MEMORANDUM FOR Executive Working Group

FROM: Tri-Service CADD/GIS Technology Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

SUBJECT: Utilization of Remote Sensing Imagery for Installation Planning and Engineering Applications

1. The use of Remote Sensing Imagery (RSI) for Tri-Service installations was investigated in fulfillment of c
- Standards Manual for Remote Sensing (Satellite Imagery) Mapping. The Tri-Service CADD/GIS Technolc
funded to investigate the feasibility of using satellite imagery in lieu of aerial photography to develop maps t
and comprehensive planning needs.

2. A literature review concerning commercially available Remote Sensing Imagery (RSI) was conducted dur
January through 10 March 1998 to determine the capabilities of commercially available RSI in lieu of aerial p
Interviews with industry leaders and government agencies were also conducted during this time period to asc
of RSI as it applies to installation mapping needs. The overall consensus is that RSI does not have the capat
engineering demands for installation mapping nor will that capability exist in the near future.

3. It is recommended that this project is cancelled and the funds ($40K) for this project are reallocated for us
recommended that these funds be directed to the completion of the GIS Implementation Guide, which has no
high demand exists for a document that will provide potential GIS users a step-by-step guide through the imp
This will eventually save time, money, and resources throughout the DoD community.

1 Attachment
White Paper

BRYAN L. PERDUE
Tri-Service CADD/GIS
Technology Center

Utilization of Satellite Imagery in Lieu of Aerial Photography for Engineering and Comprehensive Planning Applications

A White Paper

By

Bryan L. Perdue
20 April 1998

INTRODUCTION

The use of Remote Sensing Imagery (RSI) for Tri-Service installations was investigated in fulfillment of cer
Standards Manual for Remote Sensing (Satellite Imagery) Mapping. The Tri-Service CADD/GIS Technolog
funded to investigate the feasibility of using satellite imagery in lieu of aerial photography to develop maps t
and comprehensive planning needs.

A literature review concerning commercially available Remote Sensing Imagery (RSI) was conducted during
through 10 March 1998 to determine the capabilities of commercially available RSI in lieu of aerial photogra
industry leaders and government agencies were also conducted during this time period to ascertain the capat
applies to installation mapping needs. The overall consensus is that RSI does not have the capability to meet
demands for installation mapping nor will that capability exist in the near future.

BACKGROUND

The submitted proposal (TSC #98-155) requested a study be conducted to:

1. *Identify the current minimum mapping standards being used by the Department of Defense.*
2. *Validate accuracy requirements.*
3. *Investigate RSI technology and methodologies, and apply established standards.*
4. *Establish minimum standards for remote sensing maps.*
5. *Develop a template "**Statement of Work**" for installation use.*

The ***justification*** used to support the proposal states that:

> *"Currently military bases are required to map their installations using aerial photography. This is due t*
> *maps that are accurate to within 1/40th of an inch in the horizontal plane. Until recently, commercially*
> *sensing did not meet these accuracy standards. Now that 1-2 meter resolution remote sensing imagery i*
> *available, the government may be able to cut the cost of this required mapping in half. The use of remot*
> *the pre-aerial photography ground control setup cost and all film processing costs*".

FINDINGS

This paper addresses the five requests stated in TSC #98-155.

a. The first request stipulates: *identify the current minimum mapping standard being used by the Departmen*

Research indicates that the Department of Defense (DoD) has not adopted a specific standard of its own. In separate standard DoD uses the guidance contained in the Office of Management and Budget (OMB Circula ***Participation in the Development and Use of Voluntary Standards***. This circular prescribes that federal ag use of industry standards. "Specifications for surveying and mapping shall use industry consensus standards national professional organizations such as The American Society of Photogrammetry and Remote Sensing (are several professional groups that have established "industry" standards. The Army Corps of Engineers ha ASPRS standards for large scale mapping (mapping needs for areas under 10,000 acres) and through agreeme Department of the Army and the Department of the Air Force follow suit on this adoption. The Department c adopted any specific standards. However, the Federa Committee (FDGC) draft report on "Geospatial Positi Standards - Part 4" does recommend adoption of the Large Scale Mapping (Table 1 and Table 2) and, whe establishes the ***standard*** for all government agencies. ASPRS Standards.

ASPRS Limiting RMSE in X or Y				
Target Map Scale 1"= x ft	Ratio ft/ft	(Feet) Class 1	Class 2	Class 3
5	1:60	0.05	0.1	0.15
10	1:120	0.10	0.2	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1.667	1:20.000	16.7	33.3	50.0

Table 1 ASPRS Planimetric (Horizontal) Feature Coordinate Accuracy Standard (X or Y in feet) for Well-Defined Points

ASPRS Limiting RMSE in X or Y			
Target Contour Interval ft	Topographic Feature Points Class 1	Class 2	Class 3
0.5	0.17	0.33	0.50
1.0	0.33	0.66	1.00
2.0	0.67	1.33	2.00
4.0	1.33	2.67	4.00
5.0	1.67	3.33	5.00

b. The second request is to *validate accuracy requirements.* Horizontal accuracy requirements are establishe
Horizontal (planimetric) Standards for Large Scale Mapping (Table 1) and the ASPRS Vertical (Topographic
establish vertical accuracy requirements for Large Scale Mapping. These limits of accuracy pertain to well-d
points only. Horizontal spatial accuracy is defined as the circular error of a data set's horizontal coordinates a
level. As depicted in Figure 1, using second order survey ground control marks, the probability distribution
using a 1:24,000 (1"=2,000') scale map.

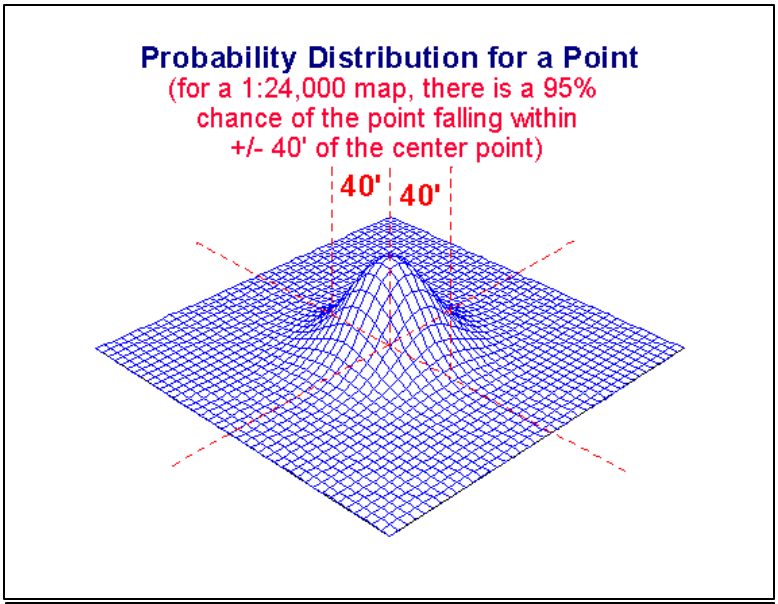

Figure 1: Probability Distribution for a Point (95% Confidence)

Vertical spatial accuracy is defined by the linear error of a data set's vertical coordinates at the 95% confidenc
Figure 2, using second order survey ground control markers, the probability distribution for a line is +/- 40' u
(1"=2,000') scale map.

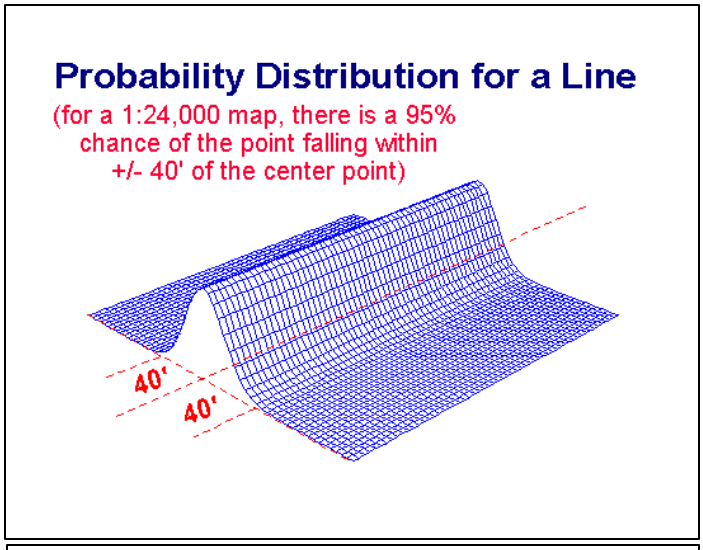

Figure 2: Probability Distribution for a Line (95% Confidence)

Basically this means, that when we see a point (feature) on a map we know we have the "probable" location in the above examples within 40 feet. Caution must be exercised here; we must remain cognizant of the dang -that is reading locational information from map levels of accuracy beyond which they we created. This is in systems that allow the user to pan and zoom at will to an infinite number of scales. Accuracy is tied to the o does not change even if the user zooms in and out. Zooming in and out can mislead the user into the false be has improved. See Figure 3.

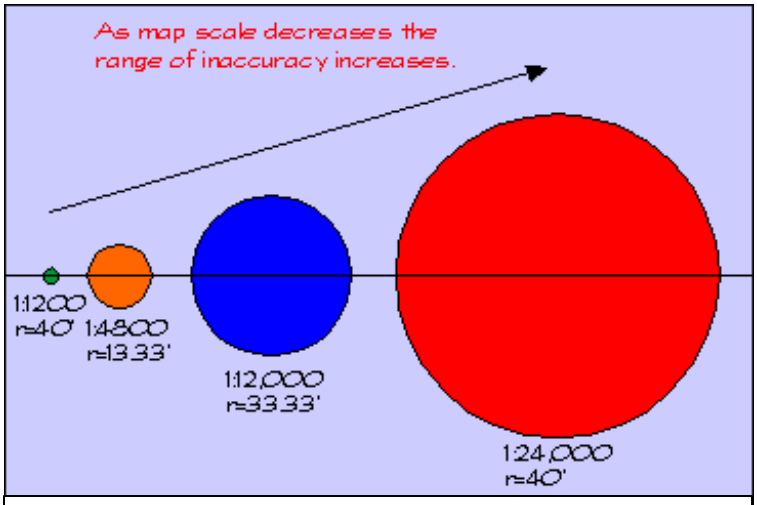

Figure 3: Map Accuracy vs Map Scale

Accuracy reported at the 95% confidence level means that 95% of positional accuracy would be equal to or s reported accuracy value. The reported accuracy value is the cumulative result of all uncertainties, including local project control coordinates, field topographic surveys, photogrammetric compilation, or final extraction values in the spatial data. The reference scheme for radial or linear errors must be defined as relative to abso reference networks or local (internal construction) schemes. Spatial data may be compiled to comply with or

the vertical component and another in the horizontal component. In both cases, establishing well-defined gro necessary to develop the horizontal and vertical accuracy needed by military installations.

These are considered valid accuracy standards for both the civilian and military agencies.

c. The third request is to *investigate RSI technology and methodologies, and apply established standards.* T using space-borne platform in lieu of aerial photography to produce ***accurate*** installation maps. The literatur mapping at 1:2,400 (1"=400') is feasible using remotely sensed satellite imagery. Mapping scales down to feasible with aerial photography. Since the requirement for engineering functions (utilities) remains at 1:60(Force and 1:100 for the Army and (construction) remains at 1:240 (1'=20') then by default we recognize that imagery cannot be used in lieu of aerial photography. To establish the necessary accuracy the base map mus highest required tolerance or the greatest accuracy needed or a 1:240 map scale. Accuracy greater than this n ground methods. It is recommended that the installation map be produced using a scale of 1:600 (1"=50) usi and subsequent imagery can be obtained using satellite imagery.

It is essential that mapping and surveying specifications originate from the functional requirements of the pro requirements are realistic and economical. Specifying mapping accuracies in excess of those needed to acco results in increased costs. See Appendix B for general guidance for typical projects - extracted from the Geo Accuracy Standards, Part 4: Standards for A/E/C and Facility Management.

In order to ensure mapping accuracy, satellite images must have ground control points (marked in advance) ju aerial photography. The assumption that ground control is not necessary for satellite imagery is false. Grou the accuracy of the final mapping product and facilitates the photogrammetry process.

d. The fourth request is to *establish minimum standards for remote sensing maps.* Again, these standards ha industry. Those adopted by the Departments of the Air Force and Army are from the American Society of P Remote Sensing (ASPRS).

e. The last request is to *develop a template "**Statement of Work**" for installation use.* A template SOW is pr TSSDS and in the Tri-Service guide "Geographical Information Systems Implementation Guide"

CONCLUSIONS

Satellite based remote sensing imagery has not evolved to the point where it meets the needs of military com
development, utilities management, construction projects, or installation master/comprehensive planning. Pla
installation level requires vectorized maps with scales of 1:600 (1"=50') for utility planning and 1:240 (1"=20
There must be sufficient resolution for a planner to determine the location of a feature within acceptable accu
example, 125 feet from edge of a flight line apron to a fixed or mobile object, or 200 feet from center of taxi
object. That level of sophistication is not present in todays commercially available satellite technology.

Remote sensing imagery is appropriate for small-scale (large area) applications e.g., identifying wetland area
land use categorization, change over time etc. These are broad applications where pinpoint accuracy isn't ne
case care should be taken to ensure that redundant imagery--satellite imagery and aerial photography--is not
doesn't mean that satellite imagery is redundant. There is an appropriate time and place for this technology e
environmental change over time, tracking wetland vegetation, vegetation growth, and vegetation health and
concerns.

Until remote sensing industry advances its capabilities, then this technology will not meet the needs of the in
their Master/Comprehensive Planning effort.

BIBLIOGRAPHY

Antenucci, John et.al., 1991. Geographic Information Systems: A Guide to the Technology. Van Nostrand

Avery, Thomas E., Berlin, Graydon L., 1992. Fundamentals of Remote Sensing and Airphoto Interpretation. Publishing Company, New York

Corbley, Kevin P., 1997. Untitled. Advanced copy of article for Government Technology (Oct 97 Issue).

Department of the Army, 1996. *Engineering and Design Standards for Maps, Drawings, Engineering Surve Plans, and Related Geospatial Data Products, EC 1110-87.*

_____, 1996. *Engineering and Design: Geospatial Data and Systems.*

_____, 1997. *Guidelines for the Use of Remotely Sensed Data*, US Army Engineer Waterways Exp Vicksburg, MS

Federal Geographic Data Committee, 1998. *Geospatial Positioning Accuracy Standards. Part 4: Standards Engineering, Construction (A/E/C) and Facility Management*. Public Review Draft.

Foote, Kenneth E and Huebner, Donald J., 1996. The Geographers Craft Project, Department of Geogrphy, U Austin. *Managing Error.*

Holliman, John, 1998. *The view from space, all it takes is time and money.* CNN Interactive News.

Kennie, T., Mathews, M., 1985. Remote Sensing in Civil Engineering. John Wiley and Sons, New York.

Kish, Jon et.al.,, 1997. *Guidelines for the Use of Remotely Sensed Data: Management of Natural and Cultu Image Processing, CDD, and GIS Technology.*

NASA, 1998. The Remote Sensing Tutorial. Goddard Space Flight Center, Applied Information Sciences B

National Center for Geographic Information analysis (NCGIA), 1998. Maps and Maps Analysis.

_____, 1998. The Raster GIS

_____, 1998. Raster GIS Capabilities
_____, 1998. Vector GIS Capabilities

_____, 1998. Digital Elevation Models

_____, 1998. Urban Planning and Management Applications

Perdue, Bryan L., 1994. Class Notes - Introduction to Remotely Sensed Imagery, Defense Mapping School,

Stafford, Donald B., 1991. Civil Engineering Applications of Remote Sensing and Geographic Information S
Society of Civil Engineers.

Virtual Geography Department, 1998. Remote Sensing Tutorial.

INTERVIEWS (Personal Communications):

Huffman, Mike. Research System Inc., Remote Sensing and Imaging, Boulder. CO

LaDue, Denise. Cartographer, Topological Engineering Center, Alexandria, VA

Maguire, James. Woolpert Inc., Federal Planning Division, Dayton, OH

McVey, Kelly. Environmental Institute of Michigan, Information Analysis Center, Yipsilanti, MI

Ramage, Laura. ERDAS Inc., Greenville, SC

Ramseur, Lt. Col. Battlespace Surveillance and Operations Division: Geo-information Requirements and Pol

Reed, Larry. Environmental Research Institute of Michigan, Information Analysis Center. Yipsilanti, MI.

Zumwalt, Joseph F. Woolpert Inc., Photogrammetry and Remote Sensing Division, Dayton, OH

Appendix A. American Society of Photogrammetry and Remote Sensing Accuracy Standards for

Table A-1: ASPRS Coordinate Accuracy Standard (X or Y in feet) for Well-Defined Points--RMSE

Target Map Scale		ASPRS Limiting RMSE in X or Y (Feet)		
1" = x ft	Ratio ft/ft	Class 1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1,667	1:20,000	16.7	33.3	50.0

Table A-2: ASPRS Coordinate Accuracy Standard (X or Y in feet) for Well-Defined Points--95% C

Target Map Scale		ASPRS Radial Accuracy 95% Confidence Level (feeet)
1" = x	Ratio ft/ft	ASPRS Class 1
5	1:60	0.12
10	1:120	0.25
20	1:240	0.50
30	1:360	0.7

40	1:480	1.0
50	1:600	1.2
60	1:720	1.5
100	1:1,200	2.5
200	1:2,400	4.9
400	1:4,800	9.8
500	1:6,000	12.
800	1:9,600	20
1,000	1:12,000	25
1,667	1:20,000	40

Table A-3b: ASPRS Topographic Elevation Accuracy for Well-defined Points (Feet)--RMSE

	ASPRS Limiting RMSE in Feet					
				Spot or Digital Terrain Model		
Target Contour Interval	Topographic Feature Points			Elevation Points		
ft	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5

Table A-4b: ASPRS Topographic Elevation Accuracy for Well-Defined Points (Feet)--95% Confidenc

ASPRS Linear Error in Meters (95% Confidence)		
		Spot or Digital
Target Contour Interval ft	Topographic Feature Points	Terrain Model Elevation Points
	ASPRS Class 1	
0.5	0.33	0.16
1	0.65	0.33
2	1.3	0.6
4	2.6	1.3
5	3.3	1.6

Appendix B. Recommended Surveying and Mapping Specifications for Military Construction, Civ
Maintenance, Real Estate, and HTRW Projects

Appendix B. Recommended Surveying and Mapping Specifications for Military Construction, Civil Works, Ope Real Estate, and HTRW Projects

Project or Activity	Equivalent Target (Plot) Map Scale[1] SI Ratio/ 1 in. = x ft	Feature Location Tolerance[2] mm/ft (RMS)	Horiz Control Survey type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)
MILITARY CONSTRUCTION (MCA, MCAF, OMA, OMAF):				
Design and Construction of New Facilities:				
Site Plan Data for Direct Input into CADD 2-D/3-D Design Files	1:500/40ft	100mm/0.1-0.5ft	3rd-I	50mm/0.1-0.3ft
General Construction Site Plan Feature and Topo Detail	1:500/40ft	100mm/0.2-0.5ft	3rd-I	50mm/0.1-0.2ft
Surface/Subsurface Utility Detail	1:500/40ft	25mm/0.05-0.2ft	3rd-I	50mm/0.1-0.3ft
Building or Structure Design	1:500/30-100ft	25mm/0.05-0.1ft	3rd-I/II	25mm/0.05-0.1ft
Airfield Pavement Design Detail		250mm/0.5-2ft		100mm/0.2-1ft
Grading and Excavation Plans (Roads, Drainage, etc.)				
Maintenance and Repair (M&R), or Renovation of Existing Structures, Roadways, Utilities, etc., for Design/Construction/Plans and Specifications (P&S)	1:500/30-50ft	100mm/0.1-0.5ft	3rd-I	50mm/0.1-0.5ft

Recreational Site P&S (Golf Courses, Athletic Fields, etc.)	1:1000/100ft	500mm/1-2ft	3rd-II	100mm/0.2-2ft
Training Sites, Ranges, Cantonment Areas, etc.	1:2500/100-200ft	500mm/1-5ft	3rd-II	1 000mm/1-5ft
Installation Master Planning and Facilities Management				
Activities (Including AM/FM and GIS Feature Applications)	1:5000/100-400ft	1 000mm/2-10ft	3rd-II	1 000mm/1-10ft
General Location Maps for Master Planning Purposes	1:250/10-50ft	50mm/0.05-1ft	Relative to Structure	N/A
Space Management (Interior Design/Layout)				
Installation Surface/Subsurface Utility Maps (As-builts; Fuel, Gas, Electricity, Communications, Cable, Storm Water, Sanitary, Water Supply, Treatment Facilities, Meters, etc.)	1:1000/50-100ft (DA) 1:500/50ft (USAF)	100mm/0.2-1ft	3rd-I	100mm/0.2ft

(Continued)

Appendix B. (Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] SI Ratio	Feature Location Tolerance[2] mm/ft (RMS)	Horiz Control Survey Type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)	V l C l S T
MILITARY CONSTRUCTION (CONTINUED)					
Architectural Drawings:	**Equivalent**				
Customary Inch-Pound Scale	**SI Ratio**	**N/A**	**N/A**	**N/A**	**N**
Site Plans:					
1 in = 20 ' (Landscape Planting Plans)	1:250				
	1:500				
1 in = 50 '	1:50				
Floor Plans: 1/4 in = 1' - 0"	1:100				
1/8 in = 1' - 0"	1:200				
1/16 in = 1' - 0"	1:200				
Roof Plan: (no smaller than) 1/16" = 1' - 0"					
Exterior Elevations:	1:10				
1" or 1-1/2" = 1' - 0"	1:100				
1/8" = 1' - 0"	1:200				
1/16" = 1' - 0"					
Interior Elevations:	1:50				
1/4" = 1' - 0"	1:100				
1/8" = 1' - 0"	1:50				
Cross Sections: 1/4" = 1' - 0"	1:100				
1/8" = 1' - 0"	1:50				
1/16" = 1' - 0"	1:20				
Wall Sections: 1/2" or 3/4" = 1' - 0"					

		1:10
Stair Details:	1" or 1-1/2" = 1' - 0"	1:5
Detail Plans:	3" = 1' - 0"	1:10
	1" or 1-1/2" = 1' - 0"	

(Continued)

Appendix B. (Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] SI Ratio/ 1 in. = x ft	Feature Location Tolerance[2] mm/ft (RMS)	Horiz Control Survey Type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)	V I C I S T
MILITARY CONSTRUCTION (CONTINUED)					
Area-/Installation-/Base-Wide Mapping Control Network to Support Overall GIS and AM/FM Development[5]	N/A	varies	3rd-I or 2nd-II	varies	2 3
Housing Management (Family housing, Schools, Boundaries, and Other Installation Community Services)	1:5000/100-400ft	10 000mm/ 10-50ft	4th	N/A	4
Environmental Mapping and Assessments	1:5000/200-400ft	10 000mm/ 10-50ft	4th	N/A	4
Emergency Services (Military Police, Crime/Accident Locations, Emergency Transport Routes, Post Security Zoning, etc.)	1:10000/400-2000ft	25 000mm/ 50-100ft	4th	N/A	4
Cultural, Social, Historical (Other Natural Resources)	1:5000/400ft	10 000mm/ 20-100ft	4th	N/A	4
Runway Approach and Transition Zones; General Plans/Section[6]	1:2500/100-200ft	2 500mm/ 5-10ft	3rd-II	2 500mm/2-5ft	3
CIVIL WORKS DESIGN, CONSTRUCTION, OPERATIONS AND MAINTENANCE ACTIVITIES					
Site Plan for Design Memoranda, Contract Plans and Specifications, etc. C for Input to CADD 2-D/3-D Design Files	1:500/20-50ft	25mm/0.05-1ft	2nd-II	10mm/0.01-0.5ft	2 d
Locks, Dams, Flood Control Structures; Detail Design Plans	1:1000/100ft	1 000mm/0.5-2ft	3rd-I	100mm/0.2-1ft	3
Grading/Excavation Plans	1:1000/50-100ft		2nd-II		3

Spillways, Concrete Channels, Upland Disposal Areas	1:1000/40-100ft	100 mm/0.1-2ft	3rd-I	100mm/0.2-2ft	3
Construction In-place Volume Measurement		500mm/0.5-2ft		250mm/0.5-1ft	

(Continued)

Appendix B. (Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] SI Ratio/ 1 in. = x ft	Feature Location Tolerance[2] mm/ft (RMS)	Horix Control Survey Type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)	V I C I S T
CIVIL WORKS (CONTINUED)					
River and Harbor Navigation Projects: Site Plans, Design, Operation, or Maintenance of Flood Control Structures, Canals, Channels, etc. C for Contract Plans or Reports					
Levees and Groins (New Work or Maintenance Design Drawings)	1:1000/100ft	500mm/1-2ft	3rd-II	250mm/0.5-1ft	3
Canals and Waterway Dredging (New Work Base Mapping)[7]	1:1000/100ft	1 000mm/2ft	3rd-II	250mm/0.5ft	3
Canals and Waterway Dredging (Maintenance Drawings)	1:2500/200ft	1 000mm/2ft	3rd-II	250mm/0.5ft	3
Beach Renourishment/Hurricane Protection Projects	1:1000/100-200ft	1 000mm/2ft	3rd-II	250mm/0.5-1ft	3
Project Condition Reports (Base Mapping for Plotting	1:2500/ 200-1,000ft	10 000mm/ 5-50ft	3rd-II	250mm/0.5-1ft	3
Hydrographic Surveys: line maps or air photo plans)	1:5000/100-400ft	2 500mm/2-10ft	3rd-II	250mm/0.5-1ft	3
Revetment Clearing, Grading, and As-built Protection					
Geotechnical and Hydrographic Site Investigation Surveying Accuracies for Project Construction					
Hydrographic Contract Payment and P&S Surveys	1:2500/200ft	2 000mm/6ft (2DRMS)	N/A	250mm/0.5ft	N
Hydrographic Project Condition Surveys	1:2500/200ft	5 000mm/16ft (2DRMS)	N/A	500mm/1.0ft	N
Hydrographic Reconnaissance Surveys	X	0.15km/500ft	N/A	500mm/1.5ft	N

Geotechnical Investigative Core Borings/Probings/etc.	X	(2DRMS) 5 000mm/5-15ft	4th	50mm/0.1-0.5ft	3 4
General Planning and Feasibility Studies, Reconnaissance Reports, Permit Applications, etc.	1:2500/100-400ft	1 000mm/2-10ft	3rd-II	500mm/0.5-2ft	3
GIS Feature Mapping--Civil Works Projects					
Area/Project-Wide Mapping Control Network to Support	N/A	Varies 1:5000	2nd-I or 2nd-II	Varies	2
Overall GIS Development	1:5000/400ft	10 000mm/20-100ft	4th	N/A	4
Soil and Geologic Classification Maps, Well Points					

(Continued)

Appendix B. (Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] SI Ratio/ 1 in. = x ft	Feature Location Tolerance[2] mm/ft (RMS)	Horiz Control Survey Type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)	V I C I S T
CIVIL WORKS--GIS Feature Mapping (CONTD)					
Cultural and Economic Resources, Historic Preservation	1:10000/1,000ft	10 000mm/ 50-100ft	4th	N/A	4
Land Utilization GIS Classifications; Regulatory Permit	1:5000/400-1,000ft	10 000mm/ 50-100ft	4th	N/A	4
General Locations		20 000mm/100ft	4th	N/A	4
Socio-economic GIS classifications	1:10,000/1,000 ft		4th	N/A	4
Land Cover Classification Maps	1:5000/400-1,000ft	10 000mm/ 50-200ft			
Archeological or Structure Site Plans & Details (Including Non-topographic, Close Range, Photogrammetric Mapping)	1:10/0.5-10ft	5mm/0.01-0.5ft	2nd I/II	5mm/0.01-0.5fft	2
Structural Deformation Monitoring Studies/Surveys[8]	Large-scale vector movement diagrams or tabulations	10mm/0.03ft (long term)	N/A[9]	2mm/0.01ft	N
Reinforced Concrete Structures (Locks, Dams, Gates, Intake Structures, Tunnels, Penstocks, Spillways, Bridges, etc.)		30mm/0.1ft (long term)	N/A	15mm/0.05ft	N
	tabulations	0.2mm/0.01inch	N/A	N/A	N
Earth/Rock Fill Structures (Dams, Floodwalls, Levees, etc.) (slope/crest stability & alignment)	1:5000/400-1,000ft	10 000mm/ 20-100ft	3rd-I	100mm/0.2-2ft	2 3
Crack/joint & deflection measurements (precision micrometer)	1:5000/400ft	10	3rd-I	250mm/0.5ft	3

Flood Control and Multipurpose Project Planning, Floodplain Mapping, Water Quality Analysis, and Flood Control Studies		000mm/20ft			
Federal Emergency Management Agency Flood Insurance Studies					
REAL ESTATE ACTIVITIES (ACQUISITION, DISPOSAL, MANAGEMENT,AUDIT)[10]					
Tract Maps, Individual, Detailing Installation or Reservation Boundaries, Lots, Parcels, Adjoining Parcels, and Record Plats, Utilities, etc.	1:1000/50-400ft[11]	10mm/0.05-2ft	3rd-I/II	100mm/0.1-2ft	3
Condemnation Exhibit Maps	1:1000/50-400ft	10mm/0.05-2ft	3rd-I/II	100mm/0.1-2ft	3

(Continued)

Appendix B. (Continued)

Project or Activity	Typical Target (Plot) Map Scale[1] SI Ratio 1 in. = x ft	Feature Location Tolerance[2] mm/ft (RMS)	Horiz Control Survey Type[3]	Feature Elevation Tolerance[4] mm/ft (RMS)	V I C I S T
REAL ESTATE (CONTINUED)					
Guide Taking Lines (for Fee and Easement Acquisition) **Boundary Encroachment Maps**	1:500/20-100ft	50mm/0.1-1ft	3rd-I/II	50mm/0.1-1ft	3
Real Estate GIS or LIS General Feature Mapping Land Utilization and Management Forestry Management Mineral Acquisition	1:5000/200-1,000ft	10 000mm/ 50-100ft	4th	N/A	4
General Location or Planning Maps	1:24,000 (USGS)	10 000mm/ 50-100ft	N/A	5 000mm/5-10ft	3
Easement Areas and Easement Delineation Lines	1:1000/100ft	50mm/0.1-0.5ft	3rd-I/II	50mm/0.1-0.5ft	3
HAZARDOUS, TOXIC, & RADIOACTIVE WASTE (HTRW) SITE INVESTIGATION, MODELING, AND CLEANUP					
General Detailed Site Plans (HTRW Sites, Asbestos, etc.)	1:500/5-50ft	100mm/0.2-1ft	2nd-II	50mm/0.1-0.5ft	2 3
Subsurface Geotoxic Data Mapping	1:500/20-100ft	1 000mm/1-	3rd-II	500mm/1-2ft	3

(Modeling)	1:500/20-100ft	5ft	3rd-II	500mm/1-5ft	3
Contaminated Ground Water Plume Mapping (Modeling)	1:2500/50 - 400	1 000mm/2-10ft	3rd-II	1 000mm/2-20ft	3
General HTRW Site Plans, Reconnaissance Mapping		5 000mm/2-20ft			

EMERGENCY OPERATION MANAGEMENT ACTIVITIES

(Use basic GIS data base requirements defined above)

---

1. Target map scale is that contained in CADD, GIS, and/or AM/FM layer, and/or to which ground topo or aerial photog specifications are developed. This scale may not always be compatible with the feature location/elevation tolerances r instances, design or real property features are located to a far greater relative accuracy than that which can be scaled scale, such as property corners, utility alignments, first-floor or invert elevations, etc. Coordinates/elevations for such i input into a CADD or AM/FM data base.

2. The map location tolerance (or precision) of a planimetric feature is defined relative to two adjacent points within the or map sheet, not to the overall project or installation boundaries. Relative accuracies are determined between two pc functionally maintain a given accuracy tolerance between themselves, such as adjacent property corners; adjacent util buildings, bridge piers, approaches, or abutments; overall building or structure site construction limits; runway

(Continued)

Appendix B. (Concluded)

ends; catch basins; levee baseline sections; etc. The tolerances betw een the tw o points are determined from the end of the project/structure (e.g., field construction/fabrication, field stakeout or layout, alignment, locationing, etc.).

3. CHorizontal and vertical control survey accuracy refers to the procedural and closure specifications needed to obta accuracy tolerances needed betw een tw o functionally adjacent points on the map or structure, for design, stakeout, or 1:5,000 Third-Order control procedures (horizontal and vertical) w ill provide sufficient accuracy for most engineering w instances of small-scale mapping or GIS rasters, Third-Order, Class II methods and Fourth-Order topo/construction co used. Base- or area-w ide mapping control procedures shall be specified to meet functional accuracy tolerances w ithin structure, building, or utility distance involved for design or construction surveys. Higher order control surveys shall not w ide mapping or GIS definition unless a definitive functional requirement exists (e.g., military operational targeting or s control projects).

4. (See note 2.) Some flood control projects may require better relative accuracy tolerances than those show n.

5. GIS raster or vector features generally can be scaled or digitized from any existing map of the installation. Typically 1:24,000 (1 in. = 2,000 ft) scale quadrangle map is adequate given the low relative accuracies needed betw een GIS da or classifications. Relative or absolute GPS positioning (1m to 100m) may be adequate to tie GIS features w here no m basic area- or installation-w ide Second- or Third-Order control netw ork is adequate for all subsequent engineering, con GIS, and/or AM/FM control.

6. Typical requirements for general approach maps are 1:50,000 (H) and 1:1,000 (V); detail maps at 1:5,000 (H) and 1

7. Table refers to base maps upon w hich subsurface hydrographic surveys are plotted, not to hydrographic survey co

8. Long-term structural movements measured from points external to the structure may be tabulated or plotted in eithe vector movement normal to a potential failure plane. Reference EM 1110-2-4300, EM 1110-2-1908, and EM 1110-1-10 pressure, seismic, and other precise structural deflection measurement methods w ithin/betw een structural members, r embankments, etc.

9. Accuracy standards and procedures for structural deformation surveys are contained in EM 1110-1-1004. Horizont deformation monitoring survey procedures are performed relative to a control netw ork established for the structure. Ti Geodetic Reference System or National Geodetic Vertical Datum of 1929 are not necessary other than for general refe only USACE Third-Order connection.

10. Real property surveys shall conform to local/state minimum technical standards and/or recognized practices, and law or code.

11. A 1:1,200 (1 in. = 100 ft) scale is recommended by ER 405-1-12. Smaller scales should be on even 30m (100-ft) i