REPORT of the GHI Buildings Committee Crawl Space Task Force

December 16, 2014

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Working in the crawl space beneath a row of homes, a member of GHI's Youth Community Conservation Program is seen insulating pipes. Insulation has already been packed into the crawl-space ceiling just above head. Such work was tedious, requiring persons to spend most of the time on hands and knees as the crawl spaces vary in height from three to five feet. Photo by Don Volk

Crawl space of a frame row during the 1980s Rehab, with new insulation beneath floors.

Williamson, Mary Lou. *Greenbelt: History of a New Town 1937-1987.* (Copyright 1987: City of Greenbelt. Norfolk, VA:The Donning Co./Pub.,1987) p. 244

ABSTRACT

Overview and scope

This report will give a history of events pertaining to the HIP and GHI crawl spaces, including the formation of the task force and current remediation being undertaken by GHI staff. We will attempt to demystify the space beneath the homes by describing the types of crawls in GHI and their purpose, and the processes that affect them; briefly recall changes in the 1980s rehab, explain the pros and cons and theory that are driving the Task Force's recommended remediation strategies, and propose a schedule structure for remediation that can begin this year. These crawl spaces are over 70 years old. There are no quick and easy solutions. Following are separate documents:

1) *CS_ActionPlan_Draft_rev3b_29Dec2014.docx: Suggested Action Plan with tentative schedule*
2) *ImagesGHI_CrawlSpaces_29Dec2014_rev2a.docx: Pictures of problems*
3) *See GHI crawl space problem stories_v5.docx: Member Stories*
4) *Encapsulating a GHI Crawl Space through Pictures 29Dec2014 rev3a.docx*
5) *Insulation-ProCons-29Dec2014-rev2a.docx*

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REPORT of the GHI Buildings Committee Crawl Space Task Force

Building science has changed dramatically since the first family moved into GHI on Sept. 30, 1937, 77 years and three months ago. [1] Standards for foundations, the first and perhaps most critical element of any building, have evolved in response to the changing energy landscape, new technological possibilities, and in some regions even climatic changes. Crawl spaces ("crawls"), one of the three basic foundation types and the one most common in GHI homes, provide, at reasonable cost**,** a place to conceal heating ducts, water pipes, sanitary piping, electrical and telecommunications wires and other functional but unattractive building elements that would otherwise need to be put elsewhere—like closets or exterior walls--without them. But crawl spaces, like their basement and slab foundation counterparts, do deteriorate over time and require maintenance; building science also understands a lot more about how they interact with the elements, soils and the regional geography, and how these interactions affect the home structure.[2]

Crawls in both GHI frame and masonry homes have become a growing source of frustration for members and consternation for GHI staff. There are reports of foul odors every time it rains, and of humidity increases so great that wood floors warp, interior doors stick and musical instruments go in and out of tune. Sump pumps heard normally during rains go silent, are repaired and go silent again. During the winter members feel the cold air through their floors.[3] Evidence of standing water in both crawl spaces and adjacent boiler rooms has been reported (with photographic evidence) by members, staff and increasingly by home inspectors hired by prospective buyers; some reports have described what appears to be mildew, black mold and other fungal growth on joists, subflooring due to excessive moisture. (At this time GHI has a mold detection and re-mediation procedure for the living spaces.) In rare but not insignificant cases, some crawls have even shown signs of incipient structural failure in joists and sub-flooring. Mammals including raccoons and cats seek shelter in the crawls through unsecure vent screens, and telecomm contractors report seeing frogs and even snakes.

Through GHI maintenance requests and the many informal channels of communication around town, then, it comes as no surprise that crawl space conditions have been a part of the Buildings Committee's discussions since its inception in 2008, and were also a part of the research and pilot study begun in 2010 with the NAHB Research Center, Inc. (now Home Innovation Research Labs or H.I.R.L.).

In spring of 2014, as pilot homes data were being assimilated by the board and relevant committees and being released to the community, a memo by then-Maintenance Director Matt Berres on the conditions in frame crawls catapulted these concerns to the fore**.** The April 29th memo, based on inspections done every three, five or seven years (depending on staffing and

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[1] Williamson, Mary Lou. Greenbelt: History of a New Town 1937-1987. P. 74

[2] Nationally, crawl space foundations were used in 16% of new homes, compared to basements (31%) and slab (52%). http://www.nahb.org/generic.aspx?genericContentID=64030

[3] The "stack effect", when hot air rising out of a building draws cold air into cracks at the bottom: http://www.greenbuildingadvisor.com/stack-effect-when-buildings-act-chimneys

other priorities), described problems with: insulation either incorrectly installed or completely lacking; vapor (water) barriers torn or missing; uneven soil floor grading causing inadequate drainage; animal incursions due to faulty foundation vents or unsealed steam tunnels; and a spaghetti bowl of telecom and electrical wiring, water supply and waste discharge lines, and now-obsolete steam pipes from the old boiler system. In addition, GHI staff observed that the pilot homes' spray foam insulation, which otherwise provides a good seal, encapsulates wires and piping which could make future problem diagnosis and repair difficult.[4]

Crawl Space Task Force formed

By June 2014, at the behest of the board and BC, the Crawl Space Task Force ("TF") was formed to examine these challenges and consider options. Although impelled by the frame crawls report, the TF's scope broadened to include masonry units as they share many of the same concerns, particularly involving moisture. Unexpectedly but perhaps not surprisingly, TF meetings consisted of a small group of "regulars" accompanied by a revolving door of members and even a real estate agent, all of whom wanted to, well, talk about their crawl spaces.[5]

The TF analyzed H.I.R.L.'s reports and recommendation as well as the April memo, listened to members and viewed photographs taken from inside or through crawl vents, and "toured" pilot home crawl spaces (one each of a frame, brick and block) to look at H.I.R.L.'s recommended improvements in situ. During that tour, we paid particular attention to the spray foam used to insulate subfloors in frames and additions, and how it was used to seal vapor barrier gaps along the walls and floors. With all of the input, **the need for immediate and more detailed inspections** of all of GHI's 337 rows (or 1600 units) became apparent**—**both to assess the scope of the problems and to begin collecting data useful to GHI staff. Meanwhile, environmental concerns, TF research, and the supportable observation that most 80-year-old buildings are likely to need a little work from time to time, all compelled the TF **to take a step back** from the H.I.R.L. recommendations and study approaches to foundations that consider the structural health and soundness of the entire building, instead of just sealing off the home unit from the space below in a what-happens-in-the-crawl-space-stays-in-the-crawl-space approach. Finding the most authoritative and impartial sources on both building science and environmental and sustainable practices became priorities as did understanding the properties of our mid-Atlantic "mixed-humid climate,"[6] and the relatively impermeable clay soil dominant in this area.

Immediate Action: Assessment, repairs and replacement

It soon became apparent to everyone involved, including the GHI board of directors and staff, that more assessment was urgently needed. In late August GHI staff undertook to inspect, in greater detail, 20 randomly selected frame unit rows (a 10% sample). Major findings contained in the subsequent report generally support the complaints of moisture and odor during the rainy months and chilly floors in the cold months (the frames were the source of a majority of complaints verbalized by members at TF meetings). GHI staff reported: that only 20% of sump pumps were found operable; numerous vapor barriers (meant to cover the dirt floors) were in

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[4] Frame pilot rows 10A-D Southway and 4A-D Laurel Hill)
[5] The task force will be compiling stories and pictures by unit, in the interest of providing the data to GHI.
[6] http://www.nrel.gov/docs/fy05osti/38448.pdf

poor condition; and a significant percentage of fiberglass batt insulation was either upside down or missing. The majority of crawls were reportedly dry at the time inspected. There was one instance each of a plumbing leak and a cracked joist. GHI handled those critical repairs and is continuing the inspection and repairing or replacing where needed all frame row sump pumps, to be completed by April 2015. As they have repaired a number of sump pumps at this time, GHI is discovering the failure rate closer to 50% as opposed to 80% as seen in the initial quick look. After April GHI will do the same for sump pumps in the masonry units.

Recommended:
For 2015 GHI should undertake a second round of inspections after the heavy spring rains. This inspection combined with known problem areas can be used to identify and prioritize the first set of crawl spaces to be remediated. In subsequent years, this process of inspecting a set of crawl spaces after the heavy spring rains should be continued to identify and prioritize the next set of crawl spaces to be remediated.
(See Action Plan – separate document)

Continuing Assessments of Landscape Grading and Drainage Issues

In addition to fixing the buildings themselves, an understanding of how water flows around the exterior and interacts with the foundations is necessary. Geomorphological [7] changes are to be expected. The land as graded for drainage in the 1930s and 1940s no longer exists in that form in many spots due to biological and runoff processes. Invasive plants that crowd out natives better suited to soil retention causes sediment to fill drainage channels, and landscaping by members blocks swales causing water to back up or run elsewhere. During heavy rainstorms the existing drainage system often cannot handle the sudden and intense runoff from streets and parking lots (some of which appear not to drain into the storm system) adequately, and water flowing downhill collects at building foundations.   GHI staff does have a long-term program identifying drainage issues and prioritizing the worst-case scenarios. (See Appendix A).

Recommended:
GHI staff is planning a row by row observational inspection of GHI exteriors this winter when weather permits. The TF recommends that staff contact the members of rows to be inspected about a week prior so that members have an opportunity to meet and add their own observations to GHI's data store. This would include issues not obvious in a one-time visual inspection during a dry spell, such as water ponding problem spots, swales draining to an appropriate discharge point (storm, gutter, etc.), regular gutter or downspout overflows, or parking lot drainage problems during heavy rains. Data aside, GHI staff and member interaction is important to the future of the HIP.

Preventing bulk water intrusion into crawl spaces is one key to the long-term maintenance of GHI crawl spaces. High priority should be given to identifying damaged passive drainage systems in the community and install new systems where appropriate.

[7] Meaning the topographical feature of the land, such as berms and swales; we are avoiding the term "landscape" here to avoid confusion with gardening-related topics.

Crawl Spaces Demystified

1. Types in GHI - Vented and Unvented.

Frame and masonry homes have visibly different crawl spaces. Frame crawls are vented; open to the outside air with rectangular vents about one foot wide visible on exterior foundation walls, usually two per unit (service side and garden side). Beneath the frame homes, wood subfloors rest on wood joists. Brick and block home crawls on the other hand are unvented, or closed, with smooth concrete floors (i.e. no visible joists) beneath the unit. Additions may vary. None of the crawlspaces are "conditioned" i.e., climate controlled.

Typically frame rows south of Northway, have accessible boiler rooms at one end; the actual crawl spaces extending from there beneath the rows range in height from roughly 1.5 to 4 feet. North of Northway, there are no boiler rooms; from the 1940s until the early 1980s heat was supplied via a system of interconnected steam tunnels.[8] These crawls are also observed to be from 1.5 to 4 feet high while ground level may or may not be uniform. North of Northway there were four free-standing boiler buildings (now demolished), while south of Northway each court has only one boiler room, which is attached to one end of one of the rows in the court. Typically masonry boiler rooms are located under the middle of the building.

Recommended:

Building science literature does not in general recommend a vented crawl space in a mixed humid climate unless the home is in a flood plain. Based on this literature the TF has determined that vented crawlspaces are no longer recommended for the mix-humid climate of Greenbelt. The TF is recommending sealing and semi-conditioning with mechanical ventilation. Note: There is discrepancy with H.I.R.L. recommendation for frame units and what TF is recommending that needs to be resolved. H.I.R.L is concerned about the multi-family nature of buildings. Their method addresses that issue but does not reconcile with other building science recommendation for this climate zone. Future discussion with H.I.R.L. is required.

2. Crawl Spaces and the 1980s Rehab:

During the early1980s rehab, with the change from oil-fired boilers and crawl space steam pipes to in-unit electric baseboard heaters, **frame** home subfloors were fitted with fiberglass insulation batts which were tucked up between the floor joists, held in place by friction (i.e. nothing) or occasionally with wire. A "vapor barrier" in the form of a 3mil plastic sheet was installed over the dirt floor to about two feet from the foundation walls. Floors were graded (to an unknown degree) and sump pumps were installed, one per row. A perimeter drainage system, (it appears

[8] The key issue with the tunnels relevant to the HIP is animal incursions, which is referenced in this report. So a further detailed description of the steam tunnels is not necessary at this time.

these were installed during the 1980-1984 rehab) **exists** to channel water from the inside perimeter to one or more sump pumps in the row. Some frame rows with repeated water problems have two or more sump pumps. In the **masonry** homes, rigid foam board was mounted to the perimeter walls for its thermal properties. There is no insulation directly beneath the concrete floors of masonry homes.

3. Insulation: Fiberglass Batts in Frame Units

Current research indicates that fiberglass batt insulation (of the type used in the 1980s) in a vented crawlspace is double trouble in our climate region. To briefly explain why, it helps to think of summer rainstorms when warm air (which holds more moisture) collides with a cold front and drops its moisture in the form of rain. Likewise, the humid air from the outside often has more moisture in it than the crawl space air you're trying to vent to the outside. And as the humid air moves into the cooler crawl space the water vapor gets trapped, creating a damp environment that encourages mold and mildew growth. Now add fiberglass batts tucked up between the wood joists which, when they become moisture-laden, will either fall down due to the extra weight, or stay in place and wick moisture to the wood floors and joists. If they remain wet for a long time they enhance the environment for mold and mildew growth, not a good thing whether sitting on the crawl space dirt floor or tucked up against the unit subfloor. Prolonged dampness in wood components is known to promote fungal growth and eventually rot, which can potentially lead to structural failure.   In addition, batts that do remain in place beneath the floor also lose their insulating properties when wet. The TF has concluded that the presence of fiberglass batts, particularly the type available in the 1980s, contributes in several ways to crawlspace problems.

Recommended:
The TF recommends an approach that ideally should not require batting materials beneath the floors (instead placing minimum 2 inch rigid foam insulation along the foundation interiors, creating semi-conditioned crawl spaces with the use of mechanical ventilation). However, the TF also recommends researching alternative non-faced batting (fiberglass or rock wool) materials to insulate specific problem spots such as under kitchen or bathroom floors, or at the base of plumbing wall spaces if members still feel cold.   The TF recommends making sure all holes and penetrations at the base of shared plumbing walls be sealed. (Note: Rock wool has a number of desired features that bear further investigation if batt insulation is required as part of the strategy)

<u>Above</u>: Frame crawlspace c. 2004 showing Fiberglas® batt insulation, pipes and wires, and plastic vapor barrier (left) and bare clay floor (right).
<u>Top right</u> : Same crawlspace, showing bare sub-floor.
<u>Middle right</u>: Same, showing partial vapor barrier and animal scat.
<u>Lower right</u>: Foundation vent, automatic type; uses set-screws which do not secure to masonry.
(All views from GS vent shown at lower right)

Sample Frame Crawl Space 1

Sample Frame Crawl space 2

Fiberglass installed upside down

Vapor barrier not extending to wall

Fiberglass Batts Falling Down

Crowded with pipes

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4. Floor Vapor Barriers and French Drains

Polyethylene vapor barriers (essentially thick plastic sheeting) of a minimum thickness of 10 mil are recommended to replace the 3 mil thickness installed during the 1980s (some of which are torn or missing). Their purpose is to prevent water from entering the crawl space from the floor, and they should be sealed to foundation walls or any wall vapor barriers. In the pilot homes we saw, vapor barriers are sealed around the perimeter with a five-inch mound of spray foam. In the masonry homes, the crawl space walls are covered with foam board insulation, and the vapor barrier and any other seams are also sealed with spray foam.

These vapor barriers should be thick enough to avoid being easily torn, and consideration should be given to finding a means to protect them from tears in the future such as creating access corridors with plywood, indoor/outdoor carpeting or rubber mats.

As mentioned earlier, a French drain system is in place around the inside perimeter of the frame row foundation walls. This system (common in all foundation types) uses the power of gravity to draw water into a perforated pipe buried in a gravel-filled trench that slopes toward sump pumps where it can be pumped away from the building. French drains are used to prevent flooded basements and soggy agricultural fields; a simple variation of a French drain can be seen in sidewalks around Greenbelt where they drain ponding water.

Now, the 10mil vapor barriers if used with French drains present a challenge, but not an insurmountable one. The TF supports H.I.R.L.'s recommendation to replace the vapor barriers with thicker polyethylene and extend it to the perimeter walls, but a method will need to be found that allows any water that might find its way into the crawl (such as in a plumbing leak) to be channeled to the French drains and to the sump pump. Grading needs to be done where water does not flow properly to a sump.

5. Sump Pumps

Sump pumps were installed beginning the 1980s and as reported previously are undergoing inspection and replacement due to widespread failures. Manual monitoring of systems like sump pumps does, however, take a back seat to emergencies and logged maintenance requests, except that now they themselves have become the emergency. Much of the cost for sump pump is covered by replacement reserves.[9] Some of the issues with reliance on these pumps, discussed at length in TF meetings, include monitoring and notification when they break, and operation during a power outage. See appendix C for more thoughts on sump pumps.

> **Recommended:**
> *The TF recommends that we find a way to electronically check sump pump operation in conjunction with the need for physical inspection on a regular schedule.*

[9] See Memorandum to Jim Cohen from Tom Sporney dated 10/20/2014 titled Staff Frame Units' Crawl Space Report, p. 3.

Pilot Homes: Frame Crawl Space Insulation Strategy

To test a more perfect air (thermal) and water (vapor) seal between units and crawl spaces, two frame rows (the only type of unit with insulation beneath the floor, remember) were fitted with new thicker vapor barriers and had approximately 3 inches of **closed-cell spray polyurethane foam** ("SPF" for our purposes) applied to the sub-floors between joists and partially on the joists themselves. This was recommended by H.I.R.L. and done three years ago as part of the pilot study. This method provides an insulation value of R-19; clearly an improvement over that provided by haphazard or missing fiberglass batts.[10] The SPF also effectively isolates the units from each other.
The SPF has excellent insulating as well as air and vapor barrier properties. However, it is not without other problems, as staff and the TF identified, through observations of the pilot homes (plumbing and electrical wiring covered by SPF,[11]). There is ongoing research on potential health and environmental issues with the installation SPF.[12]

Issues with spray foam include:

--Utility boxes, junctions, and most wires and pipes should not be covered, as this would cause future maintenance problems. As observed in the pilot crawls, this may be a factor of installer error, or in tight spaces may be difficult to accomplish. The process will necessitate stringent and objective quality control during application. Covering plumbing and wiring may potentially affect members' ability to upgrade kitchens and bathrooms. This observation is a very good argument for doing a pilot study on local conditions.

-- EPA has concerns about potential serious health risks for workers if they disturb foam once installed and cured, in particular where workers need to use heat as part of their work. At minimum they might need to wear same type of hazmat suit that original installers are required to use. This could be problematic for GHI workers and contractors performing plumbing related work where pipes have been covered in spray foam.
http://www.epa.gov/dfe/pubs/projects/spf/exposure_potential.html#potential

--It could be advantageous in some cases to try and remove obsolete steam pipes and telecom wires, for improved access before any other re-mediation is started.

--A 3-inch thickness of SPF, as was done in the pilot, leaves the lower portion of wooden joists exposed to the high humidity in the crawls, causing problems with moisture wicking upward

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[10] R-value is a measure of insulation's ability to resist heat moving through it. Recommended levels of insulation for floors in retrofitted wood-frame buildings in our area are R25-R30.
https://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table

[11] In the pilot study some SPF covered wires; this is most likely due to either accessibility (difficult-to-reach places in 50-60 horizontal spaces only two feet high), or a lack of quality control (GHI supervision). According to H.I.R.L., boxes or electrical junctions should not be encapsulated. H.I.R.L. commented on this in the April memo.
[12] For a reasonably unbiased discussion of the pros and cons, see
http://www.greenbuildingadvisor.com/blogs/dept/building-science/joe-lstiburek-spray-foam

toward the wood subflooring which cannot as easily dry out. GHI might need to recommend against using vapor impermeable floor coverings such as vinyl in kitchens due to the potential for trapped moisture between the two layers. Encapsulating the entire floor joist in SPF appears to mitigate this potential problem. Need to make sure joists dry out before encapsulating.

--SPF has a low ignition point so any soldering in the crawl space could be risky without precautions.

- Environmental concerns appear to be largely at the installation level, due to the presence of isocyanates, implicated in work-related asthma. The SPF is mixed at point of application (like epoxy, for example), and proper and controlled mixing and installation is critical.[13]

-The curing period is 24 hours to 72 hours, and members would be recommended to avoid their unit for that period (similar to polyurethane floor finishing). The industry claims that most SPFs do not emit HFCs or HCFCs, and no VOCs are measured after 30 days.[14] We would need to find an unbiased source for comparison.

-Some members have expressed concern over the use of any petrochemical products that are still under study by the US EPA. Research is ongoing. See http://www.epa.gov/dfe/pubs/projects/spf/types_of_spray_polyurethane_foam_products.html

Recommended Sealing and Insulation Strategy for Frame Buildings:

Current building science literature recommends an unvented crawl space for a mixed humid climate such as the one found in Greenbelt unless the building is in a flood plane or severe moisture problems that cannot be mitigated. (http://web.ornl.gov/sci/buildingsfoundations/handbook/section3-1.shtml)

Below is a list of items required for sealing and encapsulating crawl space at the perimeter.

- Encapsulating the perimeter foundation walls of frame units with minimum of two inches of rigid foam board (as has been done in the masonry pilots)
- Sealing all crawl space vents
- Correctly installing a 10 to 20mil polyethylene vapor barrier on the floor and have it partially extend up the foundation wall.
- Seal all seams between vapor barrier types, with appropriate waterproof material. Note that in the frame and masonry pilot homes, these seams are sealed with a five-inch pile of SPF. TF has concern that this might not be the most appropriate and cost effective adhesive.
- Semi-condition the frame crawl spaces, which would involve a small ventilation fan sized per code to exhaust out the crawl spaces
- In at least some rows, add dehumidifier(s) to ensure dryness of the space.

[13] https://www.osha.gov/dep/greenjobs/weather_spf.html
[14] http://www.icynene.com/en-us/homeowners/resources/icynene-answers#emissions

- Consider a method to insure that any water that still permeates the space can drain properly to the sump pump. The sump pumps will still be handling water that flows beneath the vapor barrier.

A second approach where moisture cannot be mitigated involves sealing the ceiling plane (under the floors and floor joists) of the crawl space. Place un-faced batt insulation between the joists leaving a 1-inch minimum gap between insulation and subfloor. Next attach rigid-foam insulation to bottom of floor joists and seal joints between rigid foam boards. 20 mil vapor barrier should be placed on ground and extend up wall leaving three inch gap for termite inspections. Seams appropriately sealed. GHI steam pipes would need to be removed to make this option viable.

http://www.buildingscience.com/documents/insights/bsi-009-new-light-in-crawlspaces

http://web.ornl.gov/sci/buildingsfoundations/handbook/section3-2-vented.shtml

Regardless of insulation strategy chosen, H.I.R.L. and other experts state that **water incursion must be mitigated** through appropriate interior and exterior drainage strategies. In addition, any possibility of termite and carpenter ant incursion must be addressed. Air tightness is of particular importance to the unvented crawl space in order to decouple the humidity behavior of the interior environment from the exterior environment. Air is major transport of moisture.

It also acknowledged that, depending on specific circumstances; SPF may be the only appropriate material to use (there is a difference between one and two part spray foams – see appendix which describes different insulation materials). GHI should investigate the possibility of using sprayable caulk instead of polyurethane spray foam for air sealing purposes to mitigate health and fire risks of installing and/or removing SPF.

Currently, to facilitate maintenance and cost, sealing and encapsulating perimeter is TF's preferred method. By sealing up the vents this has the advantage of removing access for animals such as raccoons, squirrels, cats, and mice. In addition staff would no longer have to seasonal open and close vents. This method is particularly appealing for those buildings that show no moisture problems. There might be some buildings that have crawl spaces that will require an alternative method because of moisture problems that cannot be prevented.

Recommendation: *See appendix D for complete description of TF recommendation on sealing and encapsulation strategy.*

Previously Department of Energy guidelines for insulating crawl spaces recommended R-11 for crawl space perimeter walls or R-19 under floor for this climate zone. Recently the updated guidelines suggest R-25 to R-30. This report is following previous guidelines. New guidelines should be examined before work is started.

Recommended Sealing and Insulation Strategy for Masonry buildings:

The masonry buildings receive the same recommendations for sealing and encapsulation as the frame buildings except for the possible exclusion of a ventilation fan. However a dehumidifier should be installed in buildings that have evidence of moisture problems. However they must have bulk water sources managed as well as the frame buildings before sealing and encapsulation should be fully implements.

Masonry buildings also have a major water intrusion problem that needs to be dealt with. A major source seems to be failing interior drainage systems located in the boiler rooms. Typically the floor of the boiler room is located much deeper than the floors of the adjacent masonry crawl spaces. This floor can be up to 8-12 feet below grade. These rooms can act as giant sumps for water during major storms. Failed storm systems can allow water to back up into the passive drain systems causing boiler room to flood. This is in particularly true where exterior passive drainage systems have been corrupted over time such as swales being degraded by weather events or simply by members filling in swales. Additionally waterproofing that was applied to foundations when originally built degrade over time. There is at least one block unit that had water infiltrate main unit because of this degradation. Other boiler rooms have window wells where seals have failed around window allowing water to infiltrate boiler room. Also, there is at least one masonry building, which has so much water pressure allowed to build up against foundation during heavy storms that a weep hole has been creating, allowing water to pour into building's sump. This water is then evacuated by sump pump. Every time this building has a power outage during a storm boiler room floods because sump no longer functions. This building has two basements. These basements will also flood when boiler room floods.

RECOMMENDATION: *Masonry buildings should be sealed and insulated along the perimeter. Appropriate vapor barrier should also be installed properly. Most of the recommendations that apply to frame buildings should be applied to masonry buildings as well. See frame recommendations for complete description. Ventilation fan might not be required in masonry buildings because ceiling of crawl spaces are concrete which effectively seals boiler room and crawl spaces from living space. However all penetrations at the base of common party walls should be sealed in the building's crawl space and boiler room. Also, all plumbing and electrical penetrations in kitchen areas and other locations should be sealed.*

RECOMMENDATION: *All buildings that have flooding when there is a power outage during a storm should have some sort of backup system installed for sump pump(s).*

Some Additional Concluding thoughts

Before 1980 there were approximately 80 staff members, many of whom focused on boiler maintenance and many of whom were let go after the abandonment of the boiler system. Currently there are about 38 staff members, many cross-trained to do a variety of jobs.

In 1972 GHI hired two consultants, one of whom focused on administration and recommended that GHI add middle management positions and hire additional professional personnel.[15]

We may need to re-imagine the way members view their involvement with GHI and issues of maintenance and repair, in areas of monitoring and proactive reporting even incipient problems via a communication channel that gets logged and responded to on a consistent basis. It's thought that some members view GHI as a big apartment complex, where someone else is paying attention to all of the building systems and where you only need to call maintenance when a water faucet falls off in your hands or a circuit breaker malfunctions. With 1591 attached and nine detached homes in a wide variety of shapes and sizes and varying heating and cooling systems, GHI staff can and should be able to rely on members to be their eyes and ears on the

[15] Williamson 1987, p. 224

ground, monitoring their homes and landscapes and reporting when something doesn't look quite right. It's also important for members to feel comfortable doing so, and to know that their request, be it a formally logged maintenance request or an email or call to a staff member, is heard and acknowledged, and attended to, and not considered pesky.

As a case in point, in more recent years the triage of emergencies and maintenance requests has pushed proactive monitoring of sump pumps to the back burner, a reliance on members that leaves monitoring of a critical system to chance at best and consequently lets problems (like failed sump pumps) go unnoticed and unfixed until they become larger issues. In other words, something that should have been handled as routine maintenance first, or a maintenance call second, has now mushroomed into a technical issue involving building structures…that has its own Task Force.

Appendix A: Flooding and Drainage

Staff has a long-term program of identifying drainage issues and prioritizing the worst cases for contract work in each year's operating budget. The 2015 budget includes a 250% increase in funding for external drainage projects (from $30,000 in 2014 to $75,000 in 2015). This includes swale/drainage improvements at:
37K Ridge Rd,
45 L&Q Ridge Rd,
3M Research Rd,
10 Southway (c/a),
8 A-D Plateau Pl,
59 A-D Ridge Rd

In future years GHI should continue taking a more pro-active approach to assessing and remediating large-scale drainage issues. Examples of large-scale issues would be parking lots not draining to storm system but into inner walkways. Locations at higher elevations such as near Greenbelt Elementary draining towards GHI buildings at lower elevations but missing surface drainage systems such as swales; or, swales not draining to appropriate locations. Fix common areas that do not drain properly. GHI might need to contract with a civil engineer consultant with expertise in drainage problems for assistance in this project.

When discussing drainage issues GHI needs to pay close attention to the specific soil types here. One useful resource for this is the USDA soil survey for Prince Georges County; although the scale of mapping in this survey is not adequate for what we need to do, it does provide a place to start. A common soil type here is Beltsville silt loam, which has a distinctive layer of naturally cemented sediments called a fragipan horizon at about 20 to 40 inches below the natural surface (varies of course depending on grading from development activities). The impermeability of the fragipan has significant implications for drainage.

Two main drainage management techniques are 1) swales to move surface water away from foundations and towards engineered drainage structures (gutters, storm drains, and/or water gardens); and 2) 'french drains' which enable moisture in the subsurface to be directed towards sumps or into 'tile fields' which are designed to allow the collected moisture to be distributed into a larger volume of permeable soil (likely engineered given our ubiquitous clay-rich soils). In any case, as with appropriate surface grading, moving water away from foundations and crawl spaces is the goal - in some cases, the approaches can be combined if sufficient space is available.

For 'localized ponding' of storm water, one can create vertical permeability pathways that are basically augur holes that go down several feet and are back-filled with pea gravel. These work well in garden beds where mulch can cover the gravel fill. Such structures probably cannot be used widely but depending on the local situation, these could be enlarged with more powerful equipment to take more water from the near surface and allow it to drain vertically away from a problem area (basically allows a local lowering of the water level in the soil so that in times of high moisture, there is more capacity to draw water away from the surface).

One other method that may be relevant, primarily for the worst situations, is horizontal drilling for installing permanent subdrains. This may be what is really needed for the rows that have 'springs' in their subsurface for example. Note, you do not need a steep slope necessarily to install these, you can dig a 'drain pit', drill the horizontal drains from it, and then connect the pit to the storm drain system. More evolved equipment allows directional control of the drilling head.
http://web.mst.edu/~rogersda/umrcourses/ge441/online_lectures/subsurface_drainage/GE441-Lecture5-11.pdf
https://www.youtube.com/watch?v=fTxausNX3VE (also see other videos from other sources)

Appendix B: Keys to success.

Keys to success:

1) Prevent and Mitigate moisture intrusion
2) Interior moisture drains downhill into a sump
3) Dry out crawl space
4) Seal and Insulate properly
5) Condition space appropriately
6) Facilitate maintenance and upgrades
    a. Create access corridors on materials which protect vapor barrier
    b. Install LED lighting
    c. Install telecommunication conduits
    d. Remove obstacles where possible (i.e. steam pipes and trash)

7) Provide warning system for when things fail
8) Inspect regularly and often - leveraging technology such as remotely operated vehicles to facilitate inspection and documentation of crawl spaces

Appendix C: Notes and Questions about GHI Sump Pumps

How many sump pumps does GHI use? Currently there are 189 sump pumps under replacement reserves, one for each frame rows, which were proactively installed during the last rehab. Not clear was whether or not the original pumps were installed because there were known water problem in all frame buildings or installed because there were sufficient buildings that had water problems and it was simpler to install in all units then to check for the need in each building. Over time many more were installed in the frame, masonry, and the modern town homes of the 1970's as new water infiltration issues were identified. Some frame buildings have as many as five sump pumps. As part of the inspection and repair of sump pumps in the community GHI is inventorying the number of sump pumps in the community at large.

What kind of sump pump does GHI use? GHI uses a submerged sump pump instead of a pedestal type due to the low ceiling heights of the crawl spaces.

Does GHI have any feel for how they are failing at such a high rate? Or what is failing in these sump pumps? Because of the high rate it would be important to identify issues and mitigate them.

Submerged sump pumps tend to fail for several different reasons.
1) Underpowered for the amount of water that needs to be pumped out.
2) Debris can clog up submerged sump pump especially if not installed properly
3) The switch does not work properly because it gets lodged against something and stays in the on position
4) When older submerged sump pumps are allowed to dry out, the gaskets can then start cracking.
5) Air lock can cause failure. If no appropriate weep hole in discharge line and sump dries out air can get into discharge line and prevent check valve from working properly
6) Missing check valve can cause water to flow backwards, which causes problems.
5) Old age
6) Misc other reasons.

Item 1 would have to be assessed before installation and monitored after initially installing to see that it keeps up.

Items 2 and 3 would be indicative of a need for regular maintenance. Manufacturers seem to indicate a need for minimally inspecting once a year and more frequently if there is heavy use. Some switches come with cages to prevent getting jammed. Apparently the vibration of the motor can shift the float switch into a bad location or debris can jam the float. Debris can also clog the unit, which would require it to be cleaned out. Also a sealed cover over sump can help keep debris out.

Item 4 is of interest because that might indicate one of the following: the space is actually dry and no sump is needed, or the sump pump is in the wrong space, or the flooding is very infrequent. The dryness of the sump and walls together might be a useful diagnostic. If sump is not needed that could save GHI money in the long run and with fewer sump pumps to inspect and replace in the future.

All these issues might relate to why submerged sump pumps have such a wide range of service life of 5 to 15 years. Most sump pump companies recommend testing sump pumps 1-4 times a year depending on usage. A standard test seems to be a two-part test. First test the motor to see that it operates. Make sure sump pump submerged in water before testing motor. Can cause damage to submerged sump pump if dry tested. Next pour sufficient water from 5-gallon bucket or equivalently using water from a water hose to confirm that water is being evacuated out of the house and into appropriate discharge point such as underground storm system.

One goal for GHI should be to minimize the need for sump pumps because of the extreme service requirements. This means utilizing passive systems such as surface drainage techniques such as swales and underground drainage techniques such as French drains to move water away from the building structures. Proper functioning gutters and down spouts drain to an appropriate location to protect foundations of GHI buildings.

Buildings should have a positive grade away from home – at least 6 inches for every 10 feet. This will help prevent water being trapped against foundation wall. If a negative grade cannot be avoided then swales and French drains should be used to divert water away from foundation. A broad discussion should occur as to what motivates people to fill in swales and what can be done to mitigate those motivations; unless motivations are addressed people will probably continue to fill in swales. Plantings that are very water intensive, that are within three feet of foundation, can have negative impact.

All of these passive water mitigation systems are critical to the reduction of GHI reliance on sump pumps and to the long-term maintenance of GHI crawl spaces.

RECOMMEND:

TF recommends that every year a new set of buildings is assessed as to the true need for a sump pump as part of the crawl space two-phase re-mediation process. First phase set of building's crawl spaces assessed in spring time after heavy rains for bulk water intrusion problems in the crawl spaces. Second phase set of crawl spaces remediated the following year. Members should look to create a positive grade away from structure of their homes and minimize water intensive plantings within 3 feet of buildings. If positive grade not possible then french drain with clean out might be required.

Appendix D: Sample Encapsulated Crawl Space

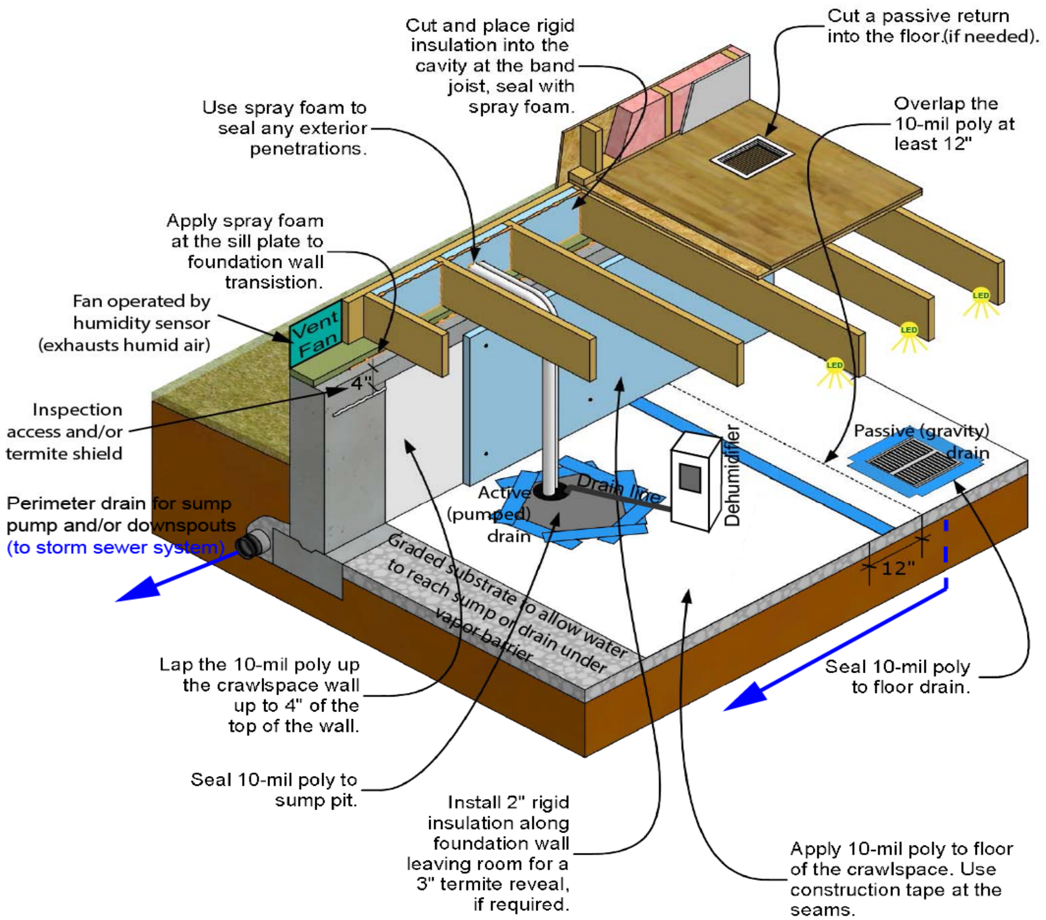

Figure 1 (ES). Crawlspace interior details of idealized NREL frame crawl space adapted for GHI units that includes a sensor-controlled vent fan and dehumidifier and both active (sump pump) and passive (gravity drain) outlets, as appropriate, for water that infiltrates under the vapor barrier. See Figure CSTFx for details of sealed access door.

Figure based on image from "Guide to Closing and Conditioning Ventilated Crawlspaces", Bruce Dickson, IBACOS, Inc., 2013.
http://www.epa.gov/indoorairplus/technical/moisture/images/large/13.jpg

Perimeter Sealed and Insulated Crawl Space:

a. 10-20 mil vapor barrier covers floor and extends to appropriate height on all external walls and piers.
b. Perimeter walls are sealed and insulated with minimum of two inch rigid foam
c. Band joists properly sealed and insulated with mimimum of two inch rigid foam
d. Indoor/Outdoor carpet or plywood used to protect and facilitate access corridors over vapor barrier
e. Lighting such as LED Christmas lights used to provide lighting to facilitate work in crawl space.
f. Conduits for telecommunications
g. All units that require a sump pump have interior drainage leading to sump.
h. Sump Pumps
    a. Sumps are properly sealed and vented to proper exterior drainage system
    b. Suitable alarm system
    c. Backup sump pump where high water table or deliberate drainage of water into crawl space might have problems when power outages occur during rain event or near major rain event.
        i. Battery backup
        ii. Water backup sump pump via municipal water supply
i. Mechanical Exhaust for frame units (1 CFM per 50 Square Feet) and ensure suitable make up air available from building above.
j. Crawl space dehumidifier(s) for all unit types which require them.
k. Airtight access doors
l. Termite barrier strip or Termite reveal for inspections at top of rigid foam board on perimeter walls
m. Alarm system for excess moisture
    a. Hygrometer
    b. Water sensor
    c. LED alert
    d. Audio alert

APPENDIX E: Notes on Facilitating Maintenance in Crawl Space

Members of TF interviewed former GHI plumbers, one of whom was also a former WSSC supervisor, about ways to make crawl space easier to access and maintain. The obvious advantage being that future labor costs would drop due to less time required to finish similar tasks. Members report that some telecommunication workers unwilling to install wires in crawl space because of conditions found there. There are strong disincentives to do proper inspections where areas are hard to reach and unpleasant to be in.

Both plumbers thought removing the former steam pipes would make the biggest difference. Crawling around steam pipes greatly extends the time to fix problems. Sometimes, due to pipes, workers would have to crawl all around the crawl space in order to get to adjacent areas. At least remove enough steam to pipes to facilitate access corridors throughout crawl spaces.

Both former GHI workers also indicated that removing pipes is doable. One plumber says he has already cut out some pipes to facilitate his work. Former WSSC supervisor suggested hiring a salvage company to specifically do that work. He felt a salvage company would charge much less than other types of companies. The pipes should be cut in 4-6 ft sections in order to facilitate removal. Steam pipes would have to be marked to make sure correct pipes are removed.

Former WSSC supervisor mentioned that support hangers for metal pipes might be spaced to far apart when these pipes are replaced with new PVC pipes. This can cause pipes to sag and water problems to develop. As metal pipes are replaced in future with PVS pipes additional support hangers might be needed.

Simply providing lighting such as string of LED Christmas lights, as installed in a pilot home crawl space, would create a better workspace.

Also, providing water sensors as an early warning system will provide a critical service between inspections.

> Using remotely operated vehicles (ROV) has the potential to greatly reduce crawl space inspection times. This could proof critical to the long-term maintenance of the GHI structures.

APPENDIX F: RECOMMENDATIONS EXTRACTED:

Recommended:

For 2015 GHI should undertake a second round of inspections after the heavy spring rains. This inspection combined with known problem areas can be used to identify and prioritize the first set of crawl spaces to be remediated. In subsequent years, this process of inspecting a set of crawl spaces after the heavy spring rains should be continued to identify and prioritize the next set of crawl spaces to be remediated.

(See Action Plan – separate document)

Recommended:

GHI staff is planning a row by row observational inspection of GHI exteriors this winter when weather permits. The TF recommends that staff contact the members of rows to be inspected about a week prior so that members have an opportunity to meet and add their own observations to GHI's data store. This would include issues not obvious in a one-time visual inspection during a dry spell, such as water ponding problem spots, swales draining to an appropriate discharge point (storm, gutter, etc.), regular gutter or downspout overflows, or parking lot drainage problems during heavy rains. Data aside, GHI staff and member interaction is important to the future of the HIP.

Preventing bulk water intrusion into crawl spaces is one key to the long-term maintenance of GHI crawl spaces. High priority should be given to identifying damaged passive drainage systems in the community and install new systems where appropriate.

Recommended:

Building science literature does not in general recommend a vented crawl space in a mixed humid climate unless the home is in a flood plain. Based on this literature the TF has determined that vented crawlspaces are no longer recommended for the mix-humid climate of Greenbelt. The TF is recommending sealing and semi-conditioning with mechanical ventilation. Note: There is discrepancy with H.I.R.L. recommendation for frame units and what TF is recommending that needs to be resolved. H.I.R.L is concerned about the multi-family nature of buildings. Their method addresses that issue but does not reconcile with other building science recommendation for this climate zone. Future discussion with H.I.R.L. is required.

Recommended:

The TF recommends an approach that ideally should not require batting materials beneath the floors (instead placing minimum 2 inch rigid foam insulation along the foundation interiors, creating semi-conditioned crawl spaces with the use of mechanical ventilation). However, the TF also recommends researching alternative non-faced batting (fiberglass or rock wool) materials to insulate specific problem spots such as under kitchen or bathroom floors, or at the base of plumbing wall spaces if members still feel cold.   The TF recommends making sure all holes and penetrations at the base of *shared plumbing walls be sealed. (Note: Rock wool has a number of desired features that bear further investigation if batt insulation is required as part of the strategy)*

Recommended:
The TF recommends that we find a way to electronically check sump pump operation in conjunction with the need for physical inspection on a regular schedule.

Recommendation: *See appendix D for complete description of TF recommendation on sealing and encapsulation strategy.*

RECOMMENDATION: *Masonry buildings should be sealed and insulated along the perimeter. Appropriate vapor barrier should also be installed properly. Most of the recommendations that apply to frame buildings should be applied to masonry buildings as well. See frame recommendations for complete description. Ventilation fan might not be required in masonry buildings because ceiling of crawl spaces are concrete which effectively seals boiler room and crawl spaces from living space. However all penetrations at the base of common party walls should be sealed in the building's crawl space and boiler room. Also, all plumbing and electrical penetrations in kitchen areas and other locations should be sealed.*

RECOMMENDATION: *All buildings that have flooding when there is a power outage during a storm should have some sort of backup system installed for sump pump(s).*

RECOMMEND:
TF recommends that every year a new set of buildings is assessed as to the true need for a sump pump as part of the crawl space two-phase re-mediation process. First phase set of building's crawl spaces assessed in springtime after heavy rains for bulk water intrusion problems in the crawl spaces. Second phase set of crawl spaces remediated the following year.   Members should look to create a positive grade away from structure of their homes and minimize water intensive plantings within 3 feet of buildings. If positive grade not possible then french drain with clean out might be required.

Resources

1) "Guide to Closing and Conditioning Ventilated Crawlspaces", Bruce Dickson, IBACOS, Inc., 2013

- http://www.nrel.gov/docs/fy13osti/54859.pdf

2) "Energy Efficient Crawlspace Foundation Retrofit: Mixed Humid Climate" by M. Del Bianco, J. Wiehagen, and A. Wood, H.I.R.L. , 2013

•http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/crawlspace_found_retrofit.pdf

3) Home Moisture Problems,
https://ag.purdue.edu/extension/eden/Mold/Moisture_Problems.pdf   (accessed 10/3/14)

4) "BSI-009 New Light in Crawlspaces" by Joseph Lstiburek, Building Science Corporation, 2008

•http://www.buildingscience.com/documents/insights/bsi-009-new-light-in-crawlspaces

5) "Insulating Raised Floors in Hot Humid Climate", LSU AgCenter Pub. 3187, sponsered by LSU AgCenter, Forest Service Laboratory, 2011?

•https://www.lsuagcenter.com/NR/rdonlyres/D33F711D-DC4B-4E4C-9ED6-A97DCE9DB026/79805/pub3187insulatingraisedfloorsLOWRES.pdfhttp://www.epa.gov/dfe/pubs/projects/spf/spray_polyurethane_foam.html

6) EPA and Spray Foam

- http://www.epa.gov/dfe/pubs/projects/spf/spray_polyurethane_foam.html

7) http://www.epa.gov/mold/moldcourse/imagegallery5.html

8) http://www.epa.gov/mold/moldcourse/

9) http://www.epa.gov/dfe/pubs/projects/spf/exposure_potential.html#potential

Oak Ridge National Laboratory: Foundation, Crawl Spaces, and Insulation

10) http://web.ornl.gov/sci/buildingsfoundations/handbook/toc.shtml

11) http://web.ornl.gov/sci/buildingsfoundations/handbook/chapter3.shtml

12) http://web.ornl.gov/sci/buildingsfoundations/handbook/section3-1-insulation.shtml