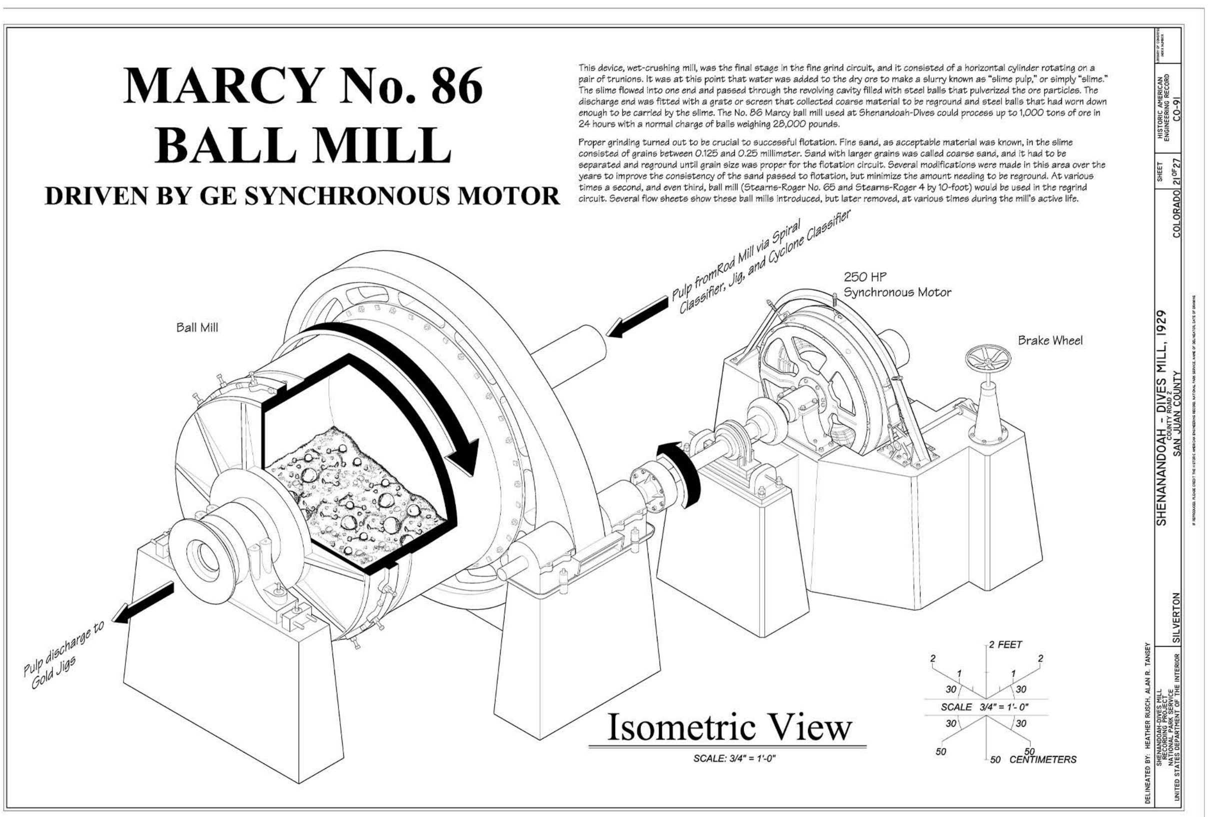
RECORDING HISTORIC STRUCTURES & SITES

FOR THE

HISTORIC AMERICAN ENGINEERING RECORD



U. S. Department of the Interior
National Park Service
Heritage Documentation Programs

TABLE OF CONTENTS

INTRODUCTION

The Historic American Engineering Record (HAER) was founded in 1969 by the American Society of Civil Engineers, the Library of Congress, and the National Park Service after it became apparent to many in the preservation community that industrial and engineering resources demanded a different sort of interdisciplinary documentary approach from that applied to historic architecture. Modeled on the Historic American Buildings Survey (HABS), founded in 1933, HAER set out with historians, architects, engineers, and photographers to capture vanishing industrial and engineering treasures in rural and urban areas nationwide. In 1986, the American Society of Civil Engineers was joined by the American Society of Mechanical Engineers (ASME), the American Institute of Mining and Metallurgical Engineers (AIMME), and the Institute of Electric and Electronic Engineers (IEEE) as signatories to HAER's mission.

HAER documentation comes from three sources. The HAER Washington office produces documentation internally and with field teams (made up primarily of students) working all over the country, generally for twelve-week terms in the summer. HAER also receives documentation from federal and state agencies that are required to mitigate any adverse impacts of federal actions under sections 106 and 110 of the National Historic Preservation Act. . Those preparing mitigation documentation should contact the appropriate regional National Park Service office (a list is provided on our website) or HAER Washington staff for review of drawings and to answer any questions. HAER also accepts donated documentation from interested members of the public. The HAER Washington office will assist people producing documentation in meeting these requirements for transmittal to the Library of Congress. Completed HAER projects are archived in the Prints and Photographs Division at the Library of Congress and are available in electronic format from the Library's website: http://www.loc.gov/pictures/collection/hh/.

This manual is an update of the **HAER Drawing Guidelines** written by ***Richard K. Anderson Jr.*** in **December 1994** and is intended to be a guide for generating existing conditions graphic documentation for both industrial and engineering resources that will meet HAER standards. These guidelines will discuss decisions on what aspects of a site to record and how to draw them, how to obtain measurements, accuracy requirements, the appropriate scales for drawings, fonts, and drawing types, among other things. This is intended to be general enough to encompass the variety of methods of obtaining measurements (including hand measuring, total station, and laser scanners) and the production of drawings by hand or using CAD or other softwares.

Please note that separate guidelines outlining best practices for laser scanning are under development by HABS, HAER, and the Historic American Landscapes Survey (HALS).

These guidelines can be used in conjunction with:

The Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation, generally known as the *HABS/HAER Standards*, available at http://www.nps.gov/hdp/standards.

John A. Burns, ed., *Recording Historic Structures, Second Edition* (Hoboken: John Wiley & Sons, 2004).
HABS/HAER/HALS Photography Guidelines
HABS/HAER Guidelines: Recording Historic Ships
HABS/HAER Guidelines: HAER Historical Reports
Preparing HABS/HAER/HALS Documentation for Transmittal to the Library of Congress
All available at http://www.nps.gov/hdp/standards/haerguidelines.htm**.**

,

,
HABS Guide to Field Documentation, available at
http://www.nps.gov/hdp/standards/habsfieldguide.html.

1.0 ROLE OF THE RECORDER

The drawing package produced by the recorder or recording team should attempt to accurately communicate the significant features of the site or structure and explain how it operated, if appropriate. Documentation must be produced accurately from reliable sources, using primary source research and field work. The documentation package should be graphically, textually, and contextually consistent.

1.1 Team Work

It is important for recordation teams (historians, architects, engineers, and photographers) to work closely during the documentation process. Working as a team is critical to understanding the scope and complexity of a site. If a team is working on a large site, time may be best utilized if members divide the site or structure into manageable parts for individuals to record. Team members can be organized into groups to record separate parts of the site or structure, and recordation from individuals or the groups can be synthesized at a later time. Individual member skills should be identified and utilized from the onset of the project. It is important that team members are systematic in their recordation methodology so field notes and field photography are easily combined at the end of the field work.

1.2 Identification and Recordation

Technological sites encompass a wide variety of resources, sites, and complexity. Therefore, there is no set formula for a recording team to follow when documenting a particular site because each one is unique and requires individualized attention. An initial overview or reconnaissance survey of the site to be recorded is recommended. A large or a linear site, like a road or canal, may require a pedestrian or windshield survey in which research teams make an initial assessment of significant features or site elements.

The size of the site, the scope of the study, and the level of recordation desired will dictate the answers to the following questions.

1. What drawings will best explain and illustrate the significant features of the site or structure?
2. What level of detail is required in the finished drawing?

3. How many dimensions and annotations are necessary?
4. What level of accuracy is needed in the measurements?
5. What sheet size should be used?

Recordation teams, especially those with limited resources or time, must decide what features are the most important to document. What was there, including both manmade and natural features? Why was it there? How did it work? What shaped its development? How did it change over time? What are the defining features? In addition, each site or structure will probably also have interesting peculiarities that should be explored and captured.

2.0 SURVEY PROCESS

2.1 Planning

The types of surveying techniques used for a project will depend on the site or structure and the access. Once a general understanding of the site or structure has been reached, team members should develop an overall strategy or plan of attack that will result in drawings that meet the selected level of documentation. This requires defining the scope of the project and determining the access to the resource. Remember, information about some aspects of the site may be limited or nonexistent. Simply acknowledge that and move on to another pertinent area where the information is bountiful. Seek out written reports, drawings, and photographs to supplement the physical evaluation of the site or structure.

2.1.1 Determining Scope

What does the selected level of documentation entail? What elements of the site are most critical to capture? The following list of aspects to be considered can help inform decisions about the scope of the project.

Site

The physical landscape has a significant impact on the design and development of sites and structures. Aspects to consider include the following: topography; geology (this can be of importance when documenting a civil engineering structure); available minerals, building materials, and water resources; natural or man-made barriers or obstacles; and transportation systems and utilities.

Structures

Identify and assess every structure within the scope of the project to determine which are of greatest interest and significance. The following are things to consider when analyzing a structure: function; date of construction; the associated architect, engineer, and/or builder; materials; form; machinery and systems; length of use; whether it is unique or typical; and any association with significant individuals, inventions, or events.

Depending on the information obtained, you and the team may conclude that:

1. a particular structure is relatively insignificant in terms of both form and function, and therefore merits minimal study and documentation;

2. the structure's function, rather than its form, is of primary interest (i.e., the operations or work taking place in the structure are more important than the physical structure itself);

3. the structure's form is of primary interest; or

4. the structure's form *and* function are of interest and should be documented in detail.

Each important structure on the site should be dealt with individually, while also identifying how the structures were related and interconnected. Conceptualizing the assemblage as a system and exploring the interrelationships and interdependencies that may have existed is useful.

Functions
If a site is of interest because of its function, rather than the structures, the documentation should focus on how that function was executed; for example, how the work was organized or how the mechanical components functioned. Topics to consider include: identification of machines and tools used, as well as manufacturers and dates of the equipment; how machinery was located within the structure; how the machinery was driven; how power was transmitted; the materials being processed and the products being made; and the labor force.

Technological Changes
It is not unusual for civil engineering works, like dams and bridges, to survive into the present with minimal change. Manufactories, on the other hand, seldom escape alterations. They may have absorbed new technologies, been outfitted with new machinery and equipment, employed different types of labor forces, and constantly altered or updated products.

Because of the short duration of most projects, it can be difficult to document in depth the effects of time and technological changes. Begin by recognizing that not all time periods are equal in significance. Generally, the three blocks of time most relevant and that require the most intensive study are the development period, the "high-water" mark, and the period of demise. In assessing the technological changes, try to discover the instigator and reason for the changes and what new machinery and processes were required.

2.1.2 Considering the Relative Significance of the Site
Recordation teams should start to consider the relative significance of the site or structure during the planning process. The areas of significance will help identify priority areas for surveying and documenting.

2.1.3 Physical Condition
What is the physical condition of the site or structure? Determine if valuable features have been removed or adapted or if portions of the site or structure are no longer accessible.

Safety should be of utmost concern. Buildings or structures are frequently empty, abandoned, and/or deteriorating. Measuring elevations and structures may require working at heights on ladders, scaffolding, or cherry pickers. All participants should adhere to the standards and regulations of the Occupational Safety and Health Administration always. This may require special training or obtaining protective gear like hard hats, harnesses, asbestos suits, or respirators.

2.1.4 Integrity

Typically, site integrity involves the following elements: location, design, setting, materials, workmanship, feeling, and association, as defined by the National Register of Historic Places.

2.1.5 Budgeting Time

Once the initial assessment of the site has been made, teams should be prepared to schedule the recordation process. Time should be allotted for research/inventory, fieldwork at the physical site or structure, and drawing. A checklist of tasks to be completed with general timeframes is a helpful tool. The project supervisor, in consultation with the sponsor or with any contractual documents stipulating the documentation, should develop a list of drawings. It is recommended that at least one-half to two-thirds of the project time be allotted to the final drawings stage of the project.

2.2 Research

An initial inventory of available resources is an essential part of the planning process. The team's historian can be a valuable source of such information. The following is a list of potential sources for existing resources and records associated with a site.

City/County/State/Federal/Private: Repositories/Archives/Libraries/Collections
State Historic Preservation Offices
USGS Quadrangle Maps
Sanborn Maps
Digital Ortho Quarter Quadrangle Maps
LandSat Land Use/Land Cover Data
Geo-Rectified and Geo-Referenced Aerial Photography
Private Owner Records
Historical Societies
Web-based Resources
Engineering Journals

During the recordation process, it is important that all members of the team stay in communication. As the site or structure history develops, the chronology and evolution of the site will become apparent. The team should work together to unearth clues about the site.

2.3 Field Records

Field notes are an essential part of the recordation process. The primary function of the field notes and photographs is to record significant dimensional and relational data about your site.

Field forms and sketches will become the basis for all measured drawings and maps produced for the site or structure, so it is imperative that these be consistent. They must be carefully annotated and neatly labeled so others can understand the information. Hasty or illegible fieldwork invariably includes errors or omissions that can result in repeated trips to the site or flaws in the final drawings.

Field records may consist of copies of original drawings annotated with later alterations or additions, dimensioned sketches and measurements on graph paper, metadata of digital documentation, and photographs. The production of the field records should follow the progression of drawings: horizontal and vertical reference planes, block out the structure, and then details. Therefore, the first notes should show the instrument setups and reference plane locations. The sketch of the structure or the site plan need only have an outline. Be sure you include a north arrow in your plans.

It should be noted that the field records are part of the final submission to the Library of Congress, so it is important they are orderly and legible for reproduction. However, they are considered informal documentation because they are not rigorously archival.

2.3.1 Preparing Field Notes

Materials

Field sketches, dimensions, and notes should be drawn on graph paper with eight divisions per inch. Only one side of the paper should be used. HAER typically uses 17" x 22" sheets as they can be easily folded into 8-$^{1}/_{2}$" x 11" to fit the folders. These sheets may be glued together with white glue or polyvinyl acetate (PVA) glue for larger sheets. Tape is unacceptable because its adhesive fails. Field notes should be, but are not required to be, on archival paper.

Sketching is best done with a sharp #2 pencil or a lead holder with dark, non-smearing lead. Dimensions, dimension strings, and witness lines should be recorded in red pencil or pen to clearly distinguish them from black pencil lines. Large mistakes should simply be crossed out rather than erased.

Content

The graph paper grid should be used to lay out the sketch proportionally. Sketches should be made on only one side of the paper, and sketches on a single sheet should be related. Field note sketches should be drawn large enough to accommodate long strings of dimensions neatly. Complex elements should be simplified. It may be necessary to exaggerate certain features to have enough room to write the dimensions legibly. Details like door and window jambs should be sketched separately (typically on another sheet) at a larger scale and referenced appropriately.

For particularly large or complicated structures, it may be necessary to lay out individual drawings over multiple sheets of field notes. Care should be taken in the location of break lines, as well as to make sure the individual sheets are appropriately referenced to one another.

Each note should be devoted to a layer of detail or to the dimensions of and locations of a similar class of features (like windows, valves, trestle bents, etc.). Repetitive details can be drawn once in field notes, and, if necessary, a table of dimensions keyed to the sketch can record variations.

For highly complex planar details (castings, gear teeth, lettering, architectural carvings), consider making full-size rubbings. Any rubbings should be accompanied by overall measurements made directly from the object as a check against the rubbing being distorted by slippage. The accuracy of rubbings is greatly improved by carefully creasing the field note paper along the edges of the object. The crease remains in the paper, and it can be traced with a pencil, thus avoiding the blurry mess caused by applying a crayon or graphite stick directly to the sheet over the object. Be careful not to depress the paper when you make creases, or the rubbing will be artificially stretched. Most rubbings can be held to tolerances of +/- $^{1}/_{16}$" or +/- $^{1}/_{8}$".

Fixed objects, such as light fixtures or machinery, may be shown if historically significant or if required by the project sponsor. Movable objects (like furniture) are typically not shown.

Efficient field notes are a mixture of line sketches, dimensions, and verbal annotations. Always label parts, rooms, materials, and special measurement conditions. Reference other sketches and call attention to special conditions in your notes.

Clarity is achieved by recording what you did NOT do as well as what you accomplished. This applies particularly to situations where data might be expected. Note what areas are inaccessible and why. Also annotate dimensions with an atypical error tolerance.

Format

Each field note needs to be labeled with the following in a consistent location on the sheet:

Site Name and Location
HAER number
Specific View/Feature (site plan, detailed elevation, etc.)
Name(s) of Field Recorder(s)
Date
Organization
North Arrow (if applicable)
Scale (if applicable)

2.3.2 Field Photography

In addition to verifying dimensional data, field photographs capture in minute detail the actual on-site appearance of site features. Most efficient fieldwork will require a balance between dimensioned sketches/field notes and thoughtfully taken field photographs. The relative significance of each object and features documented should guide reliance on either tool. The applications for field photographs are numerous. Aside from general survey photography at the site, photographs capture data about materials, textures, massing, opacity, and condition. They can also be used for comparative purposes with historic photographs.

NOTE: Often two or more photographs must be compared to narrow down tolerances. Any corrections or additions made to field notes based on field photographs should be so noted in the field notes. If a recorder derives a substantial number of dimensions of a feature from field photographs, he/she should make a dimensioned field sketch and annotate it with references to field photographs used.

2.3.3 Other Field Notes

All born-digital field data should be saved when possible and archived for future reference, including digital photographs, photogrammetric images, points taken with a laser total station, and three-dimensional laser scanning "point clouds."

As of 2019, HABS/HAER/HALS is exploring long-term storage of born-digital data and appropriate file formats. Further guidance on this will be forthcoming.

2.4 Tools for Measurement in the Field

Below is a list of basic equipment recommended for field work, some of which is used to establish reference planes in hand measuring. Note that tapes and rulers should be graduated in the English system, not the metric. The tools required will differ depending on the measuring techniques being used and the site or structure being recorded.

Storage containers:

Toolboxes

Reference devices:

Transit (with tripod)
Laser level
String level
Plumb bobs
Surveyor's twine, string

Measuring devices:

300-foot tapes, $^1/_8$" graduations [NOTE that only metal tapes should be used as cloth and fiberglass tapes have a tendency to stretch over long distances]
100-foot tapes, $^1/_8$" graduations
50-foot tapes, $^1/_8$" graduations
6, 12, 16, 25-foot retractable tapes, $^1/_{16}$" graduations
Folding carpenter's rules
Digital Distance Finder (Disto)
Theodolite (Total Station)
Terrestrial Laser Scanner

Marking devices:

Lumber crayons (red, black, yellow)
Masking and duct tapes
Chalk line reels (with bottles of powdered chalk for refills)
Felt markers
Pens
Pencils

Holding devices:
Masking tape
Hammer and nails

Gauges:
Contour gauge ("molding comb")

Hand tools:
Hammer
Pliers
Screwdrivers
Utility knife and blades
Flashlights / Headlamps and batteries

Apparel:
Gloves
First-aid kits
Dust masks / Respirators

Data storage:
Clipboards
17" x 22" gridded field paper
Field notebooks
Portable Hard Drives
USB Drives

Other: Other tools that might be utilized by a field team include a carpenter's square, strong magnets (for temporarily securing tapes or plumb lines to steel structures), digital level, calipers, calculators, and a magnetic compass.

2.5 Methods for Obtaining Measurements in the Field

2.5.1 Reference Planes (Datum Lines)

Before measuring any site or structure, independent horizontal and vertical reference planes (often referred to as "datum lines") need to be established and marked on the structures. These planes are essential to accurately establishing where the heights of different features within a structure lie, the inclination of sloped areas, and the vertical orientation of walls.

a. Datum planes should be set at heights as convenient as possible for access throughout the building or site.
b. Once a beginning point has been selected, try to transfer the level of that point to as many other places within your site as possible.
c. Mark the datum plane on structures. On some structures, you may have to make these marks unobtrusive or put them on removable tape to not to damage the finish.
d. Always reference the datum plane in the field notes where measurements will be taken.

There are several devices that can be used for setting **horizontal reference lines**, including string levels, laser levels, and transits and theodolites, which are discussed in more detail below.

The *string level* works best over distances less than 20 feet. A string level consists of a bubble level with hooks on each end hung on a strong string. The bubble level should be equidistant between suspension points so the level and the string ends are parallel despite the sag induced by the level's weight. This device depends on its hooks for accuracy. If they are bent or damaged, check the bubble level against itself by reversing its position on the string. If the bubble settles at the same relative position towards the marked end of the vial, then the string is level, even though the bubble may no longer lie between the centering marks.

Once properly leveled, *laser levels* project a visible red or infrared laser beam horizontally, rotating it to describe a datum plane with a beam of light. You can then mark a structure using the beam as a guide or measure from features to the light plane, recording the dimension where the beam crosses your scale.

Transits and theodolites measure angles (horizontal and vertical) and distances (range from the instrument station). Once leveled, they can be used to set a datum plane on structures through the telescope reticle (cross hairs). Once you begin to set reference marks, make sure you set all you will need or can see from the instrument station because it is impossible to set the instrument up at exactly the same datum plane again. Try to set up a station at a building corner where you can spot at least two elevations from one point, or even see into or through buildings to others beyond. Inside structures, try to shoot as far as you can down hallways or into adjacent spaces; avoid setting up a station on easily deflected floors—anyone walking around the instrument will upset the instrument's level plane.

On most sites, you will need at least two transit stations (and perhaps many more) to set a horizontal reference plane. There are two ways to continue a datum plane. One is setting your next series of marks at the second horizontal reference plane after the instrument is leveled. Be sure you measure and record the distance between the two planes in your field notes. The second way is measuring and recording the distance between the new instrument height and the original reference plane after leveling the instrument. Each subsequent sighting indicates where the new plane lies, but you measure the recorded distance back to the original plane and mark it on the structure.

Vertical reference planes can be set using plumb bobs, and transits, discussed below.

The simplest vertical reference line instrument is the *plumb bob*. Measure several points horizontally from a vertical feature to this datum to determine how far out of plumb the feature is. The plumb bob can also be hung to align with a specific feature so that a horizontal measurement can be taken from other known features. This is useful where direct measurements are obscured by obstacles.

The vertical circle in the *transit and theodolite* can be used to set vertical reference planes. Move the telescope until equal measurements are sighted through the reticle on two rules set at the base of a wall (or whatever feature is to be measured). Lock the horizontal circle and take swing ties from features to the plane of the vertical circle. Read dimensions with the telescope.

2.5.2 Additive vs. Running Measurements

Running measurements should be used whenever possible. *Additive measurements* are "chained," meaning each succeeding measurement begins where the last one ended. Grouped and overall measurements are obtained by adding individual measurements. While this method reduces a lot of measurements to a size that an unassisted person can make with a tape, tolerances/errors accumulate. *Running measurements*, on the other hand, use the same starting point for all measurements made in a common direction. For example, to measure the window openings in a building façade, you would hook the tape at one corner and continue (or "run") down the façade, taking the measurement of each opening edge as it is read from the tape. In this approach, tolerances/errors do not accumulate.

2.5.3 Tolerances

HAER normally measures to the nearest $^{1}/_{8}$ inch. Be aware of how you are positioning the measuring device to assure the most accurate measurement.

2.5.4 Writing Dimensions

Write the dimension on the fieldnote denoting *feet* then *inches* then *eights of an inch* separated by a period.

e.g. Ten and one-half inches or 10-$^{1}/_{2}$" would be written 0.10.4 (0 feet.10 inches.4/8 inches)

2.4.5 Other Measuring Techniques

Swing Ties: The correct distance from a point to a line lies along a second line running from the point square to the first line. Put the zero end of your tape or rule on the point (feature whose location you are measuring) and swing the tape by the reference line. The minimum measurement on the tape is the true dimension, known as a "swing tie."

Trilateration: Hand trilateration is a simple and relatively foolproof method for locating points and determining the shape of just about anything, so long as the measurements were carefully taken, recorded, and plotted. This can be used to measure small site plans, building plans, layouts of columns, and the shapes of curves and irregular features. Measuring multiple points from single or multiple known positions can help create triangles of measurement to locate free standing or oddly shaped features.

Telescoping Measuring Poles: Poles can be an excellent tool for reaching features up to 20 feet from you and faster than moving a ladder.

2.5.6 How to Measure Diameters

Measuring diameters of small piping and round decorative features can be accomplished with jaw or spring calipers. The diameters of tanks, penstocks, and columns can be determined by taping their circumferences and dividing by *pi*. An architectural column must have circumferences taken at numerous measured locations along the shaft to determine the column entasis.

2.5.7 How to Measure Site Plans

Site plans can be measured using several systems.

1. *Trilateration*: First establish a horizontal reference plan such as two corners of a building. Then measure from both points to other features or points to create triangles. Eventually you will want to measure two or more triangles per point in a site plan as checks against errors and as reinforcement of the accuracy. For large sites, begin with large overall triangles and work smaller ones within them to control errors.

2. *Total Stations*: These are complete electronic instruments for taking bearing and range data and converting it to 3D coordinates. This data can be downloaded into CAD programs. Insure that the measured units are carried over or converted into the CAD drawing units correctly.

3. *Web Resources*: There are several web-based resources for digitized data. This includes sites like Google Earth. Terraserver (www.terraserver.com) offers digital aerial photographs as well as digitized USGS information. Various Geographic Information Systems (GIS) clearinghouses around the country may also have digitized aerial and base data for a site. All digitally acquired materials should be checked for quality and resolution, and if they are used in final materials, their copyright status must be confirmed.

4. *GIS Data*: GIS (Geographic Information System) is a computer-based tool for analyzing and mapping existing features. Esri (http://www.esri.com) offers GPS data for many sites. Each data set has a source scale from which it was originally collected. Mixing data from one source scale to another also mixes the spatial accuracy of the data. Users should be well acquainted with the metadata that accompanies each dataset to understand the source scale as well as other parameters such as projection system, datum, map unites, attribute definitions, and shelf life of the data they have acquired.

2.5.8 How to Measure Buildings

Total stations, photogrammetry, and/or laser scanning are now typically used for recording structures. These digital measurements are supplemented by hand measurements where required. Consider using a building's floors, windows, and fire escapes as scaffolding. Tapes can be dropped to datum lines for vertical measurements and can be rigged horizontally from window to window. Ladders are best for heights under 20 feet. Above this, scaffolding or cherry pickers are recommended for safety. Make sure you set and mark reference planes on the structure(s) first. These will be your best (and often only) means to sew together a complex structure accurately. Always obtain overall measurements first, and work down to smaller levels of detail. Repetitive features (columns, windows, details) can be drawn once and any variable measurements recorded in a table.

Measurements should be written on the fieldnote perpendicular to the dimension line and next to the appropriate tick mark, rather than between two tick marks. It is important to mark the zero on the field note for each dimension string.

NEVER assume buildings are square. After the building perimeter is established, move on to wall thickness (determined from doors and windows or accessible holes), then to interior spaces. Interior plans may require a variety of approaches depending on the geometry of spaces, access to walls and corners, and the presence of columns and large objects. Don't forget to set reference planes first. In subdivided rooms, every wall should be measured room by room, with at least one diagonal taken in each space. If obstructions prevent you from taking diagonals in one space, you may have to rely on swing offsets and trilaterations from a reference string or use the geometries of surrounding rooms to establish the shape of a less accessible space. Plumb lines can be used for features high above floors.

Measuring plans give you half the dimensions for cross sections and internal elevations. You have horizontal but not vertical coordinates. Horizontal dimension strings taken for constructing a section for multiple floors must be coordinated vertically by relating each string to a common vertical datum line (such as might be established by a plumb line). Vertical coordinates can be established from one or more horizontal datum planes. The shape of odd or deformed geometries in section or elevation can be determined by trilateration.

Elevations of repetitive features like roof trusses usually require measuring one and assuming the others are the same when no obvious differences appear to the eye or are required by function. Lower chord joints in trusses can be located by raising a pole with a plumb line to the joint centerline or by tossing a ball of string over the joint. A plumb line or measuring tape can then be tied to the string and raised to measure vertical heights or establish plan dimensions. A transit, plumb lines, and tapes can be used, although for every point you sight you must derive three coordinates for the data to be useful.

To accurately position floors, try looking for holes in floors through which to drop plumb lines, or hang them in stairwells or pipe chases. Measure the locations of the suspension point on the upper floor and of the plumb bob tip on the floor beneath and plot these points in the plans of the two floors being checked. Two such plumb lines are needed to "lock" the two floors together.

2.5.9 How to Measure Bridges

When measuring trussed structures, try to locate engineering drawings before resorting to complete measurement. If field measurement is required, the measurements needed to record a truss break down into several easily defined groups, regardless of the truss type. On bridges, the span between the center line of the truss bearing points must be measured first (a) followed by the distance between the center lines of the truss planes (b), then the distance between the center line of the top and bottom chords (c) (if the truss has parallel chords). If a bridge is skewed in plan, the relative position of the trusses can be obtained by trilateration in plan. You should also sight along the upper and lower chords to check for vertical camber.

Considerable time can be saved measuring a metal bridge by taking advantage of its numerous symmetries. First, the two trusses of a simple bridge span are usually the same, even if the bridge is skewed in plan. Second, an individual truss is usually symmetrical about its centerline between ends. Third, these same observations apply to decks and upper chord bracing.

After obtaining overall dimensions, the dimensions of truss panel points must be taken and recorded. In most bridges, the panel points are evenly spaced along the top and bottom chords, but this is not always the case. Measuring between panel points of a metal truss bridge is easy if the bridge is old enough to be pin connected—dimensions are simply taken between the centerline of each pin along the chords and for all diagonals and verticals. The pin centerline is frequently marked in the ends by dimples or countersunk holes used to turn the pin in a lathe. If the bridge is wooden or has riveted joints, it is better to measure between the edges and joints of members. The lines of action are difficult to determine in the field for these structures. Pin-connected bridges usually had members with symmetrical cross sections, so lines of action were the same as the geometric centerline of each member. Determining the location of lines of action in a riveted truss with asymmetrical cross sections will require finding original drawings, engineering handbooks, or structural steel catalogs.

It is imperative to not only measure the member length but also the cross section as well. This is especially true for built-up members. Cast-iron members are often hollow, and the dimensions of their cores may be hard to obtain unless the end can be seen. Look for manufacturer's names rolled or cast into bridge members.

It is important to take notes and dimensions that will help analyze joint assemblies in a bridge. Typical joints are shoes and panel points, but there may be other specialized connections depending on the truss design.

When measuring bridges, be sure to record the materials used in the structure, including wood species and types of stone metal.[1] Deformations, deterioration, asymmetries, and missing members should be recorded since they may be important clues to a bridge's original design, detailing, and construction. Builders' and dedication plates and decorative features should be recorded. For masonry bridges, the exterior can be recorded by the same methods used for buildings. The internal construction is difficult to infer without original drawings, photographs, or convenient damage. Discovery of original construction drawings is vital to properly document reinforcing bar type, size, and placement. When documenting suspension bridges, it is important to remember that the shape of the main cables follows a catenary curve, not an elliptical or circular arch. Cable construction should be carefully determined as well.

2.5.10 How to Measure Machines

There are some basic rules for measuring mechanical devices. As with other objects, finding engineering drawings will save you much sketching and measuring time. They will not only provide critical external and design dimensions but also important internal sections and arrangements that you would be unable to get without disassembling the machinery.

Machinery is, in many respects, very easy to record, no matter how intricate it is. This is because most machinery has been designed and built along center lines. Once those center lines are located, you can measure everything else with respect to them. Most machinery parts are either rectangular/prismatic or circular/cylindrical in shape, so break down equipment in terms of these shapes before you begin to sketch and measure it. Look for symmetry and repetition. These characteristics can save you time since you won't have to duplicate measurements. You may need only one side of the frame if both sides are the same; asymmetrical features are all that will need measurement on a matching side. Multiples of the same part mean you only need to dimension one of them.

All machinery has a base or frame that supports and aligns its active parts. These frames and bases provide built-in datum planes from which you can measure to other features or to the centerlines of shafts, and the surfaces of rotating and sliding parts. Most active machinery parts either slide, rotate, or reciprocate, and those that do not are usually power transmission devices like belts, chains, shafts, or connecting rods. Study each machine and figure out how it operates, if you cannot observe it in motion. An understanding of its operations will help you simplify your notes and avoid taking misleading or unnecessary measurements. It is more important to measure the configuration of parts whose relationship does not change as a machine operates rather than dimension changing relationships.

Always record center lines before details. Locate major center lines of bases, shafts, cylinders, motors, gears, etc. from each other and from primary reference surfaces such

[1] Note: wrought iron and cast iron were used exclusively in bridges until the 1860s when Bessemer steels became available. By the 1880s, wrought iron was still widely used, but by 1900, it had almost become completely supplanted by steel. Cast iron was only used for compression members and fittings where no bending occurred because of its brittleness.

as bases or datum planes. Look for physical features that define the centers of shafts, cylinders, and bases. Where no physical indications are apparent, you will have to mark center lines by halving the widths of round and rectangular elements. Once the defining center lines are documented, you can proceed to measure principal parts like pulley and gear diameters and bearing sizes. Leave small (but important) details such as nuts and bolts, pulley spokes, and piping for last. Pay special attention to the angular or radial alignment of keys, spokes, part lines, molding lines, pins, and bolts around a common shaft.

Almost all machinery comes with basic information cast into frames or embossed on manufacturer's plates mounted in a prominent place. All the information on these plates should be copied into your field notes. This data records the manufacturer's name, address, dates, serial numbers, model numbers, and sometimes patent numbers and other information. Beyond this, recording of numbers and verbal information depends on its significance to the machine and site. Numbers and letters cast into frames or embossed on parts may be part of a system of part numbers, mold numbers, serial numbers, or match numbers.

2.5.11 How to Interpret Industrial Processes

Frequently the significance of a site lies as much in the industrial process going on inside the buildings as it does in the buildings themselves or their machinery. You should carefully note the steps comprising the manufacture of a product, or the way the equipment is oriented or operated. You may need to trace pipes, belts, conveyors, tracks, shafts, tunnels, and wires to better understand where, how, and why materials and energy moved through the site. Specialized machinery and materials should be noted. Points of wear on floors, equipment, or structures can offer meaningful clues to work patterns and flows of material and products.

3.0 HAER DRAWING FORMAT

Recordation teams will be most successful if the graphic options are clearly defined and understood prior to starting the project. Measured drawings are produced from recorded, accurate measurements; if portions of the site or structure are not accessible for measurement, they should be noted as not accessible or drawn from available existing drawings and other sources so identified. No part of the measurements should be produced from hypothesis or non-measurement related activities.

3.1 Graphic Standards

3.1.1 Drawing Sizes

There are three sizes of HAER drawing sheets, 19" x 24", 24" x 36", and 34" x 44". The actual drawing space available on each sheet reduces to 15-$^{7}/_{8}$" x 20-$^{1}/_{8}$", 21-$^{3}/_{4}$" x 32", and 31-$^{7}/_{8}$" x 40" once the title block is taken in consideration. Do not mix sheet sizes in a single set of drawings.

3.1.2 Materials for Final Submission

The basic durability performance standard for HAER records is 500 years. While ink on polyester film (Mylar, four mils thick, with drawing surface on both sides) has been used in the past to meet this standard, HAER is now only using vellum that meets Federal Vellum Specification UU-P-561H, Type IV. All inks must be archival quality.

The final submission should consist of hard-copy, full-size drawings and a CD or DVD containing PDFs of the drawings from the CAD files. A document listing and describing the software used, the individual title names, and any other relevant information should accompany the final documentation.

3.1.3 Scale
Graphic bar scales should be simple. Axonometric and isometric scales should show the scales and angles of all three axes in both English and metric systems.

3.1.4 North Arrow
All site and structure plans must have unambiguous north arrows to indicate compass direction. Arrow circles should not be less than 1" diameter on 24" x 36" sheets or 1-$^{1}/_{2}$" on 34" x 44" sheets. Clarity is best met if the letter "N" or the word "North" is included.

3.1.5 Sheet Layout
Title Block
Digital versions of the HAER title block in either DXF or AutoCAD DWG formats are available from the HAER Washington office. For those doing hand drawings, pre-printed sheets are also available upon request from the HAER Washington office. If hand drawing, the pre-printed title blocks on the HAER sheets must be filled in with a Leroy lettering system (or equivalent) rather than hand lettering.

While there is free rein for creativity in terms of laying out sheets, the title block must be filled out as described below to ensure consistency across the collection.

Left corner block: Official name of the recording project, such as AVERY ISLAND SALT WORKS RECORDING PROJECT, lettered in all capitals.

Center block:
Name of Site (Record Name): The name of the site or structure is centered here and must exactly duplicate the official name used to assign the HAER number.

Date: The construction date of the site or structure follows the name, set off by two spaces.

Address: Use the address initially provided when the HAER number was assigned. Use "Vicinity of" if appropriate.

Location: Letter the name of the city (or vicinity) at the lower left of the block. Center the name of the county (or "independent city") and letter the state at the lower right. All words are spelled out.

Right corner block: This is for the HAER number assigned by the Washington office; the sheet number out of the total number of sheets for the set is next.

Leave the Library of Congress number blank; it is filled in by Library staff.

Orientation:
HAER drawing sheets can either be oriented HORIZONTALLY (with the title block to the right) or VERTICALLY (with the title block at the bottom).

3.1.6 Electronic File Sizes/Standards and File Formats

As of 2019, HABS/HAER/HALS is exploring stable electronic file sizes/standards and formats. Further guidance on this will be forthcoming.

3.1.7 Suggested Symbols

Consistency is key in graphic representation throughout the documentation package. Recorders should decide upon symbols before starting the drafting process and use those symbols throughout the delineation process.

3.1.8 Legend

A legend may be necessary to indicate commonly used symbols. Legends should be present on all sheets where symbols are used.

3.1.9 Locator Diagram

In multiple sheets, clarity and convenience are promoted by including on each sheet a small schematic diagram where a plan, elevation or section is highlighted.

3.1.10 Hatch Patterns

Common American Institute of Architect (AIA Standards) hatch patterns are used to delineate different types of construction materials. Hatch patterns show areas of distinct building materials and can be used in a variety of drawing methods including plans and sections. The use of hatch can also be helpful in graphic representation of shadow.

3.1.12 Screening

It may be desirable to screen (lighten) some information to allow the most important elements of the drawing to be more easily understood.

3.1.13 Stipple and Shadow

Stipple and shadow are graphic techniques for adding depth to orthographic (two-dimensional) graphics. Stippling (the process of making tiny dots on the page) can be used to delineate texture or materials, such as masonry or concrete. Shadow indicates shaded areas in orthographic views. Shadows can consist of hatches, stippling, or lines. Shadowing should not obscure plan graphics. All stippling or shadows should be legible if plans are reduced to 8-1/2 x 11 size.

3.2 Methods for Recording Drawings

3.2.1 Existing Information

Existing information should be presented within the drawing package. All historic photographs and drawings should be properly cited to their source and in the public domain or a copyright release form obtained.

3.2.2 Hand Drawing

For hand drawings, high-quality drafting is essential. Only permanent, waterproof, carbon-based black inks formulated for drafting films ("acetate inks") are permitted. Latex-based inks, while darker, will deteriorate. Accepted inks include: Pelikan-FT™, Koh-I-Noor™ "Universal Drawing Ink," or Pentel® "Ceran-O-Matic."

The individual drawing is executed first as a preliminary hardline precision-drafted pencil drawing. In this process, it is necessary for the final scale of the drawing to be determined prior to commencing the pencil drawing. The pencil drawing is then affixed to the drafting surface, a sheet of pre-printed HAER vellum is placed over it, and the final drawing is produced by tracing the pencil drawing with technical ink pens. Only waterproof black ink (Pelikan FT, or equivalent) may be used.

3.2.3 Line Weights

See Section 4.

3.2.4 Digital Recordation

See Section 4.

3.2.5 Interpretive Drawings and Thumbnail Sketches

As an adjunct to measured drawings, interpretive drawings are schematic or illustrative representations of processes. These drawings may be scaled or diagrammatic. Interpretive drawings go beyond orthographic views to clarify, explain, and emphasize distinctive relationships between features and functions of the site or structure. Such drawings may range from reconstructed historical perspective views of a site, exploded axonometrics, cutaway views, flow charts of processes, or step-by-step schematics illustrating the evolution of a site. Choice of these views, or combinations, will be governed by the nature of the site and the specific recorded features. In planning a series of drawings, the recordation team must decide where drawings do the best documentary job and where photographs and histories would be more appropriate.

3.3 Types of Graphic Representation

Generally, a drawing set should be organized as follows: Title Sheet (with location maps), Site Plans, Site Sections, Building or Structure Plans, Elevations, Sections, Details (plans and elevations, sections, exploded views, isometrics), Process Diagrams (isometrics, flow charts, schematics, etc.), and Other Interpretive Views.

Not all sites will receive coverage as complete as the list above, nor is it necessary to devote a minimum of a single sheet to each view or subject listed. The extent of the documentation should depend first on the site's significance and the importance and number of specific features, as well as the project's goals.

3.3.1 Title Sheet

This introductory sheet contains a brief historical summary, project credit statement, a graphic or major map or site plan, and location maps showing regional and local orientation. The site or structure name should go at the top of the sheet in letters at least $^{3}/_{4}$" to 1-$^{1}/_{2}$" high. This name should match the official name used in assigning the HAER number. The site location (city and state, no county) is located underneath the title. The letters should be $^{5}/_{8}$" to 1" high and can either be all capitals or upper/lower case. The construction years are $^{3}/_{4}$" to 1-$^{1}/_{4}$" high, but smaller than the title.

The statement of significance highlights the site's historic and/or engineering significance and important aspects of its history. This should be written in upper/lower case.

The project credit statement should also be written in upper/lower case. The following is the standard language:

> This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is part of Heritage Documentation Programs and is administered by the National Park Service, U.S. Department of the Interior. The [NAME OF PROJECT] Recording Project was cosponsored in [YEAR] by HAER under the general direction of [LIST NAMES].
>
> The field work, measured drawings, historical reports and photographs [or whatever is applicable] were prepared under the general direction of [NAME], Chief of HAER and by [NAME], HAER project leader [and others involved in managing the project]. The team consisted of [NAMES, SCHOOL IF A SUMMER TEAM OR PRODUCED BY UNIVERSITY STUDENTS]. The historical report was produced by [NAME] (if applicable). Large-format photography was done by [NAME] (if applicable).

Inclusion of location maps for the site is a requirement. Typically, the site is pointed out within a state or region in a schematic map at a scale of 1" = 100 miles or more. Major cities are labeled, with the site name itself in the largest, boldest lettering. Major geographic features (such as mountains or rivers) are depicted if they are crucial to the site. The second location map is more detailed and is usually based on a USGS 7.5-minute quadrangle topographic map (scale 1" = 2,000'). Rivers, lakes, and other geographical features must be shown. Label any major routes. In addition to location maps, some sites merit a large overall site plan on the title page to orient the user to a building complex, localized industrialized system, or the surrounding community. Scales should range between 1" = 400' to 1" = 100' depending on the site and its complexity.

The latitude/longitude of the site/structure needs to be determined. The coordinate should be expressed in decimal degrees or converted from the UTM format. Information about the source should be provided: 1) identify the location of the coordinate relative to the structure; 2) indicate the date the coordinate was obtained; 3) identify the method by which the coordinate was obtained; 4) provide an estimate of the coordinate's accuracy expressed in +/- meters; 5) specify the coordinate's datum; and 6) indicate any restrictions on releasing the structure's location to the public.

When a useful site plan would be too extensive to include on a title sheet, move it to the second sheet and substitute a principal elevation or an aerial view of the site. Pictorial views can be derived from photographs (historic or current) and combined with well-designed graphics. If historic images are reproduced on the drawings, a copyright release form from the holding institution must be acquired.

Finally, an index to the drawings can be included for sets with ten or more sheets to help users quickly locate particular views.

3.3.2 Existing Conditions Plan
An existing conditions plan is a graphic that documents and identifies current elements present in the site. The level of detail and accuracy varies depending on the type of site and scale of information required for the project.

3.3.3 Site Survey/Topographic Plan
Some sites may require a site survey or topographic plan, such as a mining site or water system. If topographic or survey information is obtained, it should be presented as existing conditions.

3.3.4 Section
Section drawings are vertical cuts through a structure or site that show the vertical arrangement of spaces and objects. Section drawings are useful because they provide vertical information, as well as structural details and relation of function.

3.3.5 Elevation
An elevation is an orthographic projection (side view). The viewer is usually perpendicular to the frontal plane of the object. Section and elevation drawings are more realistic and easier to comprehend than plan drawings. All flat surfaces parallel to the drawing surface and perpendicular to the observer's line of site retain their scaled size, shape, and proportion.

3.3.6 Detail
A detail is a small-scale drawing that delineates the fine features of a site or structure element. It may include elevations, sections, or plan views of a specific site feature.

3.3.7 Site Perspective
A perspective is a dynamic view of three-dimensional objects created when the viewer is looking at an object from an angle. Variables in perspective drawings include distance of the viewer from the object and the angle of view relative to the surfaces of the object. There are several methods for setting up perspective drawings, including one- and two-point perspectives and the use of perspective charts.

3.3.8 Axonometric

Axonometric drawings show overall space relationships in perspective-like drawings and are most useful for showing plan views in three dimensions. Axonometric drawings use three axes of length, width, and height for measurement. Measurements remain absolute rather than the relative dimensions of a perspective.

3.3.9 Isometric

An isometric is a way of drawing a three-dimensional object without the distortions created by perspective. In a drawing based on true perspective, parallel lines converge in a vanishing point, just like objects appear in real life. An isometric drawing shows that parallel lines in actuality do not converge, and represents the object's real proportions and spatial relationships. In an isometric drawing, all three visible surfaces have equal emphasis.

3.3.10 Cutaway or Exploded View

A drawing that graphically removes portions of a subject to reveal details underneath.

4.0 COMPUTER AIDED DRAFTING AND DESIGN RECORDATION (CAD)

4.1 Archival Media

Final plots must be made on Vellum that conforms to Federal Vellum Specifications UU-P-561H, Type IV.

4.2 Plotter Requirements

Inkjet plotters that use pigmented inks meet the standards of the Library of Congress. Die-based inks are not acceptable.

Plots made by electrostatic and laser plotters meet archival standards and therefore may be used to make the final plots of HAER drawings.

PDF files may be presented to the HDP office so that they can be printed on archival material for submission to the Library of Congress.

4.3 Text

HAER recommends the use of a sans-serif or Roman serif font for drawing text. Only one font for major titles should be used per project. All fonts should be TrueType (TTF) format.

TITLES

Titles for sheets should be 1" high and use all upper-case lettering.
(suggested font - Times Bold 108pt)

Sub-Titles

Sub-Titles for drawings should be $^{3}/_{4}$"high and use upper- and lower-case lettering. Note: This size may also be used for Titles.
(suggested font - Times bold 72pt)

Main Labels

Main labels for drawings should be $^{3}/_{8}$" high and use upper- and lower-case lettering. (suggested font - Times New Roman 36pt)

Minor Labels

Minor labels for drawings should be $^{1}/_{4}$" high and use upper- and lower-case lettering.
(suggested font - Technical 24pt)

General Text, Notes and Small Titles

General text, notes, and small titles should be $^{3}/_{16}$" high and use upper- and lower-case lettering.
(suggested font - Technical or Arial 20pt)

DIMENSIONS AND SECONDARY KEYS

Dimensions and secondary keys should be $^{3}/_{16}$" high and use all upper-case lettering.
(suggested font – Arial 16pt)

NO LETTERING SHOULD BE LESS THAN $^{1}/_{8}$" HIGH.

4.4 Line Weights

HAER follows a simple rule for layer colors and their assigned pen weights**:** AutoCAD colors from **left/lightest pen weight** to **right/heavier pen weight**. We have created two **plotstyles** that use the following line-weight settings.

Full Size Plot 24x36 or 34x44

Red	Lightest Pen Weight---------	0.1mm
Yellow		0.15mm
Green		0.25mm
Cyan		0.3mm
Blue		0.5mm
Magenta		0.75mm
White/Black	Heavier Pen Weight---------	1.0mm
Color 8		1.3mm
Color 9		1.5mm
Color 10		1.5mm
Color 11		1.5mm
Color 12		1.5mm
Color 100 (Border)		1.0mm
Color 200 (Border)		0.6mm

Reduced Size Plot 8.5x11 or 11x17

Red	Lightest Pen Weight---------	0.05 mm
Yellow		0.075mm
Green		0.15mm
Cyan		0.2mm
Blue		0.3mm
Magenta		0.4mm
White/Black	Heavier Pen Weight --------	0.5mm
Color 8		0.6mm
Color 9		0.7mm
Color 10		0.8mm
Color 11		0.9mm
Color 12		1.0mm
Color 100 (Border)		0.4mm
Color 200 (Border)		0.2mm

4.5 Layer Naming Standards

HAER recommends the use of a layering system based on the *CAD Layer Guidelines* developed by the American Institute of Architects (AIA), as adapted to the specific needs of the project.