TECHNICAL SPECIFICATIONS

FORT OWEN EAST BARRACKS PRESERVATION PROJECT #22-08

Montana Fish, Wildlife & Parks
Stevensville, Montana
14 April 2022
For Bid

Prepared by:
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SECTION 011000 - SUMMARY

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Work covered by the Contract Documents.
2. Use of premises.
3. Work restrictions.
4. Specification formats and conventions.

B. Primary Importance:

1. Fort Owen is a Montana State Park surrounded by a ranch in private ownership. The contractor shall respect the rancher's privacy and property, coordinating use as necessary. The work hours shall be strictly enforced.
2. Fort Owen is recognized by the state and federal government as being individually listed in the National Register of Historic Places. All work shall comply with the Secretary of the Interior's Guidelines for the Preservation of Historic Properties.

a. **Preservation** is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.
b. The grounds and structures within the site, not specifically called out for work in these documents, shall be protected from damage.
c. Excavation work shall be monitored by Montana Fish, Wildlife & Parks and an archaeologist. Digging in areas other than indicated on the drawings is forbidden. The Contractor shall be responsible for repairing any damage caused by the execution of this Contract.
d. Each employee of the Contractor and his sub-contractors shall be informed of the historic nature of Fort Owen. Any artifacts discovered in the course of the work – nails, glass, bones, wood, etc. – are valuable and are the property of the State of Montana. Any such findings shall be reported to Montana Fish, Wildlife & Parks and NOT be removed from site by other than Montana Fish, Wildlife & Parks.

3. All existing materials scheduled to remain will be protected from damage.

1.2 WORK COVERED BY CONTRACT DOCUMENTS

A. Project Identification: Fort Owen East Barracks Preservation

1. Project Location: Fort Owen State Park; Stevensville, Montana

B. Owner: Montana Fish, Wildlife & Parks

1. Project Manager: Philip Jagoda, P.E., Lead Engineer
2. Park Manager: Maci MacPherson
3. Regional Park Manager: Loren Flynn

C. Architect: Gilmore Franzen Consulting LLC, 180 North Low Bench Road, Gallatin Gateway, MT 59730

D. The Work consists of the following:

1. Repairing and repointing adobe, including removal of cementitious parging, patches, and slurry.
2. Repairing and repointing concrete block.
3. Treatment of wood with protective clear coating.
4. Replacement of one viga.
5. Flashing work at two chimneys.
6. Painting of steel plates at east wall.
7. Alternate No. 1: Removal of concrete apron and reconstruction of exterior face of east adobe wall.
8. Alternate No. 2: Removal of deteriorated lower two courses of adobe at interior face of east adobe wall in Rom #100 and #103.
9. Alternate No. 3: Replacement of entry ramp.

1.3 TYPE OF CONTRACT

A. Project will be constructed under a single prime contract.

1.4 USE OF PREMISES

A. General: Contractor shall have full use of premises for construction operations, including use of Project site, during construction period. Contractor's use of premises is limited only by Owner's right to perform work or to retain other contractors on portions of Project.

B. Use of Site: Limit use of premises to areas within the boundaries of Fort Owen State Park. Do not disturb portions of Project site beyond areas in which the Work is indicated.

C. Use of Existing Building: Maintain existing building in a weathertight condition throughout construction period. Repair damage caused by construction operations. Protect building and its occupants during construction period.

D. Fort Owen State Park is open to the public for touring from 9:00 a.m. to 6:00 p.m. daily.
1. Contractor shall coordinate with Montana Fish, Wildlife & Parks to determine which days the park should be closed to visitors.
2. Contractor shall provide signage indicating closure.
3. Contractor shall protective barriers as required to protect the public from the Work.
4. The entrance gates at the road are closed between 6:00 pm and 9:00 am.
5. MFWP will have the ability to close the East Barracks for a few days to facilitate the work, at the request of the Contractor. Contractor shall provide two-week notice for such closing.

E. The construction site is adjacent to an active ranch and education center. Limit on-site equipment operation and other noise generating activities to the hours from 8:00 a.m. to 6:00 p.m. in any one construction day.

1. If Contractor wants longer hours on site, Contractor shall coordinate with MFWP, giving two weeks' notice.
2. The Contractor shall provide full-time continuous on-site management personnel for project oversight. Management personnel shall be properly trained and experienced in the position held. While scheduled work operations are being conducted by the Contractor or subcontractors, regardless of day or work hour, on-site management oversight by the Contractor shall be provided.
3. The Contractor shall be responsible for the safety of all workers and the quality of all work. The Contractor's designated on-site job foreman or supervisor shall be responsible for supervising and implementing the safety and quality control plans required by this Contract, the job foreman's staff or assigned technicians may assist.

F. The Contractor is responsible for proper storage of materials within the construction limits of the Park. Coordinate deliveries so that deliveries fit available storage area. Refer to Drawings for designated staging/storage area available to the Contractor. Final staging location shall be coordinated with and reviewed by MFWP.

G. The following conditions shall be followed during the Contractor's presence in the Park:

1. To prevent the unnatural attractants to animals, no foods, garbage, drinks, trash, or food and drink containers shall be placed outside trailers or buildings, except during actual use. Outside cooking at the construction site is prohibited.
2. Pets are prohibited.
3. Feeding of any wildlife or livestock is prohibited.

H. Preservation of Natural Features: Confine all operations to work limits of the project. Prevent damage to natural surroundings. Restore damaged areas, at no additional expense to the Owner.

I. Existing Utilities: Notify Architect/Engineer and utility companies of proposed locations and times for excavation.
1. Contractor shall be responsible for locating and preventing damage to known utilities. If damage occurs, repair utility at no additional expense to the Owner.
2. If damage occurs to an unknown utility, repair utility. An equitable adjustment will be made in accordance with Contract.
3. Do not interrupt existing utility services serving occupied buildings without the approval of the Owner's representative and utility authority. 72 hours-notice is required for any planned utility interruptions. Substitute utility service shall be provided for utility service interruptions lasting more than four hours. To the greatest extent possible, utility service interruptions shall be limited to non-working hours.

1.5 FIELD VERIFICATION

A. Contractor to verify and document existing conditions prior to start of work or ordering products.

1.6 CONTRACTOR-FURNISHED ITEMS

A. All materials, including borrow and aggregates, shall be Contractor-furnished from outside the park, unless otherwise indicated.

1.7 OWNER'S OCCUPANCY REQUIREMENTS

A. The building will be occupied during the construction period.

B. Contractor shall provide protected entry into at least one of the building rooms for visiting public.

1.8 WORK RESTRICTIONS

A. On-Site Work Hours: Work shall be generally performed at the existing building during normal business working hours of 8:00 a.m. to 6:00 p.m., Monday through Friday, except as otherwise indicated by the Park.

1. If later stopping of work is required to address threatening weather, review with the Owner’s Project Coordinator.

B. Existing Utility Interruptions: Do not interrupt utilities serving facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated:

1. Notify Owner not less than two days in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without Owner's written permission.
3. Contractor shall be responsible for making **all** necessary repairs if any damage occurs to a “located” utility.

C. Nonsmoking Building: Smoking is not permitted within the building or within 25 feet of entrances.

D. Controlled Substances: Use of tobacco products and other controlled substances on Project site is not permitted.

1.9 SPECIFICATION FORMATS AND CONVENTIONS

A. Specification Content: The Specifications use certain conventions for the style of language and the intended meaning of certain terms, words, and phrases when used in particular situations. These conventions are as follows:

1. Abbreviated Language: Language used in the Specifications and other Contract Documents is abbreviated. Words and meanings shall be interpreted as appropriate. Words implied, but not stated, shall be inferred as the sense requires. Singular words shall be interpreted as plural, and plural words shall be interpreted as singular where applicable as the context of the Contract Documents indicates.
2. Imperative mood and streamlined language are generally used in the Specifications. Requirements expressed in the imperative mood are to be performed by Contractor. Occasionally, the indicative or subjunctive mood may be used in the Section Text for

clarity to describe responsibilities that must be fulfilled indirectly by Contractor or by others when so noted.

a. The words "shall," "shall be," or "shall comply with," depending on the context, are implied where a colon (:) is used within a sentence or phrase.

3. Specification requirements are to be performed by Contractor unless specifically stated otherwise.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 011000

SECTION 012200 - UNIT PRICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes administrative and procedural requirements for unit prices.

1.2 DEFINITIONS

A. Unit price is a price per unit of measurement for materials, equipment, or services, or a portion of the Work, added to or deducted from the Contract Sum by appropriate modification, if the scope of Work or estimated quantities of Work required by the Contract Documents are increased or decreased.

1.3 PROCEDURES

A. Unit prices include all necessary material, plus cost for delivery, installation, insurance, applicable taxes, overhead, and profit.

B. Measurement and Payment: See individual Specification Sections for work that requires establishment of unit prices. Methods of measurement and payment for unit prices are specified in those Sections.

C. Owner reserves the right to reject Contractor's measurement of work-in-place that involves use of established unit prices and to have this work measured, at Owner's expense, by an independent surveyor acceptable to Contractor.

D. List of Unit Prices: A schedule of unit prices is included in Part 3. Specification Sections referenced in the schedule contain requirements for materials described under each unit price.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 SCHEDULE OF UNIT PRICES

A. The Unit Price numbering below matches the Item # on the Bid Proposal Form.

B. Unit Price 2: CMU patching.

1. Description: Removal and replacement of deteriorated or missing cmu parts.
2. Unit of Measurement: Linear foot.

C. Unit Price 3: Repointing of concrete block.

1. Description: Removal and replacement of deteriorated or missing mortar, including at cracks.
2. Unit of Measurement: Linear foot.

D. Unit Price 4: Repair/patching of adobe.

1. Description: Removal of concrete and patching of adobe.
2. Unit of Measurement: Square foot.

E. Unit Price 5: Repointing of adobe.

1. Description: Removal and replacement of deteriorated or missing mortar. This includes removal of concrete patching or mortar in the joint.
2. Unit of Measurement: Linear foot.

F. Unit Price 6: Fabrication of adobe.

1. Description: Removal and replacement of deteriorated or missing adobe brick with 9" deep adobe brick.
2. Unit of Measurement: One brick unit 9" deep.

G. Unit Price 12: Training of crew by visiting adobe specialist.

1. Description: Dedication of masons' time to being trained by visiting adobe specialist.
2. Unit of Measurement: Three masons, three days (9 man days).

H. Unit Price 13: Removal of concrete apron along base of east wall per Detail 2, Sheet 7. (Part of Alternate No. 1)

1. Description: Removal of concrete apron.
2. Unit of Measurement: Square foot.

I. Unit Price 14: Removal of adobe and placement of replica adobe per Detail 2, Sheet 7. (Part of Alternate No. 1)

1. Description: Removal and replacement of deteriorated or missing adobe brick with 9" deep adobe brick.
2. Unit of Measurement: Square foot.

J. Unit Price 15: Provision of bentonite seal, drain pipe, and gravel fill per Detail 2, Sheet 7. (Part of Alternate No. 1)

1. Description: Provide bentonite seal, drain pipe, and gravel fill per Detail 2, Sheet 7.
2. Unit of Measurement: Square foot.

K. Unit Price 16: Replace adobe at base of two interior walls per Details 1 & 2, Sheet 7. (Alternate No. 2)

1. Description: Removal of lower two courses of adobe and replacement with replica adobe (of half-wall depth).
2. Unit of Measurement: Square feet.

L. Unit Price 17: Replace ramp with low-slop ramp integrated into walkway per Sheet 10. (Alternate No. 3)

1. Description: Dedication of masons time to being trained by visiting adobe specialist.
2. Unit of Measurement: One mason, one day.

END OF SECTION 012200

SECTION 012300 - ALTERNATES

PART 1 - GENERAL

1.1 SUMMARY

A. This section includes non-technical descriptions of Alternates. Refer to specific sections of the Specifications and to Drawings for technical descriptions of Alternates.

B. Coordinate related work and modify surrounding work as required to integrate Alternates into the Work.

C. Base Bid includes all work indicated, except work described as Alternates.

D. The Owner reserves the right to award none, any one, or more in any order, or all Alternates in combination with work covered by Base Bid.

E. Alternates will not be awarded without awarding Base Bid.

F. The Owner reserves the right to determine low bid as Base Bid alone or sum of Base Bid and any combination of Alternates.

G. Each Alternate is intended to cover all work required for a complete finished job.

H. Alternates are additive to the Base Bid. Provide costs in appropriate spaces provided on Bid Form.

I. Submit bids for Base Bid and all Alternates listed on Bid Form. Failure to quote an amount, or insertion of the words "no bid," "none" or words of similar meaning, will be considered as not completing the proposal and may constitute disqualification of entire bid, at the Owner’s discretion. When there is no change in base bid due to using the Alternate, use the words "No Change". The words "No Change" will be interpreted to mean that work described in the Alternate shall be completed at no adjustment or change in cost of Base Bid.

J. Base Bid and Alternates are exclusive in their scope of work. There is no overlap between or among Base Bid and Alternates. The cost of any item of work shall be included only once, in Base Bid or in Alternates.

1.2 DESCRIPTION OF ADDITIVE ALTERNATES

A. Additive Alternate 1: Remove existing concrete apron and deteriorated adobe, provide bentonite seal and install replica adobe, drain pipe and gravel fill at exterior side of east wall, as shown on Details 1 & 2, Sheet 7 of the construction drawings.

B. Additive Alternate 2: Remove existing deteriorated adobe at lower two courses of interior side of east wall. Install replica adobe as shown on Details 1 & 2, Sheet 7 of the construction drawings.

C. Additive Alternate 3: Remove existing entry ramp and provide replacement ramp as shown on Sheet 10 of the construction drawings.

PART 2 - PRODUCTS NOT USED

PART 3 - EXECUTION NOT USED

END OF SECTION 012300

SECTION 013591 - HISTORIC TREATMENT PROCEDURES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes general protection and treatment procedures for entire Project and the following specific work:

1. Historic removal and dismantling.
2. Shoring of existing wall.

1.2 DEFINITIONS

A. Consolidate: To strengthen loose or deteriorated materials in place.

B. Dismantle: To disassemble and detach items by hand from existing construction to the limits indicated, using small hand tools and small one-hand power tools, so as to protect nearby historic surfaces; and legally dispose of dismantled items off-site, unless indicated to be salvaged or reinstalled.

C. Existing to Remain: Existing items that are not to be removed or dismantled.

D. Historic: Spaces, areas, rooms, surfaces, materials, finishes, and overall appearance which are important to the successful restoration and reconstruction as determined by Architect/Engineer. All the materials being repaired in this Project are designated historic materials.

E. Match: To blend with adjacent construction and manifest no apparent difference in material type, species, cut, form, detail, color, grain, texture, or finish; as approved by Architect/Engineer. This does not discount the inherent improvements associated with new materials, provided they are not on visible surfaces.

F. Reconstruct: To remove existing item, replicate damaged or missing components, and reinstall in original position.

G. Refinish: To remove existing finishes to base material and apply new finish to match original, or as otherwise indicated.

H. Reinstall: To protect removed or dismantled item, repair and clean it as indicated for reuse, and reinstall it in original position, or where indicated.

I. Remove: Specifically for historic spaces, areas, rooms, and surfaces, the term means to detach an item from existing construction to the limits indicated, using hand tools and hand-operated power equipment, and legally dispose of it off-site, unless indicated to be salvaged or reinstalled.

J. Repair: To correct damage and defects, retaining existing materials, features, and finishes while employing as little new material as possible. Includes patching, piecing-in, splicing, consolidating, or otherwise reinforcing or upgrading materials.

K. Replace: To remove, duplicate, and reinstall entire item with new material. The original item is the pattern for creating duplicates unless otherwise indicated.

L. Replicate: To reproduce in exact detail, materials, and finish unless otherwise indicated.

M. Reproduce: To fabricate a new item, accurate in detail to the original, and in either the same or a similar material as the original, unless otherwise indicated.

N. Restore: To consolidate, replicate, reproduce, repair, and refinish as required to achieve the indicated results.

O. Retain: To keep existing items that are not to be removed or dismantled.

P. Reversible: New construction work, treatments, or processes that can be removed or undone in the future without damaging historic materials unless otherwise indicated.

Q. Salvage: To protect removed or dismantled items and deliver them to Owner.

R. Stabilize: To provide structural reinforcement of unsafe or deteriorated items while maintaining the essential form as it exists at present; also, to reestablish a weather-resistant enclosure.

S. Strip: To remove existing finish down to base material unless otherwise indicated.

1.3 MATERIALS OWNERSHIP

A. Historic items, relics, and similar objects including, but not limited to, cornerstones and their contents, commemorative plaques and tablets, nails and hardware, glass, antiques, and other items of interest or value to Owner that may be encountered during removal and dismantling work remain Owner's property. Carefully dismantle and salvage each item or object.

B. Coordinate with Owner's architect, who will establish special procedures for dismantling and salvage.

1.4 STORAGE AND PROTECTION OF HISTORIC MATERIALS

A. Salvaged Historic Materials:
1. Clean only loose debris from salvaged historic items.
2. Pack or crate items after cleaning; cushion against damage during handling. Label contents of containers.
3. Store items in a secure area until pick-up by Owner.

B. Historic Materials for Reinstallation:
1. Repair and clean historic items as indicated and to functional condition for reuse.
2. Pack or crate items after cleaning and repairing; cushion against damage during handling. Label contents of containers.
3. Reinstall items in locations indicated. Comply with installation requirements for new materials and equipment unless otherwise indicated. Provide connections, supports, and miscellaneous materials to make item functional for use indicated.

C. Existing Historic Materials to Remain: Protect construction indicated to remain against damage and soiling from construction work.

D. Storage and Protection: When taken from their existing locations, catalog and store historic items within a weathertight enclosure where they are protected from wetting by rain, snow, condensation, or ground water, and from freezing temperatures.

1. Identify each item with a nonpermanent mark to document its original location. Indicate original locations on plans elevations, sections, or photographs by annotating the identifying marks.
2. Secure stored materials to protect from theft.

1.5 SUBMITTALS: Submit shoring plan prior to beginning foundation work, and proposed method of building protection.

PART 2 - PRODUCTS - (Not Used)

PART 3 - EXECUTION

3.1 PREPARATION

A. Provide temporary supports and protection for parts of the structure to remain. Complete dismantling that might damage new construction before starting new work.

B. Where the drawings indicate excavation along the east wall, proceed in four-foot-long portions maximum. Provide and secure wood cribbing to support wall above.

3.2 HISTORIC REMOVAL AND DISMANTLING EQUIPMENT

A. Removal Equipment: Use only hand-held tools except as follows or unless otherwise approved by Architect on a case-by-case basis:

B. Dismantling Equipment: Use manual, hand-held tools, except as follows or otherwise approved by Architect/Engineer on a case-by-case basis:

1. Hand-held power tools and cutting torches are permitted only as submitted in the historic treatment program. They must be adjustable so as to penetrate or cut only the thickness of material being removed.
2. Pry bars more than 18 inches long and hammers weighing more than 2 lb are not permitted for dismantling work.
3. No vibrating equipment shall be permitted.

3.3 EXAMINATION

A. Preparation for Removal and Dismantling: Examine construction to be removed or dismantled to determine best methods to safely and effectively perform removal and dismantling work. Examine adjacent work to determine what protective measures will be necessary. Make explorations, probes, and inquiries as necessary to determine condition of construction to be removed or dismantled and location of utilities and services to remain that may be hidden by construction that is to be removed or dismantled.

1. Verify that affected utilities have been disconnected and capped.
2. Inventory and record the condition of items to be removed and dismantled for reinstallation or salvage.
3. Before removal or dismantling of existing building elements that will be reproduced or duplicated in final Work, make permanent record of measurements, materials, and construction details required to make exact reproduction.

B. Survey of Existing Conditions: Record existing conditions by use of preconstruction photographs.

3.4 PROTECTION, GENERAL

A. Ensure that supervisory personnel are on-site and on duty when historic treatment work begins and during its progress.

B. Protect persons, motor vehicles, surrounding surfaces of building, building site, plants, and surrounding buildings from harm resulting from historic treatment procedures.

1. Use only proven protection methods, appropriate to each area and surface being protected.
2. Provide barricades, barriers, and temporary directional signage to exclude public from areas where historic treatment work is being performed.
3. Erect temporary protective covers over walkways and at points of pedestrian and vehicular entrance and exit that must remain in service during course of historic treatment work.
4. Contain dust and debris generated by removal and dismantling work and prevent it from reaching the public or adjacent surfaces.
5. Provide shoring, bracing, and supports as necessary. Do not overload structural elements.
6. Protect nearby adjacent components of the building, such as other masonry units, windows, trim, doorways, etc.
7. Protect floors and other surfaces along haul routes from damage, wear, and staining.

C. Scaffolding: Scaffolding shall not be allowed to be anchored to the masonry units of the building. If scaffolding is leaning against the building, all such contact points shall be securely isolated from the building with protective cushioning that is stable.

D. Temporary Protection of Historic Materials:

1. Protect existing historic materials with temporary protections and construction. Do not deface or remove existing materials.
2. Do not attach temporary protection to historic surfaces except as indicated as part of the historic treatment program and approved by Architect.

E. Comply with each product manufacturer's written instructions for protections and precautions. Protect against adverse effects of products and procedures on people and adjacent materials, components, and vegetation.

F. Protection of Masonry: During construction, cover tops of walls, projections, and sills with waterproof sheeting at end of each day's work. Cover partially completed masonry when construction is not in progress.

1. Extend cover a minimum of 24 inches down both sides of walls and hold cover securely in place.
2. See Masonry Specification sections for further protection requirements.

G. Utility and Communications Services:
1. Notify Owner, Architect, authorities having jurisdiction, and entities owning or controlling wires, conduits, pipes, and other services affected by the historic treatment work before commencing operations.
2. Disconnect and cap pipes and services as required by authorities having jurisdiction, as required for the historic treatment work.
3. Maintain existing services unless otherwise indicated; keep in service, and protect against damage during operations. Provide temporary services during interruptions to existing utilities.

3.5 PROTECTION FROM FIRE

A. General: Follow:

1. Comply with NFPA 241 requirements unless otherwise indicated.
2. Remove and keep area free of combustibles including, rubbish, paper, waste, and chemicals, except to the degree necessary for the immediate work.
   a. If combustible material cannot be removed, provide fire blankets to cover such materials.
3. Prohibit smoking by all persons within Project work and staging areas.

B. Fire Extinguishers, Fire Blankets, and Rag Buckets: Maintain fire extinguishers, fire blankets, and rag buckets for disposal of rags with combustible liquids. Maintain each as suitable for the type of fire risk in each work area. Ensure that nearby personnel and the fire watch are trained in fire-extinguisher and blanket operation.

C. No flamecutting or explosives shall be permitted.

3.6 GENERAL HISTORIC TREATMENT

A. Ensure that supervisory personnel are present when historic treatment work begins and during its progress.

B. Halt the process of deterioration and stabilize conditions unless otherwise indicated. Perform work as indicated on Drawings. The following tenets have guided the preparation of the bid documents and shall be respected by the contractors:

1. Retain as much existing material as possible; existing divots and holes are to remain. Holes caused by removal of concrete patches shall be repaired.
2. Use additional material or structure to reinforce, strengthen, prop, tie, and support existing material or structure.
3. Use reversible processes wherever possible.

4. Use historically accurate repair and replacement materials and techniques unless otherwise indicated.

C. Record existing work before each procedure (preconstruction) and progress during the work with digital preconstruction documentation photographs. The photographs will be labeled with building name and keyed to the associated location on the building. Each of the following shall be documented with a minimum of three photographs before, during, and after restoration:

1. Each material type.
2. Each damage/repair type.
3. Each building elevation.

D. Notify Architect of visible changes in the integrity of material or components whether due to environmental causes including biological attack, UV degradation, freezing, or thawing; or due to structural defects including cracks, movement, or distortion.

1. Do not proceed with the work in question until directed by Architect.

E. Where missing features are indicated to be repaired or replaced, provide features whose designs are based on accurate duplications rather than on conjectural designs, subject to approval of Architect.

F. Where Work requires existing features to be removed or dismantled and reinstalled, perform these operations without damage to the material itself, to adjacent materials, or to the substrate.

G. Identify new and replacement materials and features with permanent marks hidden in the completed work to distinguish them from original materials. Record a legend of identification marks and the locations of the items on record Drawings.

3.7 HISTORIC REMOVAL AND DISMANTLING

A. General: Have removal and dismantling work performed by a qualified historic removal and dismantling specialist. Ensure that historic removal and dismantling specialist's field supervisors are present when removal and dismantling work begins and during its progress.

B. Removing and Dismantling Items on or near Historic Surfaces:

1. Do not use pry bars. Protect historic surface from contact with or damage by tools.
2. Unfasten items to be removed, in the opposite order from which they were installed.
3. Support each item as it becomes loosened to prevent stress and damage to the historic surface.
4. Dismantle anchorages.

C. Masonry Walls:

1. Remove masonry carefully and erect temporary bracing and supports as needed to prevent collapse of materials being removed.
2. Remove wall in easily managed pieces.

3. During removal, Contractor is responsible for the stability of the partially remaining wall. Notify Architect of the condition of temporary bracing for wall if work is temporarily stopped during the wall's removal.

END OF SECTION 013591

SECTION 040150 – UNIT MASONRY REPOINTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings of the Contract apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Repointing of concrete masonry unit joints.
2. Repointing and pointing of adobe.
3. Alternate No. 1: Installation of through-wall flashing at base of adobe wall.

B. Related Sections: Section 045000 “Adobe and CMU Repair.”

1.3 ALTERNATE PRICES

A. Alternate No. 1: Remove concrete apron and provide replica adobe faces along length of east wall. See Details 1 & 2, Sheet 7 for all work entailed.

B. Alternate No. 2: Rebuild lower two courses of interior east walls of Room #100 and #103. See Details 1 & 2, Sheet 7 for all work entailed.

1.4 UNIT PRICES

Work of this Section is affected by unit prices specified in Section 012200 "Unit Prices."

1. Unit prices apply to authorized work covered by estimated quantities.
2. Unit prices apply to additions to and deletions from Work as authorized by Change Orders.

1.5 DEFINITIONS

A. CMU(s): Concrete masonry unit(s).

B. Adobe: Clay-based unbaked masonry unit.

C. Rebuilding (Setting) Mortar: Mortar used to set and anchor masonry in a structure, distinct from pointing mortar installed after masonry is set in place.

1.6 SEQUENCING

A. See Section 045000 “Adobe and CMU Repair” for sequencing of work.

1.7 QUALITY ASSURANCE

A. Contractor shall provide skilled labor in accordance with the requirements stated in Section 045000 “Adobe and CMU Repair.”

B. Adobe Mortar Testing:

1. Compressive Strength: Contractor shall cast 2” mortar cubes from mortar trial mixtures for testing to verify strength. Test specimens shall be sun-dried and ambient-cured for seven (7) days prior to testing.

C. Mockups: Build mockups to demonstrate aesthetic effects and to set quality standards for materials and execution.

1. Repointing of adobe:
   a. 24 lineal inches of joint preparation.
   b. 24 lineal inches of pointing.
2. Repointing of concrete masonry units.
   a. 24 lineal inches of joint preparation.
   b. 24 lineal inches of pointing.

3. Protect accepted mockups from the elements with weather-resistant membrane.
4. Approval of mockups is for color, texture, and quality of repointing; and aesthetic qualities of workmanship.

   a. Approval of mockups is also for other material and construction qualities specifically approved by Architect in writing.
   b. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.

5. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Store masonry units on elevated platforms in a dry location. If units are not stored in an enclosed location, cover tops and sides of stacks with waterproof sheeting, securely tied. If units become wet, do not install until they are dry.

B. Store cementitious materials on elevated platforms, under cover, and in a dry location. Do not use cementitious materials that have become damp.

C. Store aggregates where grading and other required characteristics can be maintained and contamination avoided.

D. Store hydrated lime in manufacturer's original and unopened containers. Discard lime if containers have been damaged or have been opened for more than two days.

E. Store masonry accessories, including metal items, to prevent corrosion and accumulation of dirt and oil.

1.9 FIELD CONDITIONS

A. Protection of Masonry: During construction, cover partially completed masonry when construction is not in progress.

B. Stain Prevention: Prevent grout, mortar, and soil from staining the face of masonry to be left exposed or painted. Immediately remove grout, mortar, and soil that come in contact with such masonry.

1. Protect base of walls from rain-splashed mud and from mortar splatter by spreading coverings on ground and over wall surface.
2. Protect sills, ledges, and projections from mortar droppings.
3. Protect surfaces of window and door frames, as well as similar products with painted and integral finishes, from mortar droppings.
4. Turn scaffold boards near the wall on edge at the end of each day to prevent rain from splashing mortar and dirt onto completed masonry.

C. Cold-Weather Requirements: Do not use frozen materials or materials mixed or coated with ice or frost. Do not build on frozen substrates. Remove and replace unit masonry damaged by frost or by freezing conditions. Comply with cold-weather construction requirements contained in TMS 602/ACI 530.1/ASCE 6.

1. Cold-Weather Cleaning: Use liquid cleaning methods only when air temperature is 40 deg F and higher and will remain so until masonry has dried, but not less than seven days after completing cleaning.

D. Hot-Weather Requirements: Comply with hot-weather construction requirements contained in TMS 602/ACI 530.1/ASCE 6.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Source Limitations for Mortar Materials: Obtain mortar ingredients of a uniform quality, including color for exposed masonry, from single manufacturer for each cementitious component and from single source or producer for each aggregate.

2.2 ADOBE MORTAR MATERIALS

A. Same as adobe mix, with modifications noted below. Referred to as “mud mortar.”

B. Sand:
1. From Yoder Gravel. If sand is sourced from a location other than Yoder Gravel, contractor shall have proposed sand checked for mineralogy and particle shape.
2. As per testing, major constituents shall be as follows, in approximate order of decreasing abundance:
a. Quartz

b. Feldspars (plagioclase and potassium feldspars in approximately equal amounts)
c. Micas (biotite, chlorite, and white mica)
d. Iron oxides/hydroxides
e. Amphibole and tourmaline

3. Sand particles shall be predominantly angular and of a geologically young source.
4. Maximum size of 1.5mm, with an estimated 90-95% of particles passing No.16 US standard sieve.
5. Blend several sands as necessary to achieve suitable match.

C. Hydrated Lime: ASTM C207 Type SA. Bondcrete by Graymont.

D. Water: Potable.

E. Mix:
1. Clay: 10-15% silt and clay.
2. Sand: 75%. Particle size distribution as stated in the testing report *Fort Owen East Barracks:Materials Analysis of Historic Adobe*, dated April 6, 2022 for percentages of constituents in original adobe mortar.
3. Hydrated lime: Up to ¼ part of the mix.
4. Supplement the clay with an equal quantity of fine angular particles screened from the clay.
5. No additives.
6. Compressive strength: no more than 300 psi.
7. Moisture content: no more than 15% at the time of installation.
8. The actual quantities of the above should be determined in the field by evaluating the plasticity or workability that can be achieved by combining the clay with incremental amounts of water and grit.

2.3 DRY-PACK MORTAR

A. As recommended by Cornerstones:

1. Dry dirt (with clay content) that has been screened.
2. Do not use sand.
3. Add screened dry dirt to the normal wet mortar mix until the wet mortar mix feels almost completely dry to the touch.
4. The resulting mix will hold its shape when a handful of it is squeezed together. The moisture content will be about 5%.

B. Dry-packing allows repairs to occur with a minimal amount of shrinkage.

C. Dry-pack mortar: dry dirt that has been screened. Do not use sand. Add the screened dry dirt to the normal, wet mortar mis until the wet mortar mix feels almost completely dry to the touch, i.e., the resulting mix will hold it s shape when a handful of it is squeezed together (moisture content of about 5%).

D. Always moisten all surfaces before dry-packing to create good adhesion.

2.4 MORTAR MATERIALS FOR CMU

A. Portland Cement: ASTM C 150/C 150M, Type I or II, except Type III may be used for cold-weather construction. Provide natural color or white cement as required to produce mortar color indicated.

1. Alkali content shall not be more than 0.1 percent when tested according to ASTM C 114.

B. Hydrated Lime: ASTM C 207, Type S.

C. Portland Cement-Lime Mix: Packaged blend of portland cement and hydrated lime containing no other ingredients.

D. Masonry Cement: Not allowed.

E. Mortar Cement: Not allowed.

F. Mortar Pigments: Natural and synthetic iron oxides and chromium oxides, compounded for use in mortar mixes and complying with ASTM C 979/C 979M. Use only pigments with a record of satisfactory performance in masonry mortar. Only for potential use at cmu joints.

G. Aggregate for Mortar: ASTM C 144.

1. For mortar that is exposed to view, use washed aggregate consisting of natural sand or crushed stone.
2. For joints less than 1/4 inch thick, use aggregate graded with 100 percent passing the No. 16 sieve.
3. White-Mortar Aggregates: Natural white sand or crushed white stone.
4. Colored-Mortar Aggregates: Natural sand or crushed stone of color necessary to produce required mortar color.

H. Cold-Weather Admixture: Nonchloride, noncorrosive, accelerating admixture complying with ASTM C 494/C 494M, Type C, and recommended by manufacturer for use in masonry mortar of composition indicated.

I. Water: Potable.

2.5 THROUGH-WALL FLASHING

A. Type 304 stainless steel, 24 gauge.

B. Metal Flashing: Provide metal flashing as follows:

1. Fabricate through-wall flashing with drip edge unless otherwise indicated. Fabricate by extending flashing 1/2 inch out from wall, with outer edge bent down 30 degrees and hemmed.
2. Fabricate metal drip edges for ribbed metal flashing from plain metal flashing of same metal as ribbed flashing and extending at least 3 inches into wall with hemmed inner edge to receive ribbed flashing and form a hooked seam. Form hem on upper surface of metal so that completed seam sheds water.

2.6 MISCELLANEOUS MASONRY ACCESSORIES

A. Compressible Filler: Oakum.

2.7 MORTAR MIXES

A. General: Do not use admixtures, including pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, or other admixtures unless otherwise indicated. See Repointing specification for mortar for face brick.

B. Mortar for Adobe: Same mix as for the adobe units. See Specification Section 045000.

C. Mortar for Unit Masonry: Comply with ASTM C 270, Proportion Specification. Provide the following types of mortar for applications stated unless another type is indicated.

1. For exterior, above-grade, concrete masonry unit walls use Type N.

PART 3 - EXECUTION

3.1 REPAIR SPECIALIST

A. Adobe Repair Specialist: Firm to have at least five years of experience in similar scope and size project on buildings listed in the National Register of Historic Places. Firm shall submit Qualifications Form S0045X as part of the bid package.

3.2 INSTALLATION, GENERAL

A. Matching Existing Masonry: Match coursing, bonding, color, and texture of existing masonry.

B. Wetting of Masonry Unit: Wet unit before laying if initial rate of absorption exceeds 30 g/30 sq. in. per minute when tested according to ASTM C 67. Allow units to absorb water so they are damp but not wet at time of laying.

3.3 TOLERANCES

A. Dimensions and Locations of Elements:

1. Match existing tolerances. The wall is not intended to be straight and true like new.

B. Lines and Levels:

1. Match existing tolerances. The wall is not intended to be straight and true like new.

C. Joints:

1. Match existing joint widths.
2. The joint widths of the adobe vary from 1” – 1¾”.

3.4 REPOINTING ADOBE and CMU

A. Raking shall be performed by hand methods. Power tools are not allowed.

B. Rake out and repoint joints to the following extent:

1. All joints in areas indicated.
2. Joints with the following defects:

a. Holes and missing mortar.
b. Cracks that can be penetrated 1/4 inch or more by a knife blade 0.027 inch thick.
c. Cracks 1/8 inch or more in width and of any depth.
d. Hollow-sounding joints when tapped by metal object.
e. Eroded surfaces 1/4 inch or more deep.
f. Deterioration to point that mortar can be easily removed by hand, without tools.
g. Joints filled with substances other than mortar.

C. Do not rake out and repoint joints where not required.

D. Rake out joints as follows, according to procedures demonstrated in approved mockup:

1. Use small-headed chisel no wider than half the width of the joint to remove the loose mortar, using a rubber hammer to drive the chisel.
2. Remove mortar from joints to depth of 2-1/2 times joint width, but not less than 3/4 inch or not less than that required to expose sound, unweathered mortar. At some joints, this will be as deep as 4”-5”.
3. Remove mortar from adobe surfaces within raked-out joints to provide reveals with square backs and to expose adobe for contact with pointing mortar. Brush, vacuum, or flush joints to remove dirt and loose debris.
4. Do not spall edges of adobes or widen joints. Replace or patch damaged adobes as directed by Architect.

E. Notify Architect of unforeseen detrimental conditions including voids in mortar joints, cracks, loose stone, rotted wood, rusted metal, and other deteriorated items.

F. Pointing with Mortar:

1. Rinse joint surfaces with water to remove dust and mortar particles. Time rinsing application so, at time of pointing, joint surfaces are damp but free of standing water. If rinse water dries, dampen joint surfaces before pointing.
2. Apply pointing mortar first to areas where existing mortar was removed to depths greater than surrounding areas. Apply in layers not greater than 3/8 inch until a uniform depth is formed. Fully compact each layer, and allow it to become thumbprint hard before applying next layer.
3. After deep areas have been filled to same depth as remaining joints, point joints by placing mortar in layers not greater than 3/8 inch. Fully compact each layer and allow to become thumbprint hard before applying next layer. Where existing stone has worn or rounded edges, slightly recess finished mortar surface below face of stone to avoid widened joint faces. Take care not to spread mortar beyond joint edges onto exposed stone surfaces or to featheredge the mortar.

4. When mortar is thumbprint hard, tool joints to match original appearance of joints as demonstrated in approved mockup. Remove excess mortar from edge of joint by brushing.
5. Cure mortar by maintaining in thoroughly damp condition for at least 72 consecutive hours, including weekends and holidays.
6. Hairline cracking within mortar or mortar separation at edge of a joint is unacceptable. Completely remove such mortar and repoint.

G. After mortar has fully hardened, thoroughly clean exposed stone surfaces of excess mortar and foreign matter; use wood scrapers, stiff-nylon or -fiber brushes, and clean water, applied by low-pressure spray.

1. Do not use metal scrapers or brushes.
2. Do not use acidic or alkaline cleaners.

3.5 MORTAR BEDDING AND JOINTING

A. Lay adobe with completely filled bed and head joints; butter ends with sufficient mortar to fill head joints and shove into place. Do not deeply furrow bed joints or slush head joints.

B. Tool exposed joints slightly concave when thumbprint hard, using a jointer larger than joint thickness unless otherwise indicated.

3.6 FLASHING

A. General: Install embedded flashing where indicated.

B. Install flashing as follows unless otherwise indicated:

1. Prepare masonry surfaces so they are smooth and free from projections that could puncture flashing. Where flashing is within mortar joint, place through-wall flashing on sloping bed of mortar and cover with mortar. Before covering with mortar, seal penetrations in flashing with adhesive, sealant, or tape as recommended by flashing manufacturer.
2. Interlock end joints of ribbed sheet metal flashing by overlapping ribs not less than 4 inches.

3.7 REPAIRING, POINTING, AND CLEANING

A. See other Sections for specific repairs of cmu and adobe.

B. Remove and replace masonry units that are loose, chipped, broken, stained, or otherwise damaged or that do not match adjoining units. Install new units to match adjoining units; install in fresh mortar, pointed to eliminate evidence of replacement.

C. Pointing: During the tooling of joints, enlarge voids and holes, except weep holes, and completely fill with mortar. Point up joints, including corners, openings, and adjacent construction, to provide a neat, uniform appearance. Prepare joints for sealant application, where indicated.

D. In-Progress Cleaning: Clean unit masonry as work progresses by dry brushing to remove mortar fins and smears before tooling joints.

E. Final Cleaning: After mortar is thoroughly set and cured, clean exposed masonry as follows:

1. Remove large mortar particles by hand with wooden paddles and nonmetallic scrape hoes or chisels.

3.8 MASONRY WASTE DISPOSAL

A. Salvageable Materials: Unless otherwise indicated, excess masonry materials are Montana Fish Wildlife and Parks' property. At completion of unit masonry work, package for removal from Project site, or for storage in Room #104. Coordinate with MFWP.

B. Waste Disposal: Dispose of clean masonry waste, including excess or soil-contaminated sand, waste mortar, and broken masonry units, by crushing and legally dispose of off Owner's property.

END OF SECTION 040150

SECTION 045000 – ADOBE & CMU REPAIR

PART 1 - GENERAL

1.1 SUMMARY

A. Description: The East Barracks has one remaining wall of original adobe remaining – the east elevation. The adobe at the south, west, and north walls was replaced with a similar size concrete masonry unit c. 1948. The concrete block shall remain; repairs are included herein.

B. Definitions:

1. Adobe: Sun-dried, earthen brick.
2. Apron: Concrete poured up next to the base of an eroded historic adobe wall. Also called a collar or contra pared.

C. This Section includes the following Base Bid work:

1. Repairing adobe, including replacing full and partial units.
2. Removing concrete slurry from existing adobes.
3. Removing concrete patches and joint fill from adobe wall.
4. Repairing cracks in adobe wall and cmu walls.
5. Replacing deteriorated faces of cmu jamb units, and reinstalling jamb units, where indicated on drawings.
6. Fabrication (furnishing) of replica adobe faces (up to 9” deep) as indicated on the drawings, PLUS attic stock of 25%.
7. Training of adobe fabrication and repair methods by visiting adobe expert.

D. This Section includes the following Alternate scopes of work:

1. Alternate No. 1: Rebuild lower exterior wall of east elevation. See details for extent.
2. Alternate No. 2: Rebuild lower interior wall of east elevation. See details for extent.

E. Related Sections: Section 040100 “Unit Masonry Repointing.”

1.2 ALTERNATE PRICES

A. Alternate No. 1: Remove concrete apron and provide replica adobe faces along length of east wall. See Details 1 & 2, Sheet 7 for all work entailed.

B. Alternate No. 2: Rebuild lower two courses of interior east walls of Room #100 and #103. See Details 1 & 2, Sheet 7 for all work entailed.

C. See Alternate Section 012300 for further information.

1.3 UNIT PRICES

Work of this Section is affected by unit prices specified in Section 012200 "Unit Prices."

1. Unit prices apply to authorized work covered by estimated quantities.

2. Unit prices apply to additions to and deletions from Work as authorized by Change Orders.

1.4 DEFINITIONS

A. Low-Pressure Spray: 100 to 400 psi at 4 to 6 gpm

B. As scaffolding is removed, patch anchor holes used to attach scaffolding. NOTE: anchoring into existing walls is NOT allowed. Patch holes in masonry units according to "Masonry Unit Patching" Article.

1.5 SEQUENCING AND SCHEDULING

A. Work Sequence: Perform adobe and cmu repair and repointing work in the following sequence, which includes work specified in this and other Sections:

1. Excavate test holes along base of east wall to confirm conditions and confirm count of adobe units required for rebuilding.
2. Coordinate with archaeological consultant.
3. Engage in on-site training with adobe specialist.
4. Fabricate adobe and sun-dry during the dry months of the summer.
5. Repair cmu at jambs.
6. Repoint cmu joints.
7. Remove concrete slurry and patches and mortar.
8. Repoint adobe joints.
9. Paint steel plates.
10. Clean out joints at windows and doors; fill as specified.
11. Treat windows and doors with FPL coating.
12. Rebuild base of adobe wall per Alternate No. 1 and No. 2.

B. The sequence listed above is intended to allow time for the fabrication and setting of the adobe, east wall foundation exploration, and rebuilding of the foundation wall without being subjected to rain. The Contractor may propose a different sequence for review and approval by MFWP and the architect.

1.6 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Include recommendations for product application and use. Include test data substantiating that products comply with requirements.

B. Samples for Verification: For the following:

1. Each type of adobe unit to be used for replacing existing units. Include sets of Samples to show the full range of shape, color, and texture to be expected. For each brick type, provide straps or panels containing at least four bricks. Include multiple straps for brick with a wide range.
2. Accessories: Each type of accessory and miscellaneous support.

1.7 QUALITY ASSURANCE

A. Adobe Repair Specialist Qualifications: Engage an experienced masonry repair firm to perform work of this Section. Firm shall have completed work similar in material, design, and extent to that indicated for this Project with a record of successful in-service performance. Experience in only installing masonry is insufficient experience for masonry repair work. Contractor shall provide documentation of these qualifications on the S0045X form submitted with the Proposal.

1. Field Supervision: Adobe repair specialist firm shall maintain experienced full-time supervisors on Project site during times that brick masonry repair work is in progress.
2. Adobe Repair Worker Qualifications: When masonry units are being patched, assign at least one worker per crew who is trained and qualified.

B. Adobe Repair Training: An adobe specialist is available to provide 3-day training session for the Contractor's on-site personnel. An allowance for this training is included in the Proposal Form. Contractor shall provide the requisite personnel for training. Masons who do not participate in the training will not be allowed to work on the building.

C. Mockups: Prepare mockups of adobe repair to demonstrate aesthetic effects and to set quality standards for materials and execution and for fabrication and installation.

1. Adobe Repair: Prepare sample areas for each type of masonry repair work performed. If not otherwise indicated, size each mockup not smaller than two adjacent whole units or approximately 24 inches in least dimension. Construct sample areas in locations in existing walls where directed by Architect unless otherwise indicated. Demonstrate quality of materials, workmanship, and blending with existing work. Include the following as a minimum:

    a. Replacement: Two stretcher (half-depth or less) adobe units replaced.
    b. Patching: Three small holes in adobe units (where crossing mortar joints) and less than 4" deep.
2. Concrete masonry unit repair:

    a. Patching: One jamb section (approximate size: 5½" x 2" x 2").

3. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
4. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

D. Adobe Testing:

1. Compressive Strength: Contractor shall cast 2" mortar cubes from mortar trial mixtures for testing to verify strength. Test specimens shall be sun-dried and ambient-cured for seven (7) days prior to testing.
2. Moisture:
    a. Moisture content shall be measured in accordance with ASTM D 2216. Specimens are dried to constant weight in an oven at 230 degrees F. Constant weight is typically achieved after 24 hours.

b. Moisture content % = [(initial weight – dry weight)/ Dry weight] x 100.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Deliver masonry units to Project site strapped together in suitable packs or pallets or in heavy-duty cartons and protected against impact and chipping.

B. Deliver packaged materials to Project site in manufacturer's original and unopened containers, labeled with manufacturer's name and type of products.

C. Store adobe materials on elevated platforms, under cover, and in a dry location.

D. Store hydrated lime in manufacturer's original and unopened containers. Discard lime if containers have been damaged or have been opened for more than two days.

E. Store sand where grading and other required characteristics can be maintained and contamination avoided.

F. Handle masonry units to prevent overstressing, chipping, defacement, and other damage.

1.9 FIELD CONDITIONS

A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit brick masonry repair work to be performed according to product manufacturers' written instructions and specified requirements.

B. Temperature Limits, General: Repair masonry units only when air temperature is between 40 and 90 deg F and is predicted to remain so for at least seven days after completion of the Work unless otherwise indicated.

C. Cold-Weather Requirements: Comply with the following procedures for masonry repair unless otherwise indicated:

1. When air temperature is below 40 deg F, heat mortar ingredients, masonry repair materials, and existing masonry walls to produce temperatures between 40 and 120 deg F.
2. When mean daily air temperature is below 40 deg F, provide enclosure and heat to maintain temperatures above 32 deg F within the enclosure for seven days after repair.

D. Hot-Weather Requirements: Protect masonry repairs when temperature and humidity conditions produce excessive evaporation of water from mortar and repair materials. Provide artificial shade and wind breaks, and use cooled materials as required to minimize evaporation. Do not apply mortar to substrates with temperatures of 90 deg F and above unless otherwise indicated.

E. For manufactured repair materials, perform work within the environmental limits set by each manufacturer.

1.10 ARCHAEOLOGICAL COORDINATION

A. To expose the east foundation wall, the Contractor shall carefully hand dig with trowels and shovels AFTER digging (by others) of the test pits described below. Discovery of artifacts shall

be brought to the attention of MFWP who will contact the archaeological consultant that they have engaged.

B. Montana Fish Wildlife and Parks has engaged an archaeological consultant to dig test pits at the base of the east wall of the East Barracks. This consultant will be available to monitor the Contractor's digging.

C. This archaeological monitoring will include screening a representative sample of removed material.

D. Information from previous archaeological investigations at Fort Owen will guide the archaeological consultant's current work. If few artifacts are found other than building materials (glass and nails), this will be the extent of testing work. However, if an abundance (over 5-10) of diagnostic artifacts (ceramics, beads, buttons, pipe fragments, other personal items) are found, or if the unit includes features, the unit may be expanded 50 cm in whichever direction is indicated by the finds. Decisions to expand the excavations will occur in consultation with the Heritage Program Manager and will be based on previous work at Fort Owen and the consultant's archaeological expertise.

E. The Contractor shall be prepared to stop work upon the discovery of diagnostic artifacts. The Contractor shall also be prepared to call to the archaeological consultant's attention the discover of diagnostic artifacts.

F. The archaeological consultant's monitors need not remain on-site for the entirety of the construction work, just for initial ground disturbance. Re-filling around the rebuilt foundation wall, for example, can occur without a monitor present.

G. The archaeological consultant's monitoring days will not occur concurrently. It is assumed that the construction Contractor will first excavate a small portion of the wall to evaluate the conditions of the wall below grade, then return to excavate the remainder and undertake repairs approximately 1-2 months later.

PART 2 - PRODUCTS

2.1 MATERIALS, GENERAL

A. Source Limitations: Obtain each type of material for repairing adobe (adobe, clay, lime putty, sand, etc.) from single source with resources to provide materials of consistent quality in appearance and physical properties.

2.2 ADOBE MATERIALS

A. Clay: Exposed tertiary clay from:
Yoder Gravel
4376 Eastside Highway
Stevensville, Montana
(406) 274-8348

B. Sand:
1. From Yoder Gravel. If sand is sourced from a location other than Yoder Gravel, contractor shall have proposed sand checked for mineralogy and particle shape.

2. As per testing, major constituents shall be as follows, in approximate order of decreasing abundance:
   a. Quartz
   b. Feldspars (plagioclase and potassium feldspars in approximately equal amounts)
   c. Micas (biotite, chlorite, and white mica)
   d. Iron oxides/hydroxides
   e. Amphibole
3. Sand particles shall be predominantly angular and of a geologically young source.
4. Maximum size of 2.5mm, with an estimated 90-95% of particles passing No.8 US standard sieve.
5. Blend several sands if necessary to achieve suitable match.

C. Water: Potable.

D. Mix:
1. Clay: 10-15% silt and clay.
2. Sand: 70%-80%. Particle size distribution as stated in the testing report *Fort Owen East Barracks:Materials Analysis of Historic Adobe*, dated April 6, 2022 for percentages of constituents in original adobe units.
3. No additives.
4. Compressive strength: no more than 300 psi.
5. Moisture content: no more than 15% at the time of installation.

E. Date Stamp: Provide date stamp at side of adobe unit, indicating date of manufacture or installation and Montana Fish, Wildlife & Parks. Date stamp can be written with permanent marker or impressed/etched.

2.3 FABRICATING ADOBE

A. These instructions have been extracted nearly verbatim from Cornerstones Community Partnerships' publication *Adobe Conservation: A Preservation Handbook.*

B. Do not make adobe in the winter or during the rainy season.

C. Under normal conditions a curing time of 3-4 weeks is necessary.

D. Mix mud in a concrete motor-driven mixer or in a pit.
1. In motor mixer, add water before adding the soil (clay).
2. In pit, soak soil overnight before mixing.

E. Prepare wood forms to fabricate adobe of size to match existing, with a variety of adobe the full 18" depth, and a variety the 9" half-depth. The adobe will need to be cut to fit, so as to limit the amount of sound original adobe removal.
1. The form should be perfectly smooth and clean.
2. Soak the wooden form with water. Level the forms and place mud in the damp forms.
3. Force mud into the corners of the mold by hand. Fill voids and strike the surplus mud from the top using hands or a dampened piece of wood as a screed bar.

F. Removal from form and curing:
   1. Slowly lift the forms straight up from the adobes. If surface cracks appear on the adobe, immediately sprinkler water on the top and smooth. Do not let the empty form sit too long with mud on it. Wash the adobe form before reuse.
   2. The top of the adobe will sag as it dries. This concave side will be used as the bottom face when it is laid.
   3. Leave the adobes undisturbed for three or four days. Stand them on their long edge once they are dry enough to handle without breaking.
   4. Allow the adobes to dry on their edges for at least ten to fourteen days depending on the weather. Arrange in a zigzag pattern to prevent the "domino" effect if one falls over. Scrape any loose material from the bottom of the adobes. Once dry, a brick-layer's trowel may be used to clean the surface, corners and edges of the adobes.
   5. Stack the adobes loosely and protect the top of the pile with a tarp, roofing metal, or plywood weighted with stones, dirt or concrete blocks. Do not seal the entire pile; adobes must breathe.

2.4 ADOBE REPAIR MATERIALS

A. Adobe Patching Compound: Same as adobe materials.

2.5 CONCRETE BLOCK REPAIR

A. Cathedral Stone Jahn mortar mix M90, of standard color. Confirm color with Cathedral Stone. It is likely S2-CR.

2.6 ACCESSORY MATERIALS

A. Setting Buttons and Shims: Resilient plastic, nonstaining to masonry, sized to suit joint thicknesses and bed depths of masonry units, less the required depth of pointing materials unless removed before pointing.

B. Oakum: non-tarred oakum, white.
   1. Nupak Oakum white oakum to meet federal specification #HHP-117-2.
   2. Ingredients:
      a. Bentonite
      b. Jute roving
      c. Trace of water

2.7 FOUNDATION WATERPROOFING

A. Bentoseal Trowel-Grade Sodium Bentonite Sealant.

2.8 APRON REMOVAL

A. Bentonamit, the non-explosive cracking agent.

PART 3 - EXECUTION

3.1 REPAIR SPECIALIST

A. Adobe Repair Specialist: Firm to have at least five years of experience in similar scope and size project on buildings listed in the National Register of Historic Places. Firm shall submit Qualifications Form S0045X as part of the bid package.

3.2 PROTECTION

A. Prevent mortar from staining face of surrounding masonry and other surfaces.

1. Cover sills, ledges, and other projecting items to protect them from mortar droppings.
2. Keep wall area wet below rebuilding and repair work to discourage mortar from adhering.
3. Immediately remove mortar splatters in contact with exposed masonry and other surfaces.

3.3 ADOBE REPAIR

A. Appearance Standard: Repaired surfaces are to match the existing irregular coursing and rough-edged appearance as viewed from 20 feet away by Architect.

B. Removal of concrete slurry and patches: Pick at the slurry or patch with a sharp awl to remove the thin cover incrementally. Take care to lessen the (exiting) damage to the adobe.

C. Patching a shallow hole left by removal of the concrete (and at the one location where test sample was sawn out):

1. Scrape loose material from the surface, then brush clean.
2. Fill the void in layers with a mixture of adobe. Each layer should be less than or equal to ¾”.
3. Allow each layer to dry completely before applying the next layer.
4. Dampen the area before applying the next layer.
5. Each adobe mix layer shall be hurled into the void rather than troweled on.

3.4 CRACK REPAIR IN ADOBE AND IN CMU WALLS

A. This repair method is similar to repointing masonry joints. See Specification Section 040150 – Repointing – for mortar. Use mortar specified for the substrate – adobe or concrete masonry units.

B. Rake out the cracks to a depth of 2 to 3 times the width of a mortar joint to obtain a good key/bond of the mortar to the adobe or cmu.

C. Spray the adobe lightly with water to increase the cohesive bond.

D. Use a grout gun to inject the mortar into and fill the cracks.

3.5 CONCRETE APRON REMOVAL

A. Concrete apron removal is part of Alternate No. 1.

B. Tools that vibrate or cause movement in the adjacent adobe wall are NOT allowed.

C. The existing concrete apron installed next to eroded adobe is exacerbating the moisture problem. The crack along the top of this concrete apron is allowing water to penetrate the wall. Moisture at the inside face of the adobe is apparent and damaging the adobe.

D. Base bid: Before removing the apron, remove the delaminating concrete along the top of the apron. This will provide for a horizontal surface of concrete to work with per the instructions below.

E. CAVEAT: If archaeological remains or artifacts are exposed during the excavation process, stop work and call Montana Fish, Wildlife & Parks immediately.

F. Cornerstones Community Partnerships provides the following method for the concrete apron removal (see *Adobe Conservation: A Preservation Handbook*, Sunstone Press, 2006, pages 95-98).
   1. Process: as water is added to Bentonamit, the material swells and splits the concrete, allowing it to be removed in sections.
   2. Before starting this procedure, call Cornerstones at (505) 982-9521.
   3. Beginning near the outside corner, define the four-foot long section to be removed.
   4. Excavate a six-foot long trench to depth below the section of concrete apron.
   5. Always shim underneath the concrete to prevent it from shearing off the wall and collapsing into the trench.
   6. To avoid the possibility of the wall's collapsing, dig the trenches in alternate sections with a minimum of four feet between each section.
   7. Remove the concrete via one of these three methods, noting that cracks are weak areas ideal for drilling:
      a. Option 1:
         1) Drill holes, at a slight downward angle, 12" on center, down the vertical face of the wall where you want it to break.
         2) If the section is small enough, break it completely away from the wall using a wood block for torque and a small sledge hammer an chisel. Then break it into smaller chunks and remove.
      b. Option 2: Using a hammer drill, drill 1" – 1½" diameter holes 12" deep along the center of the top of the four-foot section.
      c. Option 3: Drill holes at a 45 degree downward angle 12"-16" on center all the way across the four-foot vertical face of the section.
   8. Bentonamit Application:
      a. Wearing gloves, goggles, and a mask, carefully mix the Bentonamit following the manufacturer's instructions exactly. This includes monitoring the exterior air temperature as well as the temperature of the air in the holes drilled in the concrete.
      b. Remember to remove the shims from beneath the apron section to allow the concrete the necessary freedom of movement once the clay-based chemical begins to expand. Cover the four-foot section with plywood, a tarp or blanket to protect from flying debris as the chemical expands and the concrete begins to move. Allow the chemical process to completely finish its work, approximately 48 hours.
      c. Use common sense at all times and when in doubt, call Cornerstones for advice.
   9. Concrete removal: When the concrete has cracked, remove pieces of the concrete with a sledgehammer and chisel.
   10. Complete the repairs to one section prior to opening the next section.

3.6 ADOBE REMOVAL AND REPLACEMENT

A. CAVEAT: If archaeological remains or artifacts are exposed during the excavation process, stop work and call Montana Fish, Wildlife & Parks immediately.

B. Clean adobe surrounding removal areas by removing mortar, dust, and loose particles in preparation for adobe replacement.

C. Install replacement adobe into bonding and coursing pattern of existing adobe following the existing contours. If cutting is required, use a motor-driven saw designed to cut masonry with clean, sharp, unchipped edges.

D. Cutting adobe to fit. Use brick splitter and hammer to shape the adobe to fit the opening in the wall.

1. Only cut adobe that is thoroughly dried.
2. Groove the adobe all the way around with a nail.
3. Place the splitter at various places along the groove and tap it with the hammer.
4. Hit progressively harder until the adobe splits along the groove.
5. The tapping creates a plane of weakness.

E. Cornerstones Community Partnerships provides the following method for the replacing the deteriorated adobe exposed by removal of the apron (see *Adobe Conservation: A Preservation Handbook*, Sunstone Press, 2006, pages 101-106).

1. Provide shoring to exterior and interior (where accessible, do not remove plaster) to support the walls.
2. Remove deteriorated adobe in sections that are a maximum of four feet long. This will prevent removal of too much at one time which might cause structural failure.
3. Use the existing small trench at the base of the wall for access.
4. While cleaning out the deteriorated debris (adobe melt) shim the existing adobes to prevent collapse, fractures, or cracks using wood blocks and shims. Establish a flat base or a base that is slightly inclined into the wall for the new adobes. If rain is expected, keep trench covered with plywood or sheet metal, or to otherwise keep rainwater from accumulating in the trench. See Figure 1 below.
5. Expose the area where the new adobe is to be installed. Insert adobe into new opening and allow a space of @ ¾” around the adobe in order to insert mortar. Remove the adobe and dampen the side of the adobe facing down, or any face that will be in contact with mortar, and the area receiving the mud mortar. Place mud mortar over dampened area and set the new adobe(s) into the wall. Push and press adobe over mortar and install wood shims snugly along upper mortar gap.

6. When new adobe is in place, install wood blocks and shims to prevent existing adobes from loosening, collapsing or fracturing while new mud mortar dries and sets.
7. Repeat step five and shim.

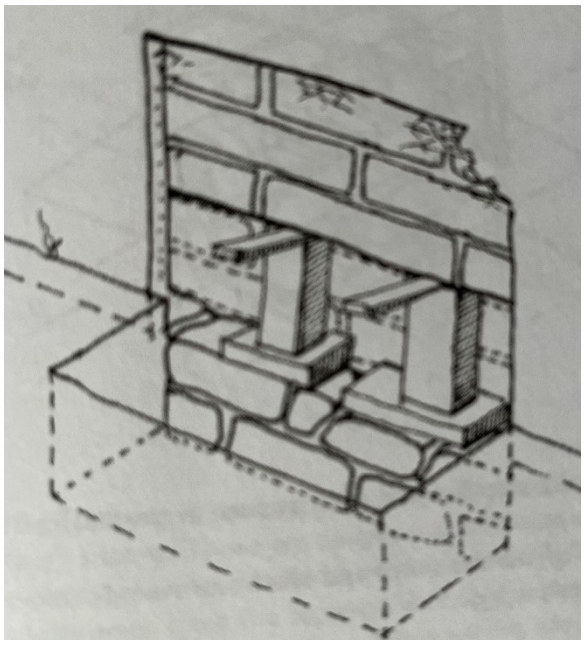

Figure 1: Provide wood blocking and shims to support the adobe wall above the work area. Image courtesy of Cornerstones (page 103).

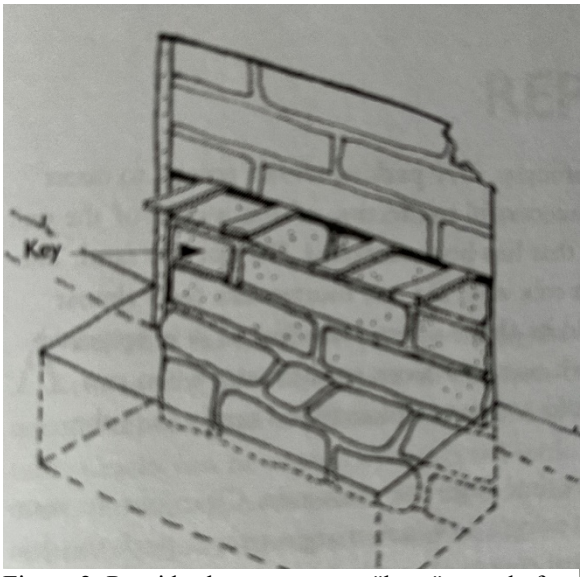

Figure 2: Provide short temporary "keys" at end of course. Replace keys later when tying the repaired wall segments together. Image courtesy of Cornerstones (page 105).

8. Once the mud mortar has dried, the upper mortar gap should be dry packed. Use a margin trowel or a slender piece of wood to push the dry pack mortar into the void and fill it tightly.
9. When all adobes have been dry packed and the wall cavity shimmed, repeat the process in step five. The overlap between vertical joints should be no less than 4 inches.
10. Install “key” adobes. See Figure 2 above. The keys are laid in mud mortar and dry packed. Once dry and in place, the last course of adobes should be shimmed tightly, allowing the mortar to dry.
11. When the mortar has completely dried, drypack the remaining gap or opening and allow to dry. Do not remove wood shims from the gap all at once; remove only enough shims to be able to dry pack a segment at a time.

F. Coordinate with new flashing, installing it in similar section lengths, allowing for 4” minimum overlap between lengths.

3.7 LAYING ADOBE WALLS

A. Lay out walls in advance for accurate spacing of surface bond patterns with matching joint thicknesses.

B. Bond Pattern for Exposed Adobe: Lay exposed masonry in bond pattern to match adjacent work; do not use units with less-than-nominal 4-inch horizontal face dimensions at corners or jambs.

C. Lay concealed adobe with all units in a wythe in running bond or bonded by lapping not less than 2 inches. Bond and interlock each course of each wythe at corners. Do not use units with less-than-nominal 4-inch horizontal face dimensions at corners or jambs.

D. Stopping and Resuming Work: Stop work by stepping back units in each course from those in course below; do not tooth. When resuming work, clean masonry surfaces that are to receive mortar, remove loose masonry units and mortar, and wet adobe if required before laying fresh masonry.

E. Notify Architect of unforeseen detrimental conditions including large voids, cracks, bulges, and loose units in existing adobe wall, rotted wood, rusted metal, and other deteriorated items.

1. Most of the replacement adobe will be at the area of concrete apron removal. The removal and replacement shall be performed in 4’-long sections.
2. Maintain joint width for replacement units to match existing joints.
3. Use setting buttons or shims to set units accurately spaced with uniform joints.

3.8 WATERPROOFING BELOW-GRADE ADOBE WALLS

A. Trowel on the specified waterproofing at minimum thickness of ¼” per manufacturer’s written product literature.

B. Compact backfill soils to an 85% modified Proctor density.

3.9 CMU JAMB PATCHING

A. Remove existing material, salvaging those scheduled for reinstallation.

1. Clean out the void and slightly wet it before applying the mortar to the back, top, and bottom before reinstalling the unit.
2. If unit is too large, use brick splitter and hammer to size it to fit.

B. For patches scheduled for replacement:

1. Clean out the void thoroughly and shape it to fit the requirements of the patch material’s manufacturer.
2. Follow manufacturer’s written instructions.

3.10 MASONRY WASTE DISPOSAL

A. Salvageable Materials: Unless otherwise indicated, excess masonry materials are Contractor's property.

B. Masonry Waste: Remove masonry waste and legally dispose of off Owner's property.

END OF SECTION 045000

SECTION 099300 - STAINING AND TRANSPARENT FINISHING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes:

1. Surface preparation and the application of FPL finish on the following exterior substrates:
   a. Exposed wood trim.
   b. Wood windows.
   c. Wood doors.
   d. Alternate No. 3: Finish wood deck/ramp planking.
2. Surface preparation and the application of paint on the steel plates on the east wall.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Filling Compounds: Linseed oil putty for wood (FS TT-P-00791), as used on the building previously.

B. Linseed Oil: Boiled, ASTM D260.

C. Mix:
1. Boiled linseed oil: 40% of weight
2. Mineral spirits: 60% of weight
3. Shaved paraffin for waterproofing properties at the horizontal surfaces.

2.2 PAINT FOR STEEL PLATES

A. Coronado Rust Scat Polyurethane exterior enamel coating, satin finish. Benjamin Moore #651 and primer as recommended. Color to blend with color of the adjacent adobe.

PART 3 - EXECUTION

3.1 PREPARATION

A. Washing exterior woodwork:
1. Dry woodwork with natural bristle brush or broom,
2. If dirt remains, wet wash to remove dirt. Use the brush to remove dirt, using as little water as possible.
3. Allow wood to dry.
4. If general cleaning is possible, begin at a lower corner and work across, then up.
5. Always work on the shady side of the building.

3.2 APPLICATION

A. Apply finishes with natural bristle and hair brushes only. No roller or spray application will be allowed.
   1. Treat trim, doors, and windows with two coats of boiled linseed oil.

B. Apply finishes to produce surface films without cloudiness, holidays, lap marks, brush marks, runs, ropiness, or other surface imperfections.

3.3 PAINTING STEEL PLATES

A. Prepare existing steel plates by hand- or wire-brushing off loose paint and surface rust.

B. Tape off and protect adjacent adobe. Do not allow primer or paint to get onto adjacent adobe.

C. Apply compatible primer as recommended by manufacturer.

D. Apply finish coat of paint.

3.4 CLEANING AND PROTECTION

A. At end of each workday, remove rubbish, empty cans, rags, and other discarded materials from Project site.

B. After completing finish application, clean spattered surfaces. Remove spattered materials by washing, scraping, or other methods. Do not scratch or damage adjacent finished surfaces.

C. Protect work of other trades against damage from finish application. Correct damage by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.

D. At completion of construction activities of other trades, touch up and restore damaged or defaced finished wood surfaces.

END OF SECTION 099300

ENGINEERING SERVICES

National Expertise. Local Solutions.

April 6, 2022

Materials Analysis of Historic Adobe
Fort Owen East Barracks
YAES Project No. ES-20220227

(Image from The Montana History Foundation website)

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Table of Contents

INTRODUCTION

At the request of Ms. Lesley Gilmore with Gilmore Franzen Consulting LLC, YA Engineering Services (YAES) has conducted materials analysis of historic adobe brick and mortar, new replica brick, and local clay-rich soil. The analyses were requested on behalf of Montana Fish, Wildlife and Parks, in conjunction with Friends of Fort Owen, to inform formulation of replacement adobe brick and mortar for preservation of the deteriorating east wall of the circa 1857 East Barracks at historic Fort Owen located in the Bitterroot Valley near Stevensville, Montana. Fort Owen was established by Major John Owen in 1850 as a trading post on the original site of St. Mary's Mission to the Bitterroot Salish Tribe and is considered the oldest continuously occupied white settlement in Montana. It became a state monument in 1956 and was added to the National Register of Historic Places in 1970.

SCOPE

Characterization of original mortar and original adobe brick was requested to inform formulation of repair or replacement materials using petrographic methods supplemented with other tests and analytical techniques as needed. Characterization of a replica adobe brick made by the Friends of Fort Owen was requested for comparison with the original adobe brick.

SAMPLES

Materials submitted by Gilmore Franzen Consulting LLC include:

- M1 – Original adobe mortar, exterior
- M2 – Original adobe mortar, exterior
- B1 – Original adobe brick, exterior
- Replica adobe brick approximately 8 inches x 4 inches x 3 inches [made by Friends of Fort Owen using 1 part clay: 3 parts river sand; 0.2-part cow manure]
- Tertiary clay used to make replica adobe brick, Yoder's Pit 2 miles east of Fort Owen
- Drawing indicating sample locations
- Mortar analysis report prepared by David Arbogast, Architectural Conservator

Original adobe brick and mortar samples were extracted by Ms. Gilmore on October 19, 2021. The mortar joints are 1 to 1 ¾ inch wide and the adobe bricks are approximately 18 inches long, 8 inches wide, and 3 ½ to 4 inches in height. The Yoder's Pit clay sample was reportedly obtained in September 2021 at the time the replica adobe brick was made.

Petrographic examination of the samples was conducted in accordance with methods described in the current version of ASTM C856, Standard Practice for Petrographic Examination of Hardened Concrete. This practice incorporates routine techniques for examination and analysis of geological materials and is applicable to materials used in construction. Thin-section petrography of the original adobe brick and Yoder's Pit clay sample were supplemented with X-ray diffraction (XRD) analysis to identify clay mineralogy. Absorption was estimated by submerging in water for 2 minutes a small portion of adobe that had been dried to constant weight. Dry density was

estimated by weighing carefully measured pieces of adobe that had been dried to constant weight. Compressive strength was crudely estimated using a rebound hammer; cubes could not be cut.

DESCRIPTIONS

Adobe Mortar

Figure 1: M1 Original exterior adobe mortar sample.

Figure 2: M2 Originally exterior adobe mortar sample.

Weight: 119.0 g (M1) and 48.9 g (M2)

Dimensions: Each sample consists of a single intact piece of mortar. M1 is 80 mm by 70 mm and is 20 mm thick. M2 is 35 mm by 60 mm and is 30 mm thick. Samples are shown in Figure 1 and Figure 2.

Physical Properties: Sensitivity to water prevents precise determination of the physical properties. Absorption is minimally 10 percent. The mortar exhibits uneven absorption due to the presence of a penetrating sealer in the outer 1 inch. Sample dimensions are not suitable for determination of compressive strength.

Munsell Color: 10 YR 7/2 pale yellowish brown on fresh fracture surfaces.

Surfaces: Weathered surfaces exhibit dark discoloration and adhered debris consisting of plant and insect detritus.

Texture: The mortar is inhomogeneous. Streaks and patches of yellowish-brown clay are common in the hand sample.

Proportions and Composition: Adobe mortar composition and texture are shown in Figure 3 and Figure 4. Weight percentages determined by crushing and sieving a portion of the M2 original adobe mortar are given in Table 1. Volume percentages of sand, matrix, and air (interstitial voids) determined by point-count analysis are 75, 13.7, and 11. The volume of plant material is 0.3 percent.

- Sand: Major constituents are quartz, feldspars (plagioclase and potassium feldspars in approximately equal amounts), micas (biotite, chlorite, and white mica), iron oxides/hydroxides, amphibole, and tourmaline. Constituents are listed in approximate

order of decreasing abundance. Sand particles are predominantly angular and typical of a geologically young source. The maximum size of sand particles is 1.5 mm.

- Matrix: The matrix contains silt, clay, clay-size mineral particles, and scattered nodules of carbonated hydrated lime (Figure 3). The abundance of lime is visually similar to the amount observed in a modern Type M mortar (up to one-quarter part hydrated lime).
- Porosity: High interstitial microporosity. Void spaces appears blue in the micrographs.

Table 1 Weight Percentages of Constituents in Original Adobe Mortar

Size Fraction	Percentage Retained	Constituents
No. 8 (2.36 mm)	0	--
No. 16 (1.18 mm)	2.3	Mineral grains, plant stems and leaves
No. 30 (0.6 mm)	3.7	As above
No. 50 (0.3 mm)	18.7	As above
No. 100 (0.150 mm)	17.8	As above
No. 200 (0.075 mm)	35.1	As above
No. 325 (0.045 mm)	18.2	As above
PAN	4.2	Silt, clay, and clay-size mineral grains
TOTAL	100.0	

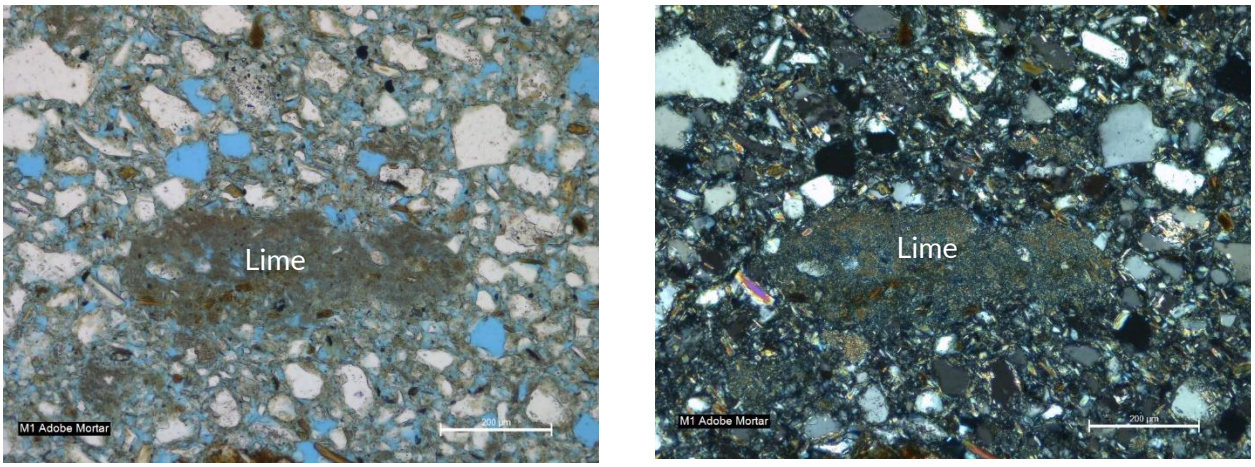

Figure 3: M1 Adobe Mortar. Thin-section micrographs show the size and distribution of constituents. A nodule of carbonated hydrated lime is labeled. Aggregate particles are small and angular in shape indicative of a geologically young source. Pores are filled with blue-dyed epoxy. Plane-polarized light on left. Cross-polarized light on right.

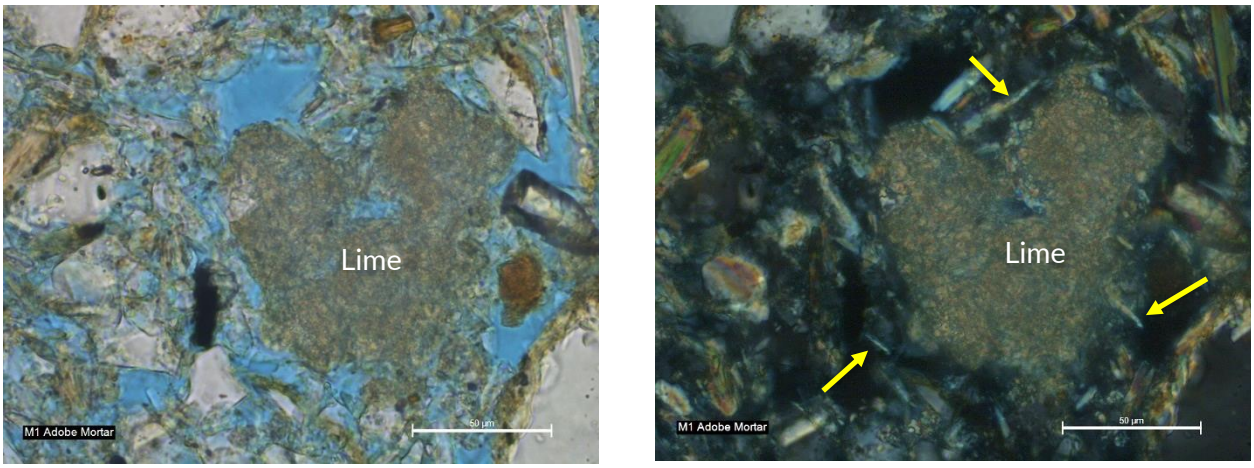

Figure 4: M1 Adobe Mortar. Thin-section micrographs show the pore structure of the adobe matrix at high magnification. Arrows in micrograph on right show examples of platy clay particles. Plane-polarized light on left. Cross-polarized light on right

Original Adobe Brick

Figure 5: B1 Original adobe brick sample.

Weight: 523.2 g

Dimensions: 90 mm wide, 30 to 60 mm thick, 50 to 120 mm long. The sample is a portion of a larger brick.

Physical Properties: Estimated compressive strength is 125 pounds per square inch. Estimated dry density is 102 pounds per cubic foot. Absorption is approximately 18 percent.

Munsell Color: 5 YR 3/4 pale moderate brown on fresh fracture surfaces.

Surfaces: Surfaces are dusty. Handling releases brown dust and grit. The brick contains scattered, flattened compaction voids. The largest void is 18 mm long, 10 mm wide, and 10 mm deep.

Texture: The brick is dense. Constituents are uniformly distributed.

Proportions and Composition: Adobe brick composition and texture are shown in Figure 6 and Figure 7. Weight percentages determined by crushing and sieving a portion of the original adobe brick are given in Table 2. Volume percentages of sand, matrix, and air are 73, 14.5, and 12. The volume of plant material is 0.5 percent.

- Sand: Major constituents are quartz, feldspars (plagioclase and potassium feldspars in approximately equal amounts), micas (biotite, chlorite, and white mica), iron oxides/hydroxides, amphibole, and miscellaneous accessory minerals. Constituents are listed in approximate order of decreasing abundance. Sand particles are predominantly angular and typical of a geologically young source. Maximum size is 2.5 mm with an estimated 90 to 95 percent of particle pass No. 8 U.S. Standard sieve.
- Matrix: The matrix contains silt, clay, clay-size mineral particles, and dark brown to black particles of ash and charred wood.
- Porosity: Abundant voids between sand particles appear blue in the micrographs.

Table 2 Weight Percentages of Constituents in Original Adobe brick

Size Fraction	Percentage Retained	Constituents
No. 8 (2.36 mm)	2.9	Charred wood, mineral grains
No. 16 (1.18 mm)	3.0	Mineral grains, charred wood, plant stems
No. 30 (0.6 mm)	13.6	As above
No. 50 (0.3 mm)	20.9	As above
No. 100 (0.150 mm)	20.1	As above
No. 200 (0.075 mm)	15.5	As above
No. 325 (0.045 mm)	8.5	As above
PAN	15.5	Silt, clay, and clay-size mineral grains
TOTAL	100.0	

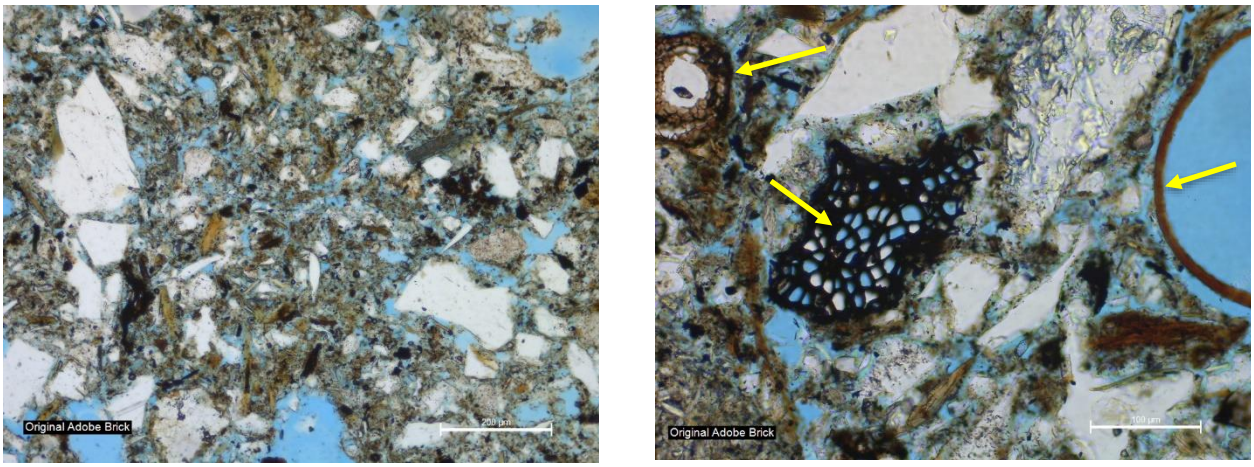

Figure 6: B1 Original Adobe Brick. Thin-section micrographs show the size and distribution of adobe constituents. Arrows in micrograph on right show plant material. Pores are filled with blue-dyed epoxy. Plane-polarized light

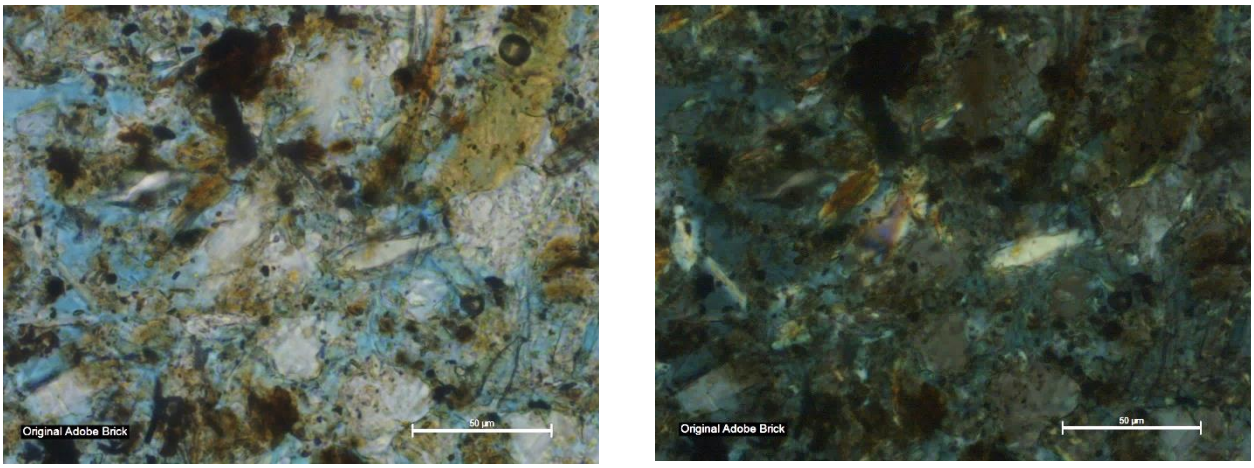

Figure 7: B1 Original Adobe Brick. Thin-section micrographs show the pore structure of the adobe matrix at high magnification. Dark specks in micrograph on left are ash and charred plant material. Small bright platelets in micrograph on right are clay particles. Plane-polarized light on left. Cross-polarized light on right

Table 3 lists quantities of mineral constituents determined by semi-quantitative XRD analysis of the clay-size fraction (smaller than 4 micrometers in diameter) of the adobe, which makes up a portion of the material passing the No. 325 sieve. Clays and clay-like micas make up 19 percent of the clay-size fraction. Quartz and feldspars make up nearly 80 percent of the clay-size fraction. The clay minerals in the original adobe brick, determined by XRD analysis, are predominantly illite, with smaller amounts of kaolinite and random-ordered mixed layer illite/smectite with 90 percent smectite layers. Illite and kaolinite are non-swelling clays. Smectite is a swelling clay.

Table 3: XRD Analysis of Original Adobe Brick Clay Fraction

Mineral	Quantity (weight percent)
Quartz	42.1
Potassium Feldspar	11.0
Plagioclase Feldspar	26.5
Illite and Mica	15.9
Kaolinite	1.5
Random Ordered Mixed Layer Illite/Smectite with 90 percent Smectite Layers	1.1
Chlorite	0.5
Calcite	0.6
Pyrite	0.8
Hematite	0
Total	100.0

Replica Adobe Brick

Figure 8: Replica adobe brick sample. Arrows in the side view of the sample, on right, show a region of poor consolidation.

Weight: 2,260 g

Dimensions: Intact brick approximately 203 mm long, 102 mm wide, and 63 mm in height.

Physical Properties: Estimated compressive strength is 250 pounds per square inch. Estimated dry density is 115 pounds per cubic foot. Absorption could not be determined due to rapid disintegration of the sample when immersed in water.

Munsell Color: 10 YR 7/2 light yellowish brown.

Surfaces: Surfaces are hard and dusty. The brick is well compacted except for a planar consolidation void that extends the length of the brick 5 to 20 mm above the bottom surface.

Texture: The brick is dense and exhibits uniform distribution of constituents.

Proportions and Composition: Replica brick composition and texture are shown in Figure 9 and Figure 10. Weight percentages determined by crushing and sieving a portion of the replica adobe brick are given in Table 4. Volume percentages of sand, matrix, and air determined by point-count analysis are 82, 7, and 10. The volume of plant material is 0.9 percent.

- Sand: Major constituents are quartz, feldspars (plagioclase and potassium feldspars in approximately equal amounts), granite, micas (biotite, chlorite, and white mica), iron oxides/hydroxides, amphibole, sandstone/siltstone, volcanic rocks, and miscellaneous accessory minerals. Constituents are listed in approximate order of decreasing abundance. Sand particles are angular to subrounded supporting mixed sources (angular particles in the clay and subrounded particles in river sand). Maximum size is 8 mm with occasional larger particles.
- Matrix: The matrix contains silt, clay, and clay-size mineral particles.
- Porosity: Abundant voids between sand particles appear blue in the micrographs.

Table 4: Weight Percentage of Constituents in Replica Adobe Brick

Size Fraction	Percentage Retained	Constituents
No. 4 (4.75 mm)	9.9	Subrounded gravel
No. 8 (2.36 mm)	14.5	As above
No. 16 (1.18 mm)	18.2	--
No. 30 (0.6 mm)	12.1	Mineral grains
No. 50 (0.3 mm)	14.3	As above
No. 100 (0.150 mm)	11.2	As above
No. 200 (0.075 mm)	7.8	As above
No. 325 (0.045 mm)	7.1	As above
PAN	4.9	Silt, clay, clay-size mineral grains
TOTAL	100.0	

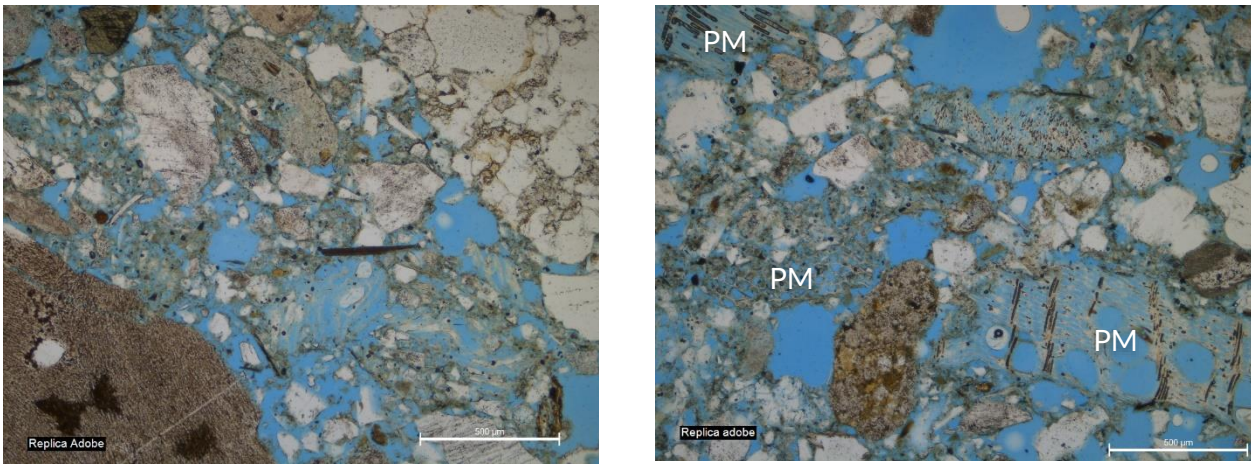

Figure 9: Replica Adobe Brick. Thin-section micrographs show the size and distribution of adobe constituents. Small aggregate particles are angular and similar to aggregate in the original adobe. Large aggregate particles are rounded and derived from a river source. Replica adobe has a coarser texture and contains larger pieces of plant material (PM in micrograph on right) compared with the original adobe. Pores are filled with blue-dyed epoxy. Plane-polarized light

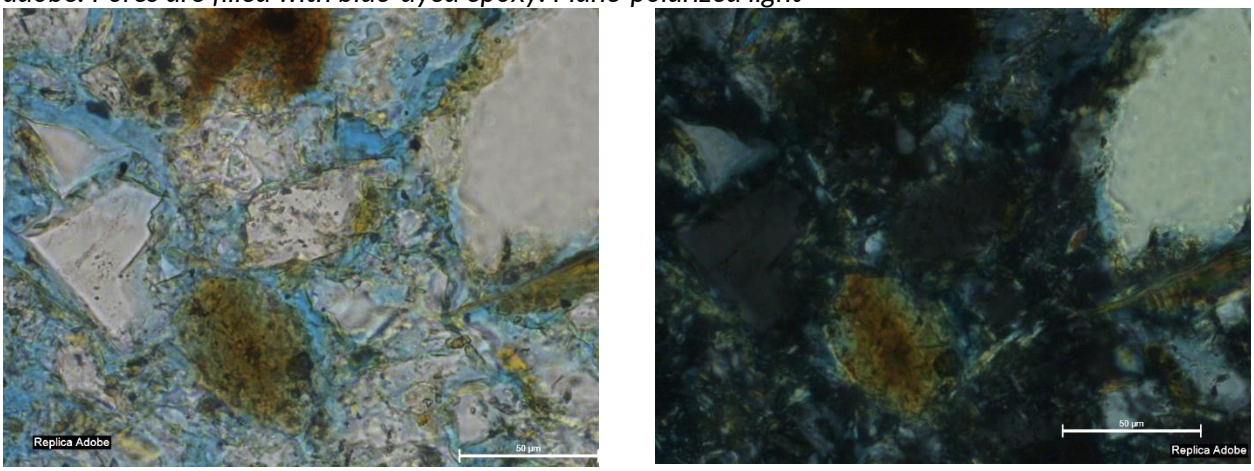

Figure 10: Replica Adobe Brick. Thin-section micrographs show the pore structure of the adobe matrix at high magnification. The matrix is less dense than the original adobe matrix. Small bright platelets in micrograph on right are clay particles. Plane-polarized light on left. Cross-polarized light on right

Tertiary Clay Yoder's Pit

Weight: 273.8 g

Dimensions: Roughly triangular fragment 115 mm by 115 mm by 90 mm, 20 to 30 mm thick.

Munsell Color: 10 YR 8/2 very pale orange with patches of 5 YR 5/6 light brown and 5 YR 5/2 pale brown. One side of the sample is thinly coated with 10 YR 6/6 dark yellowish orange clay.

Proportions and Composition: Weight percentages determined by crushing and sieving a 25-gram portion of the Yoder's Pit clay sample are given in Table 5.

Table 5: Weight Percentage of Constituents in Yoder's Pit Clay

Size Fraction	Percentage Retained	Constituents
No. 8 (2.36 mm)	0	--
No. 16 (1.18 mm)	0	--
No. 30 (0.6 mm)	8.2	Mineral grains
No. 50 (0.3 mm)	13.6	As above
No. 100 (0.150 mm)	16.6	As above
No. 200 (0.075 mm)	27.1	As above
No. 325 (0.045 mm)	24.2	As above
PAN	10.3	Silt, clay, clay-size mineral grains
TOTAL	100.0	

Table 6 lists quantities of mineral constituents determined by semi-quantitative XRD analysis of the clay-size fraction (smaller than 4 micrometers in diameter) of the adobe. The full report prepared by K/T GeoServices, Inc. is attached. Clays and clay-like micas make up 31.6 weight percent of the clay-size fraction. Quartz and feldspars make up 67.8 weight percent of the clay-size fraction. The clay minerals are predominantly illite, with smaller amounts of kaolinite and random-ordered mixed layer illite/smectite with 90 percent smectite layers.

Table 6: XRD Analysis of Yoder's Pit Clay Fraction

Mineral	Quantity (weight percent)
Quartz	35.5
Potassium Feldspar	10.5
Plagioclase Feldspar	21.8
Illite and Mica	22.5
Kaolinite	2.6
Random Ordered Mixed Layer Illite/Smectite with 90 percent Smectite Layers	6.1
Chlorite	0.4
Calcite	0.4
Pyrite	0
Hematite	0.2
Total	100.0

DISCUSSION AND RECOMMENDATIONS FOR REPLICATION

Original Adobe Mortar

The original adobe mortar was made using clay, gritty sand, hydrated lime, now carbonated, and a small quantity (0.3 volume percent) of plant material. The presence of hydrated lime is consistent with the Arbogast mortar analysis. The quantity of lime is roughly estimated at up to one-quarter part. Hydrated lime enhances the durability of the adobe mortar. The addition of hydrated lime appears to have been intentional. The gritty sand is highly angular and is similar to the grit in the Yoder's Pit clay source. Mineralogy and other characteristics do not support calcination of the clay as a source for the lime. XRD analysis showed only a trace amount of calcite in the Yoder's Pit clay. The mortar has a fine-grained texture with a maximum particle size of 0.06 inch (1.5 mm). Amounts of silt and clay-size particles passing No. 325 sieve is 4.2 weight percent compared with 10.3 weight percent in the Yoder's Pit clay sample. This suggests the Yoder Pit clay can be supplemented with an equal quantity of fine angular particles screened from the clay. The actual quantities should be determined in the field by evaluating the plasticity or workability that can be achieved by combining the clay with incremental amounts of water and grit and plant material.

The outer surface of the mortar exhibits water-repellency to a depth of 1 inch as a consequence of recent efforts to prevent degradation. It is unknown where a similar treatment was applied to the adobe brick. The fragment of Original Adobe Brick submitted for examination does not exhibit water repellency.

Original Adobe Brick

The mineralogy and clay mineral assemblage of the Original Adobe Brick and the Yoder's Pit clay are essentially identical indicating Yoder's Pit is a compatible source for replicate material. The brick contains 0.5 volume percent plant material. Yoder's Pit clay does not contain appreciable amounts of plant material. The brick has a fine-grained texture. The mineral grit in the brick and in the clay exhibit a high degree of angularity that is typical of a geologically young source. The brick contains approximately 85 weight percent grit particles retained between the No. 8 and No. 325 sieves and approximately 15 percent silt and clay-size particles. Yoder's Pit clay contains approximately 90 weight percent grit particles retained between the No. 30 and No. 325 sieves and approximately 10 percent silt and clay-size particles. The higher percentage of larger grit particles in the brick may reflect differences in the source material or may be an addition from a nearby source such as a partially decomposed granite. The dark color of the brick compared to the color of the adobe mortar and the Yoder's Pit clay is attributed to the abundance of black ash particles. Intentional addition of ash is unlikely. Technical references[1] do not mention the use of ash. The original clay source may have contained a horizon of burnt vegetation.

Replica Adobe Brick

The Replica brick is hard and dense; however, the brick fell apart when exposed to water. This behavior suggests less than optimal grading and/or proportions of constituents. The Replica Adobe

[1] Preservation of Historic Adobe Buildings. 2004. The Preservation of Historic Architecture. National Park Service, U.S. Department of the Interior. The Lyons Press, Guilford, Connecticut: 49-56.

Brick contains approximately 95 weight percent grit particles retained between the No. 4 and No. 325 sieves and approximately 5 percent silt and clay-size particles. The subrounded river sand and gravel particles are substantially coarser than the grit particles in the clay and the smooth surfaces do not interlock with the matrix. The Replica Brick exhibits coarse pore structure.

Considerations for Successfully Replicating Adobe Brick and Mortar

- Clay and silt constitute the primary binder of adobe. Typical drying shrinkage of adobe is 7 percent. Experimental work has shown that good dimensional stability is provided by high sand-to-silt ratio: 70 to 80 percent sand to 10-15 percent silt and clay[2].
- Optimum water content needed for a workable mixture should be determined by trial using material from different portions of the clay source. Vertical and lateral variations in proportions of clay, silt, and larger particles are expected. The amount of water should be less than the liquid limit.
- Too much gravel or too much clay adversely affect durability. Rounded particles do not effectively interlock with the matrix.
- High interstitial porosity exhibited by the original adobe is a characteristic feature of adobe.
- All un-stabilized adobe exhibits high absorption and is susceptible to deterioration if exposed to rainfall.
- Many building codes require adobe units to have compressive strength of 300 psi when tested in accordance with ASTM C67 (2021 International Building Code Section 2109 Empirical Design of Adobe Masonry). The compressive strength of the existing adobe brick could be determined on full bricks (five are required for the test), if sacrificing the bricks is permitted. Research conducted at the National Bureau of Standards (now NIST) measured compressive strength of adobe using 2-inch cubes cast from trial mixtures. Compressive strengths in the range of 200 to 500 psi were typically obtained.[3] Compressive strength was found to decrease with increasing moisture content. Reduction in compressive strength of over 50 percent was found to occur with moisture contents of 2 to 10 percent.
- In the present study, attempts to cut cubes from the samples resulted in fragmentation of the adobe. Compressive strength of the original adobe and replica adobe was estimated using an impact hammer. These results should not be relied upon.

CLOSING

YAES appreciates the opportunity to Gilmore Franzen Consulting LLC with this project. Please let us know if you have any questions regarding this report or if we can be of further assistance.

[2] Brown, P. W. and Clifton, J. R. 1978. The properties of adobe. Studies in Conservation 23(4): 139-146.
[3] Clifton, J. R. and Davis, F. L.1979. Mechanical Properties of Adobe. NBS Technical Note 996. U.S. Department of Commerce/National Bureau of Standards

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February 24, 2022

Laura Powers
YA Engineering Services - Milwaukee Region
12022 330th Avenue
Twin Lakes, WI 53181
(262) 358-2049
powersdoctor@gmail.com

Subject: X-ray Diffraction Analysis
K/T File No.: Z22044

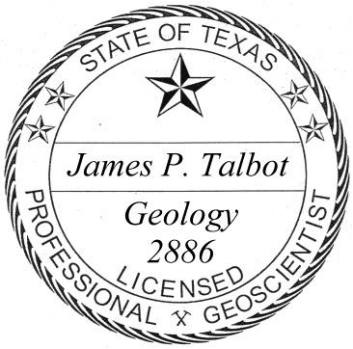
Dear Laura,

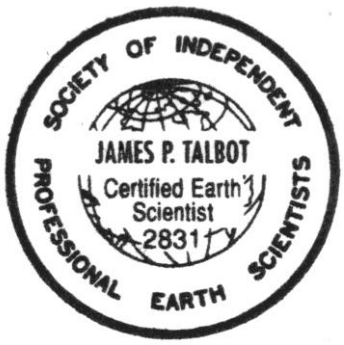
This report presents the results of Bulk and Clay X-ray diffraction (XRD) analysis. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

If you have any questions concerning these results or if you need anything else please contact me at (970) 641-1235. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,





James P. Talbot, P.G.

X-ray Diffraction Data (Weight Percent)

Sample ID	Quartz	K-Feldspar	Plagioclase	Calcite	Pyrite	Hematite	Illite&Mica	Kaolinite	Chlorite	R0 M-L I/S (90%S)*	TOTAL
Owen	42.1	11	26.5	0.6	0.8	0	15.9	1.5	0.5	1.1	100
Yoder	35.5	10.5	21.8	0.4	0	0.2	22.5	2.6	0.4	6.1	100

*R0 M-L I/S (90%S) - R0 (Random) Ordered Mixed-Layer Illite/Smectite with 90% Smectite Layers

See page 3 and 4 for mineral definitions.
See page 5 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 6.
X-ray diffraction traces are on pages 7 to 10.

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Pyrite
Pyrite (FeS_2) is an iron sulfide iron sulfide with a cubic crystal structure. Pyrite is also known as fool's gold.

Hematite
Hematite (Fe_2O_3) and its' alteration products are the most common cause of a red coloration in rocks, soils and sediments.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

Phyllosilicate (Clay) Minerals

Illite & Mica

Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Kaolinite

Kaolinite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate with the general formula $Al_2(Si_2O_5)(OH)_4$.

Chlorite

Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Clay Minerals

Clay mineral groups commonly containing Illite or Chlorite interlayered or interstratified with Smectite. The mixed-layer clay type is identified by the minerals involved, the type of order or stacking along the Z axis and the proportions of the minerals involved.

Smectite (Montmorillonite)

A clay mineral group synonymous with the montmorillonite group. The smectite group is composed of expandable (swelling) clay minerals. The general formula for Smectite is $(Na,Ca)(Al,Mg)_6(Si_4O_{10})_3(OH)_6 \bullet n\ H_2O$. Smectites are characterized by swelling in water and extreme colloidal behavior.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
XRD3 - Bulk and Clay (<4 micron) XRD Analysis
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative; there are many factors affecting the results.

XRD methods can quantify crystalline material only. Non-crystalline material in large concentrations can be detected but not quantified. Therefore, any non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of <1 to 5 weight percent. Detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

For this analytical method, the clay fraction is defined as the <4 micron (Equivalent Spherical Diameter) fraction of the sample. Clay fraction does not mean clay minerals (phyllosilicates) only, it is a size term and as such this size fraction can and almost always does include non-clay minerals (quartz, plagioclase, etc.). This size fraction is used because it typically contains abundant clay minerals.

Sample Preparation

Samples submitted for bulk and clay mineral XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of the sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random bulk mounts. A separate split of each sample is dispersed in distilled water using a sonic probe. The suspensions are size fractionated with a centrifuge to isolate <4 micron particles (<4 micron equivalent spherical diameter). The <4 micron suspensions are vacuum deposited on nylon membrane filters to produce oriented clay mineral mounts.

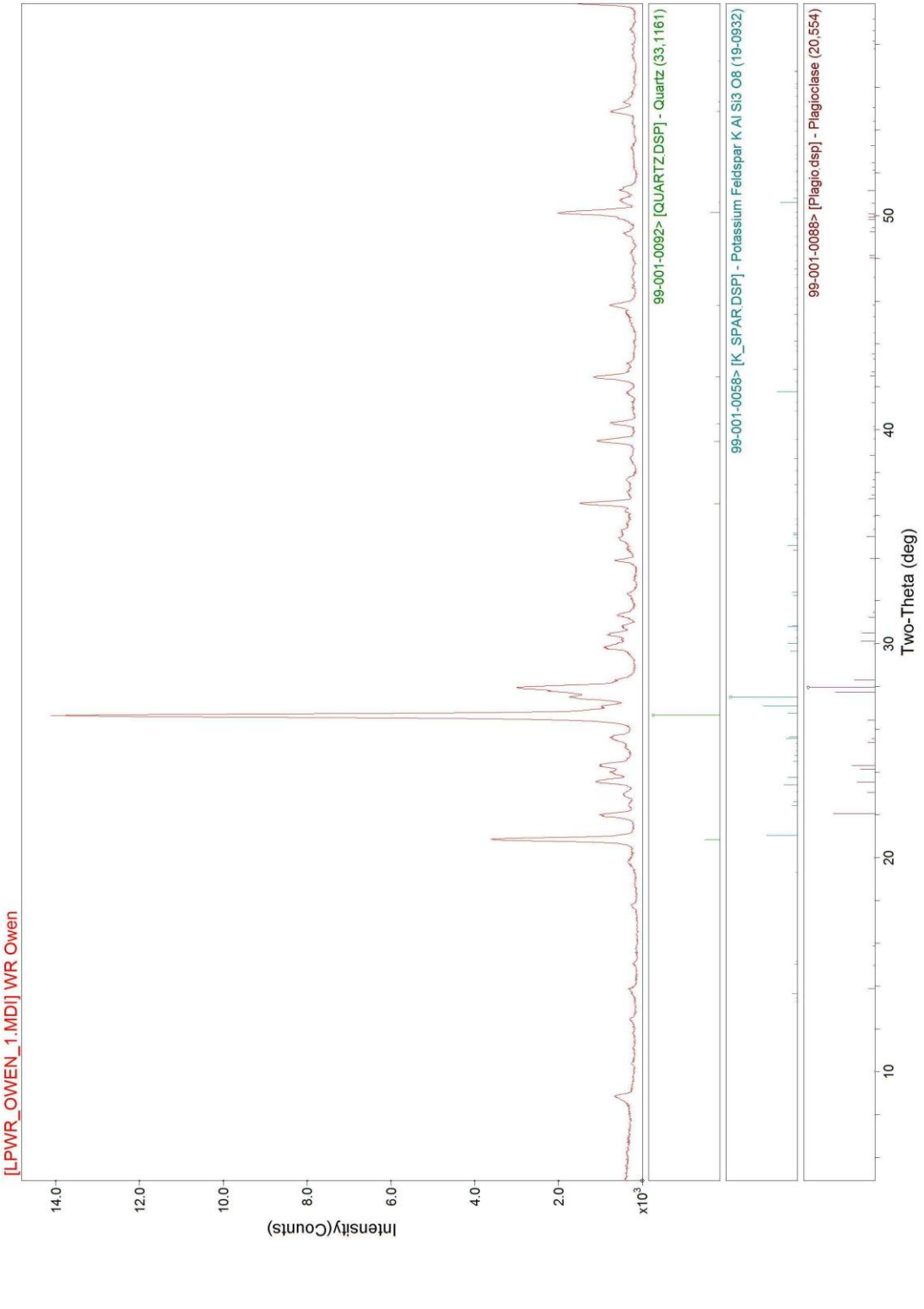
Analytical Procedures

X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The bulk powder samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute. The oriented clay mounts are analyzed over an angular range of two to thirty six degrees two theta at a scan rate of one degree per minute. Data are first collected on the air dried clay mounts. Next, the clay mounts are exposed to ethylene glycol vapor for a minimum of 12 hours and data are collected again.

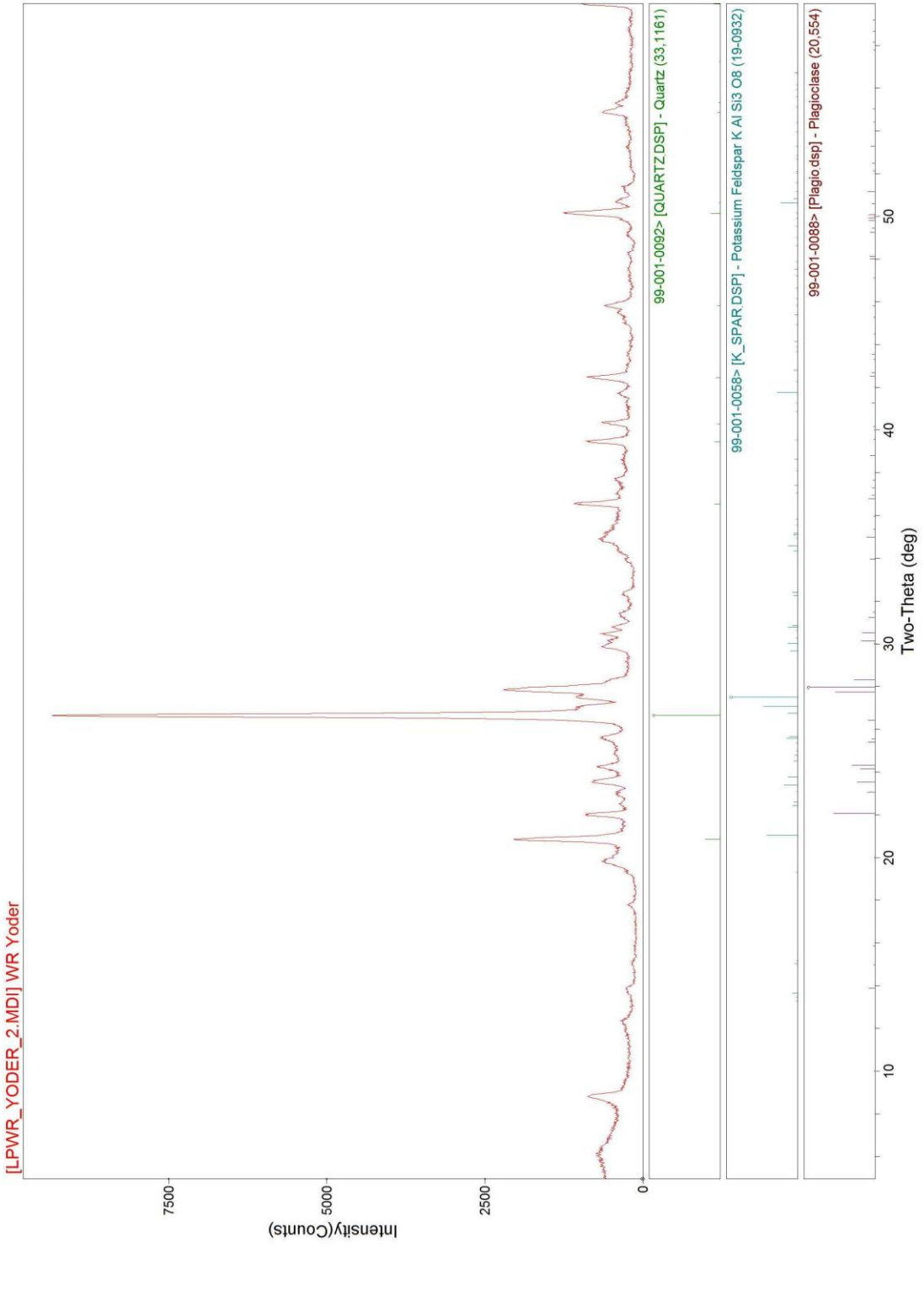
XRD patterns from air-dried and glycol-solvated clay-fraction samples are compared and qualitatively analyzed to determine the types of clays present in the samples. Determinations of mixed-layer clay ordering and expandability are done by comparing experimental diffraction data from the glycol-solvated clay mounts with simulated one dimensional diffraction profiles generated using the program NEWMOD written by R. C. Reynolds.

Semiquantitative determinations of bulk powder mineral amounts are done using Jade Software (Materials Data, Inc.) with the Whole Pattern Fitting option. All quantitative data (including clay mineral amounts) come from the bulk powder pattern. This is done by using Whole Pattern Fitting (WPF) and Rietveld refinement methods on the observed data. A diffraction model is fit to the measured pattern by non-linear least-square optimization in which certain parameters are varied to improve the fit of the model to the observed data. Modeling parameters include background, profile parameters, and lattice constants. For Rietveld refinement, a complete physics simulation is generally used in which crystal structures of the phases are required. Since the physics of scattering is well known, this method can be very exact and even allow adjustment of atomic coordinates, occupancies, and thermal parameters.

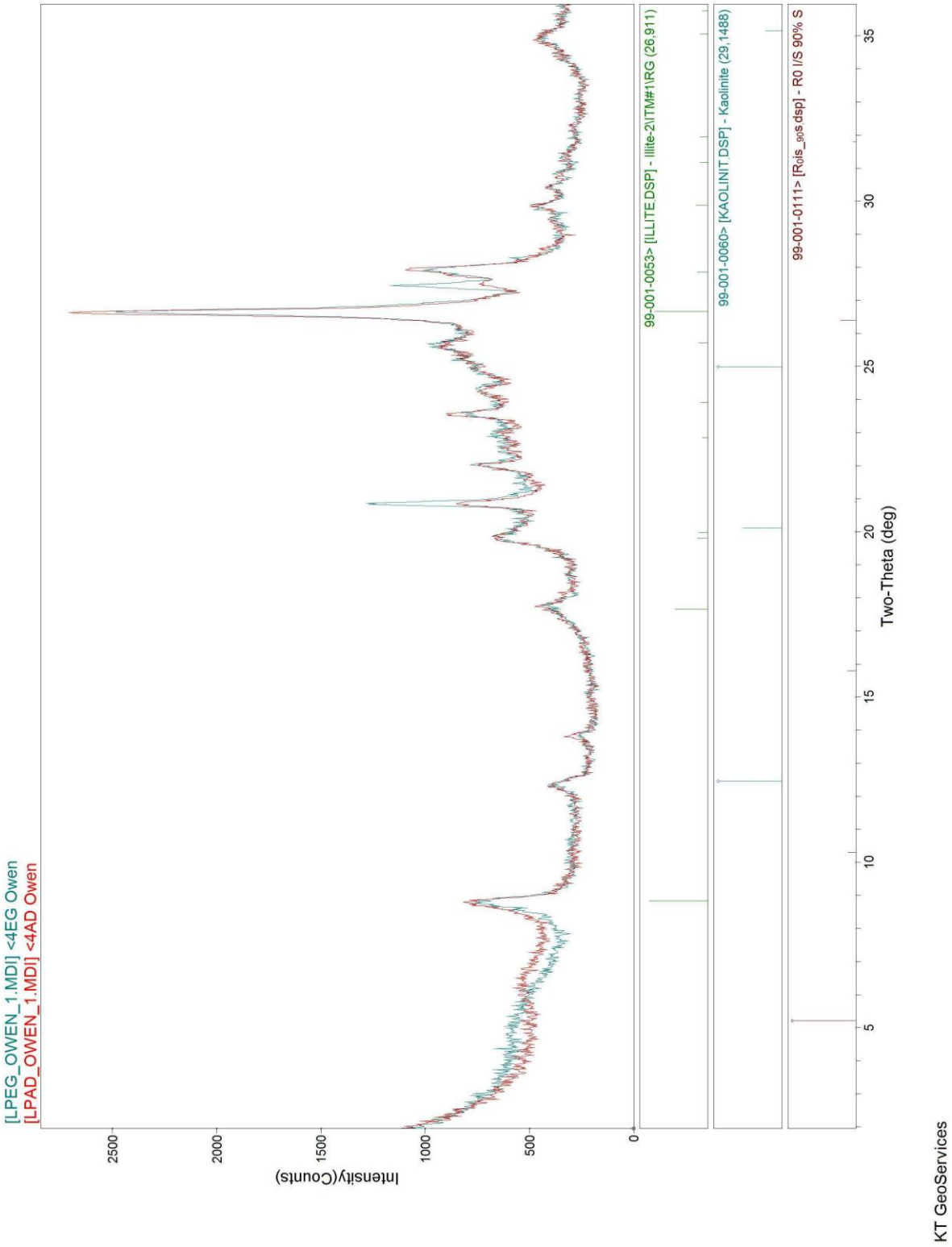
Bulk (Whole-Rock)
X-ray Diffraction Trace



Bulk (Whole-Rock)
X-ray Diffraction Trace



Ethylene Glycol (EG) Solvated Clay Fraction (<4 micron)
and Air-Dried (AD) Clay Fraction (<4 micron)
X-ray Diffraction Traces



Ethylene Glycol (EG) Solvated Clay Fraction (<4 micron)
and Air-Dried (AD) Clay Fraction (<4 micron)
X-ray Diffraction Traces