AGW
A.G. WASSENAAR, INC.

September 22, 2020

Richmond American Homes of Colorado, Inc.
4350 South Monaco Street
Denver, Colorado 80237

Attention: Mr. Eric Kubly

Subject: **Soil and Foundation Study**
Proposed Residential Structure
Lot 51, Block 6
Haskins Station
Arvada, Colorado
Project Number 202856

Purpose

As requested, A. G. Wassenaar, Inc. (AGW) performed a soil and foundation study at the subject site. The purpose of our study was to observe subsurface conditions encountered and to recommend geotechnical design criteria for the design and construction of the foundation for the proposed single family residential structure. For purposes of this study, we understand and assume the overexcavation recommendations provided in our report, "Geotechnical Site Development Study for Haskins Station, Northwest of Quail Street and Ridge Road, Arvada, Colorado", AGW Project Number 178205, dated January 18, 2018, have been followed. Density-compaction test reports (AGW Project Number 178205OX) were considered during the preparation of this study. The fill materials tested were placed in general accordance with the requirements of HUD Data Sheet 79G. This letter presents a summary of our findings and recommendations. The recommendations contained in this study must be followed to increase the chances that the foundation and slabs-on-grade will perform satisfactorily. However, following these recommendations will not eliminate the risk of foundation and slab damage. It is likely some cosmetic distress will occur (i.e., drywall cracks, slab cracking, slab movement). The Homeowner must assume the responsibility for maintaining the residence following the recommendations contained in this study regarding drainage and landscaping.

Proposed Construction

The proposed structure will be up to three stories supported upon a reinforced concrete foundation. The structure will be wood framed with a crawl space beneath the living areas. If plans change, the recommendations in this report must be reviewed by AGW prior to design and construction of the foundation.

Subsurface Conditions

The field exploration included drilling a 4-inch diameter test boring near the center of the lot. The subsurface conditions encountered are shown on Figure 1, including the results of penetration tests at the locations of sampling.

Laboratory Testing

Samples obtained during drilling were returned to the laboratory. They were visually classified and testing was assigned to selected samples in an effort to evaluate the engineering properties of the subsurface materials encountered. The test results are summarized on Figure 1. Based upon visual observation of the subsurface conditions encountered and laboratory testing for this and/or adjacent lots, it is our opinion that the subsurface materials generally exhibit low potential for expansion and compression. Refer to the Colorado Geological Survey Special Publication 43 for a description of expansive soils and their impact on structure performance.

Foundation Recommendations

Based on our evaluation of the subsurface conditions, the proposed structure may be founded upon spread or pad-type footings bearing on properly placed and compacted fill. The footings should be designed for a maximum bearing pressure of 2,500 psf with a minimum dead load pressure of 800 psf. Four-inch void material should be installed in areas where the minimum dead load cannot be attained. Footing dimensions and foundation structural elements should be determined by a structural engineer. Concrete in contact with the subsurface materials may be designed for negligible (S0 or RS0) sulfate exposure as defined by either ACI 318 (Table 19.3.1.1) or ACI 332 (Table 5.2.1) as determined from the appropriate building code for this jurisdiction. Bearing materials loosened by machine excavation should be removed prior to placing footing concrete. Occasionally, pockets of dry, hard fill or very moist, soft fill may be encountered in the foundation excavation. If this condition occurs, the footings should extend to properly moisture treated fill. Exterior footings should bear at least 3 feet below exterior grade for frost protection. The bearing materials beneath footings should be protected from freezing during construction. All footing excavations should be observed by AGW prior to placement of concrete.

The foundation walls backfilled with on-site materials should be designed for a lateral earth pressure based upon an equivalent fluid density of 65 pounds per cubic foot (pcf) for the "at rest" condition or 50 pcf for the "active" condition. The "active" condition should only be used where wall movements of at least 0.5% of the wall height are allowed. These values have been provided without considerations for sloping backfill, surcharge loading or hydrostatic pressures. Construction of a drain system and proper surface drainage as discussed later in this report may lower the potential of developing hydrostatic pressure in the backfill materials. Minor cracking of concrete foundation walls should be expected.

Potential Heave

Based upon the data gathered for this and adjacent sites and our experience working with the subsurface conditions in the area, we performed an analysis of the potential heave of the soils. This analysis assumes our design recommendations are followed and a potential depth of moisture change beneath the lot surface. We have calculated a potential garage slab heave of less than 2 inches. Using the foundation bearing pressures presented, it is our opinion that differential foundation movements of more than 1 inch are not likely unless our design recommendations are not followed, the subgrade materials are allowed to dry prior to foundation construction, or the fills are allowed to saturate after foundation construction. It must be understood that the amounts of calculated potential heave are theoretical numbers. There is currently no type of testing or correlation of factors that will definitively predict the amount of heave at a site.

Garage Slabs

If the Builder and/or Homeowner accepts the risk of slab movement, garage slabs supported by the subsurface materials should be constructed using the following criteria:

1. Slabs should be separated from exterior walls and interior bearing members with a joint which allows free vertical movement of the slab.
2. Slab bearing partitions and garage door jambs should be constructed with a minimum 2-inch void space. Doorways should also be designed to allow for vertical movement of the slab. Drywall should not be in contact with the slab. Door jambs may be constructed above slab joint material if desired. Stairways bearing upon the garage slab should be constructed in such a way as to allow at least 2 inches of slab heave. In the event of slab heave, the movement should not be transmitted directly through the partitions to the remainder of the structure.
3. Any plumbing or other utilities should be isolated from the slab and be provided with flexible connections. The Homeowner must maintain these connections.
4. If a forced-air heating system is used and the furnace is located on the garage slab, we recommend a collapsible connection between the furnace and the duct work to allow for at least 3 inches of slab heave. Utility connections should also have flexible connections capable of accommodating the same magnitude of movement as specified above.
5. Frequent control joints should be provided in the slab to reduce problems associated with shrinkage cracking and curling. We recommend additional control joints be located approximately 3 feet away from and parallel to the foundation walls.

Following these recommendations should reduce damage caused by movement of the garage slab; however, the void spaces recommended are not intended to predict total slab movement. Care should be taken to monitor and reestablish partition voids and flexible connections when necessary.

Crawl Space Construction

The crawl space ground surface should be sloped to the perimeter drain system. Trenching or dishing out of the crawl space is not recommended unless a drain system is placed in these areas in such a manner to facilitate drainage. The recommended clearance from the crawl space ground surface to the engineered floor system should meet applicable codes as well as be increased by the recommended foundation void height. In addition, all plumbing lines should be isolated from the ground surface or foundation walls by at least the height of the previously recommended foundation void thickness.

During construction, the crawl space area should be checked for standing water or very moist conditions, construction debris, and other deleterious materials. If these conditions exist, the area should be evaluated and mitigated, as necessary.

Crawl space areas should be constructed with consideration given to proper ventilation and moisture management. Provisions such as the installation of a vapor retarder should be utilized to reduce the amount of moisture (humidity) in the crawl space air. The Client and any future Owner should be aware that crawl space areas are subject to various air quality issues. A consultant specializing in ventilation and air quality control should be contacted to provide any additional recommendations.

Such recommendations are beyond the geotechnical scope of this study. The environmental division of AGW is capable of providing such services. Refer to "Homeowner's Guide to Moisture Management" by Tri-County Health Department (Brochure Number S-323) for additional information.

Fill Placement

Any fill placed beneath the foundation and slabs-on-grade should be well compacted. Prior to placement of fill, the ground surface should be scarified a minimum of 6 inches or pipes in trenches should be properly bedded. The new fill should be of similar soil type as the existing subgrade material. New fill should be placed in maximum 8-inch loose lifts. The scarified ground surface and the new fill should be compacted to a minimum of 95% of Standard Proctor (ASTM D698) maximum dry density for cohesive soils or Modified Proctor (ASTM D1557) maximum dry density for granular soils. The moisture content of the compacted material should be between optimum and 4% over optimum moisture content for cohesive soils or within 2% of optimum moisture content for granular soils. Density compaction testing must be performed upon any new fill placed beneath the foundation of the structure. Backfill around the foundation should be moistened and compacted in such a manner as to reduce future settlement.

Subsurface Drainage

As a minimum, we recommend providing a subsurface drainage system around the lowest below grade area. The purpose of the drain is to collect water which may become trapped on the surface of the excavation and enter the crawl space area. A drain should be constructed similar to one of the attached drain details (Figure 2 or 3) and should be uniformly sloped to a positive gravity discharge or sump.

If a sump pit is installed, it should be monitored for water accumulation and proper operation. The water level in the sump pit should not be allowed to rise above the bottom of the foundation drain inlet pipe(s). If this occurs, a pump should be installed (if not originally equipped) or maintenance should be performed on the existing pump.

Surface Drainage

The wetting of foundation soils and/or bedrock materials may be reduced by carefully planned and maintained surface drainage. The following recommendations should be implemented during construction and maintained by the Homeowner after the structure is completed:

1. Excessive wetting or drying of the open foundation excavation should be avoided as much as practical during construction.
2. The ground surface surrounding the exterior of the foundation should be maintained in such a manner as to provide for positive surface drainage away from the foundation. At completion of construction, we recommend a minimum fall away from the foundation of 6 inches in the first 5 feet. This slope should be continuous across the backfill zone.
3. Areas which settle should be filled as soon as possible in order to maintain positive drainage away from the foundation.
4. If lawn edging is used around the exterior of the foundation, it should be constructed in a manner to prevent ponding of surface water in the vicinity of the backfill soils.

5. Drainage swales should be constructed and maintained a minimum of 5 feet away from the foundation on side yards and 15 feet away from the foundation on back and front yards. Natural drainage swales should maintain a slope of at least 2% off of the lot. Swales must not be blocked by fences, landscaping, paths, or other Homeowner installed items.
6. Roof downspouts and drains should discharge well beyond the limits of foundation backfill. We do not recommend burying downspouts. If burying is necessary, solid, rigid pipe should be used and it should slope to an open gravity outlet. Downspout extensions, splash blocks, and outlets must be maintained by the Homeowner.
7. Irrigation should be limited to the minimum amount of water sufficient to maintain vegetation. More water will likely increase the potential for slab and foundation movements. Plants located close to foundation walls should have low moisture requirements. Watering adjacent to the foundation should be reduced as much as practical. Landscaping which requires excessive watering should not be located within 5 feet of foundation walls. Sprinkler lines, zone control boxes, and drains should be located outside the limits of the foundation backfill. Sprinkler heads should be positioned such that the spray does not fall within 5 feet of foundation walls.
8. Plastic membranes should not be used to cover the ground surface immediately surrounding the foundation. These membranes tend to trap moisture and prevent normal evaporation from occurring. We recommend the use of a weed suppressant geotextile fabric.

Limitations

We believe the professional judgments expressed in this report are consistent with that degree of skill and care ordinarily exercised by practicing design professionals performing similar design services in the same locality, at the same time, at the same site and under the same or similar circumstances and conditions. No other warranty, express or implied, is made. The location of the test boring drilled and the laboratory testing performed for this study were designed to obtain a reasonably accurate picture of subsurface conditions for design purposes. Variations in subsurface conditions not indicated by the test boring are possible and expected. Therefore, we should be retained to observe the foundation excavation and construction. If unexpected subsurface conditions are observed by others during construction, we should be called to review our recommendations.

This report was prepared for the exclusive use of our Client and for reference by the Homeowner for the sole purpose of providing geotechnical design criteria for the subject structure based upon the existing site conditions as encountered. The conclusions and recommendations contained in this report shall not be considered valid for use by Others without written authorization from AGW. Because of the constantly changing state of the practice in geotechnical engineering, this report must not be relied upon after a period of three years without AGW being given the opportunity to review and, if necessary, revise our findings.

The methods of analysis used to develop the recommendations contained in this study are not based on exact science. They are tempered with engineering judgment and experience. The recommendations are not risk-free, but include those measures which, in our opinion, increase the chances that the residence will perform satisfactorily.

The recommendations provided in this report are based upon the specified extents of the overexcavation for the original building footprint. The future Homeowner should not construct any additions to the structure utilizing the recommendations given in this report. Additional studies must be provided if any additions are to be constructed.

If we can be of further service in discussing the contents of this letter or in analysis of proposed structure from the soil and foundation viewpoint, please call our office.

Sincerely,

A. G. Wassenaar, Inc.

Aaron A. Blahut, E. I.
Staff Engineer

Reviewed by:

Kathleen A. Noonan, M.S., P.E.
Senior Geotechnical Engineer

Attachments: Figures 1, 2, and 3

AAB/KAN/bab

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CLIENT Richmond American Homes of Colorado, Inc. **PROJECT NAME** Haskins Station

PROJECT NUMBER 202856 **PROJECT LOCATION** Arvada, Colorado

DATE DRILLED August 18, 2020

DRILLING METHOD 4-inch Solid Stem Auger

NOTES

GROUND WATER LEVELS:

▽ **AT TIME OF DRILLING** 16 feet

▼ **2 DAY(S) AFTER DRILLING** 22.5 feet

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE (MC-Modified CA, SS-Split Spoon)	BLOW COUNTS (N/inch)	DRY UNIT WT (pcf)	MOISTURE CONTENT (%)	SWELL/ CONSOLIDATION(-) (%)	-#200 (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX
0		Fill (moisture treated), clay, stiff, silty, sandy, with processed claystone and sandstone and scattered gravel, moist, mottled brown									
			MC	13 / 12	110	8	-0.1				
5			MC	13 / 12	102	17	-0.4				
10		Sand and gravel, very dense, silty, clayey, moist to wet, brown	MC	50 / 10							
15		Claystone (bedrock), hard, silty, slightly sandy to sandy, with sandstone lenses, iron stained, very moist, brown to gray to olive	MC	50 / 9							
20			MC	50 / 10							

Bottom of borehole at 24.8 feet.

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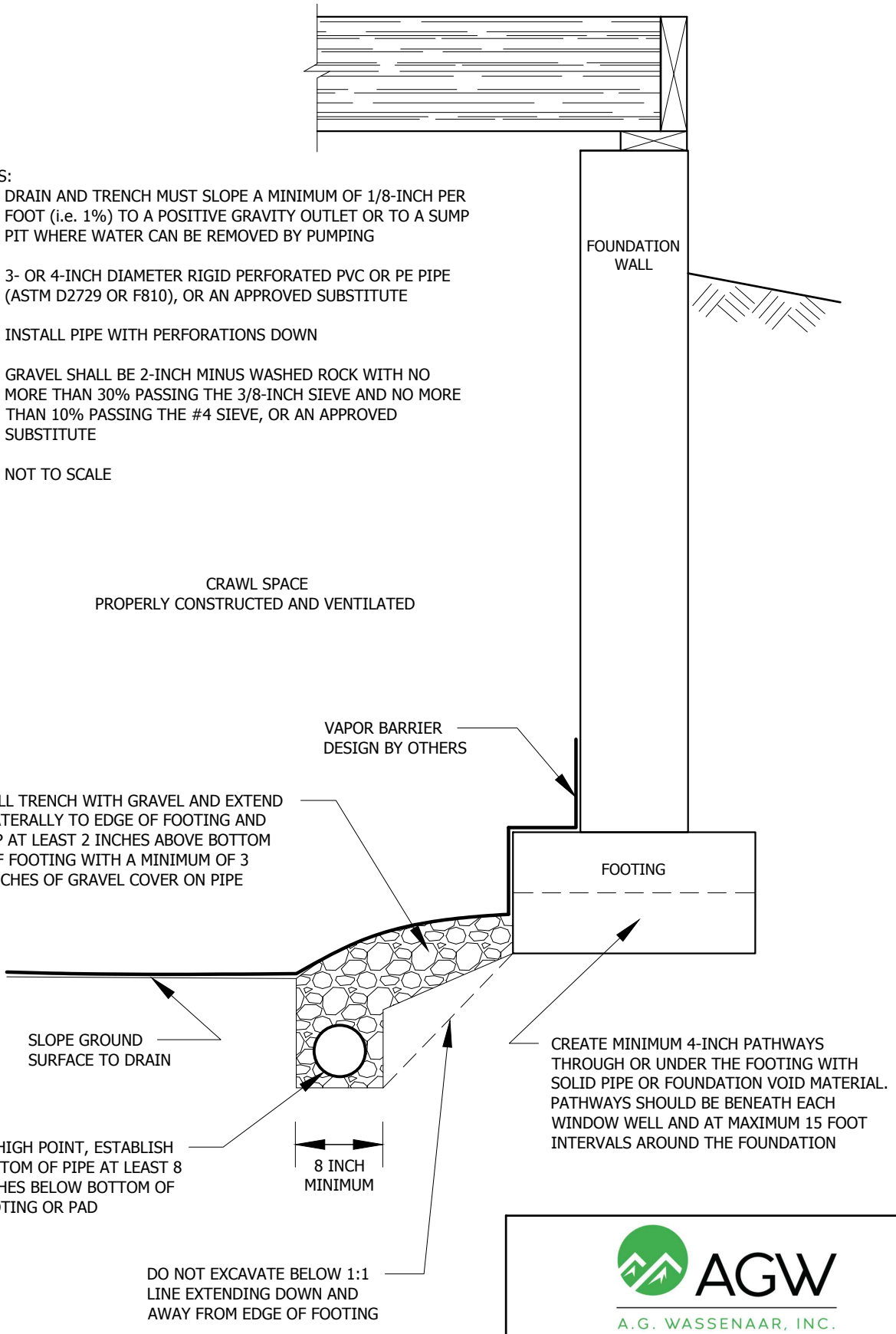
Figure 1

NOTES:

1. DRAIN AND TRENCH MUST SLOPE A MINIMUM OF 1/8-INCH PER FOOT (i.e. 1%) TO A POSITIVE GRAVITY OUTLET OR TO A SUMP PIT WHERE WATER CAN BE REMOVED BY PUMPING
2. 3- OR 4-INCH DIAMETER RIGID PERFORATED PVC OR PE PIPE (ASTM D2729 OR F810), OR AN APPROVED SUBSTITUTE
3. INSTALL PIPE WITH PERFORATIONS DOWN
4. GRAVEL SHALL BE 2-INCH MINUS WASHED ROCK WITH NO MORE THAN 30% PASSING THE 3/8-INCH SIEVE AND NO MORE THAN 10% PASSING THE #4 SIEVE, OR AN APPROVED SUBSTITUTE
5. NOT TO SCALE

CRAWL SPACE
PROPERLY CONSTRUCTED AND VENTILATED



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FOUNDATION DRAIN DETAIL	FIGURE 2

DR \ FTG 5 INT CRAWL JULY 2019

NOTES:

1. DRAIN AND TRENCH MUST SLOPE A MINIMUM OF 1/8-INCH PER FOOT (i.e. 1%) TO A POSITIVE GRAVITY OUTLET OR TO A SUMP PIT WHERE WATER CAN BE REMOVED BY PUMPING
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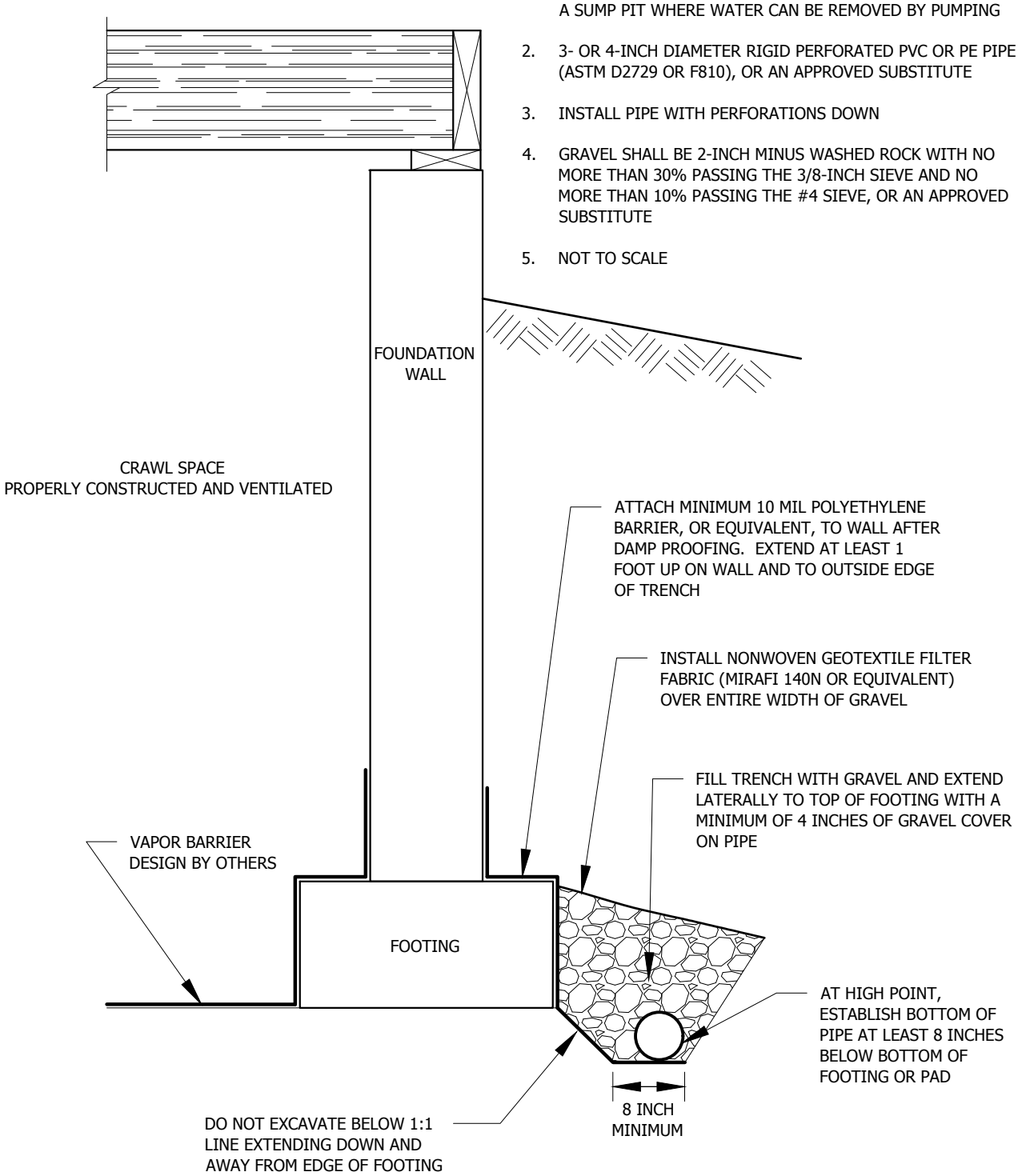
5. NOT TO SCALE



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FOUNDATION DRAIN DETAIL	FIGURE 3

DR \ FTG 6 EXT CRAWL JULY 2019