LITHOS ENGINEERING

GEOLOGIC REPORT
DRAFT

Fairview

Jefferson County, Colorado

August 2nd, 2018

Engineering from the ground down

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August 2, 2018
Project No. 18059

AG Wassenaar, Inc.
2180 S. Ivanhoe Street, Suite 5
Denver, Colorado 80222

Attention: Ms. Kathleen Noonan, PE
Senior Geotechnical Engineer

Regarding: Geological Report – Fairview
Jefferson County, Colorado

Ms. Noonan,

This report presents the results of our geological review for the proposed Fairview development. This study was conducted in general accordance with the contract between Lithos Engineering and AG Wassenaar, Inc. dated July 13, 2018. Contained herein are discussions of the general subsurface conditions and geologic reporting for the subject project as required by Jefferson County's Land Development Regulation, Section 25.

This report was prepared by a qualified professional geologist with over 10 years' experience performing geologic field mapping, site investigations, and geotechnical design in eastern Jefferson County, as required by Jefferson County.

If you have any questions regarding the contents of this report, please contact the undersigned.

Sincerely,
Lithos Engineering

Ryan Marsters, PE, PG
Geological Engineer

Robin Dornfest, PG
President

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EXECUTIVE SUMMARY

The following report presents the results of Lithos Engineering's geological review for the proposed Fairview development project. The project includes development and construction of a housing subdivision by Richmond American Homes of Colorado, Inc. The site is within Jefferson County's Designated Dipping Bedrock Area (DDBA). AG Wassenaar, Inc. (AGW) is the Geotechnical Engineer of record for the project and has retained Lithos to conduct the geological review and reporting.

Lithos relied on standard geotechnical drilling and laboratory testing conducted by AGW as well as on local experience. AGW performed five geotechnical test borings to depths between approximately 24 feet and 34 feet across the site. Laboratory testing included index testing, gradation, swell, dry density, and others. The following summarizes our general conclusions and construction considerations based on encountered geologic conditions:

1. Ground conditions were characterized as topsoil and clay overlying shallow claystone and sandstone bedrock less than 10 feet below existing ground surface. The surficial materials consist of stiff to very stiff clay. Bedrock consists of hard to very hard interbedded claystone and sandstone. Existing geologic maps indicate loess and alluvium overlie northeast-dipping Laramie Formation and Fox Hills Sandstone. The exact dip of the bedrock was not obtained during the investigation; however, geologic mapping suggests approximately 54 degrees. Groundwater was encountered in only one borehole and within bedrock.
2. Swelling soils are present at the site. Test results from clayey samples suggest surficial materials may exhibit high swell potential. Local experience with surficial units suggests swell potential may range considerably from negligible to very high. Foundation design for the proposed structures and expansive soil mitigation for the proposed construction should be in accordance with the geotechnical report by AGW. Surface drainage should be designed to quickly and efficiently remove water from nearby foundations.
3. Heaving bedrock is present at the site. Test results and local experience with claystone bedrock of the Laramie Formation suggests the bedrock is expansive. Since the Laramie Formation contains a number of interbedded sedimentary rock types, these units may exhibit varying degrees of expansion with fluctuating moisture conditions. These conditions create a risk of damage to the homes due to heaving bedrock and heaving bedrock mitigation for the proposed construction should be in accordance with the geotechnical report by AGW. Common mitigation techniques include overexcavation of bedrock, backfill with select material, and control of water away from foundations.
4. Other geologic hazards or constraints, with the exception of abandoned mine subsidence, pose little to no risk which might preclude development. The site is mapped in near proximity to the Virginia Mine, an abandoned inactive coal mine. This report does not include an evaluation of mine subsidence hazard or risk.

1 INTRODUCTION AND PURPOSE

AG Wassenaar, Inc. (AGW) retained Lithos Engineering (Lithos) to provide geological consulting for the proposed Fairview residential construction site, a Richmond Homes development which involves the proposed construction of 37 residential units in Jefferson County, Colorado (County). The purpose of this report is to present geological conditions present at the site and discuss concerns related to geological hazards. AGW is the Geotechnical Engineer of record for this project and will provide a geotechnical report under separate cover in accordance with County requirements.

The site is located within the Designated Dipping Bedrock Area (DDBA) as defined by the County. The DDBA is a zone associated with increased risk of differential heave due to steeply dipping and variably expansive sedimentary bedrock at shallow depths. This report was written in general accordance with the County's Land Development Regulation, Section 25 which includes requirements for geotechnical and geological evaluations for construction.

1.1 Project Site

The project site is shown in Figure 1 and occupies approximately three acres. The site is bounded by South Garrison Street and a car wash to the west and north, respectively. Fields and West Fairview Avenue bound the site to the east and south, respectively. The site is currently undeveloped. The site topography generally slopes downward to the southwest ranging in elevation from approximately 5,676 feet in the northeastern corner and dropping gently to approximately 5,656 feet in the southwestern corner.

2 GEOTECHNICAL INVESTIGATIONS

AGW conducted a subsurface investigation for the site in July 2018. The subsurface investigations included geotechnical drilling and subsequent geotechnical laboratory testing programs as described further in the geotechnical report. The geologic conditions encountered during the investigations are discussed in Section 3.

Five boreholes were drilled by AGW. Borings generally encountered topsoil and clay overlying weathered to intact claystone and/or sandstone bedrock. A summary of geotechnical drilling as encountered by AGW is provided in Table 2.1 below.

Table 2.1 – Geotechnical Drilling

Borehole	Materials [A]	Borehole Elevation (ft [B])	Bedrock [C] Elevation (ft)	Depth to Bedrock (ft)
AGW TB-1	Clay over claystone/sandstone	5662	5655	7
AGW TB-2	Clay over sandstone	5667	5662	5
AGW TB-3	Clay over claystone/sandstone	5658	5753	5
AGW TB-4	Clay over sandstone	5661	5659	2
AGW TB-5	Clay over sandstone	5667	5662	5

[A] Does not include topsoil.
[B] Feet above Mean Sea Level (MSL). Borehole elevations were provided by Aztec Consultants, Inc.
[C] Includes weathered bedrock

3 GEOLOGIC CONDITIONS

Subsurface conditions were determined based on the findings of the geotechnical investigation described in the previous section and from published geologic maps. Boring logs and a supplementary boring log key are provided in AGW's geotechnical report.

3.1 Geologic Setting

The geology in the area is mapped as clay, silt, sand, and gravel of the Pleistocene-aged Slocum and Verdos Alluvium and sandy and silty loess overlying bedrock. Both the Pleistocene-aged alluvium and loess are wide-spread units found on broad slopes regionally sloping eastwards towards river basins. Modern alluvium, generally comprised of silt, sand, and gravel, are found in drainage channels.

The Lower Member of the Laramie Formation underlies much of the site and is described as tan to yellowish orange, sandstone with iron concretions and dinosaur fossils, claystone, and coal. The Upper Member is predominantly claystone and clayey sandstone. Both claystone and coal in the Laramie Formation were historically mined in the Colorado Front Range. The Virginia Mine, located immediately east of the project site and below ground, is an example of historic coal stope mining. While the bedrock units were originally deposited horizontally, the uplift of the Rocky Mountains caused the bedrock units to tilt as much as 50 degrees from horizontal to the east-north-east. A nearby sandstone outcrop has a mapped dip of 54 degrees towards the northeast. The Fox Hills Sandstone is mapped as underlying the southwestern corner of the project site and is described as yellowish-orange, massive to thinly-bedded, cross-bedded, and friable fine-grained sandstone and interbedded, dark, and olive-gray shale and claystone.

The site is an example of a historic fluvial environment adjacent to mountainous terrain in which streams and rivers have incised the Rocky Mountains approximately 4 miles to the west and presently carry sediment towards the eastern plains and eventually the Mississippi River. Additionally, other geomorphological processes have shed materials under the influence of water and gravity which have accumulated at the base of the mountain ranges and have been transported and re-deposited by aeolian processes. The streams have historically meandered and changed course, depositing alluvium in a broad swath in terraces corresponding with historic stream levels and channel locations. In many urban locations, artificial fill has previously been placed on top of the natural soils to accommodate site development.

The figure below shows the mapped geology in the site vicinity.

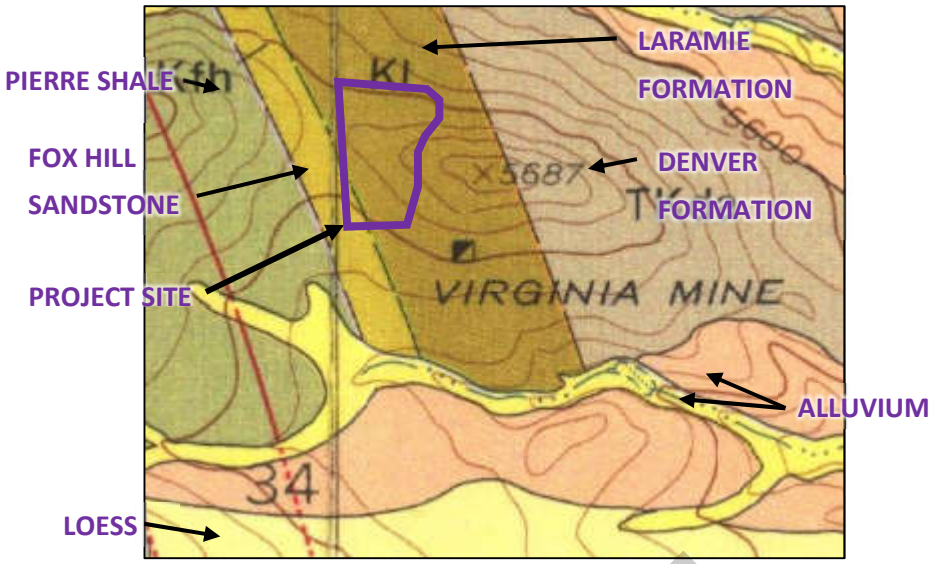


FIGURE 3.1 – Mapped geology in the project vicinity. The project site is mapped as shallow Fox Hills Sandstone (Kfh/Kf) and Laramie Formation (Kl). Thin loess and alluvium deposits are present regionally. Modified from Scott, G.R., 1962.

3.2 Historic Mining and Resources

No documented mining is known to have occurred in the western portion of the site. Maps prepared by the Colorado Geological Survey suggest the eastern portion of the site might be undermined by an inactive and abandoned coal mine, subject to further evaluation and investigation. The Virginia Mine extracted coal from the steeply dipping rock using stope mining. A separate report has been prepared by others evaluating the true extent of the mine as well as the associated subsidence risk.

The thickness of the alluvium and relative percentage of fines within the project boundaries makes the site unlikely to be economical for aggregate mining. Uranium, coal, and clay mineral resources are associated with the Laramie Formation; however, the presence of the mine suggests the resource has been already been mined out. The scope of this report does not include an evaluation of oil and gas potential at depths significantly greater than will be encountered during the proposed construction.

3.3 Surficial Materials

Surficial materials were encountered in all borings measuring from just below topsoil to 7 feet deep, not including weathered bedrock. The material is described by AGW as clay, stiff to very stiff. This material is expected to also contain silt and sand given mapped loess and alluvium nearby and proximity to the Rocky Mountains and a high-energy alluvial environment. Gradations tests were conducted and show a significant fines content of 69% and 99% in two tests. Atterberg limits testing suggests the fines consist of highly plastic lean to fat clay. Under 1,000 psf surcharge loading, one sample swelled as much as 7.5%, suggesting very high swell potential as defined by the Colorado Association of Geotechnical Engineers Guideline, 1996. In our experience, swell potential of surficial materials in this area range from very low to very high.

The suitability of this material for foundations, excavation, shoring, well development, sewer disposal, erodibility, and other residential recommendations related to geology are provided in AGW's report.

3.4 Bedrock

Bedrock was encountered in all boreholes at depths less than 10 feet and as shallow as 2 feet below existing ground surface. AGW classified bedrock as medium stiff to stiff weathered claystone, hard to very hard claystone, hard to very hard sandstone, and hard to very hard interbedded claystone/sandstone with blow counts as high as 50 blows per 1 inch. The claystone within the Laramie Formation is highly erodible, generally present in valleys or slopes rather than ridges, and rarely exposed at the surface outside of man-made cuts and excavations. Sandstone within the Laramie Formation is often more indurated and can form ridges. While bedrock dip wasn't obtained during the investigation, nearby resistant sandstone units exhibit a regional dip of approximately 54 degrees to the northeast. In the area, shale interbeds of the Foxhills Sandstone are known for being highly expansive.

Laboratory testing by AGW encountered a range of swell percentages of the bedrock from 1.1 – 4.9% under applied pressure. The unit is observed elsewhere to be interbedded with claystone, shale, limestone, coal, and sandstone. Sandstone and limestone tend to resist swelling, but claystone and shale are susceptible to expansion with changes in moisture content. As identified by Noe (1995), the Lower Member of the Laramie Formation has a major component of low- to non-swelling bedrock and only a minor component of moderate to very high swell claystone. Both the Fox Hills Sandstone and Laramie Formation exhibit overall low to moderate swell potential. However, significant claystone was encountered during the investigation and will be encountered during construction. The claystone layers, ranging from inches to several feet thick can be extremely expansive resulting in severe differential movement related to adjacent, non-swelling layers.

3.5 Groundwater

Groundwater in the region is heavily influenced by the Rocky Mountains to the west. Groundwater generally flows west to east from the high-elevation mountains. The historically meandering and avulsing easterly-flowing rivers, now channelized, have significant influence on the local groundwater levels and hydrogeology. The Denver area has semi-confined, unconfined, and perched aquifers within surficial sediments; however, none were encountered at the site. Groundwater was encountered and measured after drilling in confined aquifers. The Fox Hills Sandstone and Laramie Formation are known aquifers. A summary of groundwater depths is provided in the table below.

Table 3.1 – Groundwater Depths

Borehole	Borehole Elevation (ft)	Total Borehole Depth (ft)	Depth to Groundwater (ft)
AGW TB-1	5662	25	DNE
AGW TB-2	5667	30	DNE
AGW TB-3	5658	34	25
AGW TB-4	5661	24	DNE
AGW TB-5	5667	29	DNE

DNE: Did Not Encounter

4 GEOLOGIC HAZARDS

4.1 Negligible to Low-Risk Hazards

Lithos has reviewed the site for geologic hazards and considers the following hazards at the project site as nonapplicable or of extremely low risk based on published geologic hazard maps (primarily a series of USGS maps by Glen R. Scott in 1972 in adjacent quads with similar rock types), conventional site characterization, pre- and post-site topography, and our local experience:

- Collapsible soils;
- Landslides;
- Flooding;
- Radioactivity;
- Seismic liquefaction; and
- Natural subsidence.

There is a risk for radon gas to accumulate in poorly-ventilated sub-grade spaces. Measurable radon gas is common in the soils and sedimentary rocks underlying the project site and is usually only detected after construction. Typical mitigation methods consist of implementing additional barriers at soil gas entry areas and installing adequate ventilation in below-grade spaces and perimeter drain systems. Lithos recommends for the construction to include mitigation alternatives for radon in all structures that have habitable, below-grade spaces.

Liquefaction and other seismic-related risks are negligible for the site. Based on Lithos' experience with sites of similar surficial materials, thicknesses, and bedrock, the project site will likely meet the criteria for an International Building Code (IBC) Site Class C according to the 2012 IBC classification (Table 1613.5.2). This is based on the available geotechnical drilling encountering shallow moderately dense overburden soils less than 10 feet thick overlying soft to hard bedrock extending to depths at least 100 feet below finished grade. Seismic shear wave velocity testing was not performed as part of this scope.

As previously mentioned, a separate evaluation has been conducted for abandoned mine subsidence hazard associated with the inactive, abandoned Virginia Coal Mine immediately east of the site. Lithos' scope of work does not include an evaluation of risks related to the presence of the mine.

Each of the hazards mentioned above can be mitigated with proper planning, engineering, design, and construction and should not prohibit construction at the site.

4.2 Heaving Bedrock and Swelling Soils

The project site is susceptible to risks associated with heaving bedrock and swelling soils (Scott, G.R., 1972, and Noe, 1995). The site is within the DDBA and the subsurface investigation encountered steeply-dipping bedrock at shallow depths less than 10 feet throughout the site. Claystone units within the Lower Member of the Laramie Formation and thin shale units within the Fox Hills Sandstone are commonly expansive along the Front Range. Dipping bedrock layers can swell differentially if exposed to moisture, creating heave ridges at the surface parallel to the bedrock strike which can damage overlying infrastructure. While Noe considers the risk associated with these geologic units as low to moderate, borings encountered significant claystone with variable Atterberg limits and swell characteristics. Laboratory testing encountered high plasticity lean to fat clays with highly variable swell percentages representing low to high swell potential risk affecting conventional foundations. Laboratory testing of the

soil yielded high plasticity samples categorized as having low to very high swell risk, which is confirmed by local experience.

A preliminary visual survey of the streets immediately surrounding the area produced no confirmable visual signs of heaving bedrock; however, excavation for home construction, the presence of a foundation, and introduction of moisture for landscaping could contribute to the heaving bedrock risk. Standard practice to mitigate heaving bedrock risk is to over-excavate expansive bedrock and backfill the space between bedrock and foundation elements with specially selected, compacted soil to the required subgrade elevations. AGW's geotechnical engineering report includes recommendations and construction criteria detailing expansive soil and heaving bedrock mitigation for the proposed development.

5 LIMITATIONS

Lithos Engineering did not provide geotechnical design recommendations for the subject project. AGW will be the Geotechnical Engineer of Record for the project and is responsible for providing geotechnical design recommendations and construction criteria in general accordance with accepted geotechnical engineering practices in the area and in accordance with the DDBA guidelines outlined by the County.

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principles; no warranty, expressed or implied is made. The subsurface conditions described in this report were based on data obtained from widely spaced exploratory borings, geotechnical laboratory testing, information provided by the Client, engineering judgement, and our experience with similar subsurface conditions and projects. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types presented in this report are approximate and, in some cases, may be more abrupt or gradational than described herein. Groundwater levels may vary with time, adjacent water source levels, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

This report has been prepared exclusively for our client for informational purposes for the subject project. Lithos Engineering is not responsible for technical interpretations by others of the geologic conditions presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, Lithos Engineering should be notified immediately to determine if any changes to our characterizations presented in this report are warranted.

The geologic conditions presented in this report are only intended as an aid for the proposed design and construction as understood by Lithos Engineering at the time of issuing this report. If the proposed design and construction changes, Lithos Engineering should be notified immediately and given the opportunity to review the proposed changes and, if necessary, modify our geologic review presented herein.

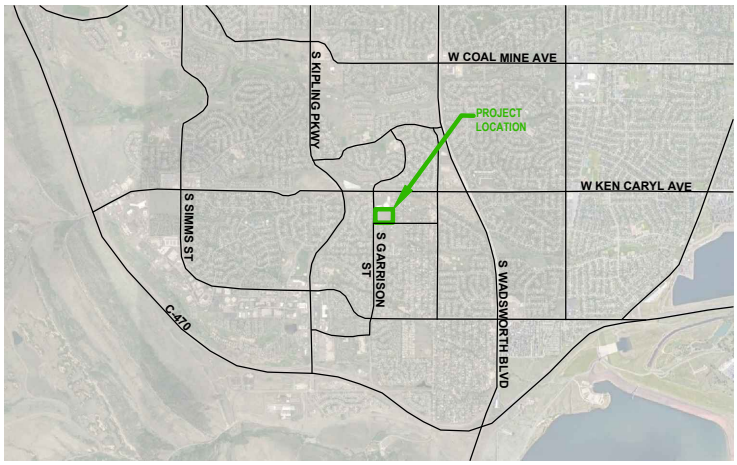
An environmental assessment and an underground mine subsidence evaluation were not included in the Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein, or related to mine subsidence hazards/risks, are only intended for informational purposes. If the client is concerned about the environmental conditions or mine subsidence hazard at the site, Lithos Engineering recommends the client and/or owner retain a

qualified firm(s) to conduct an environmental site assessment and a coal mine subsidence evaluation as appropriate.

REFERENCES

- Colorado Association of Geotechnical Engineers, 1996, "Guideline for Slab Performance Risk Evaluation and Residential Basement Floor System Recommendations (Denver Metropolitan Area)," Professional Practice Committee, Denver, Colorado.
- Das, Braja M, 2014, Principles of Foundation Engineering, 8th Edition
- Jefferson County, Land Development Regulation Section 25 – Amended 10-25-05, Golden, Colorado
- Noe, D.C., and Dodson, M.D., 1995, "Dipping bedrock overlay district: preliminary map of an area of potential heaving bedrock hazards associated with expansive, steeply dipping bedrock in Douglas County, Colorado:" Colorado Geological Survey, Open-File Report OF-95-5, scale 1:50,000.
- Scott, G.R., 1962, "Geologic Map of the Littleton Quadrangle," Jefferson, Douglas, and Arapahoe Counties, Colorado: U.S. Geological Survey, National Geologic Map Database, scale 1:24,000.

FIGURES



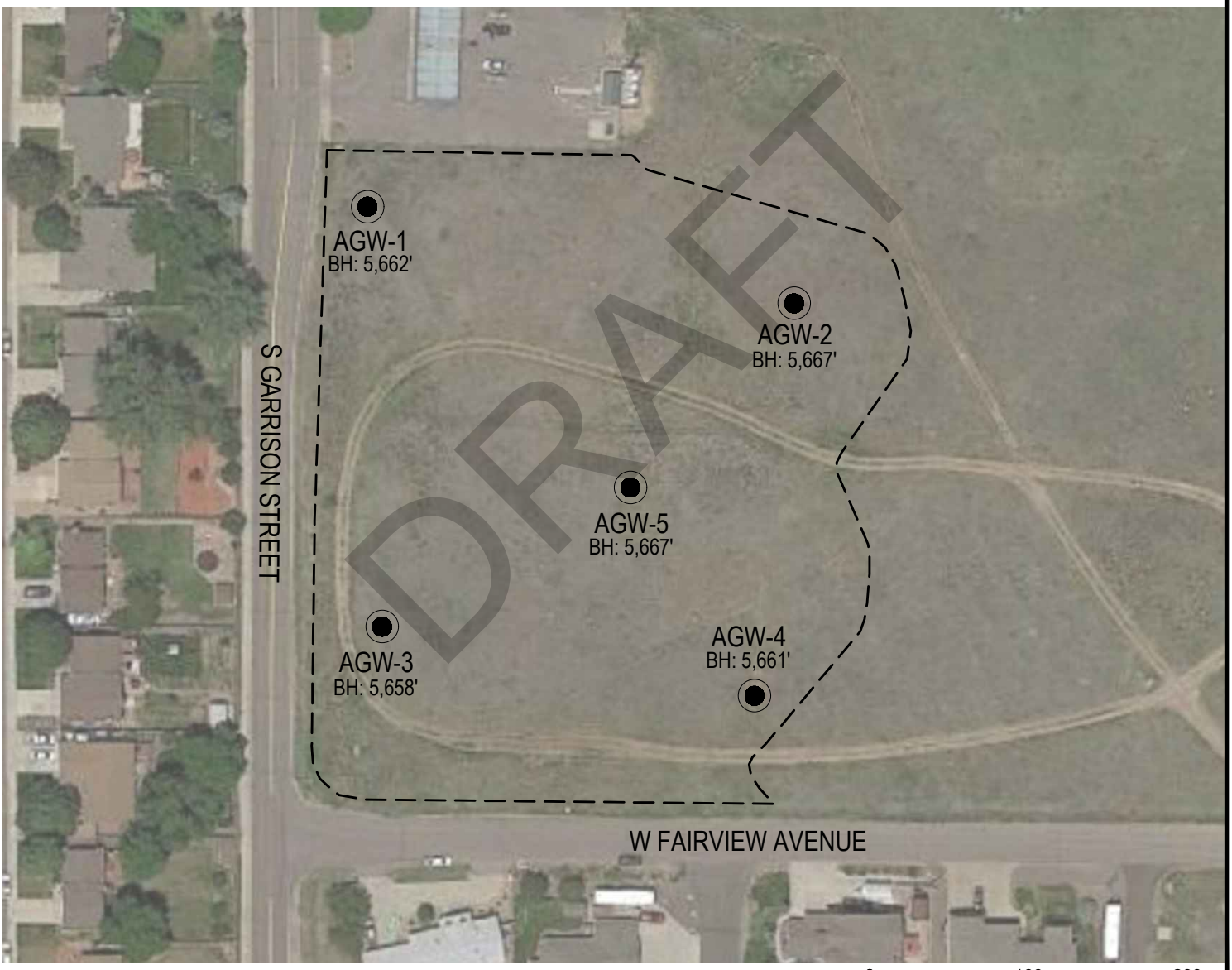
SITE VICINITY MAP

LEGEND:

- ◉ APPROXIMATE BORING LOCATION
- ----- SITE BOUNDARY

GENERAL NOTES:

1. BOREHOLES WERE STAKED AND SURVEYED BY OTHERS
2. BH = BOREHOLE ELEVATION IN FEET ABOVE MSL



BORING LOCATION MAP

0 100 200
Scale is in feet

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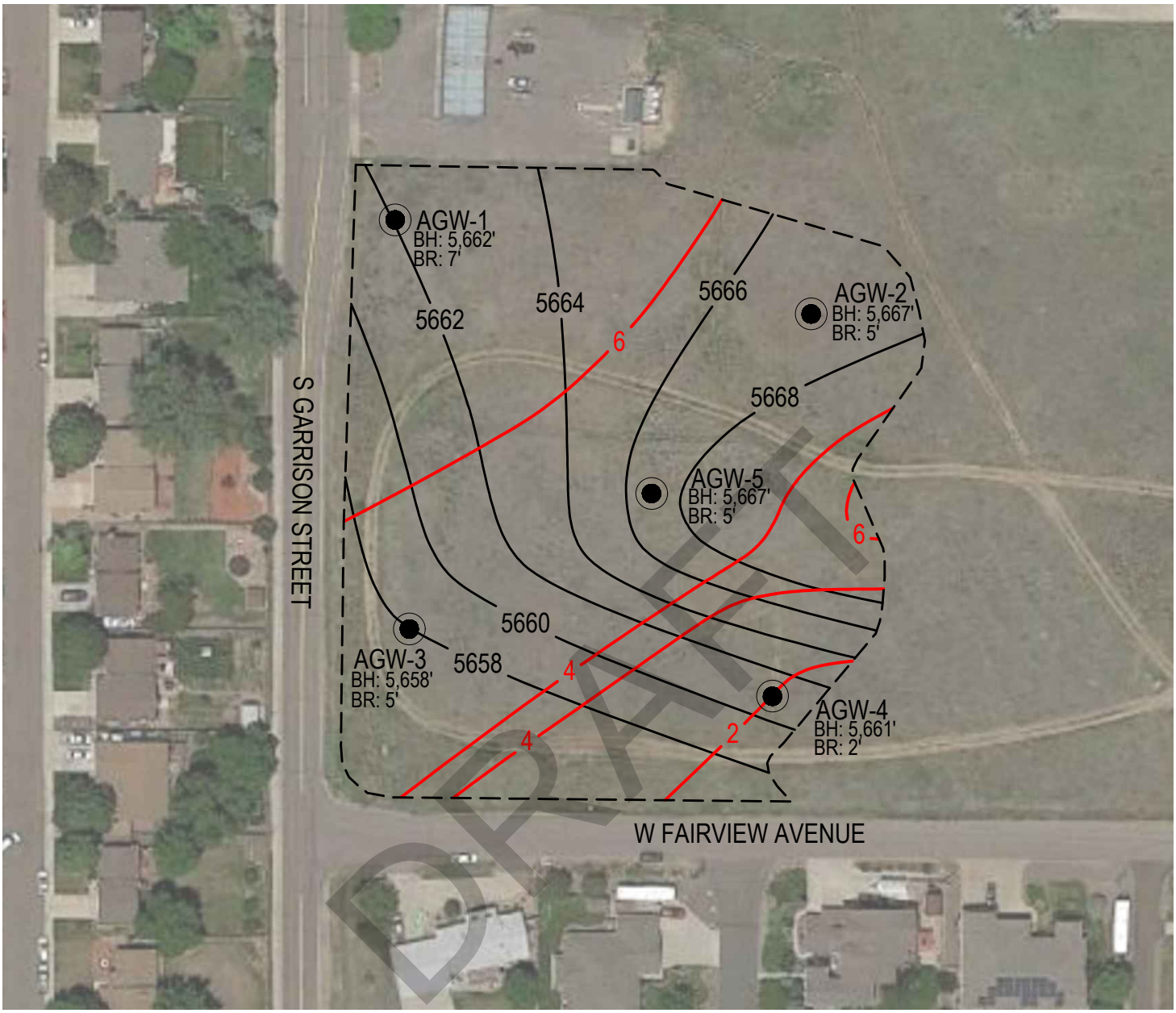
LAKEWOOD, COLORADO 80232
303-625-9502

PROJECT TITLE	FAIRVIEW GEOLOGIC REPORT	OWNER: RICHMOND AMERICAN HOMES	CLIENT: A.G. WASSENAAR INC.		FIGURE NUMBER
DRAWING TITLE	SITE VICINITY AND BORING LOCATION MAP	PROJECT NO.: 18059	DRAWN BY: AM		1
		LOCATION: Jefferson County, CO	DESIGNED BY: AM		
		DATE: July 31, 2018	CHECKED BY: RM		



LEGEND:

- APPROXIMATE BORING LOCATION
- SITE BOUNDARY
- BEDROCK ELEVATION CONTOUR (FEET)
- SURFICIAL SOILS ISOPACH CONTOUR (FEET)

GENERAL NOTES:

1. BOREHOLES WERE STAKED AND SURVEYED BY OTHERS
2. BH = BOREHOLE ELEVATION IN FEET ABOVE MSL
3. BR = DEPTH TO BEDROCK IN FEET

0 100 200
Scale is in feet

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PROJECT TITLE	FAIRVIEW GEOLOGIC REPORT	OWNER: RICHMOND AMERICAN HOMES	CLIENT: A.G. WASSENAAR INC.		FIGURE NUMBER
DRAWING TITLE	BEDROCK ELEVATION AND SURFICIAL SOILS ISOPACH MAP	PROJECT NO.: 18059	DRAWN BY: AM		2
		LOCATION: Jefferson County, CO	DESIGNED BY: AM		
		DATE: July 31, 2018	CHECKED BY: RM		