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Energy Efficient Crawlspace Foundation Retrofit: Mixed Humid Climate

M. Del Bianco, J. Wiehagen, and A. Wood
NAHB Research Center

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Energy Efficient Crawlspace Foundation Retrofit: Mixed Humid Climate

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Office of Energy Efficiency and Renewable Energy

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Golden, CO 80401

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Prepared by:

M. Del Bianco, J. Wiehagen, and A. Wood

The NAHB Research Center Industry Partnership

400 Prince George's Boulevard

Upper Marlboro, MD 20774

NREL Technical Monitor: Stacey Rothgeb

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Contents

List of Figures

Unless otherwise noted, all figures were created by NAHB.

List of Tables

This table was created by NAHB.

Definitions

BA	Building America Program
HPH	High performance home
HVAC	Heating, ventilation, and air conditioning
PDA	Pre-Design Assessment
PDA Checklist	Pre-Design Assessment Checklist which also serves as the Job Ready Checklist and a design details checklist for an assembly retrofit
QA	Quality assurance
QMS	Quality management system
SOW	Scope of work
Specs/Specification	Specifications for the project can be contained in the contract, scopes of work, or as details within the blueprints

Executive Summary

Building high performance homes (HPHs) that are energy efficient, durable, comfortable, and safe requires more than knowledge of building science principles. It also requires the ability to properly design, specify, install, and startup/commission new technologies and systems. Quality management systems (QMSs) provide the infrastructure necessary to ensure repeatability and to manage continual improvement to increase first time quality, reduce warranty, and increase customer satisfaction. QMSs are therefore needed as the industry shifts from conventional homes to HPHs, and ultimately to state-of-the-art homes such those meeting the U.S. Department of Energy's Challenge Home criteria.

As builders and remodelers strive to build HPHs, QMS is emerging as a critical need for implementing complex, whole-house changes to the conventional design and construction processes. However, residential QMSs have most often been designed for new home construction. To address quality in existing homes in the form of scopes of work (SOWs), the NAHB Research Center began with a new construction SOW and applied it to an existing home project.

This report outlines the steps of translating a new home construction SOW to SOW for retrofit. As such, the NAHB Research Center began with the new home construction SOW developed under the Building America Program (BA) for HPHs that addressed crawlspace foundations (NAHB 2010). The Research Center worked with Greenbelt Homes, Inc., a cooperative in Greenbelt, Maryland, to develop this SOW as part of the remodeling and retrofit existing home test house project and as part of Greenbelt Homes, Inc.'s pilot program. The key areas covered include:

- **Section 3: Crawlspace Foundations in a Mixed-Humid Climate.** This section outlines the details needed to address the crawlspace and aligns with other recommended BA best practices (Dickson 2010).
- **Section 4: Quality Assurance Strategy for Implementation.** This section details the recommended QA measures based on the new home construction SOW applied to the existing home project. This includes construction documentation for existing homes as detailed in this report and new construction documentation recommended by BA best practices (Lukachko et al. 2011), as applicable.
- **Section 5: Next Steps.** This section details the next steps for existing home quality strategies.

This methodology and detail can be used as guidance by architects, remodeling firms, trade contractors, and homeowners.

1 Background

The U.S. Department of Energy's Building America Program (BA) research teams work with industry partners to produce new and existing high performance homes (HPHs) that enhance energy efficiency. As BA expands its support of housing research to encompass the high performance retrofit of existing homes, the quality management of details that are unique to remodeling becomes significant to each project's efficiency, as well as programmatic proliferation, and ultimately, energy consumption reduction by the largest factor of the housing sector—existing homes.

Recognizing that quality management systems (QMSs) are key to implementing change in any industry, BA established a quality assurance (QA) research and outreach program to support the home building and remodeling industry's transition to HPH. The residential construction and retrofit industries need systematic quality management systems to adopt HPH methods on a larger scale to ensure repeatability. In addition, as houses are higher performing it is also important to address system interactions to ensure energy performance, durability, health, safety, comfort, and affordability.

Quality activities under BA began with the development of high performance scopes of work (SOWs) for HPH components. This seminal work weaves HPH building specifications and procedures into the active management and implementation strategies of a comprehensive QMS. It also addresses trade partnering and continual monitoring, feedback, and control. Some of these resources are listed and described in Appendix A.

2 Introduction

Quality has been an industry buzzword for decades. Yet, quality management is not a fuzzy concept. Instead, it is a tried-and-true framework for delivering high-quality products, on time and within budget. Builders and remodelers stand to benefit greatly from implementing QMS—in large part because of the disproportional cost of correcting defects in a finished product. Residential QMSs address the assurance of a high-quality finished product that is constructed per the designedand the ability to consistently repeat the same house or retrofit.

As builders and remodelers strive to build HPHs, QMS is emerging as a critical need for implementing complex, whole-house changes to the conventional design and construction processes. However, residential QMSs have been primarily designed for new home construction. As a result, the NAHB Research Center began with a new construction SOW and applied it to an existing home project. The goal is to address quality in existing homes using these same techniques from new construction to increase first time quality, reduce warranty, and increase customer satisfaction.

This document is intended to outline the steps of translating a new home construction SOW to SOW for retrofit. As such, the NAHB Research Center began with the new home construction SOW developed under BA for HPHs that addressed crawlspace foundations (NAHB 2010). The Research Center worked with Greenbelt Homes, Inc., a cooperative in Greenbelt, Maryland, to develop this SOW as part of the remodeling and retrofit existing home test house project and as part of Greenbelt Homes, Inc.'s pilot program. The key areas covered include:

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The templates that were developed to support this QA strategy for crawlspace retrofits are organized in the expected order of work performance for an existing crawlspace and use a system that includes a list of sources for details to the crawlspace conditions and remedies specific to a project.

3 Crawlspace Foundations in a Mixed Humid Climate

The American Housing Survey for the United States: 2007 (AHS 2008)[1] indicates that one sixth of U.S. houses are built on crawlspace foundations that are often difficult to access, hard to maneuver in, unlit, and seemingly beyond a building's envelope. For these reasons, inspection and maintenance are often deferred. Typically, when crawlspace foundations are accessed, mechanical issues are addressed or wiring is installed; additional upgrades for durability and energy efficiency are not considered. Because they are typically poorly maintained, and often poorly constructed, many crawlspace foundations are sources for heat loss, poor indoor air quality, and excessive moisture production.

Insulation and air sealing are as fundamental to the energy efficiency of existing homes as to newly constructed buildings for example, in crawlspaces (SEI 2000). Yet a package of details, specifications, checklists, and trade contractor scopes needed for this work as it relates to crawlspace foundation inspection and quality retrofit were not found in a recent literature search performed on behalf of a BA partner who is planning an energy efficiency upgrade to two 70-year-old buildings. Even architectural plans recently developed for a crawlspace retrofit were too vague for accurate bid submission and lacked performance expectations for the installers and the finished product. The experience brought to light the need for high performance SOWs in remodeling that provide sufficient description to result in an improved crawlspace foundation and allow for more accurate bids and, thus, affordable jobs.

This experience reinforced the integral role that QMS can play in high performance remodeling projects and motivated the development of this report to provide strategies for assessment, retrofit specification and detail (design), implementation with a comprehensive SOW, and inspection of the finished project to affirm completion to contract specification and expected performance. The contents follow a format that can guide architects, remodeling firms, trade contractors, and owners. The two predominant crawlspace foundation types—closed and ventilated—are addressed in the checklists.

Crawlspace foundations may be described as being constructed with continuous perimeter stem walls, typically of concrete masonry units or poured concrete. The walls are usually of sufficient height to allow access by a person "crawling" (typically 24 in. or more of clear space) and support wood or light gauge steel joists or concrete slab decks. Its floor is often dirt or gravel covered with a polyethylene vapor barrier, although 2–4 in. thick concrete slabs sometimes finish crawlspace floors. Crawlspace foundations are most common in the Marine, Mixed Humid, and Hot-Humid Climates (Figure 1) where historic frost depths are less than 30 in. In these climates, a crawlspace foundation design minimizes foundation and footing material on sites where a slab-on-grade foundation is not feasible or desirable. A crawlspace is sometimes considered more desirable over a slab-on-grade because of the access to mechanicals (electrical, plumbing, and heating, ventilation, and HVAC services).

[1] Statistics for occupied housing units.

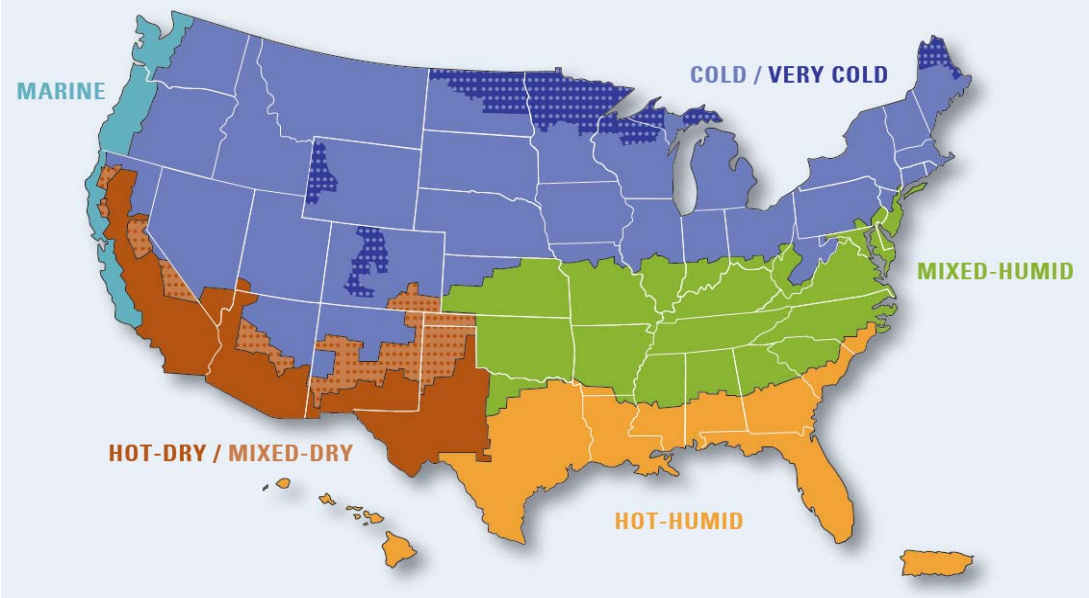


Figure 1. BA climate zone map

Sealed (or unvented) crawlspace foundations use the foundation walls as a thermal and air barrier for the crawlspace and can be conditioned or unconditioned actively (see Figure 2). Often, hot water pipes, water heaters, ductwork, or other mechanical systems provide some tempering of the temperature and humidity in the crawlspace and air exchange consists of building air leakage from the living area above into the crawlspace or vice versa. The air quality and temperature of a closed crawlspace are meant to be similar to those of a basement foundation, or even close to the living area above it. An air seal between the areas is less critical, if the crawlspace air quality and vapor content are maintained similarly to the conditioned space over the crawlspace, typically via mechanical ventilation.

Ventilated (or vented) crawlspace foundations, on the other hand, use the floor system above the crawlspace as the thermal and air boundaries between conditioned and unconditioned spaces (see Figure 3). During some parts of the year, this design relies on ambient air exchange to dry the crawlspace through above-grade air vents in the foundation wall. Despite the vented crawlspace's location outside the building envelope, many times the floor above the crawlspace is not well insulated or air sealed, the crawlspace is not well vented and/or does not have an adequate vapor barrier covering over the soil floor, or has bulk water intrusion and even standing water, allowing the space to disproportionately degrade an older home's energy efficiency, durability, indoor air quality, and comfort. Some ventilated crawlspaces can be retrofitted to a sealed crawlspace if site conditions warrant.

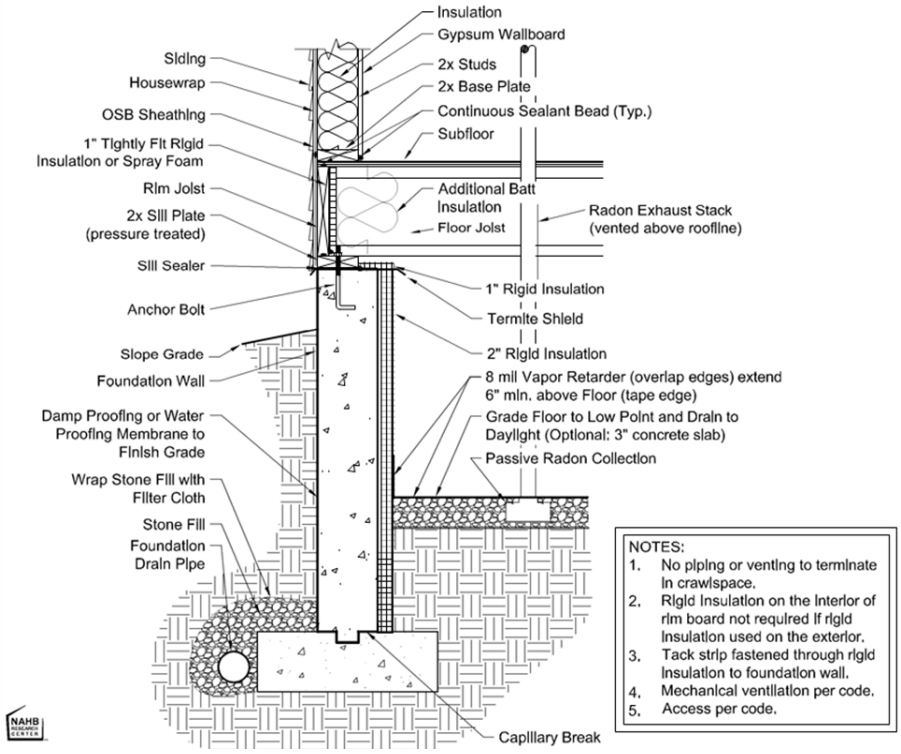


Figure 2. Sealed (unvented) crawlspace foundation section

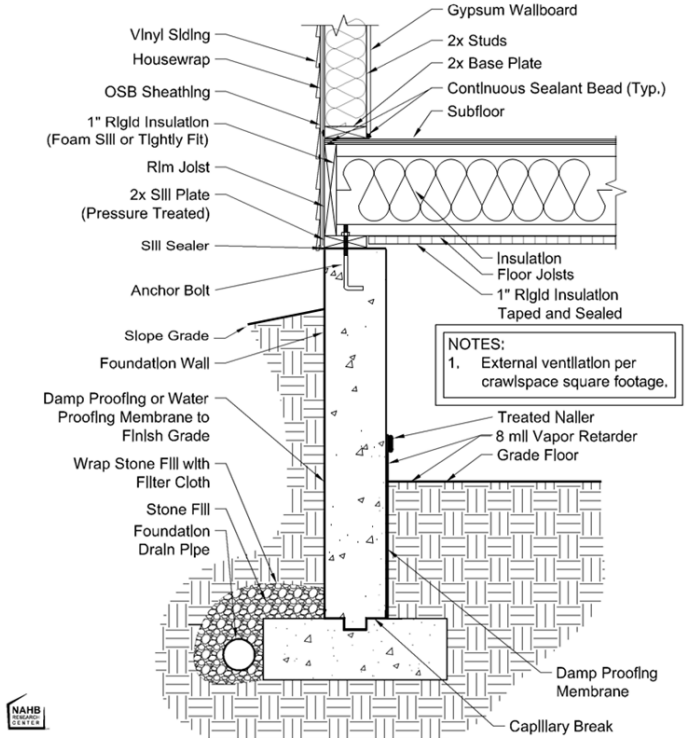


Figure 3. Ventilated (vented) crawlspace foundation section

4 Quality Assurance Strategy for Implementation

Implementation tools, including a QA strategy for components and assemblies of existing homes, is undertaken to bring the same performance rigor to remodeling as BA introduced to new home construction. The goal of this work is to incorporate technical specifications into the implementation process to ensure that the remodel is completed per the design. The QA approach to the rework and retrofit of existing homes consists of a four-step, focused approach that is facilitated by a series of checklists and SOWs that will guide the pre-design assessment (PDA), design, retrofit, and post-completion inspection of projects that are likely to encompass a plurality of outcomes that include energy efficiency, obsolete equipment replacement, durability, and occupant comfort.

This QA strategy for existing HPHs targets a building assembly, the crawlspace foundation, and its perimeter and contents, as the subject of a discrete project. This approach allows implementation of a systems methodology to building retrofit and simultaneously restricts work zone locations to minimize inconvenience to the occupants. For example, in the cases documented in Appendix C and Appendix D, the crawlspace retrofit is a small component of a whole-building energy retrofit that was implemented in fall 2011. Future phases will be performed after the winter weather has passed, perhaps by different general contractors.

The four steps to the strategy are:

1. Inspect the building.
2. Plan the design and specifications.
3. Execute the work.
4. Inspect the completed work.

Heavier emphasis is initially applied to steps 1 and 2, because the work to be performed, which is covered in the description and SOW that is developed in step 2, is less intuitive in remodeling than it would be to the specialized trades employed in new construction. Thus, defining the starting condition and determining required repairs and new installations are emphasized more than standardized methods that can be applied to the work. To facilitate this approach, line items in the PDA Checklist (Appendix B), a template developed for this retrofit strategy and introduced in step 2, include a resource code in the first column that is tied to additional sources for information that are itemized in Appendix A. Reference documents contain material for the "how-to" specific to each possible case, so that the plans and specs can be customized to the climate, architecture, and conditions encountered during the assessment.

This QA strategy for existing HPHs gives assessment, design, and planning primary emphasis over implementing the work and the continuous improvement of the installation, as each install may be significantly different than the previous, depending on the age and construction of the building. This initial strategy stresses QA process management of the assessment, plans, and specs as the means of providing specific instructions for the work.

Checklists that support this retrofit strategy are organized in the order that work is expected to follow.

4.1 Pre-Design Assessment Defines the Project's Starting Point

The project PDA will include visual inspection of the construction state of components of a given assembly. In this example, the assembly is the crawlspace foundation. Some crawlspace components may be joists, insulation, vapor barrier ground cover, plumbing pipes, HVAC equipment, and ducts. Thus, the PDA examines:

- Structural and mechanical systems
    - Wood structural members embedded in masonry, air leakage into space conditioning system ducts, etc.
- Thermal and air barrier locations
    - Evidence of moisture or bulk water intrusion, conditions present within and outside the foundation (e.g., crawlspace windows and window wells, and recommendations about how to best resolve problems related to bulk water and moisture intrusion and air leakage, and whether the retrofit should continue if those items are not fully addressed)
- Minimum prescriptions of the current building code
- BA and other industry best practice details to provide the standards to which the assembly characteristics are compared

This assessment will be aided by the PDA checklist (Appendix B) to document the features and conditions as initially encountered.

The PDA of a home's crawlspace foundation may involve one person or a small team with broad-based construction, trade, and building science knowledge to meet practical and budgetary constraints. Within the crawlspace, details such as insulation, plumbing, mechanical, framing, masonry, drainage, and grading must be observed and conditions noted. Similarly, the installation phase may be more efficiently executed with cross-trained workers rather than trade-specific specialists.

The condition of the crawlspace foundation supporting an existing home can be assessed using physical observations made from three sides of the crawlspace: floor over the crawlspace (inside the home), inside the crawlspace (within the walls), and exterior. Table 1 outlines the topics covered and entered on the PDA checklist. The PDA checklist uses the locations in Table 1 to organize the order of the field assessment from interior to exterior and leaves the dirtiest job for last, so dirt is not tracked into a home. The checklist also outlines the sequence for mitigation of moisture problems in a foundation.

Information from the PDA checklist in Appendix B will guide the design plans and SOW, which will be developed to serve as a comprehensive blueprint for the retrofit. A completed checklist also serves as the Job Ready Checklist common to the QA strategy in new construction because the PDA checklist provides information about the condition of the crawlspace. In addition to physical observations, the airtightness of the building may be measured. Physical factors such as air temperature and humidity should also be gauged and recorded.

Table 1. Outline of the PDA: Crawlspace Foundation

Location: Inside the Home
Excessive moisture (mold, odors, rust, etc.)
Occupants' observations
Blower door and duct tightness testing (before and after)
Temperature and humidity on date of inspection
Location: Outside the Crawlspace
Roof water is directed away from foundation wall
Exterior grade directs water away from foundation wall
Planting allows inspection and avoids putting pressure on foundation walls
Size, position, location and quantity of ventilation grills
Size, position, location and quantity of windows and window wells
Location and condition of sump pump outfall
Composition and condition of foundation walls and cladding
Temperature and humidity on date of inspection
Location: Inside the Crawlspace
Overhead floor assembly and connection to foundation
Condition of interior floor, slope, drainage, and vapor barrier
Location and condition of sump pit/pump and interior drains
Wood rot, mold, or condensation
Location, type, and condition of mechanicals (sealed ducts, insulated pipes, etc.)
Location of building perimeter air seal
Location, type, thickness, and condition of insulation
Lighting and power sources
Temperature and humidity on date of inspection

Interviews with the occupants may provide additional data on performance matters and potential synergies with complementary projects in progress or planned.

The SOW was organized in the general order that the work is expected to follow, which is:

A. Correct exterior drainage.
B. Remove wet products and debris from the interior.
C. Repair structural damage.
D. Repair/install interior foundation drain system.
E. Correct interior crawlspace floor moisture conditions.
F. Correct interior wall moisture.
G. Remove mold and replace rotten wood.
H. Repair/install ground vapor barrier.
I. Correct structural defects (load path tie-down hardware).

J. Repair/replace HVAC, pipes, ducts, and equipment within crawlspace (consider venting options in closed crawlspace).

K. Seal interior thermal boundaries.

L. Insulate overhead floor system and air seal assembly (ventilated crawlspace only).

M. Insulate crawlspace wall (closed crawlspace).

Each of these items must be addressed for the project to proceed.

4.2 Project Plan: Define Condition, Standards, and Scope of Work and Responsibility

The PDA Checklist will assist in composing a design with a floor plan, sections, and SOW that incorporates remedies for all noted defects and deficiencies, as well as inclusion of design features to enhance energy efficiency. To be useful, remodeling plans should be highly descriptive, perhaps even more than standard blueprint drawings for new houses. Designs should clearly detail the dimensions and state in section and floor plan views and include directions on components/areas to be removed, repaired, replaced, etc. Sections, floor plans, and detail insets should be rendered in a recognizable scale or format that ensures legibility and, thus, effective implementation. SOWs supplement the information contained on the project's plans and define the breadth of contractor responsibility. Photographs of the structure may serve for elevation details such as those shown in Figure 4 and Figure 5.

Figure 4. Front elevation Building W2, left

Figure 5. Front elevation Building W2, right

A floor plan of a closed foundation, Figure 6 conveys details of both the current and desired end state of the crawlspace. The floor plan was rendered as the design for a closed crawlspace foundation retrofit of the building in Figure 4 and Figure 5. It includes notes from the PDA and salient features of the upgrade. Showing before and after conditions in both the floor plan and drawing sections, as required, is the most accurate way to describe the project.

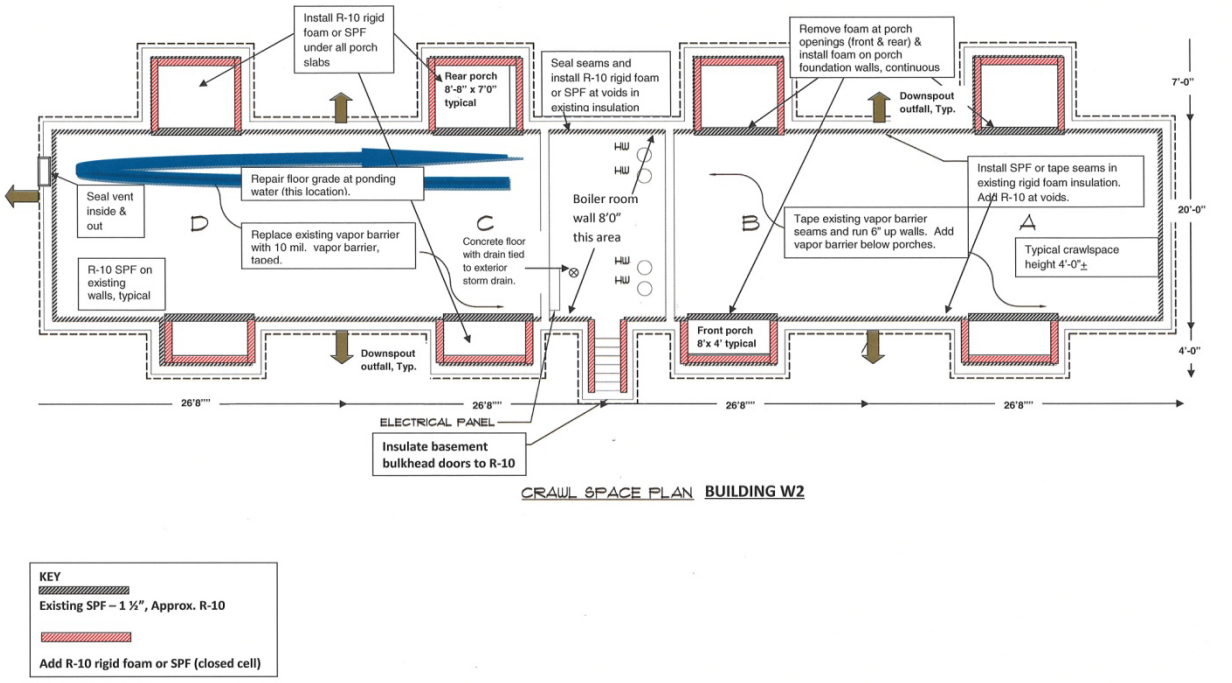


Figure 6. W2 closed crawlspace foundation plan

For bidders (remodelers and contractors pricing the work), this is a blueprint to the state of the crawlspace and the work that is required to upgrade the area to meet project initiatives. It is an indication of the working conditions in which the project will take place. With typical remodeling bid contingencies ranging from 5%–20%, the information contained on the design documents sets the tone for which end of that span is warranted in the bid submittal. Appendix C and Appendix D include all the information that would be provided to bidders. Lack of information in the design package has a variety of drawbacks, including:

- Vague descriptions that inspire questions
- Uncertainty that requires contingency planning
- Higher costs caused by planned contingencies, often a sizable percentage of the bid price.

These drawbacks can result in a nonvalue-added price-inflated project and longer payback periods (because of the higher cost:savings ratio caused by the inflated price). Ultimately, this can limit or cancel the energy retrofit project.

Figure 7 is a sectional drawing of the foundation that was completed during the pre-assessment inspection of Building W2. It further defines the current condition of the crawlspace foundation and the rework that is required to upgrade the assembly.

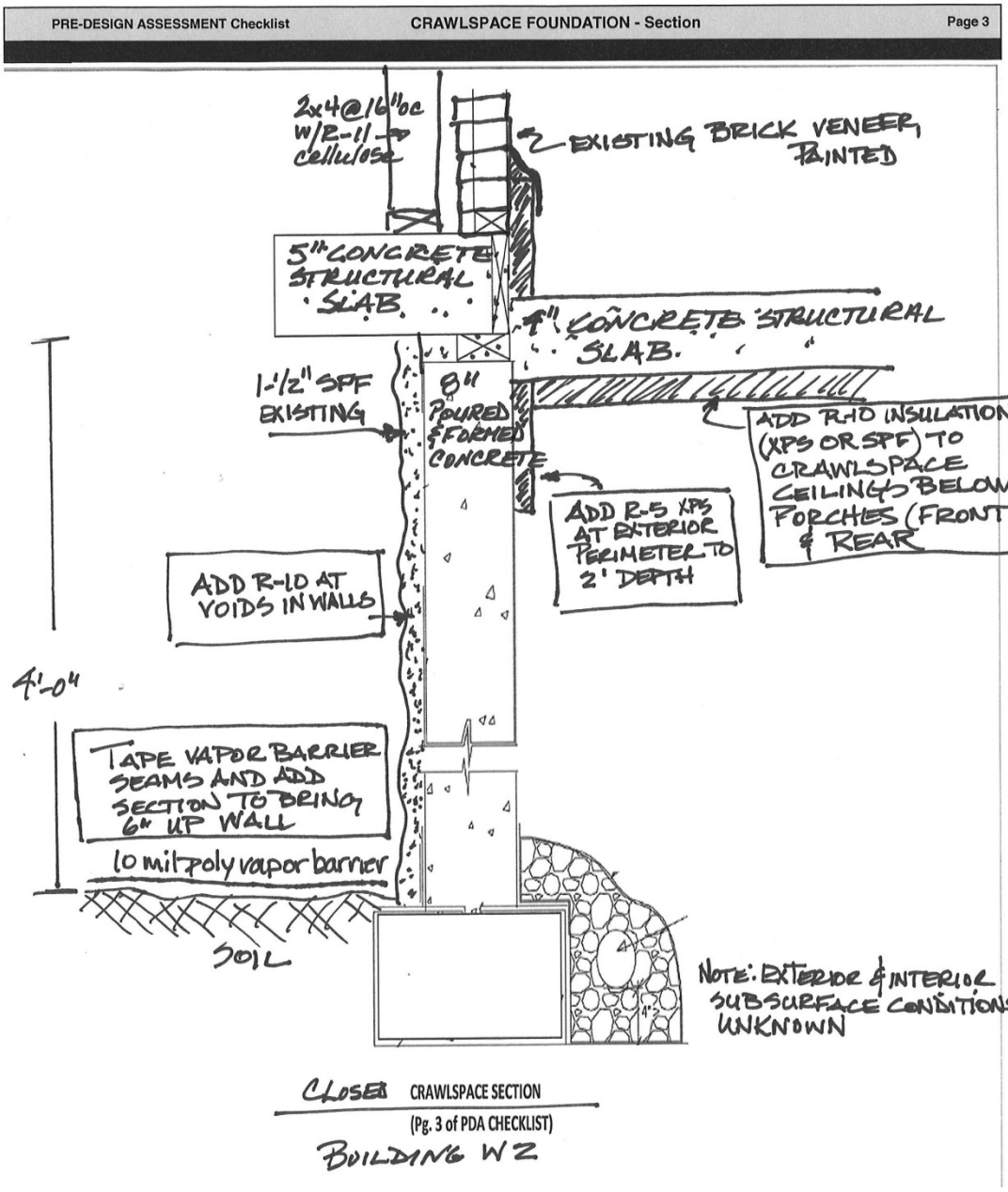


Figure 7. Crawlspace foundation wall section, Building W2

4.2.1 A High Performance Scope of Work for Energy and Durability Upgrades to an Existing Crawlspace Foundation

An SOW is the written description of the work that is contained on the project drawings. It informs all parties of the work a contractor will perform for a builder, remodeler, prime contractor, or owner. The SOW guides all the component-specific work covered by a contract and, in the case of a remodel, distinctly outlines the before condition[2] of the project, the expected job performance and extent of responsibilities, and the desired post-performance state of the assembly. The retrofit SOW for crawlspace foundations incorporates details specific to the design, as well as applicable and practical aspects of the high performance scopes for new construction, such as moisture mitigation. The SOW may include standards that exceed building code minimums, additional directions covering repair rather than replace directives, and any other details covering contractors' responsibilities or preferred materials. Conditions noted during the crawlspace PDA inspection will generate some of the items on the SOW, as each crawlspace foundation will have unique features. An SOW can serve as the bid submittal sheet, as well as a Job Completion Checklist by customizing the columns for these details.

As a point of reference, Table 402.1.1 of the 2009 IECC (IECC 2009) outlines the prescriptive insulation values for crawlspaces, as follows:

Climate Zones	R-Value	Building Location
1 - 2	R-0	Wall[1]
1 - 2	R-13	Floor
3	R-5	Wall[1]
4 - 8	R-10	Wall[1]
3 - 4[2]	R-19	Floor
4[3] - 6	R-30	Floor
7 - 8	R-38	Floor

[1] Continuous insulation
[2] Zone 4, non-marine
[3] Zone 4 marine

Because each remodeling job or retrofit project is unique, designers may need to consult a number of sources (BA Best Practice Series, International Energy Conservation Code, etc.) to determine the best practice for the condition they encounter, given a stated budget and geographical location. Features in the PDA checklist are cross referenced to citations in the References section of this report to assist in best practice, method, and material selections for any number of situations that may be encountered. The SOW is organized in the general order that the work is expected to follow; which is:

A. Moisture mitigation
B. Repair of structural defects
C. Repair of mechanical systems
D. Repair of air seal barriers
E. Repair of thermal barriers.

The designer is responsible for the blueprint detailing the extent of the labor effort and requirement for new materials. High performance remodeling plans are rarely generic and do not lend themselves to master specifications. Thus, a heavy focus has been put on the assessment and design stages as the retrofit project's initial QA strategy.

[2] The "Job Ready" state.

Not all the tasks contained on the SOW in Appendix B will pertain to every crawlspace retrofit. The project's designer will delete or add tasks based specifically on the results of a project's assessment and goals. The SOW was constructed to be as comprehensive as possible to encourage (and induce) the project planning team to address the myriad details of high performance crawlspace foundations. The SOWs in Appendix C and Appendix D are examples of the customization of the form to fit a particular project.

Cases: The PDA checklists (Appendix B) and SOW in Appendix C were completed with the data from an actual project to provide more comprehensive detail on using these templates. The cases used in this study consist of crawlspaces in a mixed humid climate—one building's crawlspace foundation is ventilated (Appendix D) and one is a closed (unvented) foundation (Appendix E).

4.3 Execute the Work

Installers must be trained in the application of the products, use of the tools of the process, and jobsite safety. The plans and SOW should provide significant comprehensive guidance for a worker thus prepared to perform the work with limited or no direct supervision. Expediencies specific to types of activities or the work approach to be taken with given architectural styles will be learned as installers perform more retrofit projects, or mount the learning curves associated with each task in the given environment. Thus, for the near term, constructability is probably the single biggest hurdle the installer faces. A good assessment of the original condition and plans detailing the desired outcome will help an experienced workforce successfully complete a project. The designer's careful consideration of the materials, methods, and sequencing will support the dual goals of constructability and performance.

Installers with experience in successful retrofits should be cross-trained in assessment and encouraged to share their observations with the design team so each project shows improvement and profitability over the last.

Enhance Project Affordability Through Quality Management

1. Assessment inspection
2. Design includes repair and energy upgrades, existing and finished conditions.
3. SOW
4. Post-installation inspection

4.4 Inspect the Finished Product

Some of the tasks contained in the SOW, such as the measures to alleviate moisture, will require inspection and sign off before other steps are completed. The SOW is ordered such that each task (line item) may be signed as complete before beginning the next. The ideal approach involves inspection for completion of the various subcomponents of the SOW while the project is in progress. In fact, no retrofit work involving the addition of new materials should take place until there is assurance that the crawlspace will remain dry. Use the SOW to enumerate the sequence of the order of completion of the tasks (from top of list to bottom) and reorder these as the project requires.

The SOW may function as the Task (line item) and Job Completion Checklist (entire SOW) and permanent record of the work performed.

In addition to proper retrofit, crawlspaces require regular inspection and maintenance to ensure conditions have not changed. The PDA checklist will serve as a comprehensive report for these periodic inspections, which should be performed annually.

5 Next Steps

As more houses are retrofitted with energy efficiency features, standardized methods and materials will emerge and the implementation (QA work execution), feedback, and improvement loop may be more explicitly defined. Ongoing research and development will identify some of the "bests" in products, practice, and performance. As an example, many products have reached the market recently that are more durable and fire resistant than 6 mil polyethylene, which was the traditional material used for crawlspace floor vapor barriers. In addition to their durability, many come in light-colored or reflective finishes that brighten the crawlspace environment, which improves interior visibility with less lighting. Light-emitting diode flashlights offer compact and hands-free options for better lighting over greater distances. These materials and tools make the crawlspace work environment safer and simpler. Materials such as spray foams, which allow application in difficult-to-reach locations, as well as superior air and thermal sealing capability, are also entering the marketplace regularly. These will contribute to the progress of completing the work efficiently.

References

"American Housing Survey for the United States: 2007". (AHS 2008). U.S. Department of Housing and Urban Development and U.S. Census Bureau. Last Accessed December 2012: www.census.gov/prod/2008pubs/h150-07.pdf

"Crawlspace Insulation". (SEI 2000). Technology Factsheet. Prepared by Southface Energy Institute. Last Accessed December 2012: http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/29238.pdf

Dickson, B. IBACOS. Guide to Closing and Conditioning Ventilated Crawlspaces, For Use With Poured Concrete Or Capped Block Walls. Deliverable 11.1. 2010.

International Energy Conservation Code 2009. (IECC 2009). Interantional Code Council, Inc.. Country Club Hills, IL.

Lukachko, A., Gates, C., Straube, J. Building Science Corporation. Strategy Guideline: Advanced Construction Documentation Recommendations for High Performance Homes, 2011.

NAHB Research Center (2010). Multi-Year Advanced Residential Building Systems Research, Appendix C, *Final Report of Quality Assurance Activities for New Homes*, 2010 www.toolbase.org/PDF/BestPractices/QualityAssuranceActivitiesforNewHomes.pdf

NAHB Research Center. (2010). Multi-Year Advanced Residential Building Systems Research, Appendix C, High Performance Scopes of Work. Latest Access: December 2012. www.toolbase.org/ToolbaseResources/level4BP.aspx?ContentDetailID=4173&BucketID=5&CategoryID=62

Appendix A: References for Use With the Pre-Design Assessment

B-1. *Building America Program's Builder's Challenge*, www1.eere.energy.gov/buildings/challenge/bcqc_criteria_glance.html

B-2. *Building America Best Practices – Mixed Humid Climate*, 2005. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/38448.pdf

B-3. Building America Program, *Basement and Conditioned Crawlspace (Unvented) Crawlspace Insulation*, 2005. www.energycodes.gov/rc/Vol3_BasementInsulation.pdf

C-1. Canada Mortgage and Housing Corporation, *Development and Assessment of Crawl Space Remediation Strategies*, 2008. www.cmhc-schl.gc.ca/odpub/pdf/65916.pdf

C-2. Cushman, Ted, Coastal Contractor, *Solving the Uplift Puzzle*. www.coastalcontractor.net/article/159.html

D-1. Dominion Power, *Crawlspace Moisture Control*. www.dom.com/about/conservation/pdf/crawlspaces.pdf

E-1. EERE, *Builder's Challenge*, www1.eere.energy.gov/buildings/challenge/about.html

E-2. EERE, *Crawlspace Insulation*. www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11480

E-3. EERE, *Measure Guideline: Sealing and Insulating Ducts in Existing Homes*, 2011. www.nrel.gov/docs/fy12osti/53494.pdf

EP-1. EPA, *Healthy Indoor Environment Protocols for Home Energy Upgrades*, 2011. www.epa.gov/iaq/homes/retrofits.html

I-1. International Residential Code, 2009.

K-1. Kansas Corporation Commission Energy Programs, *A Builder's Guide to Residential Foundation Insulation*, 1999. www.engext.ksu.edu/henergy/envelope/builderguide.pdf

N-1. NREL, *Building America Best Practices Series Volume 4: Mixed Humid Climate*, 2006 www.nrel.gov/docs/fy05osti/38448.pdf

N-2. NREL, *Building America Best Practices Series*, all volume access. http://nrelpubs.nrel.gov/Webtop/ws/nich/www/public/SearchForm

NA-1. NAHB Research Center, Multi-Year Advanced Residential Building Systems Research, Appendix C, Final Report of Quality Assurance Activities for New Homes, 2010 www.toolbase.org/PDF/BestPractices/QualityAssuranceActivitiesforNewHomes.pdf

NA-2. NAHB Research Center, Multi-Year Advanced Residential Building Systems Research, Appendix C, High Performance Scopes of Work, 2010

www.toolbase.org/ToolbaseResources/level4BP.aspx?ContentDetailID=4173&BucketID=5&CategoryID=62

NA-3. NAHB Research Center, Multi-Year Advanced Residential Building Systems Research, Revisions to Quality Management Products: Four Scopes of Work for High Performance Homes, 2008

www.toolbase.org/ToolbaseResources/level4BP.aspx?ContentDetailID=4173&BucketID=5&CategoryID=62

NA-4. NAHB Research Center, *Revised Builder's Guide to Frost-Protected Shallow Foundations*, 2004. www.toolbase.org/PDF/DesignGuides/revisedFPSFguide.pdf

NA-5, NAHB Research Center, *Durability By Design*, 2002. www.toolbase.org/PDF/DesignGuides/Durability%20by%20Design2-smll.pdf

O-1. Oak Ridge National Laboratory, DOE, *Technology Fact Sheet – Crawlspace Insulation*, 2000. www.ornl.gov/sci/roofs+walls/insulation/fact%20sheets/crawlspace%20insulation%20technology.pdf

O-2. Oak Ridge National Laboratory, *Retrofit Best Practices Guide*, 2011, www.ornl.gov/sci/roofs+walls/facts/RetrofitBestPractices/homeownerguide15b1.pdf

P-1. PNL, *What is the Building Envelope*? 2009. http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/114

T-1. Tschantz, PE, 1997. *Wet Basement and Crawlspace Problems, Causes, and Remedies – Tips for Homeowners, and Homebuyers*, 1997. http://web.utk.edu/~btschant/wet.htm

Appendix B: Pre-Design Assessment Checklist

PRE-DESIGN ASSESSMENT Checklist For Crawlspace Foundation

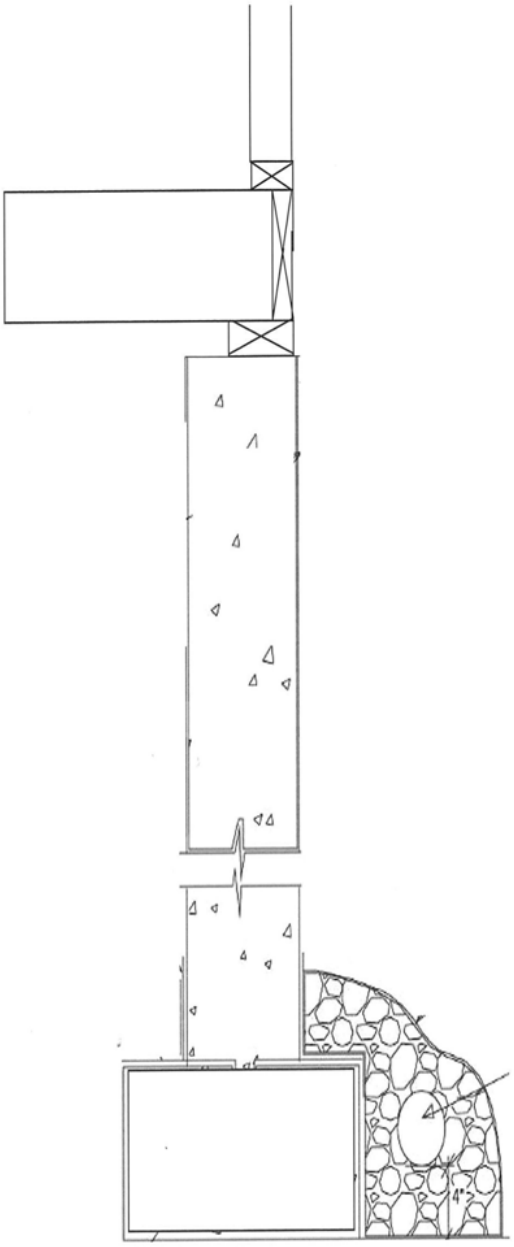
Project & Location _____ Page 1

Date *Time* _____

By: _____

Reference		Notes/Specs	Design Checklist
	Inside of House		
EP-1	Condensation on windows		
EP-1	Warped wood flooring		
EP-1	Visible mold		
EP-1	Musty odor		
	Temperature and Relative Humidity at inspection _____°F / _____% RH		
	Homeowner Interview - Crawlspace Use/Issues:		
	Outside of Crawlspace	**Notes & Specifications**	**Sign Off**
	Input foundation wall height and other dimensions on the crawlspace section. Page 3 of PDA Checklist.		
	Measure foundation and sketch onto graph paper to be used as the design's floor plan.		
	Crawlspace Ventilation (Vented Crawlspace, ONLY)		
I-1	Ventilation grills are operative and completely exposed to ambient air.		
	Size of ventilation grills		
	Note: Each 1,500 sf of crawlspace area requires 1 sf of vent with vapor barrier and cross ventilation. Otherwise, 150 sf of floor area to 1 sf of vent area.		
	Crawlspace Ventilation (Closed Crawlspace, ONLY)		
I-1	Ventilation grills are closed and sealed inside and out, or non-existant.		
	Note: Inspect interior for mechanical exhaust or conditioned air supply and note in Crawlspace Conditioning section.		
T-1, NA-5	**Moisture Management and Exterior Drainage**		
	Exterior grade for 10' from building		
B-2	Note: Maintain 5% grade for 10' from building.		
B-2	Location of downspout and sump pump outfall (Put on floor plan.)		
	Note: Runoff water should be directed a minimum of 3' away from building.		
B-2	Is drainage to storm drain or daylight? Storm Drn ____ Daylight ____		
B-2, NA-4	Foundation plantings and mulch 18"-24" from exterior wall?		
K-1, NA-4	Exterior insulation visible?		
	Durable finish above grade?		
B-1	Damproofing on foundation wall visible?		
B-1	Flashings at building penetrations?		
	Pest Control		
	Mud tunnels indicating termites, wasps, other insect infestation?		
	Feces, feathers, etc. indicating nesting of small mammals?		
	Contaminants		
EP-1	Asbestos		
EP-1	Lead paint		
	General Conditions		
	Temperature and Relative Humidity at inspection _____°F / _____% RH		
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Moisture Management & Interior Grade		
C-1	Wet building products - i.e. insulation, sheathing, etc.?		
C-1	Sump pit location.		
	Sump pump operable? (Sump pump is required if there is standing water in the sump pit.)		
	Sketch location of interior perimeter drain on floor plan. Type?		
	Condensate and overflow piping - sketch locations onto floor plan.		
C-1	Note standing water on floor plan. Investigate and note source.		
I-1	Locate ventilation grills and size on floor plan.		
	Automatic controls on vents?		
	Vapor Barrier		
B-2	Minimum 6 mil poly.		
B-2	Minimum 12" overlap at floor seams, taped. No tears and sealed where penetrated by pipes, etc.		
B-2	Minimum 6" overlap up walls or above exterior grade level whichever is greater, taped.		
E-2	**Foundation Walls**		
B-2	Wall construction and condition		
B-2	Wall insulation type and R-value		
	How is insulation secured?		

PRE-DESIGN ASSESSMENT Checklist	CRAWLSPACE FOUNDATION		Page 2
Reference			
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Crawlspace Access		
I-1	Locate crawlspace entry on floor plan. Size:		
	Weathertight?		
E-2	**Floor Assembly** (vented crawlspace)		
C-1	Inspect floor system for wood rot or mold. (Replace rotted wood. Remove mold.)		
B-3	Existing insulation type and R-value.		
	How is insulation secured?		
	Is there an air barrier at bottom of floor joists?		
B-3	Air seal at floor deck? Type and condition.		
B-3	Air seal at bandboard? Type and condition.		
B-3	Existing insulation and type and means of fastening at rim boards		
	Foundation Hardware		
C-2	Sill plate attachment to foundation with bolts/straps at ____" o.c.		
C-2	Joists connected to sill plate with toenailed connection ___ straps _____.		
B-1	Termite shield at foundation/sill plate?		
	Air & Thermal Barriers		
	Sill seal at sill plate and foundation junction? (closed crawlspace, only)		
	Insulated access door (closed crawlspace, only)		
	Appliances/Mechanicals in Crawlspace -Identify all mechanical equipment located in crawlspace.		
B-1	Furnace/Air Handler/Boiler -type, location, venting. Sealed?		
B-2, E-3	Are HVAC ducts sealed? Insulated?		
	Water heater type. Note location on floor plan.		
	Water heater venting (if gas fueled). Insulated?		
	Dehumidifier location and drain outfall.		
	Crawlspace Conditioning		
I-1	Conditioned air source		
I-1	Air exchange		
	Note: Conditioned air supply equal to 1 CFM per 50 square feet of crawlspace area. Or,A continuously operated exhaust fan operating at 1 CFM per 50 square feet of crawlspace area.		
	Dehumidification source		
	General Conditions	**Notes & Specifications**	**Sign Off**
	Pest Control		
	Evidence of termite trails or other insect infestation?		
	Evidence of mice, squirrels, or other rodents? (Animal scat and nests)		
	Investigate method of entry.		
EP-1	**Contaminants**		
EP-1	Asbestos		
EP-1	Lead paint		
EP-1	Radon		
EP-1	Carbon monoxide		
	Building product emissions (VOCs, formaldehyde)		
	Poisons for termite or rodent control.		
	Working Conditions/Work Protection Requirements		
	Adequate light?		
	Adequate area to perform work? Explain height and obstacles.		
NA-3	Insulation or debris on floor of the crawlspace?		
	Are there electric meters, communications wiring, etc. Where? Do they require protection during upgrades?		
	Temperature and Relative Humidity at inspection _____°F / _____% RH		



CRAWLSPACE SECTION
(Pg. 3 of PDA CHECKLIST)

PRE-DESIGN ASSESSMENT	CRAWLSPACE FOUNDATION - Plan	Page 4

Use to sketch Foundation Plan

Appendix C: Scope of Work

Quality Assurance Program for Retrofit of Existing Homes - CRAWLSPACE FOUNDATION-

SCOPE OF WORK

Date/Time _____

Project & Location: _____

Scope of Work - Existing Crawlspace Foundation			Installer's Initials or Bid Amt.	Date	Other Specs/ Manufacturer		Completion Checklist: Inspected By	Date
Plans have been reviewed and will be on the job at all times.								
Scope of Work has been reveiwed and will be on the job at all times.								
Insurance requirements see RFP and contract documents.								
Access to crawlspace provided by owner.								
Power provided by								
Contractor to provide adequate lighting to perform and inspect the work.								
Contractor to specify and supply all safety equipment necessary for workers to perform the work								
Contractor warrants that labor is trained in installation practices specified by the product manufacturer(s) and jobsite safety standards.								
Subcontract Trades:								
Outside of Crawlspace	**Existing**	**Repair/Upgrade**						
Crawlspace Ventilation								
Existing Overhangs								
Moisture Management & Exterior Drainage								
Existing Exterior grade								
Overhangs								
Gutters, sump outflow								
Foundation plantings, mulch								
Foundation insulation and finish								
Foundation damproofing								
Flashings at building penetrations								
Pest control								
Contaminants								
Inside of Crawlspace	**Existing**	**Repair/Upgrade**						
Moisture Management & Interior Grade								
Sump pit or floor drain								
Sump pump and pipes								
Perimeter draintile/trench								
Ventilation grills								
Vapor Barrier								
Foundation Walls								
Air barrier.								
Thermal barrier.								
Ignition barrier.								
Floor Assembly								
Air barrier.								
Thermal barrier.								
Ignition barrier.								
Load Path Tie Down Hardware								
Crawlspace Conditioning								
General Conditions	**Existing**	**Repair/Upgrade**						
Remove debris								
Building permit(s) required:								
Building permit(s)/inspection(s) scheduled and attended by subcontractor.								

Appendix D: Ventilated Crawlspace Case

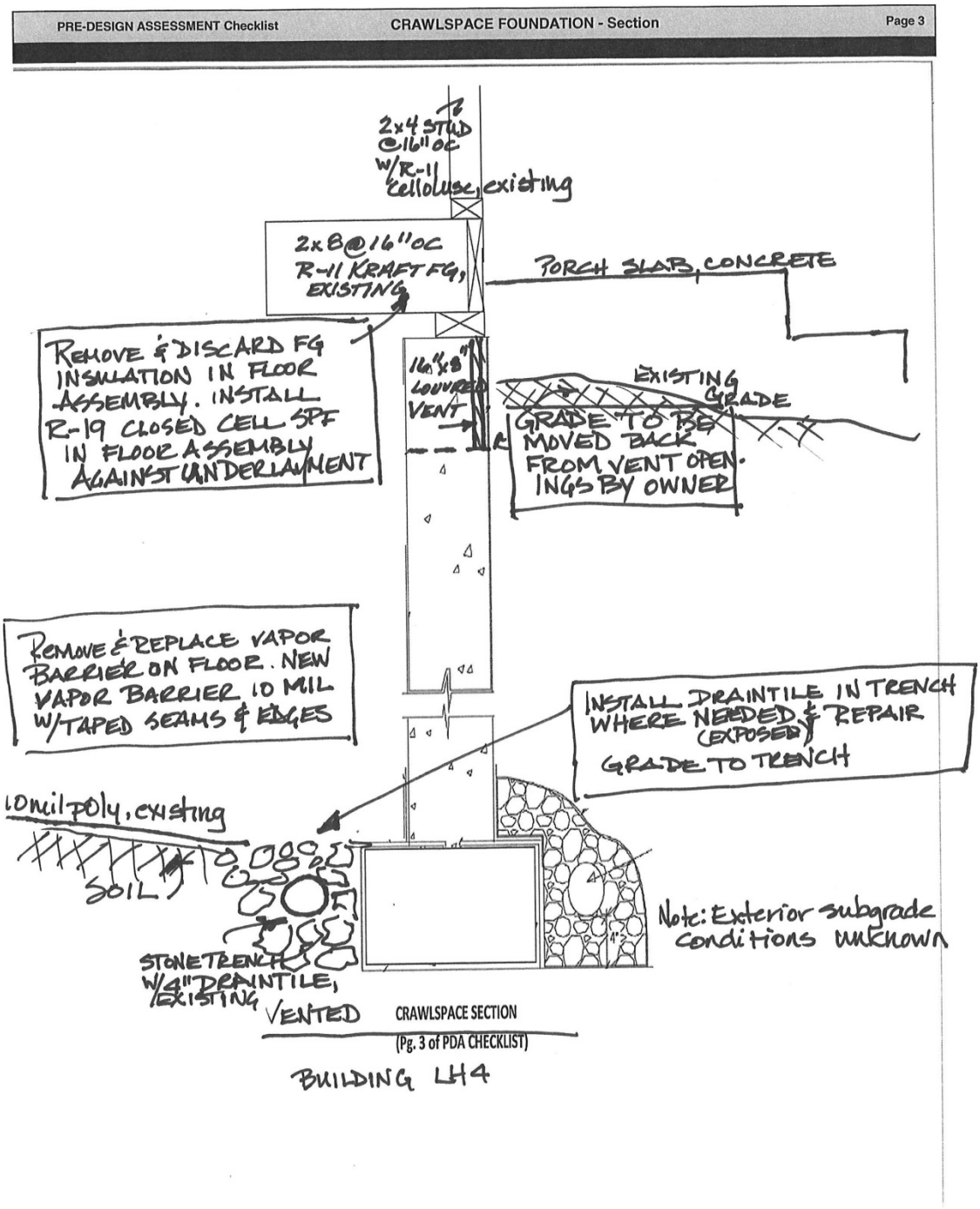
PRE-DESIGN ASSESSMENT Checklist For Crawlspace Foundation — Page 1

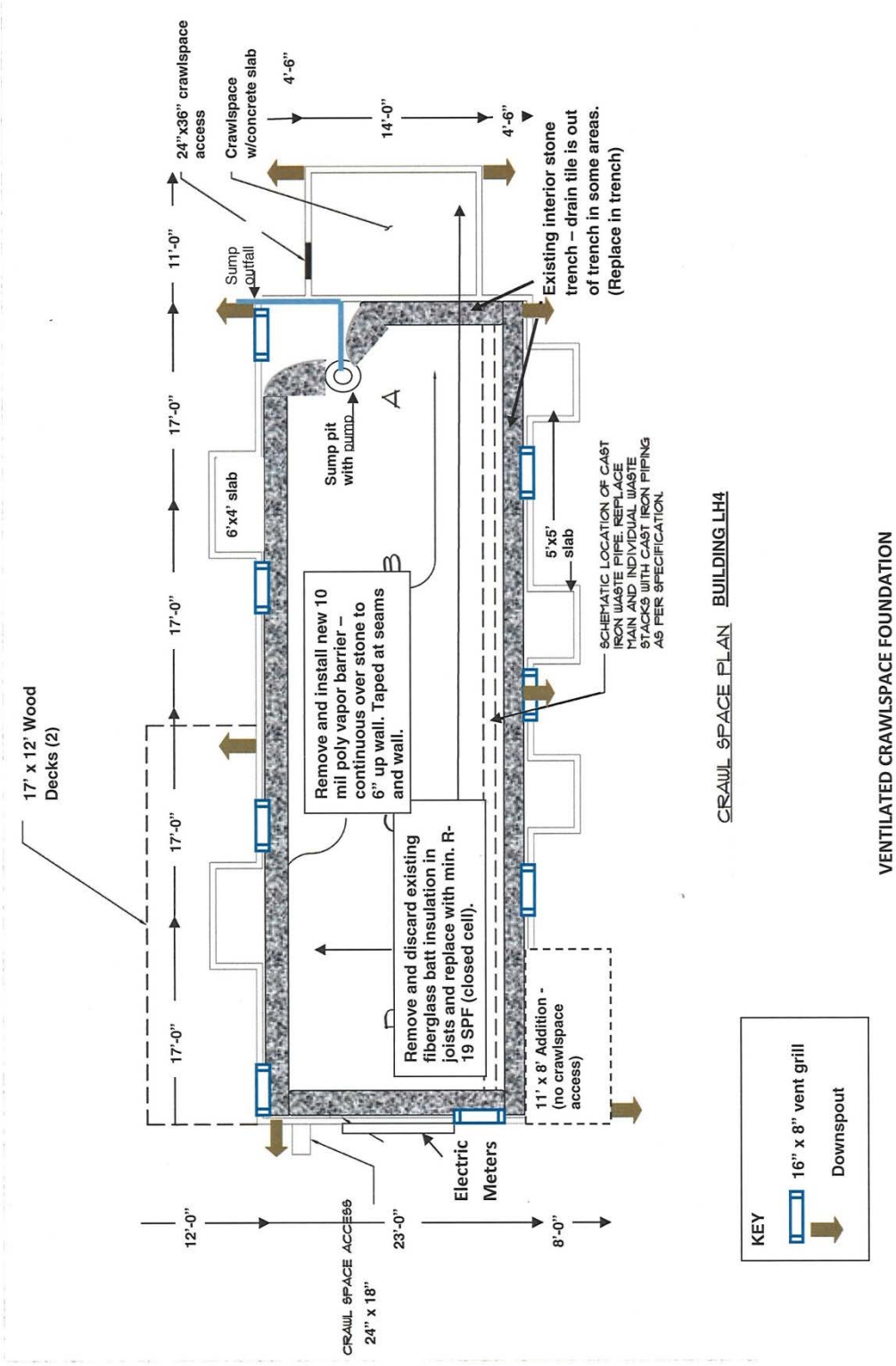
Project & Location: LH4 CLIMATE ZONE 4

Date: 10/15/10 Time: 8AM By: MTDB

Reference		Notes/Specs	Design
	Inside of House		
EP-1	Condensation on windows	YES / NO	
EP-1	Warped wood flooring	YES - ROOF ATTIC RAFTERS	
EP-1	Visible mold	YES	
EP-1	Musty odor		
	Temperature and Relative Humidity at inspection 65 °F / 50 % RH		
	Homeowner Interview - Crawlspace Use/Issues: STORMS FOR SUNROOM FALL 2010		
	Outside of Crawlspace	**Notes & Specifications**	**Sign Off**
	Input foundation wall height and other dimensions on the crawlspace section. Page 3 of PDA Checklist.		MTDB
	Measure foundation and sketch onto graph paper to be used as the design's floor plan.		MTDB
	Crawlspace Ventilation (Vented Crawlspace, ONLY)		
I-1	Ventilation grills are operative and completely exposed to ambient air.	NO — COVERED WITH MULCH/DECK BANDBDS.	
	Size of ventilation grills	16" x 8" 8 EA	
	Note: Each 1,500 sf of crawlspace area requires 1 sf of vent with vapor barrier and cross ventilation. Otherwise, 150 sf of floor area to 1 sf of vent area.		
	Crawlspace Ventilation (Closed Crawlspace, ONLY)	NO	
I-1	Ventilation grills are closed and sealed inside and out, or non-existant.		
	Note: Inspect interior for mechanical exhaust or conditioned air supply and note in Crawlspace Conditioning section.		
T-1, NA-5	**Moisture Management and Exterior Drainage**		
	Exterior grade for 10' from building	FLAT & SOMETIMES NEG. FRONT	
B-2	Note: Maintain 5% grade for 10' from building.	ONLY AT RIGHT END	
B-2	Location of downspout and sump pump outfall (Put on floor plan.)		✓
	Note: Runoff water should be directed a minimum of 3' away from building.	NEED DOWNSPOUT EXTENSIONS	
B-2	Is drainage to storm drain or daylight? Storm Drn / Daylight ✓		
B-2, NA-4	Foundation plantings and mulch 18"-24" from exterior wall?	PLANTS MULCH & STORAGE CONTAINERS	TOO CLOSE
K-1, NA-4	Exterior insulation visible? NO	6"-12"	
	Durable finish above grade? N/A		
B-1	Dampproofing on foundation wall visible? CAN'T SEE		
B-1	Flashings at building penetrations? SEEM OK		
	Pest Control		
	Mud tunnels indicating termites, wasps, other insect infestation? NO		
	Feces, feathers, etc. indicating nesting of small mammals?		
	Contaminants		
EP-1	Asbestos		
EP-1	Lead paint		
	General Conditions		
	Temperature and Relative Humidity at inspection _____ °F / _____ % RH		
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Moisture Management & Interior Grade		
C-1	Wet building products - i.e. insulation, sheathing, etc.?	Insulation in floor assembly in bad shape	
C-1	Sump pit location.	RIGHT REAR W/ STAGNANT H2O	
	Sump pump operable? (Sump pump is required if there is standing water in the sump pit.)	NO DOESN'T ENGAGE	
	Sketch location of interior perimeter drain on floor plan. Type?		✓
	Condensate and overflow piping - sketch locations onto floor plan.		✓
C-1	Note standing water on floor plan. Investigate and note source.	IN TRENCH - FRONT - DRAINTILE ABOVE TRENCH	
I-1	Locate ventilation grills and size on floor plan.		✓
	Automatic controls on vents?		NO
	Vapor Barrier		
B-2	Minimum 6 mil poly.	EXISTING 10 MIL EXCEPT OVER TRENCH	
B-2	Minimum 12" overlap at floor seams, taped. No tears and sealed where penetrated by pipes, etc.	NO	
B-2	Minimum 6" overlap up walls or above exterior grade level whichever is greater, taped.	NO	
E-2	**Foundation Walls**	16" x 8" x 8" CMU at 32" HIGH	
B-2	Wall construction and condition	DRY — GOOD COND.	
B-2	Wall insulation type and R-value	NONE FG IN FLOOR	
	How is insulation secured?	N/A	

PRE-DESIGN ASSESSMENT Checklist	CRAWLSPACE FOUNDATION LH4 10/15/10		Page 2
Reference			
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Crawlspace Access		
I-1	Locate crawlspace entry on floor plan. Size:	24x32	✓
	Weathertight?	ADJACENT DOWNSPOUT LEAKING INTO CRAWL	
E-2	**Floor Assembly** (vented crawlspace)		
C-1	Inspect floor system for wood rot or mold. (Replace rotted wood. Remove mold.)	NONE	
B-3	Existing insulation type and R-value.	R11 FG BATTS – KRAFT FACE TO CRAWL	
	How is insulation secured?	BARELY – INSET STAPLED	
	Is there an air barrier at bottom of floor joists?	NO	
B-3	Air seal at floor deck? Type and condition.	NO	
B-3	Air seal at bandboard? Type and condition.	NO	
B-3	Existing insulation and type and means of fastening at rim boards	NONE	
	Foundation Hardware		
C-2	Sill plate attachment to foundation with bolts/straps at 24" o.c.	3/8" BOLTS OK	
C-2	Joists connected to sill plate with toenailed connection ___ straps _____.	N/A	
B-1	Termite shield at foundation/sill plate?	NO	
	Air & Thermal Barriers		
	Sill seal at sill plate and foundation junction? (closed crawlspace, only)	NO	
	Insulated access door (closed crawlspace, only)	NO - NOT REQ'D	
	Appliances/Mechanicals in Crawlspace -Identify all mechanical equipment located in crawlspace.		
B-1	Furnace/Air Handler/Boiler -type, location, venting. Sealed?	NOT IN CRAWL	
B-2, E-3	Are HVAC ducts sealed? Insulated?	NO	
	Water heater type. Note location on floor plan.		
	Water heater venting (if gas fueled). Insulated?		
	Dehumidifier location and drain outfall.		
	Crawlspace Conditioning		
I-1	Conditioned air source	NO	
I-1	Air exchange	VIA AMBIENT VENTS	
	Note: Conditioned air supply equal to 1 CFM per 50 square feet of crawlspace area. Or,A continuously operated exhaust fan operating at 1 CFM per 50 square feet of crawlspace area.	N/A	
	Dehumidification source	NONE	
	General Conditions	**Notes & Specifications**	**Sign Off**
	Pest Control		
	Evidence of termite trails or other insect infestation?	NO	
	Evidence of mice, squirrels, or other rodents? (Animal scat and nests)		
	Investigate method of entry.	N/A	
EP-1	**Contaminants**		
EP-1	Asbestos	NO	
EP-1	Lead paint		
EP-1	Radon		
EP-1	Carbon monoxide		
	Building product emissions (VOCs, formaldehyde)		
	Poisons for termite or rodent control.		
	Working Conditions/Work Protection Requirements		
	Adequate light?	WILL REQUIRE ADD'L	
	Adequate area to perform work? Explain height and obstacles.	TIGHT-CONTRACTOR TO INSPECT	
NA-3	Insulation or debris on floor of the crawlspace?	YES - FG BATTS	
	Are there electric meters, communications wiring, etc. Where? Do they require protection during upgrades?	COMM. WIRES	
	Temperature and Relative Humidity at inspection _____°F / _____% RH		
PRE-DESIGN ASSESSMENT Checklist	CRAWLSPACE FOUNDATION - Section		Page 3


PRE-DESIGN ASSESSMENT Checklist
CRAWLSPACE FOUNDATION - Section
Page 3
2x4 STUD @16" OC W/R-11 Cellulose, existing
2x8 @16" OC R-11 KRAFT FG, EXISTING
PORCH SLAB, CONCRETE
REMOVE & DISCARD FG INSULATION IN FLOOR ASSEMBLY. INSTALL R-19 CLOSED CELL SPF IN FLOOR ASSEMBLY AGAINST UNDERLAYMENT
16"x8" LOUVRED VENT
EXISTING GRADE
GRADE TO BE MOVED BACK FROM VENT OPENINGS BY OWNER
REMOVE & REPLACE VAPOR BARRIER ON FLOOR. NEW VAPOR BARRIER 10 MIL W/TAPED SEAMS & EDGES
INSTALL DRAINTILE IN TRENCH WHERE NEEDED & REPAIR (EXPOSED) GRADE TO TRENCH
10mil poly, existing
SOIL
Note: Exterior subgrade conditions unknown
STONE TRENCH W/4" DRAINTILE, EXISTING
VENTED CRAWLSPACE SECTION
(Pg. 3 of PDA CHECKLIST)
BUILDING LH4


24"x36" crawlspace access
Crawlspace w/concrete slab
4'-6"
14'-0"
4'-6"
11'-0"
17'-0"
17'-0"
17'-0"
17'-0"
Sump outfall
Existing interior stone trench – drain tile is out of trench in some areas. (Replace in trench)
Sump pit with pump
A
B
C
D
6'x4' slab
5'x5' slab
Remove and install new 10 mil poly vapor barrier – continuous over stone to 6" up wall. Taped at seams and wall.
Remove and discard existing fiberglass batt insulation in joists and replace with min. R-19 SPF (closed cell).
SCHEMATIC LOCATION OF CAST IRON WASTE PIPE. REPLACE MAIN AND INDIVIDUAL WASTE STACKS WITH CAST IRON PIPING AS PER SPECIFICATION.
17' x 12' Wood Decks (2)
11' x 8' Addition - (no crawlspace access)
Electric Meters
CRAWL SPACE ACCESS 24" x 18"
12'-0"
23'-0"
8'-0"
CRAWL SPACE PLAN BUILDING LH4
KEY
16" x 8" vent grill
Downspout
VENTILATED CRAWLSPACE FOUNDATION

Quality Assurance Program for Retrofit of Existing Homes - CRAWLSPACE FOUNDATION- SCOPE OF WORK

Date 6/10/11

Project & Location: Building LH 4

Climate Zone 4

Scope of Work - Existing Crawlspace Foundation			Installer's Initials or Bid Amt.	Date	Other Specs/ Manufacturer	Inspected By	Date
Plans have been reviewed and will be on the job at all times.							
Scope of Work has been reveiwed and will be on the job at all times.							
Insurance requirements see RFP and contract documents.							
Access to crawlspace provided by owner. With 24 hour notice between 8 a.m. and 5 p.m.							
Power provided by one 110 receptacle in crawlspace - additional by contractor.							
Contractor to provide adequate lighting to perform and inspect the work.							
Contractor to specify and supply all safety equipment necessary for workers to perform the work							
Contractor warrants that labor is trained in installation practices specified by the product							
Subcontract Trades: None							
Outside of Crawlspace	**Existing**	**Repair/Upgrade**					
Crawlspace Ventilation	3 SF required; calculated vent area of 3.6 SF clear.	None Required					
	1 rear vent grill fell out of opening	See below under VENTILATION GRILLS					
Overhangs	1" & 5" gutters	None Required					
Moisture Management & Exterior Drainage							
Exterior grade	Several front vent grills blocked with mulch build up.	Remove mulch and repair grade for positive flow away from foundation. (front)			Owner to Repair		
Overhangs		No action					
Gutters, sump outflow	Gutters 5"	No action					
Rear left downspout extension	6" elbow to 2' splashblock	Extend downpsout 3'-5' away from building and crawlspace access.			Owner to Repair		
Grade at crawlspace access	Grade and downspout channeling water into crawlspace door hatch at left side rear.	Repair grade for positive flow away from crawlspace access.			Owner to Repair		
Sump pipe	Exists but inoperable	Owner will service sump.			Owner to Repair		
Foundation plantings, mulch	Shrubs and mulch within 0" of foundation	No action			Owners & occupants to address		
Foundation insulation and finish	None	No action					
Insulation in floor joists	R-11 FG batts; falling out and incorrectly installed	Remove and discard all existing insulation from joists and crawlspace.					
		Install R-19 closed cell SPF and ignition barrier as req'd by manufacturer			Name Manufacturer and thickness		
Foundation damproofing		No action					
Flashings at building penetrations	Generally in good repair.	No action			Review again at siding phase.		
Pest control		No action					
Contaminants		No action					
Inside of Crawlspace	**Existing**	**Repair/Upgrade**					
Moisture Management & Interior Grade							
Sump pit or floor drain	Yes	No action					
Sump pump and pipes	Standing water in pit; unable to engage pump.	Repair sump pump.			Owner to Repair		
Perimeter draintile/trench	Some of the draintile pipe is above the stone in the drainage trench	Replace draintile into stone trench and repair grade in and around trench to promote drainage to sump pit.					
Ventilation grills	Rear vent grill has fallen out of opening in CMU.	Install left rear vent grill with existing or similar replacement					
Vapor Barrier	Discontinuous at stone trench. Seams are not taped and overlaps at walls/columns are not taped.	Add 10 mil material from existing vapor barrier, across stone trench and 6" up wall. Tape all seams and edges.					
Foundation Walls	16"x8"x8"x32" CMU; dry cond. and good repair.	No action					
Air barrier.	Not req'd - vented foundation	No action					
Thermal barrier.	Not req'd - vented foundation	No action					
Ignition barrier.	Not req'd - vented foundation	No action					
Floor Assembly	2x8at16"oc.	No action					
Air barrier.	Provided by 3"+ of CC SPF.						
Thermal barrier.		Supply and install as required by manufacturer.					
Ignition barrier.		Supply and install as required by manufacturer.					
Load Path Tie Down Hardware		No action					
Crawlspace Conditioning	None - ventilated	No action					
General Conditions	**Existing**	**Repair/Upgrade**					
Remove debris							
Building permit by owner.					No permit required		
Building inspections scheduled and attended by subcontractor.					No permit required		

Appendix E: Closed Crawlspace Case

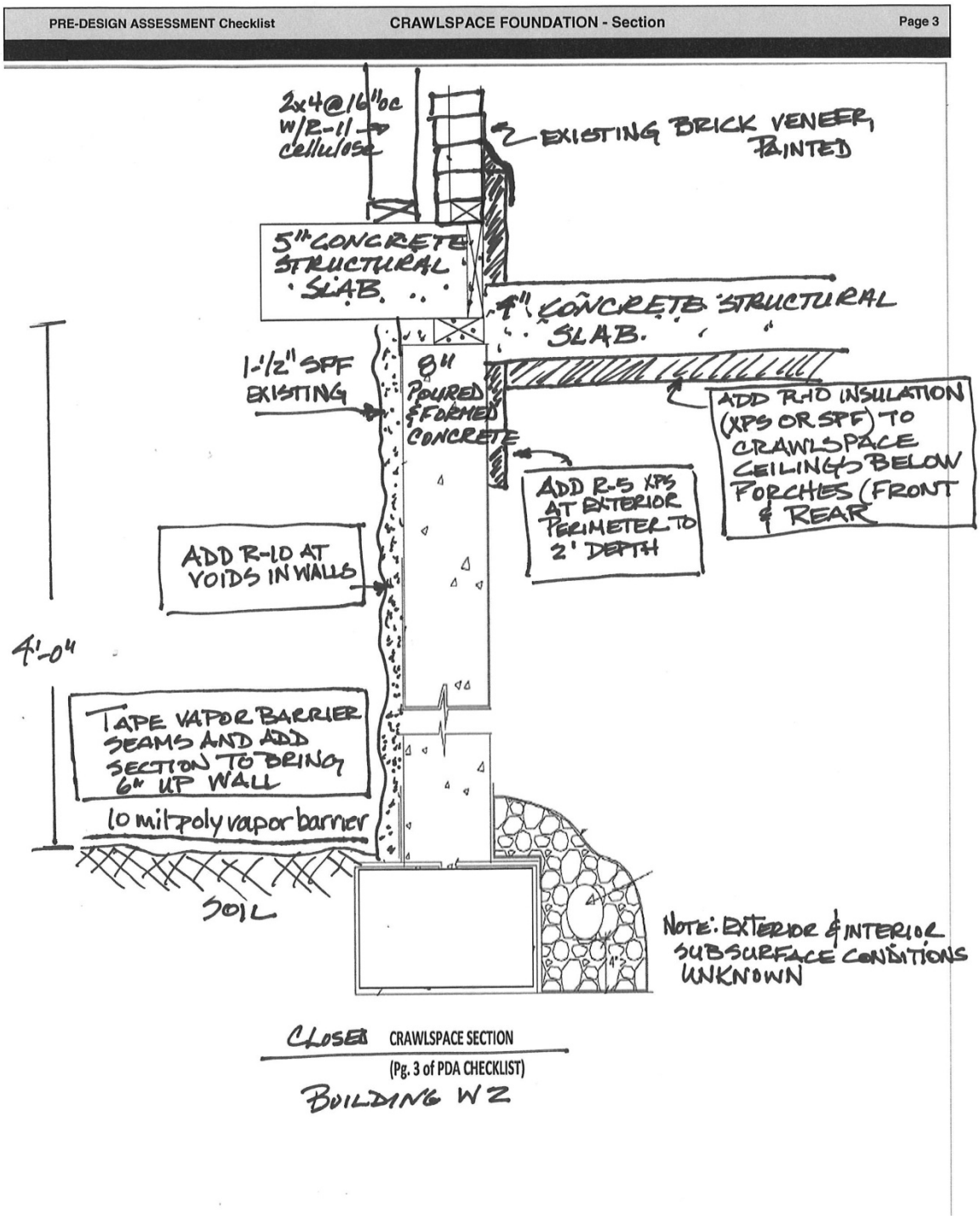
PRE-DESIGN ASSESSMENT Checklist For Crawlspace Foundation — Page 1

Date 12/11/10 Time 11:30AM — Project & Location W 2 CLIMATE ZONE 4 — By: MTDB

Reference		Notes/Specs	Design
	Inside of House		
EP-1	Condensation on windows	NO	
EP-1	Warped wood flooring	NO	
EP-1	Visible mold	YES – 2ND FLOOR	
EP-1	Musty odor	YES – " "	
	Temperature and Relative Humidity at inspection 70 °F / 45 % RH		
	Homeowner Interview - Crawlspace Use/Issues:		
	Outside of Crawlspace	**Notes & Specifications**	**Sign Off**
	Input foundation wall height and other dimensions on the crawlspace section. Page 3 of PDA Checklist.		MTDB
	Measure foundation and sketch onto graph paper to be used as the design's floor plan.		MTDB
	Crawlspace Ventilation (Vented Crawlspace, ONLY)		
I-1	Ventilation grills are operative and completely exposed to ambient air.	N/A – CLOSED	
	Size of ventilation grills	N/A	
	Note: Each 1,500 sf of crawlspace area requires 1 sf of vent with vapor barrier and cross ventilation. Otherwise, 150 sf of floor area to 1 sf of vent area.		
	Crawlspace Ventilation (Closed Crawlspace, ONLY)		
I-1	Ventilation grills are closed and sealed inside and out, or non-existant.	YES – SEALED EXCEPT LEFT REAR	ONE
	Note: Inspect interior for mechanical exhaust or conditioned air supply and note in Crawlspace Conditioning section.	NONE	
T-1, NA-5	**Moisture Management and Exterior Drainage**		
	Exterior grade for 10' from building	FLAT PERHAPS 3" IN 10'	
B-2	Note: Maintain 5% grade for 10' from building.		
B-2	Location of downspout and sump pump outfall (Put on floor plan.)	NONE – FLOOR DRAIN TO STORM DRAIN IN	
	Note: Runoff water should be directed a minimum of 3' away from building.	LACKING – SEE PHOTOS BOILER RM	
B-2	Is drainage to storm drain or daylight? Storm Drn ✓ Daylight	FROM BOILER RM DRAIN – NOT TIED	
B-2, NA-4	Foundation plantings and mulch 18"-24" from exterior wall?	YES – 10"-24" TO CRAWL?	
K-1, NA-4	Exterior insulation visible?	NO	
	Durable finish above grade?	N/A	
B-1	Damproofing on foundation wall visible?	NOT KNOWN	
B-1	Flashings at building penetrations?	Adequate	
	Pest Control		
	Mud tunnels indicating termites, wasps, other insect infestation?	NO	
	Feces, feathers, etc. indicating nesting of small mammals?	NO	
	Contaminants		
EP-1	Asbestos		
EP-1	Lead paint		
	General Conditions		
	Temperature and Relative Humidity at inspection _____°F / _____% RH		
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Moisture Management & Interior Grade		
C-1	Wet building products - i.e. insulation, sheathing, etc.?	NO	
C-1	Sump pit location.	SUBSURFACE DRAIN UNKNOWN – SPACE RELATIVELY DRY	
	Sump pump operable? (Sump pump is required if there is standing water in the sump pit.)	NONE EXCEPT STREAM OF	
	Sketch location of interior perimeter drain on floor plan. Type?	✓ WATER FROM OPEN VENT	
	Condensate and overflow piping - sketch locations onto floor plan.	NONE	
C-1	Note standing water on floor plan. Investigate and note source.	✓ FROM OPEN VENT LEFT SIDE REAR	
I-1	Locate ventilation grills and size on floor plan.	N/A	
	Automatic controls on vents?	N/A	
	Vapor Barrier		
B-2	Minimum 6 mil poly.	10 MIL EXISTING – HEAVY TRAFFIC FROM COMM. WIRE	
B-2	Minimum 12" overlap at floor seams, taped. No tears and sealed where penetrated by pipes, etc.	NO INSTALLERS	
B-2	Minimum 6" overlap up walls or above exterior grade level whichever is greater, taped.	NO	
E-2	**Foundation Walls**		
B-2	Wall construction and condition	8" Poured Concrete, Good, Dry	
B-2	Wall insulation type and R-value	1 1/2" SPF R-10	
	How is insulation secured?	SPRAYED ON.	

NOTE: NEEDS TO BE REMOVED WHERE PORCH CRAWLSPACES ARE BLOCKED BY IT. PORCH CRAWLS ARE INTEGRAL TO MAIN & REQUIRE R-10 WALLS & CEILINGS. SLAB EDGE NEEDS INSULATION ON EXT.

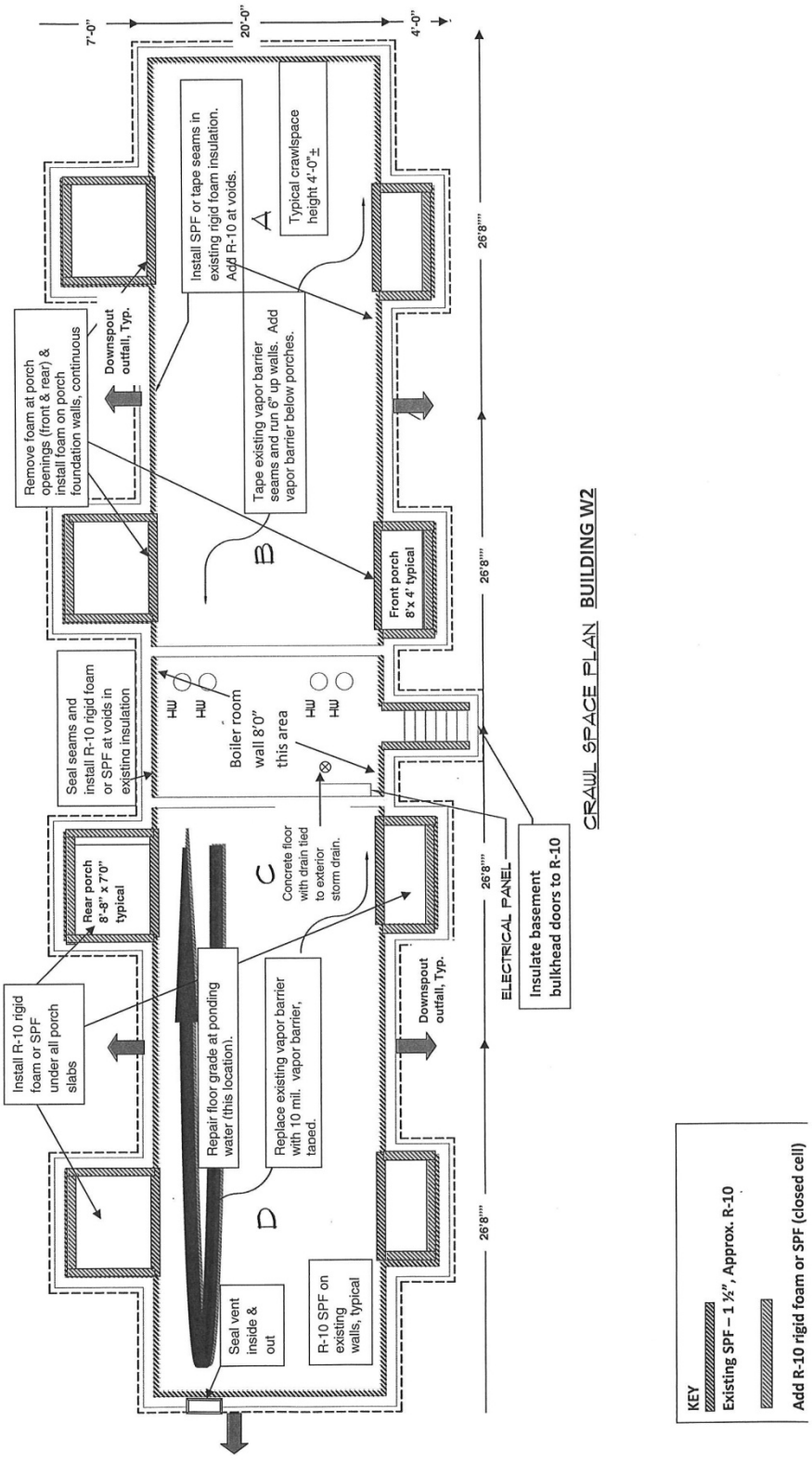
PRE-DESIGN ASSESSMENT Checklist	CRAWLSPACE FOUNDATION W2 12/11/10		Page 2
Reference			
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Crawlspace Access		
I-1	Locate crawlspace entry on floor plan. Size:	Large bulkhead door & steps to boiler room	
	Weathertight?	NO	
E-2	**Floor Assembly** (vented crawlspace)	5" STRUCTURAL SLAB	
C-1	Inspect floor system for wood rot or mold. (Replace rotted wood. Remove mold.)	NONE	
B-3	Existing insulation type and R-value.	NONE ON FLOOR — CLOSED CRAWL	
	How is insulation secured?	N/A	
	Is there an air barrier at bottom of floor joists?	N/A	
B-3	Air seal at floor deck? Type and condition.	N/A	
B-3	Air seal at bandboard? Type and condition.	N/A	
B-3	Existing insulation and type and means of fastening at rim boards	N/A	
	Foundation Hardware		
C-2	Sill plate attachment to foundation with bolts/straps at ____" o.c.	N/A —	
C-2	Joists connected to sill plate with toenailed connection ___ straps _____.	N/A	
B-1	Termite shield at foundation/sill plate?	N/A	
	Air & Thermal Barriers		
	Sill seal at sill plate and foundation junction? (closed crawlspace, only)	N/A	
	Insulated access door (closed crawlspace, only)	NO — insulate — possible?	
	Appliances/Mechanicals in Crawlspace -Identify all mechanical equipment located in crawlspace.	4 — 50 gallon electric water heaters - no blankets, semi-insulated water pipes	
B-1	Furnace/Air Handler/Boiler -type, location, venting. Sealed?	NO	
B-2, E-3	Are HVAC ducts sealed? Insulated?	N/A	
	Water heater type. Note location on floor plan.	SEE EP	
	Water heater venting (if gas fueled). Insulated?	NONE REQ'D	
	Dehumidifier location and drain outfall.	NONE	
	Crawlspace Conditioning		
I-1	Conditioned air source	NONE EXCEPT WATER HEATER	
I-1	Air exchange	VIA BULKHEAD DOORS AT ACCESS	
	Note: Conditioned air supply equal to 1 CFM per 50 square feet of crawlspace area. Or,A continuously operated exhaust fan operating at 1 CFM per 50 square feet of crawlspace area.		
	Dehumidification source	NONE	
	General Conditions	**Notes & Specifications**	**Sign Off**
	Pest Control		
	Evidence of termite trails or other insect infestation?	NO	
	Evidence of mice, squirrels, or other rodents? (Animal scat and nests)	NO	
	Investigate method of entry.	NO	
EP-1	**Contaminants**		
EP-1	Asbestos	NO	
EP-1	Lead paint		
EP-1	Radon		
EP-1	Carbon monoxide		
	Building product emissions (VOCs, formaldehyde)		
	Poisons for termite or rodent control.		
	Working Conditions/Work Protection Requirements		
	Adequate light?	NO — WILL NEED ADDL	
	Adequate area to perform work? Explain height and obstacles.	4' HEIGHT — Abandoned boiler pipes encroach	
NA-3	Insulation or debris on floor of the crawlspace?	SOME RIGID INS. BOARDS. PUSHED BACK VDB	
	Are there electric meters, communications wiring, etc. Where? Do they require protection during upgrades?		
	Temperature and Relative Humidity at inspection _____°F / _____% RH		



CLOSED CRAWLSPACE SECTION

(Pg. 3 of PDA CHECKLIST)

BUILDING W2


7'-0"
20'-0"
4'-0"
26'8""
Install SPF or tape seams in existing rigid foam insulation. Add R-10 at voids.
Typical crawlspace height 4'-0"±
A
Remove foam at porch openings (front & rear) & install foam on porch foundation walls, continuous
Downspout outfall, Typ.
Tape existing vapor barrier seams and run 6" up walls. Add vapor barrier below porches.
B
Front porch 8'x 4' typical
Seal seams and install R-10 rigid foam or SPF at voids in existing insulation
HW
Boiler room wall 8'0" this area
Rear porch 8'-8" x 7'0" typical
C
Concrete floor with drain tied to exterior storm drain.
Install R-10 rigid foam or SPF under all porch slabs
Repair floor grade at ponding water (this location).
Replace existing vapor barrier with 10 mil. vapor barrier, taped.
D
Downspout outfall, Typ.
ELECTRICAL PANEL
Insulate basement bulkhead doors to R-10
Seal vent inside & out
R-10 SPF on existing walls, typical
CRAWL SPACE PLAN BUILDING W2
KEY
Existing SPF – 1 ½", Approx. R-10
Add R-10 rigid foam or SPF (closed cell)

Quality Assurance Program for Retrofit of Existing Homes - CRAWLSPACE FOUNDATION-

Project & Location: Building W2

Climate Zone 4

SCOPE OF WORK

Date 6/10/11

Scope of Work - Existing Crawlspace Foundation			Installer's Initials or Bid Amt.	Date	Other Specs/ Manufacturer	Inspected By	Date
Plans have been reviewed and will be on the job at all times.							
Scope of Work has been reveiwed and will be on the job at all times.							
Insurance requirements see RFP and contract documents.							
Access to crawlspace provided by owner. With 24 hour notice between 8 a.m. and 5 p.m.							
Power provided by one 110 receptacle in crawlspace - additional by contractor.							
Contractor to provide adequate lighting to perform and inspect the work.							
Contractor to specify and supply all safety equipment necessary for workers to perform the work							
Contractor warrants that labor is trained in installation practices specified by the product							
Subcontract Trades: None							
Outside of Crawlspace	**Existing**	**Repair/Upgrade**					
Crawlspace Ventilation	Closed foundation. One sealed vent grill has been opened - reseal.	Install rigid XPS foam in opening from outside and inside. Secure firmly and finish to resemble crawlspace wall finish.					
Overhangs	1" & 5" gutters	None Required					
Moisture Management & Exterior Drainage							
Exterior grade	Flat	No action.			Owner to Repair		
Overhangs	1"	No action					
Gutters, sump outflow	Gutters 5"	No action					
Downspouts	Water ponding at left side rear downspout near opened vent grill.	Extend downpsout 3'-5' away from building and vent well.			Owner to Repair		
Grade at crawlspace access	Grade and downspout channeling water into crawlspace door hatch at left side rear.	Repair grade for positive flow away from crawlspace access.			Owner to Repair		
Sump pipe	Exists but inoperable	Owner will service sump.			Owner to Repair		
Foundation plantings, mulch	Shrubs and mulch within 0" of foundation	No action			Owners & occupants to address		
Foundation insulation and finish	None	No action					
Insulation in floor joists	R-11 FG batts; falling out and incorrectly installed	Remove and discard all existing insulation from joists and crawlspace.					
		Install R-19 closed cell SPF and ignition barrier as req'd by manufacturer			Name Manufacturer and thickness		
Foundation damproofing		No action					
Flashings at building penetrations	Generally in good repair.	No action			Review again at siding phase.		
Pest control		No action					
Contaminants		No action					
Inside of Crawlspace	**Existing**	**Repair/Upgrade**					
Moisture Management & Interior Grade							
Sump pit or floor drain	Yes	No action					
Sump pump and pipes	Standing water in pit; unable to engage pump.	Repair sump pump.			Owner to Repair		
Perimeter draintile/trench	Some of the draintile pipe is above the stone in the drainage trench	Replace draintile into stone trench and repair grade in and around trench to promote drainage to sump pit.					
Ventilation grills	Rear vent grill has fallen out of opening in CMU.	Install left rear vent grill with existing or similar replacement					
Vapor Barrier	Discontinuous at stone trench. Seams are not taped and overlaps at walls/columns are not taped.	Add 10 mil material from existing vapor barrier, across stone trench and 6" up wall. Tape all seams and edges.					
Foundation Walls	16"x8"x8"x32" CMU; dry cond. and good repair.	No action					
Air barrier.	Not req'd - vented foundation	No action					
Thermal barrier.	Not req'd - vented foundation	No action					
Ignition barrier.	Not req'd - vented foundation	No action					
Floor Assembly	2x8at16"oc.	No action					
Air barrier.	Provided by 3"+ of CC SPF.						
Thermal barrier.		Supply and install as required by manufacturer.					
Ignition barrier.		Supply and install as required by manufacturer.					
Load Path Tie Down Hardware		No action					
Crawlspace Conditioning	None - ventilated	No action					
General Conditions	**Existing**	**Repair/Upgrade**					
Remove debris							
Building permit by owner.					No permit required		
Building inspections scheduled and attended by subcontractor.					No permit required		

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