INTRODUCTION
This chapter introduces the surface object. A surface is a triangulated or grid data net and represents a surface’s elevations and slopes. Surface data can be points, nodes, and vector objects, Civil 3D cogo point objects, polylines, contours, boundaries, and breaklines. The various surface menus provide tools to create, edit, evaluate, and annotate surface components and characteristics. Surface styles are task orientated, allowing a user to evaluate a surface as it is being built, and to evaluate its slopes and its elevations.

OBJECTIVES
This chapter focuses on the following topics:

- Basic Surface Settings
- Overview of Surface Objects and Their Label Styles
- Surface Data Types
- How to Evaluate and Edit a Surface
- How to Analyze Slope and Elevation Characteristics
- How to Develop and Assign a Contour Style
- How to Annotate Surface Slopes and Contours
- How to Smooth a Surface
- How to Create Point Objects from Surface Elevations

OVERVIEW
A surface is fundamental to the civil design process. If surface errors or data misinterpretations are not caught early, they may have grave consequences in the following design phases. It is important that a surface be an accurate data interpretation.
To help understand if a surface correctly interprets its data, displaying specific surface components is invaluable. Displayable surface components are triangle legs, points, borders, boundaries, contours, elevations, slope arrows, etc. In this textbook, surface components are surface border(s), triangles, points, and boundaries. Surface characteristics are relief, water flow (drainage), watersheds, or slopes, and slope directions. The surface object and its label styles display these components and analyze and annotate surface characteristics.

The just-mentioned characteristics influence design strategies and present challenges to each designer. These challenges include how best to define land use, create site access, manage water runoff, or develop manageable earthwork volumes. The solutions applied to the site are in response to these challenges and the solutions may require compromises between cost and best design practices.

To create usable project surfaces, develop a consistent process to produce “good” surfaces (i.e., correct data interpretation). The process includes gathering and evaluating initial data, evaluating each surface build’s results, finding and editing errors, analyzing surface characteristics, and, finally, annotating the surface.

Developing consistent surfaces takes seven steps, ranging from using meaningful surface names to documenting everything correctly. The steps occur in related menus or selected object’s shortcut menus. However, Prospector’s Surfaces shortcut menus display the majority of the needed commands. These commands create, edit, analyze, and annotate surface components and characteristics.

Civil 3D has two terrain surface types: TIN (Triangular Irregular Network or Digital Terrain Model [DTM]) and Grid. A TIN connects all surface data with triangle legs and there is a known elevation at each leg’s end. A Grid surface is a mesh structure that has elevations at the mesh’s intersections. These elevations are generally interpolated values, not known elevations. A DEM (Digital Elevation Model) is an example of a grid surface.

Civil 3D has two volume surfaces types: TIN and Grid. A volume surface’s structure is the same as a TIN or Grid terrain surface; however, the differences in elevation between two terrain surfaces are its elevations. An earthwork volume is a volume surface property.

SEVEN SURFACE STEPS

- Create the surface object.
- Collect and assign initial point data.
- Add Contour data and/or breaklines to control triangulation in known problem areas.
- Evaluate resulting triangulation.
- Use a Maximum triangle length, Edit (add, delete, modify) the surface triangles, points, breaklines, and/or add boundaries.
- Analyze the surface components and characteristics.
- Annotate the surface.

The first step is naming and setting a surface’s type. Prospector’s Surfaces heading shortcut menu (Create Surface…) or the Ribbon’s Surfaces command drop-list Create Surface… entries display the Create Surface dialog box (see Figure 4.1). Create Surface defines a surface type, assigns a layer, name, description, surface type, style, and render material.
After assigning a name, the next step is collecting the initial data. Surface data comes from diverse sources: drawing objects, Civil 3D cogo points, point files; contours; three-dimensional polylines; boundaries; and/or DEMs (Digital Elevation Models). No matter the data source, before assigning the data, review it for obvious errors and omissions. This is because Civil 3D automatically builds a surface from a data assignment.

Another reason for clean data is a surface does not allow crossing breaklines or contours. You can toggle this off and allow data crossings, but you risk destabilizing the drawing.

The order of assigning data is important. For example, adding point data outside a boundary makes a surface ignore the boundary, adding breaklines that cross contour data creates data exclusions, and adding point data after assigning contour data limits the points’ scope in the surface. The order of data assignment is as follows:

- Data Clip Boundary
- Points (Point Groups, Point Files, drawing objects)
- Breaklines and/or Contours (not crossing)
- Maximum Triangle Length, Edits, and/or Boundaries

You may have to remove contours from the breakline area to remove potentially overlapping data. If you toggle on, letting a surface have crossing data, you run the risk of destabilizing the drawing.

The third step is adding breaklines to known or obvious problem areas. If you are starting with point data, to correctly triangulate linear features, breaklines are almost always necessary. Examples of breaklines are edges-of-travelway, slope breaks, stream banks, swales, ditches, and other linear features.

Identify breakline areas by reviewing points with similar descriptions. If you are questioning a breakline’s necessity, there are a couple of options. Consult with the original
data source, and ask about the area in question. Or, after reviewing the surface and discussing the problem with someone, edit the surface to adjust its triangulation. Editing a surface creates the same effect as adding breaklines. Be sure to understand the consequences of adding new breaklines before editing a surface.

When do you add data, set a maximum triangle length, edit, or add a surface boundary? Some surfaces have lengthy peripheral outside triangle legs. If you can identify the shortest of these long triangles and its length is greater than the remaining surface triangles, setting a maximum triangle length may remove a majority of the unwanted triangles. If you cannot set a maximum triangle length and correcting a problem takes several edits, adding new data or breaklines is advisable. If you are making only a few edits, editing is the preferred method. However, a well-designed boundary may eliminate the need for edits.

Breaklines are either two- or three-dimensional polylines, survey figures, or feature lines. When using two-dimensional polylines as breaklines, the only condition is that a point object must be at each vertex. When using three-dimensional polylines, point objects are not necessary.

**Objects that are to become breaklines must be drawn before assigning them to a surface.**

The fourth and fifth steps review the initial surface triangulation. These steps should use surface-analysis styles that emphasize specific surface components and characteristics which indicate data problems. When completing these steps, it may be necessary to add data or continue editing.

After adding new data and/or editing a surface, the last two steps are to analyze surface characteristics (elevations and slopes) and create contours.

**Unit 1**
Several settings and styles affect surfaces. The first unit reviews and sets the default values.

**Unit 2**
The second unit reviews creating a surface, surface data types, and how Prospector manages surface data. Civil 3D builds the surface after each data addition.

**Unit 3**
This chapter’s third unit covers surface review and editing. There are several options that affect what data a surface uses and how it responds to editing. Surface-editing tools are in the surface’s Definition branch’s Edits shortcut menu. Surface styles are an aid because they display necessary surface components. For example, displaying triangulation and points is best when looking for incorrect triangulation, and seeing a 3-D surface model to view bad elevations.

**Unit 4**
The fourth unit reviews developing and assigning surface-analysis styles. Examples of these style types are displaying slopes as ranged values, down slope direction as arrows, and ranged elevations. These styles are displayed as 2D or 3D objects.
Unit 5
This chapter’s fifth unit reviews developing a contour style and setting its values for intervals, layers, and labeling. After reviewing the contours, it may be necessary to smooth the surface and to document their elevations.

Unit 6
The sixth unit discusses creating points and polylines with elevations from a surface. The Create Points toolbar provides these tools.

UNIT 1: SURFACE SETTINGS AND STYLES

The Edit Drawing Settings dialog box is the highest level of control for a drawing. The dialog box settings assign basic surface object and label layer names. Surface’s Edit Feature Settings dialog box controls three basic surfaces settings: default object and labeling styles; defines the surface name template; and sets the default surface type and its initial settings.

Surface styles determine how a surface displays its components and characteristics. Civil 3D’s content templates provide several starter object styles for these components and characteristics. The user creates custom object styles to reflect individual work assignments and information needs.

EDIT DRAWING SETTINGS

Civil 3D manages surface visibility through styles and/or by layers. The Drawing Settings’ Object Layer tab assigns a base layer name with an optional prefix or suffix (see Figure 4.2). C-TOPO is the default surface layer name. When having more than one surface and not changing the default settings, all surfaces are on the same layer, C-TOPO. This situation gives little control over each surface’s visibility except by assigning no display to each surface. To remedy this situation, assign a prefix or suffix to the surface’s base layer name. Use an asterisk (*) to assign the surface name to the base surface layer name. For example, create a base layer whose name is suffixed by a surface named EXISTING. First, set the Modifier to suffix and enter the value of -*. This creates a layer in the drawing of C-TOPO-EXISTING. The dash is a separator between the base layer name and the name of the surface. This naming convention creates a layer for each named surface.

The layers in the Object layer list tie the surface object to the drawing. When differentiating a surface into existing and proposed, you do this by assigning the appropriate object styles.
EDIT FEATURE SETTINGS
Surface Edit Feature Settings sets default styles and defines the surface-naming template. An object style defines how a surface displays its components and characteristics (triangulation, border, breaklines, points, slopes, and elevations) and shows all, one, or any combination of components and characteristics. One style-defining strategy is to create styles showing surface components and characteristics appropriate for an assigned task. While reviewing a newly built surface, the user’s interest is the surface’s triangulation, breaklines, boundaries, and points. While evaluating a surface for a preliminary design, the styles display surface elevations, relief, and slopes. With specific tasks, styles should emphasize critical surface components and characteristics. Displaying critical information helps make better decisions possible.

Default Styles
The Default Styles section sets object and the surface annotation styles (see Figure 4.3). The label style types include spot elevation, slope, contours (major and minor), render material, and triangulation markers.
Contour Labeling Defaults
This section sets the default contour label styles that appear in the Add Labels dialog box. The Display Contour Label Line value should be False. If visible, this line will plot. To display this line to relocate contour labels, select a label and the line will display with grips.

Surface Defaults
This section sets if automatic rebuild is on when defining a surface.

COMMAND: CREATESURFACE
The Settings’ Surface branch, Commands, CreateSurface sets default values for this command. The CreateSurface command dialog box has two sections: Surface Creation and Build Options.

Surface Creation
The Surface Creation section sets the default surface type, the surface name format, the grid X and Y spacing, and the grid’s rotation (see Figure 4.4).}

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**Build Options**
This section sets rules for building a surface: what data to exclude, the maximum triangle length, if proximity breaklines are to become standard breaklines, and how to handle crossing breaklines (see Figure 4.4). These values can be changed at any time.

**Copy Deleted Dependent Objects**
Copy Deleted Dependent Objects specifies whether a drawing object’s data is preserved in its surface definition after erasing the object(s). The default setting is “no” and assumes the original object(s) are always present in the drawing. When using the default value (no), if the data object is deleted, it is removed from the surface triangulation. If you want to preserve the original data’s effect even after erasing it, set this value to “yes.” When set to “yes” and you delete the original object, a copy of the object’s data is added to the surface’s definition and preserves its effect on the surface.

**Exclude Elevations Above/Below**
Exclude Elevations Less Than and Exclude Elevations Greater Than exclude data by setting a minimum and maximum elevation. If the elevation data is below the minimum or above the maximum, it is not included in the surface data.

A point with no elevation is not excluded with these settings.
Maximum Triangle Length
Maximum Triangle Length has two values. First is a toggle to turn this option on or off. Second is the triangle leg’s maximum length. This deletes sliver triangles along a surface’s periphery. With this setting off, a surface connects points even if there isn’t any data supporting the triangle leg. With the setting on and a value set, a surface removes any triangle legs longer than this length. If this value is too low, it may prevent interior triangles, and as a result create interior surface holes with boundaries. Only some surfaces can use this option. Generally, this option is good for surfaces with long peripheral triangles that are longer than any of the surface’s body triangles.

Convert Proximity Breaklines to Standard
When set to “yes,” and defining 2D breaklines, the proximity breaklines (2D) convert to standard breaklines (3D). The breakline vertices’ elevations are from the point’s elevation nearest to each vertex. The 2D object remains in the drawing and is listed as a Standard (3D) breakline. Inserting the breakline into the drawing produces a 3D polyline snapped to the points. Because of this the original polyline and the inserted polyline may not be the same.

Allow Crossing Breaklines
This toggle and setting allows crossing breaklines in surface data. This includes contours. The default setting is off, or not allowing crossing breaklines. When encountering crossing breaklines their data is added, but the triangulation uses one breakline and does not include the crossing breakline’s data where they cross. A Panorama is displayed with an Events vista. Double-clicking the event displays an Event Properties dialog box with the error’s details (see Figures 4.5 and 4.6). The Events vista contains a ZOOM TO link that takes the user to the offending data. Before including the data, the error must be fixed.

When toggling this setting on, allowing crossing breaklines, the user needs to set a method determining what elevation to use. Including an intersection elevation is one of three methods: use the first breakline’s elevation, use the last breakline’s elevation, or use the average breakline elevation. If allowing crossing breaklines and their elevations are similar, the effect on the surface is minimal. However, if the elevations vary greatly, it would be better to resolve the crossing breakline issues before using them in a surface.

NOTE
A surface with this setting on tends to be unstable.
When changing one of the preceding settings after building a surface, the change triggers a surface rebuild. When exiting the surface’s Properties dialog box, the dialog box asks whether to rebuild the surface with the new settings.

**Crossing Breakline Commands**

There are two commands that identify and resolve crossing breaklines.

**Breakline Reports.** In the Toolspac’s Toolbox tab, Reports Manager, Breakline branch contains useful reports. The first report is Breakline Check. This report checks selected survey databases, survey figures present in a drawing, or surface-specific breaklines. See Figure 4.7. When reporting crossing breaklines, you have to set a minimum and maximum length and elevation values to potentially filter out non-crossing breaklines.
The second report uses the same interface as the Breakline Check Report. The reports list the crossing breaklines, the coordinates where they cross, and their difference in elevation. This report is also in the Toolspace’s Toolbox tab, Breaklines section.

**Resolve Crossing Breaklines.** On the Analyze tab, Ground Data panel’s drop command list is the Resolve Crossing Breaklines command. This command does not scan for crossing contours. The routine checks selected survey databases, survey figures present in a drawing, or surface-specific breaklines for any crossing. When you start the routine, it prompts in the command line for which object types to check. After identifying the object type, the routine scans the object for crossing breaklines and then displays a report. See Figure 4.8. When selecting an entry in the Crossing Breaklines vista, the crossing breaklines highlight in the drawing and the vista buttons become active. You can Zoom to the intersection and then choose a resolution method. Alternatively, you can trim the crossing or graphically edit the breakline to separate the crossing.

![Figure 4.8](image)

**SURFACE PROPERTIES — DATA OPERATIONS**

Data Operations identifies what surface data types to include (see Figure 4.9). This section’s intent is to define surface data. However, this section is also a way to exclude data types already included in a surface. For example, a user has a surface with point groups, breaklines, and boundaries and wants to see the surface triangulation without any breakline data. The user simply goes to this section and toggles off breaklines. When exiting the dialog box, the surface rebuilds without breakline data. You can change these settings before or after building a surface.

**SURFACE PROPERTIES — EDIT OPERATIONS**

Edit Operations lists the allowable surface-editing operations (see Figure 4.9). However, this section is also a way to exclude edits already performed on a surface. For example, a user edits a surface with add point, delete line, and surface smoothing and wants to see the surface triangulation without the delete lines. To do this, in this section toggle off Use delete line. When exiting, the surface rebuilds without the deleted line edits.
SURFACE PROPERTIES — OPERATION TYPE

Operation Type contains a surface’s history and data dependencies (see Figure 4.9). Each entry has a toggle allowing it to be included or excluded from the surface. This allows a review of the impact of each entry or a combination of entries on the surface. Control over the entry extends to reordering the entry’s location in the list, i.e., moving an entry up (earlier) or down (later) in the surface build sequence.

FIGURE 4.9

SURFACE STYLE

A surface object style affects how a surface displays its components and characteristics. This is how you differentiate existing and proposed surfaces. Surface styles tend to address a task: view triangulation; view contours; view slopes and elevations. A style showing border(s), triangulation, points, and other essential surface components is crucial to evaluating a surface under development (see Figure 4.10). After building a surface, other styles range and display an analysis of surface slopes and elevations (see Figure 4.11). What is displayed by a surface style is set by the style’s display panel values. The object has display settings for Plan, Model, and Section.
LABEL STYLES
Surfaces have four label types: Contour, Slope, Spot Elevation, and Watershed (see Figure 4.12).

TABLE STYLES
Surfaces have seven table types: Direction, Elevation, Slope, Slope Arrow, Contour, Watershed, and User Defined contours (see Figure 4.13).
SUMMARY

- Edit Drawing Settings and Edit Command Settings assign layers, and set default styles, surface types, and build options.
- If a drawing contains multiple surfaces, the Edit Drawing Settings base object layer name should contain a prefix or suffix.
- Edit Feature Settings sets default surface names and styles.
- A command’s settings can override default surface styles and parameters.
This completes the surface settings and styles review and the steps to change their values. Next, you will learn to create (name) the surface, add data, and begin the review process.

**UNIT 2: SURFACE DATA**

**STEP 1: CREATE A SURFACE**
The first step in creating a surface is naming it and assigning it a type and styles. The Ribbon’s Home, Surfaces drop-list menu’s Create Surface..., or selecting Prospector’s Surfaces heading, pressing the right mouse button, and from the shortcut menu, selecting Create Surface... both display the Create Surface dialog box.

**Create Surface from DEM**
The Create Surface from DEM routine reads and USGS STDS file and creates a grid surface.

**Create Surface from TIN**
This routine creates a Civil 3D surface by reading a Land Desktop surface TIN file. The file contains the surface triangulation and does not allow access to the data or edits done to the surface.

**Create Surface from Google Earth**
To use this routine you must have Google Earth installed and running. When starting this routine you should have a coordinate system assigned to the drawing and a location point for the surface. After identifying the surface’s location, the Create Surface dialog box displays. You identify the name, enter a description, assign a style and a material to the surface.

**Create Surface from GIS Data**
The routine connects to an Arc SDE instance, an Oracle table, or a ESRI Shape file to create a surface in a drawing.

**Create Surface from Grading**
See Chapter 10 – Unit 3 for a review of creating a surface from grading objects.

**Create Surface from Corridor**
See Chapter 7 – Unit 5 for a detail review of creating corridor surfaces.

**Create Cropped Surface**
This routine creates a new surface from a surface present in a drawing. Each cropped surface is its own surface. The cropped surface can be put into a new drawing, an existing drawing, or remain in the currently opened drawing. If you want the source surface to change the new cropped surface, save the source drawing with the source surface and then rebuild the cropped surface.
**Create Surface**

The Create Surface dialog box defaults are from the values in Edit Drawing Settings (surface layer), Edit Feature Settings (name format and style assignments), and command overrides (see Figure 4.1). The dialog box's top left lists the default surface type and can be changed to any one of the four surface types. The dialog box's top right displays the surface layer (Edit Drawing Settings, Object Layers). If you are using a layer modifier, these affect what is displayed as the layer name.

The dialog box's body contains the name, description, and the initial object and rendering material styles. If you want to change the object and render styles, clicking the value cell displays a Select Style dialog box from which you can select an alternative style.

When exiting the Create Surface dialog box, in Prospector under the Surfaces heading, an entry appears with the surface's name. The surface name is a branch heading containing surface information and data. Surface information covers surface masks and watersheds. The data is in a Definition branch listing surface data types (points, point groups, boundaries, etc.) (See Figure 4.14).

**STEP 2: CREATE INITIAL DATA**

A surface's Definition branch lists data added, deleted, and edited, thus creating a surface's triangulation. A right mouse click shortcut menu containing appropriate items to that entry is associated with each heading (see Figure 4.15).
The data assignment order is the following:

- Data Clip Boundary
- Points (Point Groups, Files, AutoCAD objects)
- Breaklines and/or Contours (they should not cross)
- Setting a Maximum Triangle Length, and/or Edits and/or Boundaries

The surface properties dialog box, Definition tab, Operation Type lists, in order, all surface actions (data assignments, edits, etc.). This list toggles their effect on or off, relocates their position in the surfaces history, or can permanently remove them from the surface definition. When changing their status, moving, or removing them from the list, when you exit the dialog box, you are prompted for a surface rebuild. If the operations type list is reordered, the effect each operation has on the surface may change.

**Boundaries**
A surface can have four boundary types: Data Clip, Outer, Hide, and Show.

**Data Clip.** This boundary excludes all data outside its edge. When this is the first surface data entry, all added data outside is not included in the surface. The surface uses all excluded data, if you delete or toggle off this boundary.

**Outer.** An outer boundary forces a surface to use the data only within its edge. The outer boundary focus is limiting surface data to a specific area (i.e., to exclude data outside the closed polyline). The difference between Outer and Data Clip is if you
are adding data outside the boundary, the surface expands past the outer boundary’s edge. If you are adding data and expanding the surface, in the surface’s properties dialog box, reorder the operation types so the boundary is at the bottom of the list. With the boundary at the bottom of the list, it once again excludes data outside its edge, but includes any new data inside its edge.

When an outer boundary crosses triangulation, there are two options to handle the crossed triangulation. The first is to create new triangles from the enclosed data out to the boundary (i.e., Non-destructive breakline) (left side of Figure 4.16). This new triangulation represents as best as possible the elevations of the original surface where the border intersects the triangles. If the boundary contains curves, there is a mid-ordinate setting to adjust the number of new triangles along its curves. The second option is to stop the triangulation at the data. This option does not create triangles between the data and the boundary (right side of Figure 4.16).

**FIGURE 4.16**

**Hide.** A hide boundary suppresses any surface triangulation within its boundary. The boundary does not need points in its interior to hide the triangulation (see Figure 4.17). It is best to toggle on Non-Destructive for this boundary type.

**FIGURE 4.17**
**Show.** A show boundary displays surface triangulation within a hidden boundary. The boundary does not need points in its interior to work when it is set to Non-Destructive.

**Point Data**
Points are common surface data. If there are cogo points in a drawing, they must be in a point group. Point data can also be external (ASCII file) and drawing objects.

**Drawing Objects.** The first point data source is drawing objects (see Figure 4.18). When selecting objects, this routine extracts their X, Y, and Z values and uses them as point data. Drawing nodes, 3D lines, blocks, text, 3D faces, and polyface mesh objects are potential surface data. This routine’s point data is in addition to point file and/or point group data. The routine does not report or generate any connections between the selected objects’ endpoints and vertices. The exception is 3D Faces and toggling on Maintain edges from objects. This preserves their 3D Face edges in the surface.  

If the drawing contains text and/or blocks, but the objects have a 0 (zero) insertion Z value, you can use two routines to place the text and blocks to the elevation they display. In Modify’s Surface ribbon, Surface Tools panel, Move Text to Elevation and Move Block to elevation, change the text’s or block’s Z insertion value to match the text’s or attribute’s value. For example, text with the contents of 723.15 is inserted at an X,Y with a zero elevation. After using the Move Text to Elevation routine, the text’s insertion point is X,Y, 723.15. This makes the text usable as a spot elevation in the surface.

**Point Files.** A second point data source is an external coordinate file. Point data imported by this option is not made into cogo points, but is exclusive to the surface. The routine uses the same Import/Export formats: the file can be ASCII text or an Access database. If you want the data to be active (cogo points), use the Points Import/Export routine.
Point Groups. A point group contains all or a selected number of cogo point objects (see Figure 4.19). For information about creating and managing point groups, see the point groups discussion in this textbook’s Chapter 2. Point groups include and exclude points by their number, elevation, description, or selection. Excluding points is necessary because of inaccurate elevation values. For example, points representing fire hydrants are observed by locating their top. These points could be from 1 to 3 feet above the surrounding ground elevations. If you include these points, they create a small hill at each hydrant location. Clearly, they should be excluded from the surface data.

Contours
Contours represent known surface elevations and are a convenient surface data source. Surfaces from contours do not have the same issues as surfaces from points, which are unable to correctly triangulate linear features. Each contour line is a break-line, which forces the triangulation between contours.

CAUTION
If you receive a contour drawing from outside your control, thoroughly check its values before using its data.

Crossing Contours. Contour data should never include crossing contours. Even though it occurs in reality, a surface cannot accommodate this situation. When assigning crossing contours to a surface, Civil 3D adds both contours as data, uses the first contour’s vertices, issues an error message about the crossing contours, and at the intersection ignores the second contour’s data. An error message in the Events vista identifies the intersection point. You should edit the contours so they do not cross (see Figure 4.20). Editing a contour may be as simple as relocating a vertex by using its grip.
Weeding Factors. Weeding removes potentially redundant contour (polyline) vertices. When reading Weeding factors, place a Boolean “AND” between the two values (distance “AND” angle). To remove data (weeding), the vertices must be less than both weeding factors.

The first decision is distance. When evaluating the distance, you evaluate the overall distance between three adjacent vertices. If the overall distance is less than the distance factor, the analysis moves to the second factor, angle (see Figure 4.21).

FIGURE 4.20

FIGURE 4.21
The angle factor is a right or left turning angle (deflection) made by the contour's three vertices (see Figure 4.22). If the angle factor is 4 degrees, this limits the insignificant turning angle to 4 degrees or less to the right or left of the line from vertex 1 to 2. If the angle is less than 4 degrees, the second vertex is considered redundant and not included. If the angle is greater than 4 degrees, the second vertex is kept as data.

If the distance between three adjacent vertices is greater than the distance weeding factor, the routine moves on to find the next set of three vertices under the Weeding's distance value.

Weeding does not change contours, but instead determines which vertices are data. How much data can be removed before encountering problems? Some experts suggest a 50 percent reduction still produces a viable surface. The number of vertices weeded is not the issue. What is important is the vertices that remain after the weeding process. The only way to evaluate Weeding's effects is to review the resulting triangulation.

**Weeding Factors**

<table>
<thead>
<tr>
<th>Distance: 10</th>
<th>Angle: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 5 Units</td>
<td>2 4.5 Units</td>
</tr>
<tr>
<td>Vertex 2 is Redundant</td>
<td>Angle of Vector 2-3 is less than 4 degrees from Vector 1-2</td>
</tr>
<tr>
<td>1 5 Units</td>
<td>2 4.5 Units</td>
</tr>
<tr>
<td>Vertex 2 is Not Redundant</td>
<td>Angle of Vector 2-3 is greater than 4 degrees from Vector 1-2</td>
</tr>
</tbody>
</table>

**FIGURE 4.22**

**Supplementing Factors.** Supplementing factors add new data to line and curve contour segments. If Add Contour Data does not encounter a vertex before reaching the distance or mid-ordinate distance value, it calculates new vertices to the data.

The distance factor is the distance along a straight segment, and the mid-ordinate distance is the distance a chord is from an arc. If the distance factor is 20.0, any straight contour segment more than 20 feet between vertices has a data vertex added along its path. If it is an arc, the mid-ordinate distance factor adds vertices representing calculated points along the arc’s path. A large mid-ordinate value creates fewer points, and a smaller value creates more points.

Like Weeding, the supplementing factors do not modify the original polylines or contours; they only create more or less surface data. The supplementing distance factor cannot be lower than the Weeding distance factor.
Contour Data Issues
There are two problems with contour data: bays and peninsulas and the lack of high and low elevations.

Bays and Peninsulas. Contours may switch back and as a result create peninsulas and bays (see Figure 4.23). In these loops, a surface switches from triangulating between different contours to triangulating along the same contour. This happens because the nearest triangulation point is along the same contour and not to the next higher or lower contour, or it is impossible to create a triangle between two different contours in the bay or peninsula.

When applying a contour style, the contours cut off the original data's bays and peninsulas. This is because the contour follows the first triangle leg that makes the jump across the bay or peninsula. The result is a surface flat spot.

The errors' net result is usually minimal, and they may even cancel each other out. Civil 3D attempts to optimize the diagonals controlling this problem by using Swapping edges. In many situations, this routine corrects the triangle leg problems; however, this routine does not correct all of the flat spots (see Figure 4.23).

Before running minimize

After running minimize
A contour data algorithm resolves the bay and peninsula problem. The algorithm looks at the surface elevation trend and adds elevation data that is slightly higher or lower on the triangle's midpoint where it connects to the same contour. This allows a surface to correctly represent contour data and faithfully re-create the original contours (see Figure 4.24). This does create larger surface files, but is well worth the overhead.

![Figure 4.24](image)

Toggles on Create Contour Data’s lower half creates this optimal surface contour data (see Figure 4.21).

**High and Low Points**

The second issue is a lack of high and low spot elevations and how to create data representing these missing values. Most aerial firms’ contour drawings contain text or blocks inserted at their label’s elevation. In addition to text and blocks, other objects can be point data: nodes, 3D lines, and polymesh objects. Including these objects as spot elevations resolves the contour data problem of not having high and low elevations.

**DEM Files**

A DEM (Digital Elevation Model) is a USGS standard surface data file. (see Figure 4.25). It is a grid with elevations at each intersection. A DEM’s area can be quite large and dwarf a project site. Also, the size of DEM cells makes it easy to show a large area surface, but is not very useful for showing a small site’s elevations.
STEP 3: ADD BREAKLINES TO KNOWN PROBLEM AREAS

A surface contains linear features as points. These features include man-made (edges-of-travelway, curbs, walls, etc.) and natural (swales, ditches, water edges, break-in slopes, etc.) features. The surface triangulation process does not correctly resolve these features. If you want to preserve the points' linear relationships, breaklines must connect the related points. Breaklines represent and preserve the points' linear trend in a surface.

Polylines (2D or 3D) or feature lines representing the points' linear connection first must be drawn before adding them as breaklines. 2D or 3D polylines cannot have curves; only feature lines can contain curves.

Breaklines

There are five breakline types, four of which control triangulation: Standard, Proximity, From File, and Wall (see Figure 4.26). Standard and wall breaklines are 3D objects, and Proximity breaklines are 2D objects. Even though different (Standard-3D and Proximity-2D breaklines), they produce the same effect. A wall breakline defines a wall's face.

The last breakline type is Non-destructive and it fractures triangulation along its length. A Non-destructive breakline can be a 2D or 3D object. Generally, Non-destructive breaklines are surface-editing tools or are helpful when defining rendering areas.

The lower half of the Add Breaklines dialog box sets weeding and supplementing values for the selected breaklines. These functions affect the breakline’s data as they would a contour. See the contour section for an explanation of these values.
On any surface, there are features that extend across several points; for example, swales, edges-of-travelway, backs of curbs, and berms. Each point’s elevation along these features is related to a point before and after it. The only way to guarantee that the TIN triangulation correctly represents this relationship is to define a breakline. A breakline instructs a surface to place triangle legs linking the connected points and not allow any triangle legs to cross the breakline.

Linear feature misrepresentation occurs consistently in point data because of the surface triangulation algorithm. Point data must be dense enough along a linear feature to both describe and delineate it from all other intervening points. In many surveys, this is not the case. A field crew’s most difficult task is viewing their survey as a triangulated surface. They see their points within the context of reality. For them, it is hard to understand why a point 100 feet away is not a part of the roadway edge in a triangulated surface. In the field, they see the roadway edge and they do not see their points triangulated. But an edge-of-travelway point and similarly described points separated by 100 feet or more lose their linear connection when creating a surface. When roadway edge points are mixed with surrounding points that do not have the same description (trees, signs, road shoulders, manholes, etc.), the nearest neighbor to a roadway edge point is probably a differently described point (see Figure 4.27). The points surrounding the two edge-of-travelway points (point numbers 17 and 18) form triangles crossing between the two pavement shots, and as a result negate their linear and elevation relationship. This same problem occurs where data is too sparse to support a correct interpretation (see Figure 4.27). The situation shown in Figure 4.28 does not have enough data to correctly resolve the diagonal connection between the 719 or 721 elevations. Without more data or a breakline, the surface creates a diagonal that is always the shortest cross-corner distance.
Another breakline function is to prevent elevation on one of its sides to connect to elevation on the breaklines other side. In essence a breakline separates data to be correct on either of its sides.

If the diagonal connects the 721 elevations, the area represents a berm.

If the diagonal connects the 719 elevations, the area represents a swale.
The solution to the preceding problem is to create additional triangulation control. The control preserves the points' linear and elevation trends or correctly controls the triangulation in sparse data. Breaklines imply links between points and prevent triangulating crossing the line-linked points. The result is correctly interpreted linear point relationships.

**Drafting Breaklines**

Breakline’s Add routine expects existing 2D or 3D polylines or feature lines. So, they must exist before using this command. If drawing a 2D polyline, create each vertex near or at a point’s location. After drafting the 2D polyline, define it as a Proximity breakline.

If drawing a 3D polyline, use the 3Dpoly command with the Transparent Commands toolbar’s point filters (point number (PN) or point object (PO)). Without using a transparent command, the 3D polyline command is unaware of a cogo point’s elevation and using the filter assigns the point’s elevation to the polyline’s vertex.

**Feature Line with Arcs**

2D and 3D polylines as breaklines cannot contain arcs. If you want breaklines with arcs, create feature lines. When defining feature lines as standard breaklines, they can contain arcs. When defined, each arc is processed by a mid-ordinate value. The mid-ordinate value controls how closely the triangulation follows an arc. The smaller the mid-ordinate value, the closer the triangulation is to the original arc.

**Allow Crossing Breaklines**

The default surface build setting does not allow crossing breaklines. If defining breaklines that cross other breaklines, the add breakline routine will add the new breakline and issue an error message about its crossing; the routine does not include some of the breakline’s data in the surface.

- Crossing breaklines may destabilize the drawing.

To allow crossing breaklines, change the toggle in the surface’s properties dialog box, Definition panel, Build section or in the CreateSurface command (see Figures 4.4 and 4.29). If setting Allow crossing breakline to “Yes,” the user needs to set how to resolve the potential elevation difference. The first option uses the first breakline’s elevation. The second uses the last breakline’s elevation. The third uses the crossing breaklines’ average elevation.
Standard Breaklines
A standard breakline is a 3D polyline. This polyline contains elevations and it is not necessary to associate cogo point objects with its vertices. The 3Dpoly command creates these objects. If you want a vertex's elevation to be a cogo point’s elevation, then use the Transparent Commands toolbar’s point number (‘PN) or point object (‘PO) point filters.

Proximity Breaklines
A Proximity breakline is a 2D polyline (zero elevation). Because it does not have an elevation, it must have a point object at or near each vertex. The adjacent cogo point objects provide elevations and the polyline provides the line across which no triangle leg can pass. Proximity breaklines cannot have arc segments.

When defining a proximity breakline, the breakline is converted to a 3D polyline snapped to the nearest point. If you were to insert the breakline back into the drawing, it would not match what was originally drawn.

Wall Breakline
A Wall breakline defines a sheer face (almost) from a 3D polyline. The preexisting 3D polyline is either the wall's top or bottom. After describing the breakline in the Add breakline dialog box, in the drawing select the polyline. After selecting the polyline, specify the offset side by selecting a point to one side or the other of the initial polyline vertex. Take care when selecting the offset side.
After identifying the wall and its offset side, the routine prompts you to set the offset side’s elevations. The first option is all. This method prompts for a single value (positive or negative amount) to add to each offset vertex, calculating its elevation. The second option is individual. This method visits each offset vertex and prompts the user for its elevation. To set an elevation, specify an absolute elevation or a delta (a change in elevation).

Introducing a wall into a surface greatly changes its slope’s report. Before adding a wall breakline, review its current minimum, maximum, and average slopes.

**Non-Destructive Breakline**
A Non-destructive breakline fractures existing triangles along its length while still preserving the elevations found at the intersection of the breakline and the triangulation. The most common situation for this type of breakline is when the user wants to delete triangles to one side of the breakline. The breakline gives the remaining surface triangles a straight or clean boundary.

**From File**
Rather than drawing a breakline, create a file to define any of the breakline types. The file has the extension of flt and contains the type of breakline, its name, coordinates, and elevations if it is a standard breakline. See the breakline file entry in Civil 3D’s Help file for more information on this type of breakline.

**Feature Lines**
The 3Dpoly command draws line only segments. If you want a 3D arc (a helix), draw a feature line. Feature lines (from Ribbon’s Home, Grading icon or the Feature Lines toolbar) are 3D and can contain arc segments. While drafting a feature line, assign elevations to each vertex by typing in the elevation or use a Transparent Commands toolbar point filter (PO object or PN point number) to transfer a point’s elevation to a feature line vertex.

Feature lines are powerful when developing design surface data. The Ribbon’s Modify panel contains all the necessary tools to create or edit them (see Figure 4.30).

**FIGURE 4.30**

To define standard breaklines from feature lines containing arcs, use a lower mid-ordinate value to better represent the arc in a surface. The lower the mid-ordinate value, the more data points are along its path and this results in triangulation closely following the arc.

This unit’s discussion does not cover all of the Feature Lines toolbar icons. Instead, this unit reviews creating feature lines, using Transparent Commands toolbar point filters, editing feature line elevations, and using Quick Profile to evaluate a surface.

**Creating Feature Lines.** The Feature Lines toolbar’s leftmost icon draws new feature lines. After selecting the icon, a Create Feature Lines dialog box opens (see Figure 4.31). This dialog box assigns a site, a name, a feature line style, and a layer.
The user accepts or defines a specific layer. At the middle right, if the user clicks the layer icon, an Object Layer dialog box opens to allow the user to define a layer modifier and its value, or a new layer (see Figure 4.32).

After exiting the Create Feature Lines dialog box, the routine prompts the user for a starting point. If a point is selected, the routine assigns the current elevation (0.00) and prompts the user to accept or to edit its value. If the user selects the first point using a point number ('PN) or point object ('PO) filter, the routine assigns that cogo point's elevation to the feature line's vertex. After selecting the first point, he or she can draft straight or arc segments. After creating the feature line, if the user wants to review or edit its values, he or she can edit it with the elevation editor.
Elevation Editor

After drafting a feature line, to review or edit its elevations, use the Elevation Editor. To edit a feature line’s elevations, select it, press the right mouse button, and from the shortcut menu, select Elevation Editor. This action displays a Panorama with a Grading Elevation Editor vista (see Figure 4.33). Edit the elevations by clicking a vertex’s elevation cell and changing its value or by changing the grade between vertices. When you are done, click the Panorama mast’s ‘X’ to close it.

Quick Profile

Quick profile is indispensable when evaluating a surface. Creating a mental surface image is difficult by looking only at triangles. A quick profile displays a surface’s elevations along a drawing object (lines, arcs, parcel lines, polylines, etc.). If the user moves the drawing object, the profile and its view are updated to show the new elevations. The preferred object is a polyline.

The Feature Lines toolbar’s sixth icon in from the left is Quick Profile. A quick profile persists only for the current drawing session. If the user exits or saves the drawing, the quick profile is discarded and has to be redefined.

After selecting the Quick Profile icon, in the drawing select the object representing the quick section. After selecting the object, a Create Quick Profiles dialog box opens (see Figure 4.34). At the dialog box’s top, select all or a combination of surfaces. The middle section sets the profile view style. After setting these values and exiting, select an insertion point to create the quick profile (see Figure 4.35).
SUMMARY

- You create a surface instance by naming, describing, and assigning it a style.
- Each time surface data is added, the surface rebuilds itself.
- Point groups are an effective way of organizing and controlling point display.
- Linear features using point data need breaklines to preserve them on the surface.
- A breakline from a feature line is the only way to represent curvilinear surface features.
- A Quick Profile is an effective way to evaluate a surface under construction.

This exercise and unit covers the initial review and modification of a surface. Civil 3D has other tools to review a surface’s properties and edit its data.

UNIT 3: SURFACE REVIEW AND EDITING

While building a surface, you should evaluate the effects of new data and breaklines. When evaluating each addition, the user may discover missing data, bad data, the need for additional breaklines and/or boundaries, incorrect triangles, and sliver triangles at the periphery—all indicative that a surface needs data tweaking and editing. The process of tweaking a surface is an iterative process involving reviewing the surface, adding or editing data, reviewing the change’s effects, and again adding to or editing the surface. It may take several passes before the surface is correct and ready for analysis and annotation.

One routine that evaluates a surface’s resulting contours for errors is in the Analyze tab’s Ground Data panel. See Figure 4.36. There is a Zoom to link at the end of each error. In the Event Viewer, when you click the Zoom to for three Errors, the crossing errors will display at the display’s center.

STEP 4: EVALUATE RESULTING TRIANGULATION

Surface Properties
The initial surface review is conducted by evaluating the values in the Surface Properties dialog box. This dialog box contains surface statistics, data and editing options, editing history, and many other settings and values.
Information Tab
The Information tab displays the surface name, its object style, assigned rendering material, if the surface is locked, and if the surface should display a tools tip.

Definition Tab
This tab has two parts: Definition Options and Operation Type. Definition Options has three sections: Build, Data operations, and Edit operations (see Figure 4.37).

Definition Options and Operation Type. This panel maintains settings that affect the building, data use, allowed edits, and the history of the surface. See the discussion in this chapter’s Unit 1.

The Definition area sets the surface data types use, toggles on or off surface data (turning off Use Breaklines removes all of the surface’s breakline data), and sets allowed editing operations.

When in Data operations, and you change Use breaklines to No, all breaklines present in the Operation Type (the bottom portion of the panel) are unchecked and are removed from the surface when the change is approved.

Civil 3D then issues a warning dialog box asking if the user wants to rebuild the surface using the new settings (see Figure 4.38). If the user answers Yes, the surface rebuilds with the new settings (rebuilt the surface without breaklines).
Statistics Tab

The initial surface review starts in the Surface Properties' Statistics tab. This simple review can identify bad surface data elevations or coordinates. The panel displays three surface properties reports: General, Extended, and TIN. General lists information about the revision number, number of data points, and the minimum, maximum, and mean surface elevation (see Figure 4.39).

General also reports basic surface information: elevation ranges, coordinate ranges, number data points, version, and elevation statistics.

Extended reports the 2D and 3D surface area, and the minimum, maximum, and mean slopes (slopes as a grade). A grade is the rise or fall of elevation expressed as a ratio. So, a 3:1 slope is a 33 percent grade and a 4:–1 slope is a −25 percent grade.

When creating slope range styles, it is important to be aware of any surface feature that distorts the surface statistics (e.g., a headwall distorting the surface slope range). By turning off the headwall breakline in the Operation Type area of the Definition panel of a surface, you could view the surface slopes without the extreme influence of the wall.
TIN reports a TIN’s area, its minimum and maximum triangle sizes, and triangle leg lengths (see Figure 4.40). Excessively long triangle legs occur around a surface’s periphery or in areas with sparse data. A surface triangulation review determines whether these triangles need deletion or the points creating the large triangles need exclusion from surface data, or whether there is a need to add or edit data to create a better surface. The user can prevent or control long triangle legs by setting the Maximum triangle length in the Surface Properties Definition tab, Build section (see Figure 4.41).
Breakline Check
This report lists all surface breaklines and survey figures that are outside of report ranges.

Crossing Breakline Report
This report creates a list of all crossing breaklines in a drawing, lists their crossing coordinates, and their elevations.

Resolve Crossing Breaklines
This routine displays each crossing and prompts you to fix the crossing. The fix maybe more complex than the routine allows. It may be better to use the Event Viewer’s Zoom to display the error and then fix it.

STEP 5: EDIT SURFACE
The surface-editing tools are in the surface’s Definition branch. When you click the Edits heading and press the right mouse button, a shortcut menu displays the editing routines (see Figure 4.42). The shortcut menu is divided into three types of editing tools: lines, points, and overall surface tools. The overall editing tools raise/lower a surface’s elevation, minimize flat faces, simplify, and smooth a surface.
A user can delete any surface edit. When you are in a surface’s Definition branch selecting the Edits heading, preview lists the edits. The edits list is from first (at top) to last (at bottom) (see Figure 4.43). Selecting an entry in preview and right mouse clicking displays a shortcut menu listing commands applicable to the selected item. The list includes Delete…. Or, you can delete an edit in the Surface Properties’ Definition panel Operation Type list by selecting the edit, right mouse clicking, and from the shortcut menu selecting Remove. When deleting an edit, the surface resolves how the deleted edit changes the surface triangulation. The surface rebuild depends on the Rebuild-Automatic toggle, which is set in a right mouse click shortcut menu when selecting a surface’s name. If off, the edit is removed from the list, but the surface does not update its triangulation. What appears is an out-of-date icon to the left of the surface name. When a surface is out-of-date, to update it, select the surface name, press the right mouse button, and from the shortcut menu, select Rebuild. If Rebuild-Automatic is on when deleting an edit from the previewed list, the edit is permanently removed and the surface automatically rebuilds with the new data and edits mix.
If you prefer not to delete an edit, but rather want to evaluate its impact or view different combinations of edits results, toggle on or off individual entries in Surface Properties, Definition panel’s Operation Type area (see Figure 4.44). After evaluating the edit’s or edit combination’s impact, the user can return to the Surface Properties dialog box and restore the edits.
Line Edits
These edits modify surface triangle legs: delete, add, or swap interior diagonal legs (see Figure 4.42).

Delete Line removes a triangle leg from a surface. Deleting an interior leg creates a hole in the surface. If you delete an interior leg, Civil 3D places a surface border around the hole. If you delete a delete line edit (from preview) or toggle it off in Surface Properties, Civil 3D removes the border and adds the leg back into the surface.

Add Line creates a new triangle leg at the surface’s periphery or forces a new diagonal leg in the surface’s interior. The first situation is where the surface did not create a triangle and you want to add it to the triangulation. Beware of doing this around the surface edges. The reason the triangle was not made is based on surface settings and it was determined that there is no real data supporting such a triangle. For example, the triangle leg might be greater than the set maximum triangle leg length.

A second use for Add Line is to change an interior diagonal. In a surface’s interior, a diagonal leg connects the two nearest points of a group of four neighboring points. The initial diagonal is based on distances and groupings. If it is not the correct solution, add a new leg to the surface to change the diagonal. If the new line crosses an existing diagonal, the surface deletes the original diagonal and replaces it with the new one. Using Add Line for this purpose duplicates the Swap Edge routine.

Swap Edge is a simpler method of changing an interior diagonal. Swap Edge changes the diagonal within a four-point group.

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NOTE
If edits represent an effort to correctly triangulate a linear feature, use a breakline to correctly resolve the feature instead of editing the triangles.

Point Edits
Add Point creates new surface data points (see Figure 4.42). These points are not cogo points or from a directly imported point file. They represent a surface elevation located within a surface’s interior. An example of this would be adding high and low elevations to contour data. Add Point only adds a surface elevation.

Delete Point removes a surface elevation. Be aware of how the point is a part of the surface. If the point is from a cogo point that is a part of a surface point group, the deletion removes the elevation from the surface, but does not affect the cogo point. To delete a surface point, select near it, and it is removed from the surface. The cogo point remains on the screen and remains a member of the original surface point group. Preview shows only deleted point coordinates. Delete Point only deletes a surface elevation.

Modify Point changes a surface elevation. If the point is from a cogo point that is a part of a surface point group, the surface elevation changes, but the edit does not affect the cogo point. If you decide to modify the surface elevation, click near the point’s location and modify its elevation. The point object remains a point group member and displays its original elevation. Modify Point only modifies a surface elevation.

Move Point changes the location of a surface elevation. If the point is from a cogo point that is a part of a surface point group, the surface elevation moves, but the edit does not affect the cogo point. If you decide to edit a surface elevation, select near the point’s location and then select its new location. After moving the surface point, the original point object remains a point group member and does not display a modified location. Move Point only relocates a surface elevation location.
The best practice for adding new points would be as new members of an existing or new point group assigned to a surface or a directly imported point file. This way the user can easily trace their additions and manage their participation in surface data.

When using any of the point edits, you are not editing the cogo point objects. These edits affect only surface points, not the cogo points that create the original data. If you are using these routines, the surface point will be out-of-sync with the point object’s values.

If you want to modify surface points that are cogo points, use Edit Points ... to edit their values and the surface will rebuild, incorporating their new values.

A user can delete any surface edit. In a surface’s Definition branch, select the Edits heading to display an edits list in preview. From the list, select an edit, right mouse click, and from the shortcut menu, select Delete.... If you don’t want to delete the edit, but want to evaluate it or a group of other edits, go to Surface Properties, Definition tab and in the Operation Type area, select and toggle off or on the desired edits.

When selecting a block of entries, select the first entry, hold down SHIFT, and select the last entry. If you want to select several individual entries, hold down CTRL while selecting the individual entries.

**Smooth Surface**

Surface smoothing is a cosmetic edit needed for document production. However, when a surface’s data is sparse, using one of the smoothing algorithms helps create a more realistic surface. The decision to smooth should wait until after approving the overall surface.

Surface smoothing has two strategies: Natural Neighbor Interpolation (NNI) and Kriging (see Figure 4.45). Both methods create interpolated surface data. The interpolated data creates better transitions between elevations and more data between sparse data points. These interpolation processes result in a “smoother” surface. The NNI method operates best with point data. Kriging extends surface trends to sparser data. Both methods require smoothing regions defined using one of the following methods: select an existing closed polyline, a parcel, draw a polygon; select a surface; or select an existing rectangle.

![Smooth Surface - Existing](image)
Natural Neighbor Interpolation (NNI)
Natural Neighbor Interpolation (NNI) uses an NNI algorithm to estimate arbitrary point elevations from a set of points with known elevations. The routine places the resulting interpolated points into the surface by one of four methods: grid, centroids, random points, or as edge midpoints.

**Grid.** Grid smoothing creates new surface elevations from existing elevations within a region based on a grid. Grid smoothing requires a defined interpolation area, grid spacing values, and a grid rotation. The result is new surface data points at the grid spacing and rotation within the smoothing boundary.

**Centroids.** Centroids create new surface elevation data from elevations at the existing triangles' centroids. A region is required to calculate the new data. After calculating new elevation data, the surface creates new triangulation using the existing and newly interpolated points.

**Random Points.** Random Points creates new elevation point data from elevations within the region. The first step is defining the number of new points and the second step is defining the interpolation area. After calculating new data, the surface creates new triangulation between the existing and newly interpolated points.

**Edge Points.** Edge Points creates new surface elevation data from elevation trends found within a region. The new points are slightly higher or lower based on the surface elevation trend. This method allows a contour data surface to correctly interpolate the elevations of bays and peninsulas in the contour data.

**Kriging**
Kriging is a much more speculative method for interpolating surface points. Kriging supplements sparse data and/or expands a surface to sparser data. Examples using Kriging are developing pollution plumes, water flow plumes, or subterranean surfaces. Generally, water flow or pollution plume data is sparse and Kriging’s interpolation method is ideal for modifying a surface that has sparse data. An understanding of the mathematics and applications of Kriging is necessary to correctly use this interpolation method.

Any surface smoothing can be deleted. In a surface’s Definition branch, select the Edits heading to display an edits list in the preview, select the smoothing, press the right mouse button, and from the shortcut menu, select Delete. If you don't want to delete the smoothing, but want to evaluate it or a group of other edits, go to Surface Properties’ Definition tab and, in the Operation Type area, select and toggle off or on each of the edits.

**Simplify Surface**
Simplify surface reduces a surface’s points or edge contraction (reducing the number of triangles). The reduction is done through a wizard and is an arbitrary number or difference in elevation change between points. This routine is for surfaces whose data contains dense point data.
SUMMARY

- Reviewing and editing a surface is an iterative process.
- To rebuild a surface after each edit, set the Rebuild – Automatic toggle on.
- Delete peripheral triangles with the Delete Line edit.
- If you delete interior triangles, the surface places a border around missing triangles.
- A boundary is an effective method of excluding unwanted data.
- A boundary is an effective method of controlling unwanted peripheral triangles.
- Instead of deleting interior triangles, consider using a hide boundary.

UNIT 4: SURFACE ANALYSIS

Next in the surface process is how to analyze a surface’s slopes and elevations. The analysis is the function of specific-use surface styles. Depending on the analysis type (slope or elevation) and its distribution, each style may use a different range calculation algorithm.

STEP 6: ANALYZE THE SURFACE CHARACTERISTICS

Because surfaces represent a project’s start and end, it is critical that they represent their data correctly. The surface properties dialog box contains a Statistics tab that reports specific information about that surface’s slopes and elevations.

However, the best way to understand slopes and elevations is to visualize them in 2D or 3D views. If a surface contains bad data, each view shows it as spikes or wells in the model. By creating analytical surface styles that emphasize these characteristics, one can visualize and communicate a surface in a more understandable way. The surface analysis styles focus mainly on TIN structure, relief, elevation, and slope.

Contour Check

The Analyze, Ground Data panel’s Contour Check command reviews the contours in a TIN surface. This is done by reviewing elevations along the contour’s sides. The check identifies areas of sparse data creating contours that do not connect. This is a typical surface edge condition.

Slope and Elevation

After focusing on surface triangulation, the next two surface characteristics that need visual review are slope and elevation. Slope is the amount of elevation change over a distance. There are two methods of expressing a slope: as a slope or as a grade. A slope of 3:1 represents a rise of 1 foot over an offset distance of 3 feet. A slope of 4:–1 represents a fall of 1 foot over an offset distance of 4 feet. A grade is the rise and fall of elevation expressed as a percentage. So, a 3:1 slope is a 33 percent grade and a 4:–1 slope is a 25 percent grade.

A slope surface style groups (ranges) triangles by their amount of slope (i.e., 0–2 percent, 2–4 percent, etc.). Each range has a color and all triangles in the range display that color. For example, the range of 0 to 2 percent has red triangles and the range of 2 to 4 percent has yellow triangles.
A slope arrow is another useful slope-analysis tool. A slope arrow displays not only the amount of slope (shows the color of its range), but also shows the direction of down slope. When combined, a slope analysis style displays triangles and slope arrows together.

Slope arrows provide more information than just magnitude of and direction of down slope. When slope arrows point toward each other, they represent a valley or swale (see Figure 4.46). If the slope arrows point away from each other, they represent a high spot (see Figure 4.47). Slope arrows also show the direction of water flow across a surface.
The last surface review styles analyze surface elevations (relief) grouped by elevation. Like slope styles, elevation styles assign colors to each elevation range and each range assigns its color to its triangles. When viewing an elevation style in 3D, the user views the surface’s relief.

**Ranging Methods**
There are three grouping or ranging methods for slope and elevation data: equal interval, quantile, and standard deviation.

This chapter’s surface has a wall occupying a small surface area, but it greatly affects the surface slope statistics. The site has lesser grades and slopes than the wall. The wall slopes are so extreme they bias or skew the statistics to the higher-end values. This was apparent when comparing the slopes before and after adding the wall. The average slope jumped from 6.2 to 225 percent and the maximum slope jumped from 210 to 350,000 percent.

**Equal Interval**
Equal interval divides the overall range difference (maximum minus minimum) by a user-specified number of ranges. This method often overgeneralizes the data. For example, the exercise surface has grades varying from 0.0 to 350,000 percent. Using 10 ranging groups, each range would represent a slope range of 35,000 percent (i.e., 0–35,000, 35,000–70,000, 70,000–105,000, etc.). When evaluating surface slopes using this interval, 0–35,000 for the first range, the range would contain 99 percent of the surface. A skewed data distribution makes the Equal Interval ranging process useless.

The equal interval method is excellent for data that is not skewed. Again, the exercise surface has elevations ranging from 725 to 739 with an average of 732. The average is almost halfway between the minimum and maximum. The equal interval method works well with this elevation data.

**Quantile**
The second method is quantile ranging. This method divides the data so that each range interval contains an equal number of members. This methodology focuses on the more frequently occurring values and deemphasizes the few high or low values. With this method, the few high values are put in a range containing lower values, creating a range that has the same number of members as the ranges for the more frequently occurring lower slopes. For example, using the slopes from the exercise surface, this method makes the last slope range contain slopes from 20 to 350,000. This range has the same number of triangles as does the range from 0 to 1.5 percent. This ranging method correctly ranges a skewed slope distribution.

**Standard Deviation**
Last is standard deviation. This method calculates and divides data based on how far values differ from the arithmetic mean. This method is most effective when the values approximate a normal distribution (bell-shaped curve). The standard deviation method is used to highlight how far above or below a specific value is in relation to the mean value. So the best use of this method is to show areas of highest and lowest values.
Watersheds
Surface analysis includes defining surface watersheds. This analysis results in a map representing water collection and discharge areas. Civil 3D creates depressions, single and multiple discharge points watersheds, and hatches each classification with a hatch pattern.

ASSIGNING AND PROCESSING ANALYSIS STYLES
Viewing an analysis style’s effect requires two steps: assign the style to a surface and in the Surface Properties’ Analysis tab create the analysis using the style’s parameters (see Figure 4.48).

The Analysis panel shows the style’s default values. Before running the analysis, the user can change the number of ranges and Legend type. After running the analysis, the user can change the individual range values. When changing the range values, change them from the highest range to the lowest (range 8, then 7, etc.). After changing the values, click Apply to reprocess the data with the new range settings.

WATER DROP ANALYSIS
The surface slopes determine and show water flow across a surface. However, the path any one drop takes can be calculated. The Ribbon’s Analyze tab’s Water Drop command calculates a water drop’s surface path (see Figure 4.49).
**CATCHMENT AREA**

The Ribbon's Analyze tab’s Catchment Area command defines a region with a depression low point (catchment point), delineates it with a boundary, and calculates its area. The Catchment Area dialog box sets the drafting properties for a catchment (see Figure 4.50).

![Figure 4.49](image1)

**SUMMARY**

- Slope analysis should include triangles and slope arrows.
- Slope analysis represents the flow of water across a surface.
- Water Drop analysis draws the path of individual water drops as they travel over a surface.
- The Equal Interval and Standard Deviation range methods work best with normally distributed data.
- The Quantile range method works best with skewed data.

![Figure 4.50](image2)

**UNIT 5: SURFACE ANNOTATION**

Surface annotation consists of contour, spot slope, and/or elevation labels. Contours display a surface’s elevation characteristic (hills, valleys, depressions, etc). A contour is a line that has a constant elevation along its entire length. Thus, a contour connects points that have the same surface elevation. There is a dynamic link between a surface...
and its contours. If a surface changes, it recalculates its triangulation and redraws the contours. How contours are displayed is an effect of a surface object style.

**NOTE**

If you turn off the surface layer, all surface labels will also turn off. To show surface labels and have the surface not display, assign the _No Display style to the surface.

**STEP 7: ANNOTATE THE SURFACE**

After completing surface editing and analysis, you next create contours and annotate elevations. Additional label styles identify spot slope and elevation at critical surface points.

**Contour Surface Style**

You display contours from a surface style assignment containing the appropriate contour settings. A contour style uses three Surface Style tabs: Information, Contours, and Display. This label style also helps differentiate existing from proposed surface contours.

**Information Tab**

The Information panel sets the name and describes the contour style.

**Contours Tab**

The 3D Geometry section contains settings that affect the contours’ makeup. This group’s settings control the contours’ 3D display mode. By default, a contour displays itself as its actual elevation, flattened to an elevation, or as exaggerated elevation showing relief. The default is to display contours at the actual elevation. When flattening contours, specify the flatten elevation. An exaggeration factor exaggerates contours (see Figure 4.51).

![Surface Style - Contours 1' and 5' (Background)](image)

**FIGURE 4.51**
**Contour Interval.** Contour interval sets the major and minor contour interval. The major interval is a multiple of minor (usually a factor of 5). For example, if the minor interval is 0.5, the major is 2.5; if the minor is 1, the major is 5; and if the minor is 2, the major is 10. When setting a minor interval, the major value responds with a value five times larger. Always check these settings to make sure they are correct (see Figure 4.52). To make the major interval different from the minor interval, first set the minor value and then set the new major value.

![Contour Style Settings](image)

**FIGURE 4.52**

**Contour Ranges.** This section sets contour range groupings. Creating contour ranges assigns different colors to contours. For example, the contour range of 700–730 is blue and 730–760 is red. These settings are related to a surface elevations analysis and when using User Contours.

**Depression Contours.** Contour Depression settings set the contour’s tick interval (frequency) and size (see Figure 4.53).
Contour Smoothing. Contour Smoothing does not add or modify surface data; it modifies the contours. The two smoothing options are: add vertices and spline. Add vertices smoothes the surface by adding vertices, but preserves as best as possible the surface elevations. When using this option, the panel’s bottom contains a slider, which sets the smoothing amount (see Figure 4.50). Spline creates the greatest smoothness by splining the contour. This option also creates the greatest number of crossing contours.

The preferred method of contour smoothing is the edit surface smoothing. See the following discussion.

Contour Labels
Add Surface Labels annotates contours, spot elevations, and slopes (see Figure 4.54). Contours, spot elevations, and slopes are surface label types and each has an entry under Label Styles in the Settings Surface branch.

Contour labels reflect two basic label strategies; major/minor or existing/proposed. Major/minor assumes a contour label’s focus is a major or minor contour no matter what the surface represents. Existing/Proposed assumes a contour label is different when labeling an existing or proposed surface. When implementing Civil 3D, you will have to decide what your office’s strategy is. In each label style you can assign a layer or by placing 0 (zero) in the layer name, the label routines will use Edit Drawing Settings, Object Layers’ defined layer name.

Surface’s Edit Feature Settings set the Add Labels dialog box and Add Surface Labels flyout’s default label styles (see Figure 4.55). The Default Styles section sets the Spot Elevation and Slope label style and the Contour Labeling Defaults set default contour label styles.
All contour labels have a label line, and by default it is on. It should be set to false, because when selecting a label the line’s grips are displayed (see Figure 4.55). You can select a line grip, stretch and relocate it, and create new labels where contours intersect the line.

FIGURE 4.54

FIGURE 4.55
Labeling contours is done by individual, multiple, or multiple at interval. Individual creates a label where a contour is selected. Multiple prompts for a beginning and end of a line, and where the line intersects contours a label appears. If you move the relo-cating line, the labels shift to the new intersections. Multiple at interval also prompts for a beginning and end of a line, and after you select the points, it prompts for a label repeat distance (see Figure 4.56).

**FIGURE 4.56**

**Spot Slope Labels**

Spot Slope labels annotate a surface’s slope at the selected point (see Figure 4.57). The best method of placing these labels is with a single pick. When labeling the slope between two points, be careful not to select two points that have several triangles between them. When selecting two points, the routine uses the difference in elevation between the two points to calculate a slope, not the changes that may occur between them.

**FIGURE 4.57**
**Spot Elevation Labels**

Spot Elevation labels annotate elevations at the selected points (see Figure 4.58).

![Figure 4.58](image)

**LABEL GRIPS**

When a slope or spot elevation label is selected, it displays two initial grips: relocate the elevation point or drag the label to a new location (see Figure 4.59). The relocate elevation point grip is the diamond grip and the relocate label is the square grip. When the label is dragged, it displays a third dot grip. Clicking the dot grip resets the label to its original position. The leader’s midpoint plus and minus grips allow you to add or remove leader vertices.

![Figure 4.59](image)
SURFACE SMOOTHING
Surface smoothing is a surface edit and its options interpolate for a selected region’s new surface data. This option is best for areas with great relief over short distances or when there is sparse data. After reviewing the initial surface contours, the user may decide to use smoothing to create more pleasing contours. See the discussion of smoothing in this chapter’s Unit 3.

EXPRESSIONS
Expressions are user-defined surface properties a label can use. Each label type has its own set of expressions; they label different surface properties. An example expression is top-of-face of curb elevation. The gutter’s elevation is from a surface and an expression defines the top-of-face elevation as a surface property.

The expression dialog box presents a calculator-like interface that has access to the label type’s object properties and mathematic functions. Once defined, the user assigns a name and description to the expression, and when exiting, the named expression becomes a label property (see Figure 4.60).

Component Editor lists the named expression and other properties as properties for a label component (see Figure 4.61).
Contour styles fall into two categories: major/minor or existing/proposed.

You can define depression contours.

Surface smoothing is effective for areas of sparse data.

Once you have a satisfactory surface, you can create points whose elevations are a surface’s elevations. These points can be data for a survey crew or a starting point for a second surface.

UNIT 6: SURFACE POINTS, LANDXML, AND UTILITIES

The Create Points toolbar creates points from surface elevations. The export LandXML command exports surfaces so other applications can use the surface. The Surfaces’ Utilities menu has several routines that are important to images, blocks, volumes, and entity extraction.

POINTS FROM SURFACES

The Create Points toolbar’s Surface icon stack has routines to create new points whose elevations are from a selected surface: Random Points, On Grid, Along a Polyline/Contour, and Polyline/Contour Vertices (see Figure 4.62). The Points menu’s Create Points or Prospector’s Points heading right-click shortcut menu Create… displays this toolbar.

The Along a Polyline/Contour and (at) Polyline/Contour vertices routines create points whose elevations are at distances along the length of or at the vertices of a polyline or contour. These routines are useful when developing a grading design and create points that represent the intersection of a grading strategy and a surface.
A surface transfer method is to export a surface as a LandXML file. Select the surface’s name, right click, and from the shortcut menu select Export to LandXML (see Figure 4.63).

LandXML exporting starts by identifying the export surface. The Export to LandXML dialog box selects the surface(s) or a surface is selected from a drawing (see Figure 4.64).
LandXML Settings

Before exporting to LandXML, check the LandXML settings and make sure they represent the correct units. By default, the LandXML file’s Imperial units are International feet and should probably be set to U.S. Foot (see Figure 4.65). The Surface Export Settings section sets the type of surface data (default points and faces) and if to include watersheds, the default number.

FIGURE 4.64

FIGURE 4.65
SURFACE UTILITIES
Surface Utilities tools apply to several specific situations.

Export to DEM
This routine creates a DEM file (see Figure 4.66). When exporting a DEM, the Export Surface to DEM dialog box opens. The dialog box sets the file name and location, coordinate system, grid spacing, elevation sampling method, and, if necessary, a custom Null elevation.

Volumes and Bounded Volumes
Volumes calculates a TIN volume by comparing two surfaces' triangulation (see Figure 4.67). This is the same as creating a TIN volume surface in Prospector's Surfaces branch. Bounded Volumes calculates an area's volume based on a volume surface (a TIN or Grid volume surface).
Bounded Volumes use a polygon over a volume surface or a user specified datum, polygon, and a second surface to calculate its values.

Command: _AeccReportSurfBoundedVolume
Select a surface <or press enter key to select from list>:
Surface: Existing
Current datum elevation: 0.000'
Select bounding polygon or [Datum]: d
Specify datum elevation <0.000'>: 722.5
Current datum elevation: 722.500'
Select bounding polygon or [Datum]:
Net volume=35544.31 Cu. Yd.<Fill>
   Cut=0.00 Cu. Yd.
   Fill=35544.31 Cu. Yd.
Net volume (adjusted)=35544.31 Cu. Yd.<Fill>
   Cut (adjusted)=0.00 Cu. Yd.
   Fill (adjusted)=35544.31 Cu. Yd.
Current datum elevation: 722.500'
Select bounding polygon or [Datum]:

Water Drop and Catchment Area
Water Drop creates a polyline trail that a water drop takes as it travels over a surface. A water drop is a good way to visualize existing ground surface slopes or to see if the design surface pulls water to drainage catch basins.

A catchment area is a surface low point depression area with a boundary and an area. This is used in hydrological analysis.

Drape Image
Drape Image places an image on a surface. If the image is larger than the surface, the image is trimmed to the edge of the surface.

Extract Objects from Surface
Extract Objects from Surface creates AutoCAD entities from the current surface style. For example, if the surface is displaying major and minor contours, the routine creates polylines at elevations from the surface contours. Or, if the surface is displaying a border and TIN triangles, this routine creates a 3D polyline and 3D lines.

Move Block to Surface
Move Block to Surface assigns the surface’s elevation to a block’s Z insertion point at the block’s X and Y coordinates.

Move Block to Attribute Elevation and Move Text to Elevation
These routines use a block’s attribute elevation value or the text’s content elevation to modify the block’s or text’s insertion Z value. For example, a text’s insertion Z is 0.0
and its content is the elevation 116.13. The routine Move Text to Elevations modifies the text’s insertion point to be the Z value of 116.13.

**SUMMARY**

- You can create points randomly or on a grid whose elevations are from a surface.
- You can place points whose elevations are from a surface on a polyline at an interval or at its vertices.
- The default Imperial Unit for exporting data to a LandXML file is International feet. Make certain its value represents the measurement value you want.

The next chapter, Chapter 5, starts the discussion of the roadway design process.