WELL LOG REPORT
REHAU MONTANA ECOSMART HOUSE PROJECT
HOY RESIDENCE
MONTANA STATE UNIVERSITY

Well borings for geothermal sensors were place east of the Hoy residence near the Hoy property line and Bridger Golf Course (figures A, B and C). The geothermal probes are part of a research project led by the Creative Research Lab and Mechanical Engineering Department at Montana State University (MSU).

Drilling was done by Bridger Drilling, Inc. Bore holes 1 through 4 are approximately 6.5 inches (in) in diameter and 300 plus feet (ft) deep. They are spaced approximately 19 ft apart. Drilling was done with a tricone bit using a Mudslayer 750 for recovery of the drilling mud. Helical holes 10 through 12 are approximately 18 inches in diameter and 30 ft deep. They are spaced approximately 11 ft apart. Drilling was done with an auger.

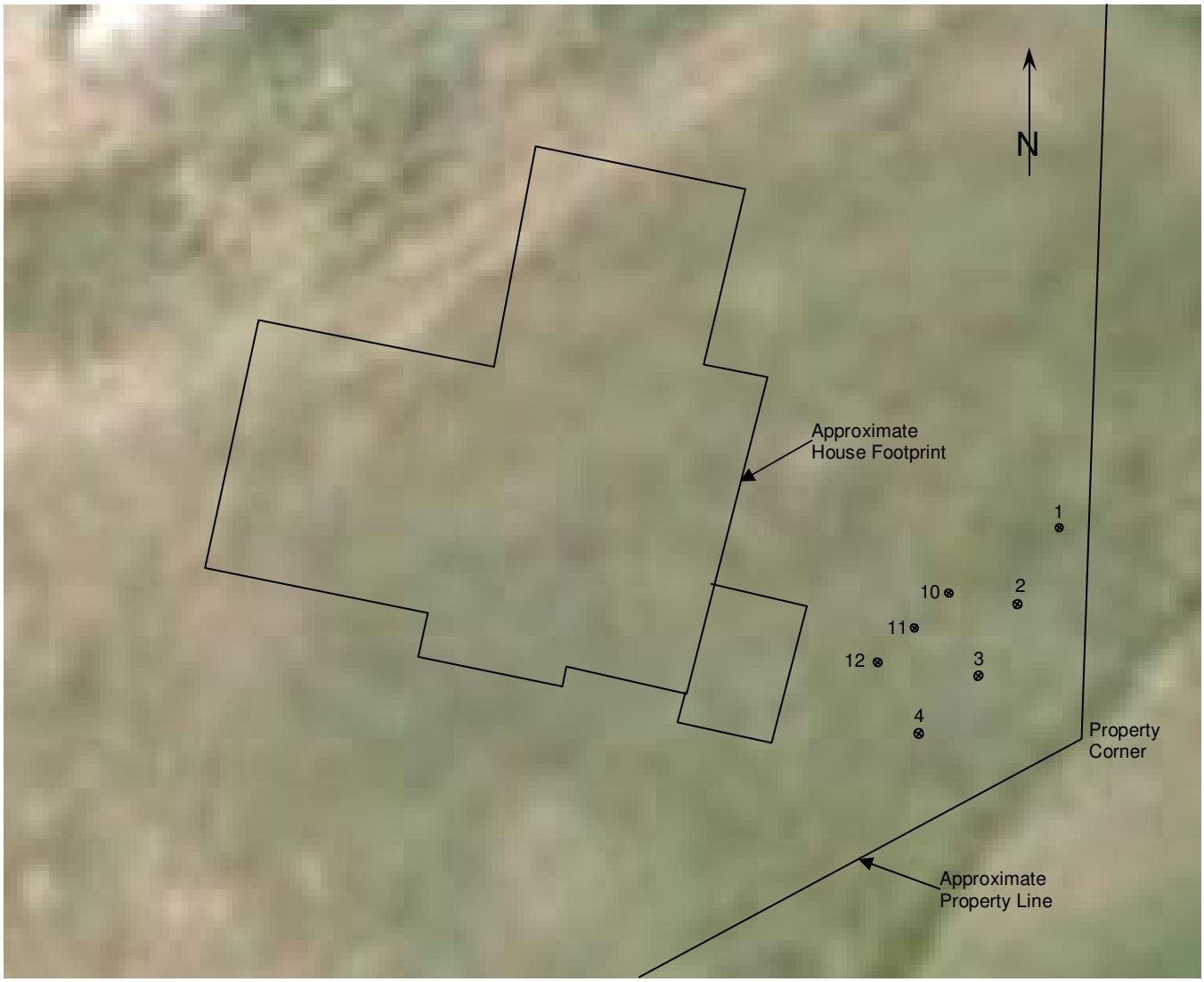
The tricone bit of the boring operation grinds the gravel size particles to very fine gravel or sand size material. The recycling operation recycles any materials smaller than 0.02 millimeters (mm) with the drilling mud. Most clay particles are less than 0.005 mm (Table 1). Therefore most of the gravel and clay particles were lost in the bore hole samples. The auger used in the helical operation yields a disturbed sample but almost all of the particles sizes are captured.

Classification was done on samples from bore hole No. 3 and helical hole No. 12. Samples were classified according to the Unified Soil Classification System (USCS) following the procedures as shown in USDA Natural Resources Conservation Service, Engineering Field Manual Chapter 4. Elementary Soil Engineering Pages 4-28 and MT-ENG-211 Rev, 12/02. A summary of the field classifications are shown in tables 2 and 3.

A comparison of MSU and Bridger Drilling field classifications are shown in table 4. As noted earlier the differences in the soil classifications are due to the drilling operation. MSU's field classification of helical hole 12 as a moderately plastic and sticky clay (CL) and Bridger Drilling's classification of bore hole 3 as a Sticky clay brown are consistent.

Photos of samples classified are attached. Plate with sample depth shown is field sample after drying and removal of a portion for classifying. Last bore hole photo shows all the field samples after drying and before separating for classifying. Helical hole photos show separated sample for classifying and settling time test.

FIGURE A
GENERAL LOCATION MAP
REHAU MONTANA ECOSMART HOUSE PROJECT
HOY RESIDENCE
MONTANA STATE UNIVERSITY
N.T.S.



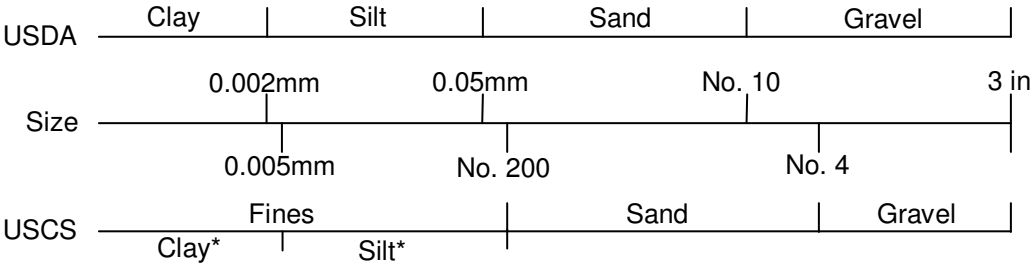
BORE HOLES are Nos. 1-4
HELICAL HOLES are Nos. 10-12

FIGURE B
WELL LOCATION MAP
REHAU MONTANA ECOSMART HOUSE PROJECT
HOY RESIDENCE
MONTANA STATE UNIVERSITY
N.T.S.

FIGURE C
WELL LOCATIONS FROM HOUSE

TABLE 1

Relationship between particle size and the USDA textural soil classes (USDA) and the Unified Soil Classification System (USCS)



*NOTE: In the USCS Silts and Clays are classified by Liquid Limit and Plasticity Index. Size break shown is only approximate.

TABLE 2
SUMMARY of FIELD CLASSIFICATION (USCS)
BORE HOLE 3

Sample No.	Depth ft	< 200 Fines %	200 – 4 Sand %	> 4 Gravel %	Dilatency	Toughness	Dry Strength	Ribbon	Liquid Limit	Stickiness	Group Symbol	REMARKS
1	0-10	10	90	0	Slight	Medium	High	Medium	Mod Fast	Medium	SP-SC	Poorly Graded sand with clay. Only a trace of gravel and coarse sand.
2	20	25	75	0	None	Medium	High	Medium	Mod Fast	Medium	SC	Clayey sand. Only a trace of gravel and coarse sand.
3	30-35	20	70	10	None	Medium	High	Medium	Mod Fast	Medium	SC	Clayey sand
4	50-55	0	95	5	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines
5	60	0	95	5	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines
6	90-108	0	95	5	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines
7	108-160	0	95	5	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines
8	160-172	5	95	0	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine
9	172-200	5	95	0	NA	NA	NA	NA	NA	NA	SW	Well graded sand
10	200-204	0	100	0	NA	NA	NA	NA	NA	NA	SW	Well graded sand. Trace of fines
11	204-223	0	100	0	NA	NA	NA	NA	NA	NA	SW	Well graded sand. Trace of fines

Sample No.	Depth ft	< 200 Fines %	200 – 4 Sand %	> 4 Gravel %	Dilatency	Toughness	Dry Strength	Ribbon	Liquid Limit	Stickiness	Group Symbol	REMARKS
12	223-241	5	95	0	NA	NA	NA	NA	NA	NA	SW	Well graded sand
13	241-263	0	100	0	NA	NA	NA	NA	NA	NA	SW	Well graded sand. Trace of fines
14	263-292	0	100	0	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines
15	292-311	0	100	0	NA	NA	NA	NA	NA	NA	SP	Poorly graded sand. Most sand is medium to fine. Trace of fines

Note: Samples 1-3 were taken from overflow from top of bore hole. Allot of fines remained in drilling mud and are not included in samples. All medium and coarse gravels were ground down by the drilling operation.
Samples 4-15 were taken from discharge of the drilling mud cleaning and recycling system. Most all clay fines remain in the drilling mud and are not included in samples. All medium and coarse gravels were ground down by the drilling operation.

TABLE 3
SUMMARY of FIELD CLASSIFICATION (USCS)
HELICAL HOLE 12

Sample No.	Depth ft	< 200 Fines %	200 – 4 Sand %	> 4 Gravel %	Dilatency	Toughness	Dry Strength	Ribbon	Liquid Limit	Stickiness	Group Symbol	REMARKS
16	0-15 (8)	85	15	0	None	High	High	Medium	Moderate	Medium	CL	Lean Clay with sand. Liquid Limit >35 and <45. Most of sample took > 30 sec to settle out in jar of water.

TABLE 4
COMPARISON MSU LOGS to BRIDGER DRILLING LOGS

MSU LOG	DEPTH (ft)		BRIDGER DRILLING LOG
Poorly graded sand with clay. Only a trace of gravel and coarse sand.	0-10	0-24	sticky clay brown
Clayey sand. Only a trace of gravel and coarse sand.	20	24-29	gravel clay mix
		29-34	sandy clay brown
Clayey sand	30-35	34-41	gravel clay mix
		41-48	brown clay
Poorly graded sand. Most sand is medium to fine. Trace of fines	50-55	48-59-	gravel clay mix
Poorly graded sand. Most sand is medium to fine. Trace of fines	60	59-85	gravel and sand
Poorly graded sand. Most sand is medium to fine. Trace of fines	90-108	85-108	clay and gravel
Poorly graded sand. Most sand is medium to fine. Trace of fines	108-160		sand and gravel
Poorly graded sand. Most sand is medium to fine	160-172		clay and gravel layers
Well graded sand	172-200		clay with sandy clay stringers
Well graded sand. Trace of fines	200-204		clay brown and sandy
Well graded sand. Trace of fines	204-223		sandy brown clay
Well graded sand	223-241		sand and gravel
Well graded sand. Trace of fines	241-263		sandy brown clay
Poorly graded sand. Most sand is medium to fine. Trace of fines	263-292		brown clay and sandy stringers
Poorly graded sand. Most sand is medium to fine. Trace of fines	292-311		large gravel and sand stratified with brown sandy clay layers

NOTE: Differences in MSU and BRIDGER DRILLING Logs are due to the drilling operation grinding gravels down to sand and the drilling mud recovery system allowing most of the clays to remain with the drilling mud.

BORE HOLE SAMPLE PHOTOS

Sample #1 0-10 feet

Sample #2 20 feet

Sample #3 30-35 feet

Sample #4 50-55 feet

Sample #5 90-108 feet

Sample #6 60 feet

BORE HOLE SAMPLE PHOTOS

Sample #7 108-160 feet

Sample #8 160-172 feet

Sample #9 172-200 feet

Sample #10 200-204feet

Sample #11 204-223 feet

Sample #12 223-241 feet

BORE HOLE SAMPLE PHOTOS

Sample #13 241-263 feet

Sample #14 263-292 feet

Sample #15 292-311 feet

Bore hole fields samples after drying
before separating for classification

HELICAL HOLE SAMPLE PHOTOS
8 feet

Separated for classification

Settling time