Chapter 1
Introduction

1-1. Purpose

This manual presents procedural guidance, technical specifications, and quality control (QC) criteria for performing aerial photogrammetric mapping activities.

1-2. Applicability

This manual applies to all major subordinate commands, districts, and laboratories performing and/or contracting for aerial photography and photogrammetric mapping services in support of planning, engineering and design, construction, operation, maintenance, and/or regulation of civil works or military construction projects. This manual is also applicable to U.S. Army Corps of Engineers (USACE) functional areas having responsibility for environmental investigations and studies, archeological investigations, historical preservation studies, hazardous and toxic waste site restoration, structural deformation monitoring investigations, regulatory enforcement activities, and support to Army installation maintenance and repair programs and installation master planning functions. Waivers from applicability should be requested by written memorandum to Headquarters, USACE (ATTN: CECW-EE).

1-3. Distribution

Approved for public release, distribution is unlimited.

1-4. References

Required and related publications are listed in Appendix A.

1-5. Mandatory Requirements

The purpose of mandatory requirements is to assure that geospatial data developed from photogrammetric methods meet accuracy requirements and corporate direction for Geospatial data collection. . **Mandatory requirements pertaining to the guidance contained in a particular chapter are summarized at the end of each chapter**. No mandatory requirements are identified in the appendices. Instead, any mandatory requirements pertaining to information contained in Appendices A through G are cited in chapters which reference those appendices.

1-6. Scope

a. This manual provides standard procedures, minimum accuracy requirements, instrumentation and equipment requirements, product delivery requirements and QC criteria for photogrammetric mapping. This includes aerial photography and standard line mapping (topographic or planimetric) products, including digital spatial data for use in computer-aided design and drafting (CADD) systems and Geographic Information Systems (GIS). The manual is intended to be a primary reference specification for contracted photogrammetric services. It should be used as a guide in planning mapping requirements, developing contract specifications, and preparing cost estimates for all phases of aerial photography and photogrammetric mapping. It may also be used as general guidance in executing some phases of photogrammetric mapping with USACE hired-labor forces.

b. This manual is intended to cover primarily those large-scale (i.e., greater than 400 feet (ft) per inch (in.)) photogrammetric mapping products that support typical USACE construction projects. These products include detailed site plan (or planimetry) feature mapping, topographic (vertical terrain) mapping, air photo enlargement plan drawings, and orthophotography mapping. The manual focuses primarily on the preparation of design drawings and other documents associated with these products, including related contracted construction performance activities.

c. Computer Automated Drafting and Design (CADD) vs. Geographic Information System (GIS). Photogrammetric mapping data collection is generally a necessary but costly process. The decision regarding final formats (CADD vs GIS) of spatial data is not always clear cut. Organization, storage, manipulation, and updating of data in a CADD system are efficient and appropriate for many engineering and mapping purposes. The decision to move from CADD to GIS stems from the requirement or desire to spatially analyze the data. While analysis capabilities are becoming increasingly more desirable, GIS databases can be more expensive to develop than CADD data. A portion of the time and cost in photogrammetric map production is the final format of the data sets. Factors that may affect the decision regarding CADD vs GIS include:

(1) Immediate and future uses of the spatial data sets collected.

(2) Immediate and future data analysis requirements for spatial data sets.

(3) Costs and time for each format requested.

(4) Project cost sharing and ownership.

d. Every attempt should be made to collect spatial data sets in the formats that will provide the most use and utility. GIS formatting costs can be minimized if the Contractor is aware of the request at the time of initial data collection. Many engineering, planning, and environmental projects can make use of and may require GIS capability in spatial data analysis. When planning a photogrammetric mapping project, both CADD and GIS formats may be required. Collection of the spatial data in both CADD and GIS will provide for the most utility of the spatial data sets and should be the first recommendation.

1-7. Standards

The use of geospatial data standards is good (sharing data, reliable decsions, etc.)

a. Throughout the manual, photogrammetric mapping criteria standards are in specific terms and are normally summarized in tables. Guidance is in more general terms where methodologies are described in readily available references or survey instrumentation operating manuals. Where procedural guidance is otherwise unavailable, it is provided herein.

b. One of the most important types of standards critical to geospatial data exchange is a data content standard. Data content standards define and organize the data captured in a geospatial database. A data content standard provides a list of “real-world” objects (e.g., roads, buildings, trees, etc.) for a given area of interest, their semantic definitions, and a logical data model to organize and encode “instances” of geospaital phenomena in a geospatial database. The Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) is the USACE data content standard, and geospatial databases shall be developed using this standard. A mapping of features that USACE traditionally collects to the SDSFIE is included in Appendix B.

c. Geospatial metadata provide descriptive information in a standard format about geospatial data sets. Metadata describe the content, quality, fitness for use, access instructions, and other characteristics about the geospatial data. Geospatial metadata increase the longevity of geospatial data by maximizing the its use. All

USACE photogrammetric mapping projects shall include metadata fully compliant with the "Content Standard for Digital Geospatial Metadata (CSDGM)," FGDC-STD-007-1998. The USACE guidance on implementing FGDC-STD-007-1998 can be found in EM 1110-1-2909. A sample metadata file for photogrammetric mapping data is presented in Appendix E of this manual.

d. Accuracy specifications, procedural criteria, product delivery requirements, and QC requirements contained in this manual shall be directly referenced in the scopes of work for Architect-Engineer (A-E) survey services or other third-party survey services. This is intended to ensure that uniform and standardized procedures are followed by contract service sources throughout USACE. The "American Society for Photogrammetry and Remote Sensing (ASPRS) Standards for Large-Scale Mapping" (ASPRS 1990) and the Federal Geographic Data Committee (FGDC), "Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management" (FGDC 1998), shall be considered the USACE accuracy standards. ASPRS Standards have three accuracy classes for photogrammetric mapping products. The three accuracy classes are defined in this manual, together with the detailed criteria, instrumentation, and procedures necessary to meet these accuracy classifications. For each class of map, procedural specifications and limitations are defined, such as allowable types of photographic or mensuration instruments, QC criteria, limiting flight altitude, photo enlargement criteria, and recommended development scales based on project functional requirements. The ASPRS, as it is applied to USACE projects, is explained in Chapter 2, and the entire ASPRS standard is in Appendix D of this manual.

1-8. Life Cycle Project Management Integration of Photogrammetric Mapping Throughout the Project Life

a. Prior to contracting for photogrammetric services, USACE is required to ensure that there are no existing data (to include aerial photography and elevation data) that would meet project requirements. The following resources for geospatial data must be checked prior to contracting for photogrammetric services:

(1) National Digitital Orthophoto Program – The U.S. Geological Survey (USGS) participates in the National Digital Orthophoto Program (NDOP) in cooperation with U.S. Department of Agriculture agencies. The effects of camera tilt and terrain relief are removed through a rectification process to create a computer file referred to as a digital orthophoto. A digital orthophoto is uniform scale photographic image and can be considered a photographic map. (Chapter 10). Orthophotoquads are distortion-free aerial photographs that are formatted and printed as standard 7.5-min, 1:24,000-scale quadrangles (15-min in Alaska) or as quarter quadrangles at a scale of 1:12,000. Prior to contracting for photogrammetric services, check the availability of NDOP products at http://mcmcweb.er.usgs.gov/status/doq_stat.html and determine whether existing orthophotoquads will meet project requirements.

(2) National Aerial Photography Program (NAPP) – Aerial photographs archived and distributed by the USGS include the repository of multiagency National Aerial Photography Program (NAPP) photos at 1:40,000 scale in color infrared or black and white; National High Altitude Aerial Photography Program (NHAP) photos at 1:58,000 scale for color infrared and 1:80,000 for black and white; and aerial photos at various scales from USGS mapping projects and other Federal agencies such as the Bureau of Reclamation, Environmental Protection Agency, and the USACE. Prior to contracting for photogrammetric services, check the availability of NAPP products at http://mcmcweb.er.usgs.gov/status/napp_stat.html and determine whether existing Aerial Photography will meet project requirements.

(3) National Spatial Data Infrastructure (NSDI) Clearinghouse Site – The Clearinghouse Activity, sponsored by the Federal Geographic Data Committee (FGDC), is a decentralized system of servers located on the Internet which contain field-level descriptions of available digital spatial data. These descriptive information, known as metadata, are collected in a standard format to facilitate query and consistent presentation across multiple participating sites. Prior to contracting for photogrammetric services, check the

availability of existing products at http://www.fgdc.gov/clearinghouse/clearinghouse.html and determine whether existing data can be used to meet project requirements.

b. USACE should also verify with Federal field offices any state and local government's potential plans to develop orthophoto, etc that may meet project requirements. In many cases, this can be done through a regional GIS User's Group or Consortia. It is important that the USACE take advantage of existing data or partner with interested parties to develop the data to reduce overall project costs.

c. Most engineering projects require some degree of surveying and mapping during each stage (i.e., planning, acquisition, design, construction, operation, and maintenance). Therefore, in the early phases of a project, a comprehensive plan should be developed to integrate the surveying and mapping requirements throughout the various stages of the life of the project. This plan shall be consistent with the Districts Geospatial Data and Systems (GD&S) Implementation Plan as outlined in EM 1110-1-2909. Development of a comprehensive surveying and mapping plan consistent with the District's overall GD&S goals will eliminate duplicate surveys performed for different purposes, of different accuracy, for different organizations, and/or at different times, and ensure that these data generated will be of maximum use to the District.

1-9. Metrics

Both metric (SI) and English (non-SI) systems of measurement in this manual are used because of the common use of both systems throughout the surveying, mapping, and photogrammetric professions. The photogrammetric industry uses both English and metric units. English units of measure are more common for some parameters such as flight altitudes in feet, and aerial film/photo dimensions in inches. Camera focal lengths are measured in either inches or millimeters (mm), with "6-in. camera" normally used rather than its 153-mm equivalent.

a. Metric scale ratios are generally required for civil works or military construction. Both English and metric scales are expressed throughout this manual. English units are generally expressed as "1 in. = x ft" notation, or more commonly, "x ft/in." Unit ratio (i.e., 1:x) scale measures may also be used for English units and are used throughout this manual for metric units.. For example, a 100-scale photo represents a 100-ft/in.-scale photo, or 1 in. = 100 ft, or 1:1,200. However, when creating a map in metric units the map scales are generally in increments evenly divided by 10 (i.e., 1:500, 1:1,000, or 1,20,000). Direct conversion from English units to metric units (i.e., 1"=100' to 1:1,200) should not be a common map scale for a mapping project intended to be metric in scale. The map scale should be the nearest common metric map scale (i.e., Converting to metric for an English map scale of 1"=100' should be 1:1,000).

b. Minimum scale limitations given in the manual for either photography or mapping imply that a scale cannot be less (i.e., smaller ratio) than the prescribed scale (e.g., a 100-ft/in. scale is smaller than a 50-ft/in. scale). Common scales in both English and metric are shown throughout the manual. Other scales may be calculated by the user.

In all cases, metric conversions are based exclusively on the U.S. Survey Foot, which equals exactly 1,200/3,937 meters (m).

1-10. Trade Name Exclusions

The citation in this manual of trade names of commercial firms, commercially available mapping products, or photogrammetric instruments does not constitute their official endorsement or approval.

1-11. Manual Development and Proponency

The Headquarters, USACE, proponent for this manual is the Technology Integration Branch, Engineering and Construction Division, Civil Works Directorate. Primary technical authorship and/or review were provided by USACE District, St Louis. Recommended corrections or modifications to this manual should be directed to:

HQUSACE-CW-EE
441 G Street, N.W.
Washington, DC 20314

1-12. Using the Manual

Digital photogrammetry is a professional specialty which is becoming more complex as time passes. In the not too distant past, all mapping was accomplished by employing a combination of manual and optical/mechanical efforts to produce a hardcopy product. Today mapping is predominantly a digital and electro/optical procedure to produce a geospatial database. Although there are several chapters devoted to technical procedures herein, it is not the intent of this manual to educate the reader to the proficiency level of a photogrammetric technician. The uninitiated user would be wise to seek technical assistance when embarking on a photogrammetric project. One such source is the Directory of Expertise for Photogrammetry in the USACE District, St. Louis.

a. Chapter 2. This chapter states the limits of allowable inaccuracy for large-scale maps and orthophotos. It contains tables that list the allowable errors for the map classes. It also contains tables to aid in determining flight altitude and photo scale which should maintain these accuracies. An appreciation of accuracy standards is vital to the mapping project planning stage, because it controls the integrity of the final product. Since mapping projects are usually costly, a flawed product equates to significant wasted time and funds. This chapter also includes discussion regarding quality control for photogrammetric mapping.

b. Chapter 3. This chapter is a prelude to some of the technical procedures addressed in successive chapters. It presents some of the basic geometric principles of aerial photographs and discusses coordinates datums and reference systems. This chapter also addresses QC procedures for all phases of a typical photogrammetric mapping project.

c. Chapter 4. This chapter discusses planning and estimating the effort and budgetary cost of a typical photogrammetric mapping project. The true cost of a project depends on many factors to include time of year, schedule, final products required, and accuracy requirements. This chapter also provides a sample scope of work and budgetary cost for a typical project.

d. Chapters 5 through10. These chapters identify and describe the successive progression of functions that are accomplished in photogrammetric projects. The careful reader will recognize areas of potential pitfalls and can strive to avoid them in an ongoing project.

(1) Chapter 5 discusses the characteristics of film and types of cameras that are available for aerial photo missions.

(2) Chapter 6 contains a discussion of the field surveys that are necessary to reference the photo image to the terrain.

(3) Chapter 7 outlines the elements of a recent innovation to aerial photo control, airborne global positioning system (ABGPS).

(4) Chapter 8 introduces the reader to aerotriangulation, which is a process of using office methods to supplement a limited amount of field survey to control the photographs for mapping.

(5) Chapter 9 defines the instrumentation and procedures to compile planimetric and topographic maps. It also discusses map editing.

(6) Chapter 10 discusses orthophotography, which is becoming more popular as a image tool to replace or enhance planimetric line mapping, especially for GIS/LIS/AM/FM projects.

e. Appendices. To facilitate contracting photogrammetric mapping services, the following appendicies have been developed to accompany this manual:

(1) Appendix B, Planimetric and Topographic Feature Depiction Specifications.

(2) Appendix C, Guide Specification for Photogrammetric Mapping and Aerial Photography Services and a sample "typical" Section C for a photogrammetric contract.

(3) Appendix D, ASPRS Accuracy Standards for Large-Scale Mapping.

(4) Appendix E, Sample Metadata.

(5) Appendix F, Sample Scopes of Work.

f. This manual is designed to be used in conjunction with the guide specification as a QC and quality assurance (QA) aid in administering contracts for photogrammetric mapping and surveying services.

1-13. Explanation of Abbreviations and Terms

Photogrammetry terms and abbreviations used in this manual are defined in the Glossary.

1-14. Mandatory Requirements in this Chapter