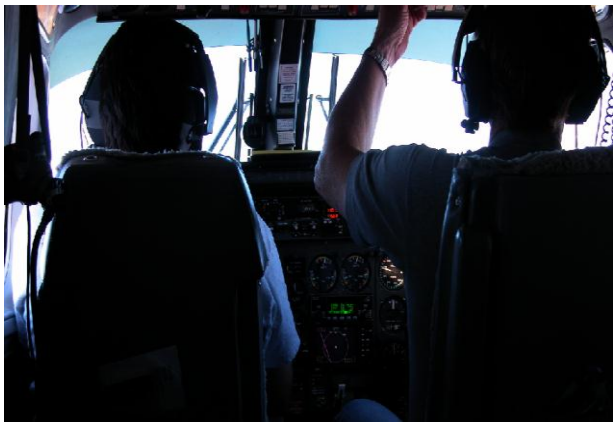
ARIZONA DEPARTMENT OF TRANSPORTATION

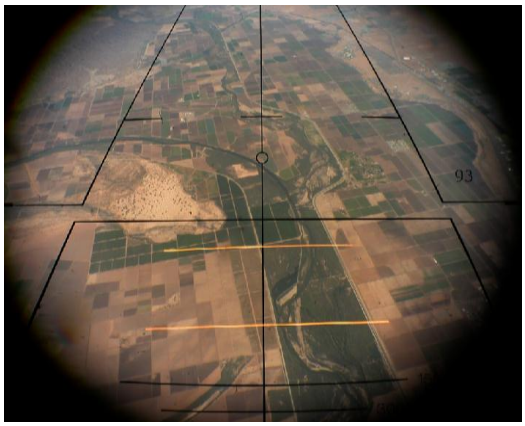
INTERMODAL TRANSPORTATION DIVISION

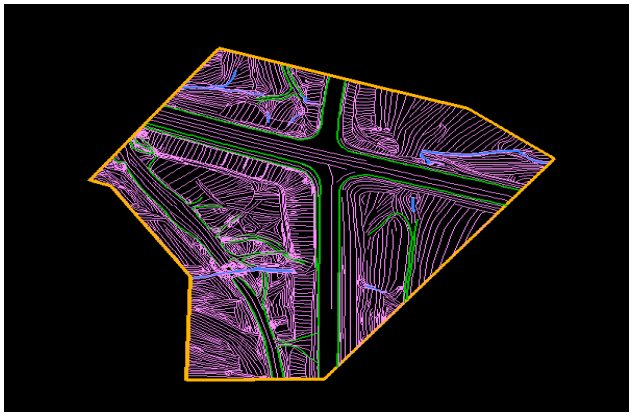
ENGINEERING TECHNICAL GROUP

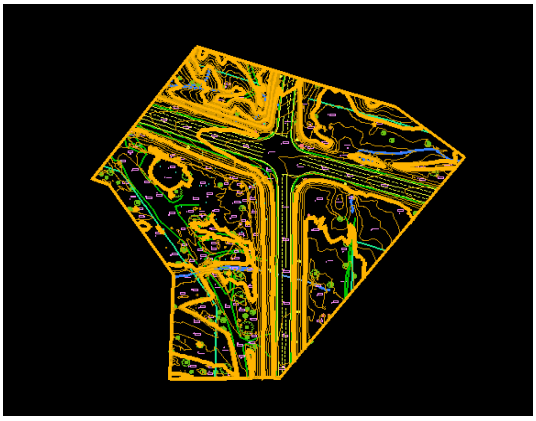
ENGINEERING SURVEY SECTION

GENERAL SPECIFICATIONS FOR PHOTOGRAMMETRIC MAPPING









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Section 1 – Introduction

1-01.00 General

This document sets forth the general specifications regarding the various products and services supplied by the Arizona Department of Transportation Photogrammetry and Mapping Section (ADOT P&M). Additionally, this publication describes various services available for use in support of Arizona Department of Transportation (ADOT) projects and activities. Items such as aerial photography, orthophotography, photo enlargements, photogrammetric mapping, and digital terrain models (DTM) are covered. Although each may be used independently, they are most often used in conjunction with one another.

1-01.01 ADOT P&M's primary role is to provide photogrammetric mapping and aerial photography services (for ADOT projects) to ADOT Project Managers or ADOT Consultants.

1-01.02 The ADOT P&M Advisor/Coordinator shall act as a technical consultant to ADOT Project Managers or Consultants. ADOT Project Managers or Consultants may seek the advice of the ADOT P&M Advisor/Coordinator for any questions or concerns at any time before, during, or after the photogrammetric mapping process.

1-01.03 Prospective Consultants will be qualified by ADOT to perform the services in the manner and time specified. ADOT shall be the sole judge of the prospective Consultant's competency and qualifications.

Section 2 - Product Requests

2-01.00 General

Requests for aerial photography, orthophotography, photogrammetric mapping, and DTM services (for ADOT projects) by ADOT Project Managers or ADOT Consultants should be made as early as possible. This provides adequate planning and production time, and allows for unpredictable delays (e.g. unfavorable weather/lighting conditions which can prevent or delay the acquisition of aerial photography). Project plans or a diagram with a detailed description of the project area to be photographed and/or mapped should be included with each request.

Section 3 - Field Control

3-01.00 General

If the Consultant is required to furnish field control data, it will be provided in accordance with ADOT Engineering Survey Section Specifications entitled, *Manual for Field Surveys,* and in accordance with the terms of the Contract.

Section 4 - Control Paneling

4-01.00 General

The photogrammetric compilation of a map from aerial photographs requires that distinct physical features on the ground (which have known horizontal and vertical coordinates) be identifiable on the photographs. In order to meet this requirement with a high degree of precision, targets (also referred to as ground

control panels or control panels) are set on the ground at specified locations. Data is subsequently collected by GPS survey methods to calculate the coordinates for each ground control target.

4-01.01 A ground control scheme of the project area will be prepared on an aerial photo mosaic and/or topographic map. The scheme will show the required location for all control panels, aircraft flight line(s), project limits, and the control panel size for the photogrammetric project.

4-01.02 Triangles will be marked on the aerial photo mosaic and/or topographic map indicate horizontal and vertical GPS control locations. If a project is to be 'tied' to an earlier photogrammetric project, every effort must be made to locate the previous control panel coordinates. This allows the new mapping project to conform to the previous mapping project. If the previous control panels cannot be located, the Field Survey Crew Chief shall notify the Field Survey Manager for instructions.

4-02.00 Placement

Control panels will be constructed in the shape of symmetrical crosses, unless otherwise stated (See Appendix A, Figure 1). If possible, they shall either be painted on pavement or constructed of white velum. Panels shall be secured to flat ground with lath and spikes in such a manner that they will remain in place for a minimum of two weeks. If the ground is similar in color to the panel material, black roofing paper shall be placed under the panel to create contrast and aid in identifying it on the aerial photograph.

4-02.01 Control panels must be centered on the surveyed point in order to precisely establish its location on the photograph. Every effort should be made to ensure that the rebar, spike, or nail used to mark the control point's location is flush with the ground. Should the rebar, spike, or nail extend above the ground, a hole shall be made in the material to allow the mark to protrude through the velum and lay flat. A note shall be made documenting the point's protrusion above the ground and forwarded to ADOT P&M.

4-02.02 Control panels shall not be placed under or near vertical objects (e.g. trees, buildings, brush, power poles, power lines, etc.). Such items may render them unusable by obscuring them on the photo and/or interfering and degrading GPS signal. Panels will be located in an area clear of overhead obstructions at a 45 degree angle in all directions, and on ground as flat and uniform as possible. (See Appendix A, Figure 2). All bushes, high grass, etc., shall be cleared to provide a flat surface.

4-02.03 Control panel size is dependent upon the desired aerial photograph scale. Appendix B, Table 1, prescribes proper panel size for common photo scales used by ADOT P&M.

4-02.04 Panels shall be placed beyond project map limits. Generally, 3 control panels will be placed at the beginning and end of every flight line. Additionally, 3 targets shall be placed at least every 3 stereo models, but not more than 4 stereo models.

4-02.05 The Consultant or ADOT Project Manager may consult the ADOT P&M Advisor/ Coordinator to review the control scheme/flight plans and/or the relocation of any control panels.

Section 5 - Aerial Photography & Laboratory Work

5-01.00 General

The work to be done consists of furnishing aerial photography, digital scanning, and laboratory work for photogrammetric mapping applications within the State of Arizona

5-01.01 Aerial photography will be provided in accordance with the terms of the Contract. All projects are located on existing highways, proposed routes or other locations which are a part of, or are proposed to be incorporated into, State Routes within the State of Arizona. Other facility locations within the state may also be considered for photogrammetric mapping projects.

5-01.02 The intent of the aerial photography specifications is to provide the details for performance and

completion of work which must be met by the Consultant when providing aerial photography services for ADOT projects. Where the specifications describe portions of the work in general terms and not in complete detail, it is understood that only the best general practice is to prevail and that only materials and workmanship of the finest quality are to be used. Unless otherwise specified, the Consultant shall provide all labor, materials, tools, equipment, and incidentals, and complete all work involved in executing the Contract.

5-01.03 Aerial photographs will primarily be used for map compilation for Project Assessments (PA), Design Concept Reports (DCR's) and Design Level Mapping (design of new roads and various road improvements). However, they may also be used for general views of an area, public hearings, legal court cases, hydrology studies, materials borrow pit quantities, and environmental studies.

5-01.04 Although black and white (B&W) photography is the standard product, color aerial photography may be obtained if there are special project requirements. Advance planning is critical in the acquisition of aerial photography since it costs more than standard B&W photography. Requests for color photography should be made well in advance to allow for the scheduling of the various parties involved.

5-02.00 Statement of Certification

Consultants providing services on ADOT projects must submit a statement certifying that the Consultant:

a) Has had previous experience in the type of specialized aerial photography and laboratory work required.

b) Has a 6 inch nominal focal length precision cartographic camera equal to or better than a Wild RC/20 or Zeiss RMK-A 15/23 with an acceptable calibration report from the United States Geological Survey (USGS). The camera shall be equipped with 8 fiducial marks and forward motion compensation. Additionally, it shall be capable of taking 9 by 9 inch standard format aerial photographs. (NOTE: ADOT does not currently have the means to support aerial photography originating from a digital aerial camera. Digital aerial cameras shall not be used to acquire aerial photography for ADOT projects.)

c) Is equipped to perform all operations for all phases of work required in these specifications, including color processing (if required). The equipment shall include the following:

i) An automatic dodging-type printer (such as Log-e-tronic Model Mark IV or equivalent) and/or a digital photogrammetric grade scanner for aerial film.

ii) Equipment for developing, drying, and processing aerial film.

5-03.00 Aircraft

The aircraft shall be suitable for photographic tasks capable of an 18,000 foot operational altitude. It shall also be capable of exposing aerial photography at a minimum flight height of 1,000 ft above terrain in areas where Federal Aviation Administration regulations permit.

5-04.00 Cartographic Camera

The camera to be used shall comply with the requirements specified in the Statement of Certification. Additionally, the camera shall be equipped with a vacuum or pressure device for holding the film flat against the platen at the instant of exposure. No film crumpling, rolling, or unevenness of any kind will be acceptable. The platen against which the film is pressed at the instant of exposure shall not depart from a true plane by more than plus or minus 0.0005 of an inch per inch.

5-05.00 Calibration

The aerial camera used to acquire aerial photography for ADOT projects must pass calibration every 3 years by the USGS. The type of aerial camera to be used and the USGS calibration report will be

submitted to ADOT upon request. Calibration reports shall be based on tests and measurements made after the final assembly of all parts of the camera-cone unit, including the lens in working position with the light filter to be employed in place on the lens. ADOT reserves the right to restrict the use of any camera based upon data contained in the calibration report or the operation results.

5-05.01 Specific information in the camera calibration report shall include:

a) Coordinates of the principal point and fiducial marks.

b) Flatness of the stereo-model.

c) The equivalent and calibrated focal length of the lens as mounted in the camera.

d) The radial distortion from the lens axis to the edge of the field in 5 or 7.5 degree intervals, or both.

e) The radial and tangential resolving power of the lens from the lens axis to the edge of the field in 5 or 7.5 degree intervals, or both.

f) A precise measurement of the distance from the vertex of the last surface of the lens to the focal plane (the back focal length).

g) Measurements of the angle between the lines joining opposite members of the pairs of fiducial marks. This angle shall be 90 degrees plus or minus 1 minute of arc, and the intersection of the lines shall indicate the true position of the principal point within plus or minus 0.03 millimeter.

h) Measurements of distance between the opposite fiducial marks with a probable error not to exceed 0.02 millimeter.

i) Measurements of the maximum tangential distortion in the image field.

5-05.02 If the camera is disturbed, repaired, or modified in any fashion, the Consultant shall submit a new camera calibration report to ADOT. ADOT reserves the right to restrict the use of any camera based upon data contained in the calibration report, or based upon operational results.

5-06.00 Light Filter

An appropriate light filter with an anti-vignetting metallic coating shall be used on cameras whose lens characteristics require such a filter in place. The two surfaces of the filter shall be parallel within 10 seconds of arc. The optical characteristics of the filter shall be such that its addition and use do not cause any undesirable reduction in image resolution, nor harmfully alter the optical characteristics of the camera lens.

5-07.00 Test Results

The calibration report shall show that the camera has exact characteristics of specific value, or be within a range (either above a minimum or below a maximum). Such characteristics shall apply to the equivalent focal length, usable angle of the field of the lens, resolving power in lines per millimeter, tangential distortion, and radial distortion.

5-07.01If requested, the Consultant shall submit a statement certifying that the camera has not been disturbed, repaired, or modified in any fashion since the calibration report was submitted.

5-08.00 Flight Tolerances

Photography shall not be taken when the ground is covered by snow or obscured by haze, smoke, or dust, or when clouds or cloud shadows appear on more than 5% of the area of any 1 photograph. Poor image quality due to excessive shadows, heat waves, image motion, poor exposure, or processing can be grounds for rejection.

5-08.01 The minimum visibility when acquiring aerial photography shall not be less than 10 miles.

5-08.02 Lateral deviation of the flight lines from those shown on the plans shall not exceed 0.5 inches on the aerial photographs. Lateral and longitudinal deviation of the spot exposures from those shown on the flight plans shall not exceed 0.5 inches on the aerial photographs.

5-08.03 Flight altitudes shall not deviate from those shown on the plans by more than 5% of the flight height above mean terrain for photography at a nominal scale of 1" = 333' or larger. The flight altitudes shall not deviate from those shown on the plans by more than 3.3% of the flight height above mean terrain for photography at a nominal scale smaller than 1" = 333'. In either case, the maximum nominal photo scale for design level mapping shall not exceed 1" = 333'.

5-08.04 Crab, as measured from the line of flight indicated by the principal points of consecutive photographs, shall not exceed 5 degrees between any two consecutive photographs, and shall not average more than 3 degrees on any one flight line.

5-08.05 Vertical tilt at the time of exposure shall not exceed 3 degrees for any exposure and shall not exceed 5 degrees between any two successful exposures. The average tilt for the project shall not exceed 1 degree.

5-08.06 Overlap within the flight line shall not be greater than 65%, nor less than 55%. Overall, the average overlap shall be 60%, plus or minus 2%. However, ADOT reserves the right to specify the overlap for any project.

5-08.07 Sidelap (overlap of parallel strips of aerial photography) shall not be greater than 40%, nor less than 20%. The overall sidelap average shall be 30% plus or minus 5%. However, ADOT reserves the right to specify the sidelap for any project.

5-09.00 Rejection of Aerial Photography

Any variation in the aerial photography exceeding the prescribed tolerances will be grounds for rejection. If rejected, aerial photography shall be re-flown at the expense of the Consultant.

5-10.00 Time of Photography

Photography shall be undertaken at the time of the day consistent with the terrain, physical conditions, and use of the photography. Photography shall be undertaken only when well-defined images can be obtained.

5-10.01 Photography shall not contain a "sun spot" or "halo" effect caused by an excessively high sun angle. Shadows detrimental to the photographic composition, caused by topographic relief and sun angle, shall be avoided when photography is taken during the time of the year when such conditions exist.

5-10.02 Photography shall not be undertaken when the sun angle is less than 30 degrees or greater than 60 degrees above the horizon.

5-10.03 The following link may be used as a guide in determining when photography can be undertaken.
http://www.esrl.noaa.gov/gmd/grad/solcalc/

5-11.00 Ownership of Material

All film (including film canisters and spools), aerial negatives, contact prints, diapositives, and digital scans shall become the property of the ADOT. ADOT P&M reserves the right to request material for ADOT projects.

5-12.00 Aerial Film

All film shall be thoroughly cleaned and shipped in suitable containers. Film canister labels shall show the breakdown for the usable negatives in each roll labeled with the usable flight and exposure number.

5-12.01 Negatives and diapositives will be listed in the order they appear on the film roll and should be neatly lettered.

5-13.00 Aerial Negatives

All negatives shall be subjected to testing with a transmission densitometer as deemed necessary by ADOT. Negatives not meeting the standards set forth below may be rejected, and will be repeated at the expense of the Consultant. Reducing or intensifying of negatives is not permitted.

5-13.01 The Consultant shall use a fine grain, high speed aerial negative film on a stable polyester base, having a thickness of not less than 0.004 inches, with a resolving power of 50 lines per millimeter or greater at a test object contrast of 16:1.

5-13.02 Exposing and processing of aerial negatives shall be done in conformance with manufacturer's recommendations and with accepted photographic practices. Negatives shall be clear and sharp in detail, have normal density, and fine-grained quality.

5-13.03 Negatives shall be free from streaks, static marks, chemical stains, dirt, finger-prints, or other deficiencies which interfere with their intended use. Care shall also be taken to avoid rolling the film tightly on drums or distorting it during processing.

5-13.04 Density readings will be taken at the thinnest and densest portion of the negative in the area within a 2 inch radius from the principal point. The density of gross fog (the combination of base density and net fog as determined by measurement of the unexposed area between negatives) shall not exceed 0.20. Minimum density shall be no less than 0.40 and maximum density shall be no more than 1.50. These readings include gross fog density. The difference in densitometer readings between minimum and maximum densities of the negative shall be no less than 0.50 and shall be no more than 1.10. Reducing or intensifying of negatives will not be permitted.

5-13.05 The characters used in making the negatives shall be approximately 1/5 inches high, mechanically stamped with opaque ink or mechanically drafted using a titling machine, or equal, lettering system with ink in such a manner as to print clearly in positive form on the image area of the photograph.

5-13.06 Each exposure shall be lettered across the exposure with the date, photo scale (expressed in inches and feet), job name or number, flight number, and exposure number. All numerals shall be Arabic. Refer to Appendix A, Figure 3 for an example of a typical aerial photograph.

5-13.07 Editing of the aerial negatives shall not obscure the camera fiducial marks.

5-14.00 Contact Prints

Contact prints and proof prints shall be of uniform color and density and to a degree of contrast that all details of the negatives will show clearly both in the shadows and highlights as well as in the half tones between the shadows and the highlights. An adequate variety of grades of contrast paper shall be used in making prints to accomplish this purpose.

5-14.01 Contact prints shall be clean and free from chemicals, stains, uneven spots, vacuum anomalies, light fog, streaks, static marks, and other blemishes which interfere with their intended purposes. Contact prints shall be delivered in a smooth and flat condition. All delivered contact prints and contact proof prints shall be arranged in order by flight lines.

5-14.02 Contact prints used for photo index layouts will not be accepted. Contact prints shall be trimmed without removing the data recorded in the area between the frames. Contact proof prints shall be identifiable by camera exposure numbers or by a form of preliminary editing. The flight line number and the job name or number shall be indicated on the first and last photo in each flight.

5-14.03 Contact proof prints shall be furnished on the same paper as the final edited contact prints. The

number used in the preliminary editing of the proof prints shall represent the numbers to be assigned on the final edited contact prints.

5-14.04 Contact prints from aerial negatives will be furnished on single weight glossy, single or double weight semi-matte, or RC paper. Exposures will be made with an automatic dodging-type printer (such as Log-e-tronic or equivalent).

5-15.00 Diapositives (Black and White)

Diapositives shall be centered on 10 by 10 inch, dimensionally stable polyester base film, with a minimum thickness of 0.007 inches.

5-15.01 Processing shall be done in conformance with manufacturer's recommendations and shall have density readings, as determined through the use of a transmission densitometer. Direct viewing in an analytical plotter or soft-copy workstation shall have a density scale of 1.20 with no readings less than 0.30 or more than 1.50.

5-15.02 Chemically reducing or intensifying diapositives will not be permitted; ADOT shall chemically and physically test such diapositives as deemed necessary.

5-15.03 Exposures are to be made with an automatic dodging-type printer (such as Log-e-tronic or equivalent). Exposure shall be made through the aerial film base producing diapositives that are "right reading" on the base (emulsion down).

5-15.04 Diapositives shall be clear and sharp in detail, uniform in range of density, and of fine-grained quality. They will have a degree of contrast which clearly show all details in both the shadows and highlights, as well as in the half tones between the shadows and highlights.

5-15.05 Diapositives shall be free from streaks, static marks, chemical stains, scratches, finger marks, or other deficiencies, which interfere with their intended purpose.

5-15.06 Excessive contrast between exposures will be cause for their rejection.

5-15.07 Diapositives shall be individually inserted into plastic sleeves for their protection.

5-16.00 High Precision Digital Scanning

The high precision digital photo scanner used shall be capable of monochrome or color, positive or negative, 10 by 10 inch film sheets into continuous tone digital raster images. The scanner must be calibrated to produce original (not resampled) imagery which exhibits a Room Mean Square Error (RMSE) of less than or equal to 2 microns per axis.

5-16.01 The range of image resolutions provided by the Consultant shall be selectable from at least 7.5 micron pixels to 112-micron pixels.

5-16.02 A unique histogram will be created for each separate flight line and applied accordingly. The histogram will be generated from the exposure being most representative of the average distribution of the flight line. Excessive variance in contrast between images shall be cause for rejection.

5-16.03 The aerial film material, diapositives, or negatives must be scanned so that the labled annotation (photo numbers) appears on right-hand side of the film image and the film counter/data strip appears in the lower left corner.

5-16.04 The output image should always be a positive, right reading (non-mirrored) image regardless of

the input film polarity or sense.

5-16.05 The image files shall be 14 or 15 microns, uncompressed, untiled, 8 bits per pixel for B&W or 24 bits per pixel for color, and in TIFF format unless otherwise specified by ADOT.

5-16.06 The images shall be uniform in range of density, resolution, and contrast to show all details of the orginal negative or diapositive. The images shall also be sharp, clear and free from scan lines, blemishes, or other deficiencies.

5-17.00 Aerial Photography Deliverables

The aerial photography scale will be stated in the terms of the Contract. Refer to Appendix B, Table 2 for a description of common ADOT photo scales, map scales, contour intervals, and their typical uses.

5-17.01 If requested by ADOT, an aerial photography index will be furnished by the Consultant.

5-17.02 The image file shall be delivered on an acceptable media approved by ADOT such as DVD or CD. The files shall be identified as prescribed by ADOT.

5-17.03 The image files shall be delivered with no overviews or pyramids.

5-17.04 Refer to the terms of the Contract for further specifications regarding film, negatives, diapositives, digital scanning, and contact prints.

5-18.00 Photo Enlargements

Photo enlargements are black and white images reproduced on paper from the original 9 by 9 inch aerial film. Copies can be made up to 10X the scale of the film negative.

5-18.01 If an enlargement factor greater than 4.4X is required, the entire image of the 9 by 9 inch contact print will not fit on the maximum paper size of 40 by 40 inches. Thus the enlargements will be limited to just a portion of the photo or made in sections. Because of the substantial overlap between consecutive photos within a single flight strip (60%), and sidelap between adjacent flight strips (30%), continuous coverage is obtained by ordering enlargements for alternate (all even or all odd numbered) photos in a flight strip.

5-18.02 Two types of enlargements are available: Standard and Scale-Ratio. Standard enlargements are not scaled. They have an enlargement factor applied (i.e. 2X, 3X, 4X, etc., up to 10X).

5-18.03 Scale-ratio enlargements are scaled by comparing the photo distance of two photo identifiable points (usually along a highway alignment), with a known ground distance for the same two points. This provides improved accuracy over standard enlargements.

5-19.00 Photo Material

Enlargements are available on photographic paper. Enlargements on photographic paper have a continuous tone emulsion which gives the sharpest image quality, and are not reproducible.

5-20.00 Uses

Photo Enlargements have a variety of uses including: public hearings, legal displays, guardrail studies, traffic intersection studies and improvements, advanced engineering studies, environmental studies, sign location studies, right-of-way plans, preliminary design work, transportation planning, landscape design, and highway plans.

5-21.00 Delivery

Enlargements are normally available within 3 to 5 days of request. Orders are processed in the order they are received. However, the Office of the Attorney General takes priority over all orders.

5-21.01 Requests for products and services can be made by contacting the Aerial Photo Lab/Desk at 602-712-8578 or 602-712-8561.

5-21.02 Payments for products and services can be made at ADOT Engineering Records Services.

Section 6 – Aerotriangulation

6-01.00 General

Aerotriangulation (sometimes referred to as 'bridging') consists of generating X, Y, and Z coordinates for photogrammetrically selected points using targeted control panels (Section 4) which cover the dimensions outside the mapping limits. This reduces the number of required field surveyed points by densifying ground control and provides a means of verifying the accuracy of the control survey.

6-01.01 An analytical stereoplotter or a digital soft-copy system will be used to conduct aerotriangulation.

6-01.02 Aerotriangulation shall use a minimum of 10 pass (analytical, pug, photogrammetric, Von Gruber, etc.) points per stereo model (5 per image), and must use a least squares adjustment method of adjusting more than 1 flight of photography. Additionally, the 8 fiducial marks of the aerial photograph will be measured.

6-02.00 Horizontal Accuracy

The measurement of the X, Y (horizontal) coordinates of each horizontal control point targeted on the ground before photography and any other required horizontal control points shall be measured to the greatest accuracy obtainable. 90% of the points measured will not have an error of more than the flying height (H) of the bridging photos divided by 8000 (H/8000) when a 6 inch focal length lens is used. (For example, if the photo scale is 1" = 250 feet, H is 1500 feet. 1500/8000 = 0.1875. Therefore, 95% of the measured points will not have an error of more than 0.1875 feet). The remaining 5% shall not have an error of more than the flying height (H) of the bridging photos divided by 6000 (H/6000) when a 6 inch focal length lens is used.

6-03.00 Vertical Accuracy

The measurement of the Z (vertical) coordinates of each vertical control point targeted on the ground before photography and any other vertical control points required for orientation and leveling of the stereoscopic models to be used in mapping shall be measured to the greatest accuracy obtainable. 95% of the points measured will not have an error of more than the flying height (H) of the bridging photos divided by 6000 (H/6000) when a 6 inch focal length lens is used. (For example, if the photo scale is 1" = 250, H is 1,500 feet. 1500/6000 = 0.25. Therefore, 95% of the measured points will not have an error of more than 0.25 feet). The remaining 5% shall not have an error of more than the flying height (H) of the bridging photos divided by 4000 (H/4000) when a 6 inch focal length lens is used.

Section 7 - DTM and Planimetric Maps

7-01.00 General

The work to be done consists of creating Digital Terrain Models (DTM's) using photogrammetric methods supplemented with spot elevations at a specified scale as described in the terms of the Contract. The work may require the Consultant to furnish the topographic field control data and materials necessary for creating the topographic maps.

7-01.01 The work will be planned for a soft-copy photogrammetric workstation.

7-01.02 The aerial photo scale, map (compilation) scale, and contour interval to be used by the Consultant may be submitted to ADOT P&M Advisor/Coordinator by the ADOT Project Manager for approval. The mapping limits, dimensions, and orientation of the final maps will be as shown on the plans.

7-01.03 International feet will be used for all mapping projects except when matching or extending existing mapping based on North American Datum of 1927 (NAD 27).

7-01.04 The North American Datum of 1983/1992 (NAD 83/92) will be used for horizontal control

7-01.05 The North American Vertical Datum of 1988 (NAVD 88) will be used for vertical control.

7-01.06 Unless otherwise specified, all mapping will be placed on a ground datum utilizing the Arizona State Plane Coordinate System Grid Adjustment Factors (see *ADOT Manual for Field Surveys, Sec 4.01.1.1 and 4.03.2*).

7-01.07 Labels will be oriented to north (0 degrees rotation).

7-01.08 Final maps will show all grid ticks as well as horizontal and vertical control.

7-02.00 Stereocompilation Guidelines

ADOT P&M uses Cardinal System's VR Photogrammetry suite for internal mapping production. These files are then translated into the most current version of MicroStation format for editing and delivery to the end-user.

7-02.01 To ensure the Consultant's maps are compatible with the ADOT Computer Aided Design and Drafting (CADD) System, the following requirements must be met:

a) Maps produced on a CADD system by the Consultant will conform to ADOT's current CADD Standards. This includes levels, line codes, line weights, line color, cell/symbols, and text.

b) The Consultant's photogrammetric CADD software must be capable of importing or directly reading the orientation files provided by ADOT P&M. Typical measurement file types are ISAT, PATB, ALBANY, and VRAT.

c) The data files provided by the Consultant will be in the most current version of MicroStation vector file format. If the Consultant uses the current Cardinal System VR suite, they must install and use the function keys and symbol libraries provided by the ADOT P&M. Failure to do so may result in rejection of submitted data. File formats such as DXF or DWG are not acceptable.

d) All files provided by the Consultant will be delivered on either CD or DVD (depending on project file sizes). CD's will be recorded as type "Mode 1" and conform to the "ISO+Joliet" file system standard. DVD's will conform to the "ISO+Joliet+UDF" file system standard.

e) Prior to delivery, the Consultant will scan the deliverable media for the presence of viruses or other malicious code. Failure to do so may result in rejection of submitted media.

f) The use of reference files or pen tables to achieve particular plotted effects is not allowed.

g) The delivered data will be cleanly edited and will not contain crossing breaklines or mismatched elevations.

h) Each file will contain all 3D terrain and planimetric features. Use of planimetric levels for DTM triangulation is permissible (e.g. edge of pavement, centerline stripes, drainage lines, etc.). ADOT

P&M will provide the Consultant with a list of planimetric levels (Appendix B, Table 6) used for of DTM triangulation.

i) Planimetric features used for DTM triangulation will not contain complex lines or shapes which cannot be triangulated. Use of arcs is permissible only if the DTM engine can successfully triangulate that feature without error.

j) Files will be compiled with coordinate values to the nearest thousandth (0.000) of a foot. Coordinate values for all features will be based on the grid system indicated by the control data.

k) The MicroStation design file working units will be: Master Units = 1 Foot, Sub Units = 10 (1/10 Ft), Positional Units = 100 (1/1000 Ft).

l) The global origin will be set so the working units' origin (0.0) will be at the center of the design plane. See the *ADOT CADD Standards Manual,* available from ADOT Engineering Records Services for more information. The current ADOT MicroStation seed file (seed3d.dgn), may be obtained from the ADOT website or will be provided to the Consultant upon request. CADD resources may be obtained directly from ADOT CADD Management & Support (CMS).

m) All digital data will be measured directly as a function of the soft-copy operation. Auto-correlated points or interpolated line strings are not allowed. Post-compilation digitizing of features is not permitted.

n) Each data file will have an exterior boundary breakline along the outside edge of the mapping limits. The breakline will be photogrammetrically digitized and will follow the terrain three-dimensionally (auto-correlated or draped 2D lines are not allowed). The exterior boundary will be digitized no more than 5 feet outside the mapping limits.

o) Adjacent map files will edge match exactly. Matching features will be snapped three-dimensionally between adjacent files. Overshoots and undershoots are not acceptable.

p) The Consultant will conform to cells/symbols dictated by the *ADOT CADD Standards Manual*. If an appropriate cell/symbol does not exist, the Consultant shall contact the ADOT P&M Coordinator/Advisor for guidance.

q) The Consultant shall ensure breakline data properly generates contours and does not contain crossing segments or mismatched elevations.

Section 8 - Map Contents

8-01.00 General

All features will be collected with the appropriate symbol, line style, and width in accordance with the *ADOT CADD Standards Manual*.

8-01.01 Grid ticks will be shown as 1 inch long cross-ticks, oriented to north (0 degrees rotation), and spaced at 10 inch intervals at final map scale. Grid ticks on adjacent maps will be a continuation of the 10 inch interval.

8-01.02 Grid ticks will be labeled along the perimeter of the map.

8-01.03 When a mapping project ties to a previous one, there shall be a minimum of 2 grid ticks in common to both maps. Intermediate grid tick intervals will be used when necessary to fulfill this requirement; intermediate grid ticks need not be labeled.

8-01.04 Grid tick coordinate values will be designated X and Y.

8-02.00 Topographic/DTM Features & Spot Elevations

A DTM is a mathematical model of the earth's surface formed by three-dimensional coordinates (X, Y, & Z) embedded within breaklines and other features. Breaklines are collected where 2 or more elevation planes intersect. Breaklines, along with other dtm features, are used to generate contour lines.

8-02.01 Breaklines and other dtm triangulated features (i.e. curb, gutter, stream, asphalt road) will be collected in a way that correctly models the terrain in accordance with the map accuracy standards in Section 9 of this document.

8-02.02 Breaklines will not be gridded so as to interpolate vertices between collected points.

8-02.03 In obscured areas greater than 50 feet, a breakline will be digitized around the exterior. A boundary line will also be digitized and the area labeled 'obscured.'

8-02.04 Spot elevations will be shown at intervals not greater than 2 inches at final map scale when the profile grading is 2% or less.

8-02.05 Spot elevations will be shown at intervals not greater than 2 inches at final map scale along the boundary of the area to be mapped at locations where the nearest contour is over 1 inch from the boundary.

8-02.06 Spot elevations will be shown at all sags and crests regardless of gradient.

8-02.07 Spot elevations will be shown on summits, depressions, saddles, and road intersections. Additionally, spot elevations will be shown along the center of dikes, roads, ditches, and railroads.

8-02.08 All spot elevations will be observed and measured photogrammetrically. Spot elevations may not be snapped to breaklines nor are they to be derived from breaklines.

8-02.09 Spot elevations will be labeled with decimal values giving their elevation to three significant figures, rounded to the nearest 0.10 of a foot (e.g. an elevation text label of 2574.136' will be shown as 74.1).

8-02.10 Spot elevation labels will be oriented to north (0 degrees rotation).

8-02.11 In densely wooded areas where the ground is obscured by dense brush or tree cover, spot elevations will be placed in places where the ground is visible.

8-02.12 In areas not obscured by grass or brush, at least 90 percent of all spot elevations will be within 0.25 contour interval of their true elevation; 100 percent will be within 0.5 contour interval of their true elevation.

8-03.00 Planimetric Features

Planimetric features are either cultural/manmade objects (e.g. utilities, roads, buildings), or natural objects (e.g. trees, drainage features). They are features which do not represent the relief of the natural ground.

8-03.01 See Appendix B, Table 4 for 1" = 50' scale planimetric mapping feature collection.

8-03.02 See Appendix B, Table 5 for 1" = 100' (or smaller scale) planimetric mapping feature collection.

8-03.03 Additionally, the following requirements will be met:

a) Symbols such as signs, mast lights, guy wires, etc., will be properly rotated to reflect the object's orientation.

b) The use of shared cells is not acceptable.

c) Orchards planted in regular rows may be symbolized by a dot for each tree, except for the outer rows which will be shown by appropriate symbol. Free standing trees having a crown diameter of 15 feet or more will be shown.

d) Schools, parks, playgrounds, cemeteries, public buildings, hospitals, churches, institutions, and similar places of public gatherings will be shown.

e) Roadway lane striping will be delineated by the appropriate line style. Centerlines, fog stripes, gore point striping, and crosswalk lines will be shown.

f) Collection of turn arrows and handicapped parking symbols painted on asphalt surfaces is not required.

g) Features such as dirt piles, parking lots, areas under construction, etc. will be labeled. Labels will be oriented to north (0 degrees rotation).

8-03.04 Roads, streets, and sidewalks will be shown as the separation between curb faces, hard surface edges, travel paths, or shoulder lines. The drafting of road alignment should be carefully executed.

8-03.05 Linear patterns visible but not easily identifiable on the aerial photographs will be located and shown on the map by fine dotted lines.

Section 9 – Orthophotographs

9-01.00 General

An orthophotograph is an aerial photograph which has been rectified to a DTM, eliminating distortion caused by ground relief, scale variation, and other geometric distortions. In most cases, an orthophoto (also referred to as an orthophotomap or orthophotomosaic) is a composite of several aerial photos mosaicked seamlessly together to show a continuous area. Since an orthophotograph has been rectified, it is considered geometrically corrected.

9-01.01 Orthophotos will be delivered as TIFF & TFW, GeoTIFF, or SID & SDW file formats. If a SID & SDW file format is submitted, the original TIFF & TFW or GeoTIFF image files must be also provided.

9-01.02 Black and white image data will be represented as 8-bit binary data; color image data will be represented as 24-bit binary data.

9-01.03 Images will be re-sampled/transformed using the bilinear interpolation method. The cubic convolution method will also be accepted but is not required. Orthophotographs re-sampled using the nearest neighbor method will not be accepted.

9-01.04 Orthophotographs will be rectified using the Arizona State Plane Coordinate System, NAD 83/92, NAVD88, and international foot.

9-01.05 Orthophotographs will have the uppermost left-hand pixel designated as the origin (0, 0) and have a pixel rotation of 0 degrees.

9-01.06 Orthophotographs will be submitted with an over-edge/background color of 255 (white). This facilitates plotting hardcopies for public displays.

9-01.07 Orthophotographs will be free of visual anomalies such as smears, fingerprints, lint, etc., which render the imagery visually unaesthetic at a zoom scale ratio of 1 to 1.

9-01.08 Orthophotographs will be compatible with the most current version of MicroStation and delivered on CD or DVD (file sizes will be limited to what can fit on a CD or DVD). Jewel case and CD labels will contain route number, beginning and ending mile posts, project name, and ADOT Tracs number.

9-01.09 The pixel resolution/ground sample distance of orthophotographs will be produced in accordance with table 2-10 of the *US Army Corps of Engineers (USACE) Manual No. 1110-1-1000*, (dated 31 July, 2002) available at: EM 1110-1-1000 (01 July 2002)

9-01.10 The Consultant will furnish orthophotograph metadata to ADOT P&M Section. The metadata may be a simple text file and will include: ADOT Tracs number, project name and description, route number, mile posting, number of delivered orthophotographs, number of CADD files, number of disks delivered, date of delivery, consultant company, project manager, contact information, coordinate system zone, NAD/NAVD data type, original photography date and scale, camera, film and file type, pixel resolution, compression type and ratio, and tile size (if applicable).

9-01.11 DTM's or DEM's used for the creation of Orthophotographs will not be used for other purposes unless approved by the ADOT P&M Advisor/Coordinator.

Section 10 - Map Accuracies

10-01.00 General

ADOT P&M has adopted the National Standard for Spatial Data Accuracy (NSSDA) method for evaluating map accuracies. Previously, ADOT P&M followed the National Map Accuracy Standards (NMAS) guidelines which applied to only hard-copy paper maps compiled at a specific scale. However, since the transition to digital photogrammetric compilation, digital data can be easily manipulated and output to any scale. The NSSDA offers a means of statistically testing positional accuracy independent of map scale.

10-01.01 The NSSDA reports accuracies as the Root Mean Square Error (RMSE) of evaluated test points for each spatial data set (i.e. horizontal and vertical) at the 95% confidence level. Simply stated, the RMSE is a measure of the difference between a set of calculated values and a set of the most probable values.

10-01.02 Map accuracies specified herein applies to the final map products.

10-01.03 Refer to Section 8-02.12 for accuracies regarding Spot Elevations.

10-02.00 Accuracy Testing (Design Level Mapping Only)

At least 20 test points will be used to assess map accuracy. Points will be comprised of a combination of blind control panels and other well-defined points. Refer to Appendix B, Table 6 for guidelines pertaining to test points.

10-02.01 Test points must be of higher order accuracy (collected by field survey methods) than the points used for mapping (collected photogrammetrically). Selected points shall be easily visible (on the map and in the field), recognizable, and recoverable, and be located within the map limits. Right angle intersections of linear features such as sidewalk corners and paint stripes may be used as well-defined points.

10-02.02 The distribution, collection, and managing of design level mapping test point data will be as follows:

a) Blind Control Panels: Column 2 of Appendix B, Table 6 gives the appropriate number of blind panels required for a mapping project of a specified length. Blind control panels will be placed and surveyed along with the original control panels, and will be constructed in the same manner, with the same dimensions as the control panels described in Appendix B, Table 1. The blind panels will be shown on the flight plans. Horizontal and vertical values for the blind panels will not be used in the aerotriangulation. Instead, they will be kept in a separate file and used to test spatial accuracy once the mapping project is completed.

b) Well-Defined Points: The remaining test points (Column 3 of Appendix B, Table 6) will be made up of well-defined points. These points may be selected after the contact prints have been made to aid in collecting the horizontal and vertical data. The collection and use of photo ID point data will be managed and used in the same manner at the blind control panel data.

10-02.03 The ADOT P&M Advisor/Coordinator will be the focal point for test point data inquiries.

10-03.00 Horizontal Testing

Horizontal testing is done by comparing the planimetric (X & Y) coordinates of the compiled data set (collected photogrammetrically) to those of higher-order test points (collected by field survey methods) described above in Section 10-02.01.

10-03.01 The following formula is used to measure horizontal accuracy: **

$$RMSE_X = \text{sqrt}[\Sigma(X_{data} - X_{test})^2/n]$$
$$RMSE_Y = \text{sqrt}[\Sigma(Y_{data} - Y_{test})^2/n]$$

Where: X_{data} = the X coordinates of the compiled data
X_{test} = the X coordinates of the higher order test data
Y_{data} = the Y coordinates of the compiled data
Y_{test} = the Y coordinates of the higher order test data
n = the number of test points

$$RMSE_r = \text{sqrt}[\Sigma((X_{data} - X_{test})^2 + (Y_{data} - Y_{test})^2)/n]$$
$$= \text{sqrt}[RMSE_X^2 + RMSE_Y^2]$$

10-03.02 The resulting value is then multiplied by 1.7308 to determine the final horizontal map accuracy.

** A horizontal accuracy calculation spreadsheet is available for download at:
Horizontal accuracy calculation spreadsheet — Federal Geographic Data Committee

10-03.03 In the above spreadsheet, enter the higher order (field survey) X and Y coordinates in columns C and G respectively (labeled *independent)*. Enter the X and Y coordinates (photogrammetric) from the final map in columns D and H respectively (labeled *test)*.

10-03.04 The resulting value, labeled NSSDA, is the horizontal accuracy.

10-03.05 The resulting value for horizontal accuracy shall not exceed 0.50 feet for design level mapping.

10-04.00 Vertical Testing

Vertical testing is done by comparing the elevation (Z) values of the compiled data set (collected photogrammetrically) to those of higher-order test points (collected by field survey methods) described above in Section 10-02.01.

10-04.01 The following formula is used to measure vertical accuracy: **

$$RMSE_Z = sqrt[\Sigma(Z_{data} - Z_{test})^2/n)$$

10-04.02 The resulting value is then multiplied by 1.9600 to determine the final vertical map accuracy.

** A vertical accuracy calculation spreadsheet is available for download at:
Vertical accuracy calculation spreadsheet — Federal Geographic Data Committee

10-04.03 In the above spreadsheet, enter the higher order vertical (Z) coordinates in column C (labeled *independent)*. Enter the vertical (Z) coordinates from the final map in column D (labeled *test)*.

10-04.04 The resulting value, labeled NSSDA, is the vertical accuracy.

10-04.05 The resulting value for vertical accuracy shall not exceed 0.40 feet for design level mapping.

10-05.00 Accuracy Reporting

The NSSDA states "…accuracy is reported in ground distances at the 95% confidence level." This means, "…95 % of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value."

10-05.01 The Consultant will submit statements giving the horizontal and vertical accuracies in the terms of the RMSE with the project. The statements will read:

"Tested ____ feet horizontal accuracy at 95% confidence level"
"Tested ____ feet vertical accuracy at 95% confidence level"

10-05.02 Enter the resulting accuracy values from the spreadsheets in the proper statement. Numerical values shall be rounded to the nearest hundredth (0.00) of a foot.

Section 11 – Inspection and Delivery of Materials

11-01.00 General

A photogrammetric project (from initial planning to delivery of the final product) can take several weeks up to several months to complete depending on the project's length, width, complexity of the terrain, scale of photography, and type of products requested. Exact times of completion and deliverable materials will be dictated in the terms of the Contract.

11-01.01 Due to design and construction commitments, final products must be delivered as soon as applicable. Consultants should be prepared to meet as needed to discuss issues with the ADOT Project Manager to ensure the most timely and best quality product.

11-02.00 Delivery Costs

Normal delivery costs of material shipped to ADOT shall be borne by the Consultant.

11-03.00 Delivery and Documentation

The Consultant shall provide a suitable delivery memorandum for each item. The memorandum shall include the Contract number and identification of the item, quantity and type of material delivered, and material sizes, if applicable.

11-03.01 Unless otherwise specified in the Contract, the Consultant will furnish:

a) CD’s or DVD’s in the specified format which can be loaded into ADOT's CADD system (see Section 7-2.01 for map file requirements). The disk sleeve will be labeled with the ADOT P&M project number and file names found on the enclosed disk. Files subjected to compression schemes such as ZIP, TAR, GZ, etc., are not acceptable.

11-04.00 Acceptance or Rejection

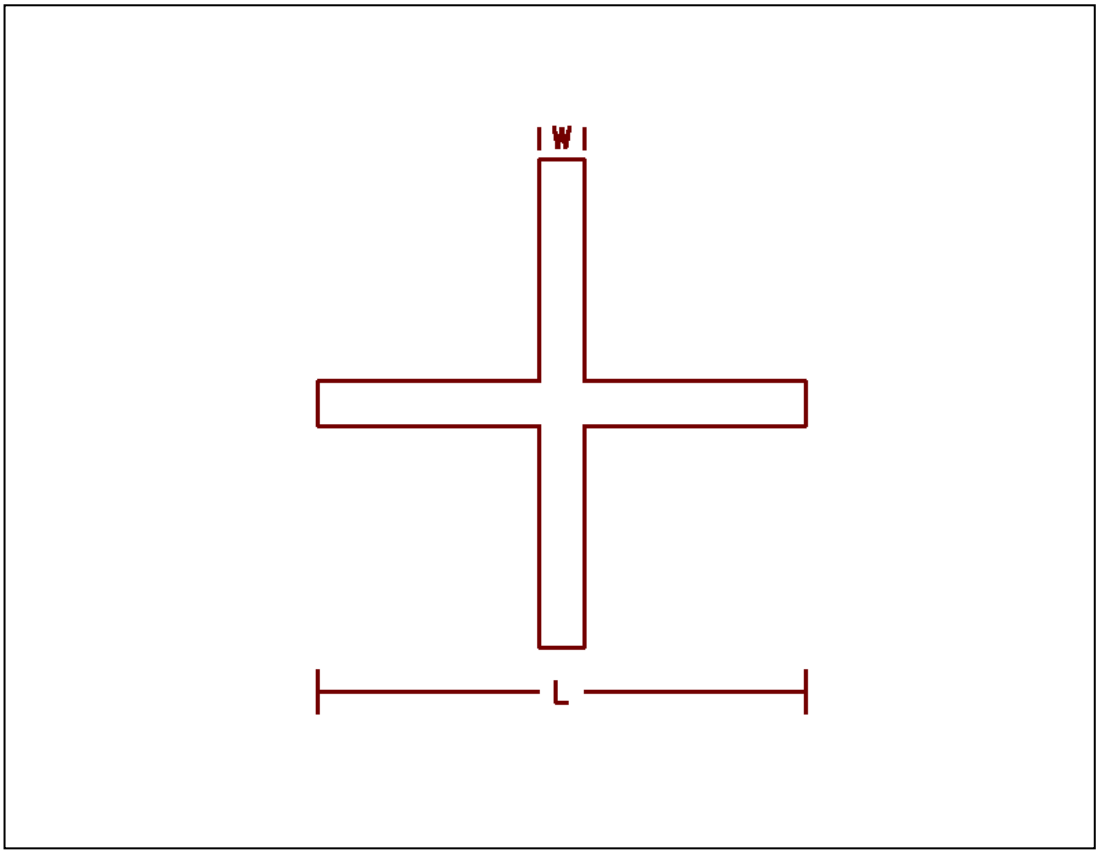
Resubmittal of rejected work shall be made within the same time specified for the initial delivery starting on the day of receipt of verbal notice of rejection. Verbal acceptance or rejection will be confirmed in writing by ADOT.

Appendix A

Figures

Figure 1

Ground Control Panel Diagram



Refer to Appendix B, Table 1 (pg. 28) for 'W' and 'L' dimensions.

Figure 2

Unobstructed Ground Control Panel

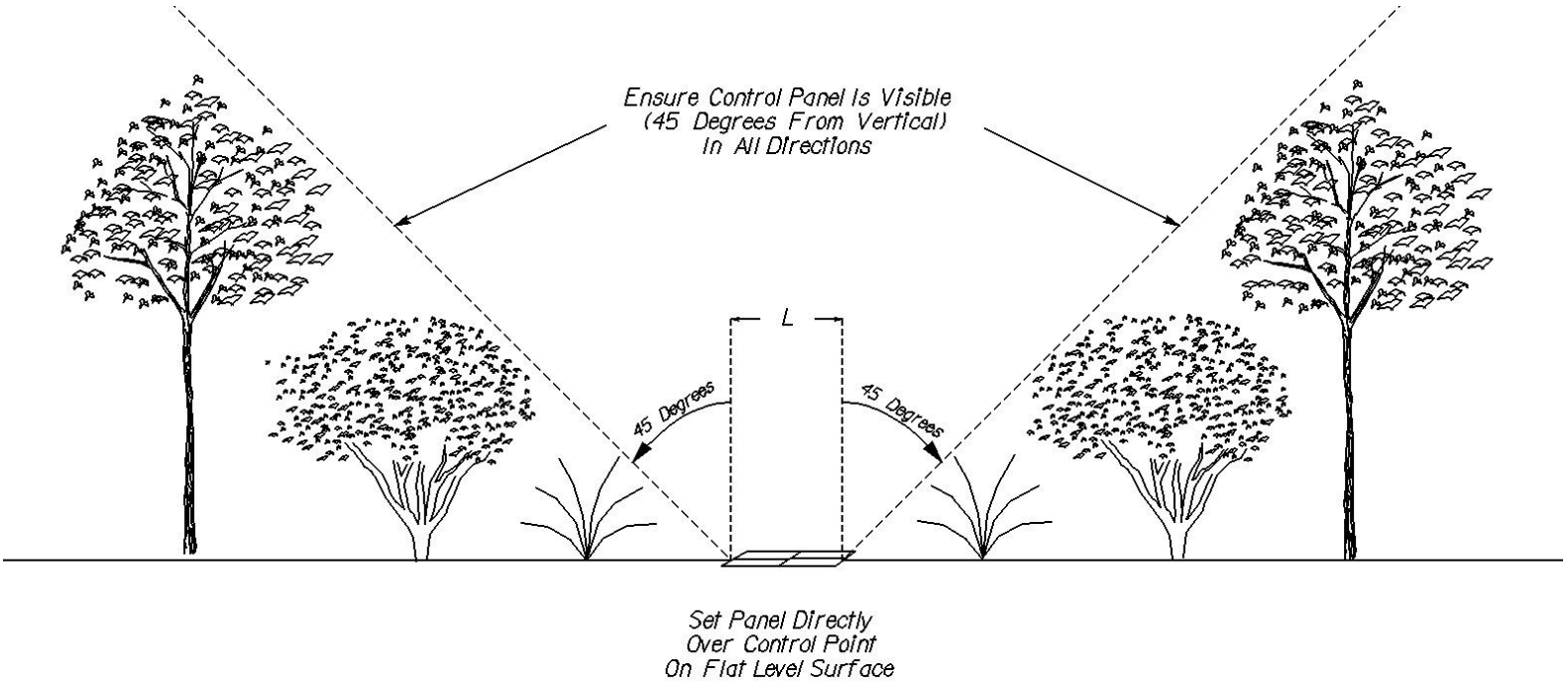


Figure 3

Typical Aerial Photograph (Contact Print)

Figure 4

Breakline Data

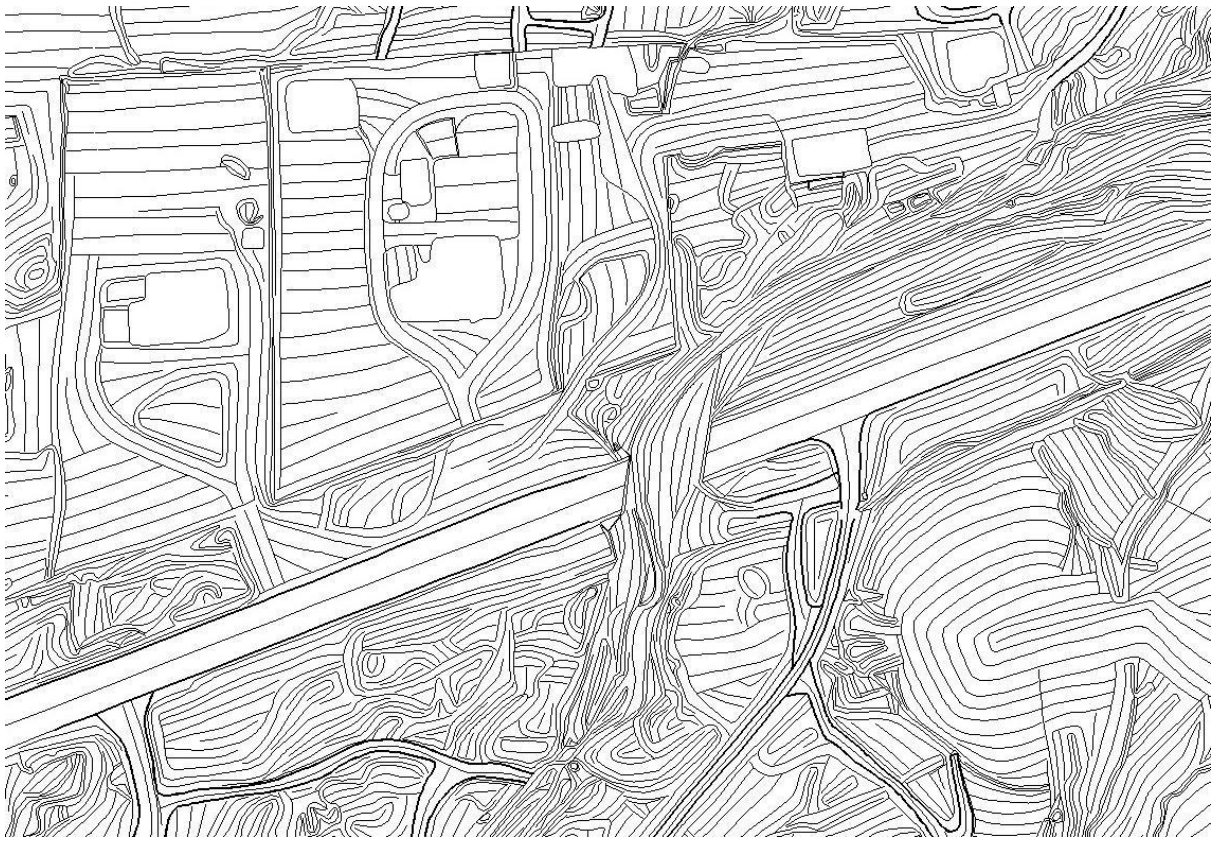


Figure 5

Triangulated Irregular Network (TIN)

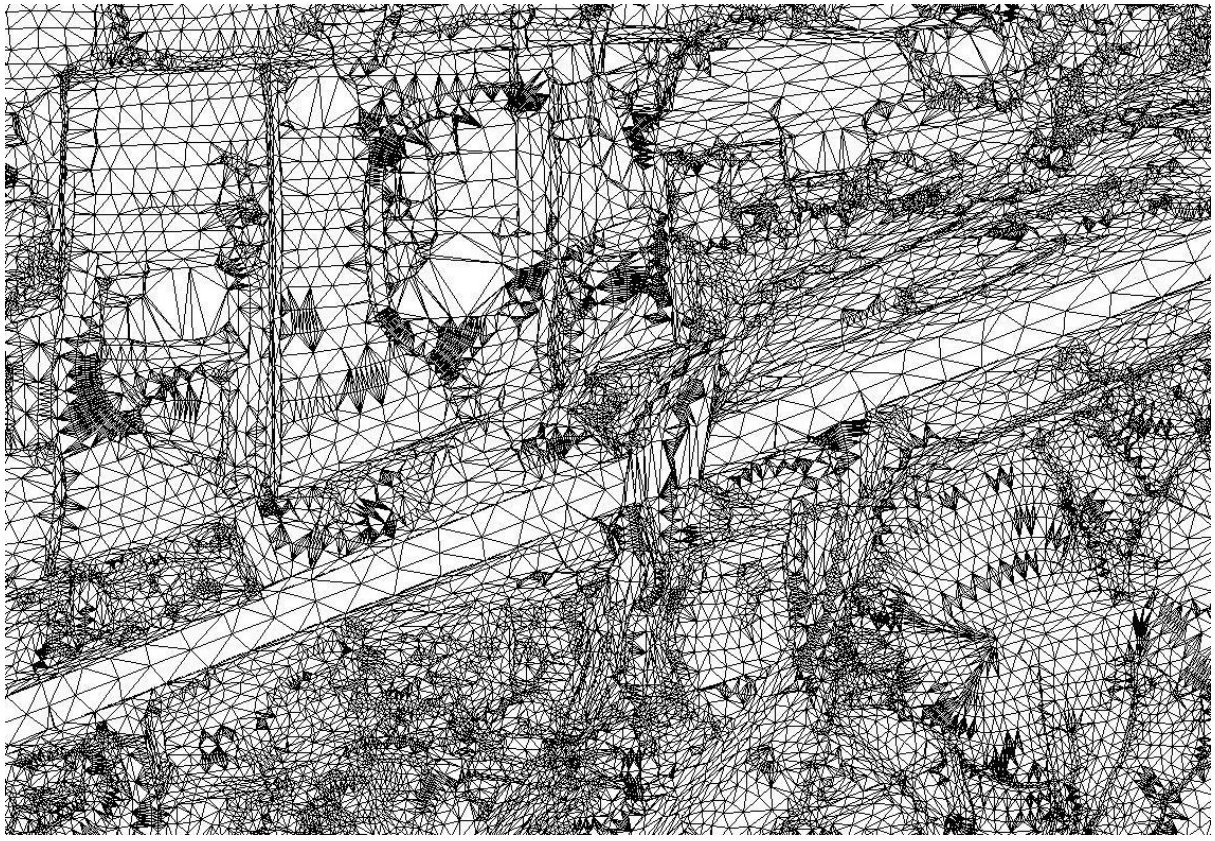


Figure 6

Planimetric Data

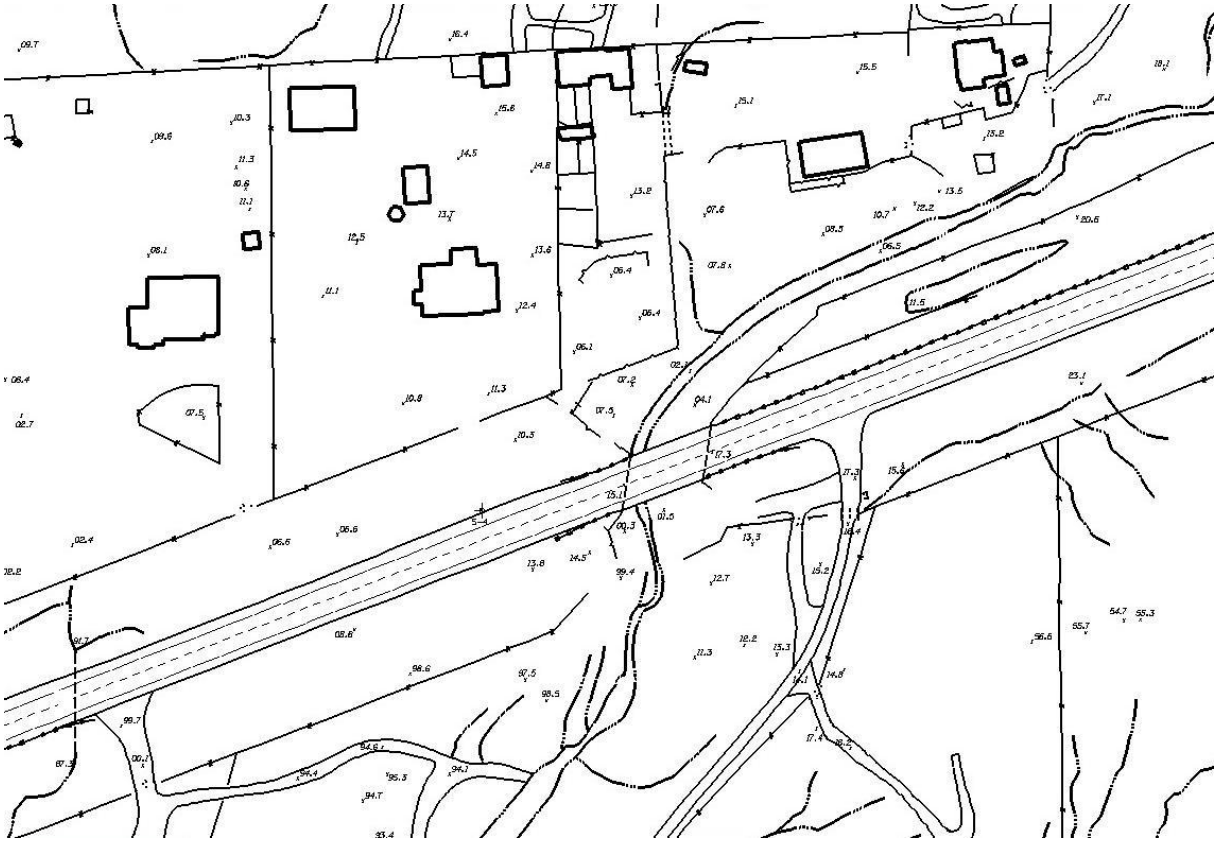
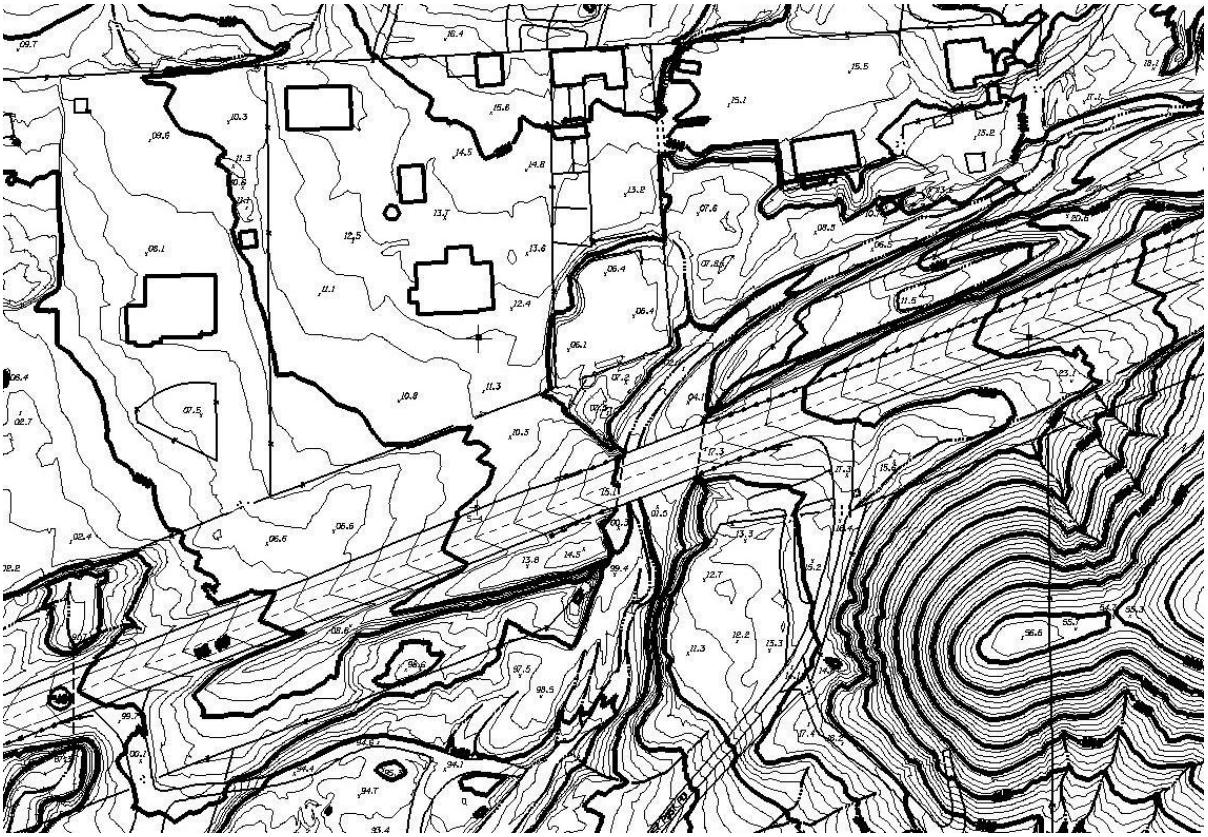


Figure 7

Final (Topographic) Map



Appendix B

Tables

Table 1

Common Control Panel Sizes used by ADOT P&M

Photo Scale	Control Panel Width in **Feet** (W)	Control Panel Length in **Feet** (L)
1" = 250'	0.5	6
1" = 300'	0.5	6
1" = 500'	1	10
1" = 1000'	2	20

Determining Control Panel Size

Width of Legs: W = (Photo Scale Denominator in feet) * 0.002
Length of Legs: L = (10) * W

Example: 1" = 500 ' Photo Scale

W = (Photo Scale Denominator in feet) * 0.002
W = 500 * 0.002
W = 1 Ft Wide

L = (10) X W
L = 10 X 1 = 10
L = 10 Ft Long

Refer to Appendix A, Figure 1 (pg. 20) for 'W' and 'L.'

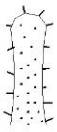
Table 2

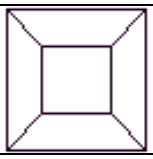
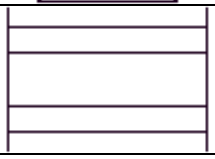
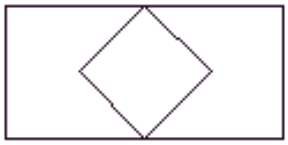
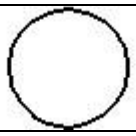
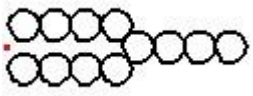
Common Photo Scales and Uses

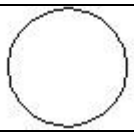
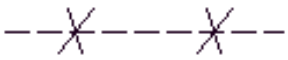
Photo Scale	Map Scale	Contour Interval	Typical Uses
1" = 250'	1" = 50'	1	Final design, earthwork computations, volumes
1" = 300'	1" = 50'	1	Final design, earthwork computations, volumes
1" = 500'	1" = 100'	2	Route selection, preliminary design, DCR's
1" = 1000'	1" = 200'	5	Route selection, preliminary design, alternative selection

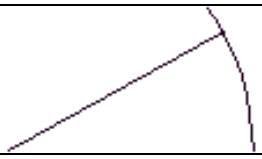
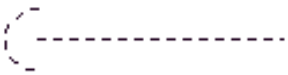
Table 3

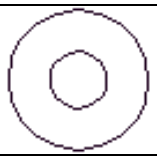
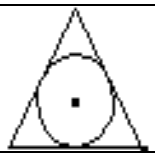
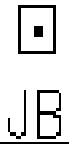
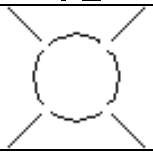
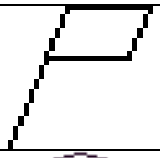
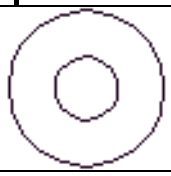
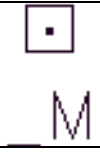
ADOT Photogrammetry Standard Symbology

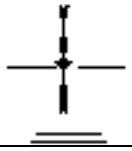
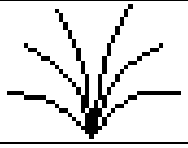
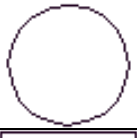
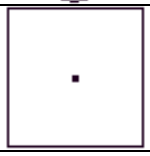
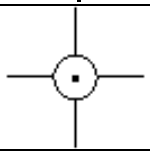
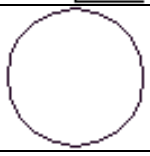
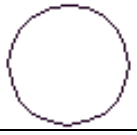
Micro-Station Level	Description	Symbology	Triangulated
13	Apron	Solid	No
16	Asphalt Road	Solid	**Yes**
13	Bank Protection		No
3	Breaklines	Solid	**Yes**
22	Bridge Deck	Line Code 5	No
22	Bridge Walkway	Solid	No
7	Brush Line		No
9	Building	Solid	No
9	Building Un-Squared	Solid	No
23	Cable Barrier		No
7	Cactus Saguaro		No
9	Canopy	Solid	No
13	Catch Basin Curb		No
13	Catch Basin Med		No

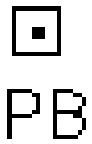
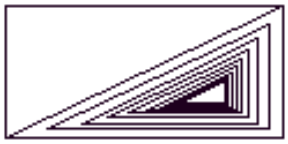
Micro-Station Level	Description	Symbology	Triangulated
13	Catch Basin Off Road		No
9	Cattle Guard		No
17	Centerline 3D		**Yes**
17	Centerline Bridge		No
13	Concrete Drain	Line Code 5	No
16	Concrete Road	Line Code 5	No
9	Concrete Slab	Line Code 5	No
5	Contours Index	Solid	No
5	Contours Index Depression		No
6	Contours Intermediate	Solid	No
6	Contours Intermediate Depression		No
17	Control Box		No
23	Crash Barrel Single		No
23	Crash Barrel Stacked		No

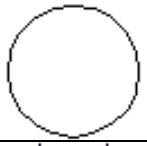
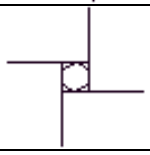
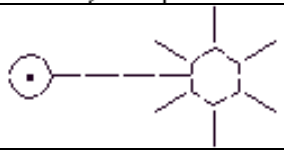
Micro-Station Level	Description	Symbology	Triangulated
13	Culvert		No
23	Curb	Solid	**Yes**
13	Dam		No
13	Dike / Levee		No
16	Dirt Road		**Yes**
16	Dirt Trail		**Yes**
13	Ditch Concrete		No
13	Ditch Earth		No
13	Down Drain	Line Code 5	No
13	Down Drain Grate		No
17	Driving Stripe		No
25	Exterior Boundary	Solid	**Yes**
29	Fence		No

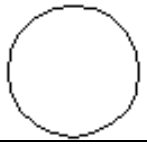
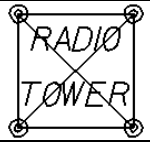
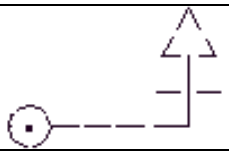
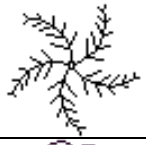
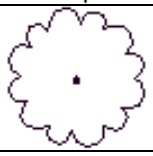
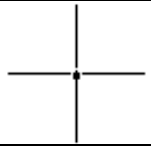
Micro-Station Level	Description	Symbology	Triangulated
11	Fire Hydrant		No
9	Flag Pole		No
8	Flow Term		No
8	Flowline		**Yes**
29	Gate Double		No
29	Gate Single		No
29	Gate Sliding		No
23	Guardrail		No
23	Gutter	Solid	**Yes**
11	Guy Wire		No

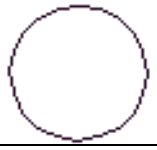
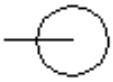
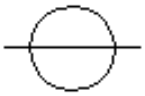
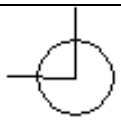
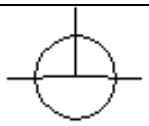
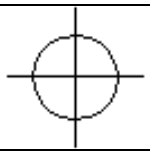
Micro-Station Level	Description	Symbology	Triangulated
13	Hand Hole		No
9	Handicap Ramp	Solid	No
9	Handrail	Solid	No
22	Headwall	Solid	No
2	HV Control		No
11	Junction Box		No
17	Light Pole		No
9	Mailbox Multiple		No
9	Mailbox Single		No
13	Manhole		No
1	Mapping Limits	Solid	No
25	Match Line	Solid	No
23	Median Barrier		No
11	Meter		No

Micro-Station Level	Description	Symbology	Triangulated
9	Mine Prospect		No
25	North Arrow		No
33	Obscured Area	Line Code 3	No
7	Ocotillo		No
9	Parking Meter		No
11	Pedestal		No
17	Pedestrian Light		No
2	Photo Centers		No
13	Pipe	Line Code 3	No
13	Pipe Capped		No
11	Pole		No
9	Pools	Solid	No
9	Post Misc		No

Micro-Station Level	Description	Symbology	Triangulated
11	Pullbox		No
55	Rock Outcrop		No
11	RR 100		No
11	RR 50		No
11	RR Cabinet		No
11	RR Gate		No
11	RR Switch		No
9	Ruins	Solid	No
9	Satellite Dish		No
9	Sidewalk Concrete	Line Code 5	**Yes**
9	Sidewalk Paved	Line Code 2	**Yes**
9	Sign Billboard		No
17	Sign Bridge		No

Micro-Station Level	Description	Symbology	Triangulated
17	Sign Cantilever		No
17	Sign Delineator		No
17	Sign DS1P		No
17	Sign DS2P		No
25	Sign Milepost		No
17	Sign SS1P		No
17	Sign SS2P		No
17	Sign Street		No
13	Spillway	Line Code 5	No
2	Spot Elevations		No
17	Streetlight Mast		No

Micro-Station Level	Description	Symbology	Triangulated
9	Tank Circular		No
9	Tank Gas		No
11	Telephone Booth		No
11	Tower Radio		No
11	Tower Trans		No
17	Traffic Signal		No
7	Tree Palm		No
7	Tree Scaled		No
7	Treeline		No
2	Unidentified Panels		No

Micro-Station Level	Description	Symbology	Triangulated
33	Unknown Circular		No
33	Unknown Square	Solid	No
11	Utility Pole 1T		No
11	Utility Pole 2T		No
11	Utility Pole 2T CR		No
11	Utility Pole 3T		No
11	Utility Pole 4T		No
11	Utility Pole Tick		No
11	Valve		No
29	Wall Block		No
22	Wall Bridge		No

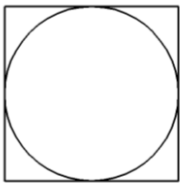
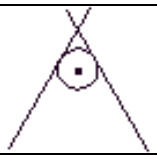
Micro-Station Level	Description	Symbology	Triangulated
22	Wall Retaining		No
11	Well		No
11	Windmill		No
22	Wingwall	Solid	No

Table 4

Planimetric Feature Collection 1” = 50’ Scale Mapping

ROADWAY	MANMADE	HYDROLOGY	UTILITIES
Asphalt Road	Building	Apron	Control Box
Bridge Deck	Canopy	Bank Protection	Fire Hydrant
Bridge Walkway	Concrete Slab	Catch Basin Curb	Guy Wire
Cattle Guard	Flag Pole	Catch Basin Median	Junction Box
Centerline	Handicap Ramp	Catch Basin Offroad	Handhole
Centerline Bridge	Mailbox	Concrete Drain	Light Pole
Curb	Mine Prospect	Culvert	Manhole
Concrete Road	Obscured Area	Dam	Meter
Dirt Road	Pools	Dike or Levee	Pedestal
Dirt Trail	Post Misc	Ditch Earthen	Pole Misc
Driving Stripe	Rock Outcrop	Ditch Concrete	Pullbox
Gutter	Ruins	Down Drain Grate	Streetlight Mast
Parking Meter	Satellite Dish	Flowline/Drainage	Transmission Tower
Pedestrian Light	Tank Circular	Headwall	Utility Pole
Railroad	Tank Gas (Propane)	Pipe	Valve
Railroad Cabinet	Telephone Booth	Spillway	
Railroad Gate	Tower Radio	Well	
Railroad Switch	Unknown Object	Wingwall	
Sidewalk Concrete	Windmill		
Sidewalk Paved			
Traffic Signal			

BARRIERS	SIGNAGE	VEGETATION	TOPOGRAPHIC
Cable Barrier	Sign Billboard	Brush Line	Exterior Boundary
Fence	Sign Cantilever	Saguaro Cactus	Spot Elevations
Gate Double	Sign Delineator	Ocotillo	
Gate Single	Sign Milepost	Tree Palm	
Gate Sliding	Sign Bridge	Tree	
Guardrail	Sign Roadway	Treeline	
Handrail	Sign Street		
Median Barrier			
Wall Retaining			
Wall Block			
Wall Bridge			

Table 5

Planimetric Feature Collection 1” = 100’ Scale Mapping

ROADWAY	MANMADE	HYDROLOGY	UTILITIES
Asphalt Road	Building	Bank Protection	Control Box
Bridge Deck	Canopy	Catch Basin Curb	Fire Hydrant
Bridge Walkway	Concrete Slab	Catch Basin Median	Junction Box
Cattle Guard	Flag Pole	Catch Basin Offroad	Light Pole
Centerline 3D	Handicap Ramp	Concrete Drain	Manhole
Centerline Bridge	Mailbox	Culvert	Meter
Concrete Road	Mine Prospect	Dam	Pedestal
Dirt Road	Obscured Area	Dike or Levee	Pole Misc
Driving Stripe	Pools	Ditch Earthen	Streetlight Mast
Railroad	Post Misc	Ditch Concrete	Transmission Tower
Railroad Cabinet	Rock Outcrop	Down Drain Grate	Utility Pole
Railroad Gate	Ruins	Flowline/Drainage	Valve
Railroad Switch	Satellite Dish	Headwall	
Sidewalk Concrete	Tank Circular	Pipe	
Sidewalk Paved	Tank Gas (Propane)	Spillway	
Traffic Signal	Telephone Booth	Well	
	Tower Radio	Wingwall	
	Unknown Object		
	Windmill		

BARRIERS	SIGNAGE	VEGETATION	TOPOGRAPHIC
Cable Barrier	Sign Billboard	Saguaro Cactus	Exterior Boundary
Fence	Sign Cantilever	Ocotillo	Spot Elevations
Gate Double	Sign Milepost	Tree Palm	
Gate Sliding	Sign Bridge	Tree Scaled	
Guardrail	Sign Roadway	Treeline	
Median Barrier	Sign Street		
Wall Retaining			
Wall Block			
Wall Bridge			

Table 6

NSSDA Test Point Guidelines

1	2	3	4	5	6
Project Length (miles)*	Blind Panels	Well-Defined Points	Total Test Points	Test Points per Segment	Points Allowed to Fail**
Less Than 10	4	16	20	2	1
10 - 20	6	34	40	4	2
20 - 30	8	52	60	6	3
30 - 40	10	70	80	8	4
40 - 50	12	88	100	10	5

Test Point Placement:
The project will be broken into 10 equal segments.
10% of the total number of test points (Column 4) will be located in each segment.

Blind Panel Placement:
Blind panels (Column 2) will be distributed equally among the length of the project.

***Note:** Testing is not required for projects less than 1 mile.

****Note:** Column 6 equals the 5% failure rate allowed by NSSDA Standards.

Example: A project of 22 miles (Column 1) will have a total of 60 test points (Column 4). 8 blind panels and 52 well defined points will be used for testing. 3 points will be allowed to fail (Column 6) since: 60 X .05 = 3

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GLOSSARY

Aerial Negative – An aerial photograph whose light and dark areas are reversed from the original exposure.

Aerial Photography – The process of taking photography from an aircraft.

Aerial Survey – A survey made from an aircraft in which an onboard aerial camera is the primary source of data collection.

Analytic Point – A point added to each neat model to produce adequate horizontal and/or vertical control; eliminates the need for additional photo control panels that otherwise would require field control surveys. Also known as an artificial point or “pug” point.

Block (of photography) – Aerial photography from a set of adjoining flight lines used to cover an area not possible with a single flight line.

Breakline – An elevation poly line which contains horizontal and vertical values at each vertex. Breaklines are collected where 2 or more planes of elevation intersect.

CADD (Computer-Aided Drafting and Design) - First introduced in the mid 1960's as a tool for the production of drawings without the use of traditional drafting tools. Drawings are created and displayed by manipulating graphic elements on a computer screen instead of drawing them by hand.

Camera Calibration Report – A report which specifies various quantities of a cartographic camera, namely, the calibrated focal length, lens distortions, principal point location, fiducial mark locations, and lens resolution among others.

Cartographic Camera – Also referred to as an Aerial Mapping Camera. A camera specifically designed and calibrated for the acquisition of vertical photographs from an aircraft for mapping purposes.

Central Meridian – The line which is the axis of symmetry for a particular zone, used as the Y-axis in computing state plane coordinate values.

Contact Print – A photographic hard-copy of an exposure from aerial film. Contact prints are normally 9 inches by 9 inches in size. (See Appendix A, Figure 3)

Contour Interval (C.I.) – The difference of elevation between adjacent contours.

Contour Line – A line on a map representing equal elevation.

Control, Field – Horizontal/Vertical control data collected by field survey methods in support of the photogrammetric process.

Control, Horizontal – Control points having accurate horizontal (X & Y) coordinates used to provide horizontal control for other coordinates.

Control Point (Ground Target) – A point on the ground, established by surveying and used in aerotriangulation to determine the scale and orientation of aerial photographs.

Control Scheme – A diagram (shown on an aerial photo mosaic and/or topographic map) indicating horizontal and vertical GPS control locations.

Control, Vertical – Control points which have accurate elevations used to provide elevations for other points or surveys.

Coordinate – An ordered set of values which designate the location of a point in a space of dimensions or system.

Coordinate System – A set of points, lines, and/or surfaces and a set of rules, whereby each point in a given space (grid network) can be identified by a unique ordered set of values.

Crab – The condition caused by failure to orient the camera with respect to the track of the aircraft during flight.

Cross Section – A section perpendicular to the center line of a proposed construction of a linear feature such as a road.

Datum, Horizontal/Vertical – A system of points used as a reference in determining subordinate points for the purposes of surveying and mapping.

Design Concept Report (DCR) – A report which develops, evaluates, and recommends transportation project alternatives.

Design Cube - A defined and finite space within MicroStation (CADD software) considered to be the drawing plane (2D) or drawing cube (3D). It has a fixed size based upon the way MicroStation stores the coordinates of lines, points, and other elements within the design.

DGN - A file format used in MicroStation CADD applications.

Diapositive – A positive photograph on a transparent medium (such as glass or plastic) used in an analytical stereo plotter for photogrammetry purposes.

Digital Elevation Model (DEM) – A discreet representation of a topographic surface.

Digital Terrain Model (DTM) – A discreet arrangement of topographic data consisting of a group of horizontal and vertical coordinates which describe a surface.

Digitize – The process of converting an analog or non-digital signal or data to a numerical representation. Because it can be stored and easily retrieved, digital data allows for greater flexibility of use.

Dodging – A method used to correct tone variations on an aerial photograph.

Earthwork – The movement of large amounts of earth in the preparation of constructing roads, canals, railroads, buildings, etc.

Feature – Map graphic features or elements can be classified as points, lines, and areas (vector data), or pixels (raster data). In a GIS, these features are grouped together to form more complex objects such as "networks" of streams or roads, three-dimensional terrain surfaces, and multi-polygon regions.

Fiducial Marks – A set of markers (usually 8) found on an aerial photograph. They are located at the corners and along the edges and are used to identify the principal point of an aerial photograph.

Filter, Anti-Vignetting – An optical filter used to produce uniform tone and balance across aerial photographs caused by inherent lens characteristics.

Flight Line –The path flown by an aircraft during an aerial survey. A line drawn on a map which represents the path flown by an aircraft.

Focal Length – The portion within the lens cone assembly of an aerial mapping camera which is the distance between the focal plane and the center of the lens.

Forward Motion Compensator (FMC) – A mechanism on the aerial camera system used to compensate for the forward movement of the aircraft during the time the shutter is open thereby reducing image distortion. The FMC causes the film to move forward slightly in the same direction and speed as the aircraft.

Grid Adjustment Factor (GAF) – A numerical value used to convert grid mapping coordinates to real-world ground coordinates.

Ground Sample Distance – Also referred to as Pixel Resolution. The physical dimension or size of a pixel.

Histogram – A graphical representation of the distribution of the pixel brightness values of a digital aerial photograph.

Image - A graphic representation or description of an object that is typically produced by an optical or electronic device. Common examples include remotely sensed data such as satellite data, scanned data, and photographs. An image is stored as a raster data set of binary or integer values representing the intensity of reflected light, heat, or another range of values on the electromagnetic spectrum.

Index, Aerial Photography – Also referred to as a Photo Index. An assemblage of aerial photographs showing their relation to one another, and to features found along their flight path (e.g. terrain, drainage, and cultural features). Indexes are useful for reconnaissance, area studies, and control planning.

Level – CADD technology treats digital data as electronic drawings that are basically made up of graphic elements organized into "layers" or "levels." Each type of graphical element such as roads, buildings, or DTM elements is assigned to separate "levels" which facilitates manipulation or isolation of these elements.

Map, Base – Existing maps and/or photography used for the purpose of planning mapping extents and requirements.

Map, Planimetric – A map containing features which do not represent the relief of the natural ground. Features can be either cultural/man-made objects (e.g. roads, buildings, utilities), or natural objects (e.g. trees, drainage features). Appendix A, Figure 6 shows an example of a planimetric map.

Map, Topographic – A map depicting ground elevations using contour lines and/or spot elevations. The map represents the horizontal and vertical positions of features. It is a graphic representation delineating natural and man-made features of an area in a way that shows their relative positions and elevations. Appendix A, Figure 7 shows an example of a Topographic Map.

Monochrome – Having only one color.

Mosaic - An assemblage of overlapping images, whose edges have been matched to form a continuous representation of the ground surface.

National Standard for Spatial Data Accuracy (NSSDA) – A method (set forth by the National Spatial Data Infrastructure of the Federal Geographic Data Committee) of evaluating and reporting map accuracies. The NSSDA offers a means of statistically testing the positional accuracies of digital data.

Neat Model – The viewable stereo portion made up of the area between the principal points of 2 adjoining aerial photographs, extending outwardly in both directions.

Orthophotograph – An aerial photograph with correction applied to account for sensor tilt and terrain-induced distortion. An orthophotograph is considered to be spatially correct.

Orthorectification – The process by which an aerial photograph is corrected for sensor distortion and terrain relief.

Overlap (Forward Lap) – The overlap between 2 successive aerial photographs in a flight line. Overlap between photographs should be 60%.

Photogrammetric Compilation – The collection of map features (topographic and planimetric) through the use of photogrammetry.

Photogrammetric Mapping – The production of maps showing planimetric and/or topographic data employing the use of photogrammetry.

Photogrammetry - The art or science of gathering information about physical objects through the use of aerial photography and satellite imagery.

Photo Identification Point (Photo ID) – A point identified on an aerial photograph used to supplement ground control points.

Pixel – Abbreviated from picture element. It is the smallest portion of a digital image. Black and white digital photographs are made up of pixels ranging in brightness values from 0 (black) to 255 (white).

Pixel Resolution – See Ground Sample Distance

Principal Point – The center of an aerial photograph found by drawing imaginary lines between fiducial marks.

Raster Data – Data made up of pixels which range in brightness values. Digital images are raster data.

Root Mean Square Error (RMSE) – The square root of the sum of squares between an observed value and its calculated value.

Scale – The ratio between distances measured on a map or orthophotograph and the corresponding distance measured on the ground.

Sidelap – The overlap between photographs taken on parallel lines of flight. The overall amount of sidelap should be 30% plus or minus 2%.

Soft-copy Workstation – A photogrammetric workstation capable of collecting data using digital aerial photography and a specialized viewing system.

Spot Elevation – The elevation of a point of particular significance commonly printed on a map next to a mark indicating the point to which it corresponds.

State Plane Coordinate System – A horizontal coordinate system consisting of zones. Zones divide the U.S. into sections each with its own grid network. Zone boundaries follow state and county lines. Each zone has a central meridian which passes through its origin. The state of Arizona has three zones.

Stereoscopic - Pertaining to the use of binocular vision for observation of a pair of overlapping photographs or other perspective views, giving impression of depth.

Survey – The measurement of distances, angles, and heights to determine the relative location of points above, on, or above the earth.

TFW – A file extension. ASCII text file used in conjunction with a TIFF (with the same file name) and allows an image to be georeferenced.

TIFF – Tagged Information Format File. A file format type used for digital images.

Tilt – The rotation or displacement of an aerial photograph from the true vertical position.

Triangulated Irregular Network (TIN) – A system of triangles made up of connecting data points which accurately represents the terrain. Appendix A, Figure 5 shows an example of a TIN.

Vector Data – Digital data made up of points and lines rather than pixels.

Velum – Material used by field survey personnel to place ground control panels.