Flood Control District of Maricopa County

Mapping Services for Palo Verde Area Drainage Master Plan

Technical Data

June 6, 2008

WILSON
&COMPANY
ENGINEERS & ARCHITECTS

Summary

Wilson & Company, Inc., Engineers & Architects was selected by the Flood Control District of Maricopa County to perform Mapping Services for Palo Verde Area Drainage Master Plan in early 2007. This work was performed under Contract FCD 2006C028 with a Notice-to-Proceed of May 16, 2007.

The project team and tasks were:

- Wilson & Company
  - Project management
  - Photo control surveys
  - ABGPS base stations
  - Structure surveys
  - Road profiles
  - Photogrammetric mapping
  - CAD and GIS file development
- A Team Professionals, Inc.
  - ABGPS base stations
  - Blind panel surveys
  - DTM check point surveys
  - Cross section surveys
- Western Air Maps, Inc.
  - ABGPS aerial photography

Aerial Photography

Western Air Maps captured black and white aerial photography at a photo scale of 1:7,200 (3,600-ft AMT) using a Zeiss RMK Top 15 precision photogrammetric camera. This camera has a focal length of 153.294 mm, an AWAR of 104 and was calibrated May 17, 2006. A complete camera report is included.
The photo scale was selected using an 1,800 C-factor for a two foot contour interval.

The flight plan was developed by Wilson & Company and submitted to Western Air Maps for execution. The aerial photography was successfully captured on June 12, 2007. The aerial photography was 35 flight lines and 802 aerial photos.

Wilson & Company and A Team Professionals both provided GPS base stations to collect data during the aerial photo mission.

Aerial Triangulation

The photos were scanned on a Vexcel VX400 scanner at 15 micron resolution.

The control point standard deviations were set to 0.30 feet. The control was targeted and well distributed. Blind points were used to evaluate the adjustment by the District. In addition, intermediate adjustments were provided with various combinations of control points used as check points to validate the integrity and reliability of the adjustment including measurements, control, AGPS/IMU, and adjustment parameters chosen.

Two points could not be measured (4EK1 and PP137) as they were both outside the imagery.

AGPS and IMU data was provided. The AGPS std devs were set to 0.5 feet and the IMU omega/phi std dev was set at 0.008 gons while kappa was set at 10.0 gons. Basically kappa was eliminated as it is redundant when control is present.

Drift and shift parameters were not used for this project. Instead a single 7-parameter transformation was employed to account for any differences present in the AGPS and ground control systems. In the end there was almost no rotational or scalar differences with only some small shifts in XYZ. The AGPS and IMU data was very well behaved.

A typical set of distortion parameters were used for the adjustment to compensate for all image distortions.

The BINGO free network adjustment yielded a 3.52 micron sigma and the controlled adjustment yielded a sigma of 3.46 microns. The ground control statistics are tabulated as follows:

RMS control point residuals:	0.171 0.223 0.145 ft
Maximum control point residuals:	0.619 0.664 0.504
RMS GPS residuals:	0.156 0.308 0.118
Maximum GPS residuals:	0.828 1.185 0.553
RMS IMU residuals:	0.0082 0.0059 0.0115
Maximum IMU residuals: (Computed from real residuals)	0.0789 0.0610 0.0333

These results are very good and well within mapping specifications for this job.

The survey control points were not overwritten. All data from BINGO was imported (EO and XYZ points).

RO and AO solutions were computed for all models. Earth curvature and atmospheric refraction were applied. Single Photo Resections were computed for all photos as a final step.

Wilson & Company provided the blind panel coordinates to the District for review. The resulting RMS values were Y=0.259, X=0.190, and Z=0.238 feet. The District approved the AT results on July 24, 2007.

The adjustments before and after including the blind points as control were compared. The results demonstrate that the blind points fit very well and actually contribute very little to the end solution. In summary, the differences were:

	X	Y	Z
Average	-0.053	-0.037	0.008 ft
Minimum	-0.125	-0.196	-0.263
Maximum	0.010	0.055	0.268

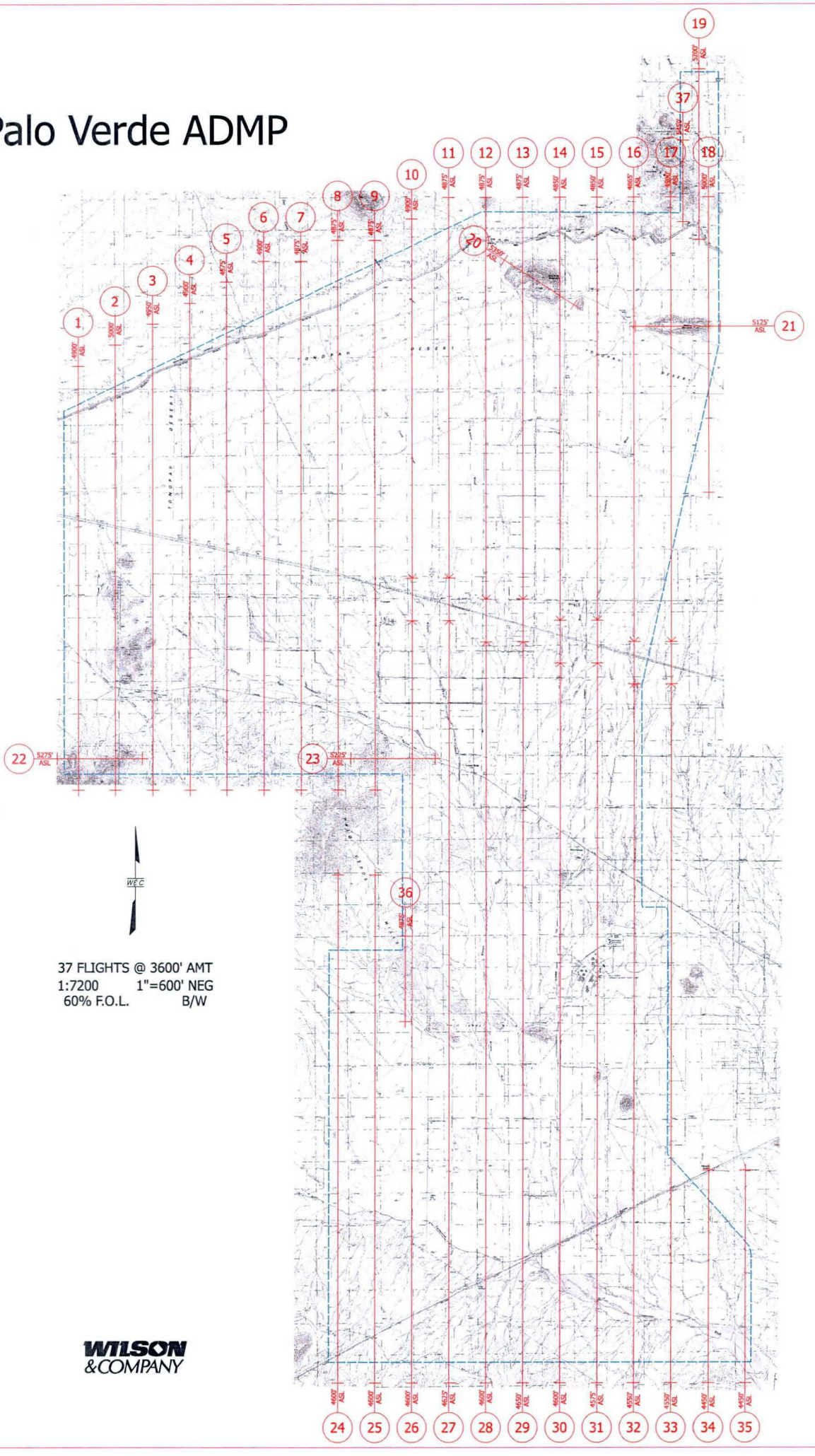
Photogrammetric Map Compilation

Wilson & Company compiled all 738 stereomodels using Z/I Photogrammetric Workstations directly into MicroStation v8. The resultant DTM was split into four blocks for submittal to the District for review and comparison to field cross sections and DTM check points. All DTM data was approved by the District.

CAD & GIS File Creation

Contours were generated from the DTM files in MicroStation using Bentley InRoads software. All planimetric features were imported to ArcInfo v9.2 and coverage files were delivered to the District.

Palo Verde ADMP



37 FLIGHTS @ 3600' AMT
1:7200 1"=600' NEG
60% F.O.L. B/W

WILSON &COMPANY

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION
of Aerial Mapping Camera

May 23, 2006

Camera type:	Zeiss RMK Top 15*	Camera serial no.:	149987
Lens type:	Zeiss Pleogon A3/4	Lens serial no.:	150002
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Western Air Maps, Inc.
Overland Park, Kansas

Reference: Western Air Maps, Inc. purchase order No. 4-10711, dated May 17, 2006.

These measurements were made on Agfa glass plates, 0.19 inch thick, with spectroscopic emulsion type APX Panchromatic, developed in D-19 at 68° F for 3 minutes with continuous agitation. These photographic plates were exposed on a multicollimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 153.294 mm

II. Lens Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	0	1	1	1	-1
Decentering (um)	0	0	1	2	3	4

Symmetric radial distortion parameters	Decentering distortion parameters	Calibrated principal point
$K_0 = -0.8308 \times 10^{-5}$	$P_1 = -0.2021 \times 10^{-6}$	$x_p = 0.013$ mm
$K_1 = -0.2330 \times 10^{-8}$	$P_2 = 0.1518 \times 10^{-6}$	$y_p = -0.004$ mm
$K_2 = 0.2034 \times 10^{-12}$	$P_3 = 0.0000$	
$K_3 = 0.0000$	$P_4 = 0.0000$	
$K_4 = 0.0000$		

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion (K_0, K_1, K_2, K_3, K_4), Decentering Distortion (P_1, P_2, P_3, P_4), and Calibrated Principal Point [point of symmetry] (x_p, y_p) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation (σ) of ±3 microns.

* Equipped with Forward Motion Compensation

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 104

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	134	159	134	113	113	95	95
Tangential lines	134	159	113	95	113	80	80

The resolving power is obtained by photographing a series of test bars and examining the resultant image with appropriate magnification to find the spatial frequency of the finest pattern in which the bars can be counted with reasonable confidence. The series of patterns has spatial frequencies from 5 to 268 cycles/mm in a geometric series having a ratio of the 4th root of 2. Radial lines are parallel to a radius from the center of the field, and tangential lines are perpendicular to a radius.

IV. Filter Parallelism

The two surfaces of the USGS TOP 15 test filter KL-F (60%) No. 142399 are within 10 seconds of being parallel. This filter, in conjunction with the internal "B" filter, was used for the calibration.

V. Shutter Calibration

Indicated time (sec)	Rise time (μ sec)	Fall Time (μ sec)	½ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/100	3646	3711	10.82	1/120	79
1/200	1761	1796	5.19	1/250	79
1/300	1151	1198	3.51	1/360	79
1/400	907	878	2.66	1/480	79
1/500	707	709	2.07	1/620	79

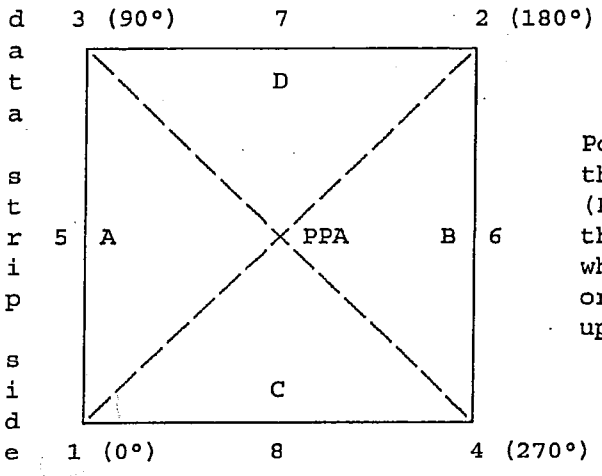
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is described in International Standard ISO 516:1999(E).

VI. Magazine Platen

The platens mounted in T-MC film magazines No. 151634 and No. 151642 do not depart from a true plane by more than 13 um (0.0005 in).

The platens for these film magazines are equipped with identification markers that will register "151799" for magazine No. 151634, and "151813" for magazine No. 151642 in the data strip area for each exposure.

VII. Principal Points and Fiducial Coordinates



Positions of all points are referenced to the principal point of autocollimation (PPA) as origin. The diagram indicates the orientation of the reference points when the camera is viewed from the back, or a contact positive with the emulsion up. The data strip is to the left.

	X coordinate	Y coordinate
Indicated principal point, corner fiducials	0.011 mm	-0.010 mm
Indicated principal point, midside fiducials	0.011	-0.014
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.013	-0.004

Fiducial Marks		
1	-112.982 mm	-113.010 mm
2	113.006	112.993
3	-112.993	112.987
4	113.017	-113.010
5	-112.990	-0.018
6	113.019	-0.009
7	0.012	112.990
8	0.009	-113.020

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.606 mm 3-4: 319.617 mm

Lines joining these markers intersect at an angle of 89° 59' 59"

Midside fiducials

5-6: 226.008 mm 7-8: 226.009 mm

Lines joining these markers intersect at an angle of 89° 59' 49"

Corner fiducials (perimeter)

1-3: 225.997 mm 2-3: 225.999 mm

1-4: 225.999 mm 2-4: 226.003 mm

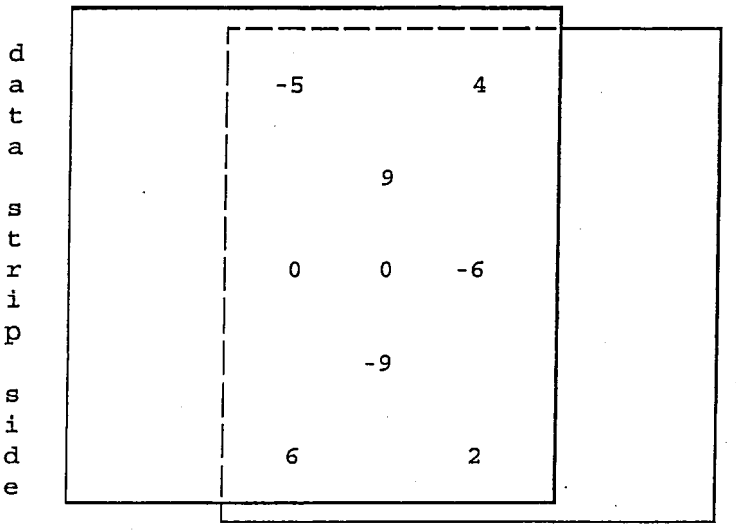
The method of measuring these distances is considered accurate within 0.003 mm

Note: For GPS applications, the nominal entrance pupil distance from the focal plane is 254 mm with a 10 mm filter thickness. Additional filter thickness will increase entrance pupil distance by 0.34 X added thickness.

IX. Stereomodel Flatness

FMC Magazine No.: 151634 Base/Height ratio: 0.6

Platen ID: 151799 Maximum angle of field tested: 40°



Stereomodel
Test point array
(values in micrometers)

The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereo models. The values are based on comparator measurements on Kodak 4425 copy film made from Kodak 2405 film exposures. These measurements are considered accurate to within 5 μm.

X. System Resolving Power on film in cycles/mm

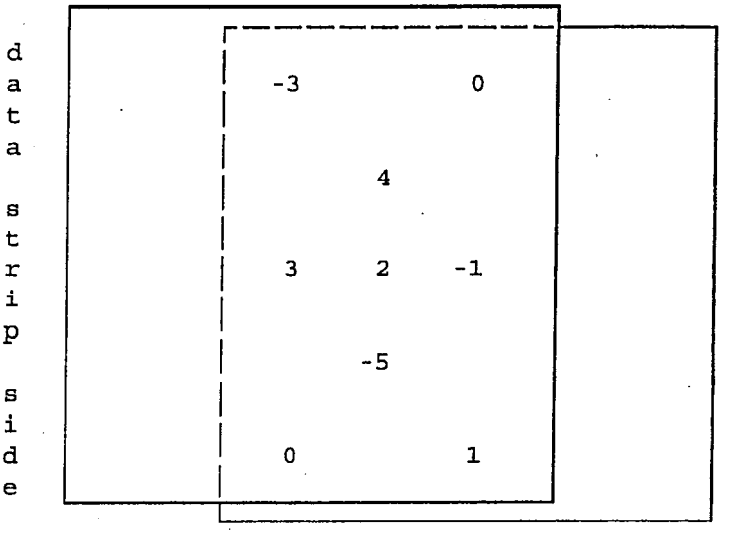
Area-weighted average resolution: 47 Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	48	48	48	48	48
Tangential lines	57	48	48	48	48	40	40

IX. Stereomodel Flatness

FMC Magazine No.: 151642 Base/Height ratio: 0.6

Platen ID: 151813 Maximum angle of field tested: 40°



Stereomodel
Test point array
(values in micrometers)

The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereo models. The values are based on comparator measurements on Kodak 4425 copy film made from Kodak 2405 film exposures. These measurements are considered accurate to within 5 μm.

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Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	48	48	48	48	48
Tangential lines	57	48	48	48	48	40	40

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2979, dated October 6, 2003.

Gregory L. Stensaas
Remote Sensing Technologies Project Manager
Geography Discipline

Detailed Aerial Triangulation Report

Point Information

Number of points measured in 2 photos: 836
Number of points measured in 3 photos: 4567
Number of points measured in 4 photos: 459
Number of points measured in 5 photos: 1269
Number of points measured in 6 photos: 1946
Number of points measured in 7 photos: 37
Number of points measured in 8 photos: 26
Number of points measured in 9 photos: 7
Number of points measured in 10 photos: 7
Number of points measured in 11 photos: 2

Summary of photo data:

No. of used points : 9156
No. of used photos : 802
No. of used cameras : 1
Max. photo rays per point : 11
Max. photo measurements per point: 11
Used points per photo - minimum : 17
Used points per photo - median : 45
Used points per photo - maximum : 123
Max. photo index difference : 556

No. of photo orientation data : 802
No. of approximate coordinates : 9156
No. of camera input statements : 2

FREE NETWORK BUNDLE ADJUSTMENT FOR ENGINEERING APPLICATIONS

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Free Network Adjustment

RESULTS OF ADJUSTMENT SIGMA 0 = 0.00352 mm

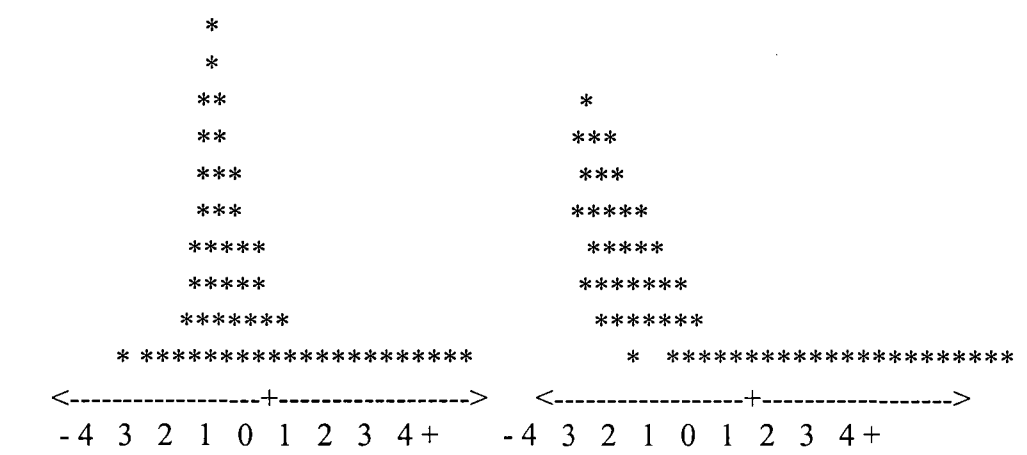
Residuals of photo measurements (x', y') in photo space:

RMS	2.5	2.7
MAX	14.1	17.8

RMS residuals of all other photo measurements transformed to object space:

RMS	0.002	0.002	0.001

Frequency of photo measurement residuals N(0,1) :



A posteriori variance-component estimation

Test value = s(a posteriori) / s(a priori)

Group		Test Value	No. of Obs.	Redundancy
Photo coordinates	:	0.70	71704	39429.00

Controlled Adjustment

RESULTS OF ADJUSTMENT SIGMA 0 = 0.00346 mm

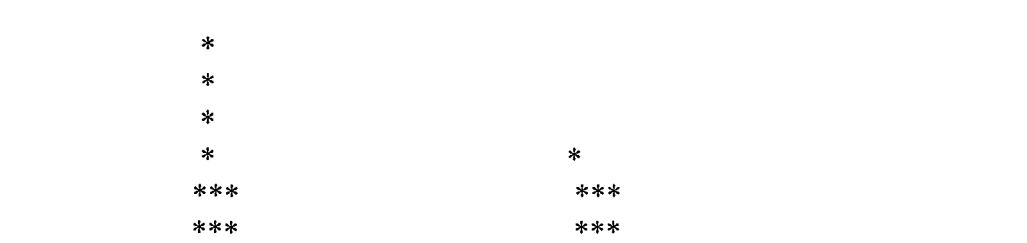
Residuals of photo measurements (x', y') in photo space:

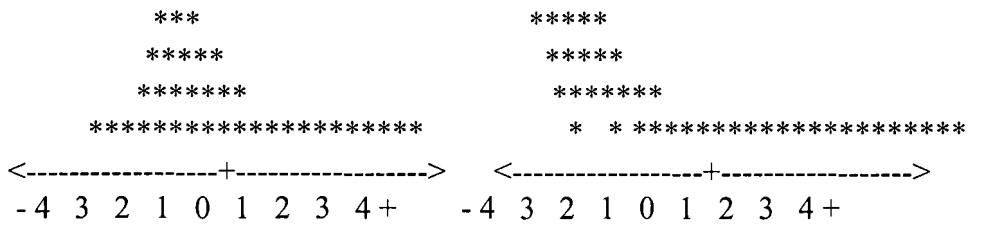
RMS	2.4	2.7
MAX	13.5	19.1

RMS residuals of all other photo measurements transformed to object space:

RMS	0.057	0.053	0.025

Frequency of photo measurement residuals N(0,1) :





GPS datum transformation parameters

Type	Parameter	+-S	
DX	-0.6086	0.0239	adjusted
DY	-1.2490	0.0234	adjusted
DZ	0.1623	0.0254	adjusted
Phi	-0.000303	0.000082	adjusted
Omega	-0.000367	0.000044	adjusted
Kappa	0.000028	0.000037	adjusted
Scale	1.00000449	0.00000058	adjusted

Camera data

Camera 1

Diff. angle of rotation delta : -0.0511 0.0249 -0.0126
+-S : 0.0002 0.0002 0.2440

Additional parameters : Format factor = 0.996000

1 2 3 5 6 7
19 21

-0.0027 0.0010 -0.0395 -0.0013 -0.0076 0.0003
0.0053 -0.0100

Radial symmetric lens distortion from additional radial parameters (1/1000)

Distortion values; First value for R = 10.0 (= Step width)

0.0 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1
0.1 0.0 0.0 -0.1 -0.2 -0.3

*
* Control point residuals for graphical output
*
* <___Vx_Max__><___Vy_Max__><___Vz_Max__>
VMAX 0.619 0.664 0.504

*

*<Point_No>	<Vx>	<Vy>	<Vz>	Key
100	0.307	0.002	0.217	XYZ
101	0.165	0.264	0.272	XYZ
102	0.096	0.313	0.099	XYZ
103	0.337	0.433	-0.387	XYZ *
104	0.330	-0.335	-0.011	XYZ
105	0.099	0.057	-0.334	XYZ
106	-0.125	0.258	0.078	XYZ
107	0.121	-0.353	-0.025	XYZ
108	0.029	0.186	0.020	XYZ
109	0.000	0.000	-0.295	Z
110	0.619	0.342	0.222	XYZ **
111	-0.049	0.129	-0.192	XYZ
112	0.096	0.229	-0.140	XYZ
113	-0.073	0.044	0.039	XYZ
114	0.219	0.175	0.072	XYZ
115	0.008	-0.086	0.044	XYZ
116	0.077	-0.093	-0.027	XYZ
117	0.261	-0.197	0.101	XYZ
118	0.028	-0.166	-0.184	XYZ
119	-0.024	0.003	0.057	XYZ
120	-0.008	0.164	-0.016	XYZ
121	-0.060	-0.049	0.117	XYZ
122	-0.126	0.140	0.043	XYZ
3AL4	-0.232	0.061	0.069	XYZ
3BL2	-0.194	0.135	-0.158	XYZ
3CM1	-0.013	-0.002	0.270	XYZ
3ck2	0.000	0.000	0.199	Z
4AM2	-0.143	0.205	-0.043	XYZ
4BL1	-0.178	-0.001	-0.034	XYZ
4CM1	-0.265	-0.328	-0.296	XYZ
4CO1	0.045	-0.664	-0.504	XYZ **
4DL1	-0.155	0.199	-0.063	XYZ
4DN1	0.174	-0.173	-0.157	XYZ
4EM2	0.135	0.297	-0.052	XYZ
4EO2	0.254	-0.479	-0.049	XYZ *
4FL2	0.078	0.036	0.067	XYZ
4GK2	0.039	0.221	0.188	XYZ
PP100	0.246	0.303	-0.003	XYZ
PP101	0.025	0.275	0.004	XYZ
PP102	-0.138	0.251	-0.153	XYZ
PP103	0.075	-0.007	0.136	XYZ
PP104	0.261	0.237	-0.137	XYZ
PP105	0.216	0.232	-0.278	XYZ
PP106	0.154	-0.510	-0.069	XYZ *
PP107	0.120	-0.305	-0.343	XYZ
PP108	0.224	-0.050	-0.139	XYZ
PP109	-0.195	0.068	0.195	XYZ
PP110	-0.110	0.279	0.057	XYZ
PP111	-0.111	0.161	0.051	XYZ
PP112	-0.233	0.409	0.168	XYZ *

PP113	-0.106	0.156	-0.014	XYZ	
PP114	0.182	-0.194	0.162	XYZ	
PP115	0.181	-0.132	-0.057	XYZ	
PP116	0.195	-0.469	-0.132	XYZ	*
PP117	-0.099	-0.282	-0.061	XYZ	
PP118	-0.028	-0.372	-0.098	XYZ	
PP119	0.146	-0.111	-0.263	XYZ	
PP120	0.255	-0.148	0.109	XYZ	
PP121	-0.012	0.266	0.081	XYZ	
PP122	-0.164	0.082	0.085	XYZ	
PP123	-0.160	0.311	-0.070	XYZ	
PP124	0.129	-0.374	-0.088	XYZ	
PP125	-0.049	-0.654	-0.050	XYZ	**
PP126	0.036	-0.022	-0.018	XYZ	
PP127	0.009	0.096	-0.011	XYZ	
PP128	0.011	0.074	-0.014	XYZ	
PP129	-0.142	0.131	0.034	XYZ	
PP130	0.002	0.020	-0.111	XYZ	
PP131	-0.095	0.063	0.019	XYZ	
PP132	0.024	-0.048	0.165	XYZ	
PP133	0.187	-0.340	-0.198	XYZ	
PP134	-0.080	0.122	-0.124	XYZ	
PP135	-0.284	-0.010	0.052	XYZ	
PP136	0.032	-0.145	0.057	XYZ	
PP138	-0.171	-0.057	-0.017	XYZ	
PP139	0.003	0.164	0.031	XYZ	
PP140	-0.196	-0.088	0.125	XYZ	
PP141	-0.101	0.158	0.145	XYZ	
PP142	-0.250	0.030	0.114	XYZ	
PP143	0.112	-0.063	0.080	XYZ	
PP144	-0.258	-0.132	-0.005	XYZ	
PP145	-0.126	-0.114	0.086	XYZ	
PP146	0.062	-0.155	0.123	XYZ	
PP147	-0.210	-0.051	0.121	XYZ	
PP148	-0.115	-0.076	0.070	XYZ	
PP149	-0.054	-0.022	0.098	XYZ	
PP150	-0.177	0.074	0.027	XYZ	
PP151	-0.117	-0.153	0.016	XYZ	
PP152	-0.188	-0.010	0.075	XYZ	
PP153	-0.136	-0.053	0.147	XYZ	
PP154	-0.327	-0.212	0.126	XYZ	
PP155	-0.214	0.104	0.143	XYZ	
PP156	-0.020	-0.095	0.094	XYZ	
old13	-0.101	0.023	0.064	XYZ	
old18	-0.098	0.221	0.148	XYZ	
old22	-0.269	-0.009	0.004	XYZ	
old25	0.149	0.095	-0.088	XYZ	
old28	0.203	0.047	0.000	XYZ	
old32	0.024	0.044	0.121	XYZ	

RMS control point residuals: 0.171 0.223 0.145 ft

Maximum control point residuals: 0.619 0.664 0.504

RMS GPS residuals: 0.156 0.308 0.118
Maximum GPS residuals: 0.828 1.185 0.553

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0789 0.0610 0.0333
(Computed from real residuals)

A posteriori variance-component estimation

Test value = s(a posteriori) / s(a priori)

Group	Test Value	No. of Obs.	Redundancy
Photo coordinates	0.68	71704	39983.10
Coordinates of control points	0.67	293	240.40
Control points in X	0.61	97	85.31
Control points in Y	0.79	97	85.95
Control points in Z	0.58	99	69.14
Photo positions and orientations	0.75	2406	2303.96
Photo orientation in phi	1.06	802	750.71
Photo orientation in omega	0.76	802	752.25
Photo orientation in kappa	0.00	802	801.00
Exterior orientations incl. GPS	0.80	2406	1983.54
Sum of all observations	0.69	76809	

Control Point Notes.

Targeted control. Two targets were disturbed and had to be converted to vertical only points (3ck2 and 109).

Additional blind points were included by the end client as independent check points. Initial "drive-to-coordinates" did not include any Z-value but all points were found without any difficulty.

Image Notes.

Scanned by Wilson & Company on a Vexcel scanner. IOs had larger residuals than normal but OK. Three images had to be rescanned as they were obviously defective.

AGPS Notes.

File 1: antenna.dat

GPS position read for 802 photos
802 design matrix elements read or created
*** W224 Vector ex and delta for camera 1 missing. Zero substituted.

Instrumentation and procedures.

All compilation was performed using the Intergraph (Z/I Imaging) ISAT (ImageStation Digital Mensuration) software product. See http://www.remsy.com/photogrammetry for more details on the exact procedures used for collection and adjustment.

--Intermediate results prior to adding final BLIND POINT values-

Adjustment Summary with all points as control (all units in feet or gons).

RMS control point residuals: 0.194 0.237 0.215 ft
Maximum control point residuals: 0.600 0.728 0.605

RMS GPS residuals: 0.157 0.307 0.118
Maximum GPS residuals: 0.829 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Residuals of independent check points (from individual runs)

Point No.	X	Y	Z	V X	V Y	V Z
105	378587.929	926501.593	1283.888	0.055	0.021	-0.550
106	410167.052	925511.344	1206.601	-0.206	0.263	0.109
108	394235.087	914084.501	1132.626	-0.019	0.167	-0.011
111	409960.187	897895.820	1067.703	-0.106	0.110	-0.181
116	400347.135	855672.976	898.890	0.026	-0.149	0.073
119	401655.490	840781.543	861.468	-0.091	-0.044	0.219

Residuals of independent check points (from the bulk grouping)

Point No.	X	Y	Z	V X	V Y	V Z

105	378587.929	926501.593	1283.888	0.034	0.039	-0.555
106	410167.052	925511.344	1206.601	-0.207	0.273	0.078
108	394235.087	914084.501	1132.626	-0.032	0.178	-0.038
111	409960.187	897895.820	1067.703	-0.111	0.120	-0.184
116	400347.135	855672.976	898.890	0.017	-0.142	0.081
119	401655.490	840781.543	861.468	-0.091	-0.044	0.221

RMS values of check point residuals 0.105 0.155 0.260

The following shows the adjustment differences with check points.
Using 105, 106, 108, 111, 116, and 119 as check as directed.

All 6 points:

RMS control point residuals: 0.205 0.251 0.226
Maximum control point residuals: 0.585 0.718 0.632

RMS GPS residuals: 0.157 0.307 0.119
Maximum GPS residuals: 0.828 1.188 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0606 0.0334
(Computed from real residuals)

Difference statistics of all photo stations and ground points:

*	Mean	0.012	-0.012	0.015
*	RMS	0.013	0.016	0.029
*	Max	0.038	0.035	0.103

Point 105

RMS control point residuals: 0.197 0.240 0.214
Maximum control point residuals: 0.600 0.726 0.634

RMS GPS residuals: 0.157 0.307 0.119
Maximum GPS residuals: 0.829 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	-0.001	-0.001	0.018
*	RMS	0.002	0.002	0.025
*	Max	0.018	0.016	0.098

Point 106

RMS control point residuals: 0.192 0.238 0.217
Maximum control point residuals: 0.593 0.726 0.605

RMS GPS residuals: 0.157 0.307 0.118
Maximum GPS residuals: 0.829 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	0.006	-0.007	-0.003
*	RMS	0.008	0.008	0.004
*	Max	0.023	0.025	0.027

Point 108

RMS control point residuals: 0.196 0.239 0.217
Maximum control point residuals: 0.598 0.723 0.606

RMS GPS residuals: 0.157 0.307 0.118
Maximum GPS residuals: 0.829 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	0.001	-0.005	0.000
*	RMS	0.001	0.005	0.001
*	Max	0.003	0.012	0.003

Point 111

RMS control point residuals: 0.196 0.239 0.215
Maximum control point residuals: 0.597 0.726 0.606

RMS GPS residuals: 0.157 0.307 0.118
Maximum GPS residuals: 0.828 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	0.003	-0.003	0.005
*	RMS	0.003	0.003	0.006
*	Max	0.007	0.010	0.030

Point 116

RMS control point residuals: 0.196 0.239 0.218
Maximum control point residuals: 0.598 0.731 0.604

RMS GPS residuals: 0.157 0.307 0.118

Maximum GPS residuals: 0.829 1.187 0.565

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	-0.001	0.004	-0.002
*	RMS	0.002	0.005	0.002
*	Max	0.004	0.016	0.020

Point 119

RMS control point residuals: 0.197 0.239 0.217
Maximum control point residuals: 0.597 0.726 0.602

RMS GPS residuals: 0.157 0.307 0.118
Maximum GPS residuals: 0.829 1.187 0.564

RMS IMU residuals: 0.0082 0.0059 0.0115
Maximum IMU residuals: 0.0785 0.0607 0.0334

Difference statistics of all photo stations and ground points:

*	Mean	0.002	0.001	-0.006
*	RMS	0.003	0.002	0.010
*	Max	0.012	0.008	0.043

And here's what happens if almost all of the control are used as check points (7 full control and 1 vertical, CKP=Check). We have a few Z's over 1 ft but overall the results behave pretty well.

*
* Control point residuals for graphical output
*

*	<___Vx_Max__>	<___Vy_Max__>	<___Vz_Max__>	
VMAX	0.388	0.437	0.742	
*				
*<____Point_No__>	<_____Vx____>	<_____Vy____>	<_____Vz____>	Key
3ck2	0.504	-0.081	1.375	CKP
3AL4	-0.428	0.037	0.484	CKP
3BL2	-0.326	0.113	0.391	CKP
3CM1	-0.118	-0.121	0.776	CKP
4AM2	-0.376	0.142	0.010	CKP
4BL1	-0.406	0.018	0.208	CKP
4CM1	-0.563	-0.346	-0.471	CKP
4CO1	-0.312	-0.889	-1.386	CKP
4DL1	-0.478	0.305	-0.092	CKP
4DN1	-0.169	-0.214	-0.703	CKP
4FL2	-0.295	0.202	-0.151	CKP
4GK2	-0.333	0.434	0.250	CKP
101	-0.256	0.384	-0.080	CKP

102	-0.303	0.512	-0.178	CKP	
103	-0.076	0.601	-1.320	CKP	
105	-0.297	0.066	-1.044	CKP	
106	-0.491	0.391	-0.013	CKP	
107	-0.251	-0.513	-0.909	CKP	
111	-0.317	0.191	-0.101	CKP	
112	-0.171	0.283	-0.402	CKP	
113	-0.317	0.026	0.166	CKP	
114	0.080	0.267	0.405	CKP	
115	-0.169	-0.239	0.202	CKP	
117	0.251	-0.254	1.037	CKP	
118	-0.110	-0.341	0.002	CKP	
119	-0.143	-0.090	0.583	CKP	
122	-0.230	0.054	0.741	CKP	
4EM2	-0.236	0.383	-0.469	CKP	
4EO2	-0.165	-0.613	-0.910	CKP	
old13	-0.484	0.183	0.006	CKP	
old18	-0.468	0.403	0.267	CKP	
old22	-0.588	0.087	0.148	CKP	
old25	-0.088	0.181	0.158	CKP	
old28	0.031	0.059	0.382	CKP	
old32	-0.213	0.046	0.832	CKP	
100	0.092	0.168	0.164	XYZ	
104	0.111	-0.437	-0.458	XYZ	**
108	-0.291	0.218	-0.216	XYZ	
109	0.000	0.000	-0.742	Z	***
110	0.388	0.278	-0.042	XYZ	*
116	-0.069	-0.156	0.248	XYZ	
120	-0.081	0.124	0.682	XYZ	***
121	-0.149	-0.194	0.363	XYZ	*

Here are the Blind Point coordinates:

CORD	PP100	420684.743	954536.413	1488.405	0.107	0.102	0.156	+5
CORD	PP101	404072.074	948904.789	1443.141	0.112	0.131	0.217	2
CORD	PP102	412527.011	942011.203	1319.957	0.069	0.069	0.101	+6
CORD	PP103	399737.165	941980.355	1339.115	0.077	0.077	0.129	3
CORD	PP104	387233.610	941281.303	1397.359	0.078	0.079	0.111	+5
CORD	PP105	379616.569	937419.009	1389.329	0.074	0.073	0.100	+6
CORD	PP106	360856.557	932637.501	1424.759	0.137	0.128	0.237	2
CORD	PP107	371237.173	931423.142	1360.148	0.073	0.073	0.108	+5
CORD	PP108	385518.032	931313.024	1295.934	0.076	0.073	0.127	3
CORD	PP109	399817.199	931929.067	1241.581	0.079	0.079	0.213	2
CORD	PP110	410910.680	931853.185	1244.951	0.082	0.083	0.225	2
CORD	PP111	422392.257	931347.998	1279.912	0.088	0.089	0.151	3
CORD	PP112	418115.796	922143.753	1207.920	0.079	0.078	0.137	3
CORD	PP113	402059.762	921775.984	1171.409	0.062	0.061	0.093	+6
CORD	PP114	391974.455	921814.147	1185.682	0.070	0.071	0.131	3
CORD	PP115	377009.534	921457.938	1254.133	0.082	0.081	0.222	2
CORD	PP116	360718.112	921735.031	1320.457	0.076	0.073	0.117	+5
CORD	PP117	356167.826	924441.912	1358.337	0.134	0.106	0.177	3

CORD	PP118	357928.091	912250.294	1248.681	0.091	0.093	0.159	3
CORD	PP119	371482.212	914813.406	1227.058	0.067	0.067	0.112	+4
CORD	PP120	383291.405	910976.492	1155.571	0.060	0.060	0.095	+5
CORD	PP121	395912.284	911260.212	1114.451	0.068	0.068	0.130	3
CORD	PP122	407412.396	911509.969	1130.296	0.067	0.067	0.128	3
CORD	PP123	418108.406	914436.015	1164.461	0.093	0.090	0.223	2
CORD	PP124	368210.717	908877.369	1199.433	0.064	0.064	0.105	+5
CORD	PP125	361634.799	899597.413	1247.409	0.080	0.080	0.141	3
CORD	PP126	376124.383	900980.401	1133.459	0.060	0.060	0.096	+6
CORD	PP127	391523.843	900104.673	1073.449	0.069	0.067	0.122	3
CORD	PP128	407356.081	900440.617	1074.799	0.065	0.065	0.118	3
CORD	PP129	416930.307	889560.853	1041.215	0.065	0.062	0.093	+6
CORD	PP130	402444.026	889619.722	1021.030	0.062	0.060	0.099	+4
CORD	PP131	393348.349	890260.640	1035.183	0.071	0.076	0.144	+4
CORD	PP132	383504.937	892918.433	1111.758	0.073	0.074	0.119	+4
CORD	PP133	366040.139	894090.160	1265.222	0.078	0.078	0.140	3
CORD	PP134	390570.391	880765.359	1073.861	0.098	0.080	0.137	3
CORD	PP135	404878.689	876867.527	963.113	0.076	0.068	0.130	3
CORD	PP136	419105.208	878609.936	996.480	0.082	0.082	0.136	3
CORD	PP138	413344.834	868885.746	944.525	0.067	0.067	0.106	+4
CORD	PP139	405099.067	868946.264	934.047	0.061	0.061	0.094	+5
CORD	PP140	394027.594	868203.342	998.495	0.057	0.056	0.081	+9
CORD	PP141	417255.877	860761.949	922.796	0.073	0.070	0.101	+6
CORD	PP142	406914.196	860045.695	918.636	0.072	0.072	0.129	3
CORD	PP143	400379.050	861326.314	915.664	0.082	0.079	0.213	2
CORD	PP144	389950.582	860931.508	951.424	0.069	0.068	0.105	+4
CORD	PP145	384617.680	853129.816	924.549	0.087	0.087	0.143	3
CORD	PP146	394723.147	853099.221	908.165	0.065	0.064	0.094	+6
CORD	PP147	406300.929	852239.680	893.134	0.103	0.082	0.222	2
CORD	PP148	416175.025	852826.825	892.780	0.071	0.069	0.100	+6
CORD	PP149	421733.674	844580.933	845.944	0.099	0.088	0.220	2
CORD	PP150	411104.211	843044.731	847.935	0.077	0.077	0.135	3
CORD	PP151	400323.241	847115.407	868.718	0.076	0.075	0.134	3
CORD	PP152	389769.753	842797.690	904.376	0.073	0.072	0.105	+5
CORD	PP153	385853.971	834411.378	957.517	0.088	0.085	0.119	+5
CORD	PP154	398284.533	834404.190	900.302	0.076	0.078	0.107	+6
CORD	PP155	411072.205	834338.226	838.421	0.085	0.085	0.144	3
CORD	PP156	422794.225	834903.785	804.086	0.091	0.090	0.141	3