CHAPTER 6

PHOTOGRAMMETRIC SURVEYS

Chapter Contents

Sec. 6.01 General

When the location survey necessitates the gathering of a large amount of information, or where the construction centerline is likely to be situated in a location different from the survey centerline, Photogrammetric surveys offer many advantages. Once the photography has been secured and controlled, visible features and terrain information can be collected rapidly and safely, at modest expense. **Unless specifically requested by the Department, utilities are NOT to be mapped by aerial photography.**

Sec. 6.02 Pre-Photography Control

On surveys where Photogrammetry is to be used, a map, aerial image, or Google Earth KMZ file will be marked by the Photogrammetry Section suggesting the general location for the placement of aerial targets. This marked map, aerial image or Google Earth KMZ file, along with other pertinent data needed for securing the survey, should generally be sent at approximately the same time as the survey authorization. However, it is not uncommon for the map, image or Google Earth KMZ file to be sent in advance of the official authorization to ensure the photography is obtained during leaf-off conditions.

On projects where no centerline or traverse will be established, permanent control monuments will serve as control for securing all topography, property data, elevations, etc. which cannot be secured by Photogrammetry. Care should be taken in the placement of the control monuments to facilitate securing items such as edges of pavement, property lines, etc. This field data shall be secured in accordance with the Right of Entry procedures outlined in Chapter 4 and the Location Survey procedures outlined in Chapter 7 of this Survey Manual.

On projects where survey traverse lines are established on the ground, aerial panels are to be placed along the lines at approximately seven hundred fifty-foot (750 ft) to one-thousand-foot (1000 ft) intervals, depending on the scale of the photography. When placing a panel on a centerline or traverse station a hole should be cut in the center of the panel, and the panel placed over the station as level with the ground as possible. It is important that care be given so that panels are not placed in heavy woods or in shaded areas if at all possible. Where the centerline or traverse runs for long intervals in woods, panels with leg extensions should be used to increase the possibility that the panels can be seen on the photography. It is important that the panels be placed in open areas if possible. It is permissible to move a panel fifty to one hundred feet (50-100 ft.) along the centerline or traverse to a station that is in an open or minimally obscured area. In some cases, such as dense urban areas and low altitude photography, panels may need to be placed at a much shorter interval. Likewise, for some rural areas or higher altitude photography, the panel spacing interval may increase substantially.

If a connection exceeds one thousand feet (1000 ft) in length, panels should be placed at intervals of approximately seven hundred fifty to one thousand feet (750-1000 ft) along the connection, depending on the scale of the photography and the configuration of the connection on the photography. The panel placement map provided by the Photogrammetrist shall be used to define the panel spacing, interval and density required to meet the specific project needs.

As soon as practical after mainlines, connections and traverses have been paneled, a list of all the stations paneled, along with the alignment and control information should be submitted to the GeoSpatial Program Manager and the State Photogrammetry Supervisor, or their representatives, in accordance with Section 7.09 of this manual.

Sec. 6.03 Panels (formerly and/or also called Targets)

Aerial panels are the preferred means to mark control point locations for Photogrammetry.

Prior to the placement of any aerial panels or Photogrammetry control, the Survey Manager, or their representative should notify the respective Resident Engineer responsible for the region where the project is located. The Survey Manager, or their representative, should inform the Resident Engineer of the aerial control activity that will occur. When contacting the Resident Engineer, the following information should be provided:

- Name and UPC number of the project;
- Route number and name;
- City/county/town where the project is located;
- A brief description of what action is taking place;
- The expected duration that the aerial panels will be in place;
- The expected date when the aerial panels will be removed by VDOT personnel or VDOT representatives;
- And the importance of non-disturbance of the aerial panels until removed by VDOT personnel or VDOT representatives.

This information will assist the Resident Engineer when responding to citizen inquiries regarding the panels and the presence of VDOT Survey personnel or VDOT representatives.

An effective panel may be made in the shape of a cross with the control point to be measured and placed in the center of the cross. The legs of the cross should be straight and placed on level ground if practicable. When a panel absolutely must be placed on sloping ground, choose a ground location having a consistent slope; the cross panel should then be oriented so that two of the legs that form a straight line, lie along the slope at approximately the same elevation. The panel should have good contrast with its background. The standard, printed, forty inch by forty inch **(40 in x 40 in)** cloth panel works well against any background, and may be used in open areas for **1:3600** scale and larger scale photography. White vinyl product for pre-marked aerial panels also works well, as cloth material may not be available or as economical.

When placing panels in the woods, extension legs six inches **(6 in)** wide and five feet **(5 ft)** long or longer may be needed. Figure 6-A provides standard specifications for panel dimensions based on photo scale and existing site conditions. Figure 6-B illustrates a typical panel configuration.

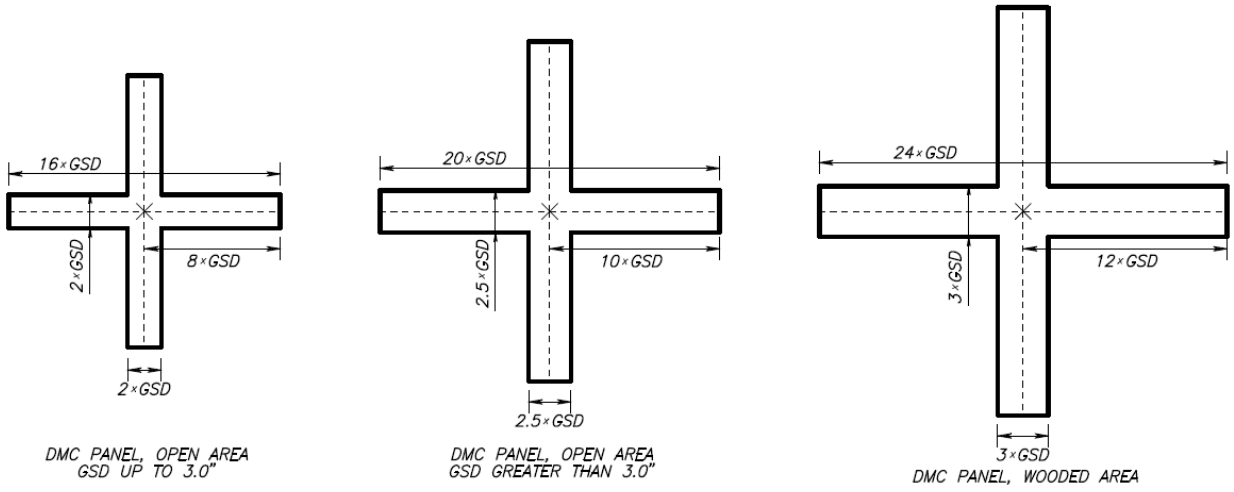
Panels painted on the pavement or sidewalk may be in the form of a cross, tee or chevron. For instance, a cross panel with an overall length of four feet **(4 ft)** and a width of four inches **(4 in)** for aerial photography scales **1:3600** (1”=300’) or larger. Using white paint on new asphalt and black paint on new concrete make excellent panels. On worn and discolored surfaces, it is often necessary to outline a white panel with black paint or vice versa.

Figure 6-A, Panel Dimensions

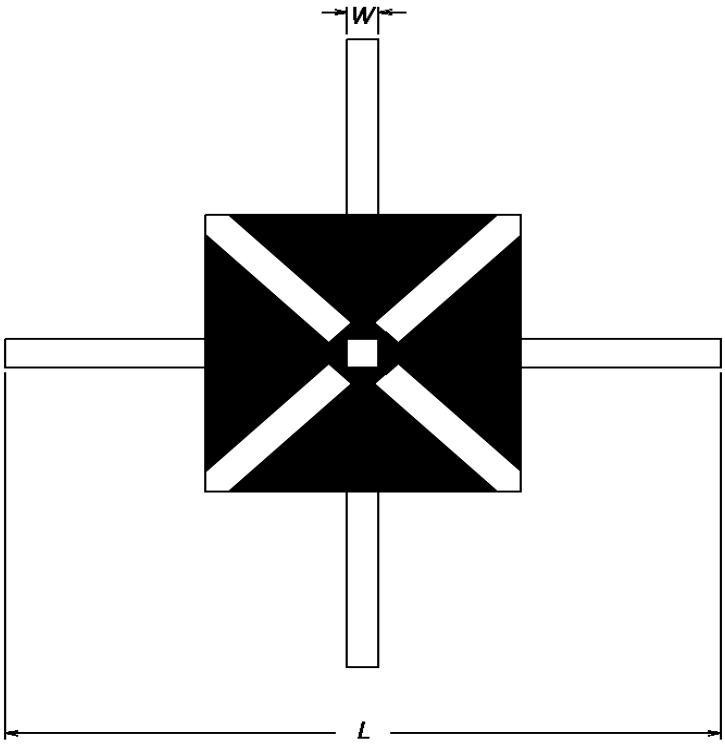
Panel Dimensions for Traditional Film

Photo Scale	Open Areas		Wooded Areas	
	L	W	L	W
Film (GSD)	Length (ft)	Width (in)	Length (ft)	Width (in)
1:3000 (1.5”)	4	4	8	6
1:3600 (2.0”)	4	4	8	6
1:4200 (2.5”)	4	6	8	6
1:6000 (3.0”)	10	9	12	9
1:9000 (4.0”)	10	9	14	9
1:12000 (6.0”)	15	12	20	12
1:18000 (9.0’)	20	12	25	18
1:24000 (12.0”)	30	18	40	36

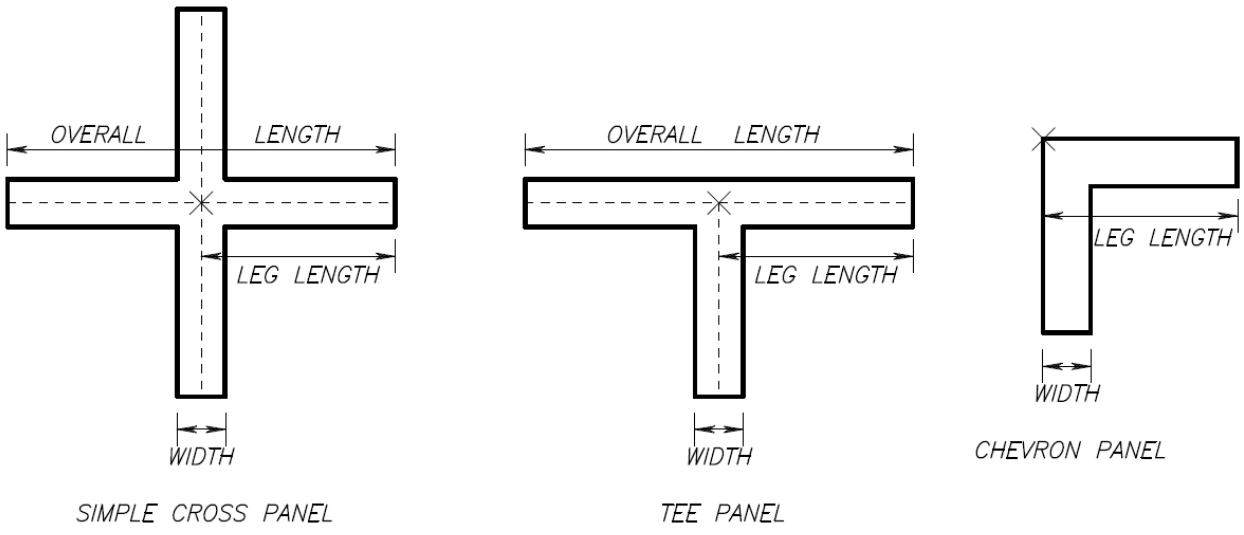
Panel Dimensions for Digital Media Cameras (DMC)



For Digital Media Cameras (DMC) use a ground sampling distance ratio to determine the minimum width and length of panel legs. In open areas with a GSD of 3” or less; multiply the GSD by two to determine the minimum width of a panel leg in inches and multiply by 8 to determine the minimum leg length measured in inches from the center point of the panel. For panels in open areas with a GSD greater than three, use a width multiplier of 2.5 and a length multiplier of 10 to obtain the minimum dimensions. In wooded areas use a width multiplier of 3 and a length multiplier of 12 to obtain the minimum dimensions. Use of “Tee” or “Chevron” panels are allowed using the minimum dimension ratios identified above. FOLLOW MANUFACTURER’S RECOMMENDATION as appropriate when a larger panel is indicated for the desired results.



Traditional Film Panel



Traditional Film and/or Digital Media Camera Panels

Figure 6-B, Panel Configuration

Sec. 6.04 Post Photography Control

Often, on Photogrammetric surveys, timing and other considerations do not allow for the placing of panels before the photography is secured. This necessitates the use of natural images, "picture points", or "PIDs" (photo-identifiable points), instead of panels for all control points. Natural image (picture point) locations must satisfy several conditions to ensure an acceptable accuracy level:

- They must be sharp, well-defined, and positively identifiable on all photos.
- They must lie in level, unobstructed locations.
- They must have thorough, accurate, and detailed descriptions written.

Natural images (picture points) are never as good as aerial panels from the standpoint of precision and identification. However, they usually have more permanence than a paneled point. Good natural image points for horizontal and vertical control include but are not limited to; intersection of parking lot markings; sidewalk corners and intersection of sidewalk edges; corners of drop inlet grates and concrete basins; painted traffic markings (points of turn lane arrows, corners of parking lot stripes, etc.), provided the traffic markings have not been changed or repainted between the time that the photography was taken, and the time of the control point survey. Be cautious, make sure these points have not been changed since the photos were taken.

Good natural image points for **vertical** control only include but are not limited to; the center of manhole covers; intersections of roads and/or trails; on pavement at the end of islands; bases of utility poles; fence corners; and fence intersections. Be cautious, make sure these points have not been changed since the photos were taken. These all work well for **vertical** control only, provided the point locations are on level terrain. Building corners; rock-outcrops; and around tree bases, should only be used in cases of extreme need when absolutely nothing else is available.

When selecting/reading any natural image (picture point), take extra care to ensure that the photo image and the actual ground location are the exact same point. Also, verify that the actual ground location is sharp; well-defined; not covered by dirt, sand, or vegetation; not obscured by shadows; is on level terrain, and not hidden by image layover (relief displacement) on the photo(s).

In most instances, the field survey crew will receive a set of imagery, .dgn design files, .pdf files, and/or .kmz or .kml Google Earth files from the Photogrammetry Unit. This photography will typically have the natural image (picture points) pre-selected. In other instances, areas will be circled in digital image files for natural image (picture point) location by the field crew. These areas are the suggested, first-choice areas that would provide the best location for a natural image (picture point) from a Photogrammetrist's perspective. The field crew is not required to limit their point locations to these circled areas if they cannot locate a suitable point within the area. It is acceptable for the field crew to select a location outside of the circled area, but every effort should be made to stay as close as possible to the circled area.

When writing natural image (picture point) descriptions, be sure to indicate if the point was read "on the ground" or on a structure. Locating natural image points "on the ground" is generally preferred by the Photogrammetrist but does not always provide the best location.

Always use the direction of flight as "North" when describing control point locations (the "North" side of a film-derived photograph corresponds to the same side that contains the date, photo scale, and exposure number). See Figure 6-C.

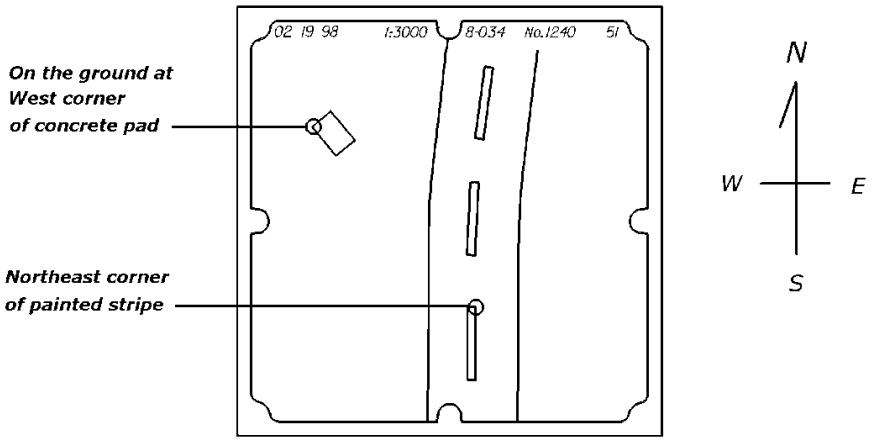


Figure 6-C, Flight "North" Reference

Sec. 6.05 Annotation of Aerial Control Points

When annotating aerial control points on the photography please follow the conventions as outlined below. This method replaces all existing methods. VDOT Photogrammetry Unit will make every effort to pre-select control point desired positions on all aerial projects.

If pre-marked panels are used, the points will be numbered sequentially, beginning with 101 and increasing one at a time, until all control points are numbered (101, 102, 103, etc.)

When natural images or picture points are used, the points will be numbered sequentially, beginning with 501 and increasing one at a time, until all control points are numbered (501, 502, 503, etc.)

The number assigned to an aerial control point must be written beside that point's location on the photograph or in an electronic image file. Also, if the point lies on a centerline or a traverse line, the corresponding station should be written beside the control point on the photograph/image file. All coordinate values of points should be annotated using the following format: ID – X – Y – Z. Control point ID numbers, coordinate values and descriptions (where applicable), should be clearly written on the backs of the contact prints using permanent ink or placed in image files.

It is critical that only one number be used to designate each control point. Never assign different numbers to the same control point within a project, even if the point appears on different photos or strips. Also, it is unnecessary to annotate control points on every film photograph. Choosing either odd or even photos is preferable for annotating control points but ensure all control points are clearly marked. When marking control points on the photographs or in an electronic image file, use the following symbology:

Δ = Full Control Point (X, Y, Z)

$\square$ = Horizontal ONLY Control Point (X, Y)

$\bigcirc$ = Vertical ONLY Control Point (Z)

Remember: Clear, concise descriptions are extremely important for all picture points.

Sec. 6.06 Delivery of Aerial Control Point Information

All data to be delivered via the ProjectWise file management system. Once all aerial control point values have been read and checked, and all contact prints/images annotated, the following items are to be delivered to the VDOT Photogrammetry Unit:

- The complete set of annotated contact prints (if applicable), or raw images, MicroStation .dgn design files, Adobe .pdf files, and/or Google Earth .kmz or kml files.
- Photogrammetric control values in ASCII text format or spreadsheet format (ID-X-Y-Z separated with at least one blank space.)
- Hardcopy of ASCII, text formatted control coordinate file.

		ID	X	Y	Z
Example of	**:**	101	11801539.488	3631516.040	74.8700
ASCII File	**:**	102	11801138.023	3631539.195	73.6500
Format	**:**	103	11801007.703	3630936.671	70.0000
		104	11801534.967	3630812.368	70.1080

For projects having the Photogrammetry performed by VDOT forces, return the control information to:

State Photogrammetry Supervisor
VDOT
1401 East Broad Street
Richmond, VA 23219

For projects having the Photogrammetry performed by consultant forces, upload into ProjectWise and send the link of the control information to the prime survey firm and copy the transmittal letter to the central office survey coordinator and the Photogrammetry Supervisor. The following Photogrammetric Control Standards document will be included with all new control requests:

Photogrammetric Control: Instructions to Surveyors

Date of Request: _____ UPC: _____

Route: _____ Activity: _____

City/County/Town: _____

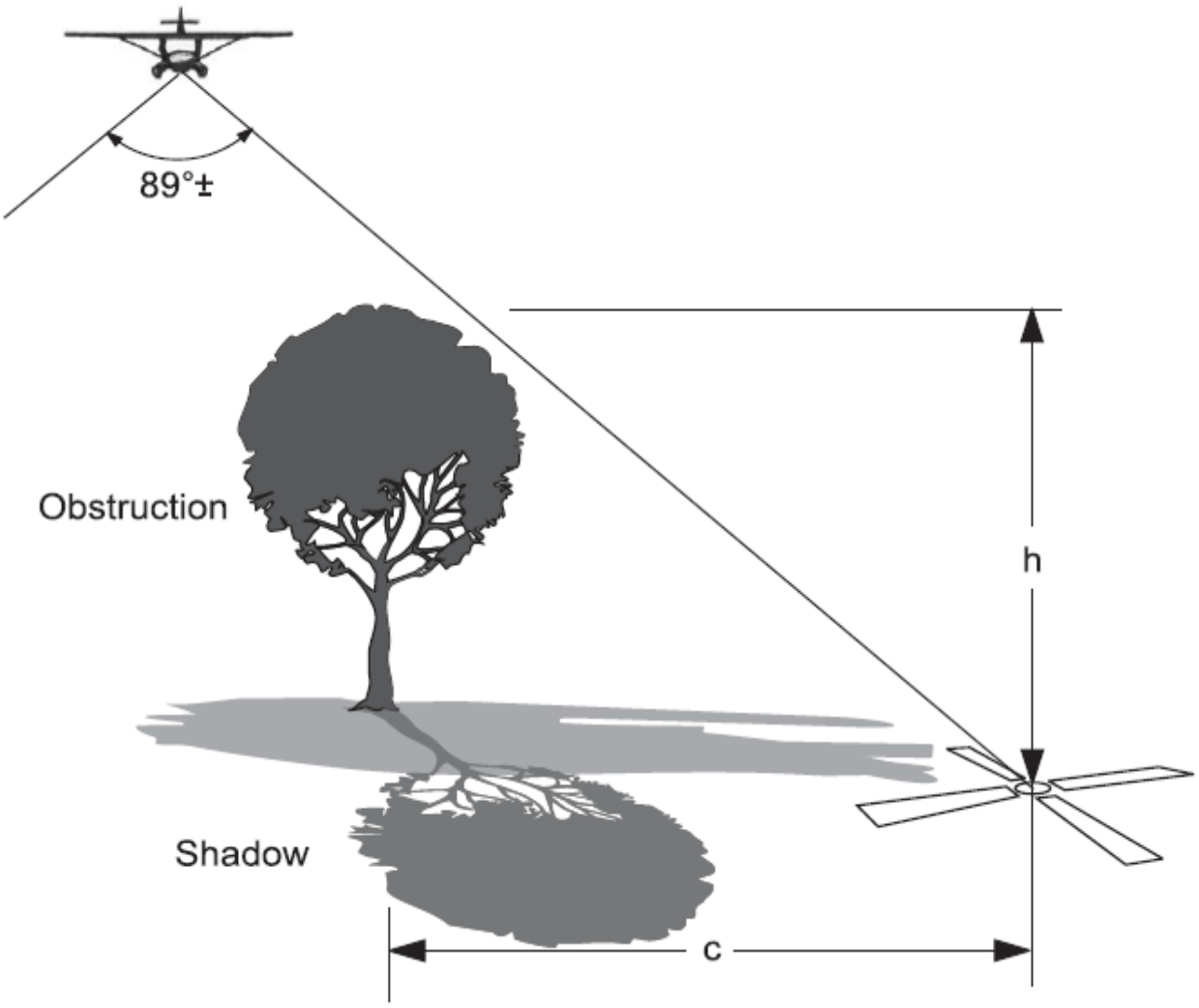
Photogrammetric Control Standards

ALL PANELS MUST BE CLEARLY SKY VISIBLE.

From each control point location, the sky must be clearly visible and free of obstructions such as trees, buildings, bridges, power lines, embankments, poles, signs, etc. (See figure on next page.)

"X" or "Cross", "Tee" and "Chevron" Photogrammetric ground control are the only acceptable pre-marked panel formats for VDOT aerial mapping projects. Acceptable panel materials are painted, cloth or vinyl varieties. **Always be cognizant of the flight path and each photo footprint.**

- Panels should be located on flat, bare ground, and level surface. Flat, grassed areas must be cut very short before placement of targets.
- Mainline & wing panel relocation maximum is 100 feet. Once again, be cognizant of the flight path and each photo footprint.
- Mainline panels limited to 50-100 feet relocation laterally. Lateral movement is along a line perpendicular to the flight line.
- Wing panels limited to 50-100 feet relocation laterally, on a line perpendicular to the flight line, and **relocated towards flight path or center of photograph.**
- Use paved shoulders (clearly sky visible) on major highways.
- Use centerline on rural roads (sky visible.)
- **AVOID placing panels on slanted or sloping ground!**



h = height of object above the
c = clearance (1.0h minimum)

All targets should be placed in a relatively flat area either on pavement or short grass, free from shadows or obstructions.

Photogrammetric Control Deliverables

Pre-marked "X" or "Cross" or "Tee" or "Chevron" Panels

A. Google Earth – .kmz or .kml 2D file containing field-surveyed control correctly located and marked with provided point ID numbers. Pre-marked Photogrammetric point ID numbers will begin with ***101***.

B. Control list with format: point #, Easting, Northing, Elevation. Include Excel spreadsheet file or formatted text (space delimited) file, in VDOT Project and Virginia State Plane Coordinate values. Both control files must contain date, units, coordinate type and county & scale factor used for conversion.

C. Provide GNSS Control Deliverables as referenced in VDOT Survey Manual, Chapter 5: Deliverables (Sec 5.06)

Picture Points

A. Unless otherwise arranged, VDOT Surveys & Photogrammetry Section provides picture point locations and ID's. Ground feature / picture identifiable Photogrammetric picture points will be annotated with ID numbers beginning with ***501***.

B. Provide detailed sketch of each **surveyed picture point location**, along with**,** a MicroStation .dgn design file, Adobe .pdf file, and/or Google Earth .kmz file with each point located and labeled.

C. Provide digital pictures of each control location at the point of measurement.

Note: A copy of the document "Photogrammetric Control Standards" (see page 6-7) will be sent with each control survey request to District or Consultant surveyors. This document supplements the guidelines for ground control surveys found in this VDOT Survey Manual. Available as a word document from the Photogrammetry section upon request.

Sec. 6.07 Digital Terrain Models, Cross-Sections, Profiles and Bridge Situations

When digital terrain models (DTMs), or cross sections are being secured by Photogrammetric methods, the survey party may be required to provide readings (as specified by the engineer) along or on all edges of pavement and concrete structures, such as curb and gutter, etc., in the required DTM format. Entrance profiles, storm water management areas and mitigation sites will be secured by Photogrammetry using the DTM method unless specifically requested otherwise. VDOT symbology for DTM collection is included in the table at the end of this section. Additional field run hard surface cross-sections may be requested as a separate deliverable and used to provide QA/QC of the photogrammetric DTM. The field run cross-sections will be performed at a pre-determined interval based on the project length and mapping scale.

Note to survey parties: For best terrain definition when collecting break lines on curved features (such as curb and gutter around entrances), the frequency of the readings should increase as the radius decreases.

On Photogrammetric surveys, DTMs should be used wherever possible when securing drainage data. The survey party should secure drainage data only when requested. On most surveys, only streambed elevations will be required.

When cross-sections or DTMs are secured by the Photogrammetric method, drainage ditch and outfall areas will be covered by contours. The survey party will secure DTM readings or cross sections necessary to cover the areas under water or otherwise obscured. On new alignment, the "drainage only" cross-section will extend left and right of the survey centerline. On existing alignment, the "drainage only" cross-section will extend left and right of centerline also and will show the invert elevations and characteristics of the existing structure(s). The "drainage only" cross-section will extend at least one hundred feet (100 ft) from centerline and up to two hundred feet (200 ft) when a parallel lane is to be constructed. The distance should be measured along the existing ditch or swale and the resultant profile should accurately show the existing conditions. In the case of existing parallel highways with wide medians, the "drainage only" cross-section must extend at least one hundred feet (100 ft) upstream and downstream from the existing structure. When a more detailed or an expanded survey to determine the adequacy of an outfall channel or drainageway is needed, the engineer is to provide the survey limits and specific survey requirements prior to the survey party collecting the “drainage specific” field data.

In addition to streambeds, there will typically be other areas obscured to Photogrammetry that the survey party will need to collect. Such areas do not facilitate accurate Photogrammetric DTM collection due to heavy vegetation cover (wooded and brushy areas), large structures covering the ground (bridges), etc. When obscure areas need to be collected by the survey party, the Photogrammetry section will furnish a list of the areas, and submit a marked set of photography, Google Earth KMZ file, annotated MicroStation file, or paper plots to the survey manager. The data will then be secured by the survey party and combined with the Photogrammetry data before the finished DTM is turned over to the design engineer.

When bridge situations are to be secured by Photogrammetric methods, sufficient data shall be secured by the survey party to complete the situation plan in accordance with both Chapter 7 and Chapter 8 of this manual.

For Bridge Site Plans - Highways and Railroads, where there are no existing structures, only pavement and top of rail elevations are needed along with the connection alignment and/or railroad traverse.

For Bridge Site Plans - Widening, all data secured shall be in accordance with Section 8.03.03 of this manual with the exception of cross sections. In lieu of cross sections, DTMs shall be secured covering the area under the structure, with sufficient data to cover the information needed to be merged with the data from the Photogrammetry section.

Note: Symbology shown below is for informational purposes only; please refer to the VDOT CADD Manual and OpenRoads Standards for a more complete and current symbology standards.

LEGACY VDOT SYMBOLOGY STANDARDS FOR DTM DATA FILES *Rev. 11/1/08*			
LEVEL	**DTM Data Source**	**Weight**	**Line Type**
3	Helicopter Photography (Low Level): Spot Shots	5	Active Point
4	Helicopter Photography (Low Level): Break lines	5	Line String
12	Obscure Areas	5	OBSC
13	Field Survey: Spot Shots	5	Active Point
14	Field Survey: Break lines	1	Line String
23	Standard Aerial Photography: Spot Shots	5	Active Point
24	Standard Aerial Photography: Break lines	1	Line String
33	LIDAR spots	5	Active Point
34	LIDAR Created Break lines	1	Line String
41	Bridge Decks: Spot Shots	5	Active Point
40	Bridge Decks: Break lines	1	Line String
43	USGS Digital Elevation Model: Spot Shots	5	Active Point
53	Low Accuracy Aerial Photography: Spot Shots (Orthophoto, Sound wall, etc.)	5	Active Point
54	Low Accuracy Aerial Photography: Break lines (Orthophoto, Sound wall, etc.)	1	Line String

2014 VDOT SYMBOLOGY STANDARDS FOR DTM DATA FILES *Rev. 3/1/14* **(For weights and line styles, refer to LEGACY VDOT Symbology Standards For DTM Data Files above)**	
LEVEL	**DTM Data Source**
PHOTO_DTM_HCOPTER_SPOT_SYM	Helicopter Photography (Low Level): Spot Shots
PHOTO_DTM_HCOPTER_BREAKLINE	Helicopter Photography (Low Level): Break lines
PHOTO_DTM_OBSCURE	Obscure Areas
SURVEY_DTM_SPOT_SYM	Field Survey: Spot Shots
SURVEY_DTM_BREAKLINE	Field Survey: Break lines
PHOTO_DTM_SPOT_SYM	Standard Aerial Photography: Spot Shots
PHOTO_DTM_BREAKLINE	Standard Aerial Photography: Break lines
LIDAR_DTM_SPOT_SYM	LIDAR spots
LIDAR_DTM_BREAKLINE	LIDAR Created Break lines
PHOTO_DTM_BRIDGE_SPOT_SYM	Bridge Decks: Spot Shots
PHOTO_DTM_BRIDGE_BREAKLINE	Bridge Decks: Break lines
NOT IN USE	USGS Digital Elevation Model: Spot Shots
PHOTO_DTM_LOWACC_SPOT_SYM	Low Accuracy Aerial Photography: Spot Shots (Orthophoto, Sound wall, etc.)
PHOTO_DTM_LOWACC_BREAKLINE	Low Accuracy Aerial Photography: Break lines (Orthophoto, Sound wall, etc.)

Sec. 6.08 Helicopter Photography

VDOT has begun utilizing photography taken from a helicopter in an effort to promote safety for the survey personnel and produce higher accuracy from Photogrammetric DTMs. Helicopters can fly at lower altitudes, and hover over the ground, unlike fixed-wing aircraft that must maintain a minimum airspeed and altitude to avoid disaster.

The photography produced from helicopter flights increases the accuracy of Photogrammetric measurements and data collection. Helicopter photography is typically acquired from three hundred to eight hundred feet **(300-800 ft)** above the ground. This produces photo scales ranging from 1:600 to 1:1600. This scale range produces a theoretical measurement accuracy of .03' to .08' respectively.

The helicopter has a hovering capability which allows it to hold position until the camera operator is ready to take the photo. This is particularly useful when working in areas of heavy traffic when vehicles are often driving across and obscuring the aerial targets.

Helicopter photography will not replace fixed-wing aircraft photography, nor will it replace the need for a field survey party, but it will provide a high-accuracy supplement for the survey data produced by traditional Survey and Photogrammetry methods.

Helicopter Photography Aerial Panels

"Cross", "Tee" or "Chevron" Panels may be used to mark all helicopter-photography Photogrammetry control points. The aerial panels used for helicopter photography are smaller than traditional panels and can be configured in the same shapes as the larger panels. See Figure 6-D**,** below for a possible helicopter-photography panel illustration. See Figure 6-E**,** for recommended helicopter-photography panel dimensions or use Figures 6-A and 6-B for DMC uses. A PK Nail should be set at the appropriate location as indicated in Figures 6-B or 6-D. The Photogrammetrist will actually be able to read the top of the nail, so careful attention must be made to place the nails at the appropriate location. The nails MUST be driven flush with the pavement. See Figure 6-F. The surveyor must read the center of the top of the PK nail as the control point location.

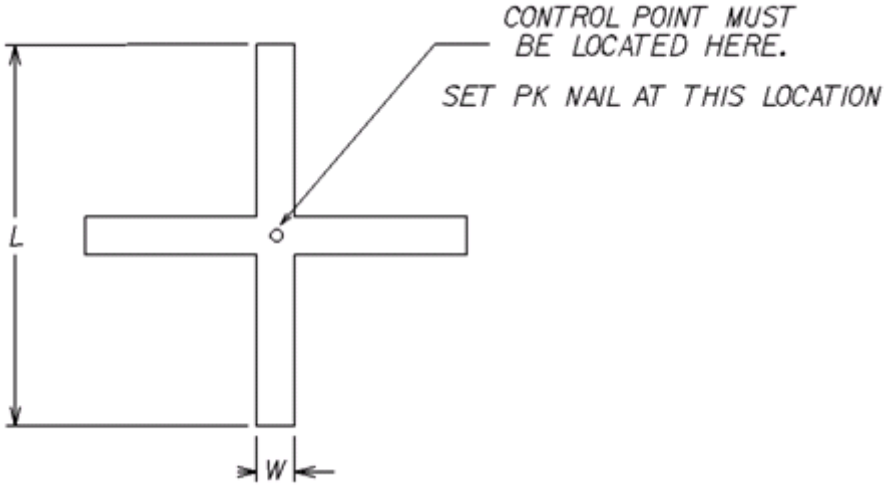


Figure 6-D Helicopter Photography Panel Illustration

"X" Configuration, Helicopter Panel Dimensions

Photo Scale	L Length (in)	W Width (in)
1:800 (1"=67')	8"	1"
1:1000 (1"=83')	10"	1"
1:1200 (1"=100")	14"	2"
1:1500 (1"=125")	18"	2"

Figure 6-E Helicopter Panel Dimensions

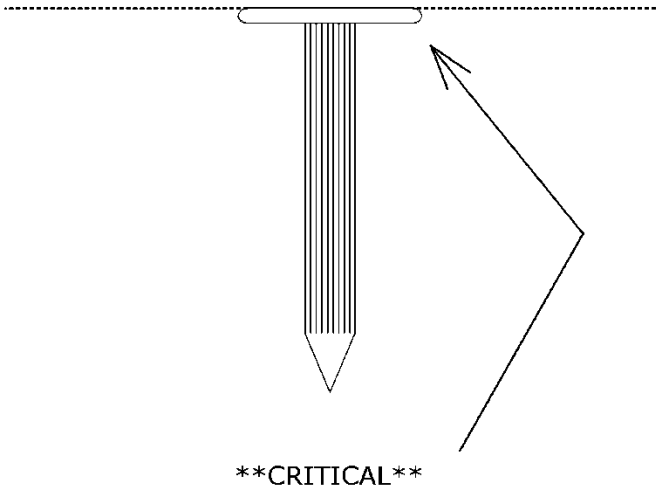


Figure 6-F Panel Nail Placement

Panels for helicopter photography can be set using either Method "A" or Method "B" below:

A: Set panels in pairs (one on the left shoulder or pavement edge, and the second, directly opposite the first, on the right shoulder or pavement edge), so that the panel pair falls on approximately every other stereo model. Panel spacing along the shoulder or pavement edge should be from 400'–550' for 1:800 – 1:1000 photo scales respectively. See Figure 6-G.

B: Set a single panel on approximately every other stereo model along the left shoulder or pavement edge then set a single panel on the right shoulder or pavement edge, staggering the panels so that one panel will fall on approximately every stereo model, alternating from the left shoulder or pavement edge, to the right shoulder or pavement edge. Panel spacing along each shoulder or pavement edge should be 400'–550' for 1:800 – 1:1000 photo scales respectively. See Figure 6-H.

- Helicopter panels must be painted on a hard and level surface.
- PK nails set at the center of the panel must be hammered flush with the surface.
- The point number should be painted next to the panel using 6-inch high numbers.
- A digital level should be used for the vertical control to keep the vertical closures as accurate as possible.

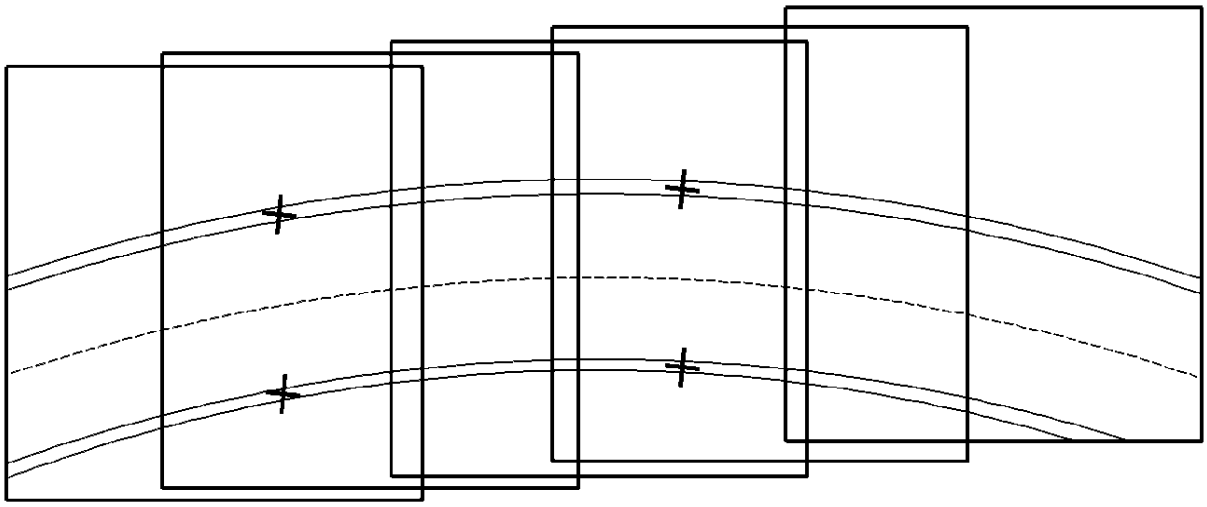


Figure 6-G, Paired Panels

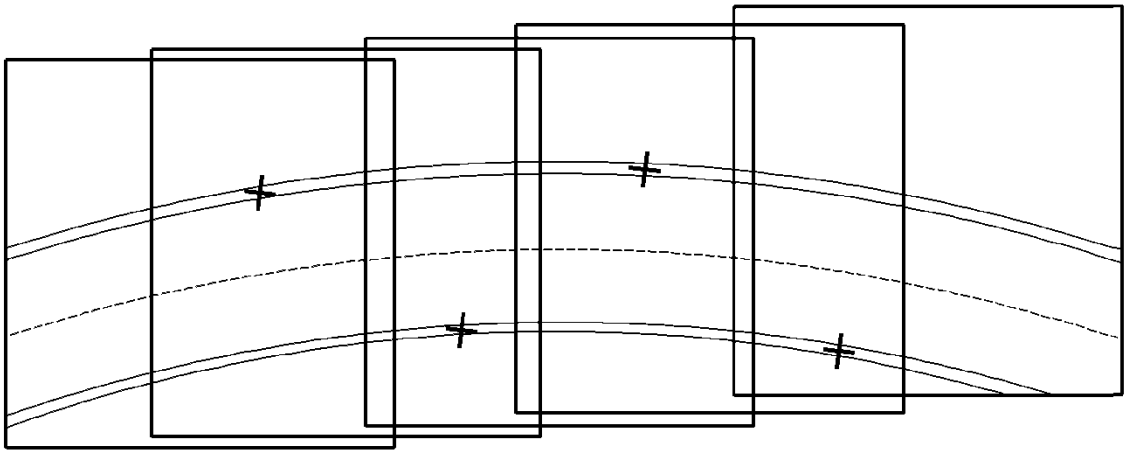


Figure 6-H, Staggered Panels

Sec. 6.09 Requesting Aerial Photography

Requests for aerial photography may be submitted any time throughout the year. Photography that is to be used to generate Photogrammetric mapping to supplement a location survey for base highway design, must be flown during leaf-off conditions, preferably in late January through mid-March. If design is the photography's intended use, the request needs to be submitted no later than the preceding December to early January (the earlier the better for scheduling purposes). Requests for general aerial photography may be sent to the Senior Aerial Photographer. Requests that require panels for Photogrammetry should be directed to the State Photogrammetry Supervisor. A copy of the request form is included on the next page. A copy is also located on the Central Office-Location and Design Division's intranet site, listed under the heading "Forms". The form number is LD-392.

Note: Be as specific as possible when filling out the form. Form LD-392

LD-392
(8-26-19)

VIRGINIA DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN
WORK REQUEST FOR AERIAL PHOTOGRAPHY AND MOSAICS

Date: Click to enter a date.			
To:	Photogrammetry Manager		
From:		Email/Phone:	
Project Information			
UPC	VA_UPC	State Project Number	VA_PRJ_NUM
City/County	VA_CO_CTY_NAME	Route	VA_ROUTE
Start Location (From)	VA_POOL_START_LOC		
End Location (To)	VA_POOL_END_LOC		

Note
1. Provide a Google Earth .kmz and/or Adobe .pdf file, depicting aerial photography coverage desired.
2. All aerial photography will be flown for engineering design scale (1" = 25') specifications unless requested otherwise
3. Provide survey project limits for design grade mapping. Limits should be delivered in a Google Earth .kmz and/or Adobe .pdf file

Additional Project Information			
Activity		Agency Use 1 Code	
UPC Lineage			

Request Information			
Check intended use of photography	☐ Design	☐ Study	☐ Other
Contact person if different from above			
Due date	Click to enter a date.		

Desired Products			
Aerial Photography	☐	Desired Photo Scale	
Ortho Mosaic	☐	Desired Ortho Mosaic Scale	
Obliques	☐		
Remarks			

cc: District Location & Design Engineer
Design Engineer
Photogrammetry Manager
Project Manager

Sec. 6.10 Requesting Photographic Products *(Photo Counter)*

Anyone requiring photographic products from VDOT's aerial photography archives, can order the products from VDOT's Photo Counter, located on the ninth floor at 1401 East Broad Street, Richmond, Virginia 23219 (Photogrammetry Section Contact Info). Examples of products that can be provided include: contact prints, diapositives, and paper enlargements. Current pricing policies are in effect. Please contact the photo counter using the web address and contacts link provided above for more information.

Any products ordered in support of a VDOT project must include the UPC number, the project number, and the activity number.

Consultants ordering photographic materials for VDOT projects assigned to them should make the request through their VDOT Survey or design coordinator, who will in turn place the order with the photo counter.

Note: Copyright laws are in effect for VDOT aerial photography and imagery.

For image processing services, and information regarding the Virginia Base Mapping Program (VBMP) orthophotos, please see Section 6-17.

Sec. 6.11 Field Responsibility for Quality Photo Control

Every effort must be taken to ensure the information supplied to the Photogrammetry Section is error free. Errors in elevation or horizontal position can adversely affect measurements made Photogrammetrically as much as 1000 feet away from where the error occurs. For this reason, it is required that you **TURN on each vertical control station** when securing elevations. A special effort should be made to ensure that the control values, both horizontal and vertical, are kept on the assigned project values. When assigning a number to a control station, **MAKE CERTAIN** that the assigned number is placed at the actual location of the control station to which it is assigned. When using GNSS (GPS) for Photogrammetry control, make certain that you tie the GNSS to existing monuments or other known points.

All survey topographic information must comply with the Model Virginia Map Accuracy Standards **Guideline** and the National Map Accuracy Standards**. All work must meet or exceed the project specific requirements using the procedural criteria outlined herein.**

Sec. 6.12 Field Responsibility for Quality Control of Photogrammetric Data

Upon receipt of the Photogrammetric data files (Aerotriangulation reports and files, planimetric, utilities, and DTM), the survey manager will initiate a series of field checks to validate the quality and accuracy of the Photogrammetric data. At a minimum, a selection of random features in the planimetric and utility files should be verified for horizontal accuracy, and the file must be reviewed for completeness. DTM file checks will include verifying invert elevations, random spot heights, and miscellaneous other features for horizontal and vertical accuracy and completeness. Field profiles or cross-sections may also be run to provide additional quality checks.

Sec. 6.13 Aerial Photography Quality Control Procedures

This section is to be used by all Virginia Department of Transportation (VDOT) personnel and consultants performing and providing aerial photography services for VDOT. It defines the appropriate and necessary procedures to follow for performing quality control/quality assurance checks on all products, data, and services provided by, and to, VDOT. The procedures outlined herein are to be explicitly followed during the development of all aerial photography data.

Film processing

The following steps will be taken to ensure the quality of the film and film processing methods used by VDOT and contractors. In all cases it is expected that the film and film-processor manufacturer's instructions and recommendations will be strictly followed for proper processing procedures and equipment maintenance. The film shall be free of scratches, static marks or other blemishes. It shall be exposed and processed with a density range of 1.0 +/- 0.2 with a minimum density of 0.3 +/- 0.1 above base fog. Base fog shall not exceed 0.15. All fiducial marks shall be sharp and clear.

1. Each roll of film will be inspected visually for image quality.
2. If there is a question as to image quality, then density readings will be taken of the affected exposures with a calibrated densitometer with a 0-3.0 range.
3. When the image quality does not meet standards, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Flight lines

The following steps are used to determine whether the photography was taken at the correct location and if atmospheric conditions were suitable for the project. Each flight line shall be flown continuously across the project area. No actual flight line shall deviate horizontally from the specified flight line by more than 10 percent of the specified flight height. The acceptable tolerance for altitude variation during image collection is plus 5% or minus 2% of the predetermined altitude.

1. Each flight line will be inspected visually to determine if the photography falls on the photo line and to ensure that the desired area is covered.
2. Each flight line will be inspected visually for excessive haze, shadows, clouds and snow cover.
3. When the photo location and/or coverage area do not meet standards or if the atmospheric conditions were unsuitable at the time of photography, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Overlap

The following steps are used to determine if there is adequate overlap to produce stereoscopic coverage. Overlap shall not be less than 55 percent or more than 65 percent and shall average between 58 and 62 percent. Side-lap shall not be less than 20 percent or more than 40 percent and shall average approximately 30 percent. Tri-lap of the mapping area shall be maintained across the project.

1. With the use of a template, the overlap of each flight line will be determined visually. Tri-lap (coverage on three consecutive exposures) will also be determined visually.
2. Side-lap for parallel flight lines will be checked visually.
3. When the overlap, side-lap and/or tri-lap do not meet specifications, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Crab

The following steps are used to determine if the crab (wind correction angle) is within specifications. Crab shall not exceed 3 degrees for any single photograph or more than 4 degrees for two or more consecutive photographs, and shall average approximately 1 degree for each flight line.

1. Each flight line will be visually inspected for excessive crabbing with the aid of a template.
2. If there is a question to the amount of crab then prints of the affected exposures will be made and the actual crab will be plotted on the prints.
3. When the amount of crab exceeds specifications, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Scale

The following steps are used to determine if the scale is correct and within specifications for the project. Actual scale shall not deviate from the specified scale by more than 5 percent high or low.

1. Each flight line will be inspected visually for proper scale. A template is used to determine proper photo coverage for a given scale.
2. If there is a question of proper scale, then the actual photo scale will be calculated.
3. When the scale is incorrect or does not meet specifications, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Tip and Tilt

The following steps are used to determine if the camera angle (level) is within specifications. The tip and tilt of the camera at the instant of exposure shall not exceed 4 degrees from vertical for any single photograph and the average throughout the entire project should be approximately 1 degree or less.

1. Each flight line will be visually inspected for proper tip and tilt.
2. If there is a question of proper tip and tilt then diapositives of the photography will be set up on a Photogrammetric instrument to determine actual tip and tilt.
3. When the tip and tilt exceed specifications, the aerial photography coordinator will be notified, and a determination will be made to accept or reject the photography. If the photography is rejected, the location will be reflown.

Additionally, flight logs will be reviewed for notes taken by the photographer during the flight and film frames will be inspected for error codes produced by the camera.

Sec. 6.14 Photogrammetry Quality Control Procedures

This section is to be used by all Virginia Department of Transportation (VDOT) personnel and consultants performing and providing Photogrammetric services for VDOT. It defines the appropriate and necessary procedures to follow for performing quality control/quality assurance checks on all products, data, and services provided by, and to, VDOT. The procedures outlined herein are to be explicitly followed during the development and delivery of all Photogrammetric products and services.

Project-Related Materials

All project related materials (flight/target maps, raw imagery, contact prints, diapositives, camera calibration report, control values, mapping scale, mapping units, mapping limits, scoping report, project specifications, adjoining project(s) and associated files, unusual circumstances, etc.) must be complete, and correct, and delivered to the internal or outsourced Photogrammetry unit performing the work. The VDOT Photogrammetry supervisor or manager will be responsible for validating the correctness and completeness of these materials. Each item must be verified by the manager or the supervisor as correct.

Prior to project start-up by the Photogrammetry unit, all diapositives and/or raw imagery are to be randomly checked to determine if any warping has occurred during the processing stage. A sample of 10%-15% of every project's diapositives is to have the interior orientations measured on an analytic or softcopy Photogrammetric instrument. Interior orientation values at each fiducial must be 20 microns or less. Any value exceeding 20 microns must be brought to the attention of the shift supervisor, and a determination will be made to accept or reject the measurement and/or the corresponding diapositive. If the raw imagery is rejected, then a new raw imagery must be produced, and this quality control process repeated.

Scanning (Softcopy Photogrammetry)

The following steps are to be used for quality assurance of the scanning process.

All equipment used for scanning aerial negative or positive film for the purpose of creating a digital image that will subsequently be used for aerotriangulation, stereo compilation, or orthophoto generation, must be certified by the manufacturer to be in good working condition to produce scans according to the manufacturer's originally stated specifications. Scanner calibration certificates (where applicable) must be current and validated by the manufacturer or a representative thereof.

All scans generated by a scanner must be of good radiometric and geometric quality. Interior Orientation values should not exceed 20 microns. These values and qualities must be verified by a senior technician or shift supervisor.

1. The material(s) being scanned (negative film or diapositive) will be visually inspected prior to scanning. The material(s) will be inspected to check for scratches, blemishes, discoloration, unusually dark or light areas, etc., which may affect the quality of the scanned images. Any material(s) failing the visual inspection will be reproduced. Any reproduced material(s) will be inspected as outlined above.
2. Normalization or calibration of CCD camera responses will be performed within manufacturer's recommended calibration range. Unacceptable normalization residuals must be corrected by authorized service, software checks, etc., before scanning commences.
3. Fiducial mark quality must be checked. All 8 fiducials should be visible, clear and sharp in the scanned image. If fiducials are of questionable quality, the affected images will be rescanned, and the original material reviewed for clarity. If appropriate, the original material will be reproduced in an effort to improve fiducial clarity and quality.
4. The manufacturer's recommended input values for Transmissivity (Tmin and Tmax), Density, and Gamma Correction, will be followed for all VDOT project-related scanned imagery.
5. A test scan will be performed on the first diapositive/negative, prior to scanning the entire project. Scanner settings will be adjusted as necessary to produce the best quality possible, meeting the requirements of the project. The test image will be visually checked for quality before final scanning is done.
6. Final scans will be reviewed for correct scan resolution, required image output format, and compression. Visual checks will be performed on the images after each scan is complete.

Aerotriangulation

The following steps are to be used for quality assurance of the aerotriangulation process:

1. Ground control delivered by the surveyor, will be assumed to be correct as verified by the quality control procedures used in the respective survey section. Input images/diapositives will be assumed to be quality-checked by the respective Photogrammetry unit, and ready for use in the aerotriangulation process.
2. The Photogrammetric technician performing aerotriangulation will verify that the correct camera calibration report is being utilized for the current project. Any discrepancies between the camera calibration report and the camera file utilized on the Photogrammetric instrument must be resolved.
3. Interior orientation of the images/diapositives must be 20 microns or less at each measured fiducial. Any value exceeding 20 microns must be brought to the attention of the shift supervisor, and a determination will be made to accept or reject the measurement and/or the corresponding image/diapositive. If the image/diapositive is rejected, then a new image/diapositive will be produced, and the quality control process repeated.
4. Relative orientation of the images/diapositives must be 5 microns or less at each measured point. Any value exceeding 5 microns must be corrected. If the point cannot be corrected by subsequent measurements, the problem must be brought to the attention of the shift supervisor. The shift supervisor will make a determination to either accept or reject the measurement, and what course of action will be taken to resolve the problem.
5. Absolute orientation measurement residuals for each control point on the images/diapositives must be .1' vertical and .2' horizontal or less for imperial-unit, 1:3000 scale photography. Any point measurement exceeding .1' vertical or .2' horizontal must be corrected. All points must be checked in stereo to ensure consistency and accuracy. If the point cannot be corrected by subsequent measurements, the problem must be brought to the attention of the shift supervisor. The shift supervisor will make a determination to either accept or reject the measurement, and what course of action will be taken to resolve the problem.
6. The residuals of each control point listed on the Photogrammetric adjustment will not exceed .1' vertical and .2' horizontal from their originally submitted values (for imperial-unit 1:3000 scale photography). Likewise, the mean residuals for all control points must not exceed .1' vertical and .2' horizontal. Any points exceeding .1' vertical or .2' horizontal must be investigated and corrected. If the point cannot be corrected by subsequent measurements or troubleshooting techniques, the problem must be brought to the attention of the shift supervisor. The shift supervisor will make a determination to either accept or reject the measurement, and what course of action will be taken to resolve the problem.
7. The final aerotriangulation adjustment must be reviewed and approved by the shift supervisor. This adjustment, which will include input and adjusted control values, will be printed onto hardcopy format. The shift supervisor will sign and date the first page of the hardcopy printout, and maintain this hardcopy record at VDOT-Central Office indefinitely.

Note: All consultants performing aerotriangulation on a VDOT project will submit the final, approved, signed and dated aerotriangulation adjustment report to the State Photogrammetry Supervisor at VDOT prior to mapping, or as soon as feasible after the start of stereo-compilation work.

Planimetric/Utility Compilation and Editing

The following steps are to be used for quality assurance of the planimetric and utility compilation and editing process. **Unless specifically requested by the Department, utilities are NOT to be mapped by aerial photography.**

1. Before starting planimetric and utility compilation, the Photogrammetry technician will verify the following project specific items and set up their work procedures accordingly:
   - Mapping Limits – delineate in separate MicroStation file, outline on contact prints or in a Google Earth KMZ file.
   - Map Scale – use appropriate feature tables, symbology, and resource files.
   - Units – Metric or Imperial.
   - Required Map Accuracy – review with shift supervisor.
   - Scheduled Due Date – verify/confirm with shift supervisor.
   - Special Project Circumstances – review with shift supervisor.
   - Obscure Areas – if obscure areas have not been collected, delineate them in a separate MicroStation file, or annotate on contact prints, or in a Google Earth KMZ file and submit to shift supervisor for submittal to the appropriate survey personnel. When obscure areas have been collected and delivered from survey, the file must be referenced, tied and merged as appropriate to the Photogrammetry data.
2. During planimetric/utility compilation, the Photogrammetry technician will perform continuous self-checks on the collected data.
3. Items to check include, but are not limited to:
   - Correct symbology and level structure as per the VDOT CADD and VDOT Survey manuals
   - Use of appropriate scales
   - Thoroughness of collected features
   - Adequate coverage of project area
   - Horizontal and vertical accuracy of collected features
   - Separation of utility information, if utilities were specifically requested, into a separate file
   - Compatible (appropriately tied) data (between stereo models, field data, and other Photogrammetry data), and clean appearance of the data (fully edited)
4. Upon completion of the planimetric/utility compilation for each stereo model, all compiled data will be reviewed by the technician that collected the data.
5. Upon completing the self-check and making any necessary edits, the Photogrammetry technician will notify a senior level technician or shift-supervisor that they have completed the stereo model, and that they require a quality review of the data contained within that stereo model.
6. The senior-level technician or shift supervisor will review and check the planimetric and utilities in the stereo model following the criteria listed in #2 above. Any errors detected by the senior technician or shift-supervisor are to be noted to the technician collecting the data so that the technician may make any necessary revisions. These revisions will be reviewed by the senior technician or shift-supervisor before final sign-off on the stereo model. The date of the final sign-off will be indicated adjacent to the senior technician or shift-supervisor's endorsement.
7. The approved, final review must be signed-off and dated by the senior technician or shift supervisor performing the final review before the Photogrammetry technician proceeds to the next stereo model. Steps 2 – 7 must be repeated for each stereo model within the project.

8. After the planimetry and utilities for the entire project have been compiled, edited, and checked as outlined above, the individual stereo model files will be merged (if necessary), and the utility data will be separated (if necessary) into a unique "utility" file. Each file (planimetric and utility) will be reviewed one final time for completeness and correctness by the shift supervisor. If any errors or omissions are detected, the shift supervisor may at his/her discretion, correct the file(s) themselves or return the file(s) to the Photogrammetry technician for correction.
9. The shift supervisor will notify the respective survey coordinator/survey technician/design technician by email or paper mail, when the files have been quality checked and approved. The shift supervisor will move the files to the appropriate location on ProjectWise, and maintain hardcopy records in the paper file of all correspondence relating to the files and the project.

Digital Terrain Model Compilation, Editing, and Processing

The following steps are to be used for quality assurance of the digital terrain model (DTM) compilation, editing, and processing process.

1. Before starting digital terrain model compilation, the Photogrammetry technician will verify the following project specific items and set up their work procedures accordingly:
    - Mapping Limits – delineate in separate CADD file. outline on contact prints or in a Google Earth KMZ file.
    - Map Scale – use appropriate feature tables, symbology, resource files; and use appropriate point spacing and DTM compilation techniques.
    - Units – Metric or Imperial.
    - Required Contour Interval – verify/confirm with shift supervisor.
    - Required Map Accuracy – review with shift supervisor.
    - Scheduled Due Date – verify/confirm with shift supervisor.
    - Special Project Circumstances – review with shift supervisor.
    - Obscure Areas – if obscure areas have not been collected, delineate them in a separate MicroStation file, or annotate on contact prints and submit to shift supervisor for submittal to the appropriate survey personnel. When obscure areas have been collected and delivered from survey, the file must be referenced, tied and merged as appropriate to the Photogrammetry data.
2. During DTM compilation, the Photogrammetry technician will perform continuous self-checks on the collected data.
3. Items to check include, but are not limited to:
    - Correct symbology and level structure as per the VDOT CADD and VDOT Survey manuals
    - Horizontal and vertical accuracy of collected break lines and spot readings
    - Appropriate point spacing and DTM collection technique
    - Thoroughness of collected features
    - Adequate coverage of project area
    - Compatible (appropriately tied) data (between stereo models, field data, and other Photogrammetry data), and clean appearance of the data (fully edited)

4. Upon completion of the DTM compilation for each stereo model, all compiled data will be reviewed by the technician that collected the data. Contours will be generated to check for high and low "spikes", and any other data abnormalities.
5. Upon completing the self-check and making any necessary edits, the Photogrammetry technician will notify a senior level technician or shift-supervisor that they have completed the stereo model, and that they require a quality review of the data contained within that stereo model.
6. The senior-level technician or shift supervisor will review and check the DTM in the stereo model following the criteria listed in #2 above. Any errors detected by the senior technician or shift-supervisor are to be noted to the technician collecting the data so that the technician may make any necessary revisions. These revisions will be reviewed by the senior technician or shift-supervisor before final sign-off on the stereo model. The date of the final sign-off will be indicated adjacent to the senior technician or shift-supervisor's endorsement.
7. The approved, final review must be signed-off and dated by the senior technician or shift supervisor performing the final review before the Photogrammetry technician proceeds to the next stereo model. Steps 2 – 7 must be repeated for each stereo model within the project.
8. After the DTM for the entire project has been compiled, edited, and checked as outlined above, the individual stereo model files will be merged (if necessary), and the entire DTM file will be reviewed one final time for completeness and correctness by the shift supervisor. Contours will be generated for the entire file to check for "spikes", data compatibility problems, and other data abnormalities. If any errors or omissions are detected, the shift supervisor may at his/her discretion, correct the file(s) themselves or return the file(s) to the Photogrammetry technician for correction.
9. The shift supervisor will notify the respective survey coordinator/survey technician/design technician by email or paper mail, when the DTM file has been quality checked and approved. The shift supervisor will move the file to the appropriate location on ProjectWise and maintain hardcopy records in the paper file of all correspondence relating to the file and the project.

Orthophoto Generation

The following steps are to be used for quality assurance of the orthophoto process.

1. The digital terrain model (DTM) file will be assumed to be correct as verified by the quality control procedures used in the respective Photogrammetry unit. Scanned images and aerotriangulation adjustments will be assumed to be quality checked by the respective Photogrammetry unit, and ready for use in the orthophoto process.
2. Individual orthophoto images created from ortho-resampling process will be visually inspected using image display software. Images of poor quality will be ortho-resampled again.

3. Ortho-rectified images will be checked for proper geo-referencing and geometric quality, and any abnormalities to the ortho images. A problem with any of these indicates problems with scanned images, DTM elevation data, aerotriangulation data or the ortho-resampling process. The problem must be investigated, and a solution determined. Final acceptance of the result will be approved by a shift supervisor, or senior technician.
4. The digital ortho mosaic will be checked for image quality. Seam line areas are checked for acceptable feathering among all individual ortho images. When seam line feathering does not pass the quality review, making the mosaic should be performed again with necessary adjustments applied. Seam lines should be placed in the least noticeable areas of image overlap.
5. The digital ortho mosaic will be checked for a uniform tonal look across the image. Image enhancement software will be used to improve the Digital Ortho Mosaic and the individual ortho images, if necessary.
6. Lastly, the digital ortho mosaic will be checked for geometric accuracy. Input control values should be checked against the corresponding positions on the ortho-rectified image. The ortho mosaic will also be checked against DTM data or other available map data for proper Geo-referencing within the coordinate plane. The scale across the image will be checked for accuracy by measuring between two known points and comparing that distance to the same measurement across the ortho images. The accuracy of the digital orthophoto must meet or exceed the project requirements and specifications.

Delivery

The following steps are to be used for appropriate notification and delivery of Photogrammetry products.

Upon completion of the quality review process for each Photogrammetric product (planimetric file, utility file, digital terrain model, orthophoto, etc.) the shift supervisor will copy the necessary files to the appropriate location on ProjectWise. The shift supervisor or unit manager will notify the respective central office survey coordinator, with a courtesy-copy to the appropriate Survey Manager, stating that the work is complete and providing the location of the files. Such notification will be made by paper mail or email with a hardcopy maintained in the Photogrammetry unit's paper files.

Important note: VDOT requires that engineering design grade Photogrammetric Surveys be performed under the direct supervision of a Land Surveyor or Surveyor Photogrammetrist, licensed in the Commonwealth of Virginia. VDOT also requires that the Photogrammetric master survey file be digitally sealed and signed by a Land Surveyor or Surveyor Photogrammetrist licensed in the Commonwealth of Virginia.

Sec. 6.15 Photogrammetry and Aerial Photography Products Delivery Schedule

The following schedules are to be observed for the various deliverables and procedures regarding consultant submittal of Photogrammetry data and aerial photography for all VDOT projects. This applies to all Photogrammetry and aerial photography work performed on any VDOT project regardless of the request origination.

Deliverable: Processed Digital Camera Imagery, Flight Map, Current Aerial Camera Calibration Report

Send To: Aerial Photography Coordinator
Virginia Department of Transportation
Location & Design Division
1401 East Broad Street
Richmond, VA 23219

Due: 30 calendar days after photo mission.

Notes: Photogrammetry consultants will upload all processed, aerial imagery to VDOT for inspection and acceptance using ProjectWise. Consultant will email a link to the ProjectWise location to the State Photogrammetry Supervisor.

One camera calibration report per camera/lens per year will be included with the first processed film submitted for each calendar year. Additional reports for the same camera/lens will not be required until the following calendar year or when the camera is recalibrated, whichever occurs first.

Deliverable: Aerotriangulation Report - Include all digital target location maps and ISAT formatted triangulation/stereo model files.

Send To: State Photogrammetry Supervisor
Virginia Department of Transportation
Location & Design Division
1401 East Broad Street
Richmond, VA 23219

Due: Immediately following acceptance of the final adjustment (typically within 2 business days).

Notes: Photogrammetry consultants are expected to submit the aerotriangulation report and electronic data files by ProjectWise. An email shall be sent with the link to the ProjectWise folder.

Aerotriangulation reports and electronic files are to include the following information:

1) VDOT Project and UPC Number
2) Units (English or Metric)
3) Input Ground Control List
4) Adjusted Point List
5) Standard Deviation Tolerances for horizontal and vertical control
6) Individual Control Point Residuals
7) RMSE values for X-Y-Z coordinates
8) Input control withheld from final adjustment (ID, X-Y-Z withheld)
9) Complete set of as flown photo center coordinates in text format.
10) For digital camera, additional deliverables include camera system project files, exterior orientation data, ground sampling distance/resolution, flight strips/images index, and target location map.

VDOT staff will review the adjustment and respond accordingly. Consultants are instructed to proceed with mapping activities after they have accepted the final adjustment.

DO NOT WAIT for VDOT's approval of the aerotriangulation report to proceed with mapping. Any noted problems regarding the adjustments will prompt immediate communication from VDOT to the respective consultant firm.

The following Photogrammetric Aerial Deliverables document will be included with all new aerial project requests:

Post-Aerial Flight Deliverables Check List

Date of Request:	UPC:
Route:	Activity:
City/County/Town:	

Consultant Responsibilities

A. Prime consultants will perform full QA/QC on all aerial photographic deliverables before providing to VDOT

B. Prime consultant will perform field and Photogrammetric Aerotriangulation QA/QC on survey control deliverables (if included as a task), before providing to VDOT. Include GNSS Control Deliverables as referenced in the VDOT Survey Manual and in the document ***VDOTProjectDeliverables.docx.*** Also include Photogrammetric Aerotriangulation QA/QC residual reports as referenced in **Section 6.15** of the VDOT Survey Manual. (Available as a word documents from the Photogrammetry section upon request)

C. Digital sensor imagery files.

D. Flight folder and maps returned.

E. Post-Flight Reports (Logs) including:
- Flying height, altitude, scale and *ground sampling distance (GSD)*
- Direction of flight for each flight line.
- Numbering order of photography frames.
- Current USGS Calibration Report for film cameras
- Applicable calibration report for *digital sensor* including internal camera parameters.
- "Actual" photo center X, Y coordinates for all frames/strips (Virginia State Plane).

F. Also required for *digital sensor imagery*:
- Number of bands in imagery.
- Bit-depth of deliverable imagery.
- Exterior orientation data.
- ISPM/ISAT project electronic files for DMC digital cameras

G. QA/QC performed ASAP. Check that the produced photos are what was ordered. Also include, but not limited to: forward overlap (58% to 62% desired), crab, drift, side stepping, film or imagery contrast, brightness, sharpness, debris, etc.

H. VDOT will provide consultant with letter or email of acceptance/rejection of aerial photography, survey control, and Photogrammetric Aerotriangulation per task order event scheduling.

Deliverable: Orthophotos and File Index

Send To: State Photogrammetry Supervisor
Virginia Department of Transportation
Location & Design Division
1401 East Broad Street
Richmond, VA 23219

Due: 5 business days after generation and quality-review acceptance of the orthophotos are completed.

Notes: Photogrammetry consultants will be expected to submit the completed orthophotos on ProjectWise. All orthophotos are to be delivered in un-tiled GeoTif (.tif), or tiff (.tif) with tiff-world-file (.tfw) format. The file index is to be a 2D MicroStation file containing vector-shape representations of each orthophoto with each orthophoto file name written within the vector shape.

Orthophotos generated for highway design must be georeferenced to the same coordinate base established for the location survey. Orthophotos generated for corridor studies may be on an arbitrary coordinate base as instructed by VDOT, providing the units are compatible with the design project. VDOT staff will review the orthophotos for radiometric and geometric quality and respond accordingly. Consultants are instructed to proceed with other mapping activities after they have completed, reviewed, and accepted the orthophotos.

DO NOT WAIT for VDOT's approval of the orthophotos to proceed with other mapping activities. Any noted problems regarding the orthophotos will prompt immediate communication from VDOT to the respective consultant firm.

Sec. 6.16 Airborne Light Detection and Ranging (A-LiDAR)

Light Detection and Ranging (LiDAR) data may be used for certain VDOT projects. Such projects include corridor location studies, and any other preliminary engineering projects that require a digital terrain model (DTM) at a lower level of accuracy than traditional location surveys. The use of LiDAR typically provides a faster delivery of data at a lower cost than conventional Photogrammetry and survey methods. VDOT does not have airborne LiDAR capabilities and relies on the consultant community for all Airborne LiDAR (A-LiDAR) services. Likewise, VDOT does not have Mobile Terrestrial Laser Scanning (M-LiDAR) capabilities and relies on the consultant community for M-LiDAR services as well.

VDOT does have limited terrestrial (ground-based) laser scanning or LiDAR capabilities for projects less than one mile in length. Terrestrial LiDAR (STLS) can be used for location studies and any other preliminary engineering projects. Refer to Chapter 9 of the VDOT Survey Manual for more information and guidelines relating to the use of STLS or M-LiDAR technologies on VDOT projects.

VDOT does demand that any consultant performing LiDAR work for the department have the necessary hardware, software, and experience that will provide a consistent, accurate, and reliable product. A-LiDAR procedures must include appropriate data filtering and editing to eliminate incorrect, non-surface readings, and reduce the file to a manageable size. Development of break lines may use a combination of aerial photography and A-LiDAR data for horizontal location (aerial) and vertical location (A-LiDAR) at the professional's discretion. **Photogrammetry must be utilized to develop break lines for the DTM and to provide a means for quality control of the A-LiDAR data**. This has become a standard practice within the industry, and will be expected by VDOT. **Break lines are to be added/confirmed by Photogrammetry along all pavement, ditches, ridges, valleys, streams, edges of water and any other significant surface feature that would require a break line for proper definition. Obscured areas may require that break lines be obtained using conventional survey methods in support of, and to verify the A-LiDAR data.**

Note: **A-LiDAR data is *not* to be used for any location survey unless written approval is given by the GeoSpatial Program Manager or the State Photogrammetry Supervisor**.

As A-LiDAR technologies improve, the requirements listed in this section will be modified. Therefore, anyone providing A-LiDAR services to VDOT will be expected to check the online version of the Survey Manual for the updates or contact the GeoSpatial Program Manager or the State Photogrammetry Supervisor.

The following list outlines a basic framework for executing A-LiDAR projects:

1. Approval/Notice to Proceed utilizing A-LiDAR.
2. Establish/set control for aerial photography as outlined herein.
3. Fly photography and A-LiDAR. The A-LiDAR platform must include a fully functioning airborne global positioning system (A-GNSS) and an inertial measurement unit (IMU.) GNSS base stations must also be utilized. (See Chapter 5, Section 5.12) Post processed A-GNSS/IMU data shall be used when processing the A-LiDAR point clouds. The guidelines from Section 6.13 relating to tip, tilt, crab, scale, etc. will apply to A-LiDAR missions. A-LiDAR sampling should be capable of collecting 10 points per square meter (10 ppsm) as referenced to the project controls and supported by Aerial imagery at 2" GSD (Ground Sample Distance) or better unless stated otherwise in the project specific requirements.
4. Aerotriangulation of aerial photography for subsequent break line compilation, quality control of A-LiDAR data, orthophoto generation, and planimetric compilation. The amount of overlap, side-lap, and tri-lap may be increased and/or adjusted at the discretion of the professional to accommodate the needs of the A-LiDAR mission.
5. Filtering/data-editing of A-LiDAR mass point clouds.
6. Photogrammetric quality control of A-LiDAR data and addition of break lines.
7. Orthophoto generation.
8. Quality review and assurance of all products.
9. Delivery of final products to VDOT.

The following table lists the deliverable and file format, for projects utilizing A-LiDAR. All VDOT projects utilizing A-LiDAR will be restricted to the following digital file formats.

Deliverable	**File Format**
Digital Terrain Model	3D MicroStation (Break lines and points)
Contours	2D MicroStation - Contour interval as required. - Provide edge-to-edge match between "cut" contour files, **No Overlap**
Planimetrics *(When required)*	2D MicroStation - Provide edge-to-edge match between "cut" planimetric files, **No Overlap**
Orthophotos *(When requested)*	Un-tiled GeoTiff (.tif and .tfw) <OR> Descartes (.hmr) - Provide edge-to-edge match between "cut" orthophoto files. **No Overlap** - File format will be determined by the project manager. - Color balancing performed, if needed
Index	2D MicroStation - File indicating the area of coverage and filenames for all files/sheets in each deliverable category.
Point Clouds	Registered point clouds in XYZI or XYZIRGB files in ASCII, CSV, LAS, LAZ, ASTM E57 3D Imaging Data Exchange Format (E2761), or other manufacturer's specific format

Sec. 6.17 Image Processing

Image Processing can be defined as the editing, manipulation, and modification of imagery in order to prepare the imagery for subsequent use. For VDOT use, imagery can be processed for numerous applications within Location and Design as well as many other divisions. Such applications include many of the same as for traditional aerial photography, but are not limited to: project scoping, public hearings, right of way claims, and project delineation, aerial photography mission planning, survey control diagrams. Imagery can be formatted for use on the primary VDOT graphics applications, in most any coordinate system and file format.

In response to increased demands for imagery (orthophotos, mosaics, etc.), the Photogrammetry Section has increased its image processing services and capabilities. VDOT has a large archive of color, and black and white aerial photography that can be converted into digital format. Rectified or non-rectified photos and mosaics can be generated from the aerial photography, and with the incorporation of a digital terrain model during processing, orthophotos can also be generated.

The Virginia Geographic Information Network (VGIN) developed the Virginia Base Mapping Program (VBMP) in 2002, which produced digital, color orthophotos at varying resolutions covering the entire state of Virginia. The Virginia Department of Emergency Management now host the orthoimagery. VDOT has procured a license to utilize the VBMP imagery. These images are updated every 2 to 4 years and are available for VDOT use on VDOT projects. The license agreement contains restrictions on the use of the imagery and users must understand and follow these restrictions.

To order VBMP imagery, complete a "Virginia Base Mapping Program Imagery Request Form" (LD-393, located at the end of this section). Also provide a location map (topographic map, Adobe .pdf, Google Earth .kmz, or other detailed project map) indicating the area of desired coverage. Submit the form and map to the Photogrammetry Unit at Central Office (email submittals are acceptable and encouraged). If the imagery will be used by a consultant performing work on any VDOT project, the VDOT project manager and the consultant must complete a contractor's agreement and submit the completed agreement along with the imagery request form and annotated map.

All users of the VBMP imagery must read, understand, and abide by the license agreement, and the restrictions associated with imagery usage. For more information regarding the VBMP imagery, the contractor's agreement, or to request non-VBMP image processing services, contact the State Photogrammetry Supervisor or the Photogrammetry Unit's Image Analyst.

Additional VBMP information available at the link:
https://www.vaemergency.gov/911-geospatial/vgin-geospatial-services/orthoimagery/

Note: Copyright laws are in effect for current VBMP imagery.

Link: http://vdotforms.vdot.virginia.gov/SearchResults.aspx?strFormNumber=LD-393

LD-393
(3-29-19)

VIRGINIA DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN
IMAGERY REQUEST FORM

Date: Click to enter a date.			
To:	Image Analyst/VGIN Coordinator		
From:		Phone:	

Project Information			
UPC	VA_UPC	State Project Number	VA_PRJ_NUM
City/County	VA_CO_CTY_NAME	Activity	

Request Information		
Intended use of imagery		
VDOT personnel using the imagery		
Has the person making this request read the L&D user instructions and the VBMP license agreement? If NO, this must be completed before requesting imagery.	☐ Yes ☐ No	
Will this imagery be distributed to consultants or other non – VDOT person/entity? If YES, a contractor's agreement must be received before imagery is released.	☐ Yes ☐ No	
Date needed	Click to enter a date.	
Image Format	☐ MrSid ☐ GeoTiff (.tif) ☐ Descartes/Microstation (.hmr)	
Coordinate System	☐ VDOT Project Coordinates ☐ Virginia State Plane-North Zone ☐ Virginia State Plane-South Zone	County Scale Factor

Note
ALL DATA IS PROVIDED "AS IS". THE COMMONWEALTH OF VIRGINIA, THE VIRGINIA GEOGRAPHIC INFORMATION NETWORK AND THEIR RESPECTIVE OFFICERS, AGENTS AND EMPLOYEES JOINTLY AND SEVERALLY DISCLAIM ANY AND ALL REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED, WRITTEN OR ORAL, IN FACT OR ARISING BY OPERATION OF LAW, INCLUDING ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY, CURRENCY, COMMERCIAL VALUE, OR FREEDOM OF DATA FROM INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

cc: District Location & Design Engineer
Project Manager
Design Engineer