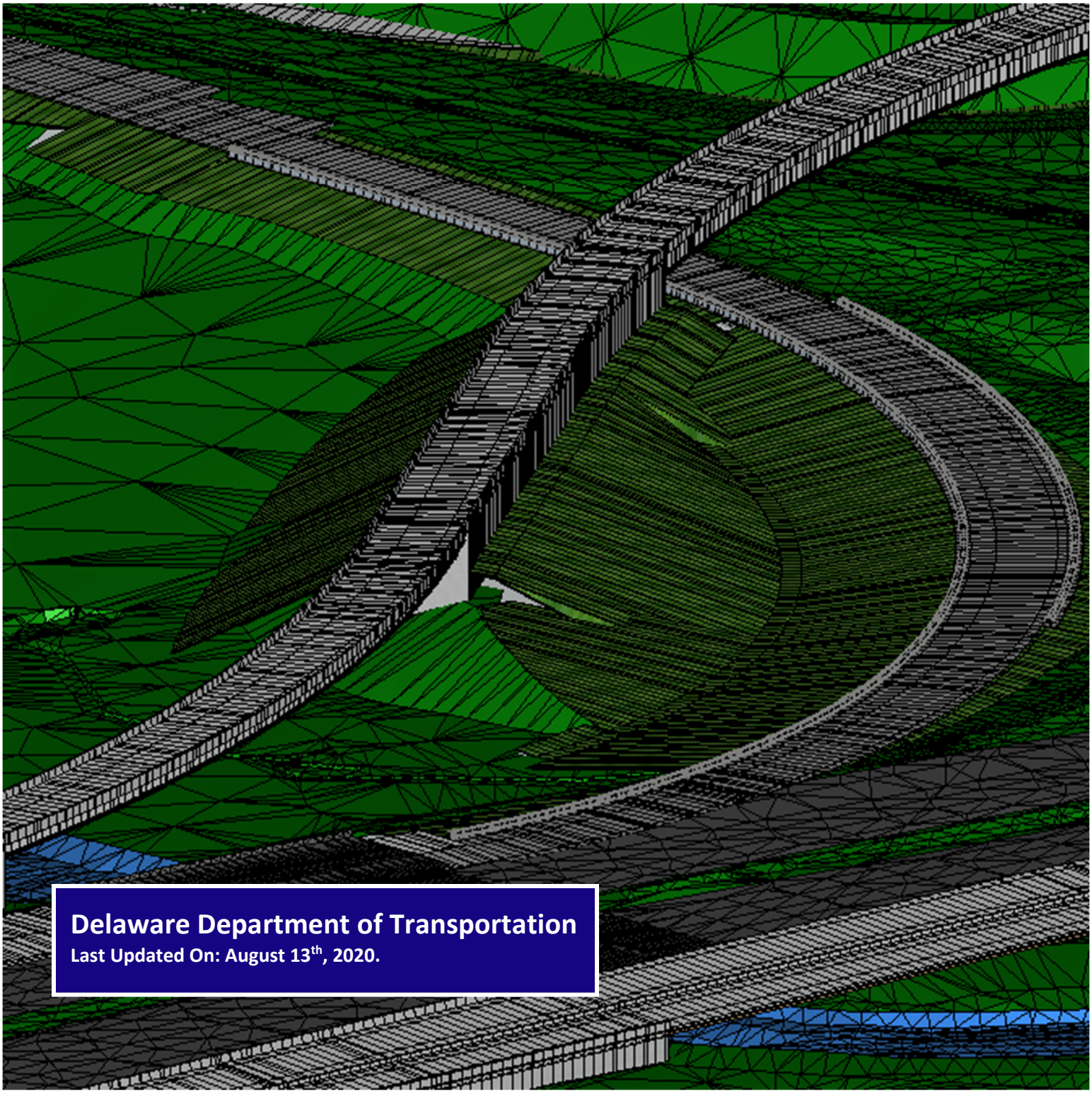
Development and Review of 3D Engineered Models for Construction



Delaware Department of Transportation

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Purpose

The purpose of this document is to outline the best practices that should be followed when developing three-dimensional (3D) engineered roadway models for Delaware Department of Transportation (DelDOT) projects. These models will ultimately be utilized in the construction phase of DelDOT projects. At this time, this document does not include best practices for the development of 3D models for bridge structures and appurtenances related to bridge structures.

This document also presents the review criteria being utilized when performing Quality Assurance/Quality Control (QA/QC) reviews of 3D engineered data and 3D models.

Should you have any questions, concerns, or suggestions pertaining to the information contained within this document, please contact the CADD Section via the following email address DOT_CADDSupport@delaware.gov.

Revisions

Updating this document is intended to be a continuous process and revisions to this document will be issued periodically. Please refer to this section of the document for revisions to the document.

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Benefits of 3D Engineered Content

DelDOT utilizes various forms of 3D engineered content throughout the lifecycle of projects as the projects progress from conceptual designs to final construction deliverables. This document focuses on the 3D engineered model portion of the 3D engineered content, herein further referred to as 3D Models.

3D models provide numerous benefits in both the design and construction phases of a project, a few of which are listed below.

Design Phase

- A more comprehensive design can be developed.
- Enables integration of several design processes, resulting in quicker updates during the design phase.
- Ability to more accurately detect and address design issues and conflicts during the design phase.
- Constructability issues are easier to detect during the design phase.
- 3D models aid in extracting more accurate quantity estimates.

Construction Phase

- Contractors can identify and rectify constructability issues prior to mobilization, saving time and money.
- Contractors have a better understanding of material quantities throughout the project site.
- Faster construction execution with Automated Machine Guidance (AMG), which has associated efficiency and safety benefits.
- Provides the contractor with insight as to the engineer's design intent.
- Enables more efficient workflows for the measurement and payment of material quantities.

3D models are extremely beneficial in analyzing clash detections during the design phase. A clash occurs when different infrastructure elements occupy the same space in the proposed design. Generating a 3D model is extremely beneficial in detecting these clashes so that remedies can be evaluated and considered during the design phase, resulting in reduced construction time delays and additional costs.

Generating a 3D model is also beneficial on large earthwork and paving projects where AMG practices may be considered during the construction phase. Projects which include the following earthwork operations will benefit from the creation of a 3D model:

- Large application of sub-base material spreading,
- Large application of paving,
- Mass earthmoving,
- Stormwater management facilities requiring grading, and
- Wetland mitigation areas requiring earthwork.

Not all projects will benefit equally from the generation of 3D models. Creating a 3D model during the design phase requires a significant investment of time and resources, which has an associated cost that should be considered individually on each project.

Surveying Considerations

In order to generate an accurate 3D model, one that accurately ties into the original ground surface, it is essential to have a complete ground survey of the existing topographical features.

Due to the levels of accuracy inherent to the various methods of data collection (Total Station Positioning, Aerial Mapping, Real Time Kinematics, etc.) designers need to recognize the potential limitations that each survey method imposes on the ultimate 3D model.

Determination of what electronic file deliverables are going to be provided to the contractor should be considered during the scoping phase of each project. Based on those considerations, the appropriate method of survey data collection should be discussed to assure the survey data accuracy levels are appropriate for the project.

Electronic File Deliverables

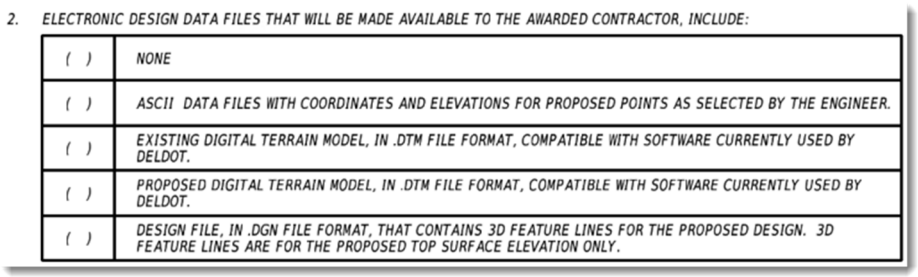
Currently, as per DelDOT's **General Note** number 2 on the "**NOTES**" sheet, the following electronic design data files may be made available to the Awarded Contractor:

- **ASCII Data Files with Coordinates and Elevations for Proposed Points as Selected by the Engineer –** These files should be made available to the contractor on all projects. The points that are provided should be chosen by the engineer but generally include all the proposed geometric points that are shown on the plans. These points can also include associated elevations at the discretion of the engineer. When provided, these files will be provided in an ASCII text file format.

- **Existing Terrain Model, in .DTM File Format, Compatible with Software Currently used by DelDOT -** Where a complete topography survey has been performed in accordance with DelDOT standards, the existing .DTM file should be provided to the contractor.

- **Proposed Digital Terrain Model, in .DTM File Format, Compatible with Software Currently used by DelDOT –** Providing the proposed digital terrain model should be considered in accordance with the guidance provided in the General section of this document.

- **Design File, in .DGN File Format, that Contains 3D Feature Lines for the Proposed Design. 3D Feature Lines are for the Proposed Top Surface Elevation Only –** Providing the proposed digital terrain model should be considered in accordance with the guidance in the "**Benefits of 3D Engineered Content"** section of this document.



2. ELECTRONIC DESIGN DATA FILES THAT WILL BE MADE AVAILABLE TO THE AWARDED CONTRACTOR, INCLUDE:

( )	NONE
( )	ASCII DATA FILES WITH COORDINATES AND ELEVATIONS FOR PROPOSED POINTS AS SELECTED BY THE ENGINEER.
( )	EXISTING DIGITAL TERRAIN MODEL, IN .DTM FILE FORMAT, COMPATIBLE WITH SOFTWARE CURRENTLY USED BY DELDOT.
( )	PROPOSED DIGITAL TERRAIN MODEL, IN .DTM FILE FORMAT, COMPATIBLE WITH SOFTWARE CURRENTLY USED BY DELDOT.
( )	DESIGN FILE, IN .DGN FILE FORMAT, THAT CONTAINS 3D FEATURE LINES FOR THE PROPOSED DESIGN. 3D FEATURE LINES ARE FOR THE PROPOSED TOP SURFACE ELEVATION ONLY.

Figure 1: Example of General Note #2.

3D Modeling Applications

The Department currently utilizes two civil design applications from Bentley Systems, Inc. to create 3D models during the design phase:

- Power InRoads SS10
- OpenRoads Designer Connect Edition

It is not the intent of this document to detail out the process for creating 3D models through the use of either of these applications, and the reader is instructed to consult the other "Training Guides" that have been developed by/for DelDOT for additional information regarding 3D model creation.

A simplified, typical workflow for generating 3D engineering content and 3D models is shown in Figure 2.

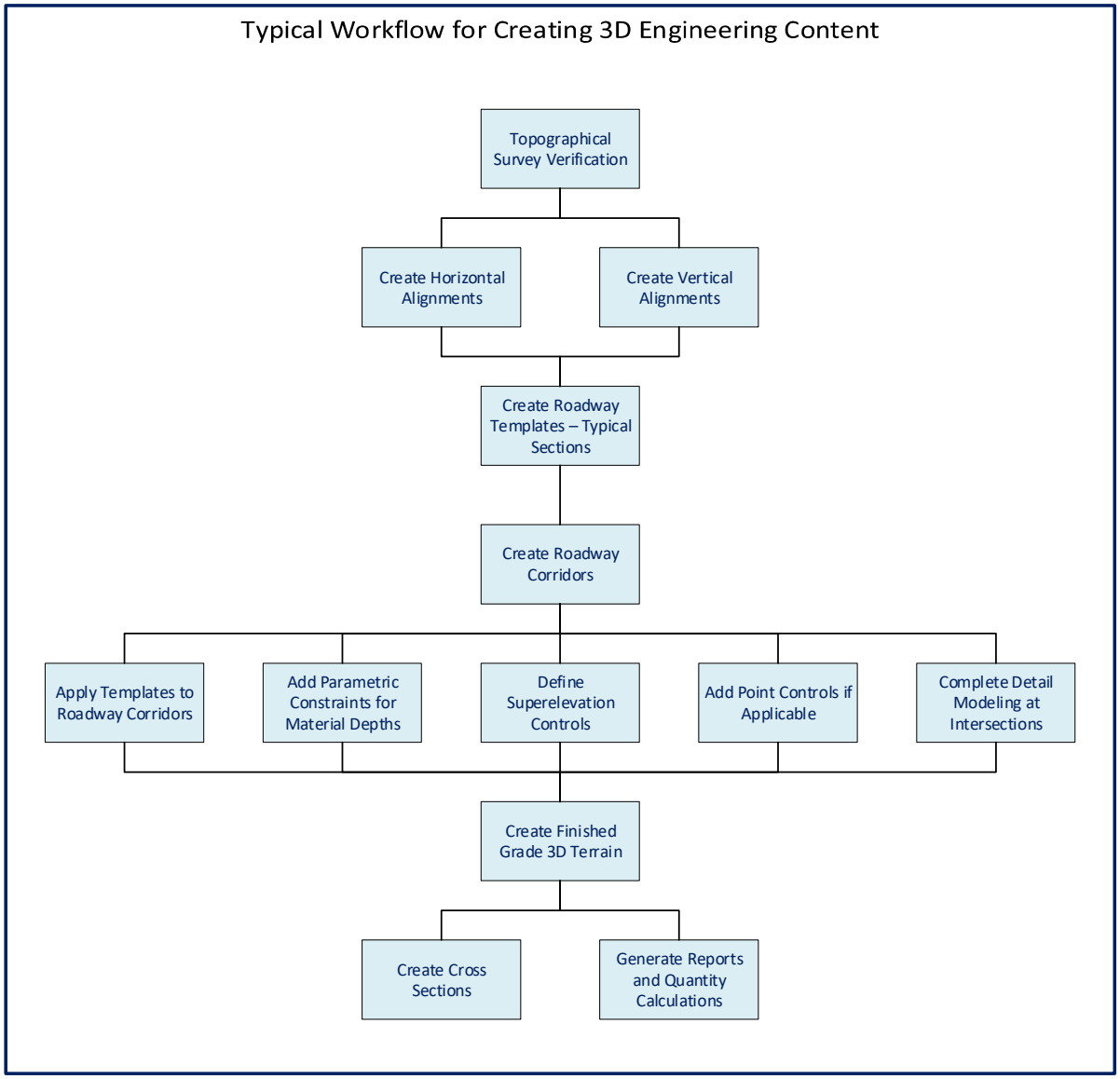


Figure 2: Typical Workflow for Creating 3D Engineering Content

3D Model Density Considerations

As indicated in ***"Figure 2 - Typical Workflow for Creating 3D Engineering Content"***, 3D models are generated as templates are assigned to a roadway corridor and then "pushed" along the assigned roadway corridor. The density of the 3D data being generated in an engineered model is controlled by the following factors:

- Initial Template Drop Interval (Set by Designer)
- Horizontal Curvature Densification Settings (Set by DelDOT CADD Standards)
- Vertical Curvature Densification Settings (Set by DelDOT CADD Standards)

During the design stage, template drop intervals are established at the time of initial placement along the roadway corridor. The following guidelines should be considered when initial template drop intervals are being established along the roadway corridor.

- Normal tangent section template drop intervals are typically 10'.
- Detailed modeling section (Intersections, entrances/driveways, etc.) template drop intervals are typically 1', 5', and 10'
- Template drop intervals should never exceed 25'.

In addition to templates being dropped at the intervals recommended above, templates should also be placed at the following key station points:

- Horizontal geometry transition points. (Ex: Shoulder widening from 8' to 10' at Station XX+XX)
- Superelevation transition points. (Start of tangent runout, Superelevation Runoff, Full Superelevation)
- Intersection of all side road alignments.

To speed up the processing times of complex roadway corridors, and temporarily reduce the model density, "**Template Drop Interval Multipliers**" can be applied through the use of "**Corridor Design Stages**". DelDOT has established the following corridor design stages, and respective template drop interval multipliers.

Corridor Design Stage	Template Drop Interval Multiplier
0 – Functional	10
1 – Preliminary	5
2 – Design	2
3 – Final	1
4 – Final w/Meshes	1
5 – Final Top Mesh	1
6 – Final Bottom Mesh	1
7 – Final Liner Features	1
8 – Final Components	1
9 – Final Top and Bottom Meshes	1

Figure 3: Corridor Design Stages and Respective Template Drop Interval Multipliers

In general, templates should be spaced at closer intervals at complex locations where grades and geometrics are changing or transitioning. In complex locations, the model density should be increased to ensure that the designer's intent is accurately captured in the 3D engineered model.

3D Model Content Requirements

Determining the required level of detail of a 3D model requires an understanding of how the 3D model will ultimately be utilized in the construction phase. In general, as the engineer is generating the 3D model, they should consider the following questions:

1. Does the 3D model, in conjunction with the rest of the Contract Documents, provide adequate information to convey the engineer's design intent?

2. If the project has the potential to utilize AMG technology, does the 3D model provide the appropriate amount of information for the contractor to be able to properly utilize AMG technology?

If the answer to either of these questions is "No", then more information should be provided in the 3D model. "**Figure 4: 3D Modeling Components**" lists the various components that are required to be included into the 3D models being developed for DelDOT projects, as well as some optional components that may be necessary to convey the designer's intent.

Finished Grade 3D Model Features	Required / Optional
Pavement Edges	Required
Pavement Cross Slope Break Lines	Required
Curbs, and Curb & Gutter Edges and Break Lines	Required
Channelization Islands Break Lines	Required
Sidewalks and Shared Use Pathway Edges	Required
Pedestrian Connection Break Lines	**Optional**
Retaining Walls, Barriers, etc. Break Lines	Required
Roadside Slope Break Lines	Required
Guardrail Maintenance Pavement Edges	Required
Guardrail End Treatment Grading Break Lines	Required
Driveway Edges and Grading Break Lines	Required
Drainage Ditches, Berms, etc. Break Lines	Required
Drainage Pipe Outlet Grading Break Lines	Required
Stormwater Management Facility Break Lines	Required

Figure 4: 3D Modeling Components

** Pedestrian connections shall be "modeled" to the extent to verify that the pedestrian connection can be built within the existing right-of-way, or within the proposed areas of takings (PE or RW).

Electronic Design Data and 3D Model Cross Checking

As indicated in the "**Electronic File Deliverables**" section of this document, the following electronic design data files may be made available to the Awarded contractor.

- **ASCII Data Files with Coordinates and Elevations for Proposed Points as Selected by the Engineer.**
- **Existing Terrain Model, in .DTM File Format, Compatible with Software Currently used by DelDOT.**
- **Proposed Digital Terrain Model, in .DTM File Format, Compatible with Software Currently used by DelDOT.**
- **Design File, in .DGN File Format, that Contains 3D Feature Lines for the Proposed Design. 3D Feature Lines are for the Proposed Top Surface Elevation Only.**

"**Figure 5: Sources of 3D Design Date Generation and 3D Model Cross Checking**" provides a brief overview of where potential electronic design data may derive from within the plan set, and where that design data is being cross checked against the 3D models.

Sheet Description	Design Data Provided	3D Model Cross Check
Title		
Index of Sheets		
Addenda and Revisions		
Legend		
Notes		
Typical Sections		X
Horizontal and Vertical Control	X	X
Construction Plans	X	X
Profiles		X
Grades and Geometrics	X	X
Construction Details	X	
Stormwater Management Plans	X	X
Environmental Compliance Plans		
Construction Phasing, M.O.T. and Erosion Control Plans		
Detour Plans		
Landscaping Plans		
Lighting Plans	X	X
Utility Relocation Plans	X	X
Signing, Striping and Conduit Plans		
Sign Structures	X	
Signalization Plans		

Figure 5: Sources of 3D Design Data Generation and 3D Model Cross Checking

Electronic Design Data

If it has been determined by the project designer that electronic design data shall be provided to the Awarded Contractor, the project designer shall review the information below to determine if the appropriate electronic design data has been generated, and reviewed, prior to inclusion in the deliverables to the Awarded Contractor.

NOTE – The document entitled "*Release for Delivery of Documents in Electronic Form to a Contractor*" MUST be signed by all parties prior to the delivery of any electronic project files. This document can be found at the following location on the DelDOT Design Resource Center (DRC):

https://deldot.gov/Business/drc/index.shtml?dc=projectmanagement#horizontalTab3

Horizontal and Vertical Control (ASCII Format)

- "Horizontal / Vertical Control Data" schedule information.
- "Construction Alignment Control" schedule information.

Construction Plan (ASCII Format)

- "Right-of-Way Monument Schedule" information.

Grades and Geometrics (ASCII Format)

- "Coordinate List" schedule information.

Construction Details (ASCII Format)

- If applicable, any design data that contains layout information or point data information shall be provided. This information shall include the Point Number, Station, Offset, Northing, Easting and/or Elevation.

Stormwater Management Plans (ASCII Format)

- If applicable, any design data that contains layout information or point data information shall be provided. This information shall include the Point Number, Station, Offset, Northing, Easting and/or Elevation.

Lighting Plans (ASCII Format)

- If applicable, any design data that contains layout information or point data information shall be provided. This information shall include the Point Number, Station, Offset, Northing, Easting and/or Elevation.

Utility Relocation Plans (ASCII Format)

- If applicable, any design data that contains layout information or point data information shall be provided. This information shall include the Point Number, Station, Offset, Northing, Easting and/or Elevation.

Sign Structures (ASCII Format)

- If applicable, any design data that contains layout information or point data information shall be provided. This information shall include the Point Number, Station, Offset, Northing, Easting and/or Elevation.

3D Model Review

If it has been determined by the project designer that a proposed Digital Terrain Model (DTM), and a design file containing proposed 3D feature lines, shall be provided to the Awarded Contractor, the project designer shall complete the "***3D Engineered Model Review Checklist***" found in ***Appendix A*** of this document, prior to inclusion in the electronic deliverables to the Awarded Contractor.

NOTE – The document entitled "*Release for Delivery of Documents in Electronic Form to a Contractor*" MUST be signed by all parties prior to the delivery of any electronic project files. This document can be found at the following location on the DelDOT Design Resource Center (DRC):

https://deldot.gov/Business/drc/index.shtml?dc=projectmanagement#horizontalTab3

Appendix A: 3D Engineered Model Review Checklist

Directions for Completing the Checklist

- This checklist indicates elements that shall be checked by both the designer and the 3D project file reviewer on a project to verify consistency between the plans and the 3D project files.
- This form shall be completed by the designer and submitted with the 3D project files to the designated 3D project file reviewer for the project.
- The form submitted by the designer shall then be used by the designated 3D project file reviewer to review the elements in the checklist for consistency between the plans and the 3D project files.
- This completed checklist will be provided back to the designer along with comments generated during the 3D project file review.
- Additional verification and review items may be requested for some projects. In these cases, the DelDOT Project Manager should communicate what additional items are to be reviewed. Similarly, some projects may not require certain elements to be reviewed by the 3D project file reviewer.

Project Information	
Contract Number:	
Contract Name:	
Maintenance Road No(s):	
Designer / Engineer of Record:	
Project Manager:	
Location of Files: **	

** **Location of Files** – All files necessary for the 3D Model review task shall be placed under the current project directory on the Y-Drive, in a folder labeled “Model Review Files”.

Review Information		
Submission	**Initial Review Submission**	**Final Review Submission**
Submission Date:		
Review Completed Date:		
Reviewer:		

- “**Initial Review Submission**” shall be made when all Preliminary Construction Plan review comments have been addressed. This typically occurs between the Department wide Preliminary Plan submission and Semi-Final Plan submission phases, and must include the appropriate grades and geometrics information that is required for the Semi-Final Construction Plan submission.
- “**Final Review Submission**” shall be concurrent with the Pre-PS&E Construction Plan review submission.

Appendix A: 3D Engineered Model Review Checklist

Items to be Submitted for Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
3D_Review.dgn – This file is generated by the designer and will be the master 3D review file with the following project files referenced into the file: ▪ Original Ground Terrain (fs.dgn) ▪ Alignments (al.dgn and/or hv.dgn) ▪ Right-of-Way (rw.dgn) ▪ Construction Plans (cp.dgn) ▪ Proposed Construction (pc.dgn) ▪ Grades and Geometrics (gg.dgn) ▪ Lighting Plans (li.dgn) ▪ Utilities/Relocations Plans (ut.dgn) ▪ Sign Structures (xx.dgn) ▪ 3D Features of Proposed Top Surface(s) (md.dgn)	☐	☐	☐	☐
Original Ground DTM (fs.dtm) - InRoads SS10 projects only.	☐	☐	☐	☐
Geometry File (.ALG) containing all the required COGO points, alignments, and essential data - InRoads SS10 project only.	☐	☐	☐	☐
ASCII exports for all alignments, both horizontal and vertical, utilized along the project corridors.			☐	☐
ASCII exports for the proposed grades and geometrics data contained within the Grades and Geometrics sheets.			☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

General Model Review Items				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Project design files utilize the correct Geographical Coordinate System (GCS)	☐	☐	☐	☐
Project Plans (PDF) files utilize the correct Geographical Coordinate System (GCS). (Georeferenced PDF files)	☐	☐	☐	☐
All guidelines discussed in the "Development and Review of 3D Engineered Models for Construction" document were followed. (Features, Intervals, etc.)	☐	☐	☐	☐
Project files utilize the latest CADD Standards for both the Plans and 3D Model.	☐	☐	☐	☐
Review of model for completeness (Visual Checks) ▪ No significant gaps along the model ▪ Spikes or depressions along seam lines ▪ Overlapping modeling components ▪ 3D model ties into the Original Grade surface	☐	☐	☐	☐
Vertical clearance clash detection – Interference Checking	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Typical Sections Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
3D Model feature widths match what is shown on the Typical Sections. (Lane Widths, Shoulder Widths, Ditch Sections…)	☐	☐	☐	☐
3D Model pavement material depths match what is shown on the Typical Sections.	☐	☐	☐	☐
3D Model pavement cross slopes match what is shown on the Typical Sections, including superelevation sections.	☐	☐	☐	☐
3D Model side slope grading matches what is shown in the Typical Sections.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Horizontal and Vertical Control Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Horizontal and Vertical Control ASCII data matches what is shown on the Horizontal and Vertical Control sheets.			☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Construction Plan Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
3D Model break lines match what is shown on the Construction Plans (Lane Widths, Shoulder Widths, etc.)	☐	☐	☐	☐
3D Model features match what is shown on the Construction Plans (Curb Lines, Guardrails, Islands, Slope Tie-Ins, etc.)	☐	☐	☐	☐
3D Model pavement tapers and transitions match what is shown on the Construction Plans.	☐	☐	☐	☐
3D Model roadside ditches, berms, etc. match what is shown on the Construction Plans.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Profiles Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verification of vertical alignment used in the creation of the 3D Model matches what is shown in the Profile sheets.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Grades and Geometrics Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Grades and Geometrics ASCII data matches what is shown on the Grades and Geometrics sheets.			☐	☐
3D Model pavement break lines match what is shown on the Grades and Geometrics sheets.	☐	☐	☐	☐
3D Model pavement tapers and transitions match what is shown on the Grades and Geometrics sheets.	☐	☐	☐	☐
3D Model radii at intersections, entrances, and driveways match what is shown in Grades and Geometrics sheets.	☐	☐	☐	☐
3D Model cross slopes match what is shown on the Grades and Geometrics sheets. (Lane, Shoulder, Sidewalk, Side Slopes, Median Crossovers, etc.	☐	☐	☐	☐
3D Model superelevation cross slopes and transitions match what is shown on the Grades and Geometrics sheets.	☐	☐	☐	☐
3D Model grades match the grades shown on the Grades and Geometrics sheets.	☐	☐	☐	☐
3D Model roadside Ditches, Berms, etc. match what is shown on the Grades and Geometrics sheets.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Construction Details Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verify any elements that are included in the Construction Details sheets which require the generation of 3D data, is complete and consistent with the 3D Model. These elements could include features in the 3D Model or points to be provided in an ASCII file.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Stormwater Management Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verify any elements that are included in the Stormwater Management Plan sheets which require the generation of 3D data, is complete and consistent with the 3D model. These elements could include features in the 3D model or points to be provided in an ASCII file.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Lighting Plan Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verify any elements that are included in the Lighting Plan sheets which require the generation of 3D data, is complete and consistent with the 3D model. These elements could include features in the 3D model or points to be provided in an ASCII file.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Utility Relocation Plans Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
If 3D Model includes utility relocation information, verify that the information matches what is shown on the Utility Relocation Plan sheets.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Sign Structure Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verify any elements that are included in the Sign Structure sheets which require the generation of 3D data, is complete and consistent with the 3D model. These elements could include features in the 3D model or points to be provided in an ASCII file.	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				

Appendix A: 3D Engineered Model Review Checklist

Cross Section Review				
Description of Item Being Reviewed	Initial Review		Final Review	
	Designer	Reviewer	Designer	Reviewer
Verify the following items within the 3D model match what is shown on the Cross Section sheets:	☐	☐	☐	☐
Pavement break line widths	☐	☐	☐	☐
Pavement cross slopes	☐	☐	☐	☐
Pavement material depths	☐	☐	☐	☐
Side slope widths	☐	☐	☐	☐
Side slope cross slopes	☐	☐	☐	☐
Drainage feature widths, depths and side slopes	☐	☐	☐	☐
Drainage and utility infrastructure sizes and locations	☐	☐	☐	☐
Initial Review Comments:				
Final Review Comments:				