.05 %

Aligned surface *i*: ☒

Exclusive drainage *i*: ☒

Minimum zone inclination *i*: ☒

Depth of material: 0 ft

Breakline *i*: ☒


Grading limit *i*: ☐

**Follow global grading objectives**

Balance cut and fill *i*: ☒

Minimize earthwork *i*: ☒

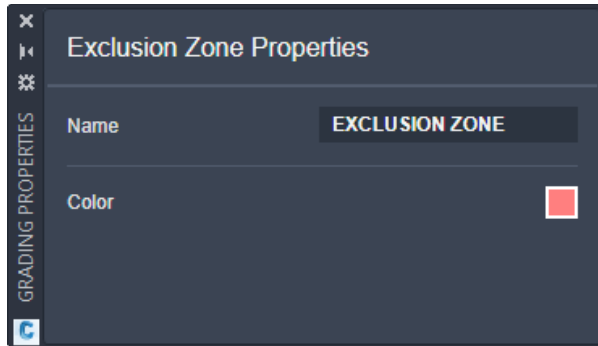
Smooth surface *i*: ☒

Color: 

GRADING PROPERTIES

## Exclusion Zone

Exclusion Zone grading object is used to represent an area of the surface that will not be optimized. Surfaces and objects within the closed geometry of the exclusion zone will not be considered during optimization. The exclusion zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.

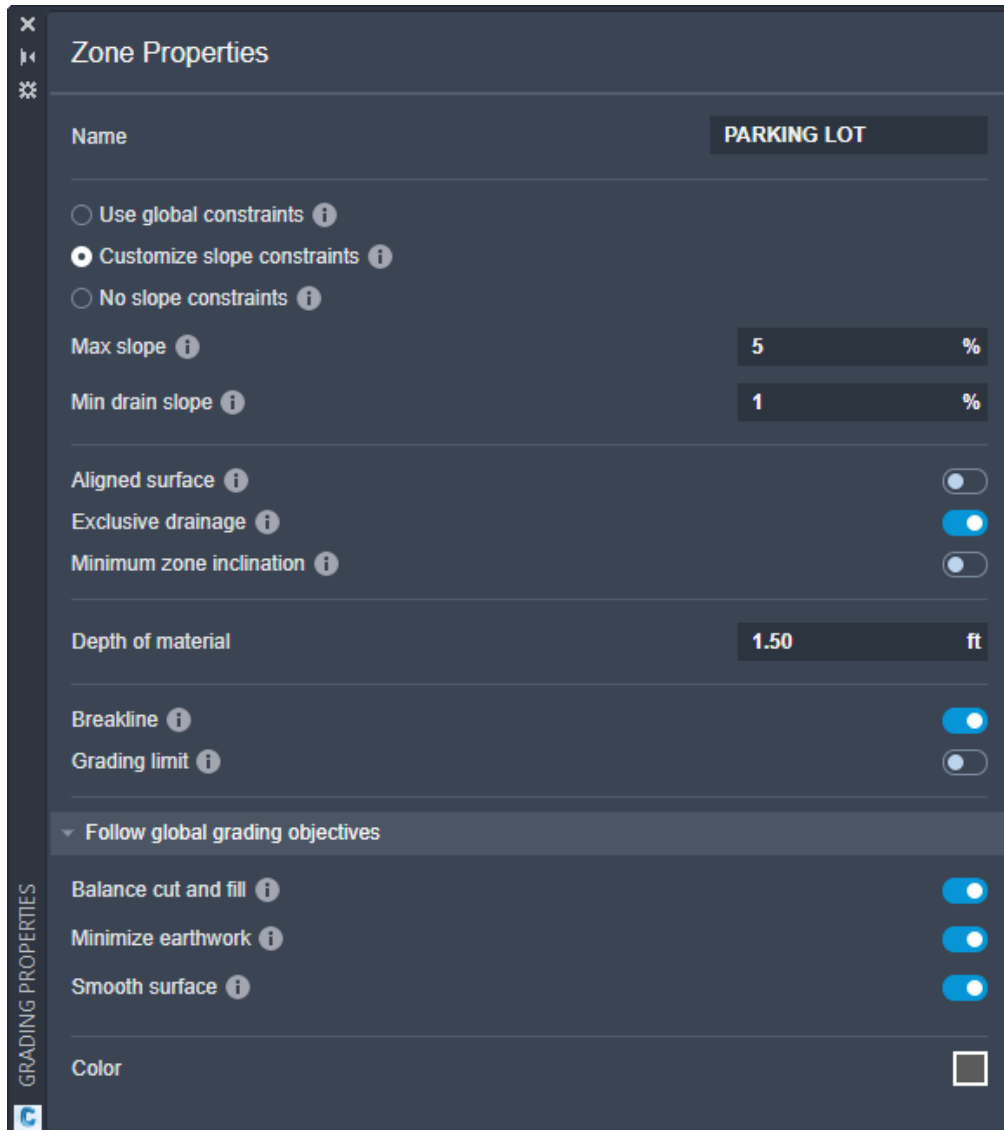


Note:

- Must be closed geometry.

## Parking Lot

The Parking Lot grading object is a preconfigured zone specifically designed to represent a parking lot with a default Depth of Material assigned to it. The parking lot zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polyline, hatch pattern, C3D Parcel and/or feature lines.



The screenshot shows the 'Zone Properties' dialog box for a 'PARKING LOT' zone. The dialog is dark-themed and contains various settings for the grading object. The 'Name' field is set to 'PARKING LOT'. Under 'Slope constraints', 'Customize slope constraints' is selected. The 'Max slope' is set to 5% and the 'Min drain slope' is set to 1%. The 'Aligned surface' toggle is off, 'Exclusive drainage' is on, and 'Minimum zone inclination' is off. The 'Depth of material' is set to 1.50 ft. The 'Breakline' toggle is on and 'Grading limit' is off. A section titled 'Follow global grading objectives' is expanded, showing 'Balance cut and fill', 'Minimize earthwork', and 'Smooth surface' all enabled. A 'Color' field with a color picker is at the bottom.

Property	Value / Setting
Name	PARKING LOT
Use global constraints	<input type="radio"/>
Customize slope constraints	<input checked="" type="radio"/>
No slope constraints	<input type="radio"/>
Max slope	5 %
Min drain slope	1 %
Aligned surface	<input type="checkbox"/>
Exclusive drainage	<input checked="" type="checkbox"/>
Minimum zone inclination	<input type="checkbox"/>
Depth of material	1.50 ft
Breakline	<input checked="" type="checkbox"/>
Grading limit	<input type="checkbox"/>
Follow global grading objectives	
Balance cut and fill	<input checked="" type="checkbox"/>
Minimize earthwork	<input checked="" type="checkbox"/>
Smooth surface	<input checked="" type="checkbox"/>
Color	<input type="color"/>

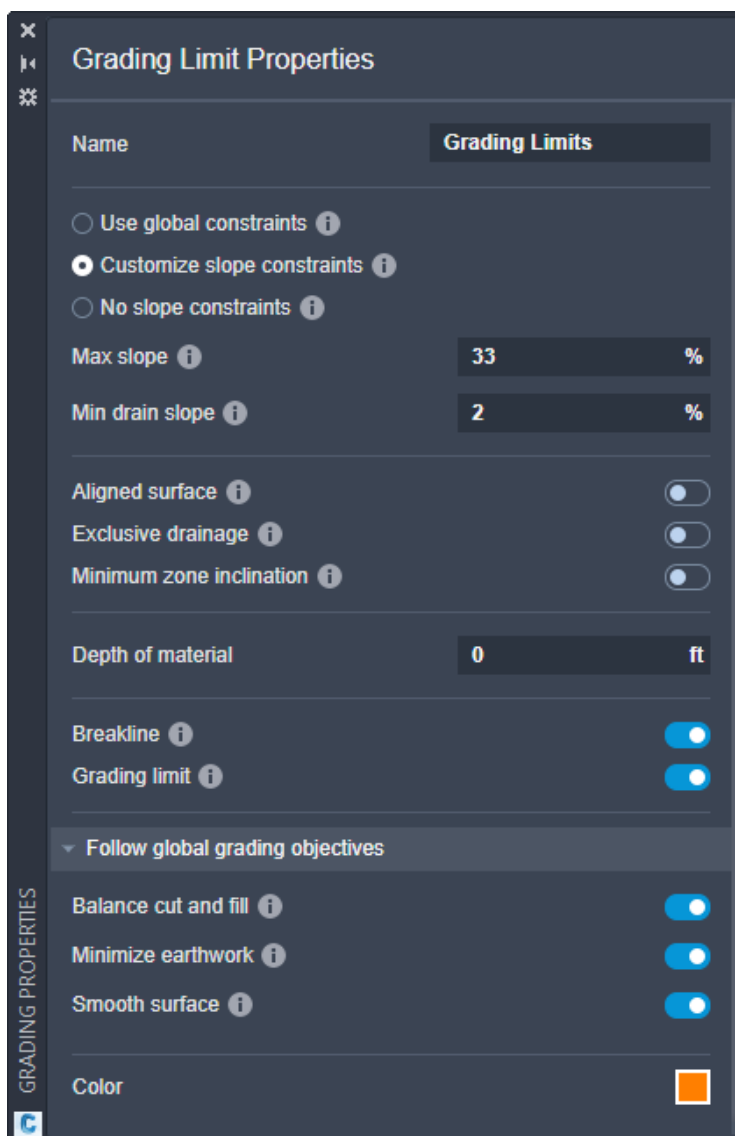
Note:

- Must be closed geometry.
- The Parking Lot zone has the following object properties enabled: Slope, Exclusive Drainage, and Breakline.

## Grading Limit

Grading Limit grading object is a preconfigured zone that is specifically designed to represent the outermost footprint of your GO project. The grading limit zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polyline, hatch pattern C3D Parcel and/or feature lines.

When a zone is considered a grading limit, surface triangles around its boundary are fixed to their original elevations and no grading occurs outside of the zone. This can help reduce optimization calculation times by narrowing the surface area to optimize.



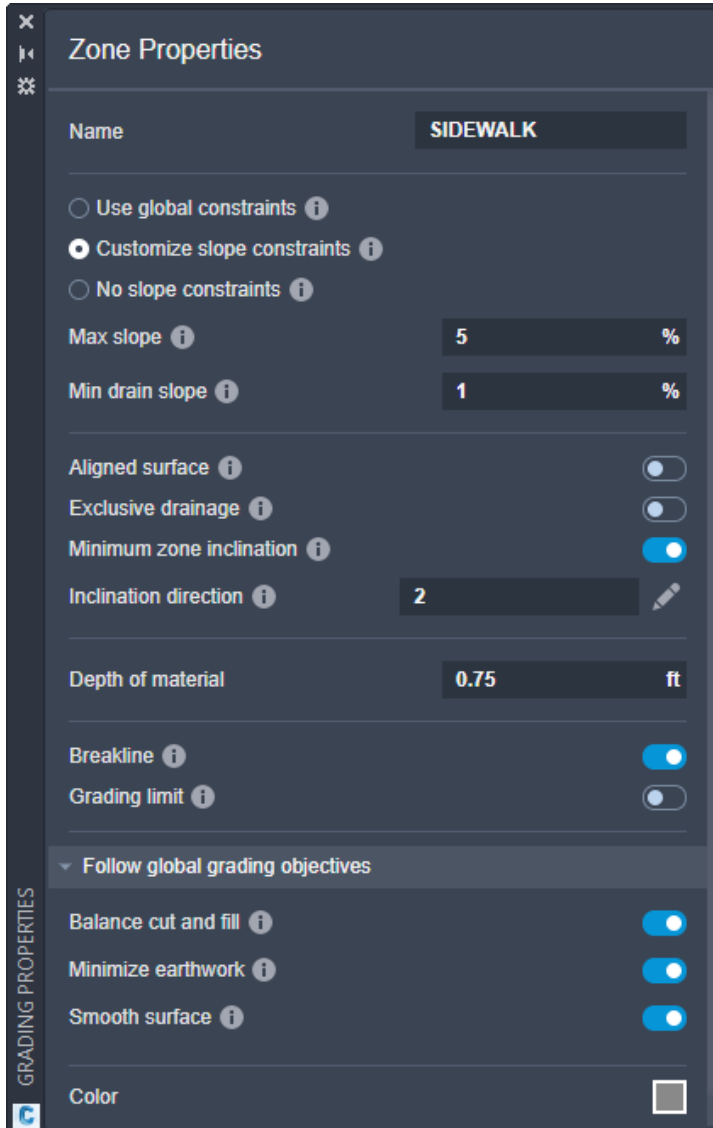
The image shows the 'Grading Limit Properties' dialog box in a software application. The dialog has a title bar with standard window controls. Inside, the 'Name' field is set to 'Grading Limits'. There are three radio buttons for constraints: 'Use global constraints' (unselected), 'Customize slope constraints' (selected), and 'No slope constraints' (unselected). Below these are two input fields: 'Max slope' set to 33% and 'Min drain slope' set to 2%. There are three toggle switches: 'Aligned surface' (off), 'Exclusive drainage' (off), and 'Minimum zone inclination' (off). The 'Depth of material' is set to 0 ft. At the bottom, there are two more toggle switches: 'Breakline' (on) and 'Grading limit' (on). A section titled 'Follow global grading objectives' is expanded, showing three toggle switches: 'Balance cut and fill' (on), 'Minimize earthwork' (on), and 'Smooth surface' (on). A 'Color' field at the bottom right shows an orange square. On the left side of the dialog, there is a vertical label 'GRADING PROPERTIES' and a small 'G' icon at the bottom.

Note:

- Must be closed geometry.
- Use grading limits in larger drawings to reduce unnecessary optimization and improve performance.
- Slopes along the boundary of the zone can result in warnings during optimization because they do not meet the maximum slope or minimum drainage slope requirements for the area of the zone.
- The Grading Limit zone has the following object properties enabled: Slope, Breakline, and Grading Limit.

## Sidewalk

Sidewalk grading object is a preconfigured zone specifically designed to represent common sidewalks with a default Depth of Material assigned to it. The sidewalk zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.



The screenshot shows the 'Zone Properties' dialog box for a 'SIDEWALK' zone. The dialog is organized into several sections. The 'Name' field is set to 'SIDEWALK'. Under 'Constraints', 'Customize slope constraints' is selected, with 'Max slope' at 5% and 'Min drain slope' at 1%. The 'Aligned surface' and 'Exclusive drainage' options are disabled, while 'Minimum zone inclination' is enabled with an 'Inclination direction' of 2. The 'Depth of material' is set to 0.75 ft. The 'Breakline' option is enabled, and 'Grading limit' is disabled. A section titled 'Follow global grading objectives' contains three enabled options: 'Balance cut and fill', 'Minimize earthwork', and 'Smooth surface'. A 'Color' field with a selection box is at the bottom. The left sidebar of the software interface shows 'GRADING PROPERTIES' selected.

Property	Value / Status
Name	SIDEWALK
Use global constraints	<input type="radio"/>
Customize slope constraints	<input checked="" type="radio"/>
No slope constraints	<input type="radio"/>
Max slope	5 %
Min drain slope	1 %
Aligned surface	<input type="checkbox"/>
Exclusive drainage	<input type="checkbox"/>
Minimum zone inclination	<input checked="" type="checkbox"/>
Inclination direction	2
Depth of material	0.75 ft
Breakline	<input checked="" type="checkbox"/>
Grading limit	<input type="checkbox"/>
Follow global grading objectives	
Balance cut and fill	<input checked="" type="checkbox"/>
Minimize earthwork	<input checked="" type="checkbox"/>
Smooth surface	<input checked="" type="checkbox"/>
Color	[Selection Box]

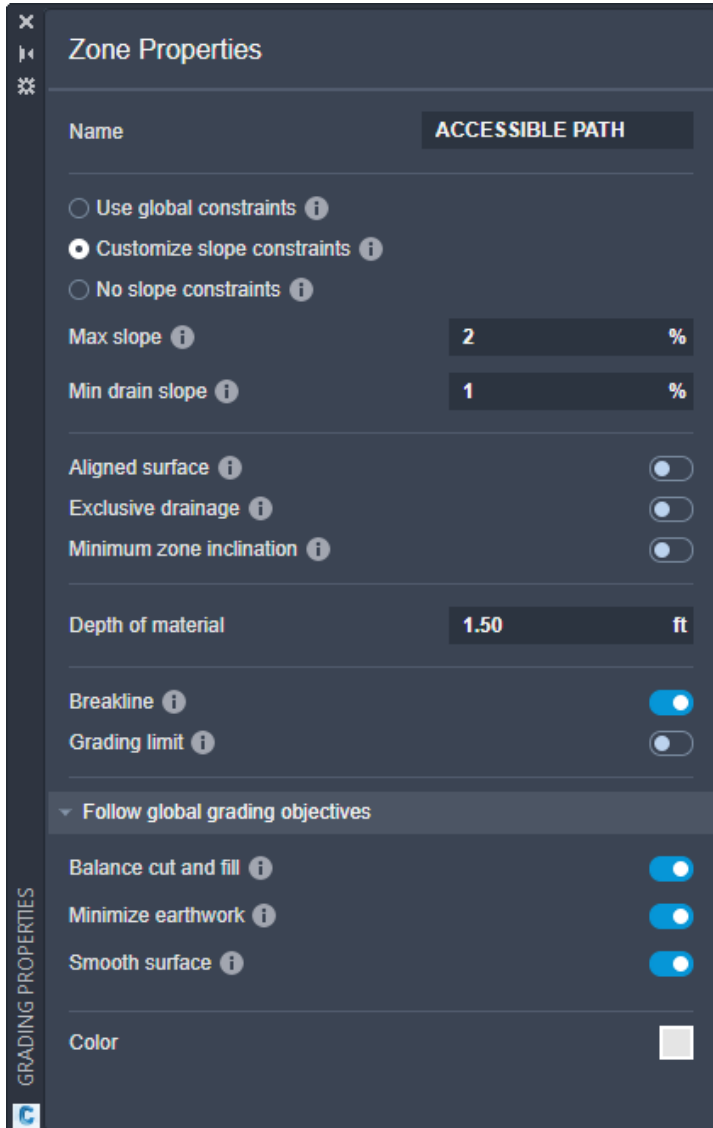
Note:

- Must be closed geometry.
- The Sidewalk zone has the following properties enabled: Slope, Aligned Surface, Minimum Slope Inclination, and Breakline.







## Accessible Path

Accessible Path grading object is a preconfigured zone specifically designed to have the required slope constraints for accessible paths. It also has a default Depth of Material assigned to it. The accessible path zone grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, hatch pattern C3D Parcel and/or feature lines.



The screenshot shows the 'Zone Properties' dialog box for the 'ACCESSIBLE PATH' zone. The dialog is dark-themed with a sidebar on the left labeled 'GRADING PROPERTIES'. The main area contains the following settings:

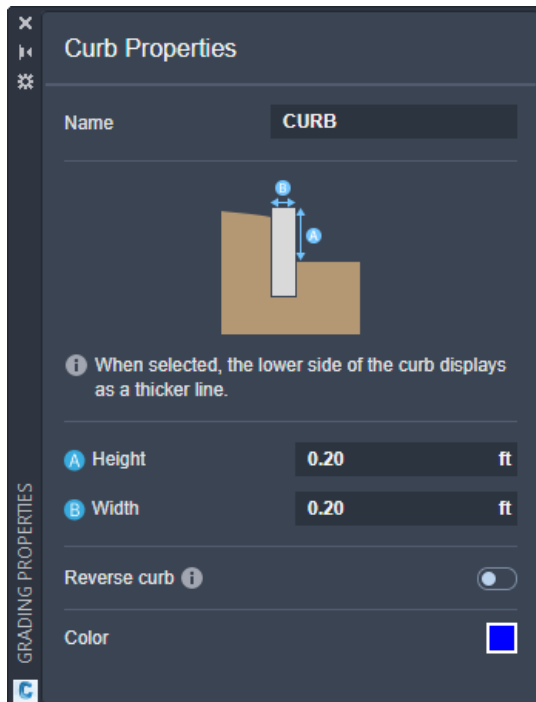
- Name:** ACCESSIBLE PATH
- Slope Constraints:**
  - ☐ Use global constraints 
  - ☒ Customize slope constraints 
  - ☐ No slope constraints 
- Max slope:** 2 %
- Min drain slope:** 1 %
- Aligned surface:** ☒
- Exclusive drainage:** ☒
- Minimum zone inclination:** ☒
- Depth of material:** 1.50 ft
- Breakline:** ☒
- Grading limit:** ☐
- Follow global grading objectives:**
  - Balance cut and fill:** ☒
  - Minimize earthwork:** ☒
  - Smooth surface:** ☒
- Color:** 

Note:

- Must be closed geometry.
- The Accessible Path zone has the following object properties enabled: Slope and Breakline.

## Curb

Curb grading object will break the terrain along the curb geometry and step the terrain at a specified height and width. The curb grading object optimization constraints can be applied to a AutoCAD 2D polylines, 3D Polylines, and/or feature lines.



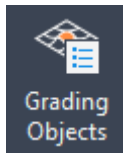
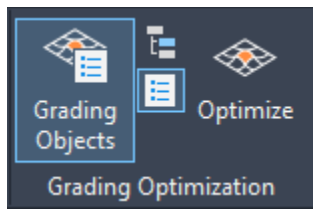
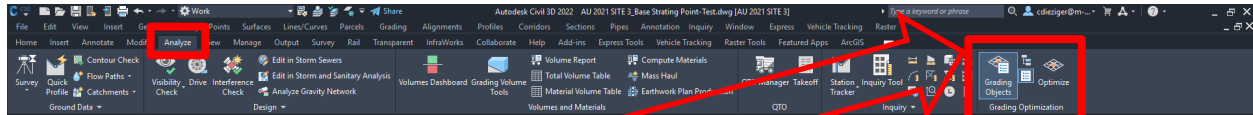
Note:

- Can be open or closed geometry.
- Open geometry creates curbs.
- Closed geometry creates islands.
- Closed geometry will step the curb up toward the inside of the geometry.
- Open geometry will step the curb up on one side, but the curb may need to be manually reversed. The side the curb steps on is based on the direction of the line was drawn.
- When the curb grading object is selected the lower side of the curb **1** is the lighter thicker (shaded) displayed line and the darker thinner line is the upper side of the curb **2** as shown here.



## GO User Interface (within C3D)

The GO User Interface (UI) within in C3D is relatively simple and easy to use. Commands and features from AutoCAD and C3D are still used. Grading object properties are applied to objects like lines, polylines, points, 3D polylines, hatch, feature lines, parcels, and COGO points. The GO UI tools with in C3D are found on the Analyze tab of the C3D ribbon on the Grading Optimization panel, as shown below.



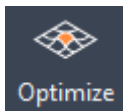
Grading Objects Button – Opens and closes the grading objects tool palette and grading object browser



Grading Object Browser Button – Open or closes the grading object browser




Grading Object Tool Palette Button – Open or closes the grading object tool palette

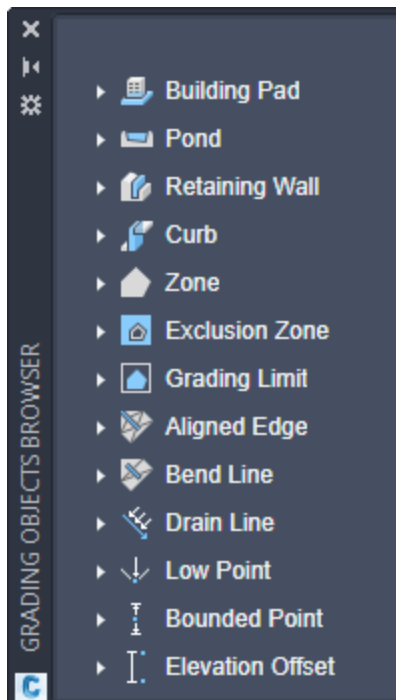


Grading Optimize Button – Launches the Grading Optimization program


## Grading Object Browser (within C3D)

Use the grading object browser button  found on the grading object panel of the Analyze tab of the C3D ribbon to navigate, select, and manage available grading objects data in the current drawing.

Grading object browser display:

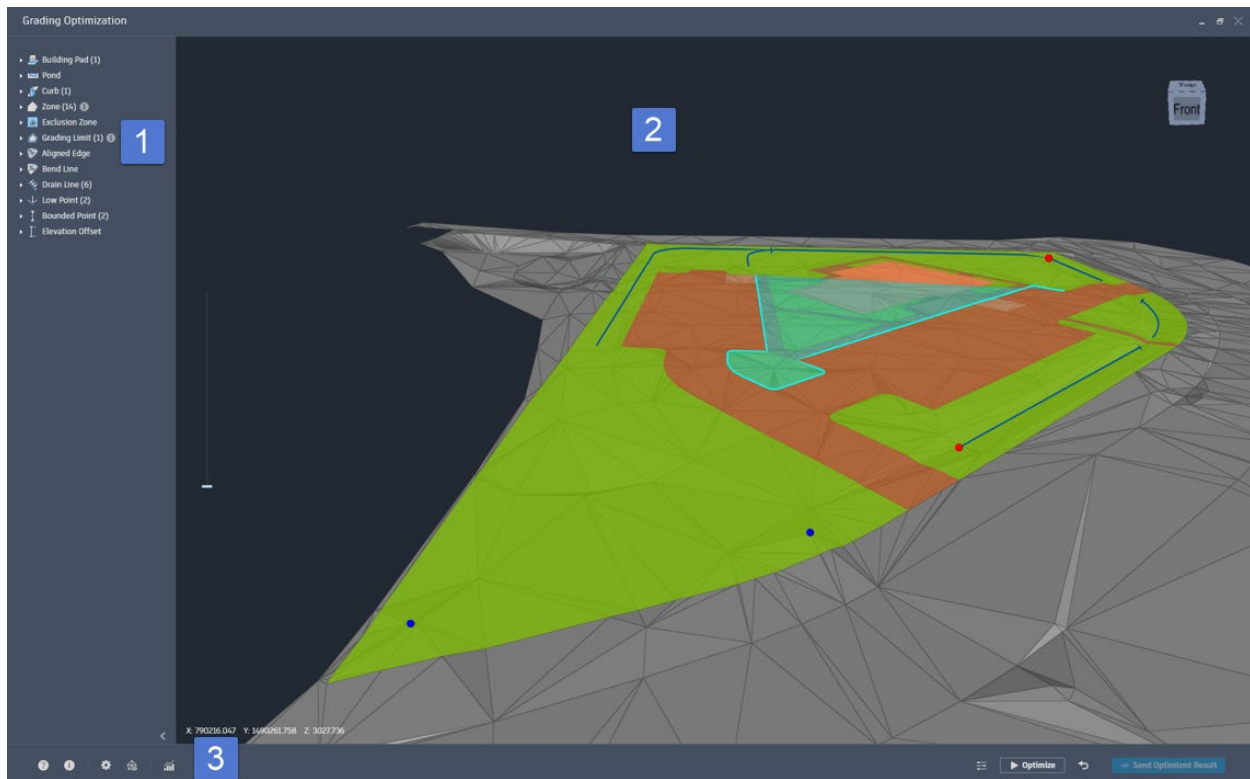


## Grading Object Tool Palette

Use the grading object tool palette button  found on the grading object panel of the Analyze tab of the C3D ribbon. Select "Grading Object tools" from the palette to add grading data to existing geometry and prepare it for optimization. These tools are described in the previous section, Grading Optimization Grading Objects.

## GO User Interface

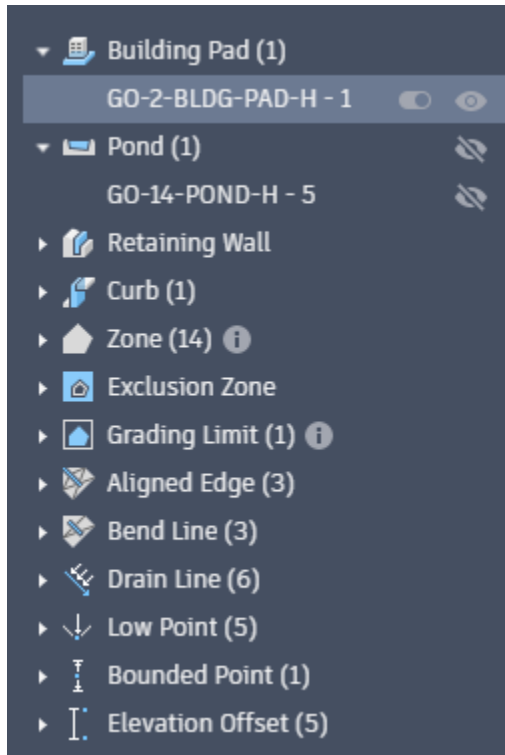
The GO UI has three basic areas: the Grading Objects Browser, the Visualization Display and the Optimization Toolbar.




1. **Grading Objects Browser** - This tree directory categorically displays each object tagged from the drawing. Selecting a grading object will display the currently specified constraints assigned to it.
2. **Visualization Display** - This is the viewing area for the optimized grading data. Several display themes are available to view the surface during and after optimization. The slide to the left of the display exaggerates the contours of the surface to help view subtle changes in elevation.
3. **Optimization Toolbar** - This bottom band of tools allows you to specify global constraints, mesh and triangle quality, visualization options, and convergence plotting views. Once everything is specified, click Optimize to begin the process.


## Grading Object Browser

The grading object browser is found as shown in the previous figure and noted as 1. This tree as stated previously is used to manage the grading objects in GO. You can select, activate, inactivate, display, turn off display, and list the grading objects within the drawing active in GO as shown below. Note the number in parenthesis next to the grading object type indicates the number of grading objects of that type in the active GO drawing.




 - Indicates that the grading object is turned to not active.

 - Indicates that the grading object is turned to active.

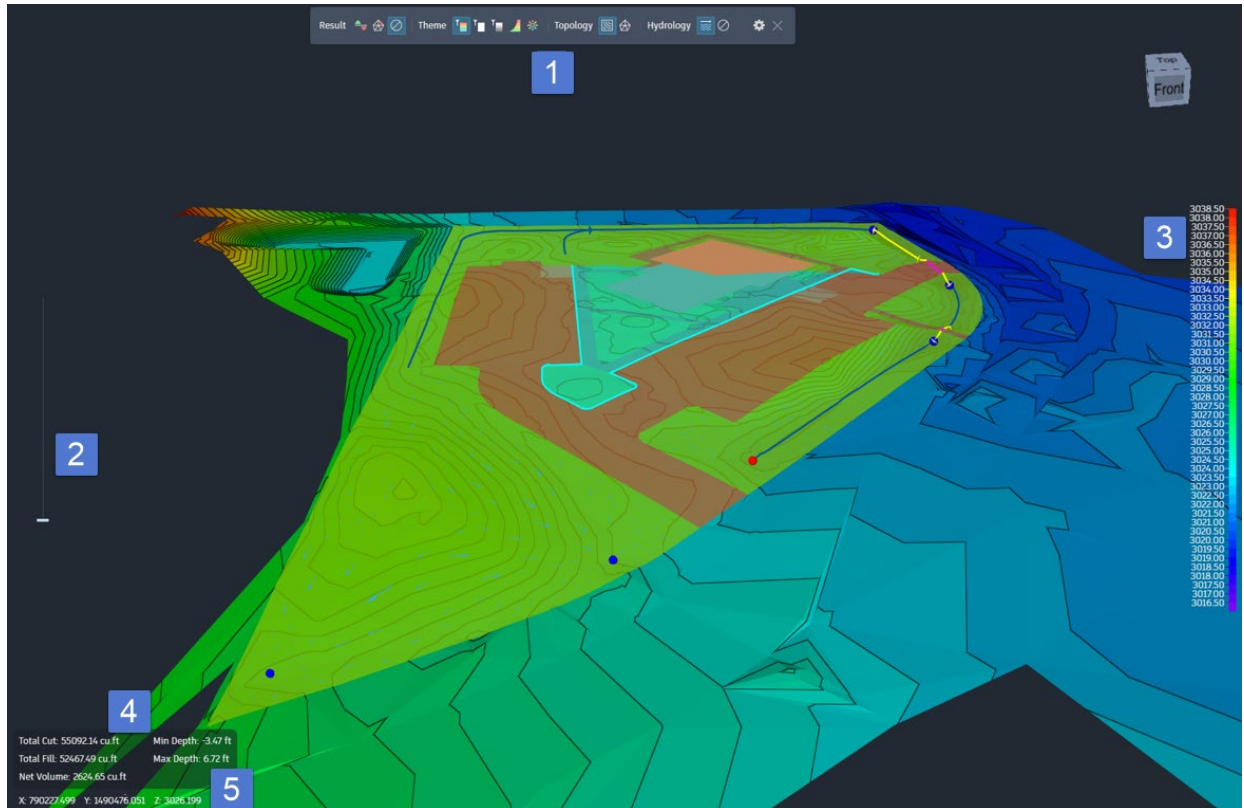
 - Indicates that the grading object is set to not be visible.

 - Indicates that the grading object is set to be visible.

 - Click to expand or collapse the grading object browser tree.

## Visualization Display

This is the viewing area for the optimized grading data. This provides feedback when modeling and when the optimization is in progress.









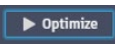
1. **Visualization Toolbar** - Several display themes are available to view the surface during and after optimization. Defined in the upcoming sections.
2. **Vertical Exaggeration Slide** - The slide to the left exaggerates the elevations of the surface to help view subtle changes in elevation.
3. **Legend Bar** - The bar to the right displays the color depictions of the different ranges of information in each visualization. These can be modified in the Visualization Settings dialog.
4. **Optimization Status** - This status window displays the current surface data during the optimization process.
5. **Cursor Position** - The XYZ surface coordinates of the position of the cursor.

## Optimization Toolbar


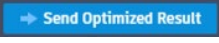
This toolbar helps you visualize and monitor the optimization process.




1.  **Help** – Displays the online documentation and other resources to assist you in GO.
2.  **About** – Displays the About dialog for GO as shown below.

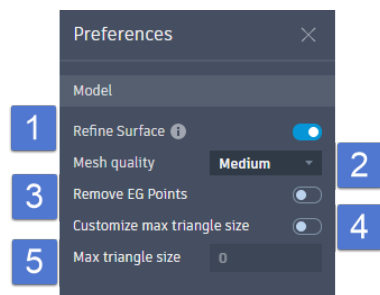
The 'About' dialog box is a dark grey window with a title bar that says 'About' and a close button. The main content area contains the text: 'Autodesk® Grading Optimization for Civil 3D® 2022 © 2021 Autodesk, Inc. All rights reserved.' followed by 'Product version: 1.1.3.12'. Below this is a paragraph about the license agreement with a link to 'here'. There is a 'Privacy' section with a link to the 'Autodesk Privacy Statement'. At the bottom, there is an 'Autodesk Trademarks' section and two buttons: 'Manage License' and 'OK'.
3.  **Model Settings** – Opens the preference dialog for GO. Defined in the upcoming sections.
4.  **Visualization Toolbar** – Opens the toolbar at the top of the visualization display in which you select themes, hydrology and topology options for the optimization. Defined in the upcoming sections.
5.  **Convergence Plots** – Opens the convergence plots dialog in which you can monitor the active optimization feasibility, cut/fill volume, and terrain smoothness. Defined in the upcoming sections.
6.  **Optimization Options** – Opens the optimization options dialog in which you can specify global slope constraints, optimization iterations, and objective weights. Defined in the upcoming sections.
7.  **Optimize** - Starts the optimization process. Click Stop to end the optimization.



8.  **Reset** - Resets the optimization to its beginning state.
9.  **Send Optimized Result** – Updates the source drawing with the optimized surface grades, feature lines, and points. Defined in the upcoming sections.

## Model Settings

Click  **Model Settings** on the Optimization Toolbar to open the Preferences dialog. Use the Preferences dialog to specify surface geometry rendering settings.




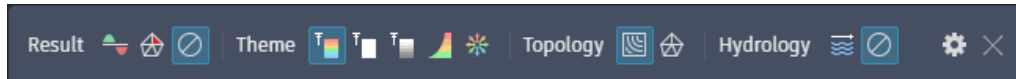
1. **Refine Surface** - Provides better surface triangulation optimization while decreasing performance in processing time. It is recommended to deselect this if you are only testing constraint settings.
2. **Mesh Quality** - Specifies the triangle mesh rendering quality for the surface. Select either Low, Medium, or High.








Note:






- Low emphasizes performance. This is recommended for testing current grading object configurations.
  - Medium prioritizes a balance of performance and surface quality.
  - High emphasizes surface optimization quality. This will likely take longer to optimize.
3. **Remove EG Points** – When enabled, the original Existing Ground (EG) triangles are removed and will retriangulate before optimization begins.
  4. **Customize Max Triangle Size** - Select to enable the Max Triangle Size setting.
  5. **Max Triangle Size** - Specifies a maximum length constraint for the three triangle edges.

## Visualization Toolbar

To open it, click  Visualization Toolbar on the Optimization Toolbar. The visualization toolbar is used to change the way you view your surface.

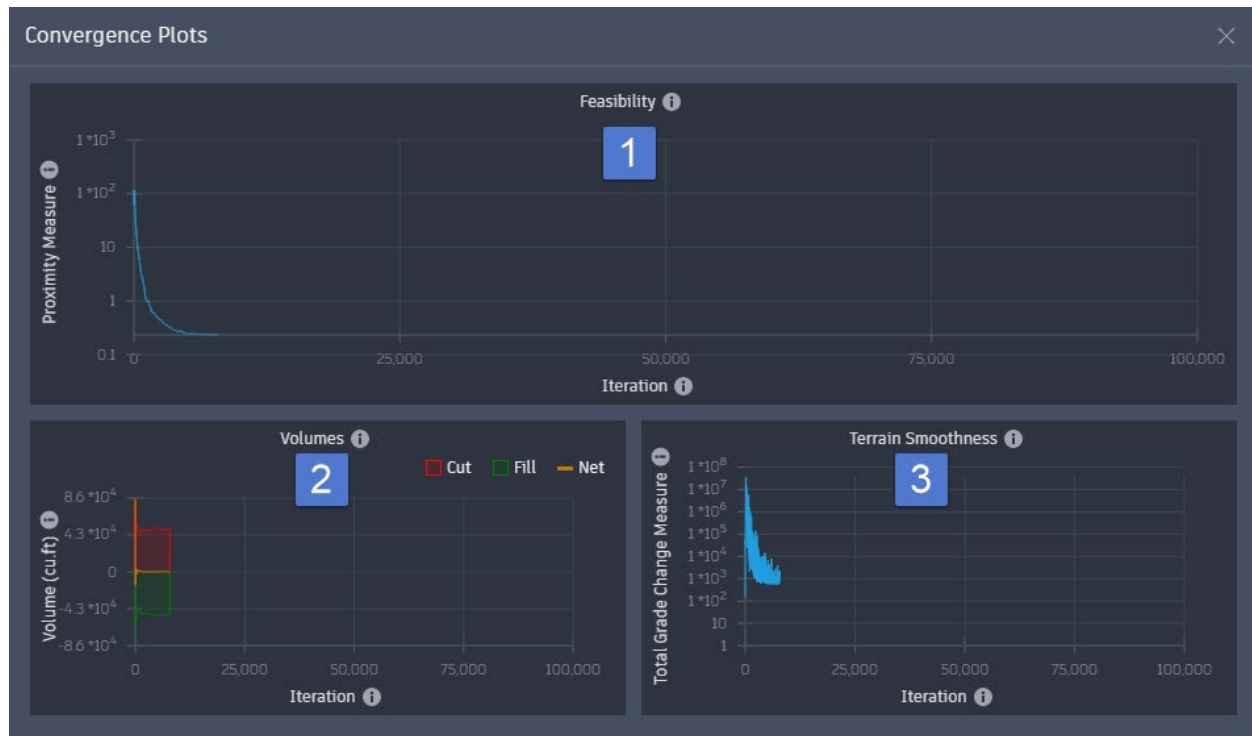


- **Result** - The Result views visualize specific data for analysis. When using Result views, you will not be able to select a theme or topology. To use Themes and Topology, you will need to disable Result views by selecting  none. There are 2 Result styles Cut-Fill and Violations.
- **Cut – Fill**  - Displays the surface triangles as either cut or fill in the optimization process. This visualization shows the degree of earthwork that will be involved. Surface triangles in a cut area are shown in red. Triangles in a fill area are shown in green. Colors darken the more the surface elevation changes. Gray triangles represent no elevation change.
- **Violations**  - Displays triangles that are not yet optimized to meet the constraints and objectives of the project in either maroon or red. Place your cursor over a maroon or red triangle to see the violation data.
- **Theme** - displays the surface by coloring the surface triangles based on specific traits: elevation, slope, or direction. Theme can use either Topology option. There are 5 Theme styles Elevation, Constant, Grayscale, Slope, and Aspect.
- **Elevation**  - The surface triangles in an Elevation view are color-coded by elevation. Purples represent the lowest elevation and reds represent the highest elevations.
- **Constant**  - The surface triangles in a Constant view are a monotone gray, regardless of their elevation. This view is useful for viewing contour and wireframe lines during optimization.
- **Grayscale**  - The surface triangles in a Grayscale view are color-coded by elevation. Black represents the lowest elevation and white represents the highest elevations. The grays get progressively lighter as elevation increases. Grayscale is useful when the contrast in elevation is necessary.
- **Slope**  - The surface triangles in a Slope view are color-coded by the percentage of their slope. You can change the number of ranges, their percentage weights, and colors, in the Visualization Settings dialog.

- **Aspect**  - The surface triangles in an Aspect view are color-coded by the direction of their slope. It uses a color-coded compass rose to represent the slope direction of the surface triangles where north is yellow, east is blue, south is purple, and west is red. Colors blend evenly around the compass.
- **Topology** - Topology specifies how the surface lines should be viewed in your selected theme. Select either Contours or Wireframe. There are 2 Topology styles Contours, and Wireframe.
- **Contours**  - Contours mark elevation changes of the surface. They can be applied to any theme. You can change the base elevation and the intervals of contours in the Visualization Settings dialog.
- **Wireframe**  - Wireframes display the surface triangles along the surface. They can be applied to any theme.
- **Hydrology** - Hydrology applies drainage visualization to your Result or Theme view. Disable Hydrology by selecting  None. There is one theme for Hydrology, Direction Vectors.
- **Direction Vectors**  - Direction Vectors overlay surface triangles with arrows showing the intended drainage direction of each triangle. The arrows are orientated toward the closest Drain Line or the closest Low Point.

## Convergence Plots

The Convergence Plots dialog allows you to visualize the overall progress of in progress optimization. This is helpful to identify possible unsolvable issues before optimization is complete. Optimization can take some time, so detecting and correcting potential constraint problems allows for a more efficient workflow. The Convergence Plots are displayed in 3 different charts, Feasibility Chart, Volumes Chart and Terrain Smoothness Chart.



1. **Feasibility Chart** - Displays the progress of optimization in relation to constraints placed on the grading objects. The progress line should trend downward and ultimately toward zero. How the line trends can hint at possible issues. It is charted in Proximity Measure which represents progress toward a potential optimization solution shown on the Y axis and Proximity Iteration which is the number of iterative attempts allocated for optimization processing shown on the X axis.
2. **Volumes Chart** - Displays a visual reference for the earthwork required from the optimization and the progress of maintaining the assigned cut/fill weighted objectives. It is charted in Volume represents the volume of earth displaced. Measures above zero are represented with a red line. Measures below zero represent fill and are represented by a green line. The yellow line represents the net earthwork volume. This is shown on the Y axis. The other measurement is Volume Iteration number of iterative attempts allocated for optimization processing. This is shown on the X axis.

Note:

- You can adjust the cut/fill (balance and minimum) objectives in the Optimization Options dialog opened from the Optimization Toolbar.

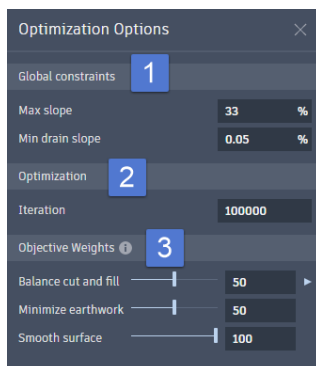
3. **Terrain Smoothness Chart** - shows the fluctuating progress of grade minimization during optimization. It is charted in Total Grade Change Measure. Which is the measure of the relative grade changes between adjacent triangles. As the triangles are brought together and attempt to be planar, the smoothness of the surface improves. This is shown on the Y axis. The other measurement is Grade Change Iteration which is the number of iterative attempts allocated for optimization processing. This is shown on the X axis.

Note:

- You can adjust surface smoothing in the Optimization Options dialog opened from the Optimization Toolbar.

## Optimization Options

Use the Optimization Options dialog to specify objectives for the Grading Optimization to work toward while maintaining the constraints of the grading objects. Leveraging these tools and the Convergence Plots dialog, you can evaluate the results of the optimization and make changes to the grading object properties or the grading objectives to achieve different results when optimizing. The Optimization Options control 3 different areas, Global Constraints, Optimization, and Objective Weights.



1. **Global Constraints** – These are globally applied constraints unless overwritten when a triangle lies within a grading object zone with different Min Drain Slope and Max Slope settings.

- Max Slope - Specifies the maximum allowed slope value as a percentage for any surface triangle. 33% is the default value based on the typical maximum allowed 3:1 slope in a grassed area.

- **Min Drain Slope** - Specifies the minimum required drainage slope as a percentage for any surface triangle. The direction of the drainage is determined by Drain Lines and Low Points.
2. **Optimization** – Is where you can specify the number of iterations the optimization will run attempt before it stops. If a solution is found within the tolerance parameter, it will stop before it reaches the maximum iterations. The Feasibility chart in the Convergence Plots dialog graphs the progress and errors at each iteration. You can stop the optimization before the maximum number of iterations is achieved.
  3. **Objective Weights** - The following parameters represent the three core grading objectives that are targets for optimization. The weights are applied as a percentage to reach the targeted objective. Zero means the objective is not considered, all other values are weighed against the values of the other constraints to proportionally consider more than one objective.
    - **Balance Cut and Fill** - Specifies the weight (0-100) with which to minimize the difference between total cut and total fill. You can also specify a target net earthwork volume from zero to a specific volume amount.
    - **Minimize Earthwork** - Specifies the weight (0-100) with which to minimize the total amount of earthwork (the sum of total cut and total fill). This tries to not raise or lower elevations unless constraints or other objectives require it.
    - **Smooth Surface** - Specifies the weight (0-100) with which to minimize the grade change between adjacent triangles on the surface. This effect smooths a surface.

## Preparing your Drawing for GO

Grading Optimization has an integrated workflow with Civil 3D. All surface grading related objects are sketched with Civil 3D commands onto your existing drawing containing a TIN surface. Once sketched, Grading Optimization grading objects are then applied to the geometry.


Some of these objects likely already exist in your project, such as building pads, parking lots, and ponds. The existing geometry can be used to apply grading objects. However, some of the more conceptual objects will need to be planned and sketched such as Drain Lines, Low Points, Zones, and Elevation Offsets. The objects influence the Grading Optimization and can simplify problematic areas.

Once applied, the grading object data is added as a property set to your drawing geometry.

From Civil 3D, open the drawing in Grading Optimization where the grading object properties are translated into location-based constraints that are the building blocks for the grading configuration.

## Placing Grading Objects

You place grading objects by assigning them to Civil 3D drawing elements. Once assigned, the grading object information is saved as Property Sets in the drawing.

1. Open your prepared drawing.
2. Open the Grading Object Tools Palette from the Civil 3D ribbon Analyze tab>Grading Optimization panel> and select the  Grading Object Tools button.
3. Select the Grading Object you wish to place from the Grading Object Tools Palette.
4. Select the AutoCAD or Civil 3D object you wish to apply the grading object to. This will activate the properties dialog box for the type of Grading Object you are applying.
5. In the Grading Object properties dialog box you will be prompted to either take the default value or the value for each of the Optimization Constraints or Optimization Objectives for the Grading object you are placing.
6. Continue steps 3 to 5 for each additional Grading Object you wish to place.


Note:

- You can pick multiple AutoCAD or Civil 3D objects at one time and then select the Grading Object to apply to them all at once from the Grading Object Tools Palette. This will then allow you to apply the same values for the Grading Objects Optimization Constraints or Optimization Objectives at the sametime.
- You can copy and place costumized Grading Objects on the Grading Object Tools Palette. This will allow you to save tools with the values of the Grading Objects Optimization Constraints or Optimization Objectives as default for easy placement in the future.
- To remove a grading object from a drawing and maintain the geometry, select the object in the Grading Objects Browser, right-click it in the drawing area, and select Remove < object >. Press and hold Ctrl to select multiple objects. This removes property sets from the geometry.
- You can change the values of a existing Grading Objects Optimization Constraints or Optimization Objectives. This is done by either selecting the Grading Object in the drawing or from the Grading Objects Browser. Once selected the Grading Objects properties dialog box opens and allows you to make changes. You can also change multiple Grading Objects at once by simply selecting multiple Grading Objects of the same type or by holding the Ctrl key by selecting multiple Grading Objects from the Grading Objects Browser.
- Geometry cannot intersect with itself to be an eligible Grading Object.

- Grading Objects can be combined by either duplicating a Grading Object and assigning another Grading Object to the duplicate, or by making a point and the end of a line common. For example you can use an Aligned Edge Grading Object with a matching Elevation Offset Grading Object. This will control the fall from one end of the Aligned Edge Grading Object. Another example is to set a Bounded Point Grading Object at end of a Drain Line Grading Object to control the end elevation of the Drain Line Grading Object.

## Starting GO

Starting GO is done from Civil 3D once you are ready to either begin the optimization process or to test how a grading object will work.

1. Open the drawing in Civil 3D with the Grading Objects you have defined and the Surface you wish to Optimize.
2. From the Civil 3D ribbon Analyze tab>Grading Optimization panel> and select the  Optimize button, to activate GO.
3. GO will now be open with the Civil 3D surface to optimize and the Grading Object defined in Civil 3D.


Note:


- Changes made to grading objects in Grading Optimization will be updated in the Civil 3D drawing.
- If you close Grading Optimization or Civil 3D before sending the results to the drawing, optimization updates to the surface will be lost.




## Review the Optimization Settings

There are three types of optimization settings that you can use to adjust to best optimize your grading project: model settings, global constraint and objective defaults, and visualization settings. Review each of these before moving forward on new projects.

Model Settings can be accessed for review by selecting the Model Settings button  from the Optimization Toolbar in the lower lefthand corner of the GO interface.

Global Constraint and Objective Defaults can be accessed for review by selecting the Optimization Options button  from the Optimization Toolbar in the lower righthand corner of the GO interface.

Visualization Settings can be accessed for review by selecting the Visualization Settings button  from the Visualization Toolbar on the far right of the toolbar in the GO interface.

## Reviewing Grading Object Constraints

Prior to starting the surface optimization in GO it is recommended that you review the Grading Object Constraints. This is done from the Grading Objects Browser and the Visualization Display within GO.

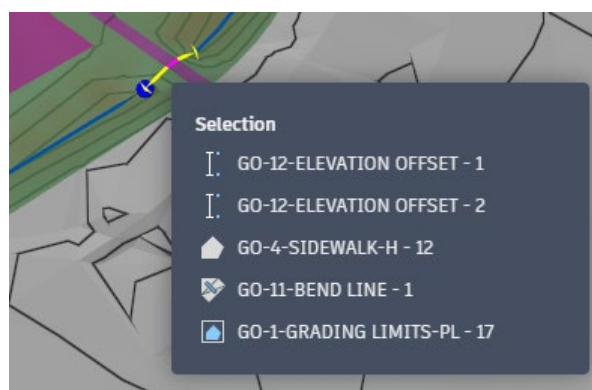
1. Select the Grading Object in which you want to review the Object Constraints in one of two ways:
  - Select the Grading Object geometry in the Visualization Display.
  - Select the Grading Object in the Grading Object Browser.
2. Once selected the appropriate properties dialog will display.
3. Review the constraint settings, keeping in mind that they may override others, including the global slope constraints.
4. Verify your drainage objects are pointing the flow in the correct direction. Checking that all exclusive drainage zones affecting the planned flow.
5. Check that the Zone priority list is in the correct order.
6. Make any changes needed.
7. Accept any changes made.

## Note:

- You can temporarily disable any grading object if you want to run an optimization without its influence. You can disable objects or object types in the Grading Objects Browser. Expand the browser to the grading object you want to disable and place your cursor over it. Select the Disable icon to disable it. Select it again to enable it.




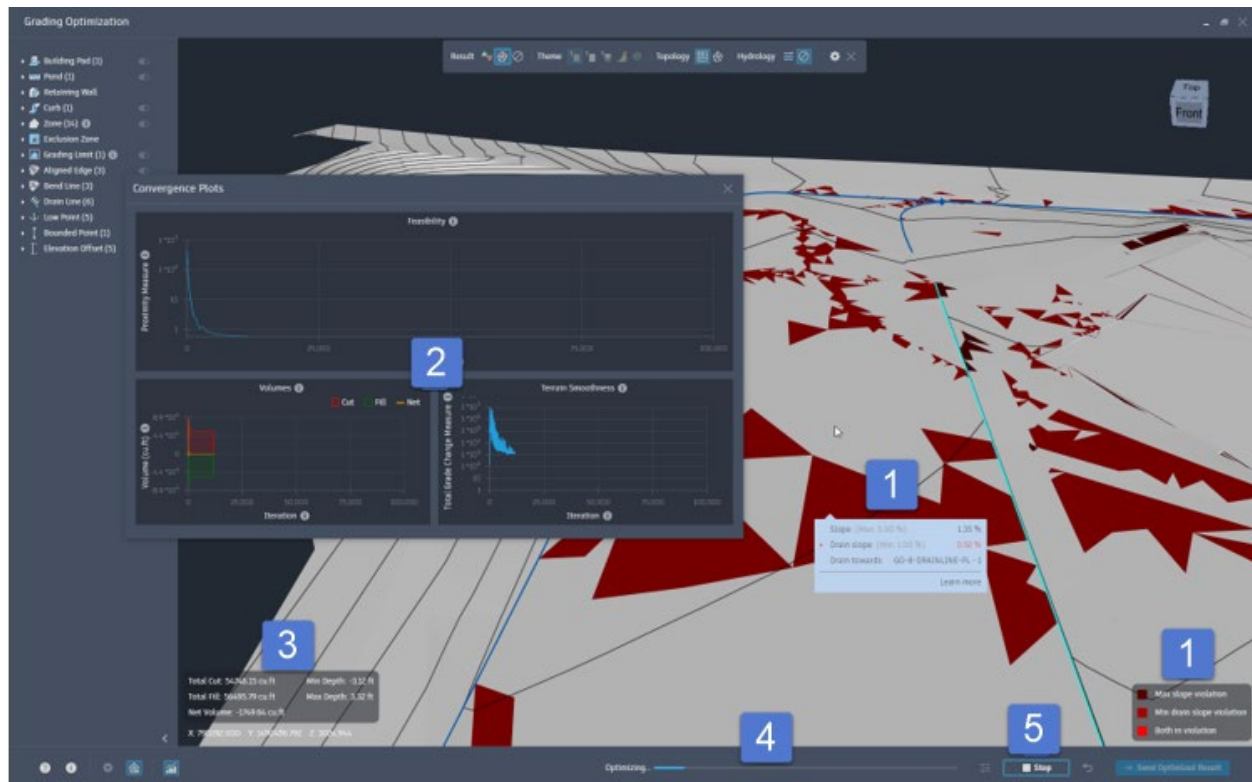
- You can not move or delete grading objects in Grading Optimization. You must go back to the source drawing and change or reposition the geometry and then return to optimize.
- Hydrology display can be on with either the results surface display or the theme surface display. It is important to understand that this display is showing the intended drainage flow direction and not the current or actual direction of flow. I have found this display to be a great way to show that I have my grading object set correctly and that they will be draining to the correct location.
- If not sure which grading object is in the Grading Object Browser, you can select it from the model. If there is more than one grading object in that area and you are having trouble selecting the grading object you want. You can select close to it and if you did not get the right grading object you can right click to have it display a list of grading objects in that area to select. Select the grading object you want from that list to activate the properties of the selected grading object.



## Running Optimization

After you have reviewed the Grading Object Constraints you should be ready to begin running the optimization of the surface.


1. To start the Grading Optimization select the Optimize  button from the right side of the Optimization Toolbar.
2. Once the Grading Optimization is started GO will do most of the work. All you need to do is use the visualization tools and the convergence plots to determine what is going on with the optimization.




1. You are looking for the violations to minimize and to meet your satisfaction that the remaining violations are ones that you can justify as being close enough or ones that you feel that you can adjust out once brought back into Civil 3D.




Note:

- There is a legend in the lower righthand corner to help identify the violation. Also by holding your mouse pointer over the area of the violation you will be given feedback to what the violation is.

2. The Convergence Plots is also giving feedback to the status of the optimization process. It gives you feedback to the volume and terrain smoothness. Along with the Feasability graph at the top of the dialog box. Which is telling the amount of changes that are needed to be made at that point in the iteration process. So you are looking for that graph to flatten out like you are seeing in the image. If it does not that will be telling you that the constraints being used need to be adjust or changed to for this to be solved.
3. There is a running cut and fill balance, and minimum/maximum depth feedback in the lower lefthand corner.
4. There is an Optimizing status bar to show you the progress to the maximum number of iterations set for the surface optimization. This is found at the bottom of the screen.
5. When you are satisfied with the surface optimization or feel that it has reached a result that it can no longer improve upon, you can stop the the optimizing by selecting the Stop  button in the lower righthand corner.

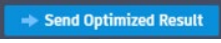
Note:

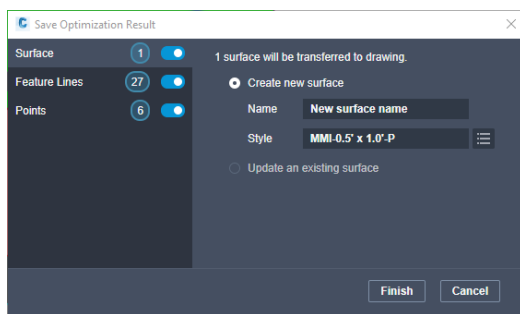
- You can also set the visualization to show cut and fill, to contours or wireframe (triangles), and whether to show the hydrology. All of these options are there to help visualize how the optimization of the surface is progressing. These all can be accessed from the Visualization Toolbar at the top of the screen when turned on from the Optimization Toolbar at the bottom of the screen. I recommend that you try other visualization options during the optimization process to find which one works best for you and your current project. The example I gave in this handout is what I tend to fall back on using the majority of the time but we all think differently so find what works best for you by testing the other options.
- You can either display the surface results or a surface theme at one time. The surface results visualization display options are cut and fill and violations. The surface theme visualization display options are elevation, constant, slope, and aspect. To apply any of the theme visualization options you must first turn off the results visualization display by selecting the none  button from the result area on the Visualization Toolbar. To see the results display again select either the cut and fill display button or the violation display button on the Visualization Toolbar. This will turn off the theme display option automatically.

- When using the cut and fill results visualization display I have found that it displays better if all the zones are turned off. The 5 types of grading objects that representative of a zone are Building Pad, Pond, Zone, Exclusion Zone, and Grading Limits. The visibility of these grading objects can be toggled by selecting the visible  button next the grading object type in the Grading Object Browser. The visible  button when set to display object will only show in the Grading Object Browser when you mouse pointer hovers over it. If turned off the visible button will show like this  and continue to show until it is selected to turn the grading objects back on.
- You do not need to wait for the optimization to complete to stop it. You can stop it at anytime. I rarely allow it to complete all the iterations I have set it to run through. You will often find that even if the optimization process is not yet complete, the results of the optimized surface may not differ much, if at all. The ability to determine this will come with time and experience.
- If you stop the optimization prior to completing, you can start the optimization again without sending it back to Civil 3D or making a change to a grading object. However, whether you have made a change or not, the optimization will start again from the point the surface was prior to the interrupted optimization.
- If you want to further optimize a surface that has been optimized you must first send it to Civil 3D and then select it to be the surface to optimize when sending it back to GO.
- Hydrology display can be turned on with either the results surface display or the theme surface display. It is important to understand that this display is showing the intended drainage direction and not the current or actual direction of flow. I have found that this view is most helpful while checking the grading objects settings. Try it during the optimization process and see for yourself. We all see and think a little differently so it may be helpful for you.

## Sending the Optimized Surface Results Back to the Civil 3D Source Drawing

Once a satisfactory optimization has been calculated, the updated geometry and TIN surface data can be sent back to the source drawing.

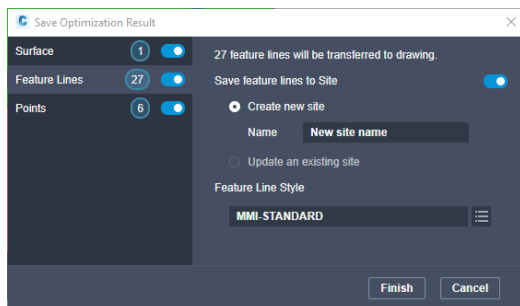
1. Click Send Optimized Result  in the Optimization Toolbar. The Save Optimization Result dialog opens.
2. Select Surface if you want to send the optimized surface back to your drawing, then do one of the following:



- Select Create New Surface, name it, and select its surface style
- Select Update an Existing Surface and specify the surface to be overwritten.

Note:

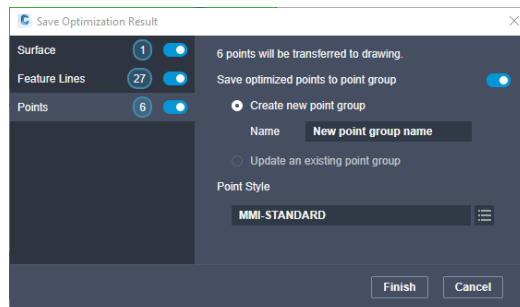
- Surface styles and updatable surfaces are determined by the source drawing.
3. Select Feature Lines if you want to send any feature lines created in the optimization process back to the drawing. If so, select Select Save Feature Lines to Site and do one of the following:



- Select Create a New Site, name it, and select a feature line style.
- Select Update an Existing Site and specify the site to be overwritten.

Note:

- Feature line styles and sites that can be updated are determined by the source drawing.
4. Select Points if you want to send any points created in the optimization process back to the drawing as a point group. If so, select Save Optimized Points to Point Group and do one of the following:



- Select Create New Point Group, name it, and select a point style.
- Select Update an Existing Point Group and specify the point group to be overwritten.

Note:

- Point styles and point groups that can be updated are determined by the source drawing.
5. Click Finish. This will make the additions to the C3D drawing that started the whole process.

Note:

- The optimized surface sent back to C3D is the full area of the original surface sent to GO. It is not limited to only the altered triangles.
- If you close Grading Optimization or Civil 3D before sending the results to the drawing, optimization updates to the surface are not saved.
- If Grading Optimization is run again, you can choose to either start with the original EG surface or with this new optimized surface. If you start with the optimized surface, the earthwork cut and fill values will be relative to this optimized surface and not the original existing ground surface.
- The feature lines imported from the optimization process can be modified and used to help refine the grading surface.

## Conclusion

While there has been a lot covered within this handout, there is much more to GO. At a minimum, I hope this discussion will start you down the right path using GO for your grading projects. This being the first release of GO, many additions and changes to this tool are likely. This is important to understand moving forward. In a lot of ways its workflow mimics the same one I would use on paper or in Civil 3D to design my grading project. The difference is that GO can go through thousands of iterations and far quicker than a designer can do it traditionally. That is the greatest advantage to using GO. It is not meant to replace the designer; it is meant to help a designer be more efficient.

When using this tool do not be afraid to try things, even in ways for which they may not be intended. If you think there is something this tool is missing or you would like to see changed don't be afraid to share your thoughts with me or with the Autodesk forums. It may even be added or changed in future releases.

Thank you for allowing me to share my thoughts and experience with you on the GO tool. I look forward to hearing your views, questions, and successes with this great new tool.