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Comparison of Photogrammetrically Derived Topography to Conventional Survey Methods in Grand Canyon

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Introduction

Five sites in Grand Canyon were selected for photogrammetric mapping based on high concentrations of archeological sites located on high terraces in these reaches. The overflight occurred on Sept.9, 1998. The sites include Nankoweap (RM 52-53 RR), Palasaides Creek (RM 65 RL), Lower Tanner (RM 70 RL), Upper Unkar (RM 71.5 RR) and 122 Mile Canyon (RR). These sites are included in GCMRC geodetic control catalog in GIS Areas 4,5,and 7 and include approximately 40 catchment basins. These features were considered critical to evaluation of stability of these cultural sites (Yeattes et al, 1998). Conventional topographic surveys were performed the previous year at three of these areas (Palasaides Creek, Lower Tanner and 122-Mile Canyon). These conventional surveys allow us to compare results between the two mapping methods.

Background

The control points for the mapping project were tied in using conventional surveying methods throughout the 1990's. The traverse network has been run through least square adjustment procedures to adjust coordinates in the State Plane Coordinate System (SPCS). The SPCS is a map projection system (Transverse Mercator for Arizona) that minimizes angular distortions and allows projection of a curved earth system onto a flat x/y coordinate system. The x/y coordinates are computed by projecting latitudes and longitudes from a mathematical approximation of the earth (NAD 83) onto a rectangular grid (Arizona State plane coordinates central zone). Elevations are referenced by a vertical datum that represents the best approximate sea level (National Geodetic Vertical Datum of 1929- NGVD29)

These control surveys are important for establishing a spatial reference framework for all mapping. Regardless of the method of data collection, (aerial photography, coordinate geometry, or Global Positioning System (GPS)), the control surveys are the necessary first step. This geodetic control network is the skeleton on which continuous and consistent maps are based. To understand the function of geodetic control it is important to realize that a map or a plane survey is a flat representation of the real, curved world. If the maps are to become an authentic representation of the real world we have to be able to "paste" small pieces of flat map contents onto a curved world. Geodetic control is the mechanism that enables us to perform this "pasting" accurately and consistently. Obviously, the need for geodetic control depends on the accuracy specifications of the map, the extent of area being mapped (the larger the area, the larger the deviation between a curved surface and a plane), and the desire for compatibility with other mapping or GIS projects. At a very minimum, the accuracy of the control network should be 3 times higher than the mapping accuracy standard. GCMRC Control is considered a second order, first class traverse with an error margin of one unit per 50,000 units measured.

The purpose of control surveys for aerial photography and photogrammetry are to determine the exact position of the aerial camera at the instant of exposure and to establish known reference points for mapping. As an airplane flies over the terrain, it snaps many exposures at specified intervals. Without control surveys there would be no way of determining exactly where the aircraft was at the instant of exposure. Control surveys are used to determine the precise geometric relationship between the physical position of the aircraft camera (its altitude and attitude) and the internal spatial geometry of the camera itself. To accomplish this task, targets are physically placed on the ground at specified locations within the project area. These targets are then surveyed to establish their location. For proper visibility, targets must be sized according to the photo scale necessary. The number of targeted control points and their overall positions within the project area is relative to the flight altitude. Lower aerial photography requires more control points than higher aerial photography. The flights for the five sites in Grand Canyon were flown at approximately 2400 above ground level (AGL). Prior to the overflight, GCMRC Survey Department personnel set approximately five panels at known control points for each site.

These panel locations were determined using conventional surveying practices of multiple angles in both direct and reverse scope and by multiple distance measurement using infra red electronic distance measurements. Vertical angles were adjusted for earth curvature and refraction and horizontal distances were adjusted by appropriate scale factors due to elevation above NGVD 29.

Comparison

The two Digital Terrain Models -DTM's, (conventional topographic survey topography and photogrammetrically created topography) have been compared through the use of cross sections and cut and fill maps. The conventional survey was used as a basemap and the photogrammetry data elevations are overlaid to determine the differences in the elevations. The cross sections give a two-dimensional assessment of the data while the cut and fill maps give a three-dimensional representation of the differences.

Results

Below is a table that describes the DTM's generated at the three sites.

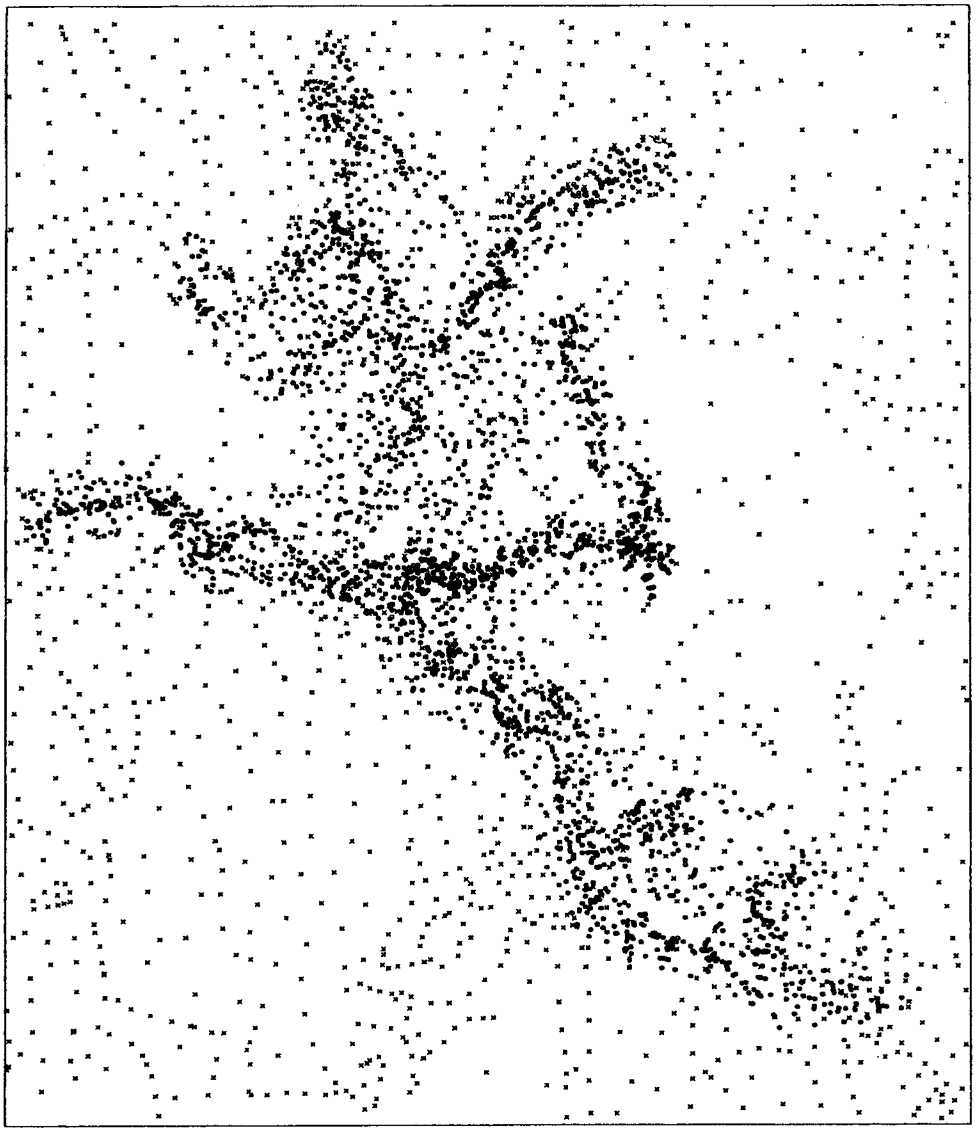
Survey Site	**Approx. Size (M^2)**	**# Photogrammetry Pts**	**# Conventional Pts**	**Photo Pt Density (# pts/ M^2)**	**Conventional Pt Density (# pts/ M^2)**
122 mile	475	36	529	0.08	1.11
Tanner	650	58	434	0.09	0.67
Palasaides	5400	563	2961	0.10	0.55

From the point densities above, it can be assumed that the conventional surveys have a tighter network and therefore these conventional surveys are more representative of the existing terrain. The conventional surveys had specifically targeted the drainages of these areas; concentrating on thalweg elevations, bank elevations and nick point locations. Representative point concentrations are shown below for the largest of the three sites-Palasaides.

Palasaides Creek Point Density

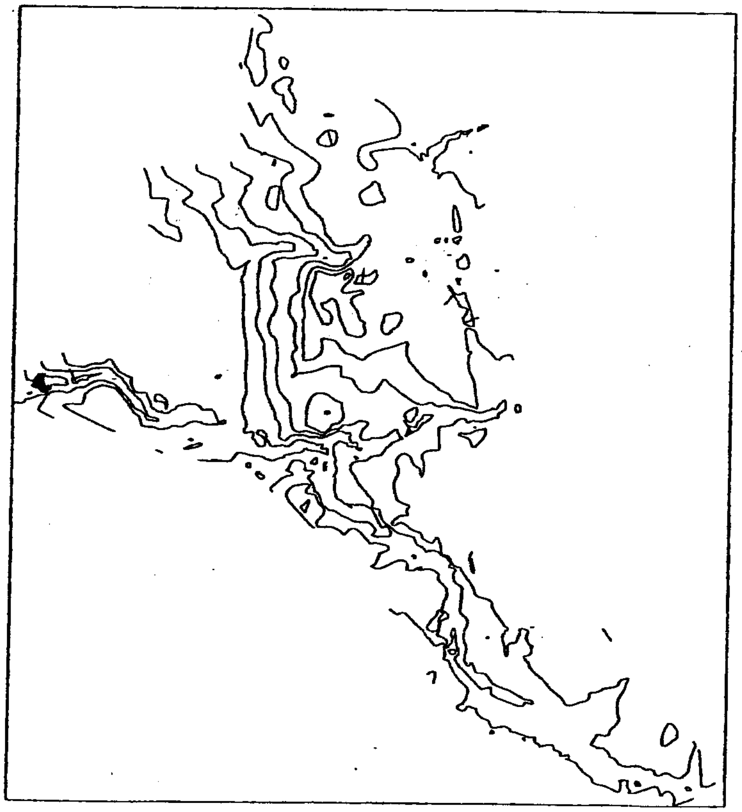
Photogrammetry -X's

Conventional -O's

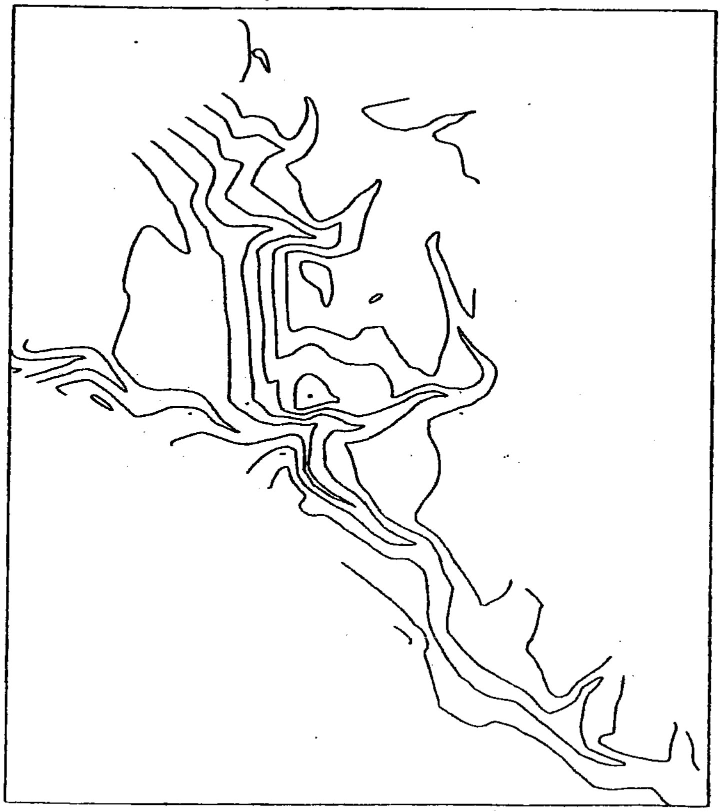


Since the DTM generated from photogrammetrically derived points had less point density, many of the drainage features are not represented as accurately in the orthophotos and resulting maps. This observation can be shown in the details of both the contours of the following maps and in the cross section comparison of Palasaides Creek. The irregular shaped lines represent the increased precision in the conventional maps due to point frequency. It should be noted, however that the contour lines are very similar for both surveys.

Palasaides Creek Conventional
1/2 meter contours

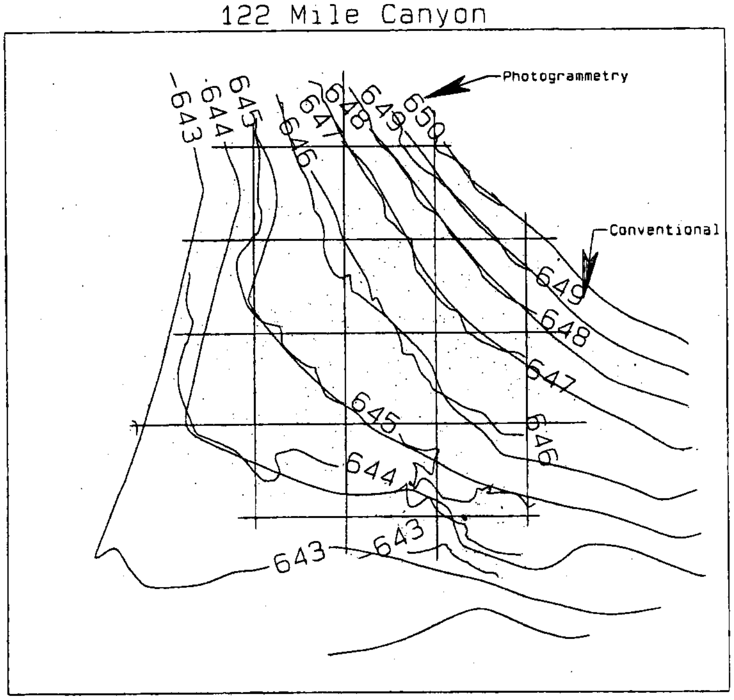


Palasaides Creek Photogrammetry
1/2 meter contours



A series of gridded cross sections have been analyzed for each of the sites. Results of the 122-mile canyon site show excellent correlation between the two surveys. Each cross section was assessed for cut and fill areas. By dividing the areas of both cut (areas where the photogrammetry DTM was lower in elevation than the conventional survey) and fill (areas where the conventional was lower in elevation than photogrammetry) by the length of the cross section, an average offset was calculated for each line. Results of all the data in these nine cross section at 122-mile canyon show that the two DTM's differ by less than 5 centimeters for the entire site. Again we see the detail difference in the contours of the two methods.

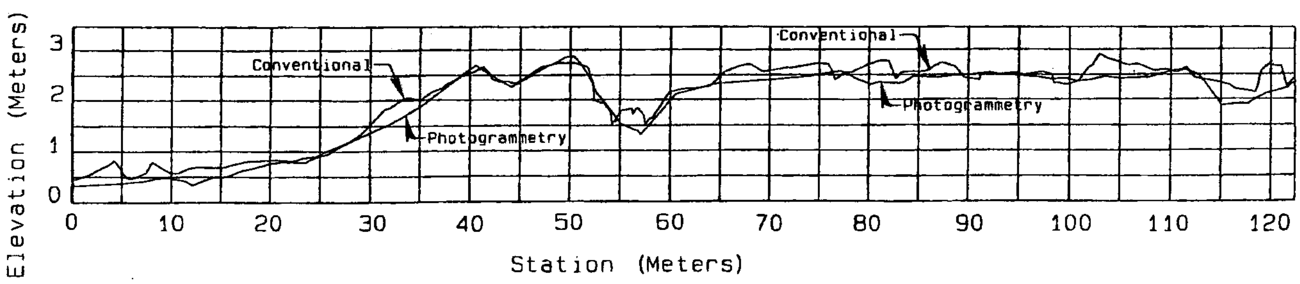
122 Mile Canyon



	Station	Area Fill (m^2)	Area Cut (m^2)	Xsect. Width (m)	Avg Delta Z (m)
E/W Xsection	5+00	1.08	3.11	21.04	-0.09648289
	10+00	2.75	1.62	25.34	0.044593528
	15+00	1.89	3.63	23.04	-0.075520833
	20+00	1.3	0.68	16.27	0.038106945
N/S Xsection	5+00	1.16	0.91	14.57	0.017158545
	10+00	4.36	0.23	25.05	0.164870259
	15+00	1.37	1.57	22	-0.009090909
	20+00	0.31	5.33	18.97	-0.264628361
	25+00	0.02	3.07	12.18	-0.250410509
				Average Delta Z	-0.047933803

Palasaides Creek Cross Section
1/2 meter contours

Palasaides Creek



Three-dimensional volumes were also compared for the sites. Elevations of the photogrammetric DTM were subtracted from elevations of the conventional DTM to create a cut and fill representation. White areas of the image show where the two methods differed by less than 0.25 meters. The darker red images show graduations where the conventional elevations are higher than the photogrammetry as blue areas show the opposite. Maximum elevation differences are singular points where a photogrammetric point is 1.41 meters over the conventional survey (a blue area at the far left) and where a conventional point is 1.31 meters above the photogrammetry (a red area upper center). We can not be sure which DTM is incorrect. Quantitative analysis of the Palasaides Creek site 87.68 cubic meters in cut and 584.48 cubic meters in fill areas. When draped evenly over the 5400 square meter site, we calculate a Delta Elevation to be 0.092 meters or less than 4 inches.

Conclusions

Aerial photography is a valuable tool for topographic mapping in Grand Canyon. Although greater detail of topography can be obtained through conventional methods, aerial photography, with accurate geodetic control, can generate large site maps with limited field time. Elevation differences were as large as 1.4 meters at one point, however, overall elevations between the two methods for the entire sites averaged between 5 and 10 centimeters or 2 to 4 inches.

Suggestions

Downcutting monitoring of arroyos require a tighter point density to determine elevations of channel bed and banks. When panels are placed for future aerial photography projects, the field surveyors, after panel location and placement, may consider mapping thalweg and bank profiles with conventional methods. This survey data can then be merged with photogrammetry to create accurate site maps that can be used for long term monitoring of these stream channels.