ATLAS
GEOTECHNICAL

101 Cooper Street
Santa Cruz, CA 95060

24 March 2016

Todd Georgopapadakos
KeikilaniHomes
421 Maono Loop
Honolulu, Hawaii, 96821

via email:
todd@dephawaii.com

Re: Rockfall Protection System Conformance - Revised
5023 KeikilaniCircle
Honolulu, Oahu, Hawaii
TMK 3-6-023:006

Ref: Atlas Geotechnical, 28 April 2015, "Rockfall Hazard Assessment and Mitigation, 5023 KeikilaniCircle, Honolulu, Oahu, Hawaii, TMK 3-6-023:006."

J.A. Schmit Architect, 28 February 2016, Sheet C001 of "Keikilani Homes New House."

J.A. Schmit Architect, 9 February 2016, Sheet C002 of "Keikilani Homes New House."

Dear Todd,

The rockfall barrier design on Drawings C001 and C002 cited above conforms to (in fact, consists of) the rockfall barrier design included in Atlas Geotechnical's 28 April 2015 rockfall hazard assessment and mitigation letter, also cited above.

Please call me at 808-282-8314 if you have any questions or if we can be of further assistance.

Yours sincerely,

Douglas R. Schwarm, P.E.
Chief Engineer

This work was prepared by me or under my supervision.

DOUGLAS R. SCHWARM
LICENSED PROFESSIONAL ENGINEER
No. 10642-C
HAWAII, U.S.A.

License expires 30 April 2018

ATLAS GEOTECHNICAL
101 Cooper Street
Santa Cruz, CA 95060

28 April 2015

Todd Georgopapadakos
Keikilani Homes
421 Maono Loop
Honolulu, Hawaii, 96821

via email:
todd@dephawaii.com

Re: Rockfall Hazard Assessment and Mitigation
5023 Keikilani Circle
Honolulu, Oahu, Hawaii
TMK 3-6-023:006

Dear Todd,

This letter summarizes a rockfall hazard assessment and mitigation design for the planned new residence at 5023 Keikilani Circle [1]. Prior work at the site includes a rockfall risk assessment for a cluster housing development that was not built [2], a geotechnical engineering investigation that I performed for that cluster housing development [3], and a geotechnical engineering investigation performed before my involvement with this site [4].

Development plans for this site have changed significantly over the past 15 years while the rockfall hazard remains largely the same. This letter adapts the available geologic and geotechnical data to the present single-family residence project.

Site Description

The site is in the Wailupe neighborhood of Honolulu, Oahu, Hawaii. Figure 1 shows the site location relative to topographic features. The majority of the site is undeveloped, steeply to moderately sloping, and rocky. Site grades extend from near 40 feet at Keikilani Circle up to 280 feet, with a graded access road crossing from the end of Kiai Place near elevation 110 to 115 feet. Figure 2 shows the planned driveway alignment and house location relative to present topography.

Surface conditions at the time of my site reconnaissance consisted of chest-high kiawe and halekoa trees with dense grasses. Basalt boulders are sparsely distributed across the graded and gently sloping parts of the site. Numerous basalt outcrops create the steeper faces above the graded terrace.

Slope StabilityHazard

The site is underlain principally by fresh to slightly weathered, moderately fractured, basalt bedrock. Soils on the site are either thin natural deposits or a graded roadway embankment. The pahoehoe flow deposits typically dip out of slope at 6 to 10 degrees. The natural outcrops and cut face exposures did not show evidence of interflow soil layers. We observed no evidence of slope instability.

Based on our observations, we conclude that the site has low risk of slope instability. The planned grading will cut into basalt materials, so the final condition should also have low slope instability hazard.

Debris Flow Hazard

Near-surface materials at the site are either fine-grained soils or blocky rock. The site is not susceptible to debris flow.

Rockfall Hazard

The lower part of the parcel has loose boulders typically between 1.5 and 3.0 feet nominal diameter that appear to correlate with exposed basalt outcrops in the higher elevations. We observed evidence of moderate rockfall activity that includes:

1. The boulder slope near and parallel to the south boundary (above the existing houses on Keikilani Circle) appears to be deliberately constructed, probably as a boneyard from previous grading.
2. We observed a boulder in the back yard of the residence on Lot 84.
3. Three boulders were observed against the drainage wall at the back of Lot 83.
4. Abundant free-field boulders were observed on ground surfaces that were otherwise smooth.

The boulder source zones are three or more terraces located above the elevation of the proposed construction (Figure 2). The source materials are generally erosion-resistant basalt flow layers that have formed near-vertical bluffs 12 to 20 feet high. We did not observe any boulders that appeared imminently unstable. We did observe one very large boulder that appeared to be loose on the grade, though flat topography immediately adjacent to the rock limits its mobility.

Figure 3 shows a typical cross-section through the planned residence. The building configuration exposes both the rear wall and the roof to likely rockfall paths. A barrier upslope of the building pad is the preferred rockfall mitigation measure in these situations.

Conclusions and Recommendations

It is our opinion that the site is suitable for the proposed residential development provided the project includes adequate rockfall risk mitigation measures. Specifically:

1. We found no evidence that debris flows or deep-seated slope instability hazards affect the site.
2. The site has moderate rockfall activity.
   - 2.1. Risk mitigation is required at the planned residence because it is downslope from at least one active rockfall source.
   - 2.2. The rockfall energy is high enough that defensive architecture and impact-resistant structure are probably not efficient, especially for the roof.
   - 2.3. The hazard is not severe enough to require protection of the access driveway. Unoccupied buildings or infrastructure have low rockfall risk.
3. We recommend that mitigation consist of a pre-engineered impact barrier between the rockfall source(s) and the planned house. Table 1 summarizes the recommended barrier parameters, which include:
   - 3.1. Considering the relatively small scale of the development, we recommend that the fence be continuous across the top of the development.
   - 3.2. Figure 2 shows a conceptual barrier alignment; we recommend that the installation contractor adjust as necessary to suit observed site conditions.
   - 3.3. The maximum likely impact energy at the barrier is 350 kJ. Typical pre-engineered barriers are rated for 100 or 500 kJ, so we recommend the larger barrier system. Geobrugg's GBE-500A is one suitable barrier for this application.
   - 3.4. We recommend that the barrier be at least 10 feet tall, nominally. The support posts need not be vertical, but the finished barrier height should rise at least 8 feet above the ground surface.

Table 1 – Recommended Rockfall Barrier

Item		Value
Rockfall Barrier Rated Energy	Minimum	350 kJ
	Design	500 kJ
Rockfall Barrier Length		185 feet
Rockfall Barrier Height		10 feet
		3 m

References

1. J.A. Schmit Architect, 10 April 2015, Drawings titled: "Keikilani Homes, New House, 5023 Keikilani Cir, Honolulu, Hawaii, 96707, TMK: 3-6-023:006."
2. Malama Civil Engineering, 10 October 2005, "Revised Slope Stability and Rockfall Hazard Assessment, 5084 Kiai Place and 5023 Keikilani Circle, Wailupe, Oahu, Hawaii, TMK's 3-6-023:006 and 3-6-023:007, File No. 2005/SUB 135."
3. Malama Civil Engineering, 13 March 2006, "Geotechnical Engineering Report, Wailupe Mauka Cluster Development, Wailupe, Oahu, Hawaii, TMK 3-6-023:006."
4. Ernest K. Hirata & Associates, Inc., 23 May 2001, "Soils Investigation, Wailupe Cluster Development, Wailupe, Oahu, Hawaii, TMK: 3-6-23: 6."

Limitations

We prepared this design for use by Keikilani Homes, J.A. Schmit Architect, and the engineers and contractors working on the New Home project. This report does not pertain to any other site, any topic besides the geologic hazards explicitly addressed, or any planned construction other than that described herein. Do not use this report in ways that it is not intended.

Atlas Geotechnical is not providing geotechnical engineering services related to grading, foundation support, or retaining walls on this project. The project geotechnical engineer should not rely on the geotechnical engineering recommendations in this report or in the reference reports that we cited. Contact Atlas Geotechnical if you have any questions about the proper use of factual data developed by prior investigations of this site.

Within the limitations of scope, schedule, and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical and barrier engineering in Hawaii at the time this report was prepared. No warranty or other condition, neither express nor implied, should be inferred from any of the discussion, conclusions, or recommendations provided in this report.

Please call me at 808-282-8314 if you have any questions or if we can be of further assistance.

Yours sincerely,

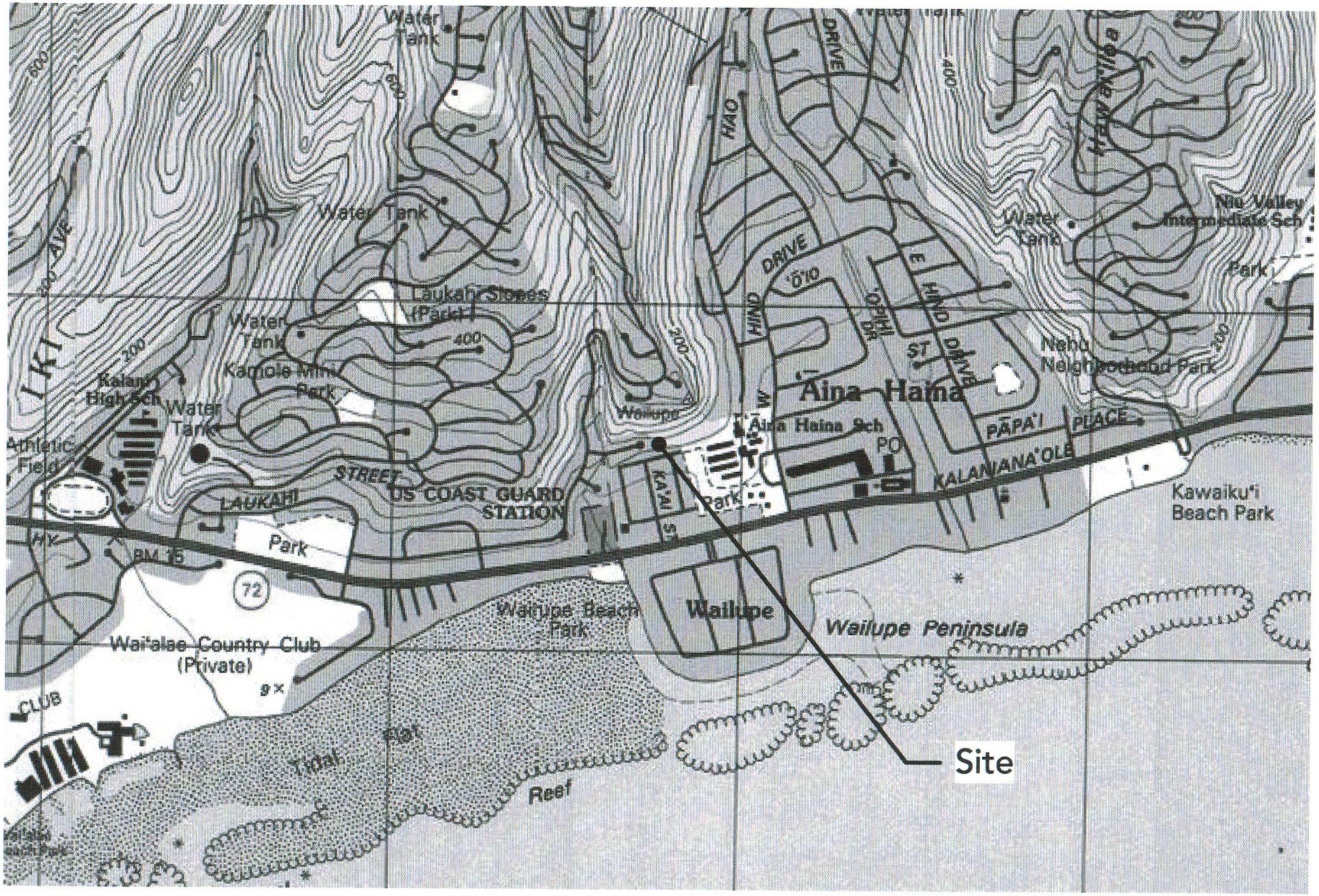
Douglas R. Schwarm, P.E.
Chief Engineer

This work was prepared by me or under my supervision

DOUGLAS R. SCHWARM
LICENSED PROFESSIONAL ENGINEER
No. 10642-C
HAWAII, U.S.A.

License expires 30 April 2016

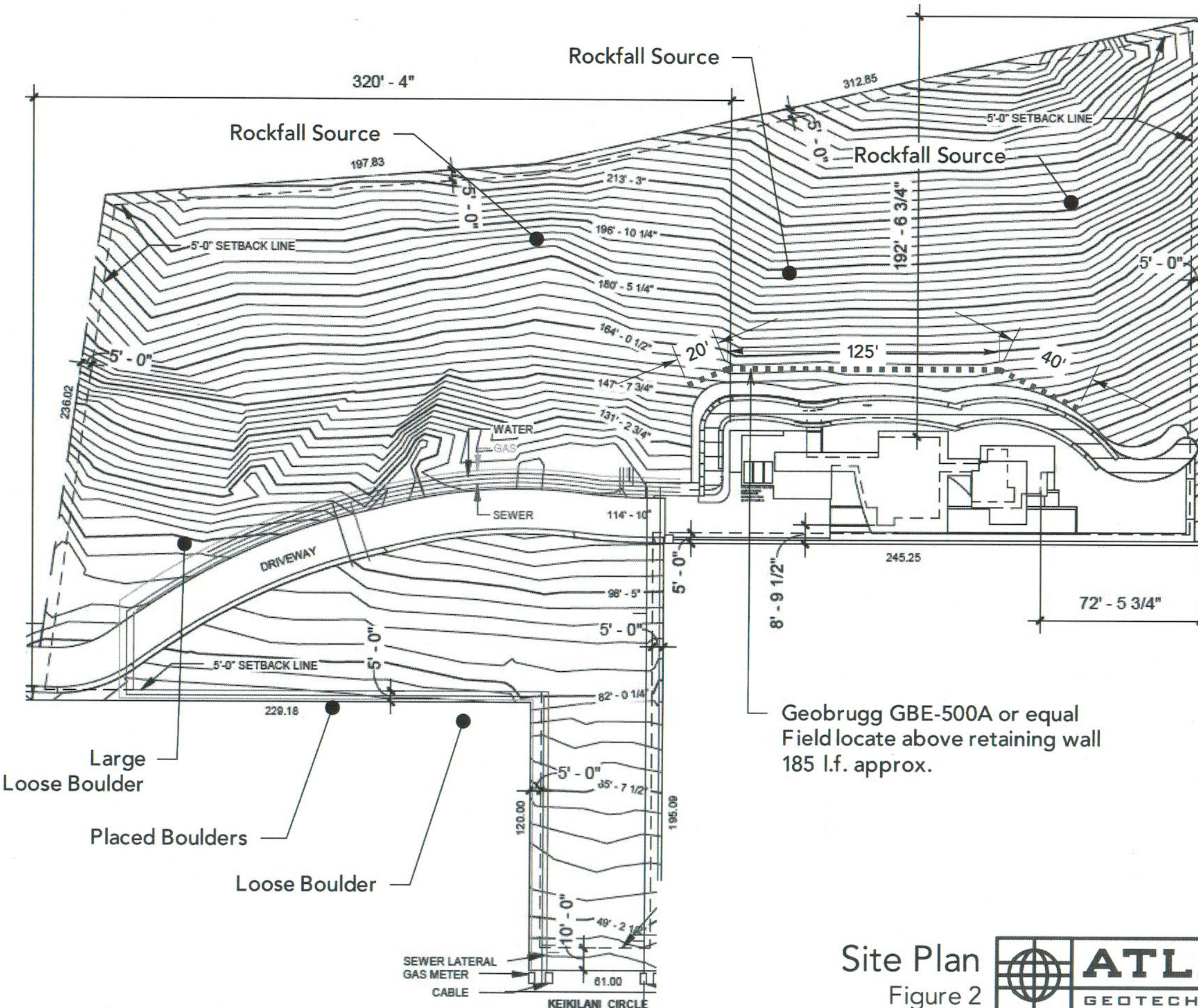
Attachments:
- Figure 1 – Vicinity Map
- Figure 2 – Site Plan
- Figure 3 – Typical Section



Vicinity Map

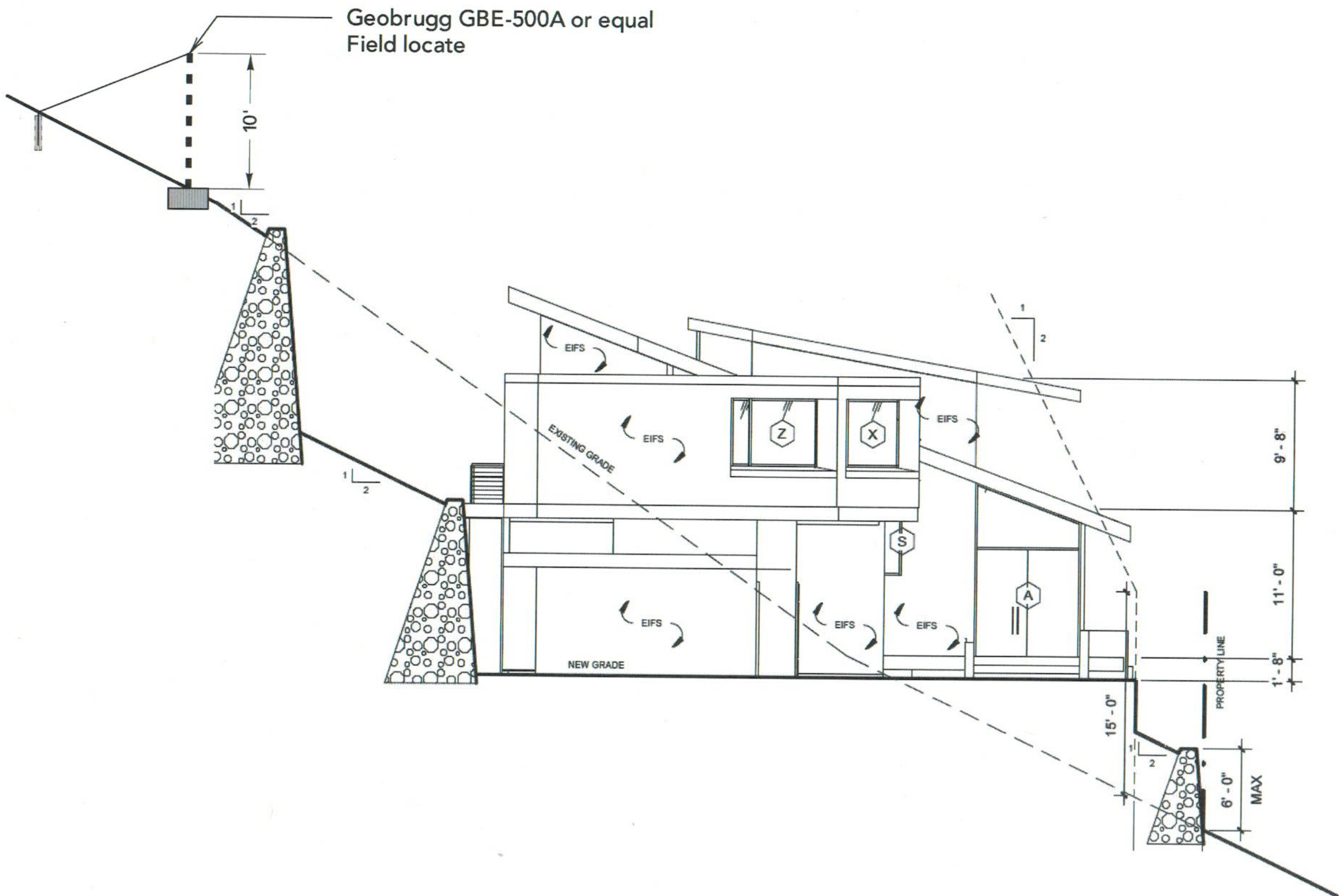
Figure 1

ATLAS GEOTECHNICAL



Site Plan
Figure 2

ATLAS GEOTECHNICAL



Typical Section
Figure 3

ATLAS GEOTECHNICAL