Առանձնացված հավելված 6 Երկրաբանական հետազոտության հաշվետվություն

LANDSLIDE DISASTER MANAGEMENT PROJECT IN THE REPUBLIC OF ARMENIA

Studies of Landslide Sites at the Arapi Community, Shirak Marz of RA and at the Getahovit Community Tavoush Marz of RA

Yerevan 2015

Content

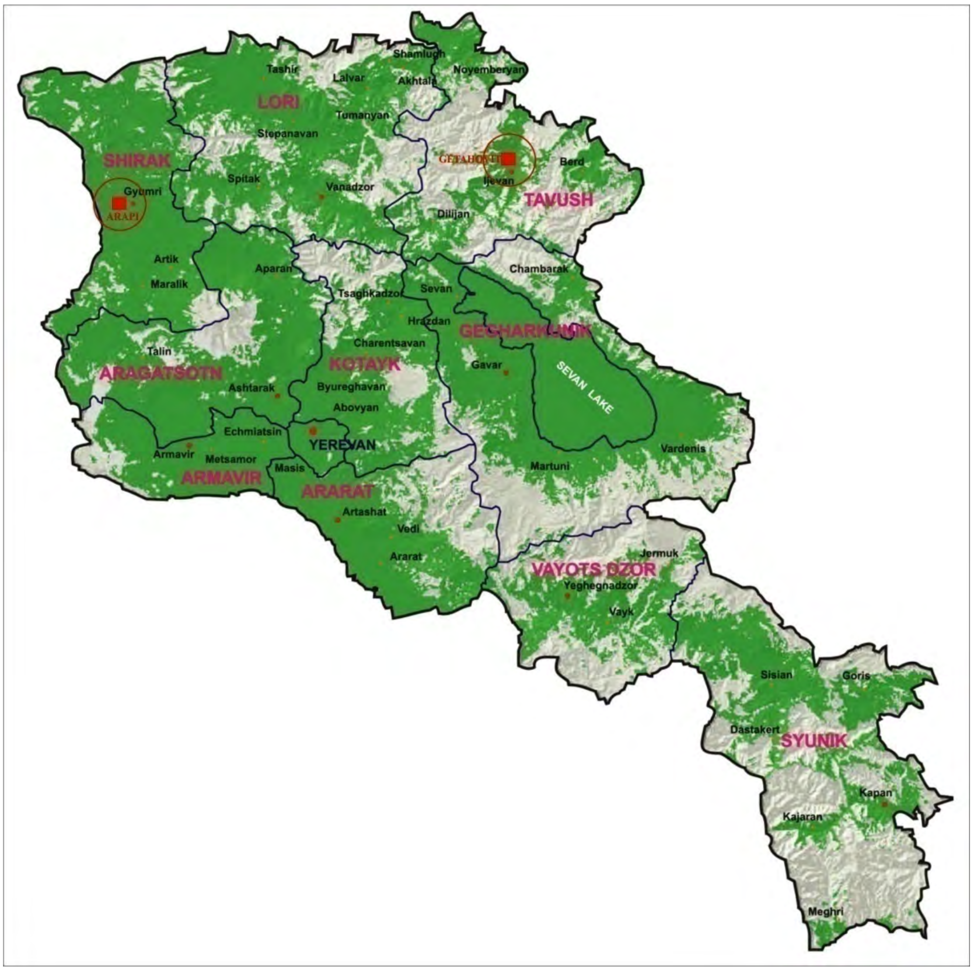
Studies of Landslide Sites at the Arapi Community, Shirak Marz of RA, and at the Getahovit Community, Tavoush Marz of RA

Background

In compliance with the Technical Specifications provided by the Client, GEORISK Scientific Research CJS Company completed the following studies within the landslide sites of the Arapi Community (Shirak Marz, RA) and in the Getahovit Community (Tavoush Marz, RA) during November-December 2014 and January 2015:

1. Topography survey
2. Geophysical surveys
3. Geological studies
4. Laboratory tests

The geographic locations of the landslide sites within the Arapi and Getahovit communities are shown on the map below.



1. Topography Survey

This Section of the Report and the annex enclosed incorporate information concerning the topographic and geodetic activities carried out by topography engineers within the Arapi community (Shirak Marz) and the Ghetahovit community (Tavoush Marz) in the framework of the geological surveys under the Project on landslide disaster management in the RA.

In accordance with the Technical Specifications, the following topographic-geodetic works were performed:

1. Deployment of planar and elevation geodetic networks;
2. Topography surveys at the scale of 1:100 along the instructed directions;
3. Desktop processing of the longitudinal sections along the instructed directions at the scale of 1:100 and at the interval of 5 meters.

The topography surveys were carried out in the WGS-84 coordinate systen (see the enclosed Digital Annex 1).

2.Geophysical Surveys

Introduction

In compliance with the Technical Specifications of the contract signed with the JICA Study Team, the group of geophysicists of GEORISK Scientific Research CJS Company performed geophysical surveys concurrently with the geological investigation. The purpose of the studies was to map the features of the subsurface geological section of the upper 40 m-thick stratum, identify underground water bedding depths and the zones of discontinuity, and develop conceptual models of the sites.

To achieve this goal, the same Technical Specifications required realization of an electrical sounding survey and a geo-radar survey within each of the sites.

To achieve this goal, the same Technical Specifications required realization of electrical sounding survey and geo-radar survey within each of the sites.

2. 1 Survey Technique

<u>The Geo-Radar Survey</u>

For the purposes of geo-radar surveys in the Arapi and Getahovit communities, SIR–3000 geo-radar system (USA, 2008) with the 200 MHz antenna was applied (Fig. 2.1).

Figure 2.1: The recording device of the SIR-3000 geo-radar system and the process of field measurements

The system scans geological section by means of pulsed electromagnetic waves, providing the greatest sounding accuracy. The system responds to distribution of densities within the geological section.

The georadar system is based on the analysis of electromagnetic pulses and record of signals reflected from layer boundaries within the sounded medium, which have different electro-physical properties. The main purpose is to determine layer boundaries, thickness and layer bedding depths.

Input parameters for the application of geo-radar system include specific attenuation and velocity of propagation of electromagnetic waves in a medium, which in turn represents the electrical characteristic of the medium. In the meantime, attenuation and velocity characterize the depth of sounding and the distance to the reflecting boundary, respectively. The velocity of electromagnetic wave propagation in a medium depends on its dielectrical and magnetic permeability rates.

Therefore, the velocity in a medium is inversely proportional to the dielectrical permeability of such medium, where C is the velocity of light in the vacuum.

$$V = \frac{C}{\sqrt{\varepsilon}}$$

Hence, dielectrical permeability of electromagnetic waves and their velocities are not essentially dependent on soil type and vibration frequency, but are strongly dependent on the rate of water saturation of a soil.

In the first approximation, propagation of electromagnetic waves is subject to the laws of geometrical optics. In the case of georadar surveying, the main processes in a medium are represented by reflection and diffraction of waves:

In case of normal incidence of wave, the reflection ratio of the two media (1 and 2), having different values of dielectrical permeability ε, is equivalent to:

$$K_{отр} = \frac{\sqrt{\varepsilon_2} - \sqrt{\varepsilon_1}}{\sqrt{\varepsilon_2} + \sqrt{\varepsilon_1}}.$$

The layout of propagation of a reflected electromagnetic wave will have the following pattern (Fig. 2.2).

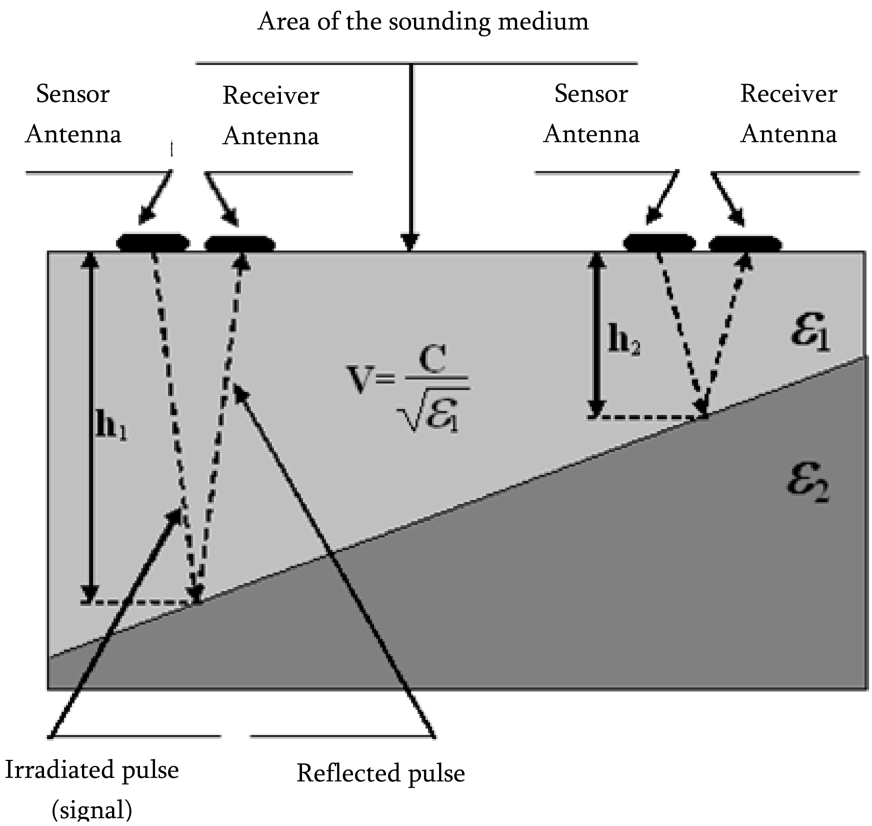


Figure 2.2: Layout of a reflected electromagnetic wave

The pattern of amplitudes and propagation differences is the following (Fig. 2.3).

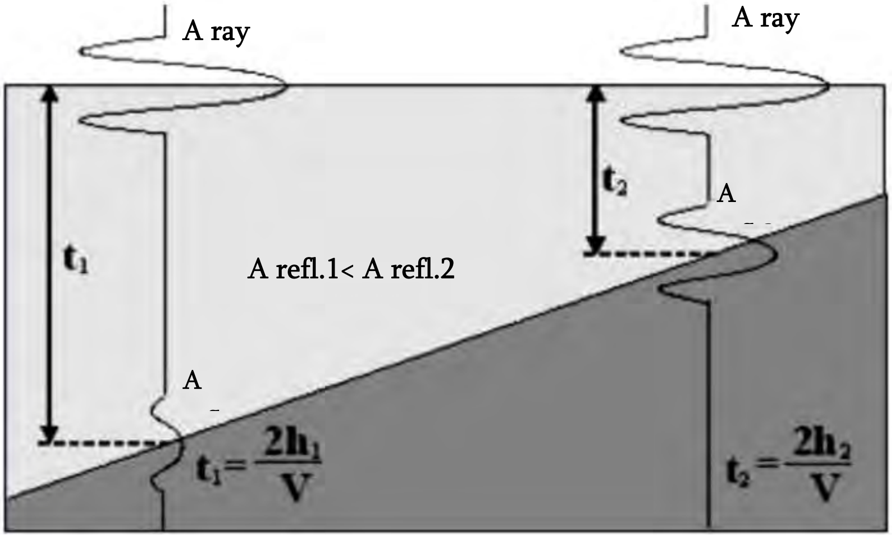


Figure 2.3: Amplitude and period of the reflected electromagnetic wave

The boundary between the two obliquely-oriented media has the following shape on the radar record (Fig. 2.4).

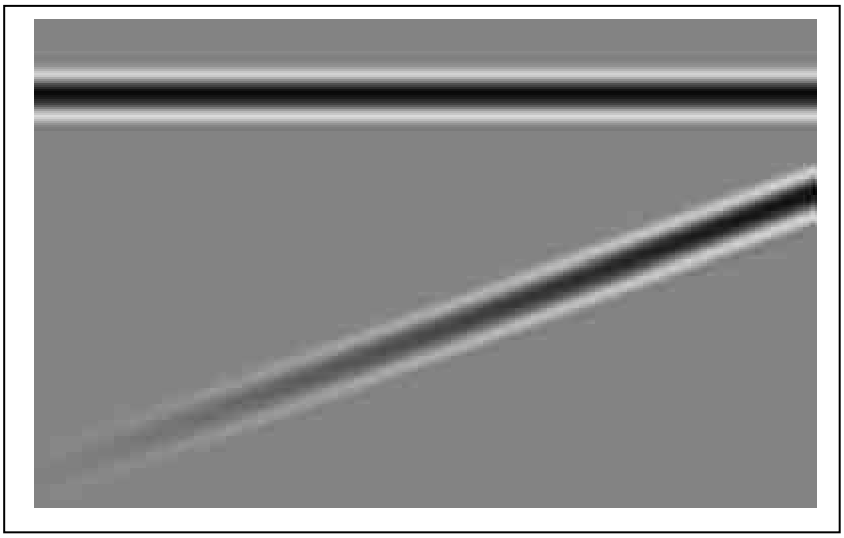


Figure 2.4: An example of distinction by colors on the radar record

Therefore, the color-based distinction of radar records corresponds to natural vibration periods of a medium or a soil, or their typical amplitudes, hence, the distribution of densities (Fig. 2.5).

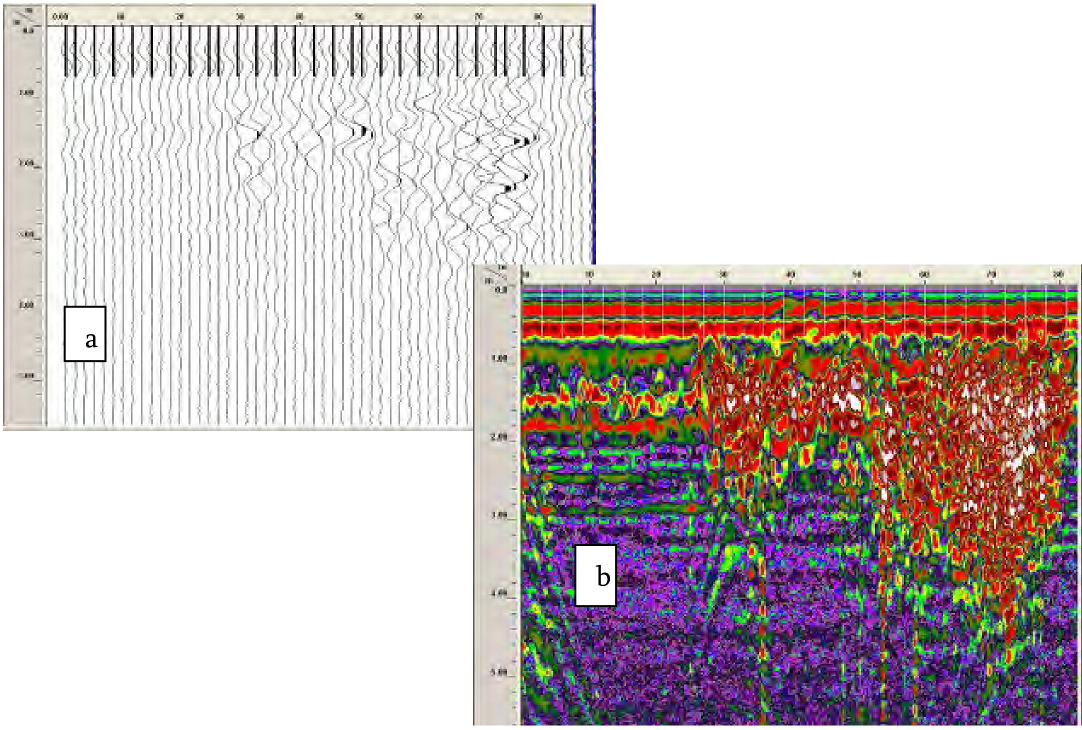


Figure 2.5: a) a group of radar records and b/ the plotted geological section (an example)

The vertical axes of radar records shown in Figure 2.5 represent depths in meters, while the horizontal ones correspond to georadar survey extension in meters.

As a result, the information collected from the antenna in the end of the survey in the form of an enormous-scale group of radar records is stored as a file of electromagnetic wave group. Later, the group is interpolated and visualized in the form of geological sections of the studied sites, which is presented below under descriptions of individual sites. Field measurement results were processed by means of *Radan 6.5* software package.

In each selected rural community, geo-radar survey covered 500 meters as shown in Figs. 2.6 and 2.7.

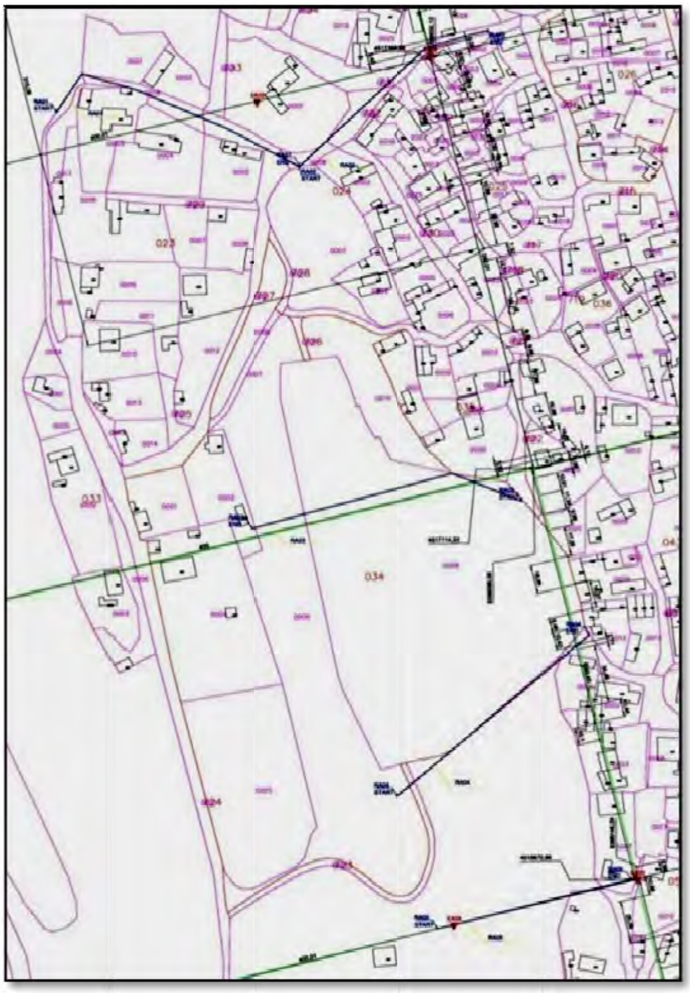


Figure 2.6: Actual location of the geo-radar survey profiles in the Arapi community

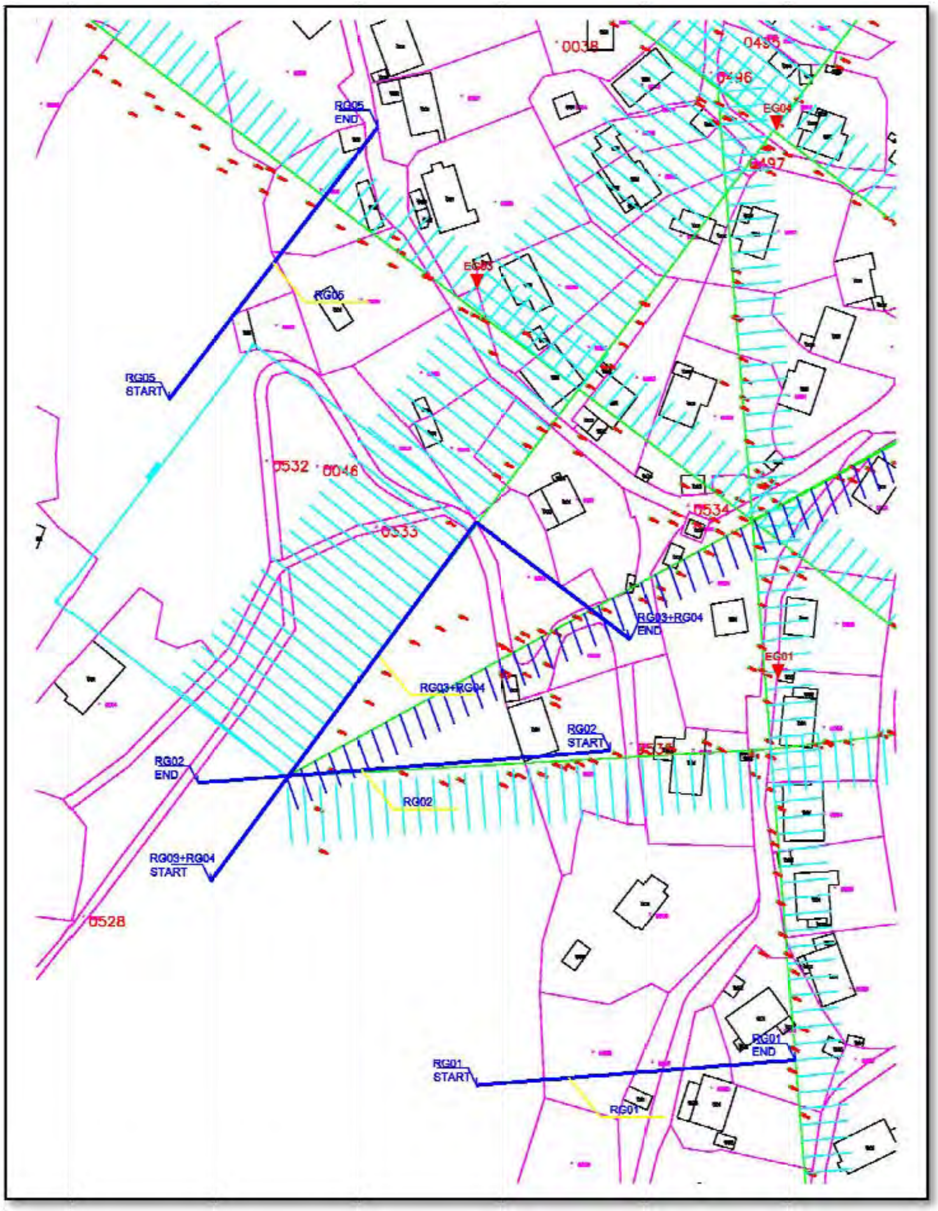


Figure 2.7: Actual location of the geo-radar survey profiles in the Getahovit community

Maps of factual materials of the geophysical surveys by communities are most accurately represented in the digital annex enclosed to the Report.

2.2 Electrical sounding works

Generally, changes of intensity and structure of layers in the Earth crust are reflected in their electro-magnetic properties, especially, in the value of electrical resistivity (ρ). This value represents an objective quantitative characteristic, the changes of which enable evaluation of the mineral and petrographic composition of rocks, their structure, features of bedding, hydro-geology conditions, etc.

Considering that changes in ρ values could be applicable for solution of the tasks indicated above, and taking advantage of the symmetric AMNB array technology proposed by Schlumberger and commonly accepted and developed worldwide, this study used the indicated electrical prospecting technique defined as *vertical electric sounding* (VES).

The excitation of the electromagnetic field was achieved by means of AB source probes in order to generate the electromotive force (EMF) in the studied medium and to measure it by means of the recording MN spread.

The four-point symmetric technology of AMNB linear spread enables it to increase the studied depth concurrently to the increase of the distance of the AB source probes spread. Electrical resistivity ρ in a homogeneous or a heterogeneous medium is measured as specific electrical resistance or as apparent electrical resistance ρ_k, respectively, in Ohm-m measurement units. The calculations of ρ_k were performed by the formula below.

$$\rho = k\frac{\Delta U}{I}$$

where ΔU is the difference of potentials in volts, I is the current intensity in amperes, and k is the AMNB spread factor. The measurements by the VES technique were carried out by means of Russian Federation-made CYCLE-VPS digital electrical prospecting station (Fig. 2.8).

The applied software (VPS-ex600) enables performing different types of field data processing.

To perform further processing of the field data and for their quantitative evaluation layer by layer, «IPI2win» software package was applied (Fig. 2.9).

In the selected two rural communities, 8 measurements were performed by the VES technique, by 4 measurements in each; the locations of the measurements are shown in Figs. 2.10 and 2.11.

Figure 2.8: CYCLE-VPS digital electrical sounding station, field measurements

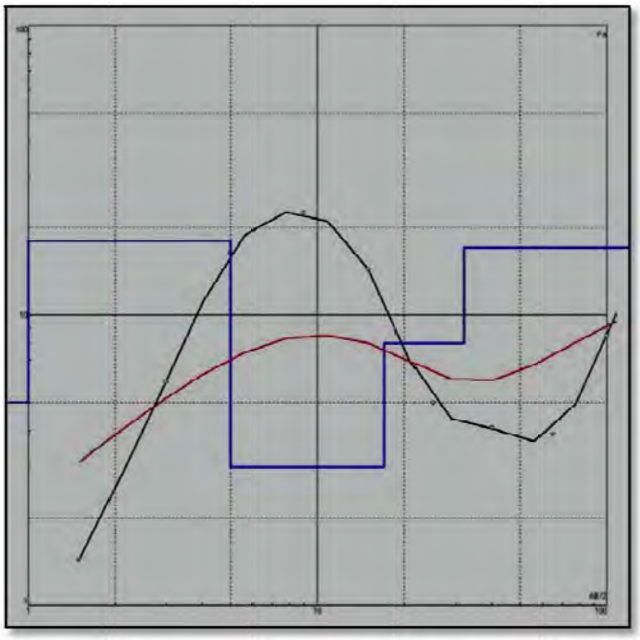


Figure 2.9: Correlation of the theoretical and actual curves by the IP2Wsoftware

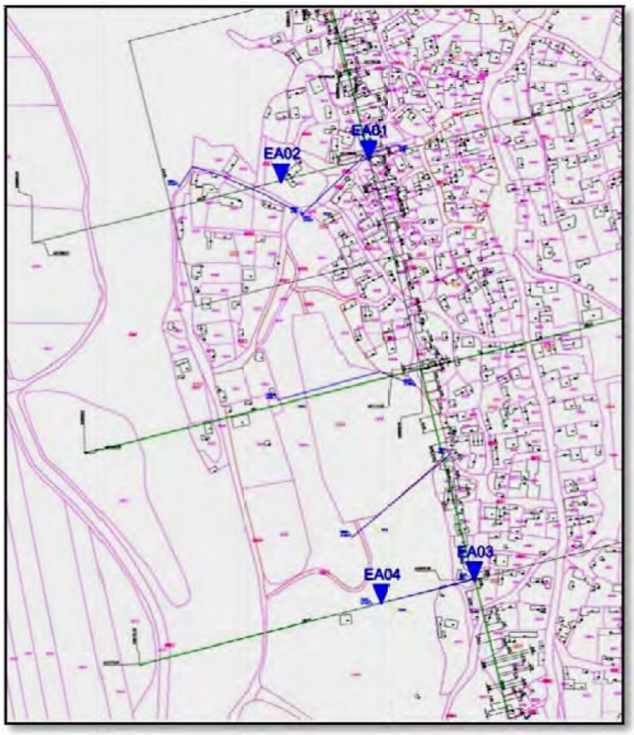


Figure 2.10: Locations of VES measurement points in the Arapi community

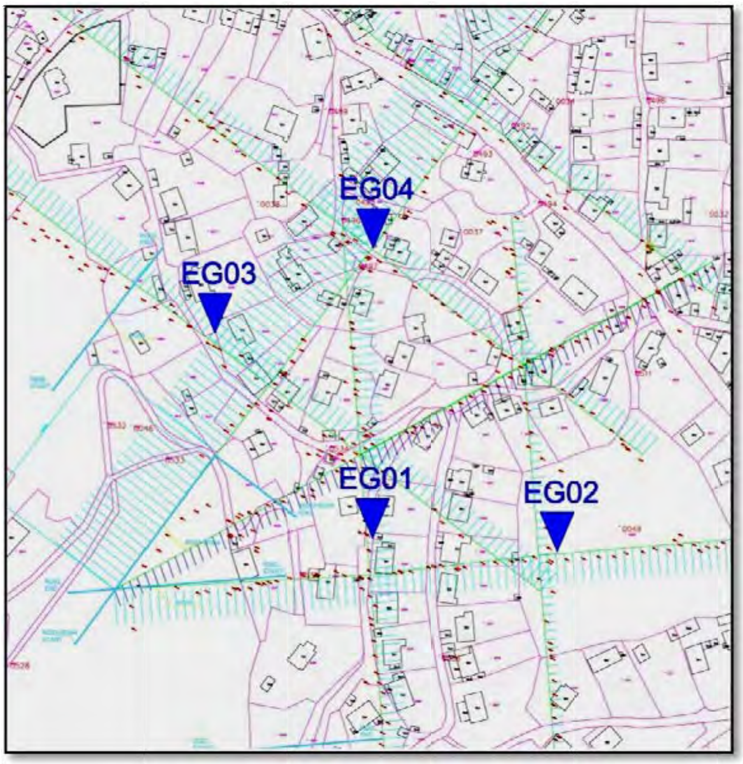


Figure 2.11: Locations of VES measurement points in the Getahovit community

2.3 Results obtained

According to the results of the field geophysical data analysis, geo-electrical boundaries were established within the upper layers of the geological section and apparent electrical resistivity characteristics were calculated for each identified geo-electrical horizon (Fig. 2.12).

The results of the electrical sounding measurements were correlated with the borehole data and as integrated sections compared to the *radargrams* produced by the geo-radar survey (Fig. 2.13).

All delivered graphical annexes are enclosed as Digital Annex 2 not to overload the textual part of the Report.

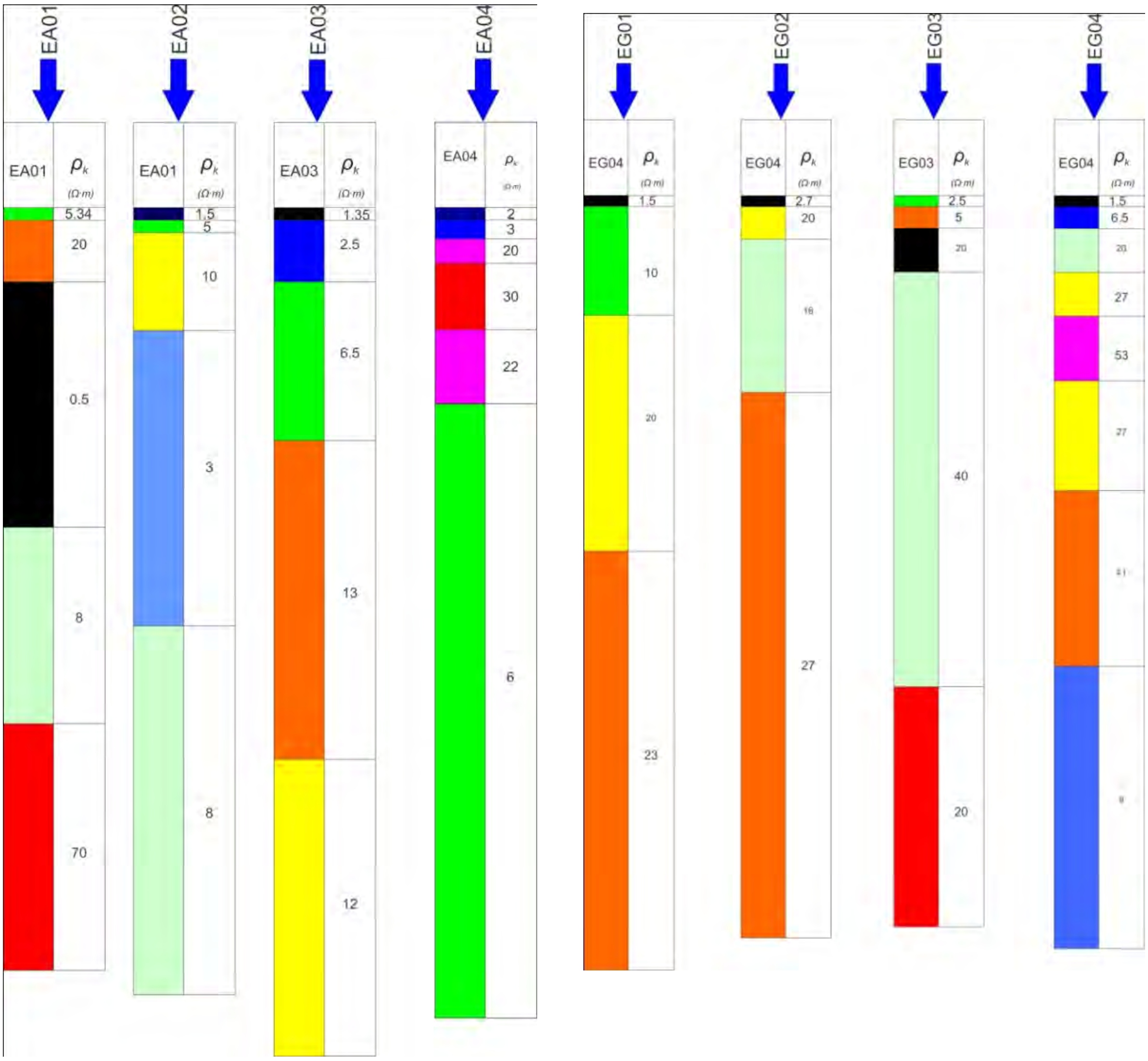


Figure 2.12: The results produced by means of VES technique and shown by communities and survey points

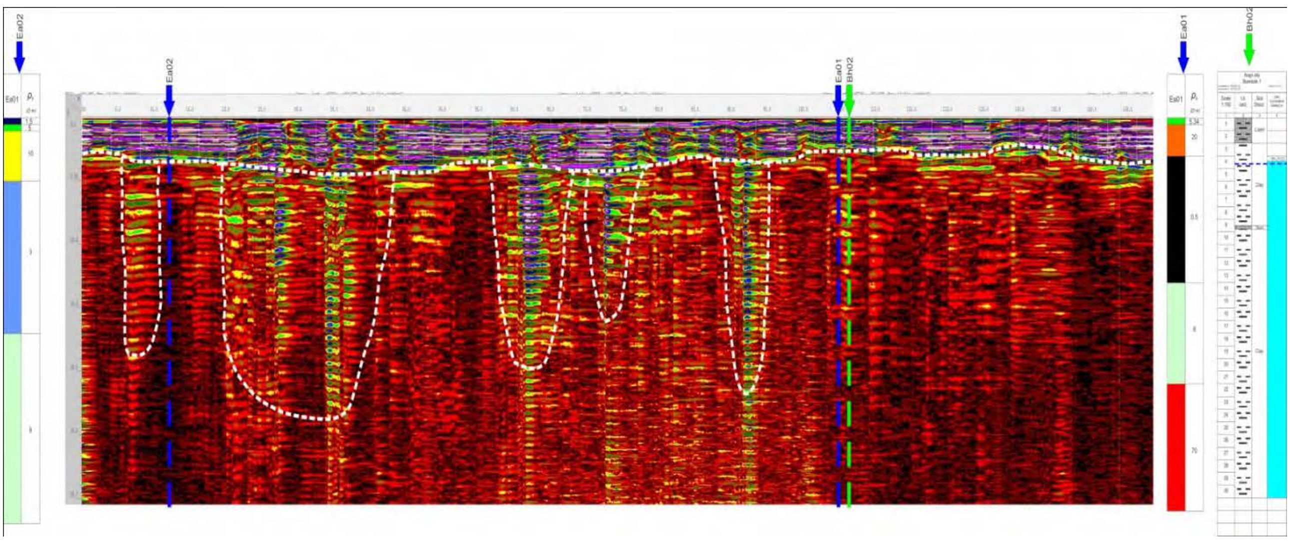


Figure 2.13: An example of correlative analysis of the actual surveys

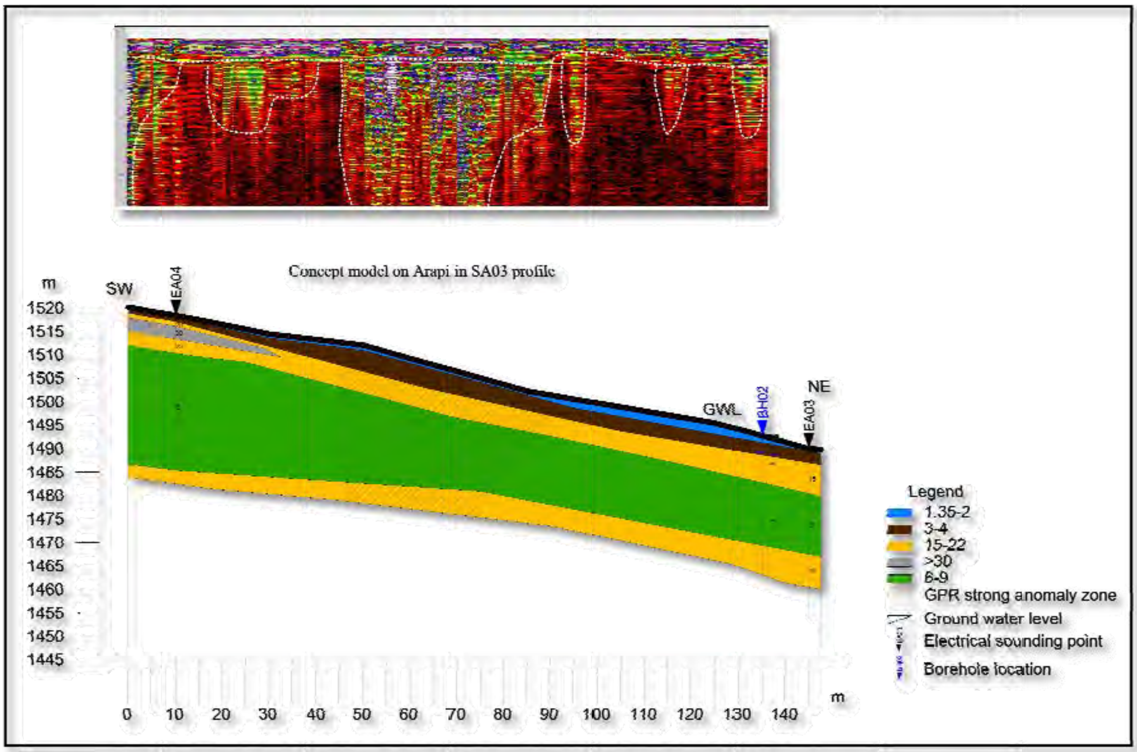
In other cases, when a point of one or another survey appeared beyond the individual geodetic profile, it was not accounted for in the course of analysis considering its remoteness from the studied profile.

At the next stage, the collected complex information was projected onto the closest geodetic sections and presented as a conceptual model for the selected section of the considered community (Figs. 2.14-2.17). The geological-geophysical models are presented below for each community separately.

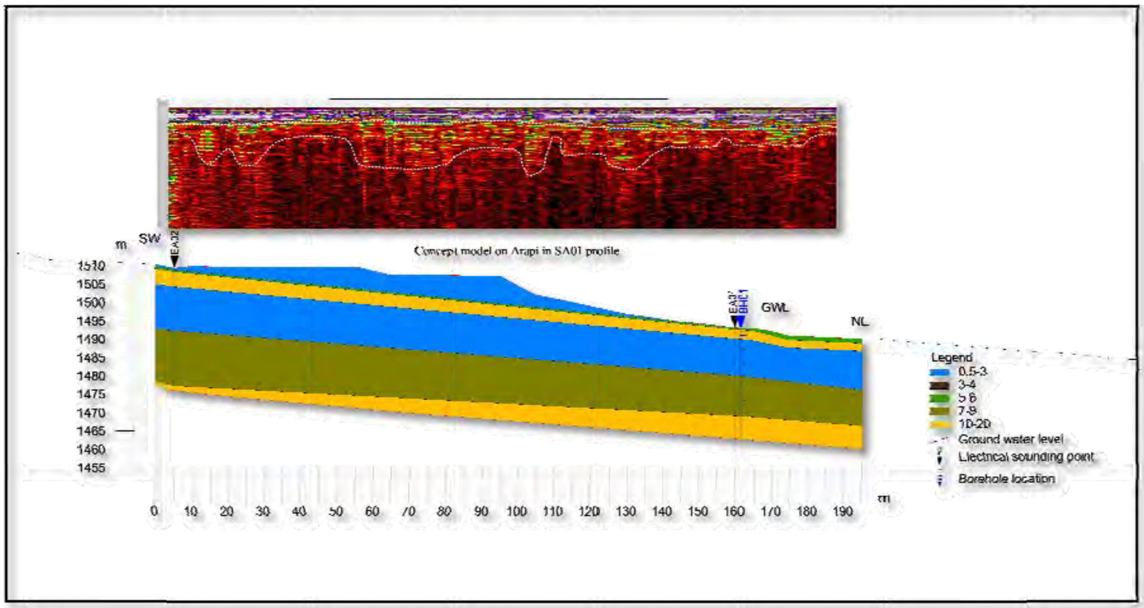
All factual data recorded in the course of field geophysical studies as well as the analyzed data are delivered as digital annexes enclosed to this Report.

Arapi Community

Model 1 Section SA 03

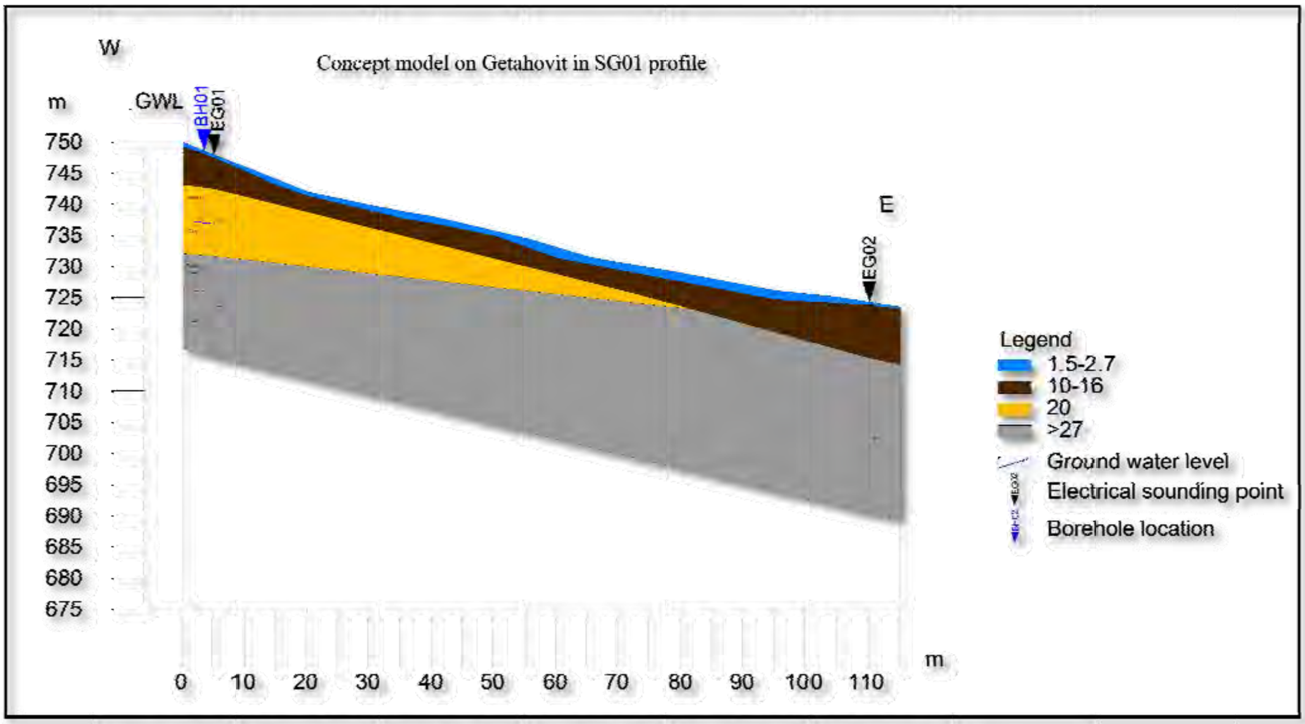


Model 2 Section 2

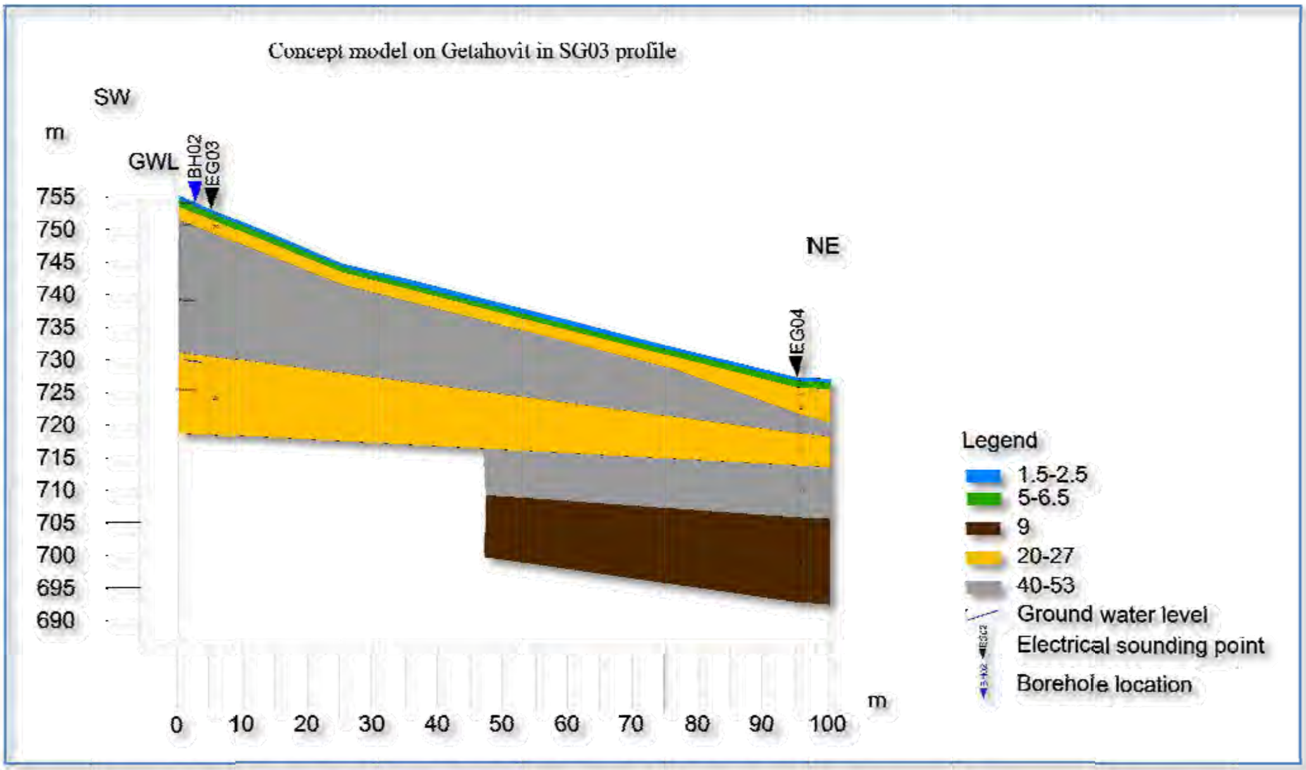


<u>Getahovit Community</u>

Model 1 Section SG 01



<u>Model 2 Section SG 03</u>



3. Geological surveys

The surveys within the landslide areas of the Arapi (Shirak Marz) and Ghetahovit (Tavoush Marz) communities included identification and description of soil sections by means of drilling and dynamic tests in the boreholes (SPT), as well as laboratory tests of the soils sampled in the course of drilling to determine their physical, shear and strength characteristics.

3.1 Geological Structure of the Sites

In terms of geological structure, the landslide sites of the Arapi and Ghetahovit communities have different features of lithology and stratigraphy of rocks common there.

The Arapi Community. The geological map of the sites shows that sedimentary formations developed within the landslide part of the built-over area of this community are relatively young and belong to the lacustrine Shirak complex of an Early Quaternary age, the so-called Arapi-1 horizon. They formations are represented by layers of clays, sandy loam and diatomaceous clays that are characterized by widespread development of landslide processes over the entire length of this horizon (Fig. 3.1.1).

From the standpoint of geology, the diatomaceous clays and diatomites drilled through by the boreholes are lake units by the settings of formation, and have biological origin considering their structure, composition and main features. The material composition of diatomite units differs from other soils by high content of silica, which determines their main physical and chemical features such as dispersion and morphology of structural elements. The main structural element of diatomaceous units is represented by shells (frustules) of diatoms (algae), having certain morphology, dimensions and microscopic-scale pores. To give an idea of the dimensions of diatoms frustules, let us consider that 1 mm^3 contains 30,000 diatom frustules. The links between structural elements are of coagulation-plastification and coagulation-condensation types. The indices of the physical properties of the diatomite units are determined mainly by soil components and by the quantitative relationship between terrigeneous and diatomaceous particles present in the soil. The physical properties depend also on the mineral composition of the terrigeneous mixture. In case the natural moisture content is greater than the molecular water-absorbing capacity maximum, the soils are stable in terms of structure, and when the natural moisture is less than the molecular water-absorbing capacity maximum the soils are structurally unstable.

According to common concepts, the granulometric composition of diatomaceous clays and diatomites is generally characterized by the following indices: the percentage of silica content it diatomaceous clays ranges up to 60- 80%, and the content of particles less than 0.001 mm in diameter takes up 30-45%. In diatomites, silica content percentage is greater than 80% and the content of particles less than 0.001 mm in diameter ranges up to 15-25%.

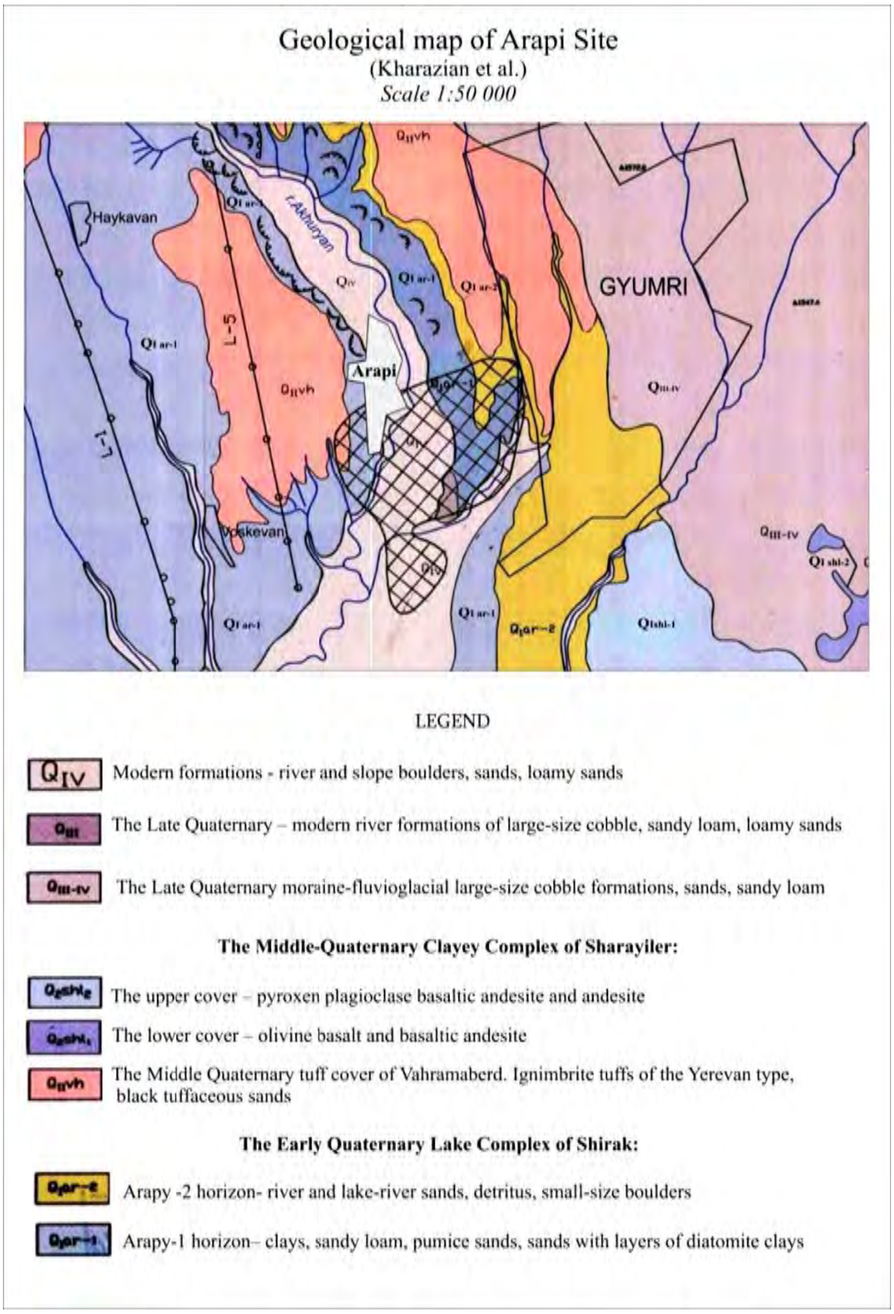


Figure 3.1.1: Geological map of the Arapi Site

Terrigeneous formations of an Early Quaternary age are developed within the landslide site of the *Getahovit* community (Fig. 3.1.2) and are represented by a stratum of loose loess-like sandy loams with the Late Cretaceous and Late Jurassic volcano-sedimentary rocks exposed in its base. These rocks are represented by strongly weathered, crushed and in places hydrothermally altered limestone, sandstone and tuff sandy loam.

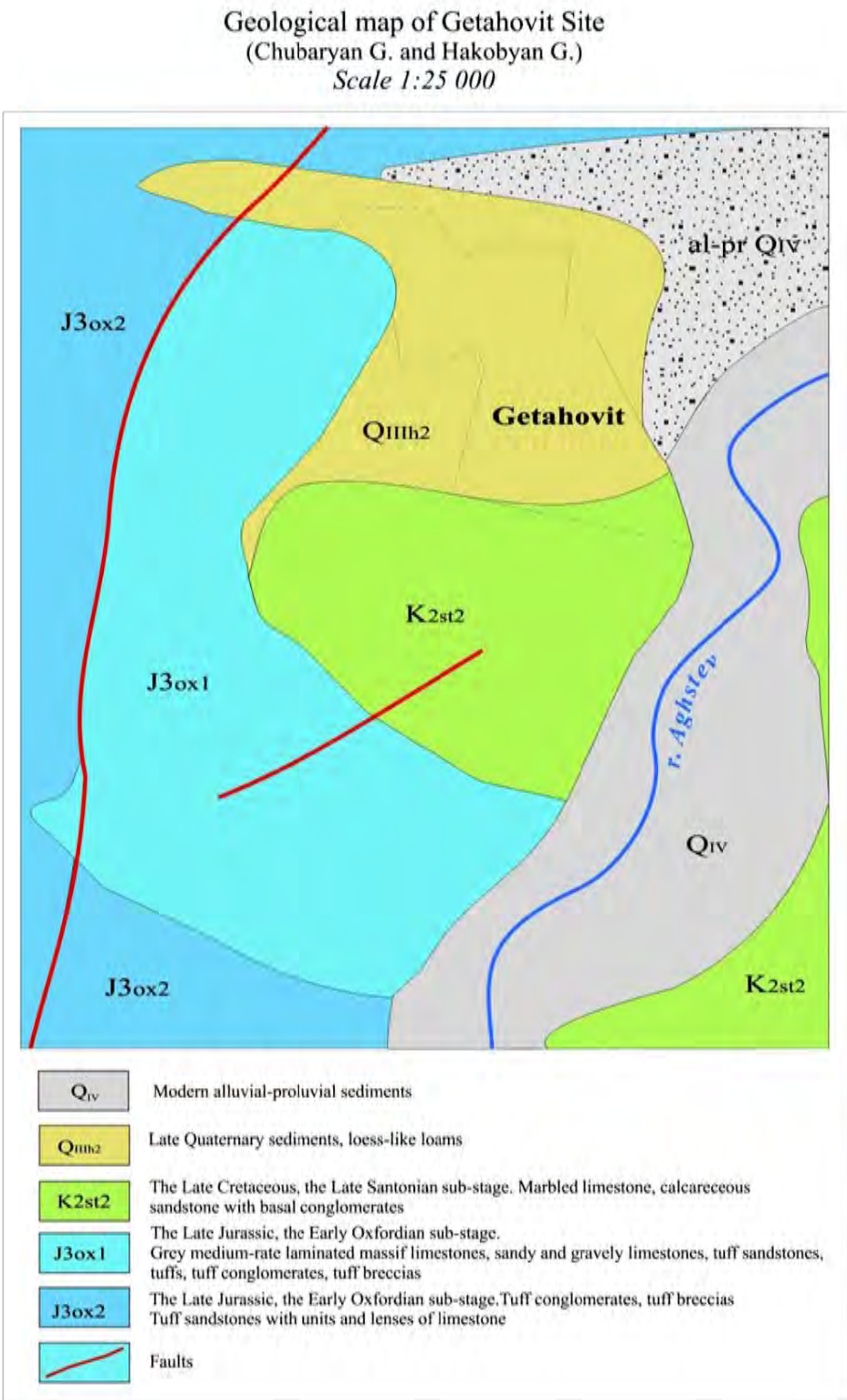


Figure 3.1.2: The geological map of the Getahovit community

These properties of rocky soils composing the sites are likely determined by the presence of a large fault zone stretching in near-meridian direction.

3.2 Drilling and dynamic testing of soils (SPT)

Drilling of 4 boreholes was performed within the landslide sites of the Arapi and Getahovit communities with the purpose of study of the soil conditions and geotechnical sections. (Fig. 3.2.1).

At each site, two boreholes were drilled each to the depth f 30 meters at the total scope of 120 r/m. Locations of the boreholes were determined beforehand, jointly with the Client, considering the highest rate of landslide hazard and most active manifestations of development of the dangerous processes.

The drilling was carried out using УГБ-50 drilling rig by the dry mechanical core drilling technique and core bits to provide for sample diameters of d=151 mm, d=132 mm and d=112 mm (Fig. 3.2.2).

In the course of drilling works, daily reports on the progress of work and soil section uncovered by the boreholes were delivered to the Client. The level of ground waters was measured in the beginning and upon completion of each working day; the data were recorded in a log book, and the fluctuations of water level were indicated on the borehole section and reported to the Client.

Sampling was done from the most representative layers of soils drilled by the boreholes: in each borehole, by 3 samples of undisturbed (monolith) and disturbed soil were taken from the core. The samples were placed into marked hermetic bags and transported to the laboratory for realization of required tests.

Standard penetration tests (SPT) in compliance with ASTM D1586 standard were carried out in the course of drilling. The tests were performed by means of Raymond Sampler E21USBR and 63.5 kg hammer once for each 3m, concurrently with the process of drilling.

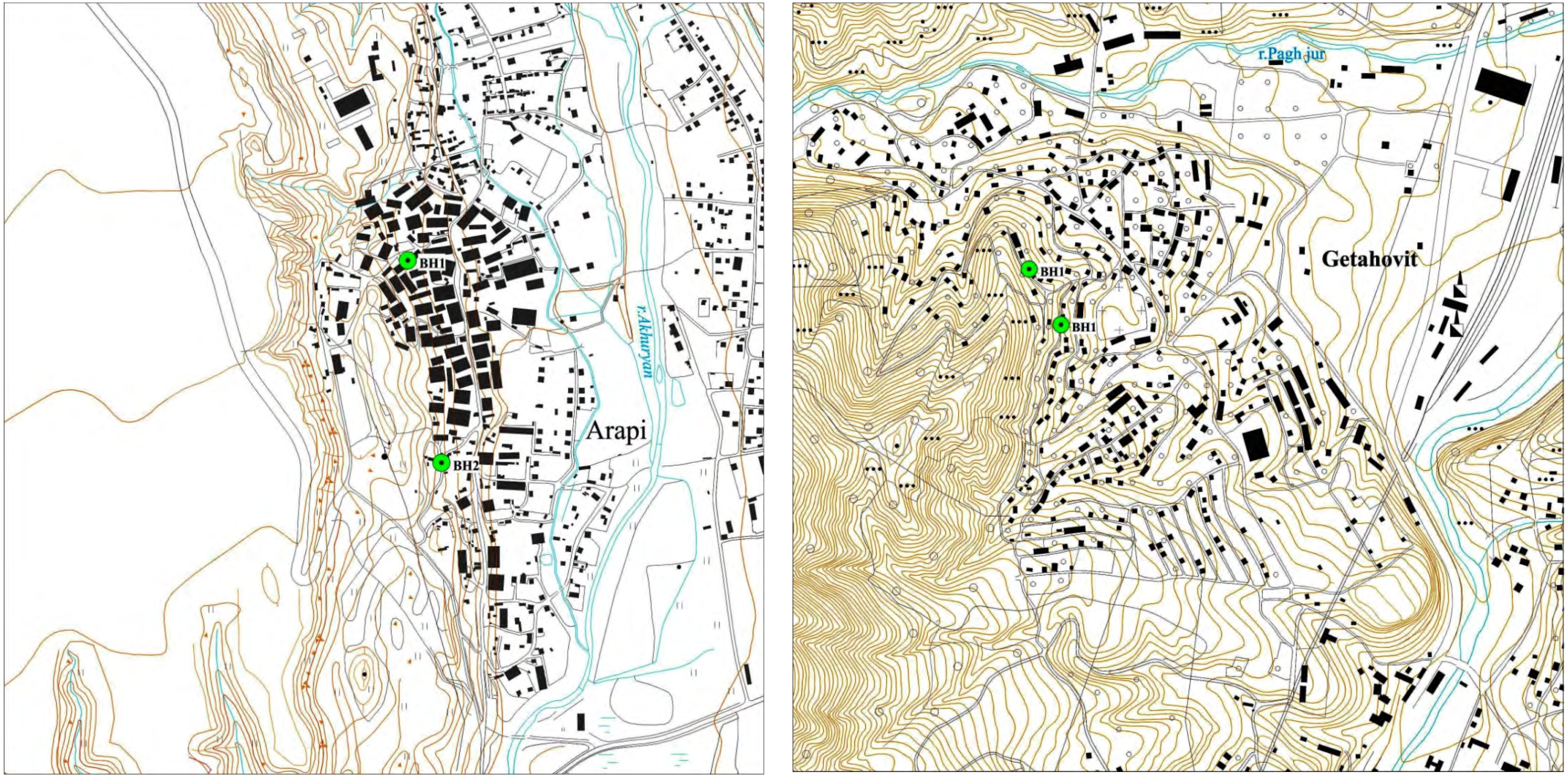


Figure 3.2.1: Locations of the drilled boreholes shown on the topography map of the landslide sites of the Arapi and Getahovit communities

Figure 3.2.2: УГБ-50 drilling rig and the core bit 151 mm in diameter attached to the drilling rod

The technical parameters of the sampler are as follows: tube length-860mm, D=35mm, open shoe angle-19°47', hammer weight –63.5 kg (Fig. 3.2.3).

The testing was conducted along depth at intervals of 3 m with penetration of the sampler by 300 mm per test. The number of blows required for each 100 mm was counted. The test was stopped encountering rocks that required more than 50 hammer blows to advance over the specified interval.

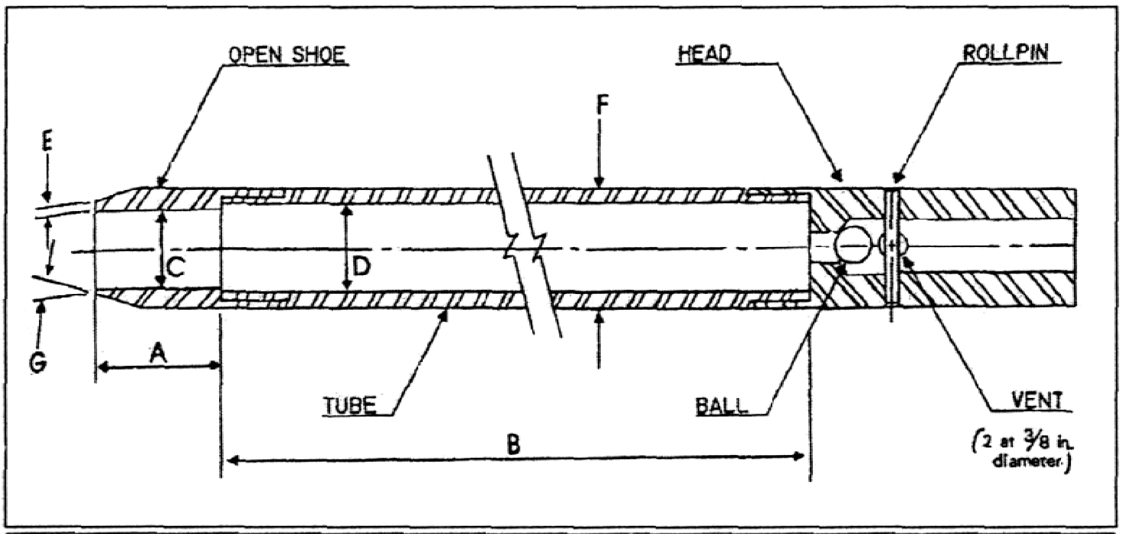
Results of the testing were recorded on the borehole section and indicated in daily reports. Soil samples taken with the sampler were classified and placed in plastic bags, which were marked with relevant borehole number and depth interval; then the samples were put in the boxes prepared for each site.

The core recovered in the course of drilling was placed according to depth intervals into wooden boxes, each having five 1 m-long sections, described in the drilling log in detail and photographed. Upon completion of the works all boxes (24 in total) were transported to the storage facilities of the Arapi and Getahovit communities.

At the end of drilling, 31 m-long PVC pipes with sensors installed in them to record stresses present in the soil mass and water level changes were lowered down into the boreholes (Fig. 3.2.4). The space between the installed pipes and borehole walls was filled with sandy filling material and then the wellhead part was closed with 30 x 30 x 20 cm-large concrete covers.

The results of drilling works and dynamic tests (SPT) performed at the landslide sites of the Arapi and Getahovit communities, as well as borehole sections and photos of the core, are shown in Figs. 3.2.5-3.2.10.

The data recorded in MS Excel format reflect the types of drilled soils, ground water level fluctuations in the borehole during each day, sampling intervals and results of penetration tests conducted in parallel to the drilling.



Part	A	B	C	D	E	F	G (degree)
Length (mm)	50	860	35	35	0	51	19°47'

Figure 3.2.3: Layout of Raymond Sampler E21USBR

Figure 3.2.4: Installation of a PVC pipe affixed to the sensors into the borehole to record ground water levels and deformation data

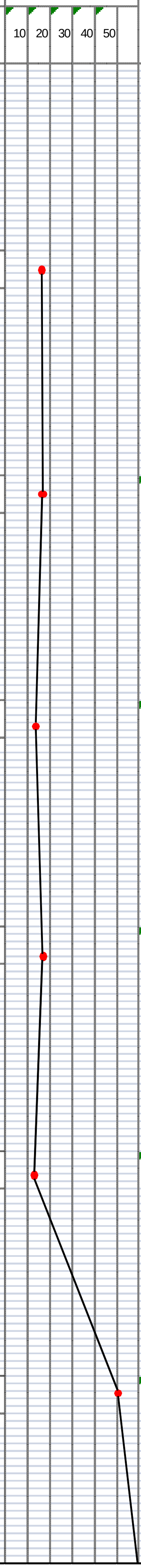
Landslide Disaster Management Project in the Republic of Armenia

Hole No.: 1		Sheet No. (1/2)	
Site: Arapi, Shirak reg.	Coordinate N: 8399037.45	Depth: 30.00 m	Drilled by: S. Sargisyan
Drill Rig: УГБ 50	Coordinate E: 4517353.63	Ground Elevation: 1493.85m	Logged by: H. Titizyan
Drilling Period 23,Nov.-01.Dec	Inclinaton: Vertical	GWL: GL-4.0m	Checked by: V. Titizyan

Depth (m)	Soil Type Rock Type	Color	Description
0.0–1.8	Sandy loam	Brown	Strongly carbonated, firm sandy loam
1.8–5.0	Clay	Brown	Semi-solid clay
5.0–9.6	Clay	Brown-to-greenish	Plastic clay
9.6–9.9	Sand	Grey	Water-saturated sand with the filling of clay of up to 10%
9.9–11.1	Clay	Brown	Moist plastic clays
11.1–12.2	Clay	Brown-to-greenish	Semi-solid clays
12.2–12.6	Clay	Bro wn-to-	Plastic clays
12.6–13.0	Clay	Bro wn	Plastic clays
13.0–20.0	Clay	Brown-to-greenish	Plastic clays, slightly carbonated

SPT

Depth (m)	0-5	5-15	15-25	25-35	35-50	N
2,5–3	1	2	3	4	6	16
5,5–6	2	3	4	4	5	18
8,5–9	1	2	3	4	4	14
11,5–12	1	3	5	4	4	17
14,5–15	1	2	3	4	4	14
17,5–18	3	6	8	10	13	40



Sample No.: B1-01 (10.2–10.6 m)

Drilling Record

Date of Drilling	GWL (GL- m)
23.Nov	7 / 3,2
24.Nov	3,2 / 3,2
25.Nov	4,7 / 3,2
26.Nov	3,6 / 3,2
27.Nov	3,2 / 3,2

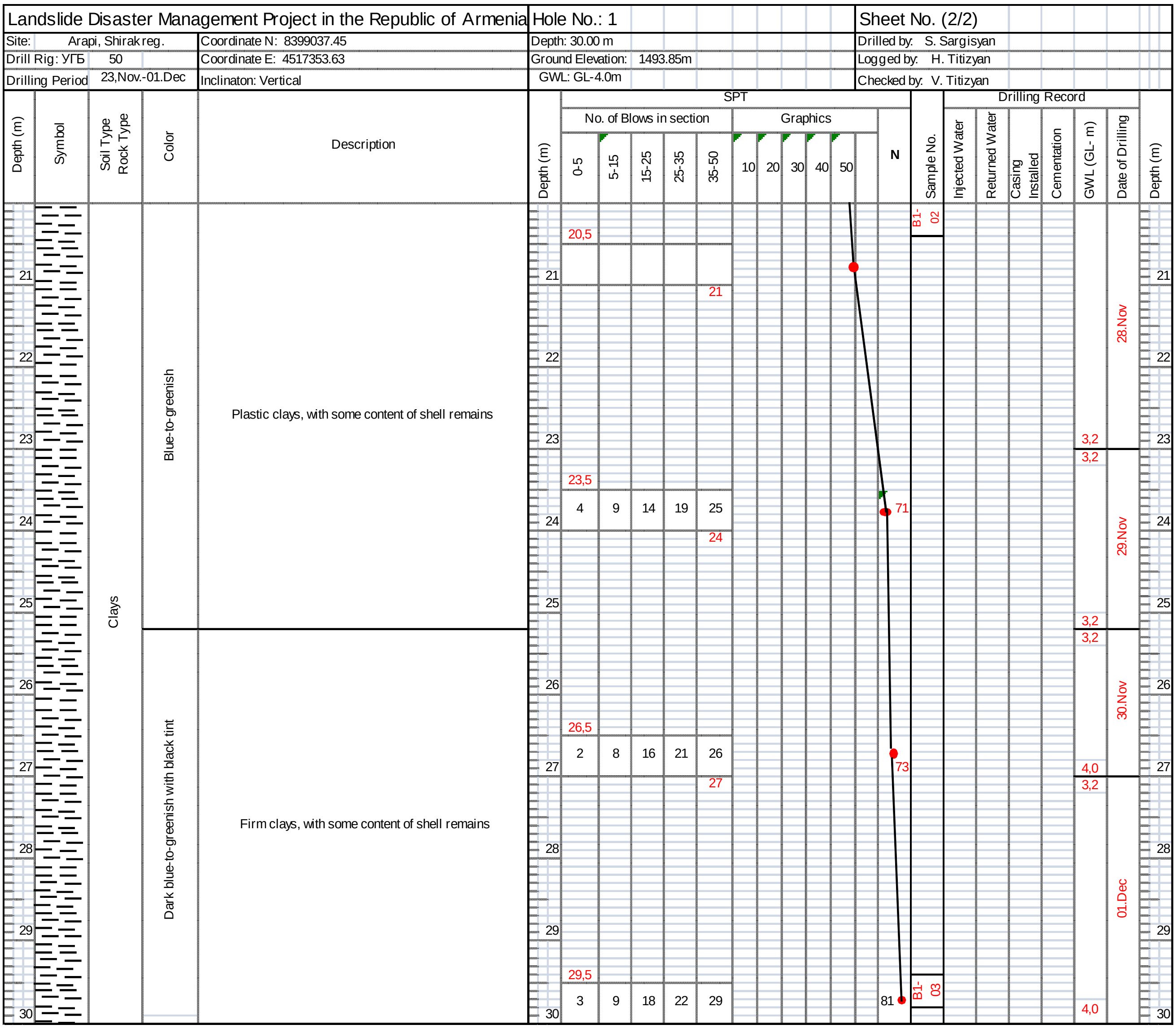


Figure 3.2.5: Section of Borehole Arapi BH1

Landslide Disaster Management Project in the Republic of Armenia		Hole No.: 2	Sheet No. (1/2)
Site: **Arapi, Shirak reg.**	Coordinate N: 8399155.88	Depth: 30.00 m	Drilled by: S. Sargisyan
Drill Rig: УГБ -50	Coordinate E: 4516871.53	Ground Elevation: 1496.45m	Logged by: H. Titizyan
Drilling Period 07.Dec- 19,Dec	Inclinaton: Vertical	GWL: GL-2,0 m	Checked by: V. Titizyan

Depth (m)	Soil Type Rock Type	Color	Description
0 – 0.2		G	Top soil
0.2 – 3.9	Sandy loams	Brown	Firm sandy loams with the content of up to 15% of crushed stone
3.9 – 5.2	Sandy loams	Brown	Semi-solid sandy loams
5.2 – 6.8	Sand	Black	Water-saturated sands of lake or river origin
6.8 – 8.2	Clays	Brown	Moist and plastic clays
8.2 – 11.7	Clays	Blue-to-greenish	Moist and plastic clays
11.7 – 20	Clays	Blue-to-greenish	Solid, in places semi-solid clays

SPT

Depth (m)	0-5	5-15	15-25	25-35	35-50		N
2,5	1	2	3	4	3	3	13
5,5	1	1	2	1	1	6	6
8,5	1	2	2	3	4	9	12
11,5	1	2	3	4	5	12	15
14,5	2	4	7	12	18	15	43
17,5	2	5	9	16	19	18	51

Graphics: 10 20 30 40 50

Sample No.: B2-01 (depth approx. 10.4–10.8 m)

Drilling Record

Injected Water	Returned Water	Casing Installed	Cementation	GWL (GL- m)	Date of Drilling
				2,0 / 2,0 (5 m)	7.Dec
				2,0 / 2,0 (12 m)	9.Dec
				3,0 / 2,0 (14 m)	10.Dec
				2,0 / 2,0 (17 m)	11.Dec
				2,0 / 2,0 (19 m)	12.Dec

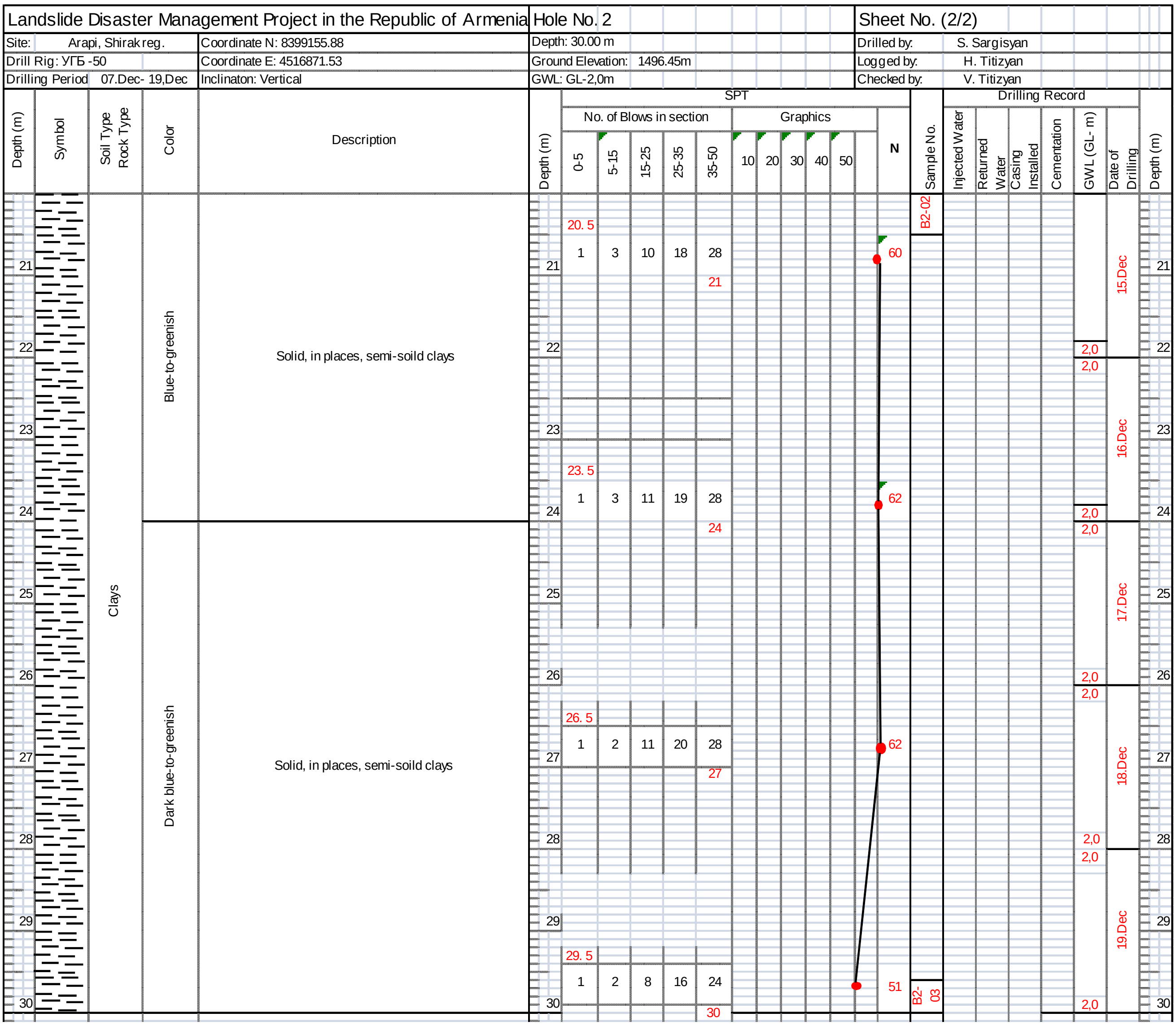


Figure 3.2.6 Section of Borehole Arapi BH2

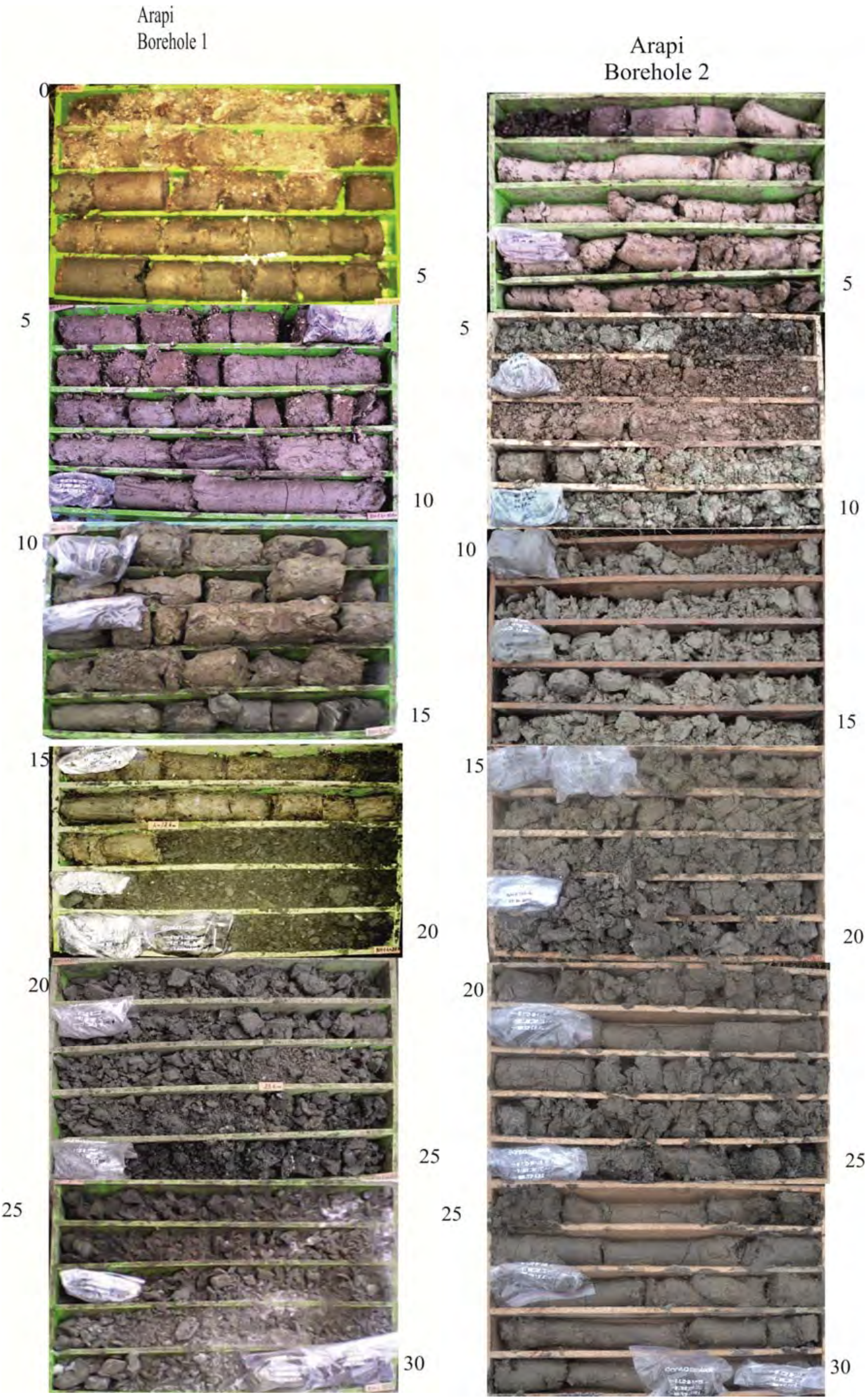


Figure 3.2.7: Core recovered from Boreholes Arapi BH1 and BH2

Landslide Disaster Management Project in the Republic of Armeni		Hole No. 1	Sheet No. (1/2)
Site: **Getahovit, Tavush reg.**	Coordinate N: 8511672.55	Depth: 30.00 m	Drilled by: S. Sargisyan
Drill Rig: УГБ -50	Coordinate E: 4529189.60	Ground Elevation: 751.03m	Logged by: H. Titizjan
Drilling Period 23.Dec-29.Dec	Inclinaton: Vertical	GWL: GL- 10.6m	Checked by: V.Titizyan

Depth (m)	Soil Type Rock Type	Color	Description
0–1	Topsoil	Black	Vegetation topsoil of loamy sand composition with fine detritus of up to 10%
1–6.5	sandy loam	chestnut-colored	Sandy loams of firm composition, containing 10-15% of fine detritus
6.5–9.1	large-fragmentary detritus	chestnut-colored	Large-fragmentary soil of detritus with the filling of loamy sand of up to 25%
9.1–15.1	Clays	Dark grey	Clays of plastic consistence
15.1–18	Clays	Dark grey	Solid, in places semi-solid consistence clays
18–19.1	Detritus	Dark grey	Large-fragmentary detrital soil, represented by weathered sandstone
19.1–20	Clay	Dark grey	Clays of soild consistence

SPT

Depth (m)	0-5	5-15	15-25	25-35	35-50	N	Sample No.	GWL (GL- m)	Date of Drilling
2,5 – 3	2	3	5	8	10	28			23.Dec.2014
5,5 – 6	2	4	4	7	11	28	BH1-01		23.Dec.2014
8,5 – 9	2	20	50	_	_	72			24.Dec.2014
11. 5 – 12	2	8	50	_	_	60			25.Dec.2014
14. 5 – 15	2	4	8	12	13	39	BH1-2a	11. 6 / 11. 6	25.Dec.2014
17. 5 – 18	1	5	10	16	22	54	BH1-02	11. 6	26.Dec.2014

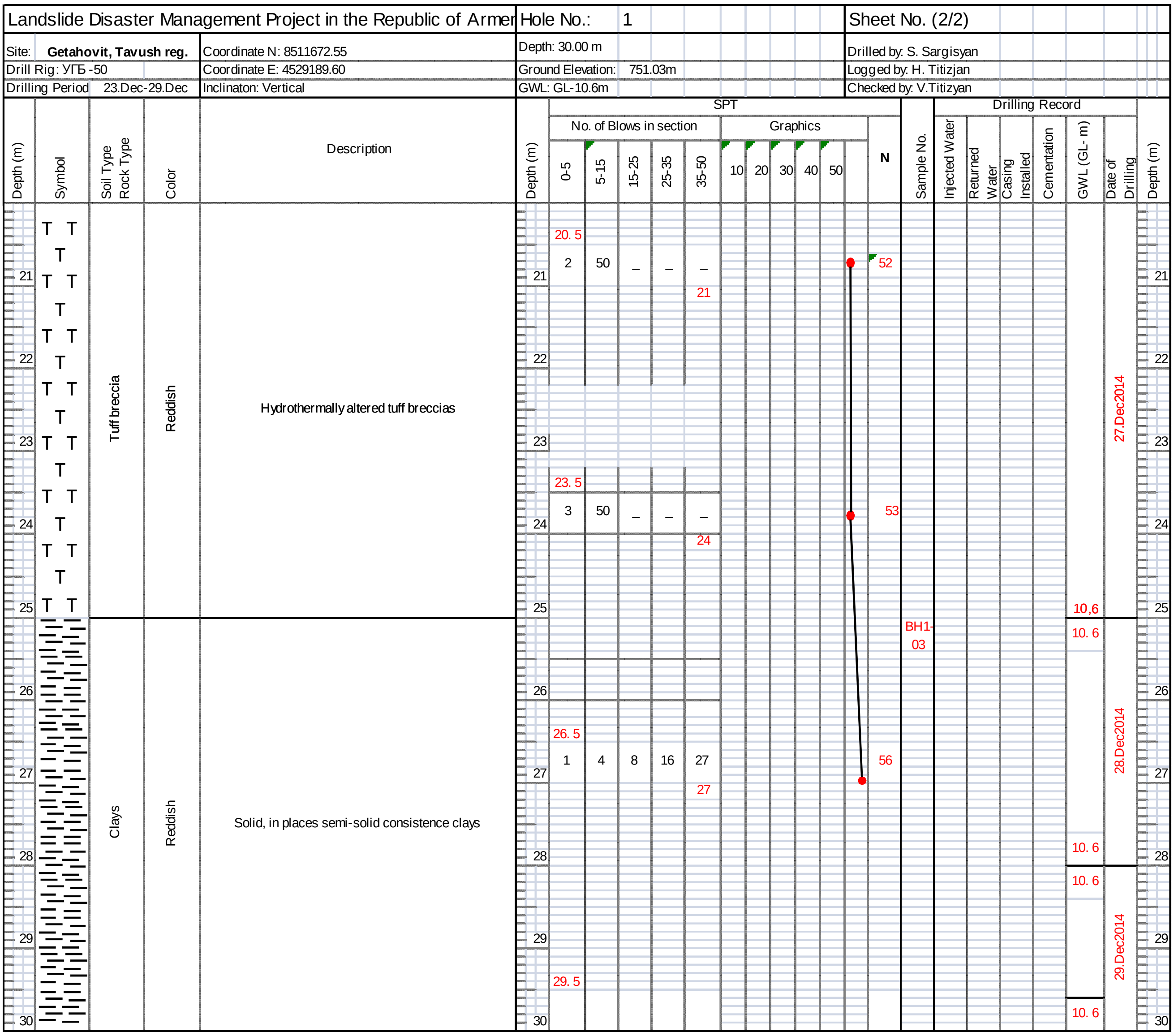


Figure 3.2.8: Section of Borehole Getahovit BH1

Landslide Disaster Management Project in the Republic of Armenia		Hole No.: 2	Sheet No. (1/2)
Site: **Getahovit, Tavush reg.**	Coordinate N: 8511593.38	Depth: 30.00 m	Drilled by: S. Sargisyan
Drill Rig: УГБ 50	Coordinate E: 4529311.54	Ground Elevation: 757.34m	Logged by: H. Titizyan
Drilling Period 09.Jan-18.Jan.	Inclinaton: Vertical	GWL: GL-20.7m	Checked by: V. Titizyan

Depth (m)	Soil Type / Rock Type	Color	Description
0 – ~0.4	Top soil	black	Vegetation topsoil of loamy sand
~0.4 – ~6.5	sandy loam	brown	Sandy loams of solid consistence containing up to 20% of fine detritus
~6.5 – 20	detritus	white, in places reddish	Detrital soil with the filling of sandy loam of up to 15-20%

SPT

Depth (m)	0-5	5-15	15-25	25-35	35-50	N	Sample No.
2,5 – 3	1	3	4	6	9	23	
5,5 – 6	2	4	5	7	10	28	BH2-01
8,5 – 9	3	15	50+	_	_	68	
11,5 – 12	5	50+	_	_	_	55	
14,5 – 15	2	50+	_	_	_	52	BH2-02
17,5 – 18	3	25	50+	_	_	78	

Drilling Record — Date of Drilling:

Depth (m)	Date of Drilling
0 – 8	09.Jan.2015
8 – 15.5	13.Jan.2015
15.5 – 17.5	14.Jan.2015
17.5 – 20	15.Jan.2015

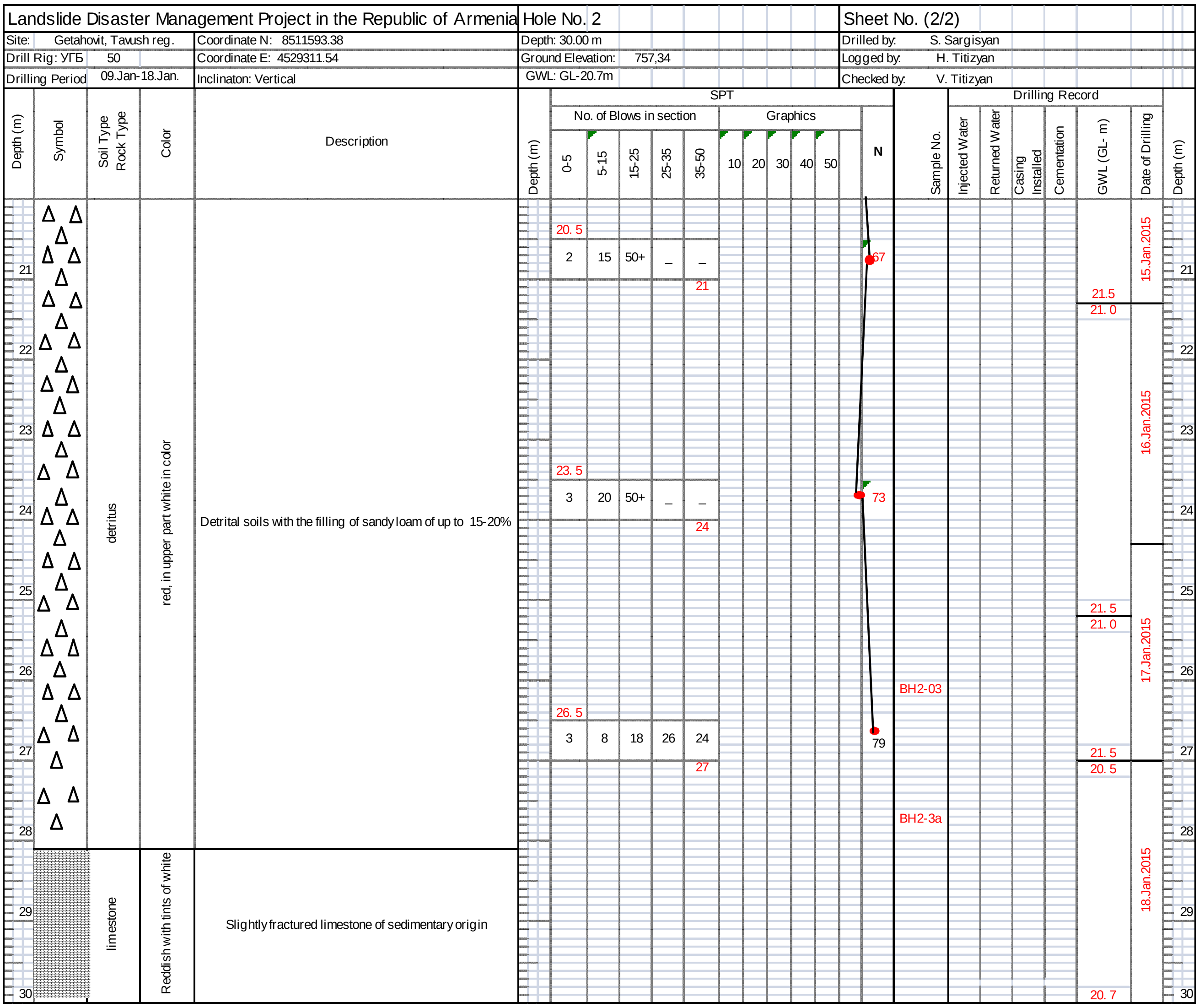


Figure 3.2.9: Section of Borehole Getahovit BH2

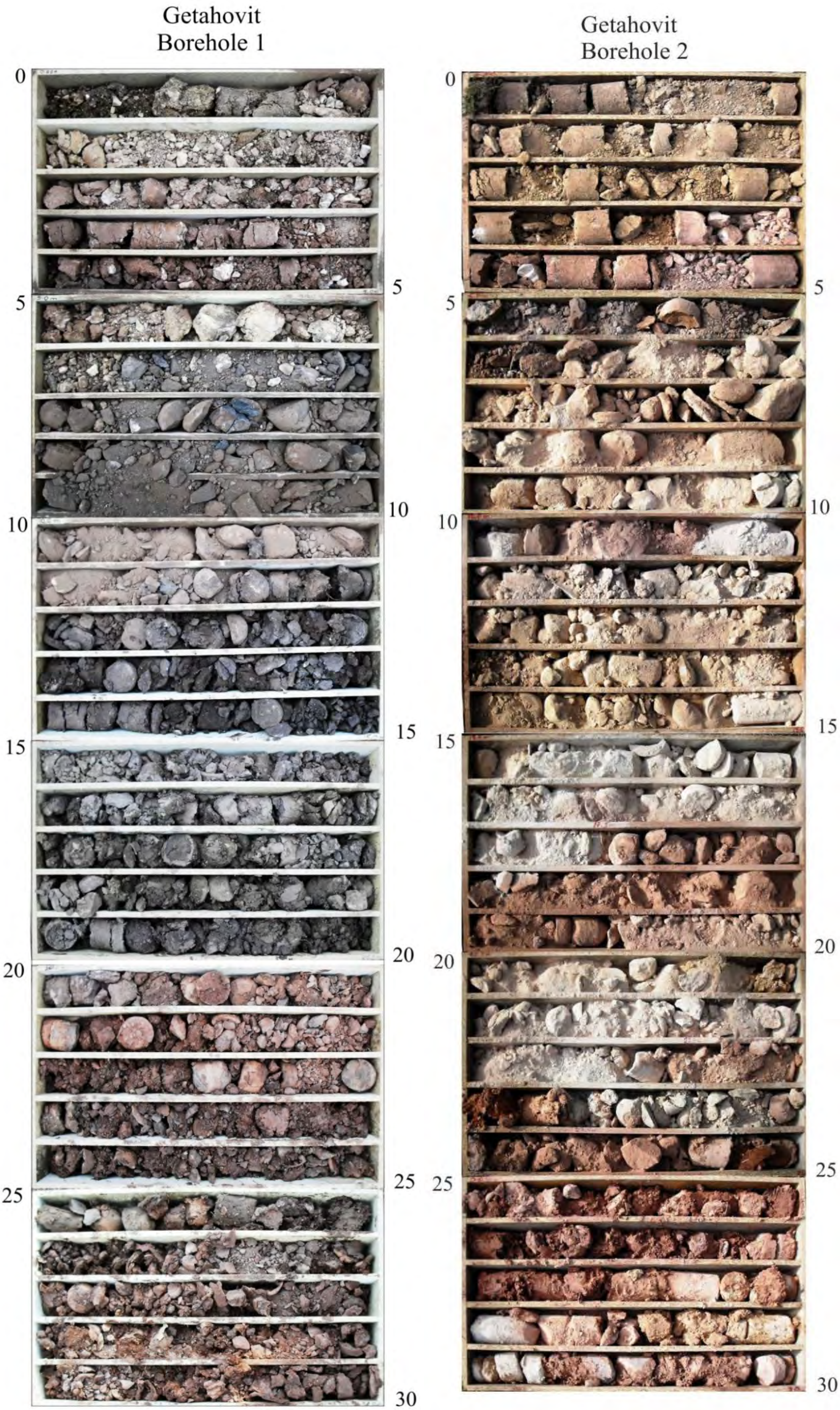


Figure 3.2.10: Core recovered from Boreholes BH1 and BH2

3.3 Laboratory Tests

The twelve samples collected from all 4 boreholes as set forth in the Technical Specifications were tested according to the layout shown in Table 3.3.1. Of the 6 samples taken at the Getahovit community landslide site, it appeared possible to perform torsion and uni-axial compression tests for 4 samples only, considering that the texture of soils had made it impossible to collect undisturbed (monolith) specimens of natural structure to meet the requirements of the standard by diameter, height and internal structure.

The estimations of the specific weight, Atterberg's limits and granulometry (grain-size) composition of the samples, as well as double-hydrometer tests were carried out according to ASTM standards. The moisture content, torsion and uni-axial compression tests were carried out according to the national standards adopted in the RA (GOST). Descriptions of the tests and the data obtained are shown below.

Table 3.3.1

Location	Borehole	Depth, m	Sample No	Moisture content	Specific gravity	Atterburg limits	Grain size/sieve analysis and hydrometer test	Double hydrometer test	Torsion test	Uni-axial compression strength	X-ray diffraction of clay minerals	Exchangeable sodium percentage
				1	2	3	4	5	6	7	8	9
ARAPI	BH-1	10.3-10.5	No. 1	+	+	+	+	+	+	+	+	+
	BH-1	19.2-19.3	No. 2	+	+	+	+	+	+	+	-	-
	BH-1	29.0-29.2	No. 3	+	+	+	+	-	+	+	-	-
	BH-2	10.3-10.5	No. 1	+	+	+	+	+	+	+	-	-
	BH-2	20.4-20.8	No. 2	+	+	+	+	+	+	+	+	+
	BH-2	29.5-29.7	No. 3	+	+	+	+	-	+	+	-	-
GETAHOVIT	BH-1	5.0-5.3	No. 1	+	+	+	+	+	+	+	-	-
	BH-1	17.0-17.2	No. 2	+	+	+	+	+	-	-	+	+
	BH-1	25.0-25.5	No. 3	+	+	+	+	-	+	+	-	-
	BH-2	5.0- 5.5	No. 1	+	+	+	+	-	+	+	-	-
	BH-2	15.0-15.5	No. 2	+	+	+	+	+	-	-	-	-
	BH-2	26.0-26.2	No. 3	+	+	+	+	+	+	+	+	+

The physical properties of the test specimens, such as density and moisture, were measured in accordance with the national standards adopted in the RA (GOST), and the same standards were applied in conducting the uni-axial compression strength, torsion, exchangeable sodium percentage and X-ray diffraction tests.

Density was estimated according to *GOST **22733-77.** Soils. A laboratory method for determining maximum density.*

Moisture content was measured according to GOST **5180-75**, which set the temperature of drying of the tested specimens at 105±2^0 C and 80±2^{0}C for clay and sand soils, and for soils containing organic compounds, respectively. Moisture content was estimated by the formula of $W=(m_1-m_2)/(m_2-m_0)$, where m_1 corresponded to the mass of moist soil with container, and m_2 corresponded to the mass of dry soil.

Shear Strength tests were performed under water-saturated and consolidated-drained condition by means of M-5 torsion test device in compliance with the Armenian standard ***ՀՄՏ 178-99 (Soils. Laboratory method for determining strength characteristics by torsion***). M-5 testing device (Fig. 3.3.2) is designated for consolidation and torsion tests of solid cylindrical specimens having 101 mm in diameter and the height of h=24 mm. From outside, tested specimen is surrounded with protective rings that rotate independently one of another, which in the course of preliminary consolidation and also in the course of torsion of the specimen prevent the possibility of its lateral extension. Samples can be tested under the action of normal stresses up to 2.5 MPa.

Uni-axial compression tests were performed by means of ZD10/90 hydraulic press in compliance with ***GOST 12248-96. Soils. Laboratory methods for determining the strength and strain characteristics***. The tests were done using cylindrical specimens; each specimen had the height of h=8-10 mm and the section area of F=25 cm^2 (Fig. 3.3.3).

For the *Arapi* landslide site***,*** it is possible to identify two *engineering geology elements:* EGE-1, which is represented by diatomaceous clays and EGE-2 represented by diatomites. Their physical properties are described in Table 3.3.2.

By its plasticity number varying in the range of 0.460-0.690, EGE-1 is represented by clays; the mean value is 0.565. The density varies in the range of 1.65-1.54 g/cm^3 and the mean value corresponds to 1.59 g/cm^3. The porosity ratio varies from 1.370 to 1.438, with the mean value of 1.370, so the soils are considered to have high rate of porosity. The consistence index varies in the range of 0.243-0.086; the mean value corresponds to 0.180, i.e., semi-solid consistence. By the rate of moisture, the soils are in water-saturated condition; the rate varies from 0.872 to 0.99; the mean value equals 0.920.

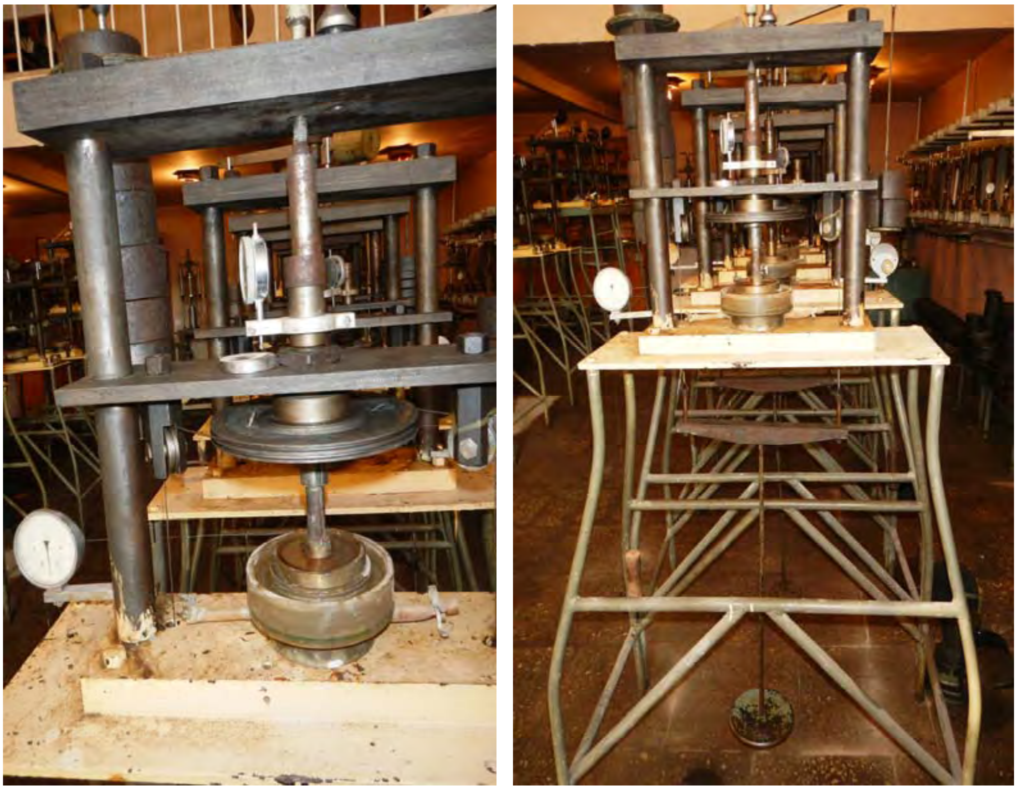


Figure 3.3.2: Torsion test device of M-5 type

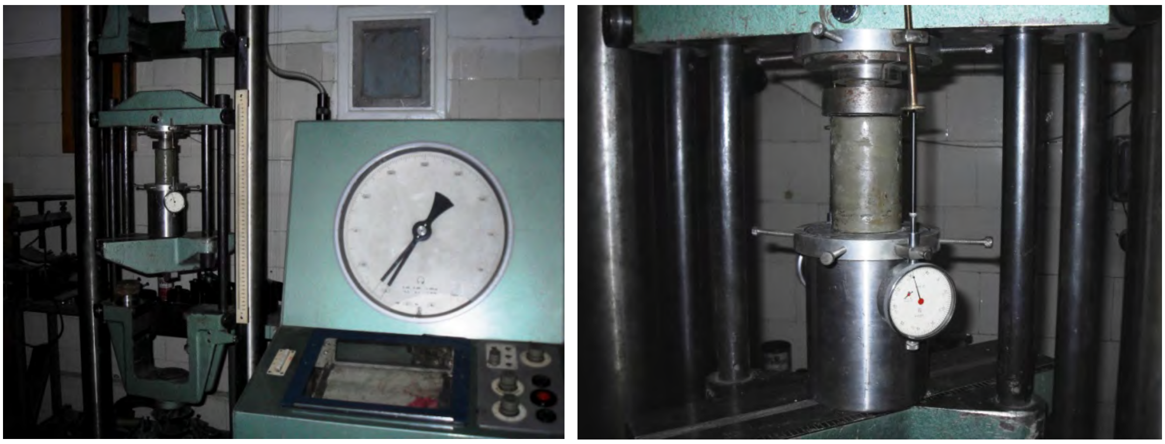


Figure 3.3.3: Hydraulic press ZD10/90 to measure compressive resistance

By its plasticity number, EGE-2 is represented by clays; the mean plasticity value equals to 0.760. The density is 1.425 g/cm^3 on average. The porosity ratio is 2,382 on average, so the soils are considered highly porous. The consistence index comprises 0.76 on average; hence this is a very soft (fluid-plastic) consistence. By the water saturation rate, the soils are in water-saturated state and the rate is 0.98 on average.

Shear strength tests of the diatomaceous clays and the diatomites were performed for 4 and 2 natural structure soil samples, respectively. The results produced by the shear strength tests of the diatomaceous clays and diatomites are presented in Table 3.3.3 and Table 3.3.4, respectively.

The compressive resistance (*R*) tests were realized on 4 and 2 natural structure soil samples of diatomaceous clays and diatomites, respectively. The results of testing are shown in Column 17, Table 1.

Data on the physical characteristics of soils within the *Getahovit* landslide site are incorporated in Table 3.3.5.

By the plasticity number, the soils are mostly clays with the exception of soil taken from Borehole BH1 (interval of 5.0-5.3 m, sandy loams). The soil sampled from the interval of 26.0-26.2m in Borehole BH2 was in semi-solid state (the fluidity index corresponded to I_L=0.55), while the rest of the soils are in solid state (the fluidity index corresponds to I_L<0). By water saturation rate, soils sampled from the intervals of BH1 5.0-5.3 m and BH2 5.0-5.5 m are in moist state (Sr=0.467 and 0.643), while the soils sampled from other intervals are in water-saturated state (Sr>0.8).

Shear strength tests were carried out on 4 natural (undisturbed) structure soils samples. The results of shear strength tests of the soils (normative and estimated indices) are demonstrated in Tables 3.3.6 - 3.3.9.

Table 3.3.2

Таблица физических характеристик грунтов Tables of physical characteristics of the soil

Объект **Арапи** Object **Arapi**

№ скважины Borehole №	№ образца Sample №	Глубина, м Depth, m	Наименование грунта Name of the soil	Плотность, г/см³ Density, g/cm³: Естественная Natural	Плотность, г/см³ Density, g/cm³: Частиц грунта Specific gravity	Плотность, г/см³ Density, g/cm³: Сухого грунта Dry soil	Влажность, % Moisture content, %	Показатели пластичности Plasticity characteristic: Граница текучести, % Liquid limit, %	Показатели пластичности Plasticity characteristic: Граница пластичности, % Plastic limit, %	Показатели пластичности Plasticity characteristic: Число пластичности, % Plasticity index, %	Показатели пластичности Plasticity characteristic: Показатель текучести Liquidity index	Пористость Porosity	Коэфф. пористости Void ratio	Влажность в водонас. состоянии Moisture saturated soil	Степень влажности Saturation	Предел прочности на одноосное сжатие, кПа Uniaxial compressive resistance, kPa
				ρ	ρ_s	ρ_d	W	W_L	W_p	I_p	I_L	n	e	W_{sat}	S_r	R
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	10.0-10.3	Диатомитовая глина Diatomaceous clay	1,54	2,47	1,0132	52,0	101,9	47,3	54,6	0,086	58,98	1,4379	58,22	0,89	140
1	2	19.0-19.2		1,57	2,54	1,063	47,7	84,8	38,8	46,0	0,193	58,15	1,3895	54,71	0,87	160
2	1	10.0-10.3		1,65	2,57	1,0714	54,0	106,2	37,2	69,0	0,243	58,31	1,3987	54,42	0,99	220
2	2	20.0-20.3		1,595	2,54	1,0719	48,8	95	38,8	56,2	0,178	57,8	1,3696	53,92	0,91	200
Средние значения			**Average value**	**1,589**	**2,53**	**1,055**	**50,63**	**96,98**	**40,53**	**56,45**	**0,18**	**58,3**	**1,399**	**55,32**	**0,92**	**180**
1	3	29.0-29.2	Диатомит Diatomite	1,35	2,36	0,6611	104,2	115	55	60,0	0,820	71,99	2,5697	108,89	0,96	280
2	3	29.5-29.7		1,5	2,59	0,8108	85,0	106,2	37,2	69,0	0,693	68,69	2,1943	84,72	1,00	250
Средние значения			**Average value**	**1,425**	**2,475**	**0,736**	**94,6**	**110,6**	**46,1**	**64,5**	**0,76**	**70,3**	**2,382**	**96,80**	**0,98**	**265**

$\rho_d = \rho/(1 + 0.01W)$; $I_p = W_L - W_p$; $I_L = (W - W_p)/I_p$; $n = 100\{1 - \rho/[\rho_s(1 + 0.01W)]\}$;

$e = n/(100 - n)$; $W_{sat} = 100(\rho_s - \rho_d)\rho_w/(\rho_s \rho_d) = 100n/[\rho_s(100 - n)]$; $S_r = W/W_{sat}$.

Table 3.3.3

Результаты испытаний грунта на сдвиг

The test results of soil shear

Object **Arapi** Soil **Diatomaceous clay**

BH-1	BH-1	BH-2	BH-2
Depth, m 10.0-10.3	Depth, m 19.0-19.2	Depth, m 10.0-10.3	Depth, m 20.0-20.3

N	1	2	3	4	5	6	7	8
σ, kPa	98,1	98,1	196,2	196,2	392,4	392,4	98,1	98,1
τ, kPa	58,86	49,05	98,10	87,31	137,34	135,38	58,9	44,1
N	9	10	11	12	13	14	15	16
σ, kPa	196,2	196,2	392,4	392,4	98,1	98,1	196,2	196,2
τ, kPa	98,10	77,50	147,15	132,44	68,67	58,86	98,1	86,3
N	17	18	19	20	21	22	23	24
σ, kPa	392,4	392,4	98,1	98,1	196,2	196,2	392,4	392,4
τ, kPa	139,30	132,44	68,67	53,96	112,82	96,14	157,0	146,2

??????????? ????????

Regulatory value

φ, °	tgφ	c, kPa	c, kg/cm²
15,45	**0,276**	**34,34**	**0,35**

????????? ????????

Design value

$φ_I$, °	tg$φ_I$	c_I, kPa	c, kg/cm²
14,49	**0,258**	**32,10**	**0,33**

Коэффициент надежности по грунту Safety factor for soil **1,07**

Среднее квадратичное отклонение Root mean square deviation **10,05** кПа kPa

Коэффициент корреляции Correlation coefficient **0,962**

Количество экспериментальных точек The number of experimental points **24**

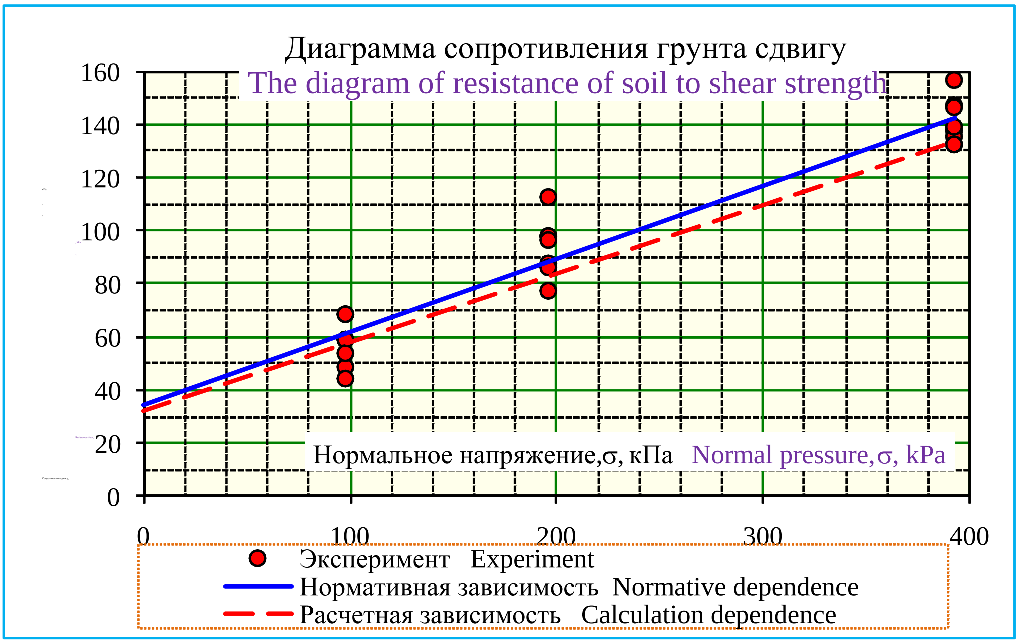


Table 3.3.4

Результаты испытаний грунта на сдвиг
The test results of soil shear

Object **Arapi** Soil **Diatomit**

BH-1	BH-2
Depth, m 29.0-29.2	Depth, m 29.5-29.7

№	1	2	3	4	5	6
σ, кПа	98,1	196,2	392,4	98,1	196,2	392,4
τ, кПа	83,39	115,76	196,20	73,58	98,10	191,30

Нормативные величины
Regulatory value

φ,°	tgφ	c, кПа kPa	c, кгс/см^2 kg/cm^2
21,75	**0,399**	**35,07**	**0,36**

Расчетные величины
Design value

$φ_I$,°	$tgφ_I$	c_I, кПа kPa	c_I, кгс/см^2 kg/cm^2
19,30	**0,350**	**30,78**	**0,31**

Коэффициент надежности по грунту Safety factor for soil **1,14**

Среднее квадратичное отклонение Root mean square deviation **9,27** кПа kPa

Коэффициент корреляции Correlation coefficient **0,988**

Количество экспериментальных точек The number of experimental points **6**

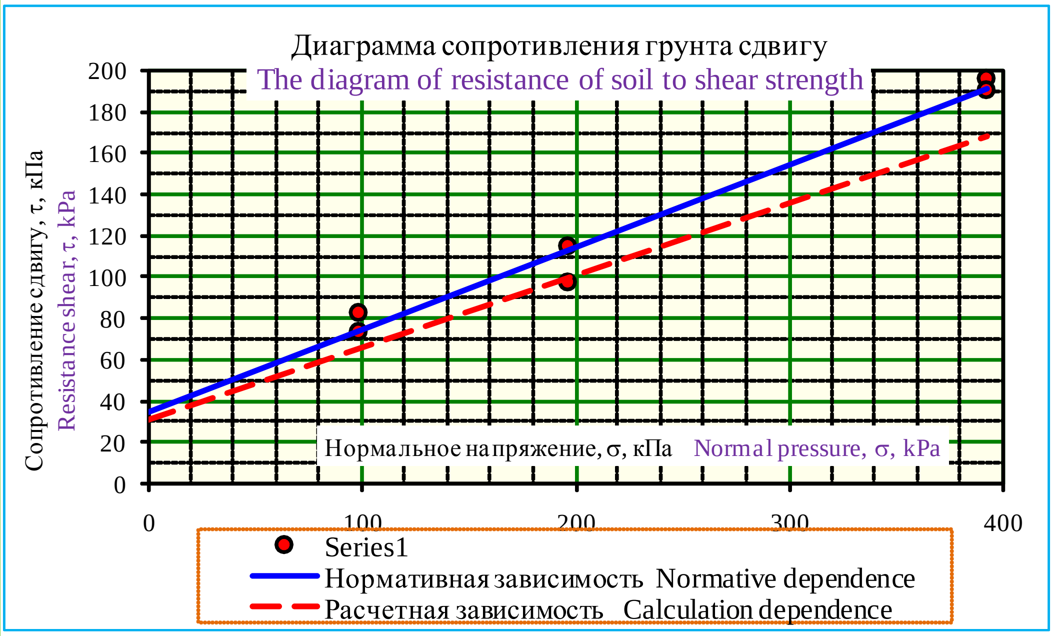


Table 3.3.5

Таблица физических характеристик грунтов Tables of physical characteristics of the soil

Объект **Гетаовит** Object **Getahovit**

№ скважины Borehole №	№ образца Sample №	Глубина, м Depth, m	Наименование грунта Name of the soil	Плотность, г/см³ Density, g/cm³			Влажность, Moisture content	Показатели пластичности Plasticity characteristic				Пористость Porosity	Коэфф. пористости Void ratio	Влажность в водонас. состоянии Moisture saturated soil	Степень влажности Saturation	Предел прочности на одноосное сжатие, кПа Uniaxial compressive resistance, kPa
				Естественная Natural	Частиц грунта Specific gravity	Сухого грунта Dry soil		Граница текучести Liquid limit	Граница пластичности Plastic limit	Число пластичности Plasticity index	Показатель текучести Liquidity index					
				ρ	ρ_s	ρ_d	W	W_L	W_p	I_p	I_L	n	e	W_{sat}	S_r	R
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	5.0-5.3	Глинистый грунт телесного цвета Flesh color clay soil	1,70	2,71	1,490	0,141	0,337	0,225	0,112	-0,750	0,450	0,819	0,302	0,467	250
1	2	17.0-17.2	Глинистый грунт темно-пепельного цвета с щебнем Dark ashy clay soil with rubble	2,09	2,59	1,813	0,153	0,364	0,161	0,2	-0,039	0,300	0,429	0,166	0,924	-
1	3	25.0-25.5	Глинистый грунт коричневого цвета с красным оттенком Clayey soil brown with red tint	1,96	2,66	1,624	0,207	0,61	0,24	0,4	-0,089	0,390	0,638	0,240	0,863	400
2	1	5.0-5.5	Глинистый грунт светлокоричневого цвета с телесным оттенком Light brown clay soil color skin tones	1,9	2,75	1,641	0,158	0,442	0,203	0,2	-0,188	0,403	0,676	0,246	0,643	200
2	2	15.0-15.5	Глинистый грунт телесного цвета с щебнем Flesh color clay soil with rubble	-	2,64	_	0,064	0,37	0,155	0,2	-0,423	-	-	-	-	-
2	3	26.0-26.2	Глинистый грунт коричневого цвета Clayey soil with brown	2,09	2,76	1,797	0,163	0,371	0,151	0,2	0,055	0,349	0,536	0,194	0,840	220

$\rho_d = \rho/(1 + W)$; $I_p = W_L - W_p$; $I_L = (W - W_p)/I_p$; $n = 1 - \rho/[\rho_s(1 + W)]$;

$e = n/(1 - n)$; $W_{sat} = (\rho_s - \rho_d)\rho_w/(\rho_s \rho_d) = n/[\rho_s(1 - n)]$; $S_r = W/W_{sat}$.

Результаты испытаний грунта на сдвиг
The test results of soil shear

Object **Getahovit** Soil **Flesh color clay soil**

BH-1
Depth, m 5.0-5.3

№	1	2	3	4	5	6
σ, кПа	98.1	98.1	196.2	196.2	392.4	392.4
τ, кПа	83.39	71.61	122.63	115.76	186.39	171.68

Нормативные величины
Regulatory value

φ,°	tgφ	c, кПа kPa	c, кгс/см² kg/cm²
18.74	**0.339**	**47.58**	**0.49**

Расчетные величины
Design value

$φ_I$,°	tg$φ_I$	c_I, кПа kPa	c_I, кгс/см² kg/cm²
16.76	**0.301**	**42.24**	**0.43**

Коэффициент надежности по грунту Safety factor for soil **1.13**

Среднее квадратичное отклонение Root mean square deviation **8.37** кПа kPa

Коэффициент корреляции Correlation coefficient **0.987**

Количество экспериментальных точек The number of experimental points **6**

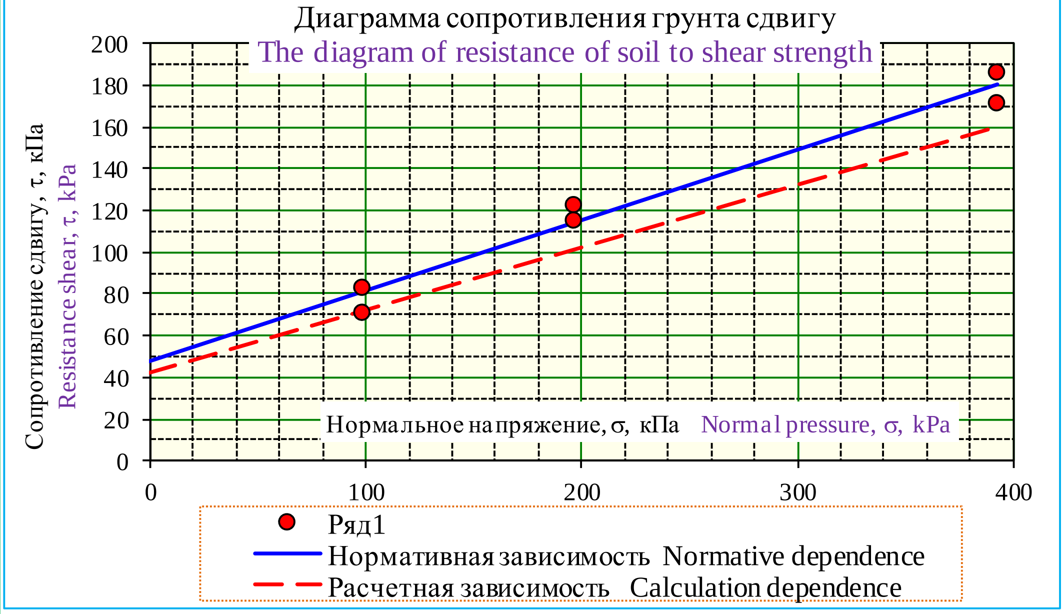


Table 3.3.7

Результаты испытаний грунта на сдвиг

The test results of soil shear

Object **Getahovit** Soil **Clayey soil brown with red tint**

BH-1
Depth, m 25.0-25.5

№	1	2	3	4	5	6
σ, кПа	98,1	98,1	196,2	196,2	392,4	392,4
τ, кПа	93,20	80,93	137,34	127,53	220,73	171,68

Нормативные величины
Regulatory value

φ,°	tgφ	c, кПа kPa	c, кгс/см² kg/cm²
20,02	**0,364**	**55,18**	**0,56**

Расчетные величины
Design value

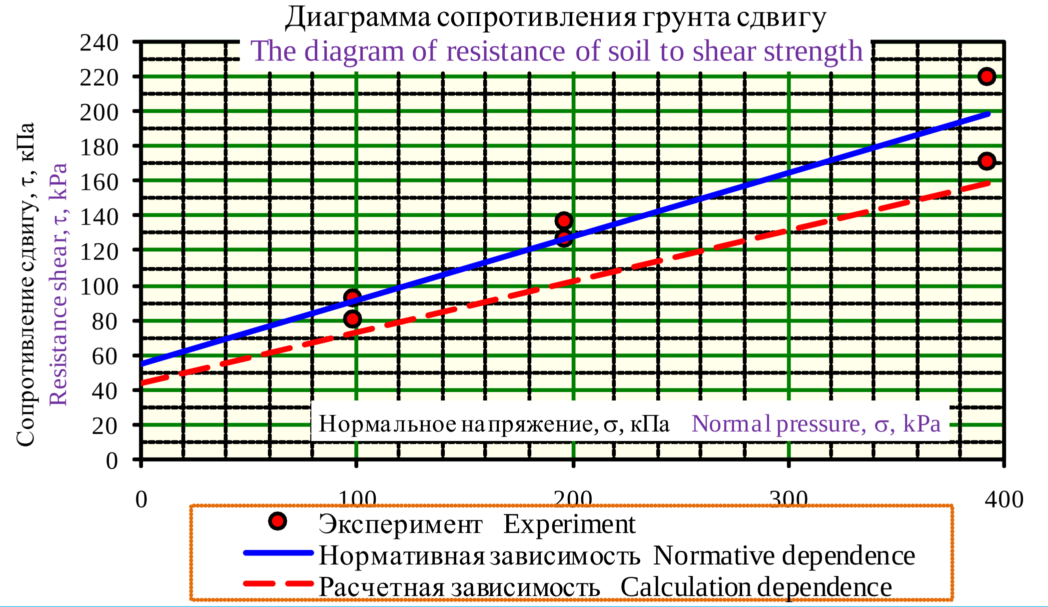
$φ_I$,°	tg$φ_I$	c_I, кПа kPa	c_I, кгс/см² kg/cm²
16,25	**0,291**	**44,15**	**0,45**

Коэффициент надежности по грунту Safety factor for soil **1,25**

Среднее квадратичное отклонение Root mean square deviation **18,91** кПа kPa

Коэффициент корреляции Correlation coefficient **0,945**

Количество экспериментальных точек The number of experimental points **6**



Результаты испытаний грунта на сдвиг
The test results of soil shear

Object **Getahovit** Soil **Light brown clay soil color skin tones**

BH-2
Depth, m 5.0-5.5

№	1	2	3	4	5	6
σ, кПа	98,1	98,1	196,2	196,2	392,4	392,4
τ, кПа	80,93	68,67	107,91	85,84	191,30	169,22

Нормативные величины
Regulatory value

φ,°	tgφ	c, кПа kPa	c, кгс/см² kg/cm²
20,20	**0,368**	**33,11**	**0,34**

Расчетные величины
Design value

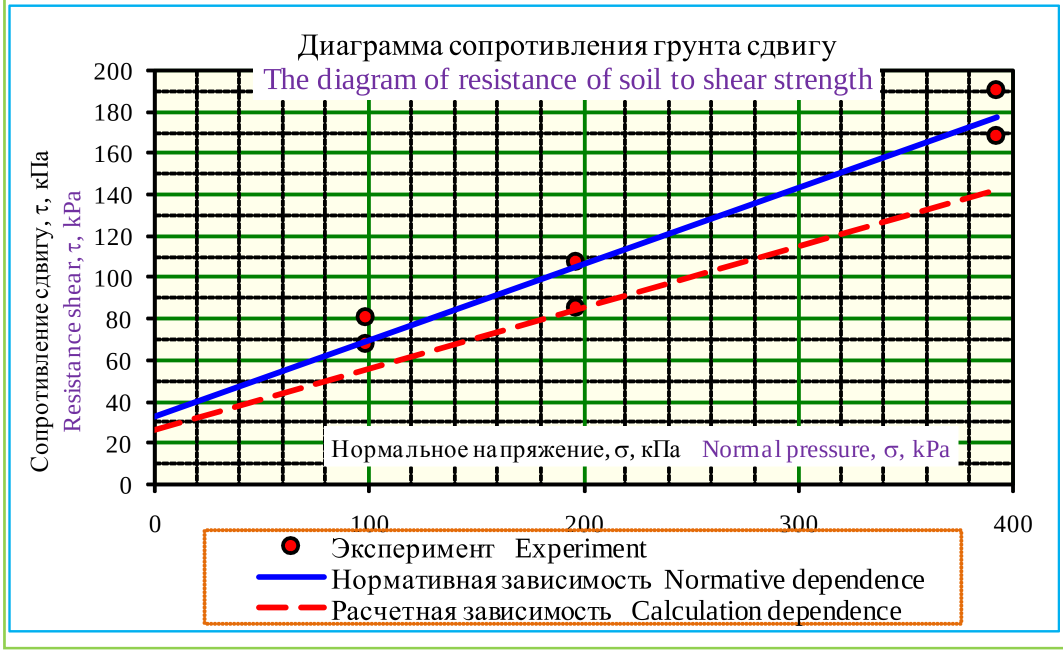
φ_I,°	tgφ_I	c_I, кПа kPa	c_I, кгс/см² kg/cm²
16,42	**0,295**	**26,52**	**0,27**

Коэффициент надежности по грунту Safety factor for soil **1,25**

Среднее квадратичное отклонение Root mean square deviation **13,99** кПа kPa

Коэффициент корреляции Correlation coefficient **0,969**

Количество экспериментальных точек The number of experimental points **6**



Результаты испытаний грунта на сдвиг

The test results of soil shear

Object **Getahovit** Soil **Clayey soil with brown**

BH-2
Depth, m 26.0-26.2

№	1	2	3	4	5	6
σ, кПа	98.1	98.1	196.2	196.2	392.4	392.4
τ, кПа	100.55	78.48	127.53	110.36	215.82	179.03

Нормативные величины
Regulatory value

φ,°	tgφ	c, кПа kPa	c, кгс/см² kg/cm²
20.38	**0.371**	**50.28**	**0.51**

Расчетные величины
Design value

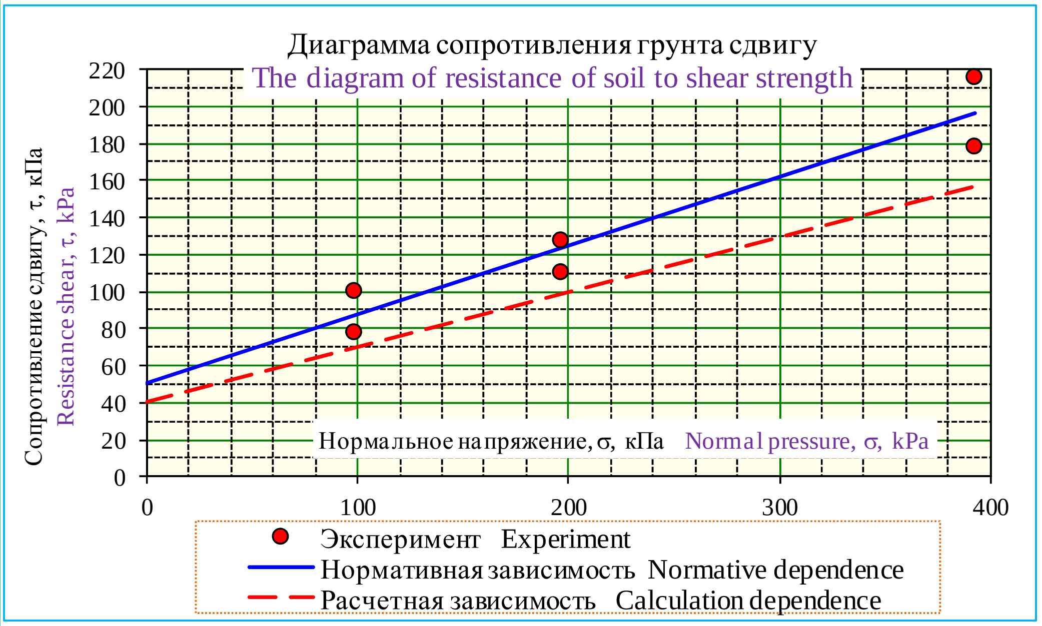
φ_I,°	$tg\varphi_I$	c_I, кПа kPa	c_I, кгс/см² kg/cm²
16.55	**0.297**	**40.22**	**0.41**

Коэффициент надежности по грунту Safety factor for soil **1.25**

Среднее квадратичное отклонение Root mean square deviation **16.75** кПа kPa

Коэффициент корреляции Correlation coefficient **0.958**

Количество экспериментальных точек The number of experimental points **6**



The measurement of exchangeable sodium percentage in soils (ESP) was carried out according to GOST 26950-86 and ISO 9961-3 standards. The results are shown in Table 3.3.10.

Table 3.3.10

№	Landslide Site	Borehole №	Exchangeable Cations mg-equivalent/100g				Exchangeable Na,equivalent -%	Salinity
			Na^+	K^+	Ca^{2+}	Mg^{2+}		
1	ARAPI	BH 1-1(10,3-10,5m)	1,71	2,82	27,44	22,07	3,16	low saline
2	ARAPI	BH 2-2 (20,4-20,8m)	1,30	2,86	26,95	26,48	2,26	low saline
3	GETAHOVIT	BH 1-2a(15,0-15,5m)	3,18	1,41	15,68	9,81	10,57	medium saline
4	GETAHOVIT	BH 2-3a(27,7-27,8m)	0,17	1,58	15,68	5,40	0,75	low saline

The core of the measurement technique is extraction of exchangeable and dissolved sodium. In case of exchangeable Na, the extraction is performed by means of ammonium solution in acetic acid (1 mole/dm^3 concentration), at the soil *versus* reagent ratio of 1:20, and in case of dissolved Na - by means of water extract (GOST 26950-86). Further determination of sodium in the extract is performed by the flame-emission technique (ISO 9961-3). In gypsum-bearing soil samples, dissolved Na is measured using water-alcohol solution.

The existing standard is applicable for soils, covering and host rocks, and sets the exchangeable sodium estimation technique for studies of soils, agrochemical and land reclamation investigations, soil condition monitoring, as well as other types of studies and investigations.

Exchangeable sodium demonstrates the rate of soil compaction and salinity. High rates of exchangeable sodium have an impact also on the physical properties of the soil.

In case the equivalent amount of exchangeable sodium in soil corresponds to 3-10% of the total exchangeable cations, the soil is considered low saline, respective percents of 10-15%, 15-20% and >20%` correspond to medium, strong salinity and saline soils. By the exchangeable Na index, the tested soils are related to the category of low-to-medium saline soils.

X-ray diffraction test

The X-ray-phase analysis was performed using URD3 diffractometer with CuKα radiation and Ni filter. The analysis of diffraction patterns was carried out by means of JCPDS-ICDD 2004 catalogue. The analysis was conducted for 4 samples – Arapi BH-1, Arapi BH-2, Getahovit BH-1 and Getahovit BH-2. Each sample was first crushed and photographed in 2Θ=4-90° (1) interval. Then these samples were dissolved in water, kept for 8 hours and then centrifuged and photographed in the interval of 2Θ=4-30° (2). Then drops of ethylene glycol were poured on them, the samples were kept for 6 hours and again photographed in the interval of 2Θ=4-30° (3). The study revealed that the samples were amorphous, and the crystalline mass took up about 5-7%. The 2nd and the 3rd diffraction patterns had been almost unchanged as compared with diffraction pattern 1; the amorphous phase had been added only.
The graphical data of the tests are presented in Annex 3.

Results of the analyzes

Arapi BH-1 (Sample 1, Interval of 10.3-10.5 m)

1.

Table 3.3.11

##	Mineral Name	d/n	2Θ	Card Number
1	montmorillonite	11,9; 4,52;2,60	7,43; 19,64; 34,35	12-0232
2	palygorskite	10,3; 6,34	8,5; 13,9	82-1872
3	kaolinite	7,15	12,38	75-1593
4	$CaCO_3$	3,03; 1,91; 1,87	29,4; 47,6; 48,65	85-1108
5	SiO_2	3,33	26,7	86-1628
6	Traces of gypsum	7,60	11,65	74-1433

2.

1. montmorillonite
2. palygorskite
3. kaolinite

3. As compared to N 2, peaks had become a little bit wider and shifted.

Arapi BH-2 (Sample 2, Interval of 20.4-20.8 m)

1.

Table 3.3.12

##	Mineral Name	d/n	2Θ	Card Number
1	Analcime	5,60; 3,43	15,8; 25,9	83-1732
2	Palygorskite	10,36,34	8,5; 13,9	82-1872
3	Traces of bentonite	15,0	5,9;	03-0015
4	$CaCO_3$	3,03; 1,91; 1,87	29,4; 47,6; 48,65	85-1108
5	SiO_2	3,33	26,7	86-1628

2.

1. Analcime
2. Palygorskite
3. As compared with 2, the sample had not been changed essentially.

Getahovit BH-1 (Sample 2a, Interval of 15.0-15.2 m)

1.

Table 3.3.13

##	Mineral Name	d/n	2Θ	Card Number
1	Fe_2O_3	2,70; 2,52	33,2; 35,6	86-0550
2	Palygorskite	10,36; 6,34	8,5; 13,9	82-1872
3	Dolomite, ferron	2,90	30,79	34-0517
4	Ferropargasite	8,50; 3,15	10,4; 28,3	26-1372
5	analcime	5,60; 3,43	15,8; 25,9	83-1732
6	$CaCO_3$	3,03;1,91; 1,87	29,4; 47,6; 48,65	85-1108
7	SiO_2	3,33	26,7	86-1628

2.

1.Dolomite, ferron

2. Palygorskite

3.Fe_2O_3

4. Ferropargasite

3. As compared with 2, the sample had not been changed essentially.

Getahovit BH-2 (Sample 3a , Interval of 27.7-27.8 m)

1.

Table 3.3.14

##	Mineral Name	d/n	2Θ	Card Number
1	Gonnardite	6,70; 3,57; 2,91	13,2; 24,9; 30,6	72-1822
2	Fe2O3	2,70; 2,52	33,2; 35,6	86-0550
3	Ferropargasite	8,50; 3,15	10,4; 28,3	26-1372
4	Palygorskite	10,36; 6,34	8,5; 13,9	82-1872
5	SiO_2	3,33	26,7	86-1628
6	Dolomite,ferron	2,90	30,79	34-0517

2.

1.Dolomite,ferron

2.SiO_2

3. Palygorskite

3. As compared with 2, the sample had not been changed essentially.

PDF # 020014, Wavelength = 1.54184 (A)

02-0014 (Deleted)

CAS Number:

Molecular Weight: 169.38

Volume[CD]:

Dx: Dm:

Sys:

S.G.:

Cell Parameters:

a b c

α β γ

SS/FOM: F = (,)

I/Icor:

Rad: MoKa

Lambda: 0.709

Filter:

d-sp:

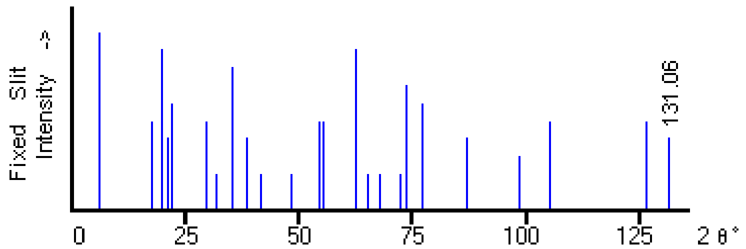
Mineral Name:

Montmorillonite (Clay)

Na Mg Al Si O2 (O H) H2 O

Sodium Magnesium Aluminum Silicate Hydroxide Hydrate

Ref: Z. Kristallogr., 87, 133 (1934)



2θ	Int-f	h	k	l	2θ	Int-f	h	k	l	2θ	Int-f	h	k	l
5.892	100b				29.380	50				48.418	20b			
17.739	50				31.846	20b				54.280	50			
19.953	90				35.482	80b				55.344	50			
20.902	40				38.471	40				62.316	90			
21.947	60				41.419	20				65.245	20b			

The following tests were carried out in accordance with **ASTM** standards:

Atterberg limits - Atterberg limit testing conforms to ASTM D4318 - Standard test method for liquid limit, plastic limit, and plasticity index of soils.

Grain size/sieve and hydrometer test – Wet sieve analysis and hydrometer testing conforms to ASTM D422 - standard test method for particle-size analysis of soil.

Dispersive characteristics/double hydrometer test – This test method is similar to the ASTM D422 test method, except that this method covers the determination of the percent of soil particles smaller than 5-μm in diameter in a soil-water suspension without mechanical agitation and to which no dispersing agent has been added.

Double hydrometer testing conforms to ASTM D4221- standard test method for dispersive characteristics of clay soil by double hydrometer.

The tests were performed using high-quality testing equipment imported from the United Kingdom (ELE International – www.ele.com).

The equipment and facilities used for the determination of *moisture content* of soil are the following: drying oven (EL78-1320/01), balance (EL78-5527/01), desiccator (EL82-2100), moisture content tin plates, gloves, and spatula.

The apparatus used for the determination of *specific gravity* is comprised of water pycnometer (EL24-2900), balance, drying oven, thermometer, desiccator-vacuum, sieve, and spatula.

The equipment and facilities used for the *Atterberg limits* are:

Liquid limit device: Casagrande cup (EL24-0434), evaporating dish, flat grooving tool with gage, moisture cans, balance, glass plate, spatula, wash bottle filled with distilled water, drying oven.

Plastic limit equipment: Moisture cans, balance, glass plate, spatula, wash bottle filled with distilled water, drying oven.

The *sieve analysis* was performed using the following equipment: drying oven, balance, gloves, ASTM sieves, sieve shaker, riffle boxes, sieve brush.

The *hydrometer test* was performed using the following equipment: stirring apparatus (EL24-4125/01), hydrometer **(**EL24-4640**),** sedimentation cylinder (EL24-4700), thermometer, sieves, water bath (EL24-4865/01), balance, oven, beaker, timing device.

The equipment and facilities used for the *double hydrometer test* are the following: sieve - 2.00-mm, balance, filtering flask—500-mL filtering flask with a rubber stopper and a side tube capable of withstanding a vacuum, vacuum pump, sedimentation cylinder, hydrometer, thermometer, timing device, drying oven.

Specific Gravity – The specific gravity of soil samples passed No. 4 (4.75 mm) sieve was determined by water pycnometers. The values of specific gravity are shown in Table 3.3.15.

Table 3.3.15. Specific gravity of the soil samples

Location	Borehole	Depth, m	Sample No.	Specific gravity
Arapi	BH-1	10.3-10.5	Sample No. 1	**2.47**
	BH-1	19.2-19.3	Sample No. 2	**2.54**
	BH-1	29.0-29.2	Sample No. 3	**2.36**
	BH-2	10.3-10.5	Sample No. 1	**2.57**
	BH-2	20.4-20.8	Sample No. 2	**2.54**
	BH-2	29.5-30.0	Sample No. 3	**2.59**
Getahovit	BH-1	5.0-5.3	Sample No. 1	**2.71**
	BH-1	17.0-17.2	Sample No. 2	**2.59**
	BH-1	25.0-25.5	Sample No. 3	**2.66**
	BH-2	5.0-5.5	Sample No. 1	**2.75**
	BH-2	15.0-15.5	Sample No. 2	**2.64**
	BH-2	26.0-26.2	Sample No. 3	**2.76**

The specific gravity test results are represented in detail in Appendix A.

Atterberg limits - The liquid limit, plastic limit and plasticity index of soil samples were determined according to ASTM D4318 standard. The results are shown in Table 3.3.16.

Table 3.3.16. Liquid limit, plastic limit and plasticity index of the soil samples

Location	Borehole	Depth, m	Sample No.	Liquid limit, %	Plastic limit, %	Plasticity index, %
Arapi	BH-1	10.3-10.5	Sample No. 1	**101.9**	**47.3**	**54.6**
	BH-1	19.2-19.3	Sample No. 2	**84.8**	**38.8**	**46.0**
	BH-1	29.0-29.2	Sample No. 3	**115**	**55**	**60.0**
	BH-2	10.3-10.5	Sample No. 1	**106.2**	**37.2**	**69.0**
	BH-2	20.4-20.8	Sample No. 2	**95.0**	**38.8**	**56.2**
	BH-2	29.5-30.0	Sample No. 3	**102.0**	**41.8**	**60.2**
Getahovit	BH-1	5.0-5.3	Sample No. 1	**33.7**	**22.5**	**11.2**
	BH-1	17.0-17.2	Sample No. 2	**36.4**	**16.1**	**20.3**
	BH-1	25.0-25.5	Sample No. 3	**61.0**	**24.0**	**37.0**
	BH-2	5.0-5.5	Sample No. 1	**44.2**	**20.3**	**23.9**
	BH-2	15.0-15.5	Sample No. 2	**37.0**	**15.5**	**21.5**
	BH-2	26.0-26.2	Sample No. 3	**37.1**	**15.1**	**22.0**

The Atterburg limits test results are represented in detail in Appendix B.

Grain Size Distribution and Double hydrometer test–The sieve analysis and hydrometer tests were carried out according to ASTM D422 standard.

The ASTM sieves and ASTM 152-H type hydrometer were used (Fig. 3.3.4).

Fig.3.3.4. ASTM Sieves and ASTM 152-H-type Hydrometer

The soil samples for particle size analysis were prepared according to ASTM D421 standard. The double hydrometer tests were carried out according to ASTM D4221 standard.

At first, hydrometer correction was done for obtaining meniscus correction (F_m), zero correction (F_Z) and temperature correction (F_T).

The results of sieve analysis, hydrometer tests and double hydrometer tests of samples are shown on pages 55-75. The results of the double hydrometer test are the average of two separate tests.

The graph for percent finer versus grain-size distribution obtained from both the sieve and the hydrometer analysis.

Sieve analysis

Location ____Arapi______ Borehole __BH-1___ Sample No. _1__ Depth __10.3 – 10.5 m___

Mass of oven dry specimen 100 g Date _12.12.2014

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
3/8 in.	9.5	0	0	0	100
4	4.75	0.5	0.5	0.5	99.5
6	3.35	0.2	0.2	0.7	99.3
8	2.36	0.2	0.2	0.9	99.1
18	1	0.4	0.4	1.3	98.7
40	0.425	0.6	0.6	1.9	98.1
60	0.25	0.3	0.3	2.2	97.8
120	0.125	0.4	0.4	2.6	97.4
200	0.075	0.2	0.2	2.8	97.2
	<0.075	97.2	97.2	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-1___ Sample No. __1__ Depth __10.3 – 10.5 m___

Dry weight of soil, W_s___50 g__ G_s__2.47___ Temperature__20°C__ Date _18.12.2014

Hydrometer type ASTM 152-H_ Meniscus correction, F_m_1_ Zero correction, Fz _+6 Temp. correction, F_T_+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	52	46,15	96,56	53	7,77	0.0144	0,056
1	52	46,15	96,56	53	7,77		0,040
2	52	46,15	96,56	53	7,77		0,028
4	51	45,15	94,47	52	7,93		0,020
8	50	44,15	92,38	51	8,09		0,014
15	48	42,15	88,20	49	8,42		0,011
30	46	40,15	84,01	47	8,75		0,008
60	43	37,15	77,73	44	9,24		0,006
120	40	34,15	71,46	41	9,73		0,004
240	38	32,15	67,27	39	10,06		0,003
480	36	30,15	63,09	37	10,39		0,002
1440	31	25,15	52,62	32	11,21		0,001

Double Hydrometer Test

Location ____Arapi_____ Borehole __BH-1___ Sample No. __1__ Depth __10.3 – 10.5 m___

Dry weight of soil, W_s ___25 g___ G_s __2.47___ Temperature__20 °C__ Date _22.12.2014

Hydrometer type ASTM 152-H_ Meniscus correction, F_m _1_ Zero correction, Fz _0_ Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	21	21,15	88,51	22	12,85	0.0144	0,073
1	21	21,15	88,51	22	12,85		0,052
2	21	21,15	88,51	22	12,85		0,037
4	20	20,15	84,32	21	13,01		0,026
8	19	19,15	80,14	20	13,18		0,018
15	17	17,15	71,77	18	13,51		0,014
30	16	16,15	67,58	17	13,67		0,010
60	12	12,15	50,85	13	14,33		0,007
120	3	3,15	13,18	4	15,80		0,005
240	0	0,15	0,63	1	16,29		0,004

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \% \ 100 \quad = \mathbf{17.7\ \%}$$

Conclusion: Percent Dispersion of sample No.1 (BH-1, 10.3-10.5m, Arapi) equals 17.7 %.

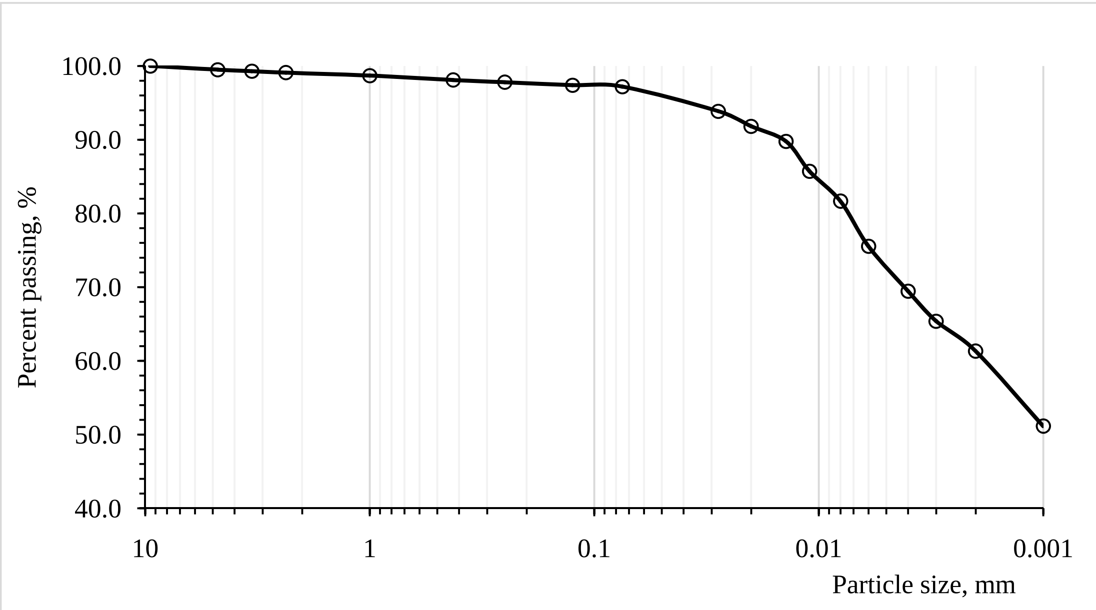


Fig. 3.3.5. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for the sample No.1 (BH-1, 10.3-10.5 m, Arapi)

Sieve analysis

Location ____Arapi______ Borehole __BH-1___ Sample No. _2__ Depth __19.2 – 19.3 m___

Mass of oven dry specimen 100 g Date _12.12.2014

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
3/8 in.	9.5	0	0	0	100
4	4.5	0	0	0	100
6	3.35	0	0	0	100
8	2.36	0	0	0	100
12	1.7	0	0	0	100
18	1	0.2	0.2	0.2	99.8
40	0.425	1.7	1.7	1.9	98.1
60	0.25	0.6	0.6	2.5	97.5
120	0.125	1.0	1.0	3.5	96.5
200	0.075	0.8	0.8	4.3	95.7
	<0.075	95.7	95.7	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-1___ Sample No. __2__ Depth __19.2 – 19.3 m___

Dry weight of soil, W_s ___50 g__ G_s __2.54___ Temperature__20 ^{o}C__ Date _22.12.2014

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	53	47,15	96,84	54	7,60	0.0141	0,055
1	53	47,15	96,84	54	7,60		0,039
2	53	47,15	96,84	54	7,60		0,027
4	52	46,15	94,79	53	7,77		0,020
8	51	45,15	92,73	52	7,93		0,014
15	50	44,15	90,68	51	8,09		0,010
30	45	39,15	80,41	46	8,91		0,008
60	43	37,15	76,30	44	9,24		0,006
120	40	34,15	70,14	41	9,73		0,004
240	37	31,15	63,98	38	10,23		0,003
480	35	29,15	59,87	36	10,55		0,002
1440	30	24,15	49,60	31	11,37		0,001

Double Hydrometer Test

Location ____Arapi_____ Borehole __BH-1___ Sample No. __2__ Depth __19.2 – 19.3 m___

Dry weight of soil, W_s ___25 g___ G_s __2.54___ Temperature __20 °C__ Date _23.12.2014

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, ($a*R_{cp}/50$)*100	R_{cL}	L (cm)	A	D (mm)
0.5	21	21,15	86,88	22	13,05	0.0141	0,072
1	21	21,15	86,88	22	13,05		0,051
2	21	21,15	86,88	22	13,05		0,036
4	20	20,15	82,77	21	13,21		0,026
8	19	19,15	78,66	20	13,37		0,018
15	17	17,15	70,45	18	13,70		0,013
30	15	15,15	62,23	16	14,03		0,010
60	12	12,15	49,91	13	14,52		0,007
120	10	10,15	41,69	11	14,85		0,005
240	5	5,15	21,16	6	15,67		0,004
480	2	2,15	8,83	3	16,16		0,003
1440	0	0,15	0,62	1	16,49		0,002

$$\%\ \text{Dispersion} = \frac{\%\ \text{passing}\ 5\ \mu\text{m (double hydrometer test)}}{\%\ \text{passing}\ 5\ \mu\text{m (hydrometer test)}}\ \%\ 100 = \frac{41.69}{73.22}\ \%100 = \mathbf{56.9\ \%}$$

Conclusion: Percent Dispersion of sample No.2 (BH-1, 19.2-19.3m, Arapi) equals 56.9 %.

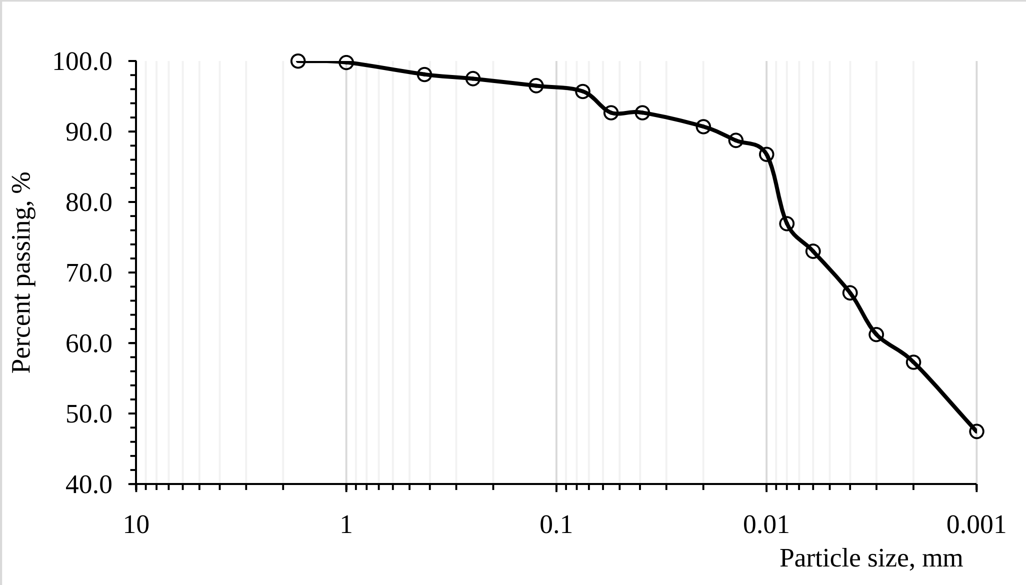


Fig.3.3.6. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.2 (BH-1, 19.2-19.3 m, Arapi)

Sieve analysis

Location ____Arapi______ Borehole __BH-1___ Sample No. _3__ Depth __29.0 – 29.2 m___

Mass of oven dry specimen 100 g Date _12.12.2014

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100\text{-}\Sigma R_n$
4	4.75	0	0	0	100
6	3.35	0.1	0.1	0.1	99.9
8	2.36	0.1	0.2	0.2	99.8
12	1.7	0.2	0.2	0.4	99.6
18	1	0.2	0.2	0.6	99.4
40	0.425	0.3	0.3	0.9	99.1
60	0.25	0.7	0.7	1.6	98.4
120	0.125	0.3	0.3	1.9	98.1
200	0.075	0.3	0.3	2.2	97.8
	<0.075	97.8	97.8	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-1___ Sample No. __3__ Depth __29.0 – 29.2 m___

Dry weight of soil, W_s ___50 g___ G_s __2.36___ Temperature__20 °C___ Date _22.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, (a*R_{cp}/50)*100	R_{cL}	L (cm)	A	D (mm)
0.5	49	43,15	93,24	50	8,26	0.015	0,061
1	48	42,15	91,08	49	8,42		0,044
2	48	42,15	91,08	49	8,42		0,031
4	47	41,15	88,92	48	8,59		0,022
8	46	40,15	86,76	47	8,75		0,016
15	44	38,15	82,44	45	9,08		0,012
30	40	34,15	73,80	41	9,73		0,009
60	37	31,15	67,31	38	10,23		0,006
120	32	26,15	56,51	33	11,05		0,005
240	28	22,15	47,86	29	11,70		0,003
480	25	19,15	41,38	26	12,19		0,002
1440	20	14,15	30,58	21	13,01		0,001

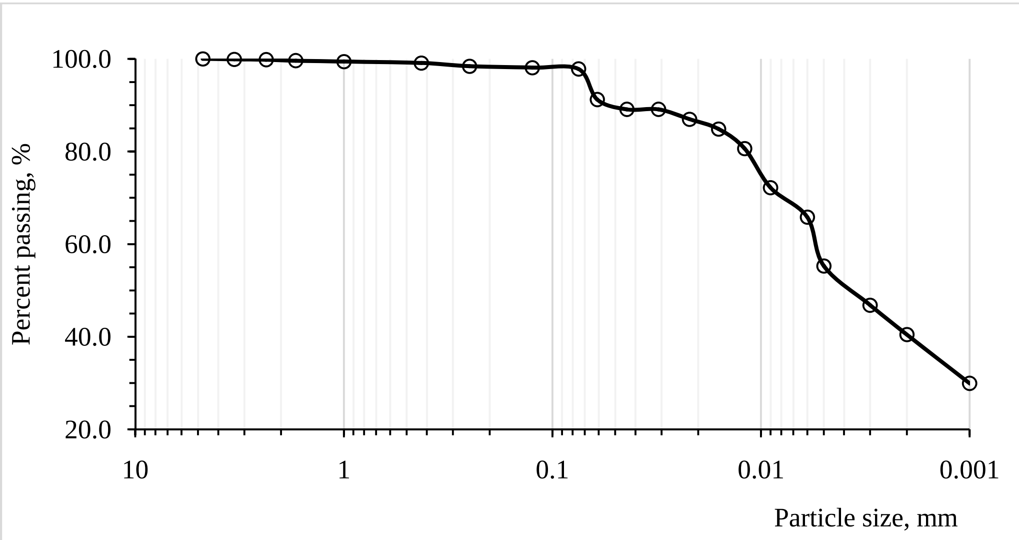


Fig.3.3.7. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.3 (BH-1, 29.0-29.2 m, Arapi)

Sieve analysis

Location ____Arapi______ Borehole __BH-2___ Sample No. _1__ Depth __10.3 – 10.5 m___

Mass of oven dry specimen 100 g Date _12.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, 100-ΣR_n
3/8 in.	9.5	0	0	0	100
4	4.75	0	0	0	100
6	3.35	0	0	0	100
8	2.36	0	0	0	100
12	1.7	0	0	0	100
18	1	0.1	0.1	0.1	99.9
40	0.425	0.6	0.6	0.7	99.3
60	0.25	0.4	0.4	1.1	98.9
120	0.125	0.3	0.3	1.4	98.6
200	0.075	0.3	0.3	1.7	98.3
	<0.075	98.3	98.3	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-2___ Sample No. __1__ Depth __10.3 – 10.5 m___

Dry weight of soil, W_s ___50 g__ G_s __2.57___ Temperature __20 ^oC__ Date _19.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.25	54	48,15	98,15	55	7,44	0.0140	0,075
0.5	54	48,15	98,15	55	7,44		0,054
1	54	48,15	98,15	55	7,44		0,038
2	53	47,15	96,11	54	7,60		0,027
4	52	46,15	94,07	53	7,77		0,020
8	51	45,15	92,04	52	7,93		0,014
15	50	44,15	90,00	51	8,09		0,010
30	46	40,15	81,84	47	8,75		0,008
60	44	38,15	77,77	45	9,08		0,005
120	42	36,15	73,69	43	9,41		0,004
240	39	33,15	67,57	40	9,90		0,003
480	37	31,15	63,50	38	10,23		0,002
1440	35	29,15	59,42	36	10,55		0,001

Double Hydrometer Test

Location ____Arapi_____ Borehole __BH-2___ Sample No. __1__ Depth __10.3 – 10.5 m___

Dry weight of soil, W_s ___25 g___ G_s __2.57___ Temperature__20 °C__ Date _19.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	20	20,15	82,15	21	13,21	0.0140	0,072
1	20	20,15	82,15	21	13,21		0,051
2	19	19,15	78,07	20	13,37		0,036
4	18	18,15	74,00	19	13,54		0,026
8	18	18,15	74,00	19	13,54		0,018
15	16	16,15	65,84	17	13,87		0,013
30	15	15,15	61,77	16	14,03		0,010
60	10	10,15	41,38	11	14,85		0,007
120	5	5,15	21,00	6	15,67		0,005
240	1	1,15	4,69	2	16,33		0,004
480	0	0,15	0,61	1	16,49		0,003
1440	0	0,15	0,61	1	16,49		0,001

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \% 100 = \frac{21.0}{77.77} \%100 = \mathbf{27.0\ \%}$$

Conclusion: Percent Dispersion of sample No.1 (BH-2, 10.3-10.5m, Arapi) equals 27.0 %.

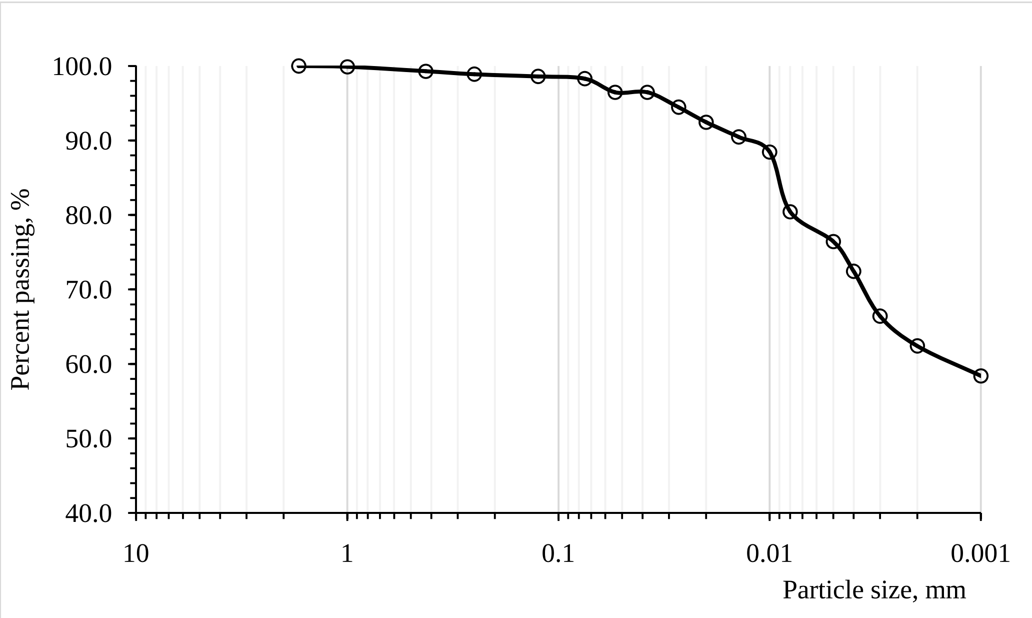


Fig.3.3.8. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.1 (BH-2, 10.3-10.5 m, Arapi)

Sieve analysis

Location ____Arapi______ Borehole __BH-2___ Sample No. _2__ Depth __20.4 – 20.8 m___

Mass of oven dry specimen 100 g Date _15.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
3/8 in.	9.5	0	0	0	100
4	4.75	0	0	0	100
6	3.35	0	0	0	100
8	2.36	0	0	0	100
12	1.7	0	0	0	100
18	1	0.1	0.1	0.1	99.9
40	0.425	1.0	1.0	1.1	98.9
60	0.25	0.4	0.4	1.5	98.5
120	0.125	0.5	0.5	2.0	98
200	0.075	1.1	1.1	3.1	96.9
	<0.075	96.9	96.9	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-2___ Sample No. __2__ Depth __20.4 – 20.8 m___

Dry weight of soil, W_s ___50 g___ G_s __2.54___ Temperature__20 ^{o}C___ Date _20.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	51	45,15	92,73	52	7,93	0.0141	0,056
1	50	44,15	90,68	51	8,09		0,040
2	49	43,15	88,63	50	8,26		0,029
4	49	43,15	88,63	50	8,26		0,020
8	48	42,15	86,57	49	8,42		0,014
15	46	40,15	82,46	47	8,75		0,011
30	44	38,15	78,36	45	9,08		0,008
60	42	36,15	74,25	43	9,41		0,006
120	37	31,15	63,98	38	10,23		0,004
240	34	28,15	57,82	35	10,72		0,003
480	31	25,15	51,66	32	11,21		0,002
1440	27	21,15	43,44	28	11,87		0,001

Double Hydrometer Test

Location ____Arapi_____ Borehole __BH-2___ Sample No. __2__ Depth __20.4 – 20.8 m___

Dry weight of soil, W_s ___25 g___ G_s __2.54___ Temperature__20 °C__ Date _19.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m 1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	20	20,15	82,77	21	13,21	0.0141	0,072
1	20	20,15	82,77	21	13,21		0,051
2	19	19,15	78,66	20	13,37		0,036
4	18	18,15	74,56	19	13,54		0,026
8	18	18,15	74,56	19	13,54		0,018
15	16	16,15	66,34	17	13,87		0,014
30	15	15,15	62,23	16	14,03		0,010
60	11	11,15	45,80	12	14,69		0,007
120	9	9,15	37,59	10	15,01		0,005
240	4	4,15	17,05	5	15,83		0,004
480	0	0,15	0,62	1	16,49		0,003
1440	0	0,15	0,62	1	16,49		0,002

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu m \text{ (double hydrometer test)}}{\% \text{ passing } 5\ \mu m \text{ (hydrometer test)}} \% 100 = \frac{37.59}{69.11} \%100 = \mathbf{54.4\ \%}$$

Conclusion: Percent Dispersion of sample No.2 (BH-2, 20.4-20.8 m, Arapi) equals 54.4 %.

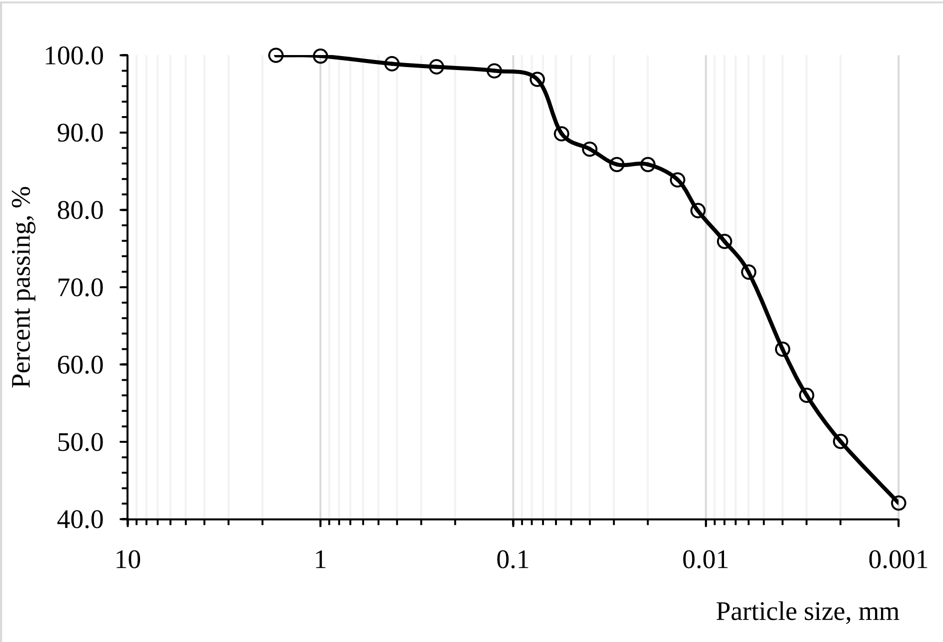


Fig.3.3.9. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.2 (BH-2, 20.4-20.8 m, Arapi)

Sieve analysis

Location ____Arapi______ Borehole __BH-2___ Sample No. _3__ Depth __29.5 – 30.0 m___

Mass of oven dry specimen 100 g Date _14.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
40	0.425	0	0	0	100
60	0.25	0.4	0.4	0.4	99.6
120	0.125	0.1	0.1	0.5	99.5
200	0.075	0.1	0.1	0.6	99.4
	<0.075	99.4	99.4	100	-

Hydrometer Analysis

Location ____Arapi_____ Borehole __BH-2___ Sample No. __3__ Depth __29.5 – 30.0 m___

Dry weight of soil, W_s ___50 g___ G_s __2.59___ Temperature__20 °C___ Date _20.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	48	42,15	85,50	49	8,62	0.0139	0,058
1	47	41,15	83,47	48	8,78		0,041
2	47	41,15	83,47	48	8,78		0,029
4	47	41,15	83,47	48	8,78		0,021
8	46	40,15	81,44	47	8,95		0,015
15	45	39,15	79,41	46	9,11		0,011
30	44	38,15	77,39	45	9,27		0,008
60	41	35,15	71,30	42	9,77		0,006
120	38	32,15	65,22	39	10,26		0,004
240	34	28,15	57,10	35	10,91		0,003
480	32	26,15	53,04	33	11,24		0,002
1440	26	20,15	40,87	27	12,23		0,001

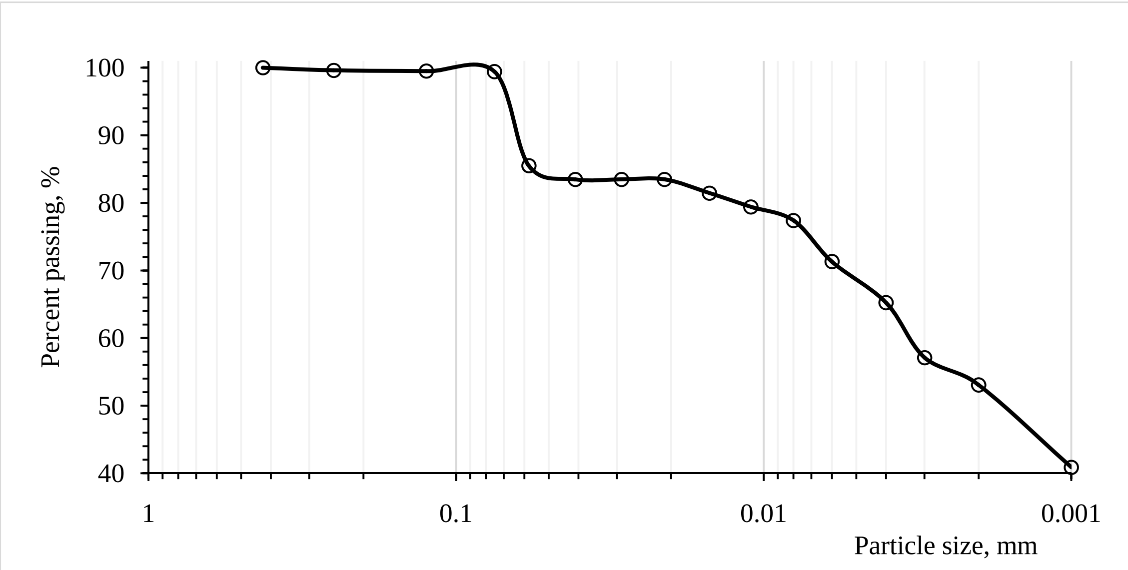


Fig.3.3.10. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.3 (BH-2, 29.5-30.0 m, Arapi)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. _1__ Depth __5.0 – 5.3 m___

Mass of oven dry specimen 500 g Date _26.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
5/8 in.	16	0	0	0	100
3/8 in.	9.5	21.0	4.2	4.2	95.8
4	4.75	16.33	3.27	7.47	92.53
8	2.36	8.33	1.67	9.14	90.86
18	1	8.33	1.67	10.81	89.19
40	0.425	9.0	1.8	12.61	87.39
60	0.25	17.0	3.4	16.01	83.99
120	0.125	18.66	3.73	19.74	80.26
200	0.075	27.33	5.47	25.21	74.79
	<0.075	374.0	74.8	100.01	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. __1__ Depth __5.0 – 5.3 m___

Dry weight of soil, W_s ___50 g___ G_s __2.71___ Temperature__20 ^oC___ Date _21.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz +6 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	50	44,15	87,13	51	8,09	0.0134	0,054
1	49	43,15	85,16	50	8,26		0,039
2	48	42,15	83,18	49	8,42		0,027
4	45	39,15	77,26	46	8,91		0,020
8	37	31,15	61,48	38	10,23		0,015
15	33	27,15	53,58	34	10,88		0,011
30	30	24,15	47,66	31	11,37		0,008
60	27	21,15	41,74	28	11,87		0,006
120	24	18,15	35,82	25	12,36		0,004
240	20	14,15	27,93	21	13,01		0,003
480	19	13,15	25,95	20	13,18		0,002
1440	16	10,15	20,03	17	13,67		0,001

Double Hydrometer Test

Location ___Getahovit_____ Borehole __BH-1___ Sample No. __1__ Depth __5.0 – 5.3 m___

Dry weight of soil, W_s ___25 g___ G_s __2.71___ Temperature __20 °C__ Date _22.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	20	20,15	79,53	21	13,21	0.0134	0,069
1	18	18,15	71,64	19	13,54		0,049
2	16	16,15	63,74	17	13,87		0,035
4	10	10,15	40,06	11	14,85		0,026
8	2	2,15	8,49	3	16,16		0,019
15	0	0,15	0,59	1	16,49		0,014
30	0	0,15	0,59	1	16,49		0,010
60	0	0,15	0,59	1	16,49		0,007
120	0	0,15	0,59	1	16,49		0,005
240	0	0,15	0,59	1	16,49		0,004
480	0	0,15	0,59	1	16,49		0,002
1440	0	0,15	0,59	1	16,49		0,001

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \% 100 = \frac{0.59}{38.78} \%100 = \mathbf{1.5\ \%}$$

Conclusion: Percent Dispersion of sample No.1 (BH-1, 5.0-5.3 m, Getahovit) equals 1.5 %.

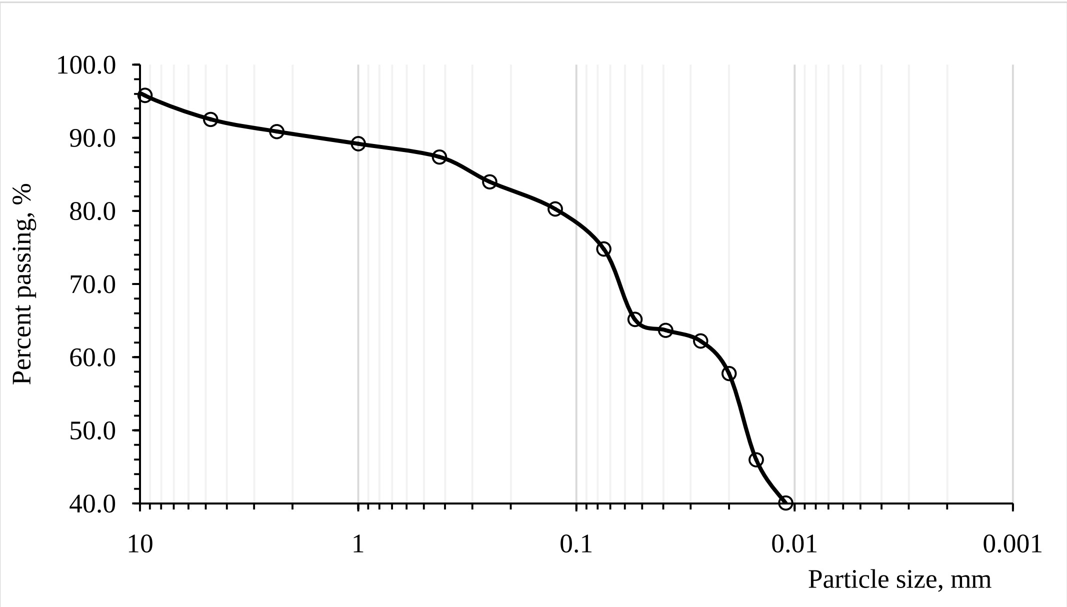


Fig.3.3.11. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.1 (BH-1, 5.0-5.3 m, Getahovit)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. _2__ Depth __17.0 – 17.2 m___

Mass of oven dry specimen 150 g Date _22.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, 100-ΣR_n
3/8 in.	9.5	0	0	0	100
4	4.75	0.5	0.33	0.33	99.67
6	3.35	0.4	0.27	0.6	99.4
8	2.36	0.7	0.47	1.07	98.93
12	1.7	0.6	0.4	1.47	98.53
18	1	1.9	1.27	2.74	97.26
40	0.425	10.6	7.07	9.81	90.19
60	0.25	14.8	9.87	19.68	80.32
120	0.125	21.0	14.0	33.68	66.32
200	0.075	14.7	9.8	43.48	56.52
	<0.075	84.8	56.53	100.01	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. __2__ Depth __17.0 – 17.2 m___

Dry weight of soil, W_s ___50 g___ G_s __2.59___ Temperature__20 °C___ Date _21.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz _+6 Temp. correction, F_T _+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, (a*R_{cp}/50)*100	R_{cL}	L (cm)	A	D (mm)
0.5	47	41,15	83,47	48	8,78	0.0139	0,058
1	46	40,15	81,44	47	8,95		0,042
2	44	38,15	77,39	45	9,27		0,030
4	43	37,15	75,36	44	9,44		0,021
8	41	35,15	71,30	42	9,77		0,015
15	38	32,15	65,22	39	10,26		0,011
30	35	29,15	59,13	36	10,75		0,008
60	32	26,15	53,04	33	11,24		0,006
120	29	23,15	46,96	30	11,73		0,004
240	27	21,15	42,90	28	12,06		0,003
480	26	20,15	40,87	27	12,23		0,002
1440	24	18,15	36,82	25	12,55		0,001

Double Hydrometer Test

Location ___Getahovit_____ Borehole __BH-1___ Sample No. __2__ Depth __17.0 – 17.2 m___

Dry weight of soil, W_s ___25 g___ G_s __2.59___ Temperature__20 ^oC__ Date _22.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	17	17,15	69,58	18	13,70	0.0139	0,073
1	16	16,15	65,52	17	13,87		0,052
2	15	15,15	61,46	16	14,03		0,037
4	15	15,15	61,46	16	14,03		0,026
8	15	15,15	61,46	16	14,03		0,018
15	14	14,15	57,41	15	14,19		0,014
30	12	12,15	49,29	13	14,52		0,010
60	10	10,15	41,18	11	14,85		0,007
120	9	9,15	37,12	10	15,01		0,005
240	7	7,15	29,01	8	15,34		0,004
480	5	5,15	20,89	6	15,67		0,003
1440	0	0,15	0,61	1	16,49		0,001

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \% 100 = \frac{37.12}{50.0} \%100 = \mathbf{74.2\ \%}$$

Conclusion: Percent Dispersion of sample No.2 (BH-1, 17.0-17.2 m, Getahovit) equals 74.2 %.

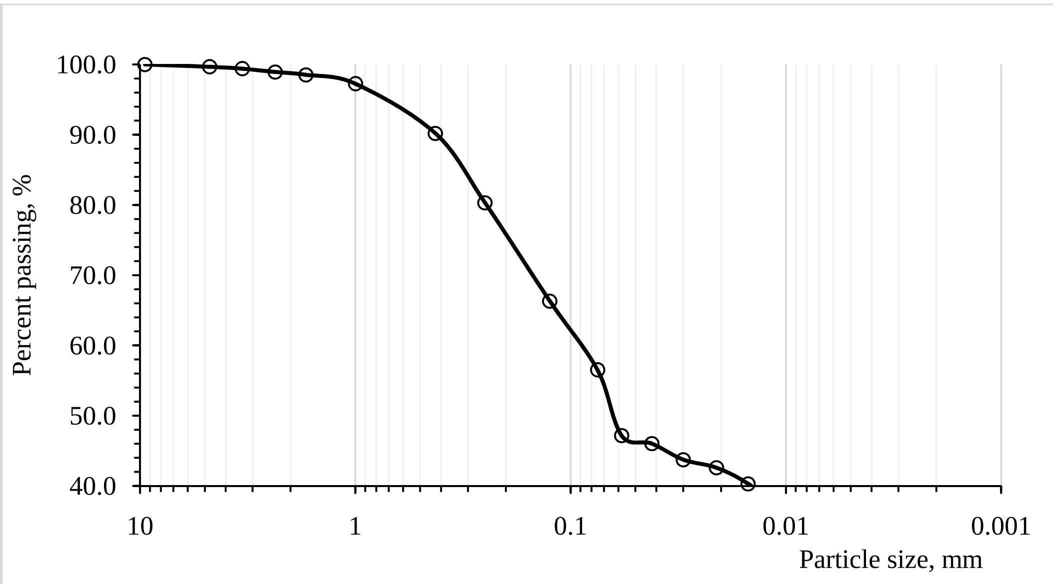


Fig.3.3.12. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.2 (BH-1, 17.0-17.2 m, Getahovit)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. _3__ Depth __25.0 – 25.5 m___

Mass of oven dry specimen 150 g Date _23.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
12	1.7	0	0	0	100
18	1	0.2	0.13	0.13	99.87
40	0.425	1.4	0.93	1.06	98.94
60	0.25	4.0	2.67	3.73	96.27
120	0.125	14.7	9.8	13.53	86.47
200	0.075	13.9	9.27	22.8	77.2
	<0.075	115.8	77.2	100	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-1___ Sample No. __3__ Depth __25.0 – 25.5 m___

Dry weight of soil, W_s ___50 g___ G_s __2.66___ Temperature__20 °C___ Date _21.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz _+6 Temp. correction, F_T_+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	49	43,15	86,10	50	8,45	0.0137	0,056
1	46	40,15	80,12	47	8,95		0,041
2	45	39,15	78,12	46	9,11		0,029
4	44	38,15	76,13	45	9,27		0,021
8	42	36,15	72,14	43	9,60		0,015
15	40	34,15	68,14	41	9,93		0,011
30	37	31,15	62,16	38	10,42		0,008
60	35	29,15	58,17	36	10,75		0,006
120	33	27,15	54,18	34	11,08		0,004
240	31	25,15	50,19	32	11,41		0,003
480	30	24,15	48,19	31	11,57		0,002
1440	29	23,15	46,19	30	11,73		0,001

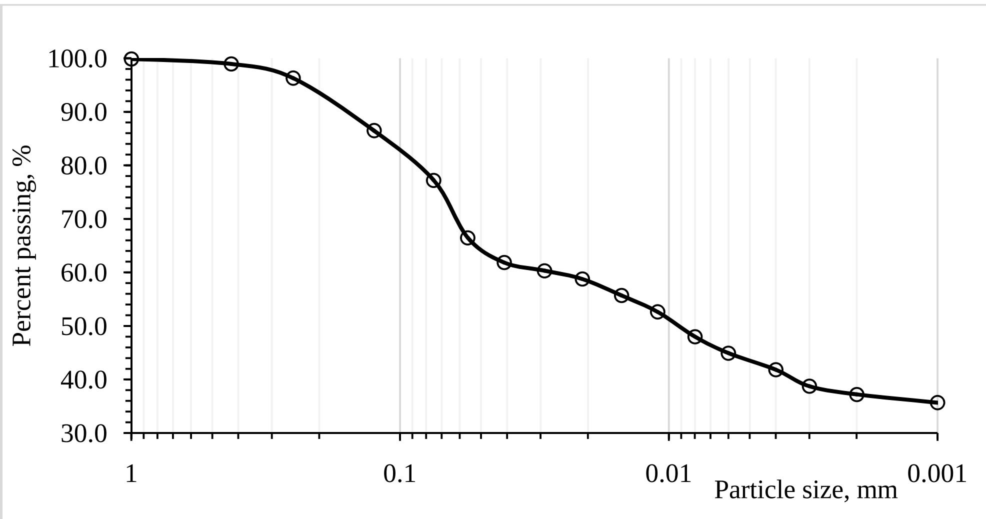


Fig.3.3.13. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.3 (BH-1, 25.0-25.5 m, Getahovit)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. _1__ Depth __5.0 – 5.5 m___

Mass of oven dry specimen 150 g Date _26.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100\text{-}\Sigma R_n$
3/8 in.	9.5	0	0	0	100
4	4.75	1	0.67	0.67	99.33
8	2.36	1.3	0.87	1.54	98.46
18	1	1.3	0.87	2.41	97.59
40	0.425	2.0	1.33	3.74	96.26
60	0.25	2.2	1.47	5.21	94.79
120	0.125	9.1	6.07	11.28	88.72
200	0.075	18.3	12.2	23.48	76.52
	<0.075	114.8	76.53	100.01	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. __1__ Depth __5.0 – 5.5 m___

Dry weight of soil, W_s ___50 g___ G_s __2.75___ Temperature__20 ^{o}C___ Date _29.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1_ Zero correction, Fz _+6 Temp. correction, F_T _+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.25	51	45,15	88,35	52	7,93	0.0133	0,075
0.5	48	42,15	82,48	49	8,42		0,055
1	46	40,15	78,57	47	8,75		0,039
2	45	39,15	76,61	46	8,91		0,028
4	43	37,15	72,70	44	9,24		0,020
8	40	34,15	66,83	41	9,73		0,015
15	37	31,15	60,96	38	10,23		0,011
30	33	27,15	53,13	34	10,88		0,008
60	32	26,15	51,17	33	11,05		0,006
120	29	23,15	45,30	30	11,54		0,004
240	27	21,15	41,39	28	11,87		0,003
480	25	19,15	37.47	26	12,19		0,002
1440	24	18,15	35,52	25	12,36		0,001

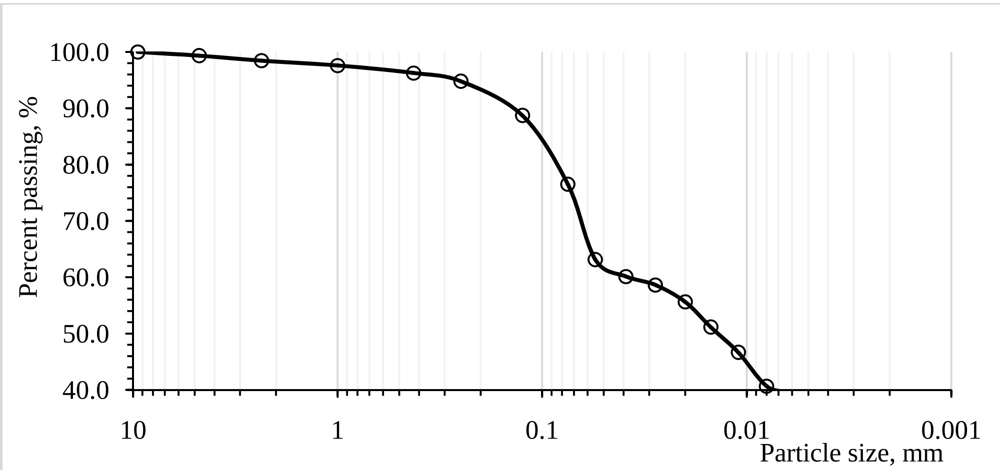


Fig.3.3.14. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.1 (BH-2, 5.0-5.5 m, Getahovit)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. _2__ Depth __15.0 – 15.5 m___

Mass of oven dry specimen 150 g Date _27.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
5/8 in.	16	0	0	0	100
3/8 in.	9.5	5.9	3.93	3.93	96.07
4	4.75	16.3	10.87	14.8	85.2
8	2.36	3.1	2.07	16.87	83.13
18	1	2.9	1.93	18.8	81.2
40	0.425	11.7	7.8	26.6	73.4
60	0.25	12.0	8.0	34.6	65.4
120	0.125	15.9	10.6	45.2	54.8
200	0.075	9.0	6.0	51.2	48.8
	<0.075	73.2	48.8	100	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. __2__ Depth __15.0 – 15.5 m___

Dry weight of soil, W_s ___50 g___ G_s __2.64___ Temperature__20 °C__ Date _29.01.2015

Hydrometer type ASTM 152-H_ Meniscus correction, F_m1__ Zero correction, Fz _+6 Temp. correction, F_T _+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	44	38,15	76,48	45	9,27	0.0137	0,059
1	43	37,15	74,47	44	9,44		0,042
2	42	36,15	72,47	43	9,60		0,030
4	41	35,15	70,46	42	9,77		0,021
8	40	34,15	68,46	41	9,93		0,015
15	38	32,15	64,45	39	10,26		0,011
30	34	28,15	56,43	35	10,91		0,008
60	33	27,15	54,42	34	11,08		0,006
120	29	23,15	46,41	30	11,73		0,004
240	27	21,15	42,40	28	12,06		0,003
480	24	18,15	36,38	25	12,55		0,002
1440	20	14,15	28,37	21	13,21		0,001

Double Hydrometer Test

Location ___Getahovit_____ Borehole __BH-2___ Sample No. __2__ Depth __15.0 – 15.5 m___

Dry weight of soil, W_s ___25 g___ G_s __2.64___ Temperature __20 °C__ Date _27.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m 1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	18	18,15	72,77	19	13,54	0.0137	0,071
1	17	17,15	68,76	18	13,70		0,051
2	16	16,15	64,75	17	13,87		0,036
4	16	16,15	64,75	17	13,87		0,026
8	13	13,15	52,72	14	14,36		0,018
15	10	10,15	40,69	11	14,85		0,014
30	2	2,15	8,62	3	16,16		0,010
60	0	0,15	0,60	1	16,49		0,007
120	0	0,15	0,60	1	16,49		0,005
240	0	0,15	0,60	1	16,49		0,004
480	0	0,15	0,60	1	16,49		0,003
1440	0	0,15	0,60	1	16,49		0,001

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \% 100 = \frac{0.6}{50.41} \%100 = \mathbf{1.2\ \%}$$

Conclusion: Percent Dispersion of sample No.2 (BH-2, 15.0-15.5 m, Getahovit) equals 1.2 %.

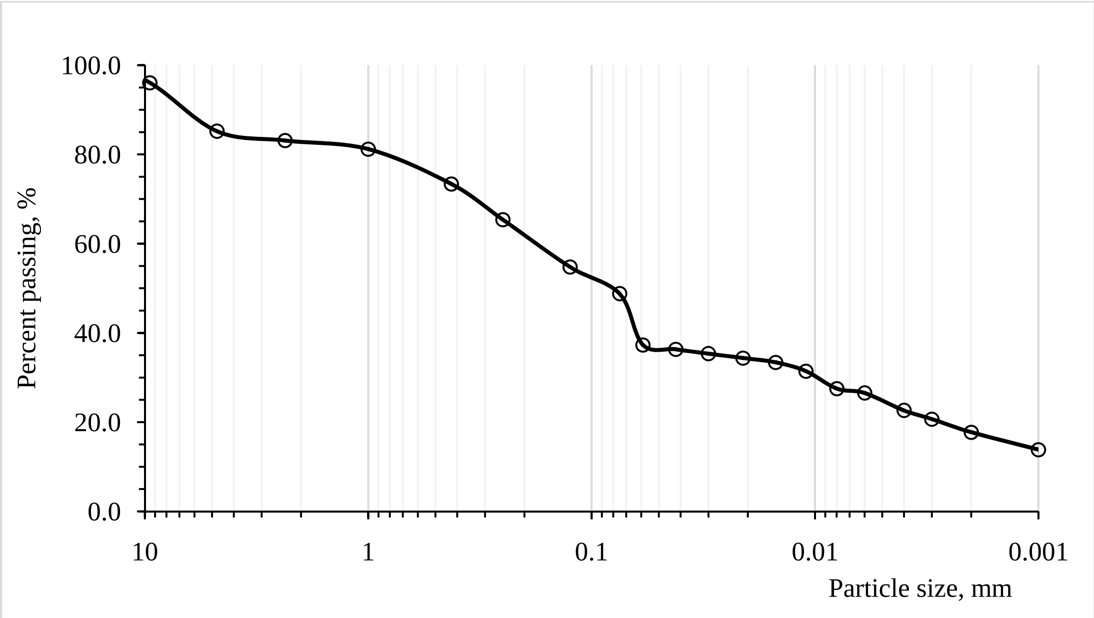


Fig.3.3.15. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.2 (BH-2, 15.0-15.5 m, Getahovit)

Sieve analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. _3__ Depth __26.0 – 26.2 m___

Mass of oven dry specimen 150 g Date _27.01.2015

Sieve No.	Sieve opening (mm)	Mass of soil retained on each sieve, W_n g	Percent of soil retained on each sieve, R_n	Cumulative percent retained, ΣR_n	Percent finer, $100-\Sigma R_n$
5/8 in.	16	0	0	0	100
3/8 in.	9.5	5.9	3.93	3.93	96.07
4	4.75	6.4	4.27	8.2	91.8
8	2.36	0.8	0.53	8.73	91.27
18	1	0.5	0.33	9.06	90.94
40	0.425	5.6	3.73	12.79	87.21
60	0.25	6.8	4.53	17.32	82.68
120	0.125	9.9	6.6	23.92	76.08
200	0.075	8.7	5.8	29.72	70.28
	<0.075	105.4	70.27	99.99	-

Hydrometer Analysis

Location ___Getahovit_____ Borehole __BH-2___ Sample No. __3__ Depth __26.0 – 26.2 m___

Dry weight of soil, W_s ___50 g__ G_s __2.76___ Temperature __20 ^oC__ Date _29.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1__ Zero correction, Fz _+6 Temp. correction, F_T _+0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	42	36,15	70,59	43	9,60	0.0133	0,058
1	42	36,15	70,59	43	9,60		0,041
2	41	35,15	68,64	42	9,77		0,029
4	40	34,15	66,69	41	9,93		0,021
8	38	32,15	62,78	39	10,26		0,015
15	37	31,15	60,83	38	10,42		0,011
30	34	28,15	54,97	35	10,91		0,008
60	32	26,15	51,07	33	11,24		0,006
120	29	23,15	45,21	30	11,73		0,004
240	27	21,15	41,30	28	12,06		0,003
480	24	18,15	35,44	25	12,55		0,002
1440	22	16,15	31,54	23	12,88		0,001

Double Hydrometer Test

Location ___Getahovit_____ Borehole __BH-2___ Sample No. __3__ Depth __26.0 – 26.2 m___

Dry weight of soil, W_s ___25 g___ G_s __2.76___ Temperature__20 °C__ Date _27.01.2015

Hydrometer type ASTM 152-H Meniscus correction, F_m1 Zero correction, Fz 0 Temp. correction, F_T +0.15

Time, t (min.)	Hydrometer reading, R	R_{cp}	Percent finer, $(a*R_{cp}/50)*100$	R_{cL}	L (cm)	A	D (mm)
0.5	17	17,15	66,98	18	13,70	0.0133	0,070
1	16	16,15	63,08	17	13,87		0,050
2	15	15,15	59,17	16	14,03		0,035
4	15	15,15	59,17	16	14,03		0,025
8	15	15,15	59,17	16	14,03		0,018
15	12	12,15	47,45	13	14,52		0,013
30	6	6,15	24,02	7	15,51		0,010
60	0	0,15	0,59	1	16,49		0,007
120	0	0,15	0,59	1	16,49		0,005
240	0	0,15	0,59	1	16,49		0,003
480	0	0,15	0,59	1	16,49		0,002
1440	0	0,15	0,59	1	16,49		0,001

$$\% \text{ Dispersion} = \frac{\% \text{ passing } 5\ \mu\text{m (double hydrometer test)}}{\% \text{ passing } 5\ \mu\text{m (hydrometer test)}} \%100 = \frac{0.59}{48.14} \%100 = \mathbf{1.2\ \%}$$

Conclusion: Percent Dispersion of sample No.3 (BH-2, 26.0-26.2 m, Getahovit) equals 1.2 %.

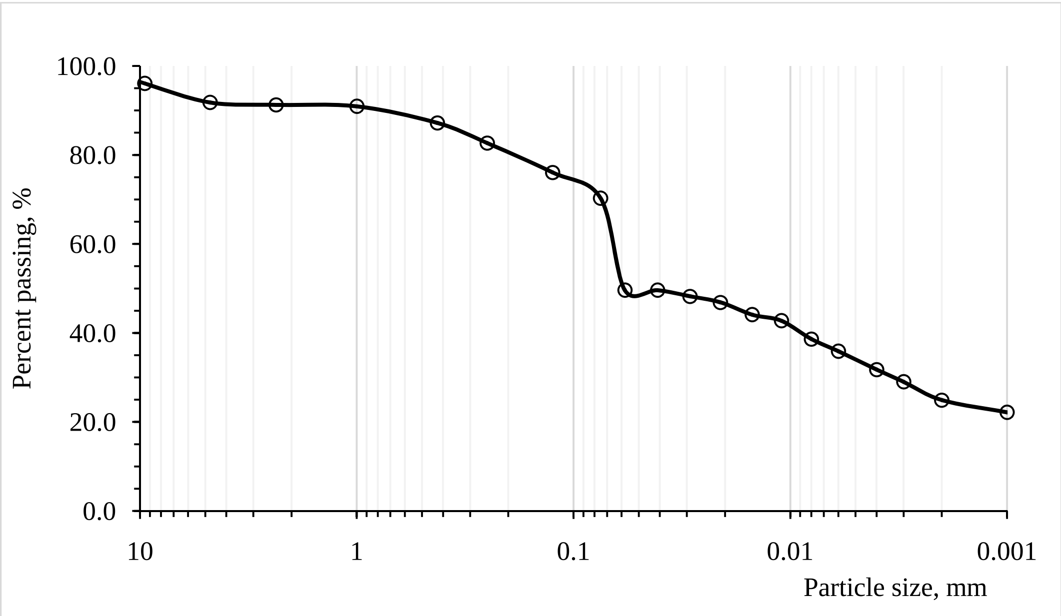


Fig.3.3.16. Grain-size distribution obtained from both the sieve analysis and the hydrometer analysis for Sample No.3 (BH-2, 26.0-26.2 m, Getahovit)

DETERMINATION OF SPECIFIC GRAVITY OF SOIL SAMPLES

BH-1, Sample No.1, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	136.53	138.67
Mass of Flask + soil + water filled to mark, W_2 (g)	142.20	144.44
Mass of dry soil, W_s (g)	9.54	9.63
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	3.87	3.86
G_s (T, ^oC) = W_s/W_w	2.46	2.49
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.46	2.49
Average G_s (20^oC)	**2.47**	

BH-1, Sample No.2, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	82.55	151.95
Mass of Flask + soil + water filled to mark, W_2 (g)	85.41	157.65
Mass of dry soil, W_s (g)	4.7	9.45
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	1.84	3.75
G_s (T, ^oC) = W_s/W_w	2.55	2.52
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.55	2.52
Average G_s (20^oC)	**2.54**	

BH-1, Sample No.3, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	135.11	136.45
Mass of Flask + soil + water filled to mark, W_2 (g)	140.59	141.93
Mass of dry soil, W_s (g)	9.54	9.49
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	4.06	4.01
G_s (T, ^oC) = W_s/W_w	2.35	2.37
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.35	2.37
Average G_s (20^oC)	**2.36**	

BH-2, Sample No.1, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	82.58	151.95
Mass of Flask + soil + water filled to mark, W_2 (g)	85.45	157.73
Mass of dry soil, W_s (g)	4.72	9.41
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	1.85	3.63
G_s (T, ^oC) = W_s/W_w	2.55	2.59
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.55	2.37
Average G_s (20^oC)	**2.57**	

BH-2, Sample No.2, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	136.65	138.7
Mass of Flask + soil + water filled to mark, W_2 (g)	142.47	144.58
Mass of dry soil, W_s (g)	9.65	9.65
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	3.83	3.77
G_s (T, ^oC) = W_s/W_w	2.52	2.56
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.52	2.56
Average G_s (20^oC)	**2.54**	

BH-2, Sample No.3, Arapi		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	135.14	136.45
Mass of Flask + soil + water filled to mark, W_2 (g)	140.99	142.36
Mass of dry soil, W_s (g)	9.57	9.56
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	3.72	3.65
G_s (T, ^oC) = W_s/W_w	2.57	2.62
T, ^oC	23	
A	0.9993	
G_s (20^oC) = G_s (T, ^oC) *A	2.57	2.62
Average G_s (20^oC)	**2.59**	

BH-1, Sample No.1, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	82.61	152.06
Mass of Flask + soil + water filled to mark, W_2 (g)	85.76	158.33
Mass of dry soil, W_s (g)	4.97	9.99
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	1.82	3.72
G_s (T, ^oC) = W_s/W_w	2.73	2.69
T, ^oC	19	
A	0.9988	
G_s (20^oC) = G_s (T, ^oC) *A	2.73	2.69
Average G_s (20^oC)	**2.71**	
BH-1, Sample No.2, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	136.72	138.79
Mass of Flask + soil + water filled to mark, W_2 (g)	142.86	144.92
Mass of dry soil, W_s (g)	10.01	9.99
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) - W_2$	3.87	3.86
G_s (T, ^oC) = W_s/W_w	2.59	2.59
T, ^oC	19	
A	0.9988	
G_s (20^oC) = G_s (T, ^oC) *A	2.59	2.59
Average G_s (20^oC)	**2.59**	

BH-1, Sample No.3, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	135.2	136.5
Mass of Flask + soil + water filled to mark, W_2 (g)	141.42	142.69
Mass of dry soil, W_s (g)	9.91	9.96
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) – W_2$	3.69	3.77
G_s (T, ^oC) = W_s/W_w	2.69	2.64
T, ^oC	19	
A	0.9988	
G_s (20^oC) = G_s (T, ^oC) *A	2.69	2.64
Average G_s (20^oC)	**2.66**	

BH-2, Sample No.1, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	82.64	152.07
Mass of Flask + soil + water filled to mark, W_2 (g)	85.83	158.1
Mass of dry soil, W_s (g)	5.02	9.45
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) – W_2$	1.83	3.42
G_s (T, ^oC) = W_s/W_w	2.74	2.76
T, ^oC	16	
A	0.9989	
G_s (20^oC) = G_s (T, ^oC) *A	2.74	2.76
Average G_s (20^oC)	**2.75**	

BH-2, Sample No.2, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	136.74	138.82
Mass of Flask + soil + water filled to mark, W_2 (g)	142.87	145.05
Mass of dry soil, W_s (g)	9.9	10.01
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) – W_2$	3.77	3.78
G_s (T, ^oC) = W_s/W_w	2.63	2.65
T, ^oC	16	
A	0.9989	
G_s (20^oC) = G_s (T, ^oC) *A	2.63	2.65
Average G_s (20^oC)	**2.64**	

BH-2, Sample No.3, Getahovit		
Item	**Test No.**	
	1	**2**
Mass of Flask + water filled to mark, W_1 (g)	135.26	136.56
Mass of Flask + soil + water filled to mark, W_2 (g)	141.61	142.96
Mass of dry soil, W_s (g)	9.96	10.02
Mass of equal volume of water as the soil solids, W_w (g) = $(W_1+W_s) – W_2$	3.61	3.62
G_s (T, ^oC) = W_s/W_w	2.76	2.77
T, ^oC	16	
A	0.9989	
G_s (20^oC) = G_s (T, ^oC) *A	2.76	2.77
Average G_s (20^oC)	**2.76**	

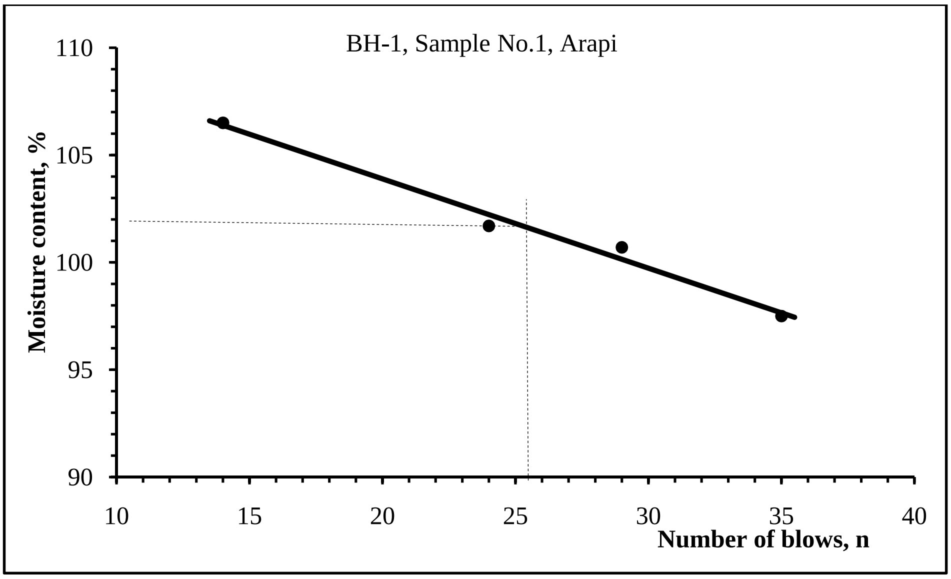
LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX

Location __Arapi_ Borehole __BH-1_ Sample No. __1__ Depth _10.3 – 10.5 m_ Date __11.12.2014__

Liquid limit Test No.	**1**		**2**		**3**		**4**	
Number of blows, n	**35**		**29**		**24**		**14**	
Container no.	*201*	*205*	*212*	*216*	*210*	*220*	*401*	*411*
Mass of container, g	19.81	19.78	19.77	19.68	19.86	19.94	19.79	19.89
Mass of wet soil+container, g	26.45	26.51	26.19	24.20	25.75	27.28	25.94	26.11
Mass of dry soil+container, g	23.16	23.20	22.97	21.93	22.78	23.58	22.77	22.90
Mass of moisture, g	3.29	3.31	3.22	2.27	2.97	3.70	3.17	3.21
Mass of dry soil, g	3.35	3.42	3.20	2.25	2.92	3.64	2.98	3.01
Moisture content, %	**98.21**	**96.78**	**100.62**	**100.89**	**101.71**	**101.65**	**106.38**	**106.64**
Average moisture content, %	**97.5**		**100.7**		**101.7**		**106.5**	

Plastic limit Test No.		**1**	**2**	**AVERAGE**
Container no.		*204*	*304*	
Mass of container	g	26.83	19.89	
Mass of wet soil+container	g	29.45	21.92	
Mass of dry soil+container	g	28.62	21.26	47.3
Mass of moisture	g	0.83	0.66	
Mass of dry soil	g	1.79	1.37	
Moisture content	%	**46.37**	**48.17**	

Liquid limit	**101.9**
Plastic limit	**47.3**
Plasticity index	**54.6**

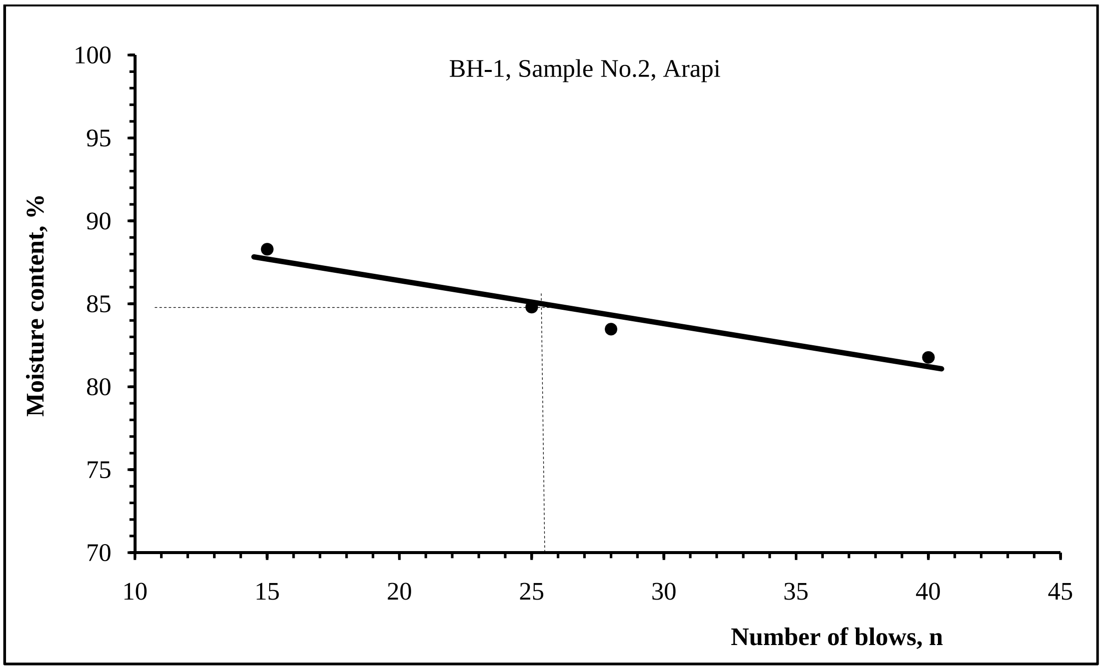


Location __Arapi_ Borehole __BH-1_ Sample No. __2__ Depth _19.2 – 19.3 m_ Date __17.12.2014__

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**40**		**28**		**25**		**15**	
Container no.	*201*	*202*	*211*	*212*	*209*	*219*	*214*	*216*
Mass of container, g	19.80	22.67	19.87	19.78	19.88	19.80	19.83	19.70
Mass of wet soil+container, g	26.81	30.22	27.0	26.96	26.06	27.89	28.48	29.18
Mass of dry soil+container, g	23.66	26.82	23.74	23.71	23.23	24.17	24.41	24.75
Mass of moisture, g	3.15	3.4	3.26	3.25	2.83	3.72	4.07	4.43
Mass of dry soil, g	3.86	4.15	3.87	3.93	3.35	4.37	4.58	5.05
Moisture content, %	**81.61**	**81.93**	**84.24**	**82.70**	**84.48**	**85.13**	**88.86**	**87.72**
Average moisture content, %	**81.77**		**83.47**		**84.80**		**88.29**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*101*	*102*	
Mass of container	g	19.81	19.77	
Mass of wet soil+container	g	24.47	24.73	
Mass of dry soil+container	g	23.17	23.34	**38.8**
Mass of moisture	g	1.3	1.39	
Mass of dry soil	g	3.36	3.57	
Moisture content	%	**38.69**	**38.93**	

Liquid limit	**84.8**
Plastic limit	**38.8**
Plasticity index	**46**

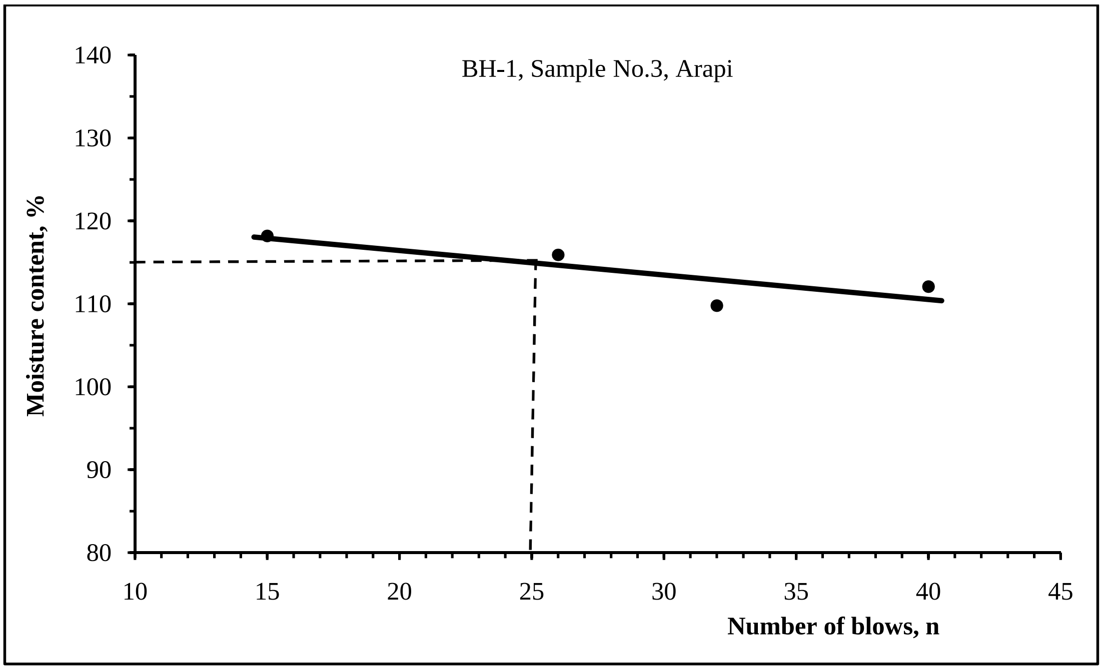


Location __Arapi_ Borehole __BH-1_ Sample No. __3__ Depth _29.0 – 29.2 m_ Date __12.12.2014__

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**40**		**32**		**26**		**15**	
Container no.	*200*	*209*	*211*	*214*	*101*	*103*	*206*	*207*
Mass of container, g	19.88	19.80	19.88	19.82	19.91	19.78	22.54	19.92
Mass of wet soil+container, g	26.56	23.98	25.17	24.01	25.64	24.35	29.91	27.43
Mass of dry soil+container, g	23.03	21.77	22.35	21.86	22.56	21.90	25.91	23.37
Mass of moisture, g	3.53	2.21	2.82	2.15	3.08	2.45	4.0	4.06
Mass of dry soil, g	3.15	1.97	2.47	2.04	2.65	2.12	3.37	3.45
Moisture content, %	**112.06**	**112.18**	**114.17**	**105.39**	**116.23**	**115.57**	**118.69**	**117.68**
Average moisture content, %	**112.07**		**109.78**		**115.9**		**118.18**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*220*	*230*	
Mass of container	g	19.65	19.91	
Mass of wet soil+container	g	21.52	21.79	
Mass of dry soil+container	g	20.85	21.13	55.0
Mass of moisture	g	0.67	0.66	
Mass of dry soil	g	1.2	1.22	
Moisture content	%	**55.83**	**54.10**	

Liquid limit	115
Plastic limit	55
Plasticity index	60

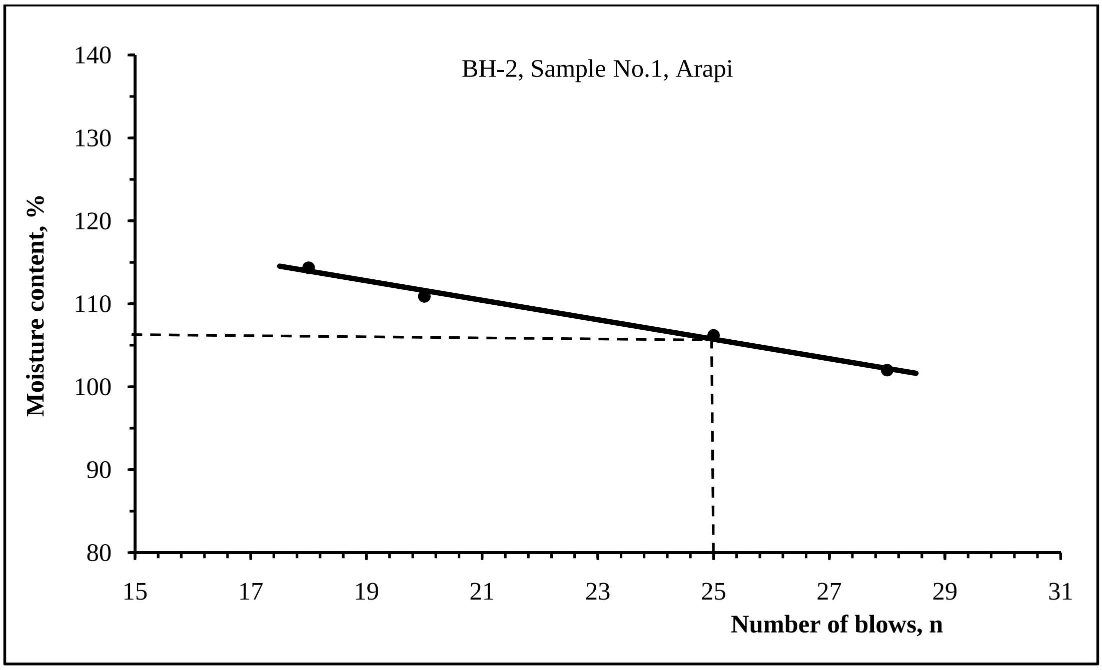


Location __Arapi_ Borehole __BH-2_ Sample No. __1__ Depth _10.3 – 10.5 m_ Date __14.01.2015__

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**28**		**25**		**20**		**18**	
Container no.	*230*	*240*	*101*	*104*	*230*	*240*	*101*	*104*
Mass of container, g	22.87	19.67	19.93	19.81	22.87	19.67	19.93	19.81
Mass of wet soil+container, g	28.53	24.78	24.25	25.28	28.53	24.78	24.25	25.28
Mass of dry soil+container, g	25.65	22.22	22.02	22.47	25.65	22.22	22.02	22.47
Mass of moisture, g	2.88	2.56	2.23	2.81	2.88	2.56	2.23	2.81
Mass of dry soil, g	2.78	2.55	2.09	2.66	2.78	2.55	2.09	2.66
Moisture content, %	**103.6**	**100.39**	**106.7**	**105.64**	**103.6**	**100.39**	**106.7**	**105.64**
Average moisture content, %	**102.0**		**106.2**		**110.9**		**114.35**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*209*	*219*	
Mass of container	g	19.88	19.75	
Mass of wet soil+container	g	23.01	22.74	
Mass of dry soil+container	g	22.16	21.93	**37.2**
Mass of moisture	g	0.85	0.81	
Mass of dry soil	g	2.28	2.18	
Moisture content	%	**37.28**	**37.15**	

Liquid limit	**106.2**
Plastic limit	**37.2**
Plasticity index	**69**

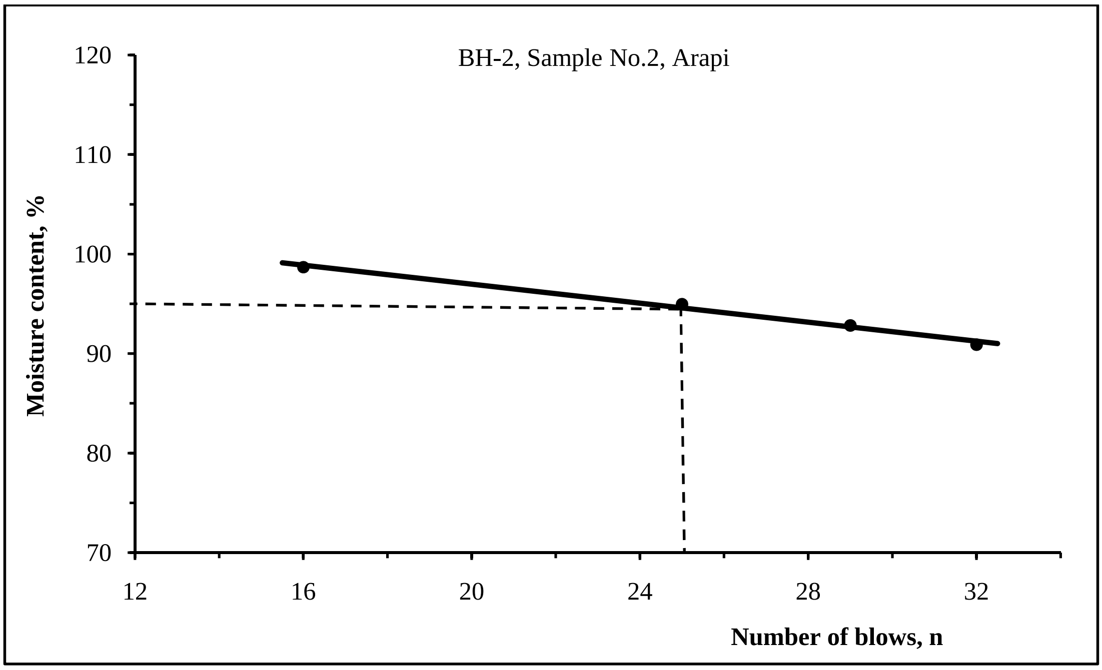


Location __Arapi_ Borehole __BH-2_ Sample No. __2__ Depth _20.4 – 20.8 m_ Date __13.01.2015__

Liquid limit Test No.	**1**		**2**		**3**		**4**	
Number of blows, n	**32**		**29**		**25**		**16**	
Container no.	*220*	*225*	*209*	*205*	*220*	*225*	*209*	*205*
Mass of container, g	19.84	19.97	19.88	19.77	19.84	19.97	19.88	19.77
Mass of wet soil+container, g	24.65	25.72	25.63	25.84	24.65	25.72	25.63	25.84
Mass of dry soil+container, g	22.37	22.97	22.86	22.92	22.37	22.97	22.86	22.92
Mass of moisture, g	2.28	2.75	2.77	2.92	2.28	2.75	2.77	2.92
Mass of dry soil, g	2.53	3.0	2.98	3.15	2.53	3.0	2.98	3.15
Moisture content, %	**90.12**	**91.67**	**92.95**	**92.7**	**90.12**	**91.67**	**92.95**	**92.7**
Average moisture content, %	**90.89**		**92.82**		**94.96**		**98.68**	

Plastic limit Test No.		**1**	**2**	**AVERAGE**
Container no.		*211*	*401*	**38.8**
Mass of container	g	19.88	19.79	
Mass of wet soil+container	g	23.08	22.88	
Mass of dry soil+container	g	22.18	22.02	
Mass of moisture	g	0.9	0.86	
Mass of dry soil	g	2.3	2.23	
Moisture content	%	**39.13**	**38.56**	

Liquid limit	**95.0**
Plastic limit	**38.8**
Plasticity index	**56.2**

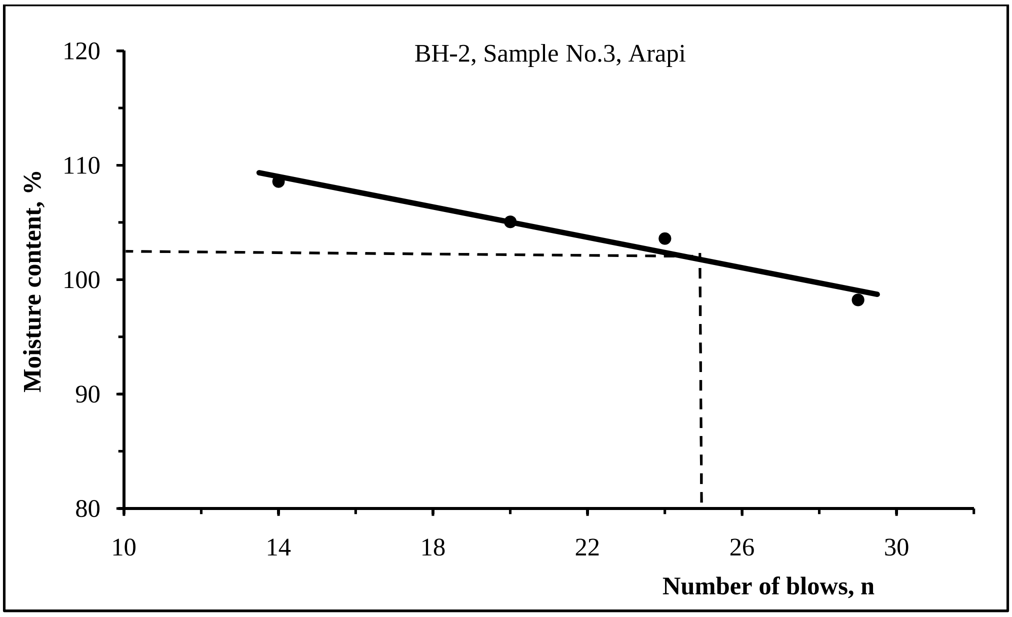


Location __Arapi_ Borehole __BH-2_ Sample No. __3__ Depth _29.5 – 30.0 m_ Date __13.01.2015__

Liquid limit Test No.	**1**		**2**		**3**		**4**	
Number of blows, n	**29**		**24**		**20**		**14**	
Container no.	*101*	*109*	*201*	*203*	*216*	*246*	*401*	*104*
Mass of container, g	19.89	19.78	19.8	19.79	19.67	19.94	19.78	19.82
Mass of wet soil+container, g	24.65	24.04	24.32	24.92	24.36	24.56	24.15	24.65
Mass of dry soil+container, g	22.29	21.93	22.02	22.31	21.96	22.19	21.88	22.13
Mass of moisture, g	2.36	2.11	2.3	2.61	2.4	2.37	2.27	2.52
Mass of dry soil, g	2.4	2.15	2.22	2.52	2.29	2.25	2.1	2.31
Moisture content, %	**98.33**	**98.14**	**103.6**	**103.57**	**104.8**	**105.33**	**108.09**	**109.09**
Average moisture content, %	**98.23**		**103.6**		**105.06**		**108.59**	

Plastic limit Test No.		**1**	**2**	**AVERAGE**
Container no.		*207*	*208*	
Mass of container	g	19.74	19.75	
Mass of wet soil+container	g	23.01	22.82	
Mass of dry soil+container	g	22.05	21.91	**41.8**
Mass of moisture	g	0.96	0.91	
Mass of dry soil	g	2.31	2.16	
Moisture content	%	**41.56**	**42.13**	

Liquid limit	**102**
Plastic limit	**41.8**
Plasticity index	**60.2**

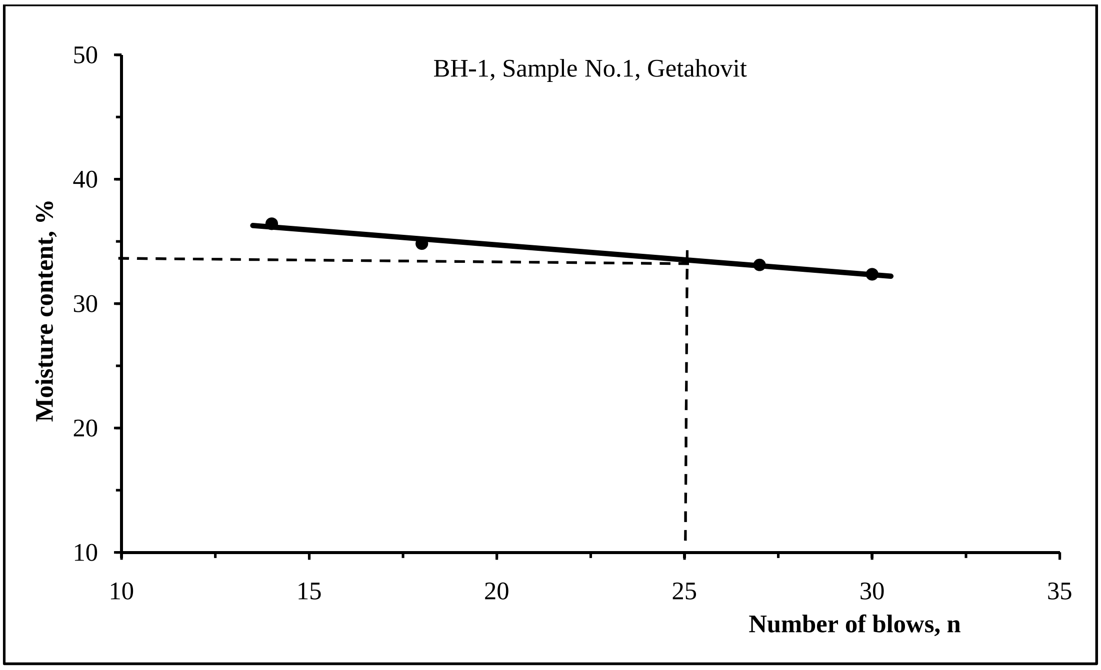


Location _Getahovit_ Borehole __BH-1_ Sample No. __1__ Depth _5.0 – 5.3 m_ Date __20.01.2015__

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**30**		**27**		**18**		**14**	
Container no.	*203*	*205*	*210*	*220*	*233*	*235*	*232*	*234*
Mass of container, g	19.78	19.78	19.91	19.86	22.84	19.95	19.82	22.76
Mass of wet soil+container, g	24.2	25.49	24.24	25.86	27.4	24.72	24.04	29.56
Mass of dry soil+container, g	23.13	24.08	23.14	24.4	26.22	23.49	22.91	27.75
Mass of moisture, g	1.07	1.41	1.1	1.46	1.18	1.23	1.13	1.81
Mass of dry soil, g	3.35	4.3	3.23	4.54	3.38	3.54	3.09	4.99
Moisture content, %	**31.94**	**32.79**	**34.06**	**32.16**	**34.91**	**34.74**	**36.57**	**36.27**
Average moisture content, %	**32.36**		**33.11**		**34.82**		**36.42**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*111*	*211*	**22.5**
Mass of container	g	19.88	19.84	
Mass of wet soil+container	g	24.49	23.88	
Mass of dry soil+container	g	23.64	23.14	
Mass of moisture	g	0.85	0.74	
Mass of dry soil	g	3.76	3.3	
Moisture content	%	**22.61**	**22.42**	

Liquid limit	**33.7**
Plastic limit	**22.5**
Plasticity index	**11.2**

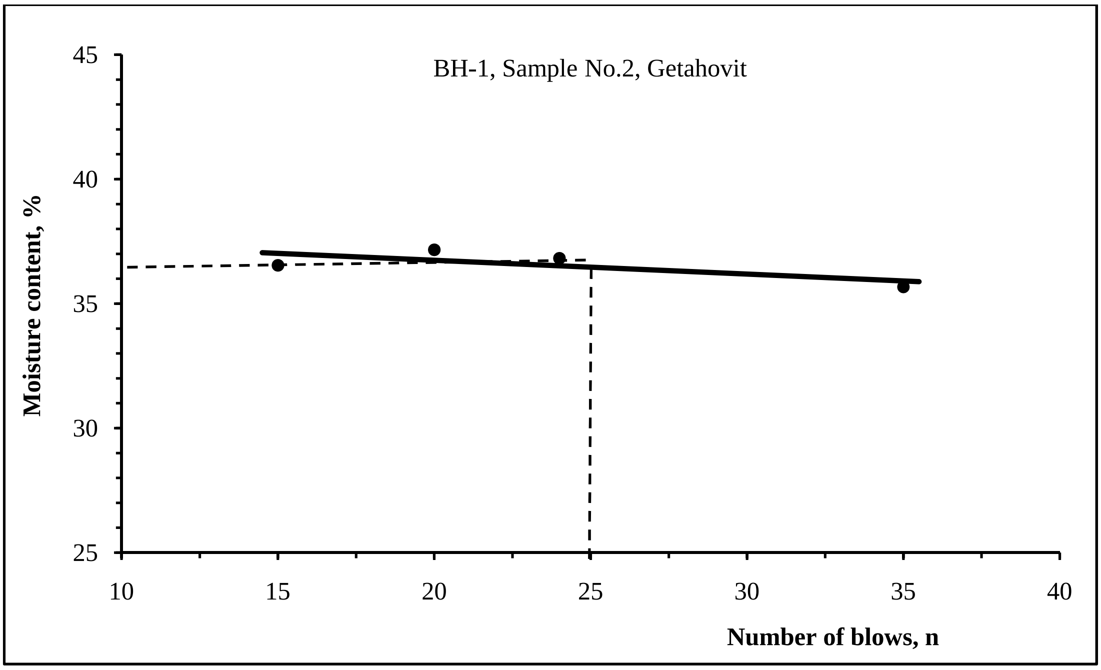


Location _Getahovit   Borehole __BH-1_   Sample No. __2__   Depth _17.0 – 17.2 m_   Date __20.01.2015_

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**35**		**24**		**20**		**15**	
Container no.	*216*	*246*	*208*	*218*	*101*	*104*	*109*	*209*
Mass of container, g	19.69	19.93	19.81	19.78	19.93	19.82	19.79	19.87
Mass of wet soil+container, g	25.77	25.49	25.29	25.15	25.65	25.21	25.42	25.78
Mass of dry soil+container, g	24.18	24.02	23.82	23.7	24.1	23.75	23.85	24.14
Mass of moisture, g	1.59	1.47	1.47	1.45	1.55	1.46	1.57	1.64
Mass of dry soil, g	4.49	4.09	4.01	3.92	4.17	3.93	4.06	4.27
Moisture content, %	**35.41**	**35.94**	**36.66**	**36.99**	**37.17**	**37.15**	**38.67**	**38.41**
Average moisture content, %	**35.67**		**36.82**		**37.16**		**38.54**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*200*	*225*	16.1
Mass of container	g	19.82	19.96	
Mass of wet soil+container	g	22.25	22.15	
Mass of dry soil+container	g	21.91	21.85	
Mass of moisture	g	0.34	0.3	
Mass of dry soil	g	2.09	1.89	
Moisture content	%	**16.27**	**15.87**	

Liquid limit	**36.4**
Plastic limit	**16.1**
Plasticity index	**20.3**

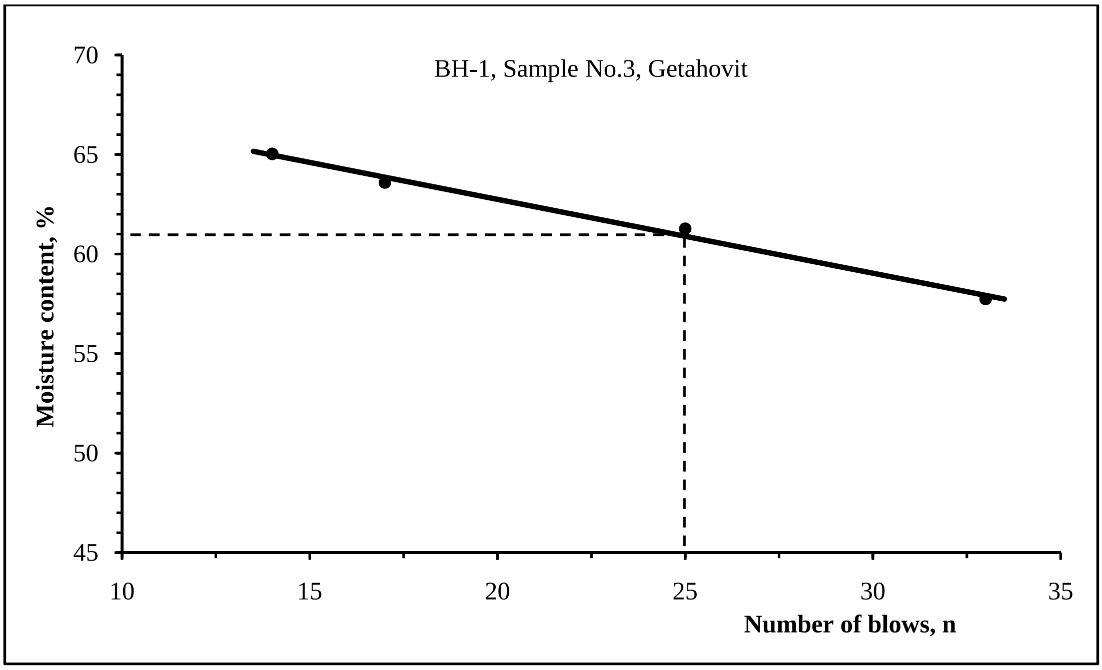


Location _Getahovit_ Borehole _BH-1_ Sample No. __3__ Depth _25.0 – 25.5 m_ Date __21.01.2015__

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**33**		**25**		**17**		**14**	
Container no.	*201*	*202*	*211*	*111*	*920*	*921*	*234*	*235*
Mass of container, g	19.79	22.68	19.88	19.89	19.85	19.89	22.76	19.95
Mass of wet soil+container, g	24.7	27.36	24.36	23.86	24.61	25.24	27.18	24.31
Mass of dry soil+container, g	22.91	25.64	22.66	22.35	22.76	23.16	25.43	22.6
Mass of moisture, g	1.79	1.72	1.7	1.51	1.85	2.08	1.75	1.71
Mass of dry soil, g	3.12	2.96	2.78	2.46	2.91	3.27	2.67	2.65
Moisture content, %	**57.37**	**58.11**	**61.15**	**61.38**	**63.57**	**63.61**	**65.54**	**64.53**
Average moisture content, %	**57.74**		**61.27**		**63.59**		**65.03**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*901*	*232*	
Mass of container	g	22.88	19.80	
Mass of wet soil+container	g	24.43	21.76	
Mass of dry soil+container	g	24.13	21.38	**24.0**
Mass of moisture	g	0.3	0.38	
Mass of dry soil	g	1.25	1.58	
Moisture content	%	**24.0**	**24.05**	

Liquid limit	**61.0**
Plastic limit	**24.0**
Plasticity index	**37**

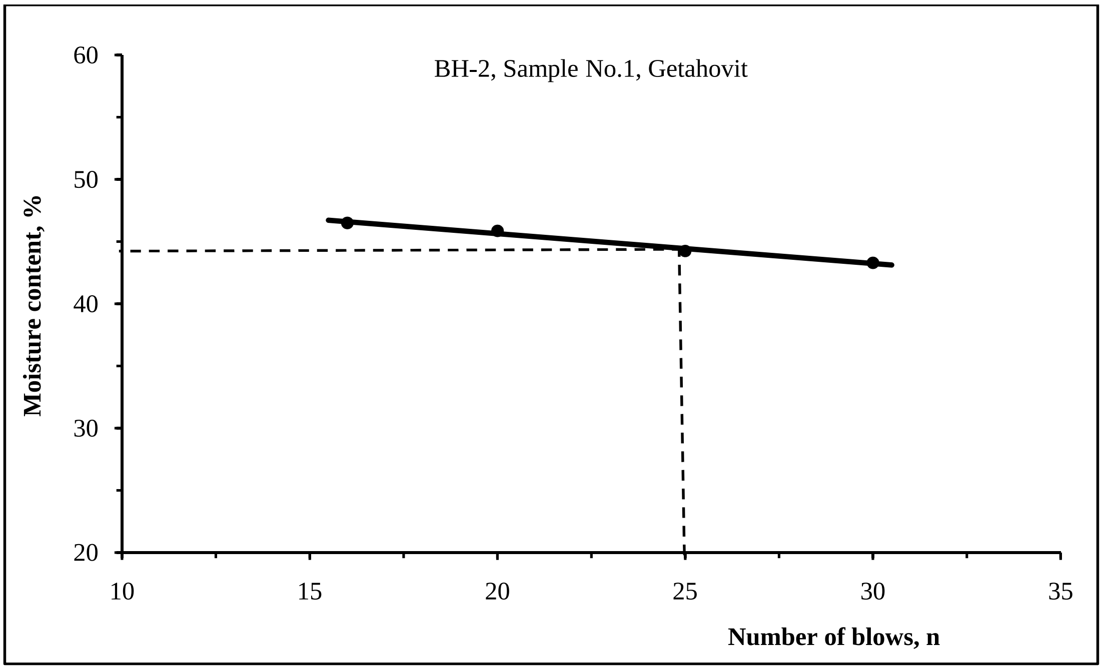


Location _Getahovit   Borehole _BH-2___   Sample No. __1__   Depth _5.0 – 5.5 m_   Date __27.01.2015__

Liquid limit Test No.	**1**		**2**		**3**		**4**	
Number of blows, n	**30**		**25**		**20**		**16**	
Container no.	*201*	*202*	*203*	*204*	*205*	*206*	*207*	*208*
Mass of container, g	19.79	22.67	19.80	26.84	19.80	22.54	19.74	19.87
Mass of wet soil+container, g	23.56	27.11	24.54	30.91	22.43	26.02	23.74	24.25
Mass of dry soil+container, g	22.42	25.77	23.10	29.65	21.60	24.93	22.47	22.86
Mass of moisture, g	1.14	1.34	1.44	1.26	0.83	1.09	1.27	1.39
Mass of dry soil, g	2.63	3.10	3.3	2.81	1.80	2.39	2.73	2.99
Moisture content, %	**43.35**	**43.22**	**43.64**	**44.84**	**46.11**	**45.61**	**46.52**	**46.49**
Average moisture content, %	**43.28**		**44.24**		**45.86**		**46.50**	

Plastic limit Test No.		**1**	**2**	**AVERAGE**
Container no.		*210*	*220*	
Mass of container	g	19.88	19.87	
Mass of wet soil+container	g	22.44	22.11	
Mass of dry soil+container	g	22.01	21.73	**20.3**
Mass of moisture	g	0.43	0.38	
Mass of dry soil	g	2.13	1.86	
Moisture content	%	**20.19**	**20.43**	

Liquid limit	**44.2**
Plastic limit	**20.3**
Plasticity index	**23.9**

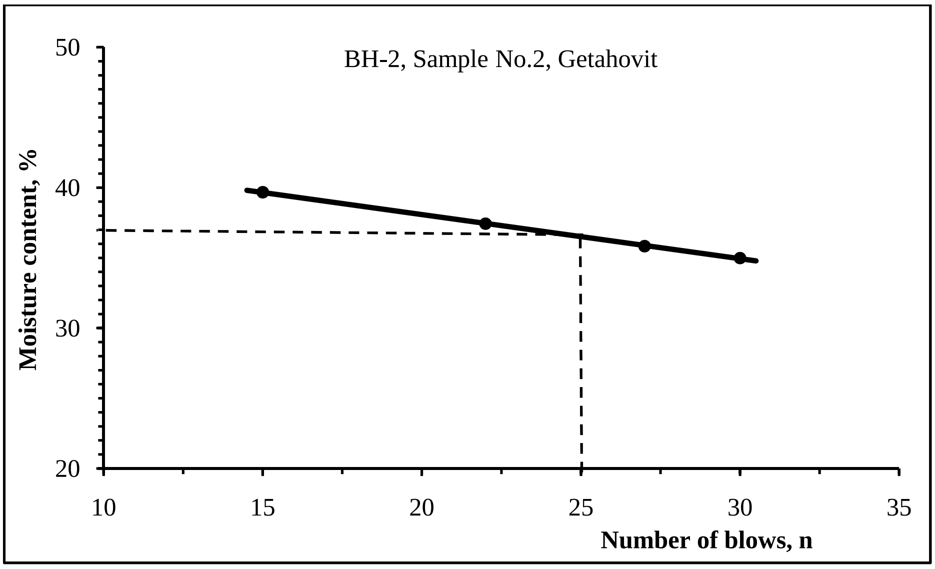


Location _Getahovit Borehole __BH-2_ Sample No. __2__ Depth _15.0 – 15.5 m_ Date __27.01.2015_

Liquid limit **Test No.**	**1**		**2**		**3**		**4**	
Number of blows, n	**30**		**27**		**22**		**15**	
Container no.	*221*	*225*	*231*	*230*	*232*	*233*	*234*	*235*
Mass of container, g	22.50	19.98	22.66	19.93	19.79	22.81	22.76	19.93
Mass of wet soil+container, g	26.10	23.94	26.42	23.41	23.82	27.26	26.99	23.52
Mass of dry soil+container, g	25.17	22.91	25.43	22.49	22.72	26.05	25.80	22.49
Mass of moisture, g	0.93	1.03	0.99	0.92	1.10	1.21	1.19	1.03
Mass of dry soil, g	2.67	2.93	2.77	2.56	2.93	3.24	3.04	2.56
Moisture content, %	**34.83**	**35.15**	**35.74**	**35.94**	**37.54**	**37.35**	**39.14**	**40.23**
Average moisture content, %	**34.99**		**35.84**		**37.44**		**39.68**	

Plastic limit **Test No.**		**1**	**2**	**AVERAGE**
Container no.		*211*	*212*	
Mass of container	g	19.87	19.78	
Mass of wet soil+container	g	22.50	23.44	
Mass of dry soil+container	g	22.14	22.96	**15.5**
Mass of moisture	g	0.36	0.48	
Mass of dry soil	g	2.27	3.18	
Moisture content	%	**15.86**	**15.09**	

Liquid limit	**37.0**
Plastic limit	**15.5**
Plasticity index	**21.5**

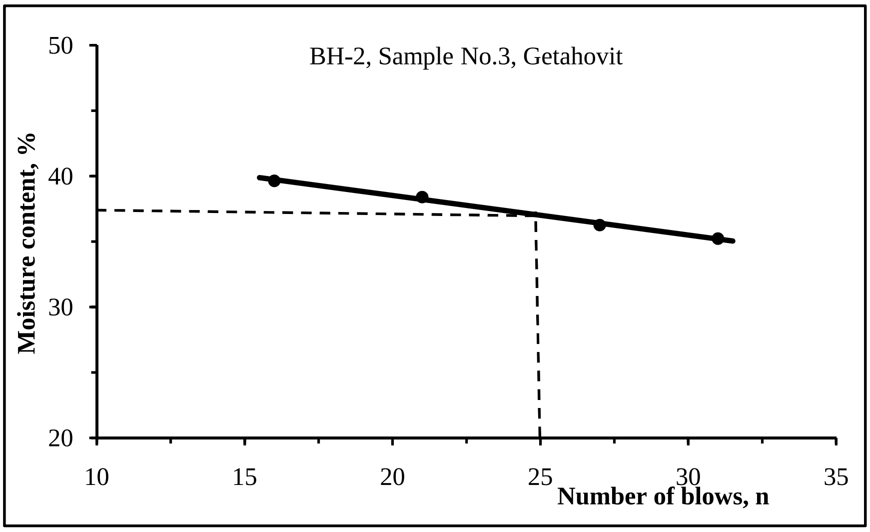


Location _Getahovit Borehole __BH-2_ Sample No. __3__ Depth _26.0 – 26.2 m_ Date __27.01.2015_

Liquid limit Test No.	1		2		3		4	
Number of blows, n	**31**		**27**		**21**		**16**	
Container no.	*200*	*300*	*101*	*104*	*111*	*401*	*901*	*921*
Mass of container, g	19.81	19.88	19.91	19.82	19.89	19.80	22.88	19.90
Mass of wet soil+container, g	23.72	24.53	23.28	24.22	23.97	24.08	28.56	25.60
Mass of dry soil+container, g	22.70	23.32	22.39	23.04	22.84	22.89	26.93	24.0
Mass of moisture, g	1.02	1.21	0.89	1.18	1.13	1.19	1.63	1.6
Mass of dry soil, g	2.89	3.44	2.48	3.22	2.95	3.09	4.05	4.1
Moisture content, %	**35.29**	**35.17**	**35.89**	**36.64**	**38.30**	**38.51**	**40.25**	**39.02**
Average moisture content, %	**35.23**		**36.26**		**38.40**		**39.63**	

Plastic limit Test No.		1	2	AVERAGE
Container no.		*216*	*246*	15.1
Mass of container	g	19.69	19.94	
Mass of wet soil+container	g	21.89	21.70	
Mass of dry soil+container	g	21.60	21.47	
Mass of moisture	g	0.29	0.23	
Mass of dry soil	g	1.91	1.53	
Moisture content	%	**15.18**	**15.03**	

Liquid limit	**37.1**
Plastic limit	**15.1**
Plasticity index	**22.0**



Առանձնացված հավելված 7 Պիլոտային ծրագրի իրականացման պլան

Republic of Armenia
Ministry of Territorial Administration and
Emergency Situations

Landslide Disaster Management Project in the Republic of Armenia

Implementation Plan on Landslide Measures in Pilot Project Area (Arapi and Getahovit sites)

June 2015

Japan International Cooperation Agency

Nippon Koei Co., Ltd

Table of Contents

List of Tables

List of Figures

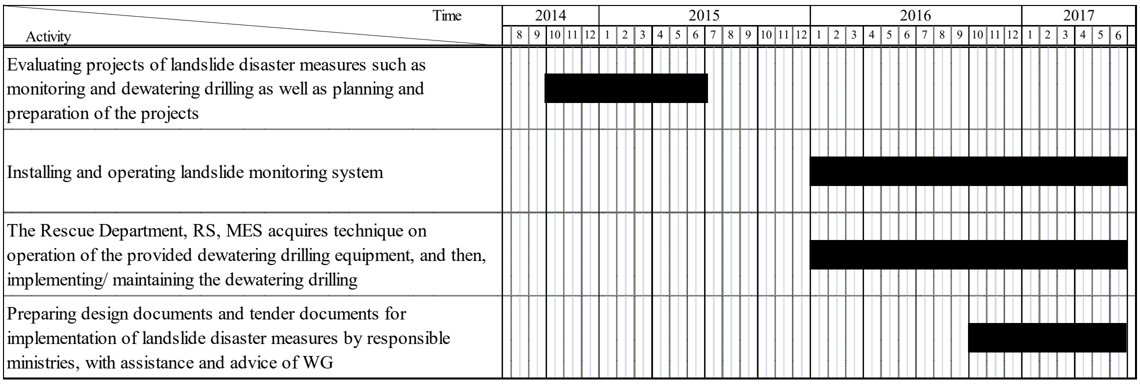
List of Attachments

1. Outline of Pilot Project

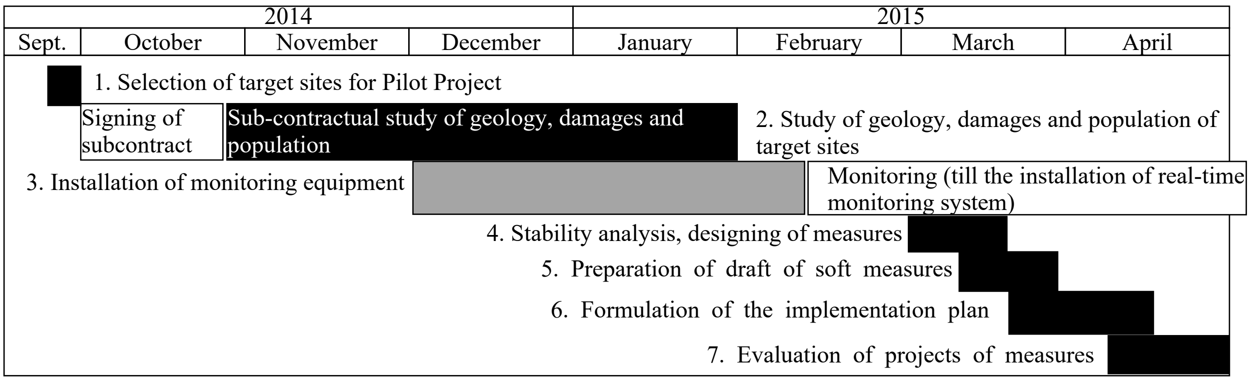
Pilot Project is an important component of the Landslide Disaster Management Project, mainly for achieving the expected Output 3 as shown below.

Project purpose	Improving landslide disaster management capacity of WG
Expected outputs	
Output 1	The members of WG acquire technology and know-how on investigation, assessment, and design/ order/ supervision of measures
Output 2	A comprehensive landslide disaster management plan in Armenia is formulated, guidelines for landslide disaster management (investigation, assessment, and design/ order/ supervision of measures) are prepared, and laws and regulations for implementation of the measures are improved
Output 3	Organizational and institutional framework for implementation of monitoring, proactive measures, emergency measures, and permanent measures is improved in related ministries and agencies, in accordance with the concept for landslide disaster management

In order to achieve Output 3, project activities are carried out on the following overall schedule.



The first activity in the overall schedule are been carrying out on the following detailed schedule.



2. Selection of target sites

Through discussion among the members of the Permanent working group of landslide disaster management (WG), 10 candidates of the target sites were picked up and criteria for the selection of two target sites were agreed as shown in Tables 1 to 3.

As shown in Table 3, Arapi and Getahovit sites were selected as the target sites.

Table 1 Criteria for the selection of target sites

Category		Rank			
1	Priority (Seriousness of hazard and risk in the areas)	A	B	C	D
2	Possibility of applying countermeasures to other areas	High	Moderate	Fair	Poor
3	Cooperation and intention of residents and local managing staffs in the areas	Excellent	Good	Fair	Poor
4	Scale of active landslide (A; ha)	A<=1	1<A<=10	10<A<=100	100<A
Point		5	3	0	-3

Table 2 Criteria for prioritization

Risk level \ Hazard level	Priority I	Priority II	Priority III
H	A	A	B
M	A	B	C
L	B	C	C

Hazard Level	
I	Damages are progressing
II	Damages were reported or recognized in the past and effective countermeasures have not performed
III	Landslide configuration are recognized, bad damages have not reported/recognized

Risk Level	
H	Many houses, public facilities, or important infrastructure are exist as risk objects Landslide is causing serious environment impact
M	Some houses, public facilities, or infrastructure are exist as risk objects. Landslide is causing serious environment impact
L	Landslide is little relation with human activity

Table 3 The result of selection of target sites

No.	Name	Map	Inventory sheet	Altitude (m)	Width (m)	Length (m)	Area (ha)	Hazard	Risk	Priority	Houses damaged	Houses in risk	Other damages	Site visit	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Evaluation Fin
1	Voghjaberd	K-38-138	KOTA-138-0160	1,570	1,913	2,906	287	I	H	A	150	250	Main road etc.	18/Aug	A	C	B	D	
															5	0	3	-3	5
2	Dilijan "Mets Tala"	K-38-114	TAVU-114-0280	1,325	900	550	62	II	H	B	2,000	2,000		22/Aug	B	D	C	C	
															3	-3	0	0	0
3	Getahovit	K-38-115	TAVU-115-0271	756	450	200	5	II	H	B	550	120		22/Aug	B	B	A	A	
															3	3	5	5	16
4	Arapi	K-38-112	SHIR-112-0020	1,484	440	220	5	I	H	A	200	600		21/Aug	A	B	A	A	
															5	3	5	5	18
5	Ayrum	K-38-102	TAVU-102-0033	510	250	100	2	I	M	B	0	0		22/Aug	B	B	C	B	
															3	3	0	3	9
6	Dilijan international school	K-38-114	TAVU-114-0120	1,389	650	700	40	III	M	C	10	10	International school	22/Aug	C	C	C	B	
															0	0	0	3	3
7	Sisian-pass	J-38-008	VAYO-008-0460	2,418	1,100	5,400	263	I	M	B	0	0	Main road etc.	19/Aug	B	B	D	D	
															3	3	-3	-3	0
8	Kapan (Manukyan)	J-38-033	(SYUN-033-2050)	874	300	500	10	III	M	C	0	Apartment buildings		20/Aug	C	B	C	A	
															0	3	0	5	8
9	Hovq	K-38-115	TAVU-115-2260	1,197	1,000	4,400	628	I	H	A	70	?	Main road etc.	22/Aug	A	C	B	D	
															5	0	3	-3	5
10	Haghatsin	K-38-114	TAVU-114-0800	1,082	950	660	49	II	H	B	17	17	Main road etc.	22/Aug	B	C	C	B	
															3	0	0	3	6

3. Information of the target sites

3.1 Arapi site

(1) Topographic and geomorphologic features

The Arapi community occupies the area of 15.166km^2 in the North-western part of the territory of the Republic of Armenia, about 4 km to SSW from the center of Gymuri, the capital of Shirak marz.

As shown in Figure 1, the Akhuryan River flows the North to South along the east edge of the community area with flat river bank of several hundred meters wide. A flat fill lies on the west part of the community area. Residential area lies on slopes between the flat river bank and the flat fill. The highest point is located on the northwestern side of the flat fill with elevation of 1,583 m, while the lowest point of about 1,470 m on the Akhuryan River in the southeastern part of the community.

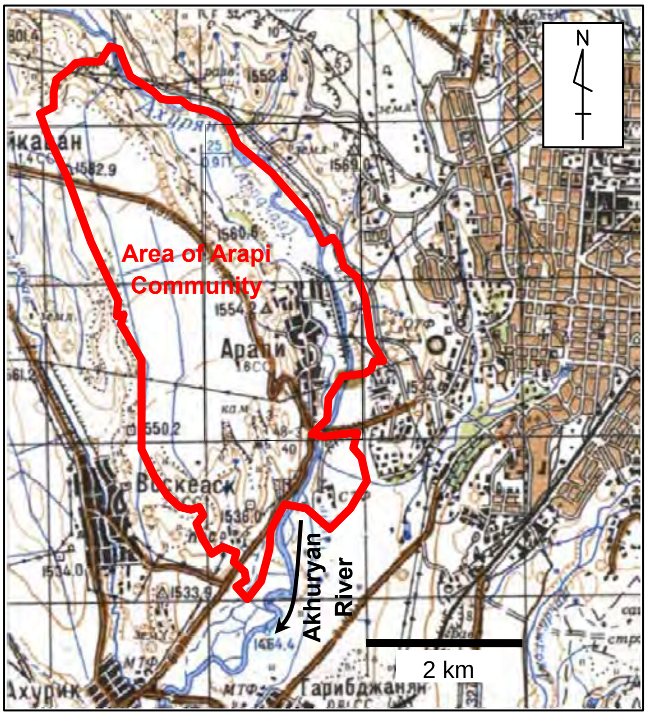


Figure 1 Topographic map of Arapi

(2) Population

The population of the community is 1,994 people. Some details are provided below.

- Up to 2 years old - 44
- 2 - 7 years old - 100
- 7 - 17 years old - 200
- Invalids – 30
- Pensioners - 220
- Pregnant women - 10
- Mothers having under-age children - 200
- Women over 17 - 844
- Men over 17 - 767

In order to clarify the situations, awareness, intention, etc. of residents, questionnaire survey was conducted for 30 families in the landslide area. The result is shown in Attachment 1.

(3) Damage

According to inventory done in 2004, damaged residential buildings are 20 in category III, 20 in category IV, and 10 in category V. Roads in the community are damaged frequently, and repaired at two to three sections for two to twice a year. Pavement of the roads has not been done for long time, and the improvement of the roads condition is one of the heigest needs of the residents. In year 2014, budget for relocation was allocated for 11 families with the total amount of 44 million AMD. As of November 2014, four families have relocated. The budget covers the cost for houses only, but not for land. Development of cracks on walls of houses is aware every year in many houses (more than 80% of responding family to questionnaire).

3.2 Getahovit site

(1) Topographic and geomorphologic features

The Getahovit community occupies the area of about 45 km^2 in the North-east part of the territory of the Republic of Armenia, about 2 km to NNW from the center of Ijevan, the capital of Tabush marz.

As shown in Figure 2, most of the area of Getahovit community lies on mountainous area with the highest peak of about EL. 2,500 m on the western edge of the community. The Aghstev River flows from the South to North along the eastern edge of the community area. The main residential area is located relatively gentle slopes on the elevation of about 500 m in the eastern part of the community area, between the mountainous area and the Aghstev River.

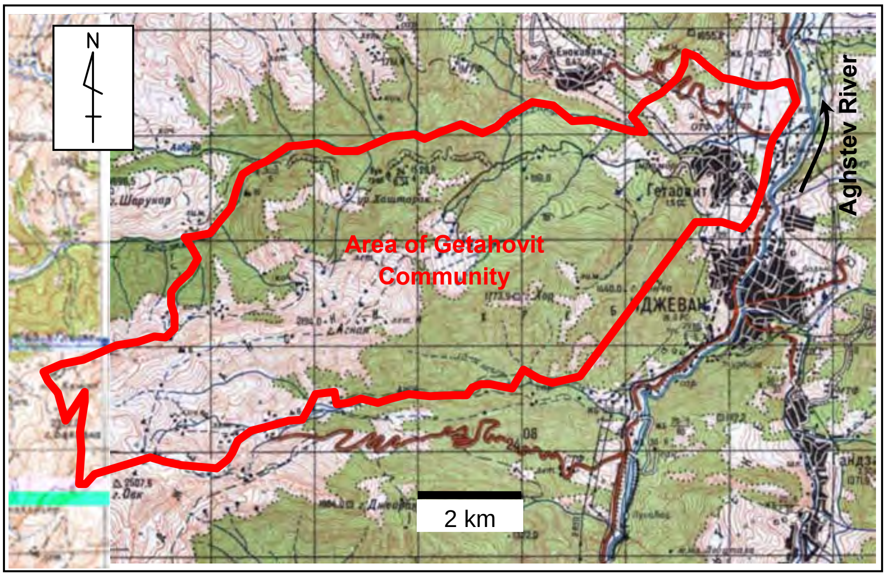


Figure 2 Topographic map around Getahovit

(2) Population

The population of the community is about 2,000 people. In order to clarify the situations, awareness, intension, etc. of residents, questionnaire survey was conducted for 30 families in the landslide area. The result is shown in Attachment 2.

(3) Damage

According to inventory done in 2004, damaged residential buildings are 180 in category III, 126 in category IV, and 2 in category V. One hospital and one school were in damage category III. Water supply system and telecommunication lines were also damaged. A block in the landslide was active in 2006 due to leakage from a water pipeline and completely destroyed two houses. Although the activity of the landslide is not so intense after the repairing of the pipeline up to 2015, cracks on wall of houses are still developing every year. In 1996 to 1997, compensation for damage to houses was paid to 7 families by the Government. The amount for each family was 3.5 to 4.2 mil. AMD.

4. Geology

Geological investigation was carried out in the Project as shown in Table 4 and the locations and list of the investigation in Arapi and Getahovit sites are shown in Attachments 3and 4, respectively.

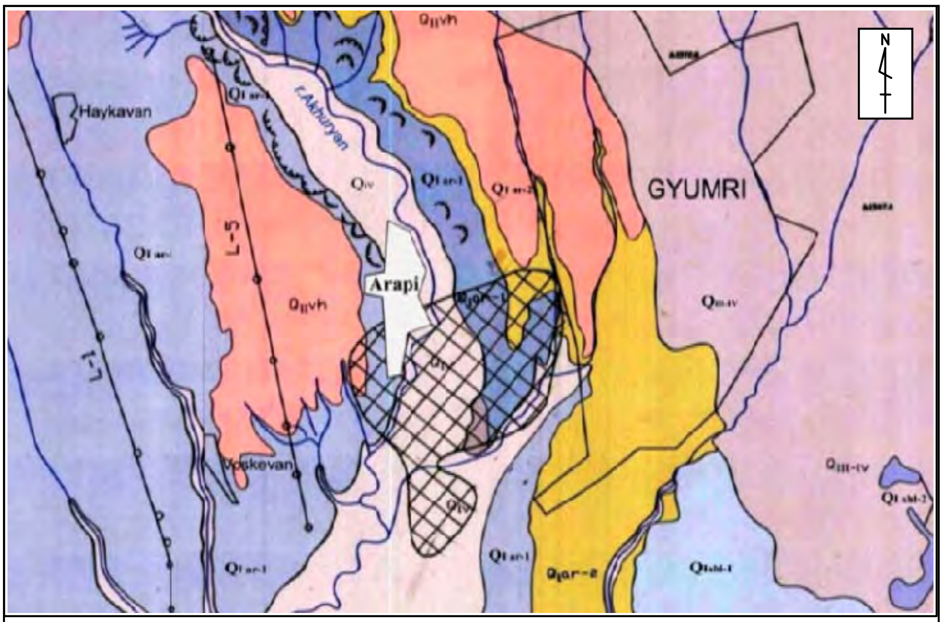
Table 4 Item and quantity of geological investigation

Item	Unit	Quantity	Remark
Topographic survey	m	4,100	5 sections
Core Drilling	m	60	2 holes
Electric prospecting	point	4	
Geo-radar prospecting	m	731	5 sections
Laboratory tests	sample	12	Physical and mechanical tests
X-ray analysis	sample	4	

The result of the laboratory tests are shown in Attachment 5 with the processed data of grain size distribution, density, and shear strength tests (torsion test).

4.1 Arapi site

The geological map of the site (see Figure 3) shows that sedimentary formations developed at the landslide areas and the built-up area of Arapi community are relatively young and belong to the lacustrine Shirak complex of Early Quaternary age, the so-called Arapi-1 horizon. The formation consists of layers of clays, sandy loam and diatomaceous clays. The formation is comparatively softer than other formations nearby and causes widespread development of landslide over the entire areas of this horizon.



Legend

Q IV	Modern formations – river and slope boulders, sands, loamy sands
Q II vIn	The Middle Quaternary Clayey Complex of Sharayiler - tuff cover of Vahramaberd, Ignimbrite tuffs of Yerevan type, black tuffaceous sands
Q I ar-1	The Early Quaternary Lake Complex of Shirak: Arapy-1 horizon – clays, sandy loam, pumice sands, sands with layers of diatomite clays

Figure 3 Geological map of Arapi (Kharazian et.al)

4.2 Getahovit site

According to geological map of the site (see Figure 4), terrigenous sediments such as loess-like loam are distributed on the residential area of Getahovit community. The foundation rocks consist of the upper Cretaceous volcano-sedimentary rocks, such as calcareous sandstone. Landslides occur in the unconsolidated sediments.

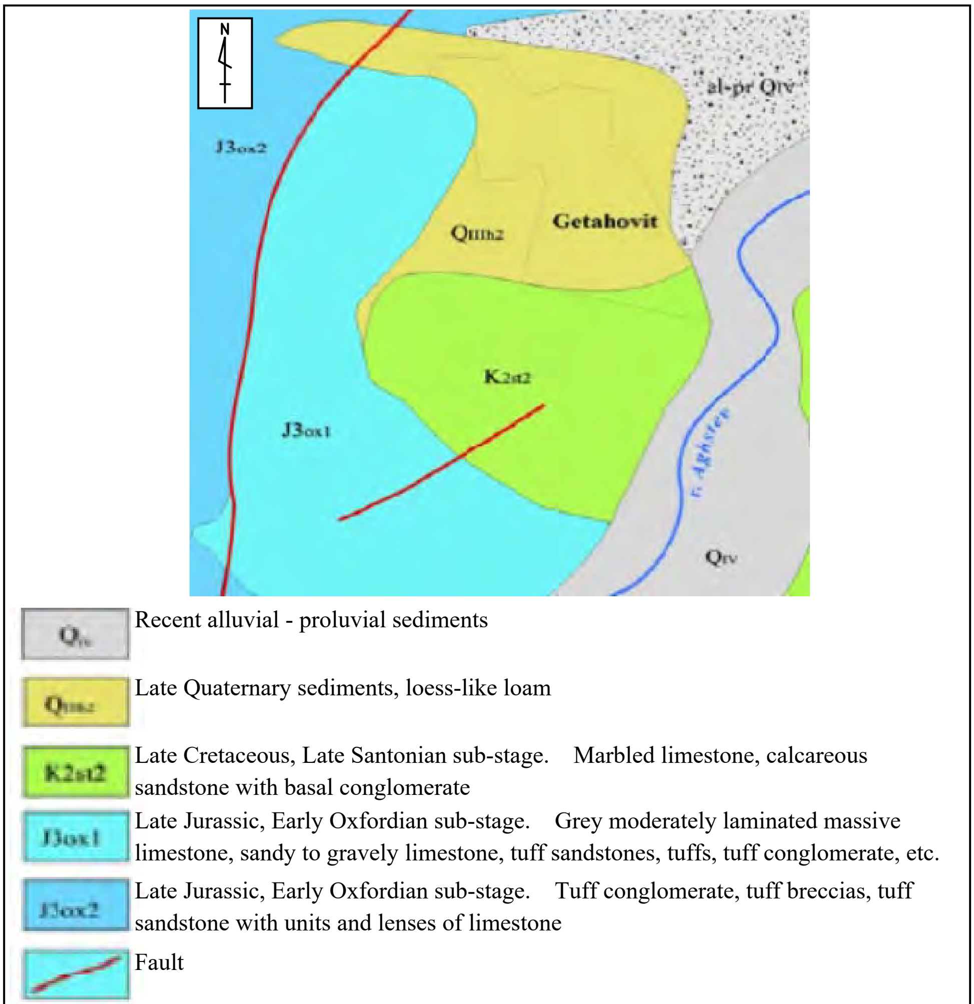


Figure 4 Geological map of Getahovit

5. Monitoring

Monitoring at the Arapi and Getahovit sites is being carried out, to clarify the landslide movement in four elements, which are surface displacement, subsurface displacement, groundwater level, meteorological condition with the equipment mentioned in Table 5 for each site. The monitoring activities are explained with manual of monitoring equipment and handed over to responsible staffs of regional rescue service with software for displaying the graphs of the monitoring results.

Table 5 Monitoring equipment in Arapi and Getahovit sites

Item	Device	Quantity	Remark
Surface displacement	Surface extensometer	2	At 2 points (S3 and S4)
Subsurface displacement	Pipe strain gauge Hole extensometer	2 2	At 2 points (H1 and H2) At 2 points (H1 and H2)
Groundwater level	Hole water level meter	2	At 2 point (H1 and H2)
Meteorological condition	Thermometer Rain gauge	4 1	At 4 points (H1, H2, S3, and S4) At 1 point

5.1 Arapi site

The location of installed monitoring equipment is shown in Attachments 6 and the results of the monitoring up to May 2015 are shown in Attachment 7.

As shown in Attachment 7, relatively clear displacement is detected in the northern block where H1 and S3 are located. The displacement is detected with the hole extensometer and surface extensometer as well as pipe strain gauge from March 2015, which is in the season of snow melt.

Abnormal extension is detected in the southern block where H2 and S4 are located, although the characteristics of the detected displacement may not due to landslide activity.

5.2 Getahovit site

The location of installed monitoring equipment is shown in Attachments 8 and the results of the monitoring up to May 2015 are shown in Attachment 9.

As shown in Attachment 9, some displacement is recorded in the southern block where H1 and S3 are located. The displacement detected in the southern block is not judged to be landslide movement, and further monitoring is required to clarify the landslide activity.

In the northern block where H2 and S4 are located, possible movement is detected with strain meter at 27 m deep in H2, although the measured displacement with hole extensometer is 0.2 mm. Surface extensometer at S3 detects some 5 mm extension, although it is not so big and relation to landslide movement is still not clear. It is necessary to continue monitoring to clarify the landslide movement in the northern block.

It is noted that groundwater outflow started in April 2015 from a drainage pipe that is installed in 2006. The amount of outflow was not much since 2006, and it may have relation to the heightening of groundwater level at H1 and H2. Careful observation is required, since groundwater level seems to have close relation to the stability of the landslide.

6. Stability analysis

6.1 Arapi site

Stability analysis has been done on two sections (SA01 and SA03), where investigation and monitoring have been done. Parameters for stability analysis have been set up as shown in Table 6, referring the result of geological investigation.

Table 6 Parameters for stability analysis for Arapi site

Item \ Material	Unit	Top soil	Sliding mass	Foundation
Unit weight	kN/m3	18.00	20.00	20.00
Internal friction angle	Degree	15.00	15.00	20.00
Cohesion	kN/m2	20.00	20.00	50.00
Groundwater level	3 cases	1. the present level, 2. the upper portion of sliding mass, and 3. nearly on the ground surface		

The analytical results are shown in Attachment 10.

The safety factors calculated for each 3 cases for 2 sections are show in Table 7.

Table 7 Safety factor calculated in stability analysis for Arapi site

Section	Case	Safety factor	Remark
SA01	Case 1	1.188	With the present level of groundwater
	Case 2	1.116	Slightly higher groundwater level
	Case 3	0.970	High groundwater level
SA03	Case 1	1.172	With the present level of groundwater
	Case 2	1.057	Slightly higher groundwater level
	Case 3	0.993	High groundwater level

The result and assessment are summarized as follows.

- The calculation result in case 1 with the present groundwater level indicates that the slope is judged to be stable.
- The calculation result in case 3 with high groundwater level (near to the surface) indicates that slope is getting unstable.
- The previous activation is considered to occur due to the heightening of groundwater.
- In order to prevent the heightening of groundwater in future, it is recommendable to install horizontal holes for groundwater drainage.

6.2 Getahovit site

Stability analysis has been done on two sections (SG01 and SG03), where investigation and monitoring have been done. Parameters for stability analysis have been set up as shown in Table 8, referring the result of geological investigation.

Table 8 Parameters for stability analysis for Getahovit site

Item \ Material	Unit	Top soil	Sliding mass	Foundation
Unit weight	kN/m3	18.00	20.00	20.00
Internal friction angle	Degree	15.00	20.00	30.00
Cohesion	kN/m2	20.00	20.00	50.00
Groundwater level	3 cases	1. the present level, 2. the upper portion of sliding mass, and 3. nearly on the ground surface		

The analytical results are shown in Attachment 11.

The safety factors calculated for each 3 cases for 2 sections are show in Table 9.

Table 9 Safety factor calculated in stability analysis for Getahovit site

Section	Case	Safety factor	Remark
SG01	Case 1	1.238	With the present level of groundwater
	Case 2	1.132	Slightly higher groundwater level
	Case 3	0.853	High groundwater level
SG03	Case 1	1.398	With the present level of groundwater
	Case 2	1.308	Slightly higher groundwater level
	Case 3	1.024	High groundwater level

The result and assessment are summarized as follows.

- The calculation result in case 1 with the present groundwater level indicates that the slope is judged to be stable.
- The calculation result in case 3 with high groundwater level (near to the surface) indicates that slope is getting unstable, although the safety factor for SG 03 is higher than 1.00.
- The previous activation is considered to occur due to the heightening of groundwater.
- In order to prevent the heightening of groundwater in future, it is recommendable to install horizontal holes for groundwater drainage.

7. Design of countermeasure works

Since the result of stability analysis indicates that heightening of groundwater level affects the slope stability, it is considered that lowering of groundwater level is an efficient measure. Although earth works such as soil removal on the higher portion or countermeasure embankment on the toe portion seem to be other effective measures, it is difficult to apply those measures, since the most of the landslide area are in densely built-up area without enough space for the earth works.

7.1 Arapi site

The possible locations of horizontal hole are shown in Figure 5 on sections and Figure 6 on a plan.

On the sections, horizontal holes will be installed from the middle portions in landslide area, so that drainage of groundwater can be done efficiently in high groundwater conditions as well as the present groundwater conditions.

On the plan, the locations have been tentatively determined, referring the elevation shown in the sections as well as the availability of area for installation of drilling works, since there are some houses and cultivated area around the tentative locations.

As shown in Figure 6, the horizontal holes will be drilled at 2 points, and the number of holes at each point is about 10 holes. In total, 20 holes will be drilled at Arapi site. The length of a hole will be about 50 m, and total length of holes will be 1,000 m.

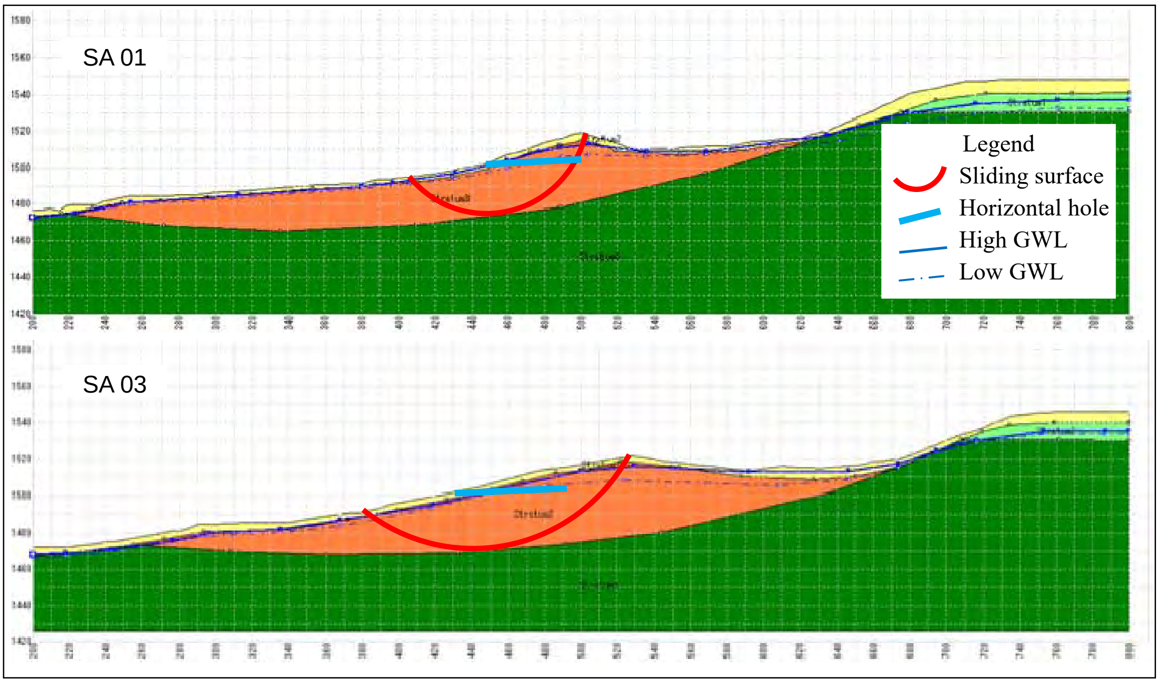


Figure 5 Possible locations of horizontal holes for Arapi site on sections

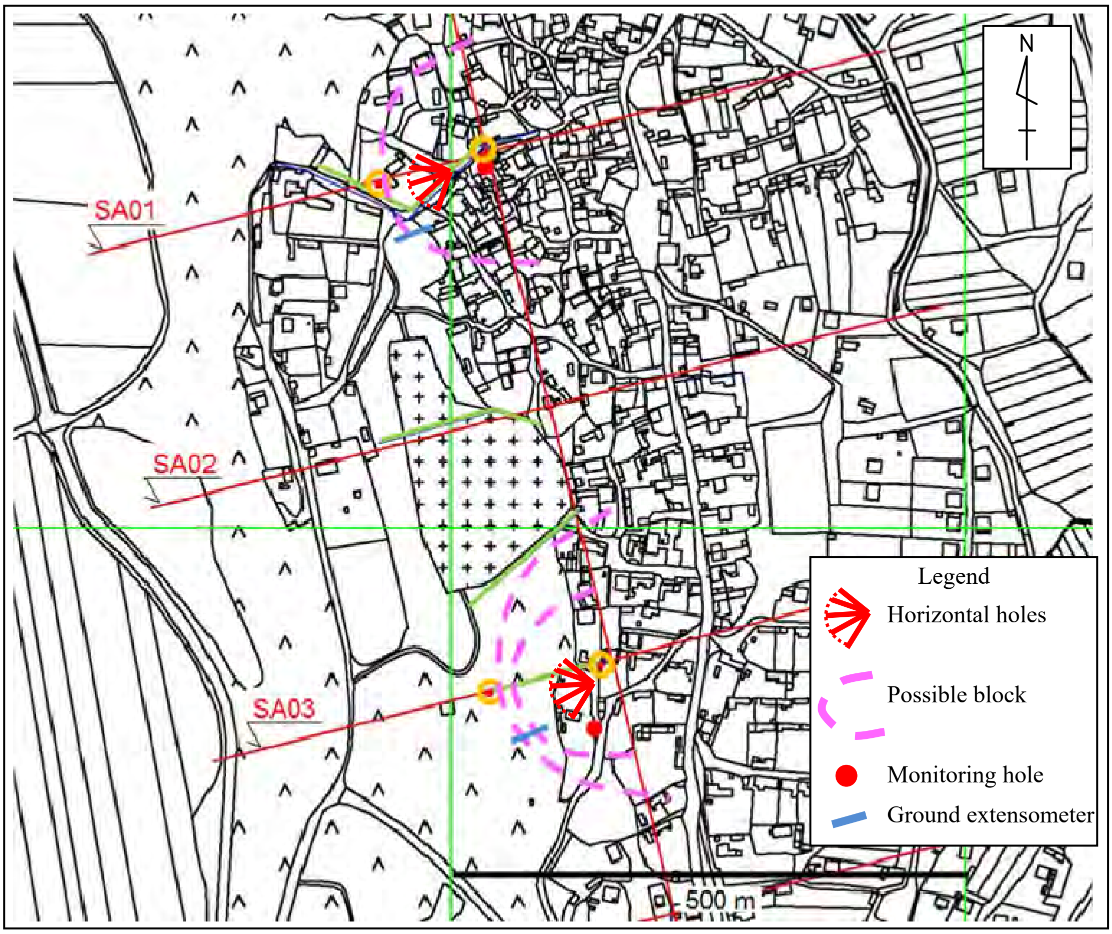


Figure 6 Possible locations of horizontal holes for Arapi site on a plan

7.2 Getahovit site

The possible locations of horizontal hole are shown in Figure 7 on sections and Figure 8 on a plan.

On the sections, horizontal holes will be installed from the middle portions in landslide area, so that drainage of groundwater can be done efficiently in high groundwater conditions as well as the present groundwater conditions.

On the plan, the locations have been tentatively determined, referring the elevation shown in the sections as well as the availability of area for installation of drilling works, since there are some houses and cultivated area around the tentative locations.

As shown in Figure 8, the horizontal holes will be drilled at 2 points, and the number of holes at each point is about 10 holes. In total, 20 holes will be drilled at Arapi site. The length of a hole will be about 50 m, and total length of holes will be 1,000 m.

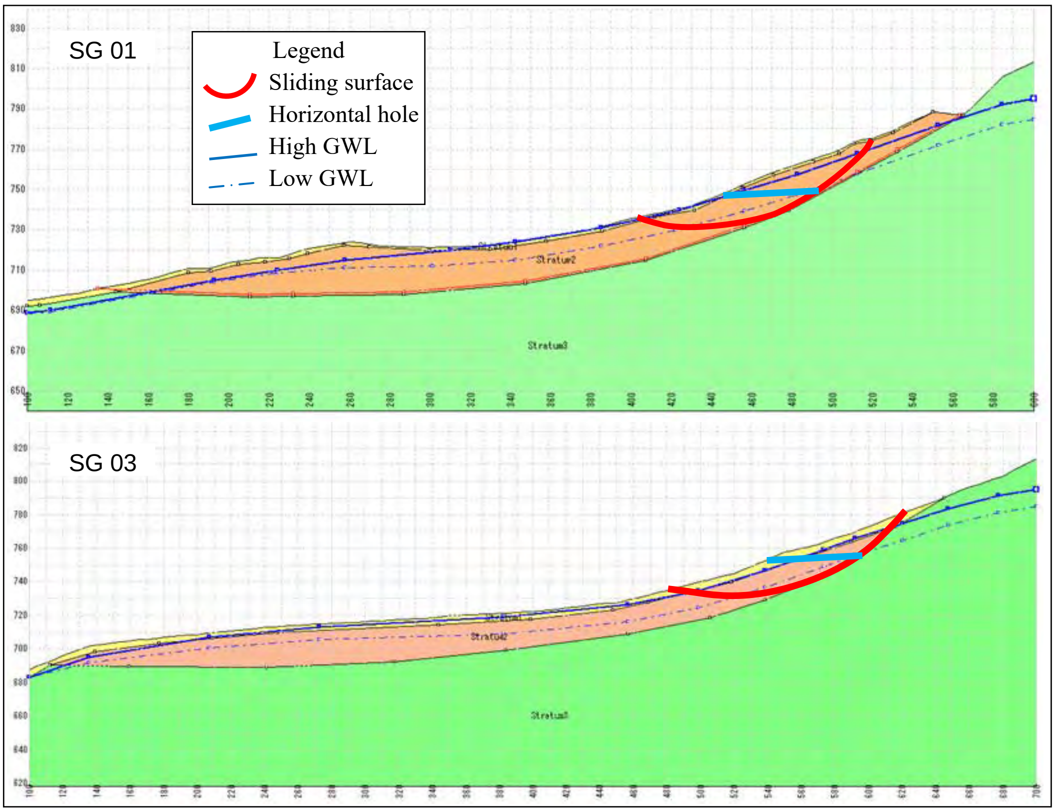


Figure 7 Possible locations of horizontal holes for Getahovit site on sections

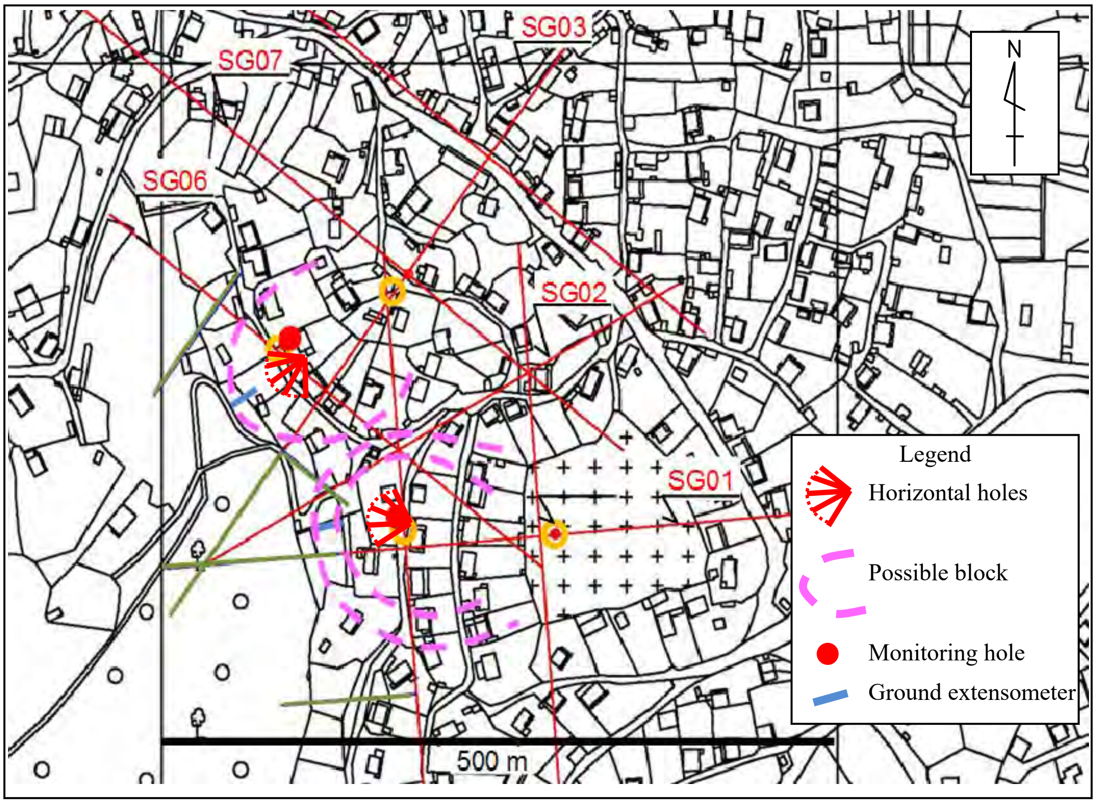


Figure 8 Possible locations of horizontal holes for Getahovit site on a plan

8. Soft measures

8.1 Basic policy

The followings are basic policy of soft measures.

1. Sharing basic issues and framework on disaster risk, proactive measures, emergency response measures, and rehabilitation/ reconstruction measures
    - Preparation of a leaflet for explanation of landslide risk
    - Preparation of a mitigation plan
    - Preparation of a preparedness plan
2. Proper and prompt information provision on risk, damage, and measures
    - Establishment of the collection/ dissemination system of proper information
    - Provision of information for proper decision/ action of the receivers
3. Promotion of autonomic and efficient activities of all actors
    - Securing budget and establishing implementation framework for promotion of countermeasure works
    - Preparation of business continuity plan of community
    - Enforcement of capacity of community on disaster management

8.2 Mitigation measures

Measures to be done by residents are as follows.

(1) Awareness of landslide risk

The residents have been aware well about damages occurred in the landslide area. For promotion and efficiency of activities by the residents, somehow scientific points on landslide risk such as mechanism, basic factors, trigger factors, etc. will be introduced to the residents as a base for their proper activity.

(2) Treatment of surface water

In Arapi community area, seepage of groundwater is seen at many points, since groundwater level is generally high, nearly to the ground surface. Spring water is used for small-scale cultivation in house yards of many houses. Surface water is generally not treated and it flows on the surface, resulting in heightening of groundwater level. Installation manual digging drain ditches and cleaning of existing drain ditches can be done by residents.

(3) Consensus and expression of needs on relocation

In Soviet time, a relocation plan was prepared, although the plan has not been realized due to the collapse of Soviet Union. The area for relocation is still available on the opposite bank of the Aghstev River which is in the area of Arapi community. Since the relocation of houses is one of possible measures, it is recommended whether the relocation plan to be promoted or not, consensus and expression of needs of residents will be clarified.

(4) Simple monitoring of cracks by residents and information of development of cracks

Cracks develop on the walls of many residential houses, and wetting of the walls also observed in some houses. Newly development (extension and/or widening) of cracks can be observed with simple method, which parts of cracks filled with mortar and new cracks on the mortar surface can be checked. The situation of developing cracks is informed to the community office and regional rescue service, according to the communication chart shown in the existing evacuation plan of Arapi community. In case that the new cracks develop quickly, the community office and regional rescue service request expert team of RS MTAES for detailed checking on landslide activities. In case that the development of the cracks is so intense (tentative criteria is 5 mm/day), the residents should evacuated autonomously or by the guidance of the community office.

(5) Disaster education and training

Disaster education and training for proper activity are important for reduction of risk and vulnerability. The result of questionnaire survey shows that the needs of residents for conducting such activity are high. The disaster education and training will be organized by JICA expert team, MTAES, regional rescue service, and community office, with assistant of CMSA (Crisis Management State Academy), using materials that explain the above-mentioned measures.

9. Implementation plan of the pilot project

The pilot project will be implemented at Arapi and Getahovit sites with the major components of 1) monitoring, 2) installation of countermeasures, 3) conducting soft measures.

9.1 Monitoring

The purpose of monitoring is clarify the characteristics and activity of landslide mainly for 1) design of measures, and 2) assessment of effectiveness of countermeasure works to be installed in the Project.

Monitoring will continue with manual data acquisition, and then, it will be done with real-time monitoring system. The schedule of installation of real-time system is shown in Figure 9.

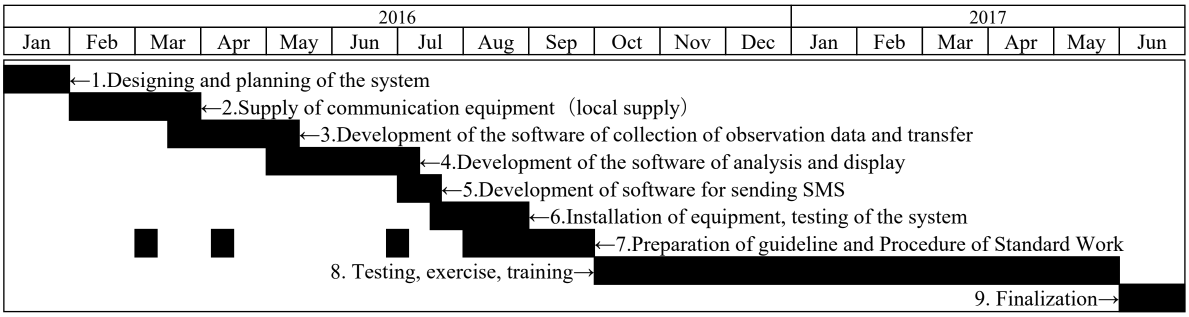


Figure 9 Schedule of installation of real-time monitoring system

(1) Manual monitoring before installation of real-time system

Before the installation of the real-time system, manual data acquisition will be done in the framework shown below.

a) Responsibility

- Overall management and evaluation of the monitoring results
  RS MTAES (Mr. Muradyan)
- Site management (including data acquisition) and processing the monitoring data
  Regional rescue service (Mr. Levon for Arapi site and Mr. Victor for Getahovit site)

b) Activity of manual monitoring

- Maintenance of installed equipment
  Site management has responsibility of maintenance of installed equipment. Maintenance activity is not special work, just observe the safety of the equipment, together with staff of community office and residents, living around the installed points. In case that the equipment is damaged, the repairing will be done by site management, based on the manual of equipment, provided and explained by JICA expert team. In case of serious damages which repairing cannot be done, the information is sent to RS MTAES to find the way of repairing.
- Data acquisition and processing
  Staffs of site management can carry out data acquisition alone after co-activity with JICA expert team The staffs will continue the data acquisition at least once two weeks. Staffs of site management will continue activity of transferring the monitoring data from media in a data logger to a computer in regional rescue service as well as data processing on excel files that is created for drawing graphs of the monitoring results by JICA expert team.

- Evaluation of the monitoring results
  Site management will send the monitoring data to MTAES and JICA expert team (overall management) for evaluation of the result. Overall management will also study the results to clarify the relation among landslide activeness, groundwater level, and precipitation.
- Emergency response
  In case abnormal displacement is detected, emergency response will be taken. The criteria and response to be taken are as mentioned on Manual 8 (Emergency response).

(2) Schedule and procedure of installation of real-time system

a) Design and plan

The person in charge of the JICA Expert Team and the Head of the Crisis Management Center and the person in charge of the system will prepare a design of the system and a general plan (design) related to installation and operation of the system with joint efforts which will be discussed and approved by WG. The general feature of the system is mentioned in Figure 10.

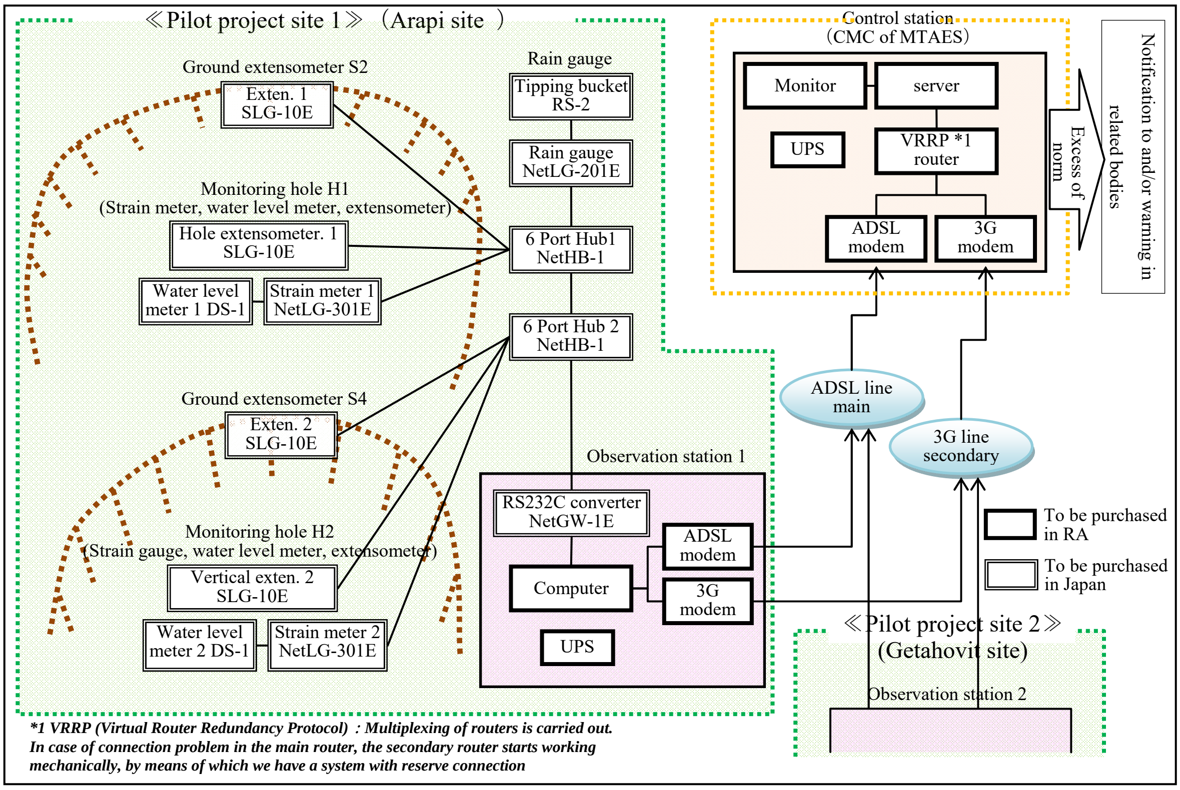


Figure 10 General feature of real-time monitoring system

b) Procurement of equipment for data transmission

Equipment for data transmission has been procured in Armenia, except modems that will be provided when internet account is open. The list of procured equipment is shown in Table 10

Table 10 List of equipment for real-time monitoring system

	Item	Spec.	Qt'y	Remark
1	Computer for observation and operation	Desk top type, CPU: Intel Core i3, RAM: 4GB, HDD:500GB	3	Operation software and business software are pre-installed
2	Server for data processing	Tower type, CPU: Intel Xeon E5, RAM: 16GB, HDD: 1 TB	1	Operation software is pre-installed
3	Monitor for computer and server	Monitor LED 21", Resolution: 1,920*1080	4	
4	Anti-virus software		4	Kaspersky for computers STAN for server
5	UPS for computer	Power capacity: 800 VA	3	
6	UPS for server	Power capacity: 1,500 VA	1	

c) Development of software for the real-time monitoring system

The software consists of three components; 1) collecting and sending monitoring data, 2) analyzing and displaying the data and result, and 3) disseminating information and/or warning through SMS to relevant organizations and residents. Based on discussion between JICA team and Crisis Management Center, RS MTAES (CMC), the development of the software will be done by a software company as sublet works. An example of the display is shown in Figure.11.

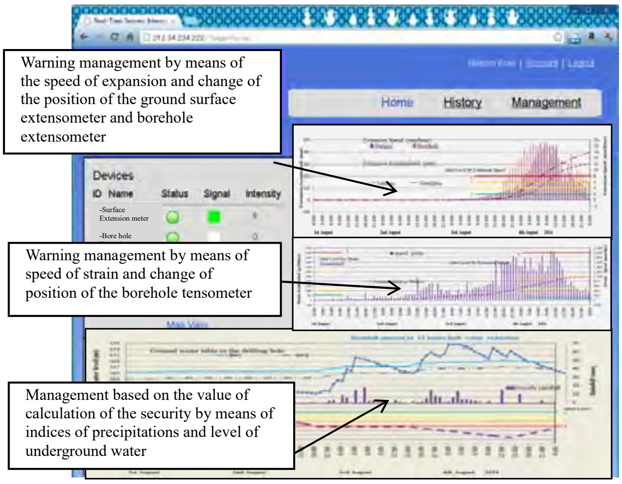


Figure 11 An example of display of real-time monitoring

d) Installation and initial operation test

After soft ware for the real-time monitoring is developed and installed, the computers will be set up at pilot project sites (observation stations) and operation room in MTAES. Initial operation test will be carried with attendance of staffs of MTAES, CMC, and regional rescue service.

e) Preparation of operation guide and standard operation plan (SOP)

The operation guide will be prepared, including necessary items for proper operation, such as 1) Maintenance, adjustment, and repairing of equipment, 2) Rule of transmission of information of landslide activity, 3) dissemination of warning and direction, 4) response of related staffs and residents, according to actual situation.

Standard operation plan (SOP) for insurance of warning and/direction will be prepared and operation system will be established.

f) Trial operation and training/lecture

Through trial operation, fixing bug of software and adjustment of equipment will be done. Training and lecture will be done with participation of staffs of related organizations and residents, using the operation guide and SOP. The result and evaluation of training will be kept for improvement of the operation.

g) Finalization

Based on the evaluation result of trial operation and training, finalization such as fixing of equipment and software, and the adjustment of guide and SOP will be done. The operation system will also be adjusted, if necessary.

9.2 Horizontal drainage drilling

Horizontal drilling for groundwater drainage is one of effective control measures for stabilizing landslide. Aiming at carrying out the horizontal drilling by Armenian side, technique of horizontal drainage drilling will be transfer through on-the job training in pilot project.

RS MTAES has established a drilling team, consisting of five RS staffs, and initial training has been carried out in April and May 2015 to the staffs, using drilling machinery transferred from Ministry of Urban Development to MTAES.

The schedule of full-scale activity is shown in Figure 12 and the procedure of horizontal drilling and training is mentioned below.

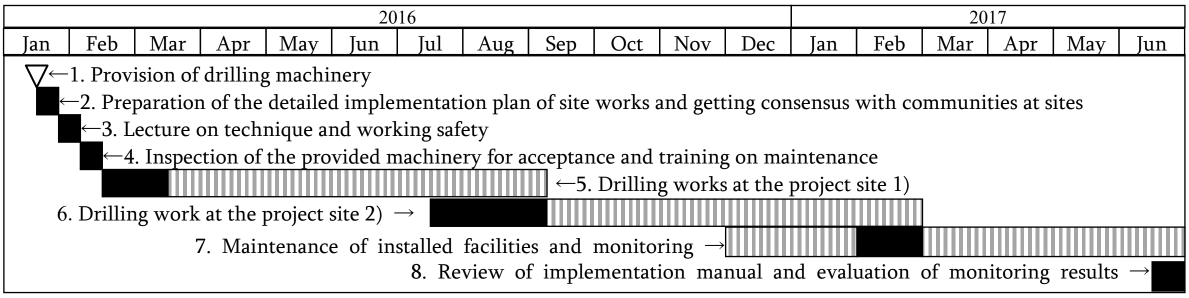


Figure 12 Implementation schedule of horizontal drainage drilling works

(1) Provision of drilling machinery

A new set of drilling machinery for horizontal drilling will be procured in Japan and provided to Armenia at the beginning of 2016.

(2) Preparation of detailed implementation plan of site works and getting consensus with communities at sites

Detailed implementation plan will be prepared, based on the design of countermeasure works. In case that budget for landslide countermeasures is approved and allocated by the government of RA, an implementation plan for the surface water drainage works or other works will be included in the detailed plan. After the clarification of the outline of measures, explanation to the communities at sites will be done for understanding, cooperation, and participation by the communities and residents.

(3) Lecture on technique and working safety

In order to share the important technical points, lectures on technique will be done, referring to the detailed implementation plan and the manual for construction management. Lectures on safety will be done about key points and procedures of safe operation.

(4) Inspection of the provided machinery for acceptance and training on maintenance

Inspection of the provided machinery and trial operation will be done at storage of MTAES. Training on disassembling/ assembling and maintenance with lubricants will be done at the storage.

(5) Drilling works at the project sites

Horizontal drilling will be done at site, according to guideline and manual for implementation management. After confirmation of work sites with the community and residents, site works will start such as safety confirmation, transportation of machinery, assembling scaffold, installation of machinery, drilling operation, cleaning of the drilled hole, installation of perforated pipes, removing machinery, disassembling scaffold, protection of outlet of the hole, construction of V-notch for measuring discharge, construction of surface drainage, cleaning of the work site, etc.

(6) Maintenance of installed facilities and monitoring

Staffs of regional rescue service will look after the installed facilities cleaning of the area around the facilities, referring to the manual for inspection and observation. The result of the site inspection will be reported to the responsible staff of pilot project of MTAES.

As for the groundwater discharge from the drainage holes, measurement of flow and checking of the water quality will be carried out the staff of regional rescue service and residents. The results will be used for the confirmation of the effectiveness of the countermeasures, together with the records of landslide movement.

(7) Review of implementation manual and evaluation of monitoring results

Based on the result of activities of the pilot project, the addition and revision of the manual on implementation management will be done for finalization. Further measures will be prepared, after evaluating the result of monitoring for 2.5 years, and clarifying the characteristics of landslide such as relation between landslide activities and precipitation or snow melt.

10. Ex-ante evaluation of the countermeasure works

10.1 Benefit

Ex-ante evaluation has been done in terms of cost-benefit comparison. Benefit is calculated as an amount of damage reduction in the following items, referring to the existing records in Armenia and Japanese guidelines.

1) Residential houses
2) Roads
3) Telecommunication lines
4) Water supply pipelines

For the above 1) to 4), direct cost (reconstruction cost) and indirect cost is calculated.

5) Human damages (Dead victims, psychological damage)
6) Loss of income source (Cattles)
7) Emergency operation (Emergency response, medical care, emergency supplies)

10.2 Cost

Cost is calculated in the following items.

1) Main construction cost
2) Land acquisition cost
3) Compensation cost
4) Indirect cost (30 % of the main construction cost)
5) Other costs (20% of sum of all the above-mentioned cost)

10.3 Arapi North

For the northern block in Arapi, the cost of each item is calculated as shown in Table 11.

Table 11 Damage cost estimate for Arapi north block (Unit of price: AMD)

Item	Direct cost				Indirect cost	
House and infrastructure	Unit	Qt'y	Unit price	Price	Unit price	Price
House	Unit	65	4,000,000	260,000,000	550	35,750,000
Road	m2	7,100	13,000	92,300,000	1.5	10,650,000
Tele-line	m	1,100	2,400	2,640,000	0.2	220,000
Water pipeline	m	1,100	14,400	15,840,000	2	2,200,000
Subtotal				370,780,000		48,820,000
Human damage and others	Unit	Qt'y	Unit price	Price		
Human loss	Person	32	4,000,000	128,000,000		
Injure	Person	48	1,000,000	48,000,000		
Psychological damage	Person	248	8,000,000	1,980,000,000		
Loss of income source	Family	65	540,000	35,100,000		
Emergency operation	Person	2,000	30,000	60,000,000		
Subtotal				2,251,100,000		
Grand total						2,670,700,000

The probability of occurrence of the landslide disaster is set up to be 1/50 years, referring to the Japanese guideline, and accordingly, the benefit is calculated as follows.

Benefit = Total amount of damage (2,670,700,000) / 50 = 53,414,000 (AMD)

Since village office and residents agreed to provide land and not to request for compensation for the countermeasure works, those costs were not included in the total cost as shown in Table 12.

Table 12 Cost estimate for horizontal drilling of 500 m long (Unit of price: AMD)

Item	Direct cost			
Direct cost	Unit	Qt'y	Unit price	Price
Drilling machine and materials	day	150	320,000	4,800,000
Transportation	day	150	100,000	1,500,000
Accommodation and allowance	day	150	500,000	7,500,000
Subtotal	13,800,000			
Indirect cost	LS	-	-	4,140,000
Other costs	LS	-	-	3,588,000
Grand total	21,528,000			

10.4 Arapi South

For the south block in Arapi, the cost is calculated as shown in Table 13.

Table 13 Damage cost estimate for Arapi south block (Unit of price: AMD)

Item	Direct cost				Indirect cost	
House and infrastructure	Unit	Qt'y	Unit price	Price	Unit price	Price
School	unit	1	100,000,000	100,000,000	20,000,000	20,000,000
House	unit	35	4,000,000	140,000,000	550,000	19,250,000
Road	m2	5,840	13,000	75,920,000	1,500	8,760,000
Tele-line	m	850	2,400	2,040,000	200	170,000
Water pipeline	m	850	14,400	12,240,000	2,000	1,700,000
Subtotal				330,200,000		49,880,000
Human damage and others	Unit	Qt'y	Unit price	Price		
Human loss	person	17	4,000,000	680,000,000		
Injure	person	26	1,000,000	25,500,000		
Psychological damage	person	134	8,000,000	1,068,000,000		
Loss of income source	family	35	540,000	18,900,000		
Emergency operation	person	2,000	30,000	60,000,000		
Subtotal				1,240,400,000		
Grand total						1,620,480,000

Benefit = Total amount of damage (1,620,480,000) / 50 = 32,409,600 (AMD)

The cost for countermeasure works in Arapi south block is the same as the cost for Arapi north block, since the quantity of horizontal drainage drilling is same.

10.5 Getahovit South

For south block in Getahovit, the cost is calculated as shown in Table 14.

Table 14 Damage cost estimate for Getahovit south block (Unit of price: AMD)

Item	Direct cost				Indirect cost	
House and infrastructure	Unit	Qt'y	Unit price	Price	Unit price	Price
Grave area	plot	1	1,000,000	10,000,000	100,000	1,000,000
House	unit	30	4,000,000	120,000,000	550,000	16,500,000
Road	m2	3,770	13,000	49,010,000	1,500	5,655,000
Tele-line	m	600	2,400	1,440,000	200	120,000
Water pipeline	m	600	14,400	8,640,000	2,000	1,200,000
Subtotal				189,090,000		24,475,000
Human damage and others	Unit	Qt'y	Unit price	Price		
Human loss	person	15	4,000,000	60,000,000		
Injure	person	23	1,000,000	23,000,000		
Psychological damage	person	114	8,000,000	912,000,000		
Loss of income source	family	30	540,000	16,200,000		
Emergency operation	person	2,000	30,000	60,000,000		
Subtotal				1,071,200,000		
Grand total						1,284,765,000

Benefit = Total amount of damage (1,284,765,000) / 50 = 25,695,300 (AMD)

The cost for countermeasure works in Getahovit south block is the same as the cost for Arapi north block, since the quantity of horizontal drainage drilling is same.

10.6 Getahovit North

For north block in Getahovit, the cost is calculated as shown in Table 15.

Table 15 Damage cost estimate for Getahovit north block (Unit of price: AMD)

Item	Direct cost				Indirect cost	
House and infrastructure	Unit	Qt'y	Unit price	Price	Unit price	Price
Public haul	unit	1	20,000,000	20,000,000	4,000,000	4,000,000
House	unit	27	4,000,000	108,000,000	550,000	14,850,000
Road	m2	3,560	13,000	46,280,000	1,500	5,340,000
Tele-line	m	510	2,400	1,224,000	200	102,000
Water pipeline	m	510	14,400	7,344,000	2,000	1,020,000
Subtotal				182,848,000		25,312,000
Human damage and others	Unit	Qt'y	Unit price	Price		
Human loss	person	13	4,000,000	52,000,000		
Injure	person	20	1,000,000	19,500,000		
Psychological damage	person	103	8,000,000	824,800,000		
Loss of income source	family	27	540,000	14,580,000		
Emergency operation	person	2,000	30,000	60,000,000		
Subtotal				970,880,000		
Grand total						1,179,040,000

Benefit = Total amount of damage (1,179,040,000) / 50 = 23,580,800 (AMD)

The cost for countermeasure works in Getahovit north block is the same as the cost for Arapi north block, since the quantity of horizontal drainage drilling is same.

10.7 Cost benefit comparison

Since calculation standard for economic evaluation has not been authorized in Armenia, cost -

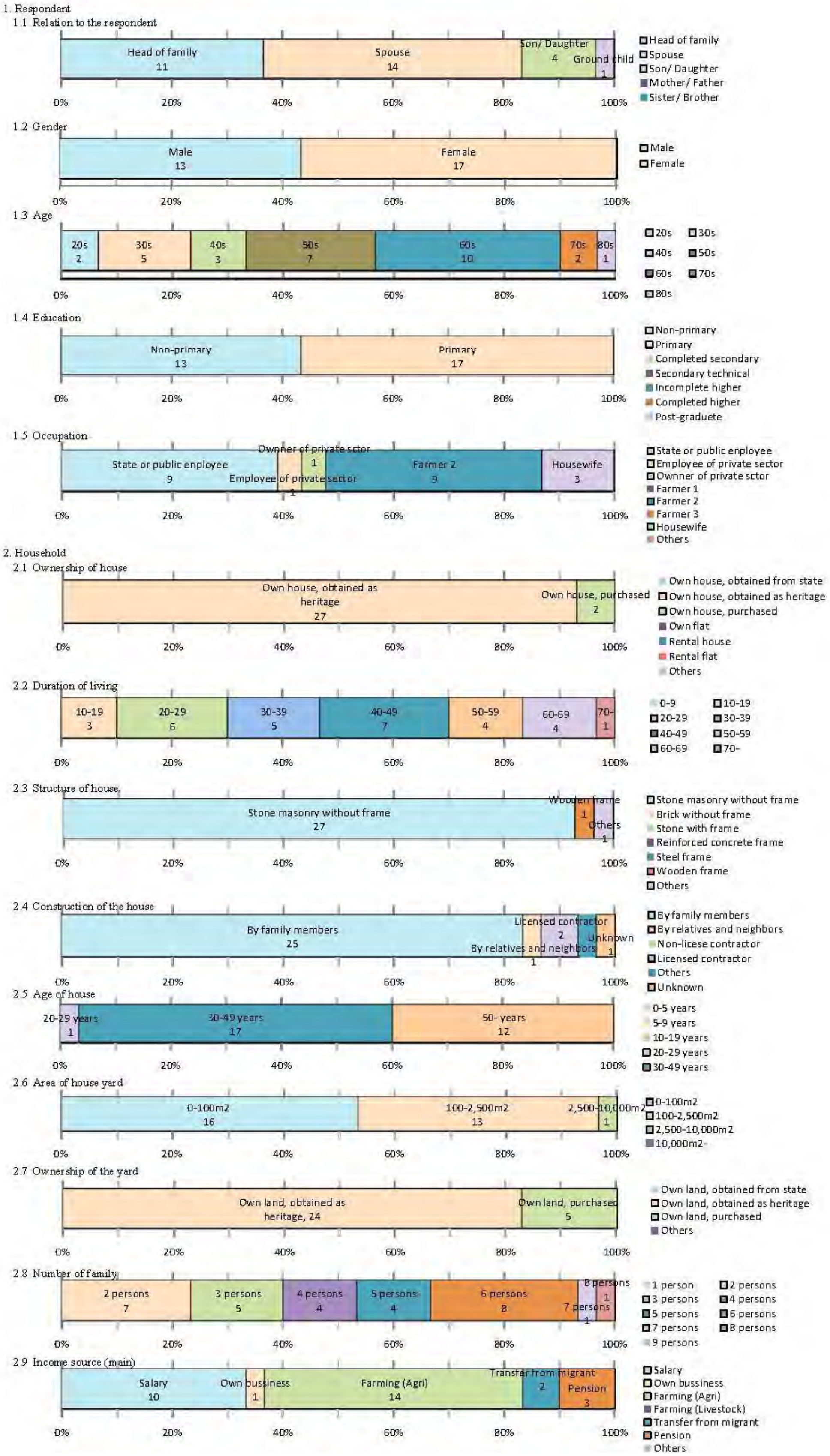
benefit evaluation is simply done as shown in Table 16.

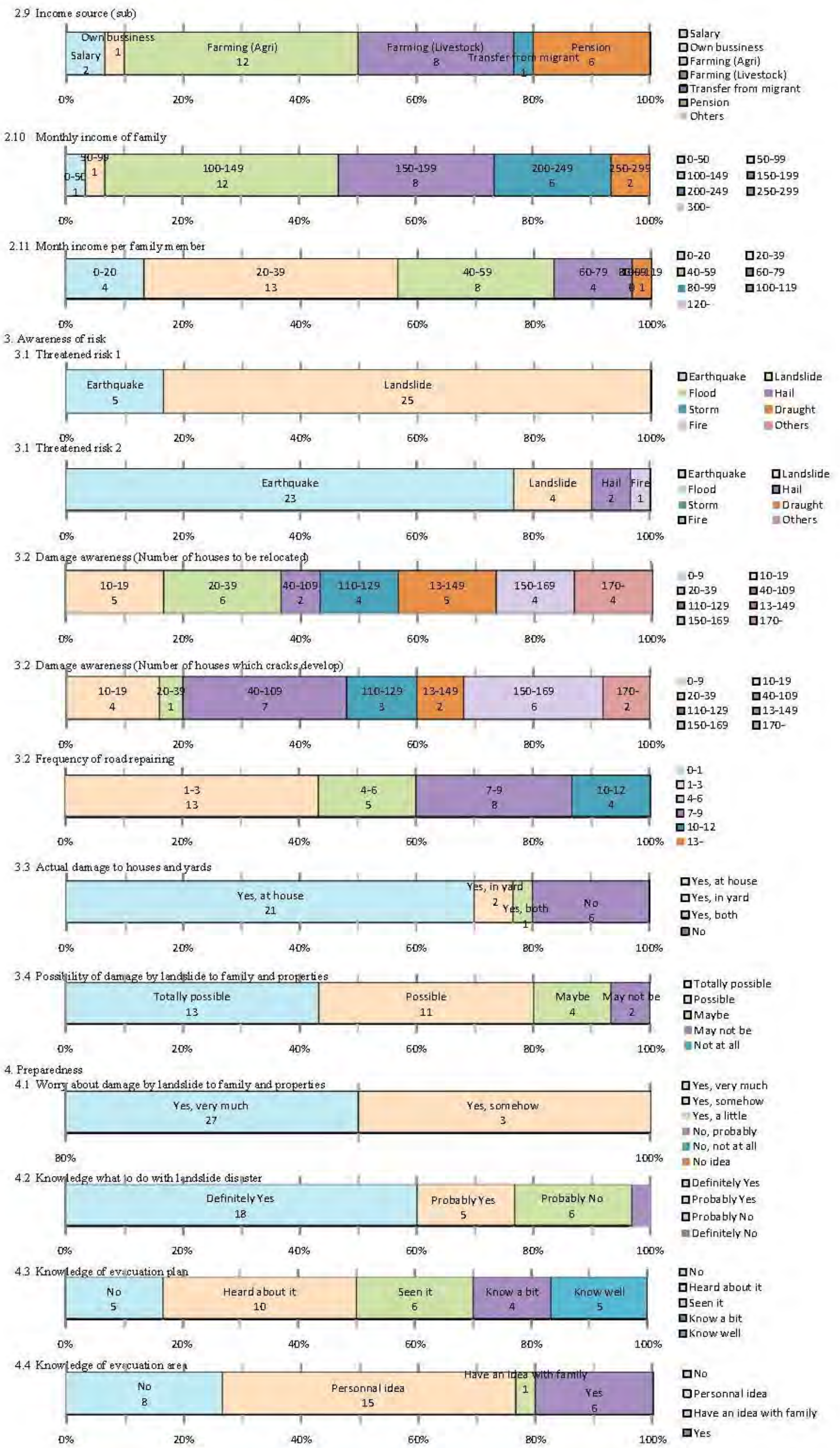
Table 16 Cost – benefit evaluation

House and infrastructure	Damage	Benefit (B)	Cost (C)	B/C
Arapi North	2,670,700,000	53,414,000	21,528,000	2.48
Arapi South	1,620,480,000	32,409,600	21,528,000	1.51
Getahovit South	1,284,765,000	25,695,300	21,528,000	1.19
Getahovit North	1,179,040,000	23,580,800	21,528,000	1.10

Although the cost benefit comparison has been done with simple method, the benefit is bigger than the cost, and thereby, the result indicates economically feasible. Considering the purpose of the pilot project, that is capacity development through implementation of measure, the pilot project will be carried out as it was planned with adjustment on details mentioned in this plan.

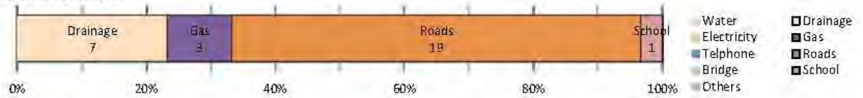
Attachment 1 Result of questionnaire survey for Arapi community



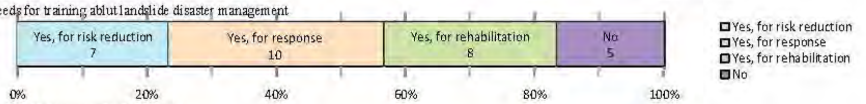

2.9 Income source (sub)
Salary 2
Own bussiness 1
Farming (Agri) 12
Farming (Livestock) 8
Transfer from migrant 1
Pension 6
Salary
Own bussiness
Farming (Agri)
Farming (Livestock)
Transfer from migrant
Pension
Ohters
2.10 Monthly income of family
0-50 1
50-99 1
100-149 12
150-199 8
200-249 6
250-299 2
300-
2.11 Month income per family member
0-20 4
20-39 13
40-59 8
60-79 4
80-99 0
100-119 1
120-
3. Awareness of risk
3.1 Threatened risk 1
Earthquake 5
Landslide 25
Earthquake
Landslide
Flood
Hail
Storm
Draught
Fire
Others
3.1 Threatened risk 2
Earthquake 23
Landslide 4
Hail 2
Fire 1
3.2 Damage awareness (Number of houses to be relocated)
10-19 5
20-39 6
40-109 2
110-129 4
13-149 5
150-169 4
170- 4
0-9
10-19
20-39
40-109
110-129
13-149
150-169
170-
3.2 Damage awareness (Number of houses which cracks develop)
10-19 4
20-39 1
40-109 7
110-129 3
13-149 2
150-169 6
170- 2
3.2 Frequency of road repairing
1-3 13
4-6 5
7-9 8
10-12 4
0-1
1-3
4-6
7-9
10-12
13-
3.3 Actual damage to houses and yards
Yes, at house 21
Yes, in yard 2
Yes, both 1
No 6
Yes, at house
Yes, in yard
Yes, both
No
3.4 Possibility of damage by landslide to family and properties
Totally possible 13
Possible 11
Maybe 4
May not be 2
Totally possible
Possible
Maybe
May not be
Not at all
4. Preparedness
4.1 Worry about damage by landslide to family and properties
Yes, very much 27
Yes, somehow 3
Yes, very much
Yes, somehow
Yes, a little
No, probably
No, not at all
No idea
4.2 Knowledge what to do with landslide disaster
Definitely Yes 18
Probably Yes 5
Probably No 6
Definitely Yes
Probably Yes
Probably No
Definitely No
4.3 Knowledge of evacuation plan
No 5
Heard about it 10
Seen it 6
Know a bit 4
Know well 5
No
Heard about it
Seen it
Know a bit
Know well
4.4 Knowledge of evacuation area
No 8
Personnal idea 15
Have an idea with family 1
Yes 6
No
Personnal idea
Have an idea with family
Yes
0% 20% 40% 60% 80% 100%

5. Needs

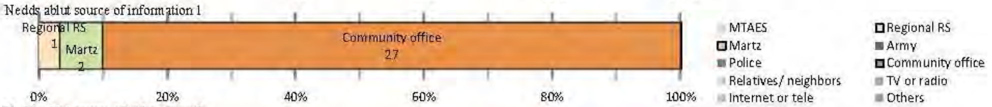
5.1 Needs for infrastructures



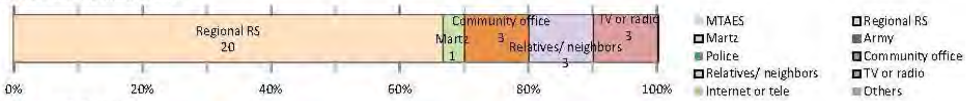
5.2 Needs for training ablut landslide disaster management



5.3 Nedds ablut source of information 1

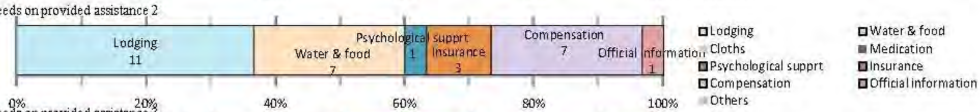


5.3 Nedds ablut source of information 2

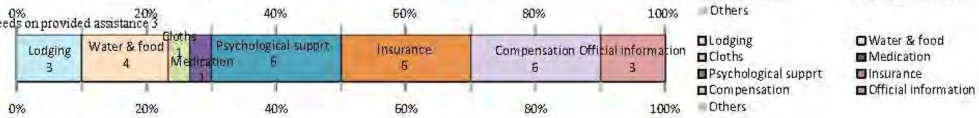


5.4 Needs on provided assistance 1

5.4 Needs on provided assistance 2

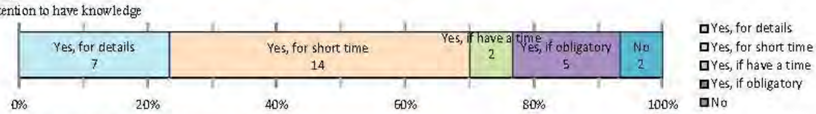


5.4 Needs on provided assistance 3

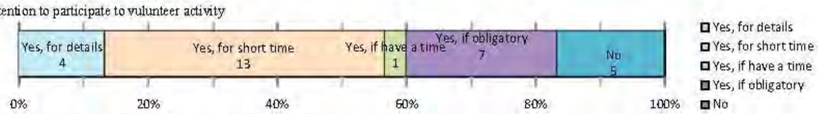


6. Intention

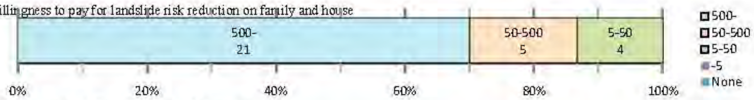
6.1 Intention to have knowledge



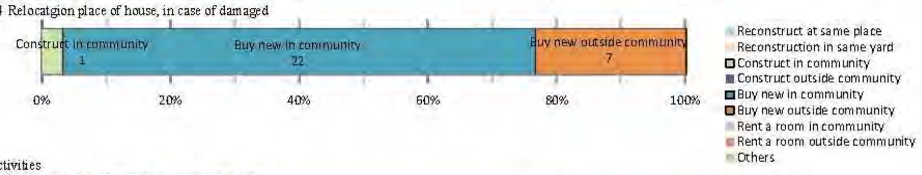
6.2 Intention to participate to vulunteer activity



6.3 Willingness to pay for landslide risk reduction on family and house

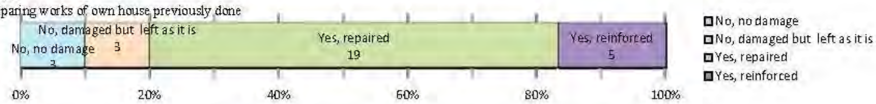


6.4 Relocatgion place of house, in case of damaged

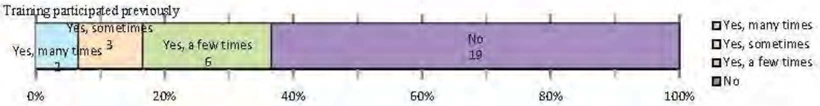


7. Activities

7.1 Reparing works of own house previously done

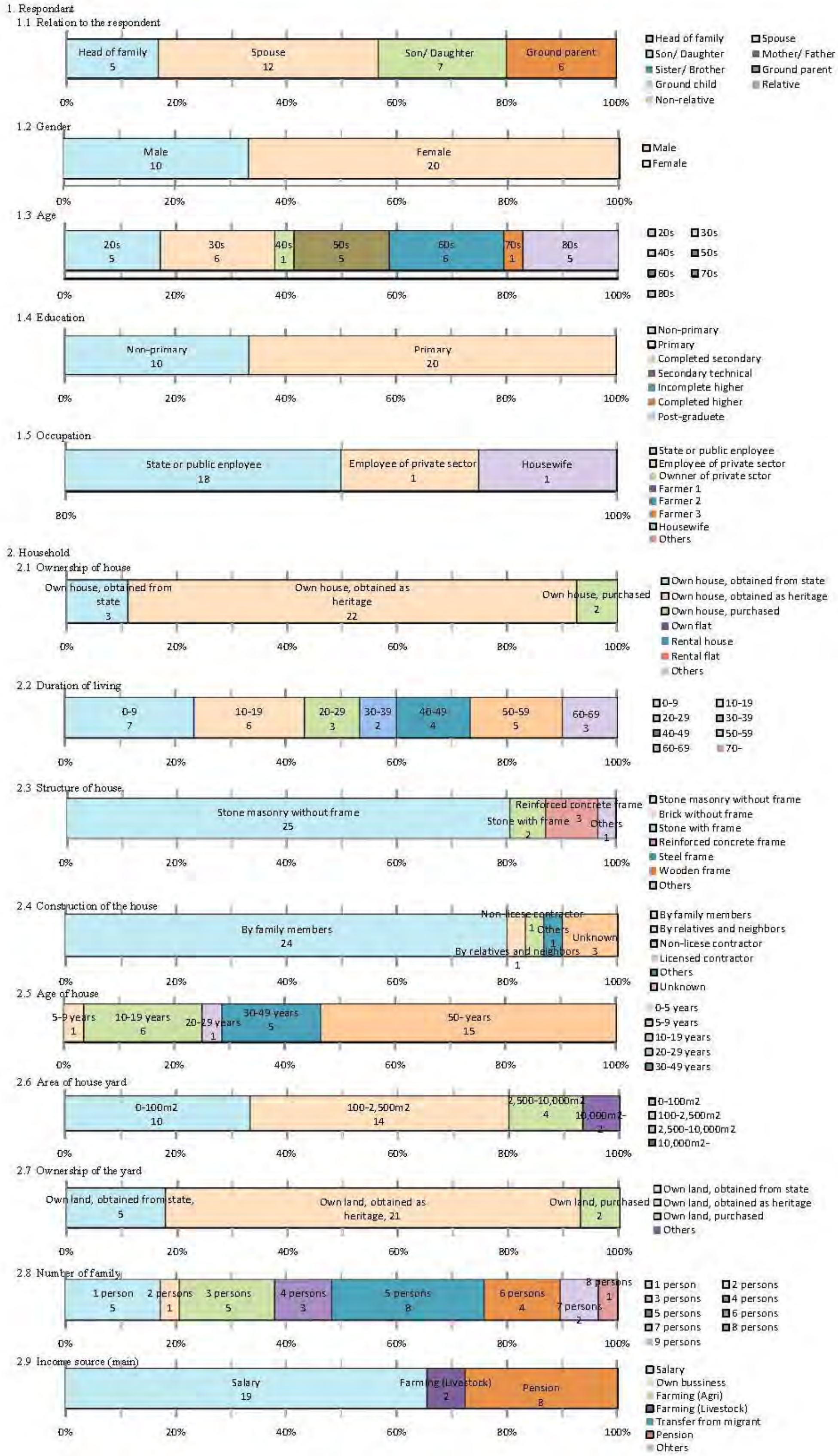


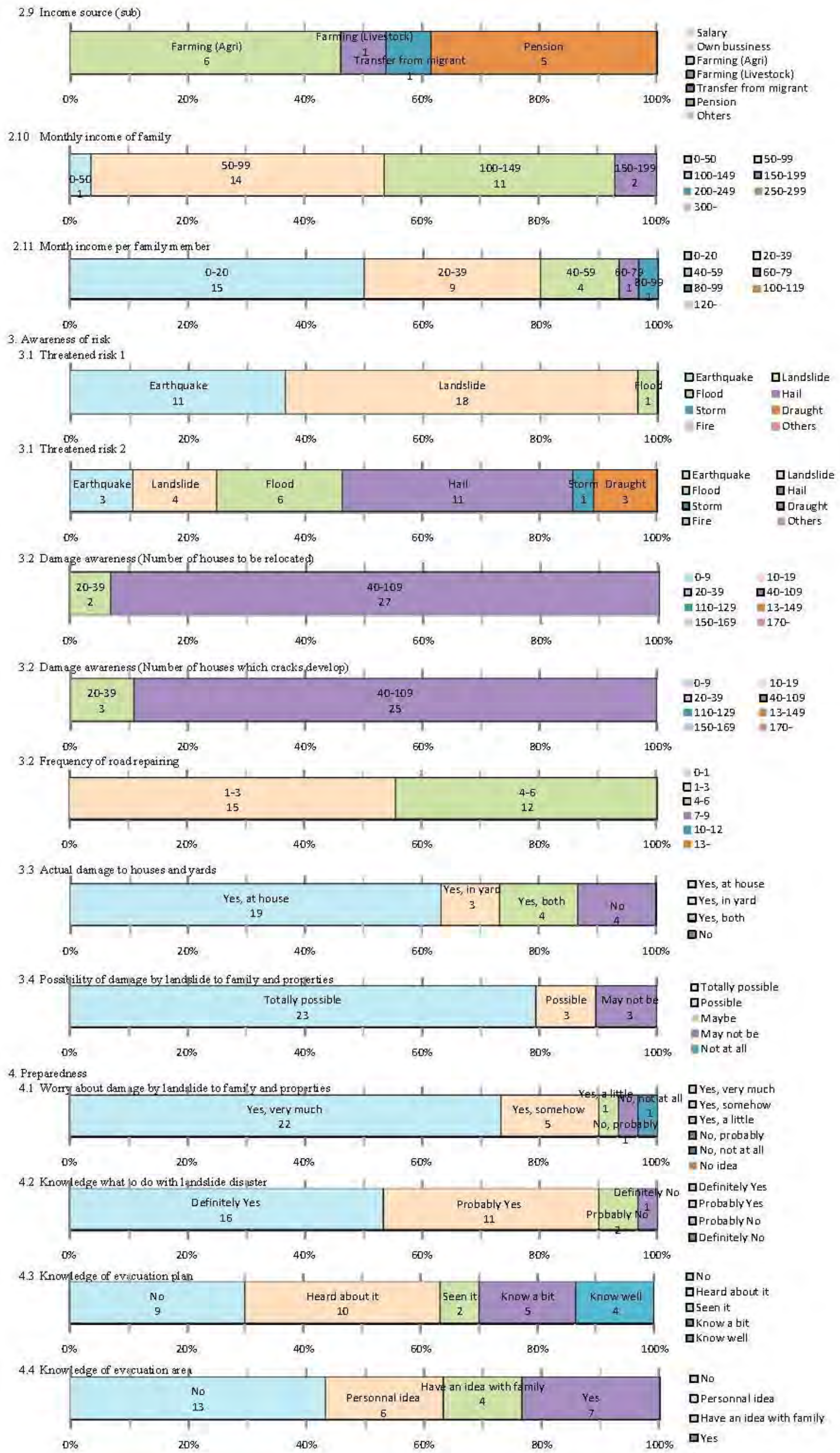
7.2 Training participated previously

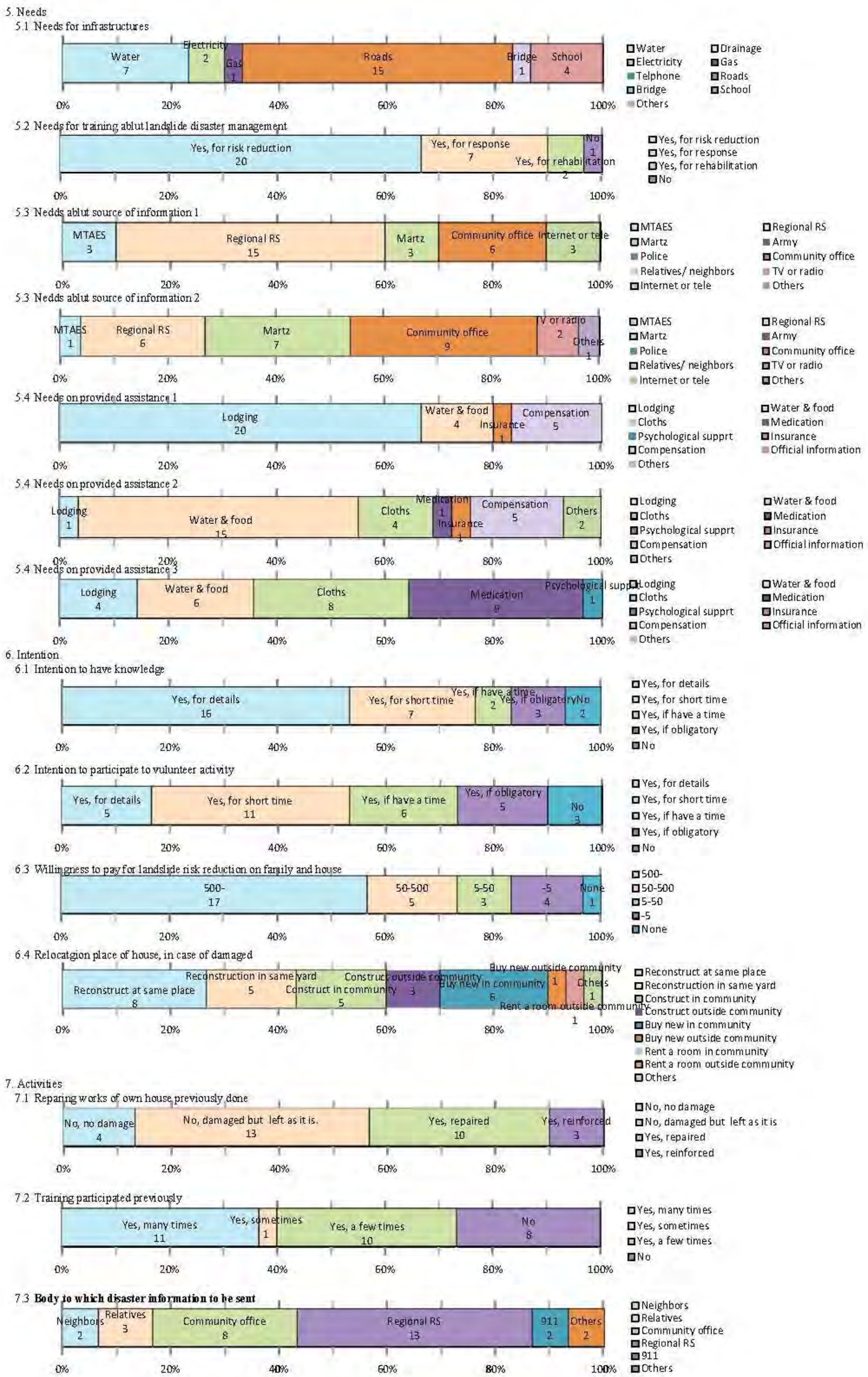


7.3 Body to which disaster information to be sent

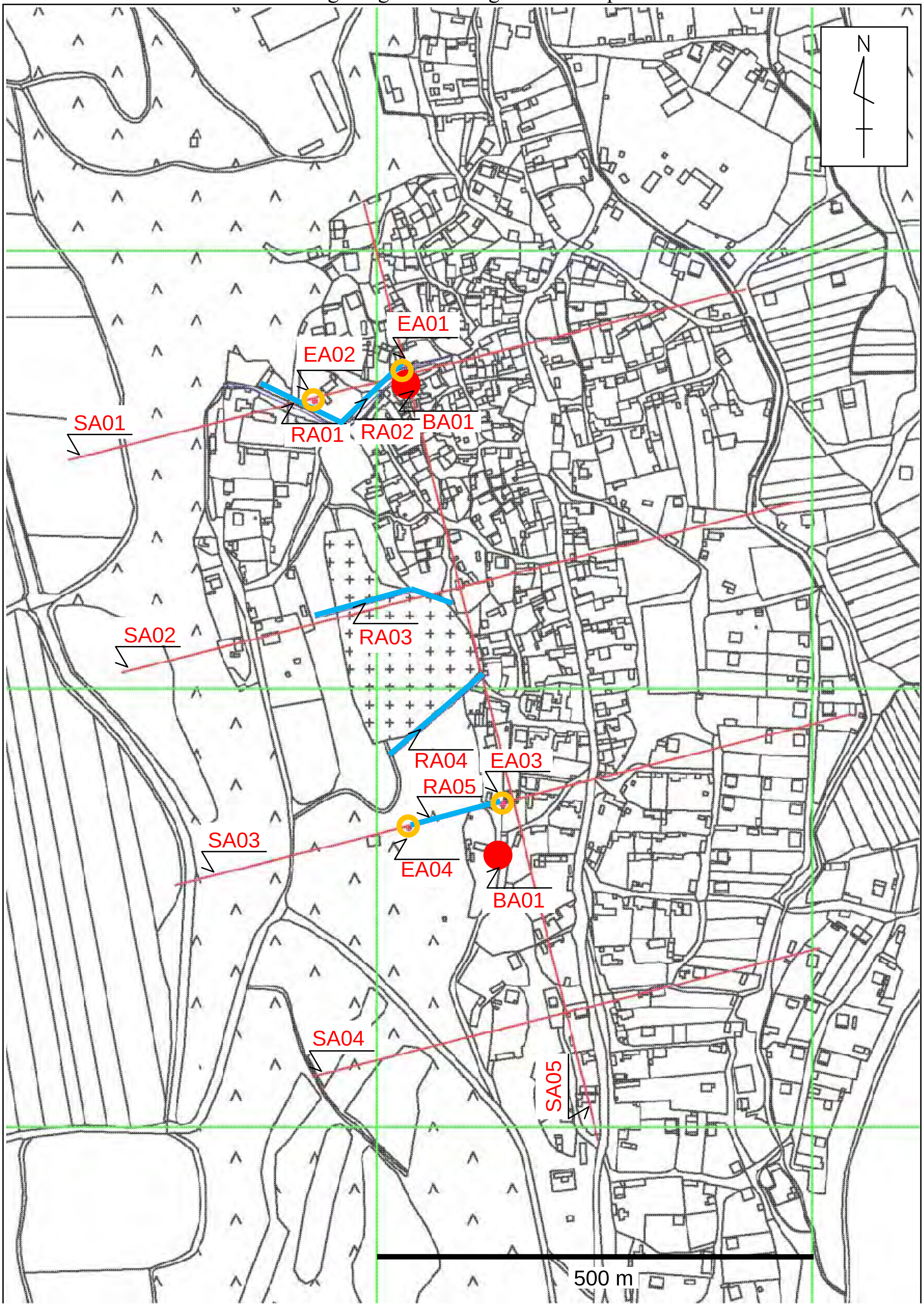
Attachment 2 Result of questionnaire survey for Getahovit community




2.9 Income source (sub)
Farming (Agri) 6
Farming (Livestock) 1
Transfer from migrant 1
Pension 5
Salary
Own bussiness
Farming (Agri)
Farming (Livestock)
Transfer from migrant
Pension
Ohters
2.10 Monthly income of family
0-50 1
50-99 14
100-149 11
150-199 2
0-50
50-99
100-149
150-199
200-249
250-299
300-
2.11 Month income per family member
0-20 15
20-39 9
40-59 4
60-79 1
80-99 1
0-20
20-39
40-59
60-79
80-99
100-119
120-
3. Awareness of risk
3.1 Threatened risk 1
Earthquake 11
Landslide 18
Flood 1
Earthquake
Landslide
Flood
Hail
Storm
Draught
Fire
Others
3.1 Threatened risk 2
Earthquake 3
Landslide 4
Flood 6
Hail 11
Storm 1
Draught 3
Earthquake
Landslide
Flood
Hail
Storm
Draught
Fire
Others
3.2 Damage awareness (Number of houses to be relocated)
20-39 2
40-109 27
0-9
10-19
20-39
40-109
110-129
13-149
150-169
170-
3.2 Damage awareness (Number of houses which cracks develop)
20-39 3
40-109 25
0-9
10-19
20-39
40-109
110-129
13-149
150-169
170-
3.2 Frequency of road repairing
1-3 15
4-6 12
0-1
1-3
4-6
7-9
10-12
13-
3.3 Actual damage to houses and yards
Yes, at house 19
Yes, in yard 3
Yes, both 4
No 4
Yes, at house
Yes, in yard
Yes, both
No
3.4 Possibility of damage by landslide to family and properties
Totally possible 23
Possible 3
May not be 3
Totally possible
Possible
Maybe
May not be
Not at all
4. Preparedness
4.1 Worry about damage by landslide to family and properties
Yes, very much 22
Yes, somehow 5
Yes, a little 1
No, probably 1
No, not at all 1
Yes, very much
Yes, somehow
Yes, a little
No, probably
No, not at all
No idea
4.2 Knowledge what to do with landslide disaster
Definitely Yes 16
Probably Yes 11
Probably No 2
Definitely No 1
Definitely Yes
Probably Yes
Probably No
Definitely No
4.3 Knowledge of evacuation plan
No 9
Heard about it 10
Seen it 2
Know a bit 5
Know well 4
No
Heard about it
Seen it
Know a bit
Know well
4.4 Knowledge of evecuation area
No 13
Personnal idea 6
Have an idea with family 4
Yes 7
No
Personnal idea
Have an idea with family
Yes
0%
20%
40%
60%
80%
100%

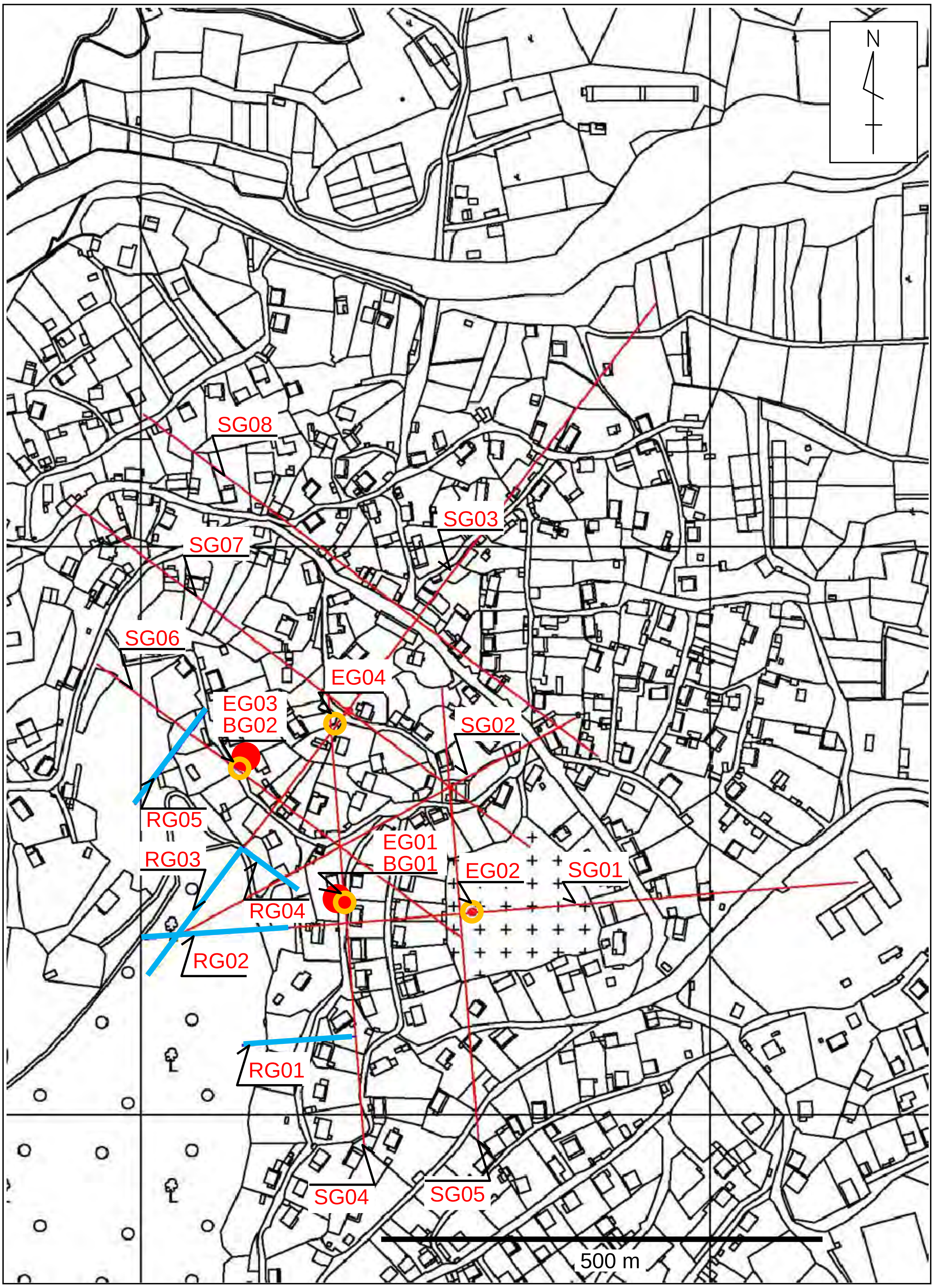

5. Needs
5.1 Needs for infrastructures
Water 7
Electricity 2
Gas 1
Roads 15
Bridge 1
School 4
Water, Drainage, Electricity, Gas, Telphone, Roads, Bridge, School, Others
5.2 Needs for training ablut landslide disaster management
Yes, for risk reduction 20
Yes, for response 7
Yes, for rehabilitation 2
No 1
5.3 Nedds ablut source of information 1
MTAES 3
Regional RS 15
Martz 3
Community office 6
Internet or tele 3
MTAES, Regional RS, Martz, Army, Police, Community office, Relatives/ neighbors, TV or radio, Internet or tele, Others
5.3 Nedds ablut source of information 2
MTAES 1
Regional RS 6
Martz 7
Community office 9
TV or radio 2
Others 1
5.4 Needs on provided assistance 1
Lodging 20
Water & food 4
Insurance 1
Compensation 5
Lodging, Water & food, Cloths, Medication, Psychological supprt, Insurance, Compensation, Official information, Others
5.4 Needs on provided assistance 2
Lodging 1
Water & food 15
Cloths 4
Medication 1
Insurance 1
Compensation 5
Others 2
5.4 Needs on provided assistance 3
Lodging 4
Water & food 6
Cloths 8
Medication 9
Psychological supp 1
6. Intention
6.1 Intention to have knowledge
Yes, for details 16
Yes, for short time 7
Yes, if have a time 2
Yes, if obligatory 3
No 2
6.2 Intention to participate to volunteer activity
Yes, for details 5
Yes, for short time 11
Yes, if have a time 6
Yes, if obligatory 5
No 3
6.3 Willingness to pay for landslide risk reduction on family and house
500- 17
50-500 5
5-50 3
-5 4
None 1
6.4 Relocatgion place of house, in case of damaged
Reconstruct at same place 8
Reconstruction in same yard 5
Construct in community 5
Construct outside community 3
Buy new in community 6
Buy new outside community 1
Rent a room outside community 1
Others 1
Reconstruct at same place, Reconstruction in same yard, Construct in community, Construct outside community, Buy new in community, Buy new outside community, Rent a room in community, Rent a room outside community, Others
7. Activities
7.1 Reparing works of own house previously done
No, no damage 4
No, damaged but left as it is. 13
Yes, repaired 10
Yes, reinforced 3
7.2 Training participated previously
Yes, many times 11
Yes, sometimes 1
Yes, a few times 10
No 8
7.3 Body to which disaster information to be sent
Neighbors 2
Relatives 3
Community office 8
Regional RS 13
911 2
Others 2
0% 20% 40% 60% 80% 100%

Attachment 3 Location and list of geological investigation in Arapi site



	No.	Length (m)	X	Y	Remark
Topo-survey lines					
Total	SA01	800	8,398,646.8843	4,517,261.3953	Starting point
4100	(Straight)		8,399,034.8348	4,517,358.8406	Intersecting point with SA04, BA01
			8,399,422.7855	4,517,456.2759	Ending point
	SA02	800	8,398,707.7851	4,517,018.9312	Starting point
	(Straight)		8,399,095.7357	4,517,116.3665	Intersecting point with SA04
			8,399,483.6862	4,517,213.8118	Ending point
	SA03	800	8,389,768.6860	4,516,776.4571	Starting point
	(Straight)		8,399,156.6365	4,516,873.9024	Intersecting point with SA04, BA02
			8,399,544.5871	4,516,971.3377	Ending point
	SA04	600	8,398,926.5744	4,516,558.3493	Starting point
	(Straight)		8,399,217.6496	4,516,630.9814	Intersecting point with SA05
			8,399,508.5003	4,516,704.5073	Ending point
	SA05	1100	8,399,254.0718	4,516,485.9517	Starting point
	(Straight)		8,399,217.6496	4,516,630.9814	Intersecting point with SA04
			8,399,156.6265	4,516,873.9024	Intersecting point with SA03, BA02
			8,399,095.7357	4,517,116.3665	Intersecting point with SA02
			8,399,034.8348	4,517,358.8406	Intersecting point with SA01, BA01
			8,398,986.1222	4,517,552.8160	Ending point
Drilling points					
	BA01		8,399,035.3680	4,517,348.1107	
	BA02		8,399,140.3499	4,516,809.7029	
Electric prospecting points					
	EA01		8,399,031.0461	4,517,355.3940	
	EA02		8,398,929.1836	4,517,328.7341	
	EA03		8,399,144.8632	4,516,868.4627	
	EA04		8,399,036.9906	4,516,842.1109	
Geo-radar prospecting lines					
Total	RA01	142	8,398,828.3987	4,517,346.3460	Starting point
731	(Straight)		8,398,957.6079	4,517,294.5197	Ending point (Starting point of RA02)
	RA02	160	8,398,957.6978	4,517,294.5559	Starting point (Ending point of RA01)
	(Bending)		8,399,032.4323	4,517,364.7681	Bending point
			8,399,088.4033	4,517,380.6414	Ending point
	RA03	165	8,398,929.2572	4,517,080.6280	Starting point
	(Bending)	(50+50)	8,399,047.7367	4,517,113.3368	Bending point
			8,399,088.7777	4,517,096.7921	Ending point
	RA04	148	8,399,014.9171	4,516,922.3470	Starting point
	(Straight)		8,399,128.3578	4,517,017.6141	Ending point
	RA05	116	8,399,038.7277	4,516,844.2861	Starting point
	(Straight)		8,399,153.1727	4,516,873.0323	Ending point

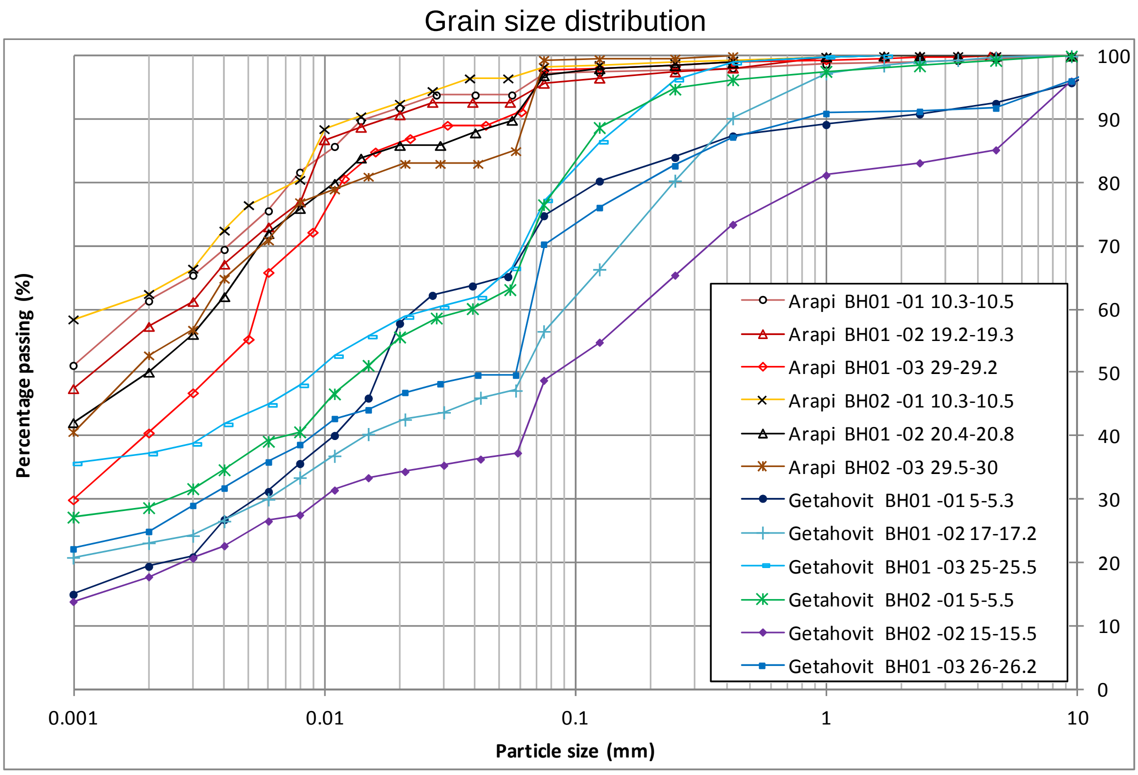
Attachment 4 Location and list of geological investigation in Getahovit site

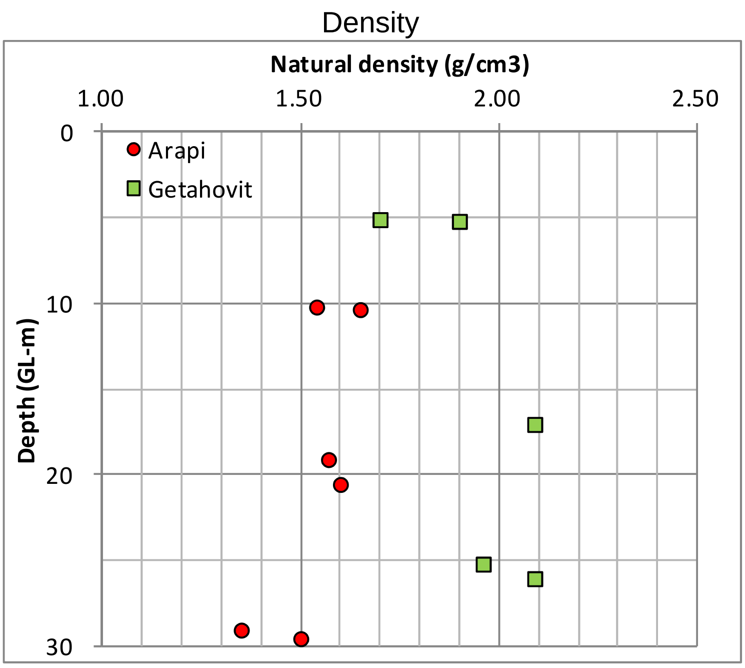


	No.	Length (m)	X	Y	Remark
Topo-survey lines					
Total	SG01	600	8,511,530.7825	4,529,156.5238	Starting point
3900	(Straight)		8,511,680.3000	4,529,168.5453	Intersecting point with SG04
			8,511,779.9784	4,529,176.5596	Intersecting point with SG05
			8,512,128.8525	4,529,204.6098	Ending point
	SG02	400	8,511,530.7825	4,529,156.5238	Starting point
	(Straight)		8,511,674.9052	4,529,235.6436	Intersecting point with SG04 and SG06
			8,511,770.9870	4,529,288.3901	Intersecting point with SG05 and SG07
			8,511,881.4205	4,529,349.0154	Ending point
	SG03	700	8,511,530.7825	4,529,156.5238	Starting point
	(Straight)		8,511,621.1915	4,529,276.2160	Intersecting point with SG06
			8,511,681.4641	4,529,356.0108	Intersecting point with SG07
			8,511,741.7367	4,529,435.8056	Intersecting point with SG08
			8,511,952.6909	4,529,715.0874	Ending point
	SG04	400	8,511,696.3287	4,528,969.1886	Starting point
	(Straight)		8,511,680.3000	4,529,168.5453	Intersecting point with SG01
			8,511,664.2714	4,529,367.9020	Ending point
	SG05	400	8,511,796.0070	4,528,977.2030	Starting point
	(Straight)		8,511,779.9784	4,529,176.5596	Intersecting point with SG01
			8,511,763.9497	4,529,375.9163	Ending point
	SG06	400	8,511,780.7811	4,529,155.6708	Starting point
			8,511,621.1915	4,529,276.2160	Intersecting point with SG03
			8,511,461.6019	4,529,396.7613	Ending point
	SG07	500	8,511,841.0537	4,529,235.4656	Starting point
			8,511,681.4641	4,529,356.0108	Intersecting point with SG03
			8,511,442.0797	4,529,536.8287	Ending point
	SG08	500	8,511,901.3263	4,529,315.2604	Starting point
			8,511,741.7367	4,529,435.8056	Intersecting point with SG03
			8,511,502.3523	4,529,616.6235	Ending point
Drilling points					
	BG01		8,511,672.5466	4,529,189.6007	
	BG02		8,511,593.3804	4,529,311.5348	
Electric prospecting points					
	EG01		8,511,683.1358	4,529,186.6978	
	EG02		8,511,790.7935	4,529,178.0290	
	EG03		8,511,589.8696	4,529,307.3082	
	EG04		8,511,682.2677	4,529,355.7142	
Geo-radar prospecting lines					
Total	RG01	100	8,511,588.6360	4,529,060.8526	Starting point (100 m offset, parallel to SG01)
532	(Straight)		8,511,688.3144	4,529,068.8670	Ending point (on the SG04)
	RG02	128	8,511,530.3866	4,529,154.5599	Starting point
	(Straight)		8,511,630.4609	4,529,164.5381	Ending point (on the SG01)
	RG03	138	8,511,507.3465	4,529,124.1373	Starting point
	(Straight)		8,511,589.3610	4,529,235.1220	Ending point (Same as starting point of RG04)
	RG04	60	8,511,589.3610	4,529,235.1220	Starting point (Same as ending point of RG03)
	(Straight)		8,511,637.1590	4,529,198.8543	Ending point (on SG03)
	RG05	106	8,511,494.4615	4,529,273.0280	Starting point (100 m offset, parallel to SG03)
	(Straight)		8,511,559.0392	4,529,357.0858	Ending point

Attachment 5 Results of laboratory tests

Location	Borehole	Sample No	Depth	Natural density	Specific gravity	Moisture content	Atterburg limits			Grain size (percentage passing)							Double hydrometer test	Torsion test		Uni-axial compression strength	X-ray diffraction of clay minerals	Exchangeable sodium percentage
							Liquid limit	Plastic limit	Plasticity index	0.005 0mm	0.075 mm	0.25 mm	1.00 mm	2.36 mm	4.75 mm	9.5 mm		Cohesion	Internal friction angle			
			m	g/cm³	g/cm³	%											Ex.Na	kPa	°	kPa		%
Arapi	BA01	1	10.0 - 10.5	1.54	2.47	52.0	101.9	47.3	54.6	72.5	97.2	97.8	98.7	99.1	99.5	100.0	3.16	29.2	16.1	140	++	3.16
		2	19.0 - 19.3	1.57	2.54	47.4	84.8	38.8	46.0	70.1	95.7	97.5	99.8	100.0	100.0	100.0		37.8	15.4	160		
		3	29.0 - 29.2	1.35	2.36	104.2	115.0	55.0	60.0	55.3	97.8	98.4	99.4	99.8	100.0	100.0		43.2	23.4	280		
	BA2	1	10.3 - 10.5	1.65	2.57	54.0	106.2	37.2	69.0	76.4	98.3	98.9	99.9	100.0	100.0	100.0		47.8	13.7	220		
		2	20.4 - 20.8	1.60	2.54	48.8	95.0	38.8	56.2	67.0	96.9	98.5	99.9	100.0	100.0	100.0	2.26	21.8	19.9	200	+	2.26
		3	29.5 - 29.7	1.50	2.59	85.0	106.2	37.2	69.0	67.9	99.4	99.6	100.0	100.0	100.0	100.0		27.0	24.9	250		
Getahovit	BG01	1	5.0 - 5.3	1.70	2.71	14.1	33.7	22.5	11.2	29.0	74.8	84.0	89.2	90.9	92.5	95.8		47.6	20.2	250		
		2	17.0 - 17.2	2.09	2.59	15.3	36.4	16.1	20.0	28.3	56.5	80.3	97.3	99.0	99.7	100.0	10.6				-	10.57
		3	25.0 - 25.5	1.96	2.66	20.7	61.0	24.0	40.0	43.4	77.2	96.3	99.9	100.0	100.0	100.0		55.2	21.9	400		
	BG02	1	5.0 - 5.5	1.90	2.75	15.8	44.2	20.3	20.0	36.9	76.5	94.8	97.6	98.5	99.3	100.0		33.1	22.1	200		
		2	15.0 - 15.5		2.64	6.4	37.0	15.5	20.0	24.6	48.8	65.4	81.2	83.1	85.2	96.1						
		3	26.0 - 26.2	2.09	2.76	16.3	37.1	15.1	20.0	33.8	70.3	82.7	90.9	91.3	91.8	96.1	0.75	50.3	22.3	220	-	0.75

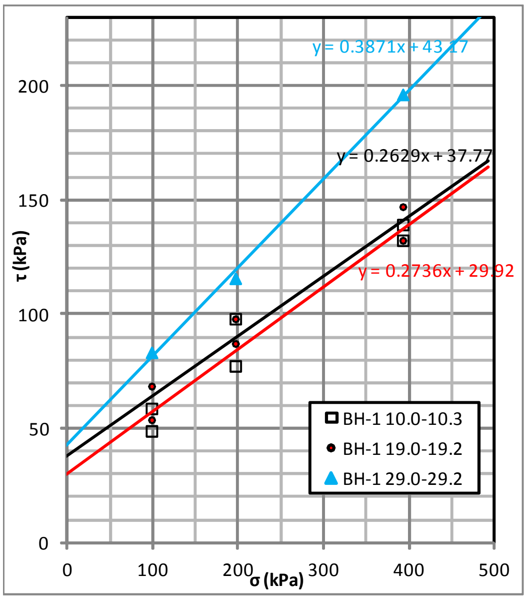

Grain size distribution
Percentage passing (%)
Particle size (mm)
0.001
0.01
0.1
1
10
0
10
20
30
40
50
60
70
80
90
100
Arapi BH01 -01 10.3-10.5
Arapi BH01 -02 19.2-19.3
Arapi BH01 -03 29-29.2
Arapi BH02 -01 10.3-10.5
Arapi BH01 -02 20.4-20.8
Arapi BH02 -03 29.5-30
Getahovit BH01 -01 5-5.3
Getahovit BH01 -02 17-17.2
Getahovit BH01 -03 25-25.5
Getahovit BH02 -01 5-5.5
Getahovit BH02 -02 15-15.5
Getahovit BH01 -03 26-26.2


Density
Natural density (g/cm3)
1.00
1.50
2.00
2.50
Depth (GL-m)
0
10
20
30
Arapi
Getahovit

Shear test (Torsion test)

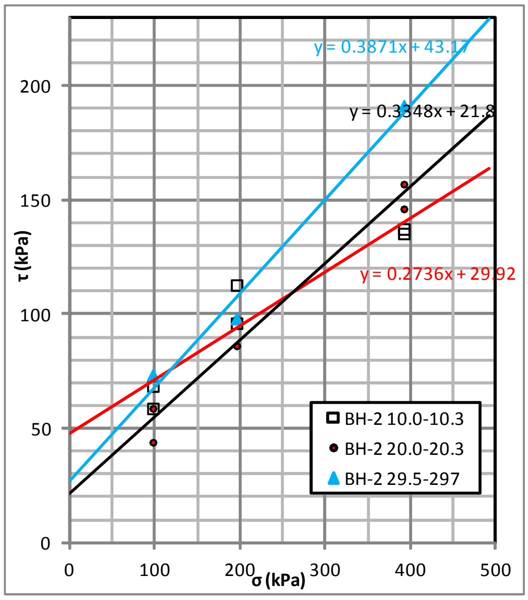
Arapi

BH-1 10.0-10.3						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	58.86	49.05	98.1	77.5	139.3	132.44
BH-1 19.0-19.2						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	68.67	53.96	98.1	87.31	147.15	132.44
BH-1 29.0-29.2						
σ	98.1	196.2	392.4			
τ	83.39	115.76	196.2			



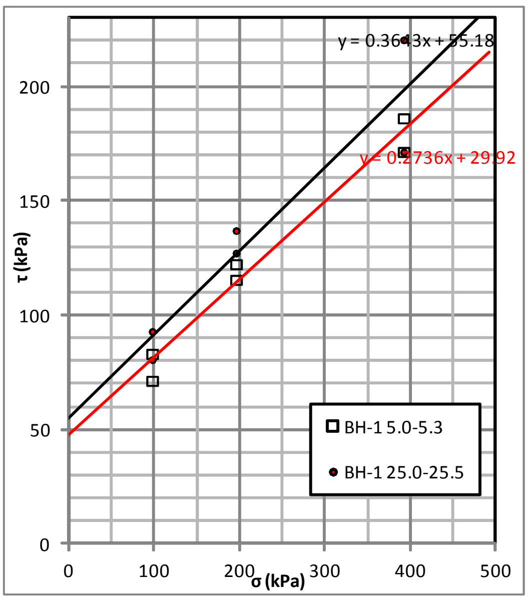
Arapi

BH-2 10.0-10.3						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	68.67	58.86	112.82	96.14	137.34	135.38
BH-2 20.0-20.3						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	58.9	44.1	98.1	86.3	157	146.2
BH-2 29.5-297						
σ	98.1	196.2	392.4			
τ	73.58	98.1	191.3			



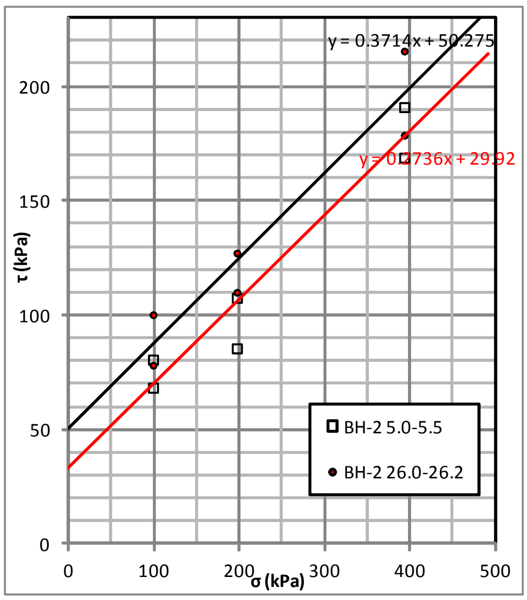
Getahovit

BH-1 5.0-5.3						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	83.39	71.61	122.63	115.76	186.39	171.68
BH-1 25.0-25.5						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	93.2	80.93	137.34	127.53	220.73	171.68

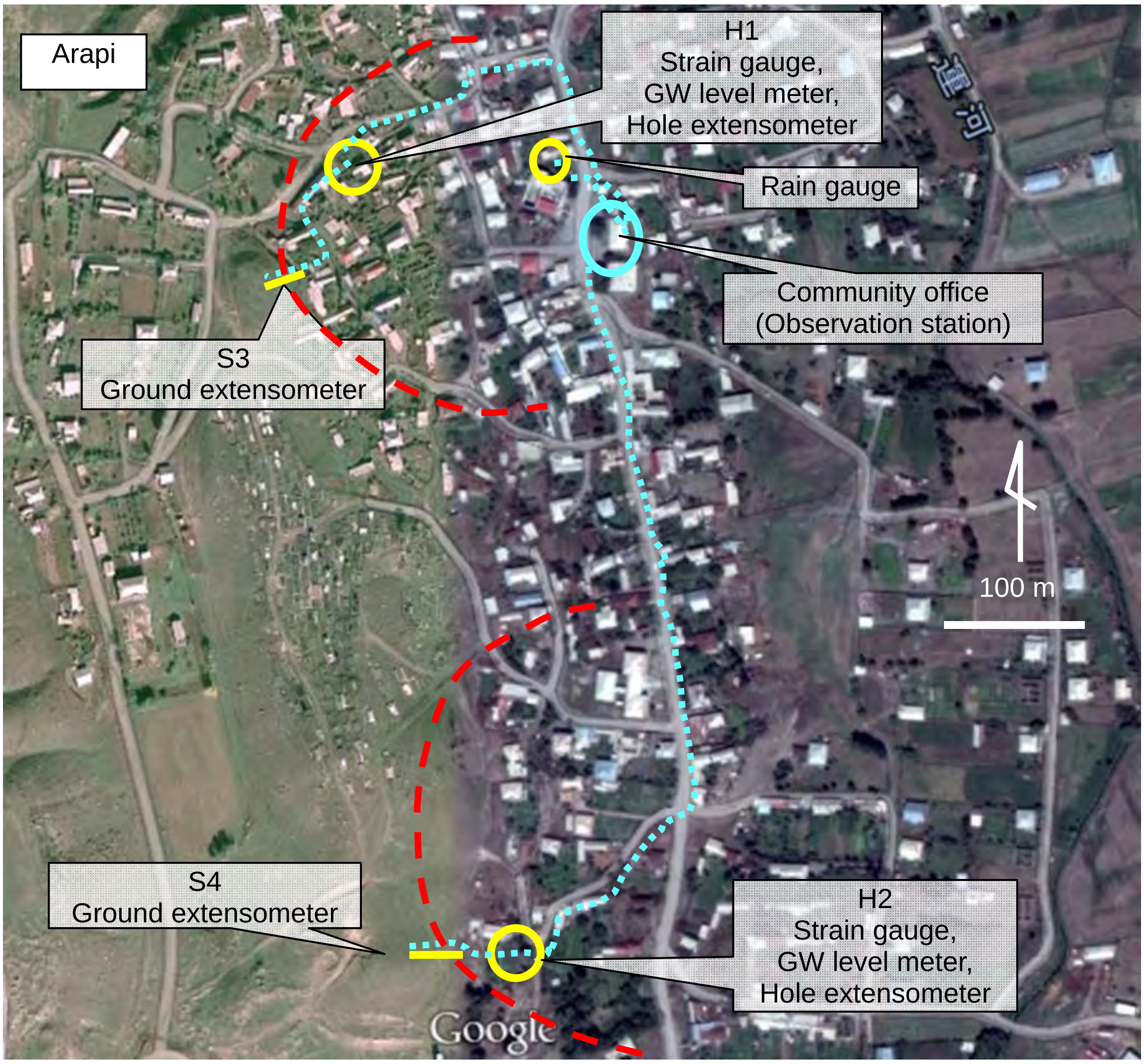


Getahovit

BH-2 5.0-5.5						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	80.93	68.67	107.91	85.84	191.3	169.22
BH-2 26.0-26.2						
σ	98.1	98.1	196.2	196.2	392.4	392.4
τ	100.55	78.48	127.53	110.36	215.82	179.03

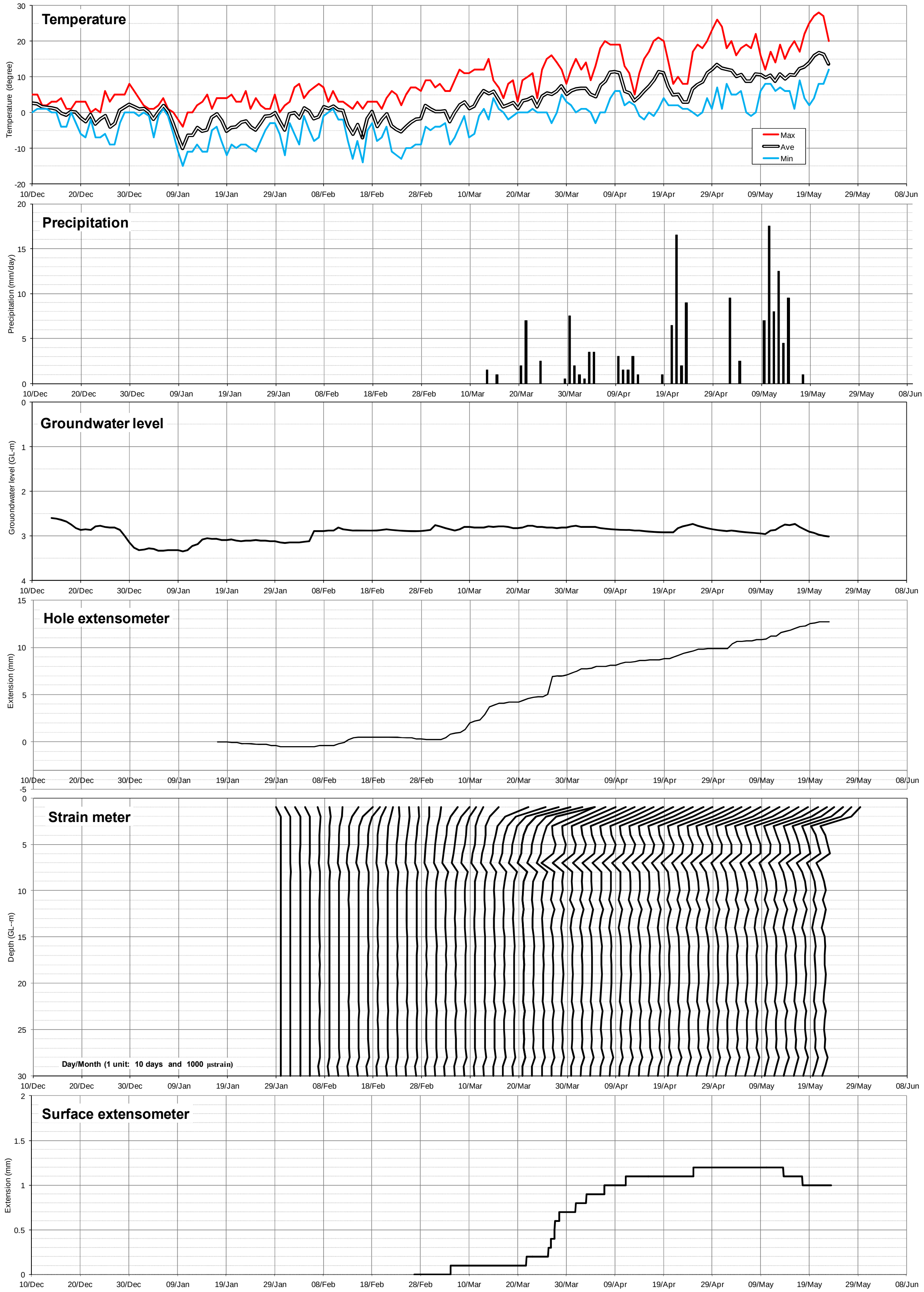


Attachment 6 Location of monitoring equipment installed in Arapi site

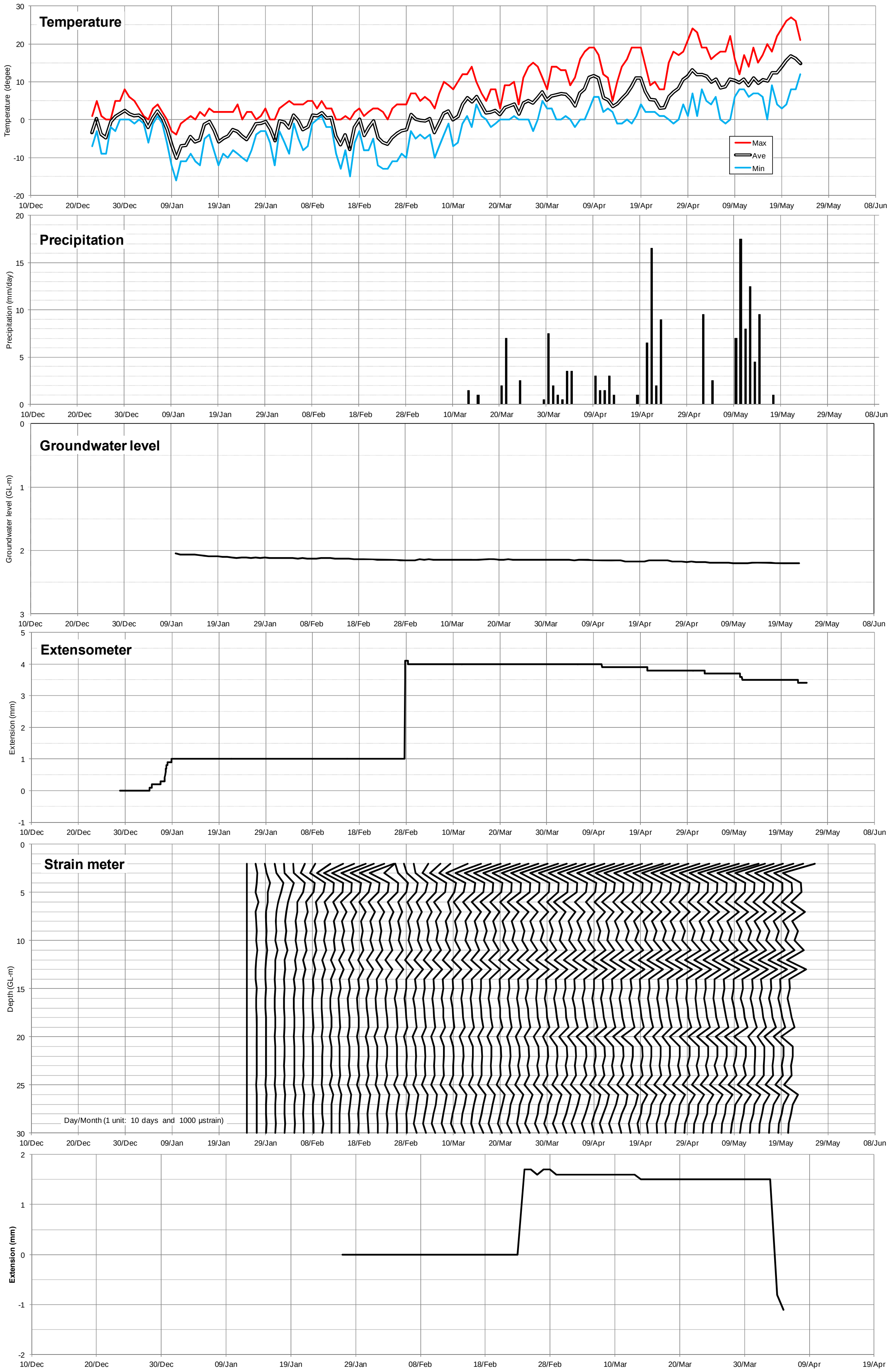


Attachment 7　Monitoring results of Arapi site

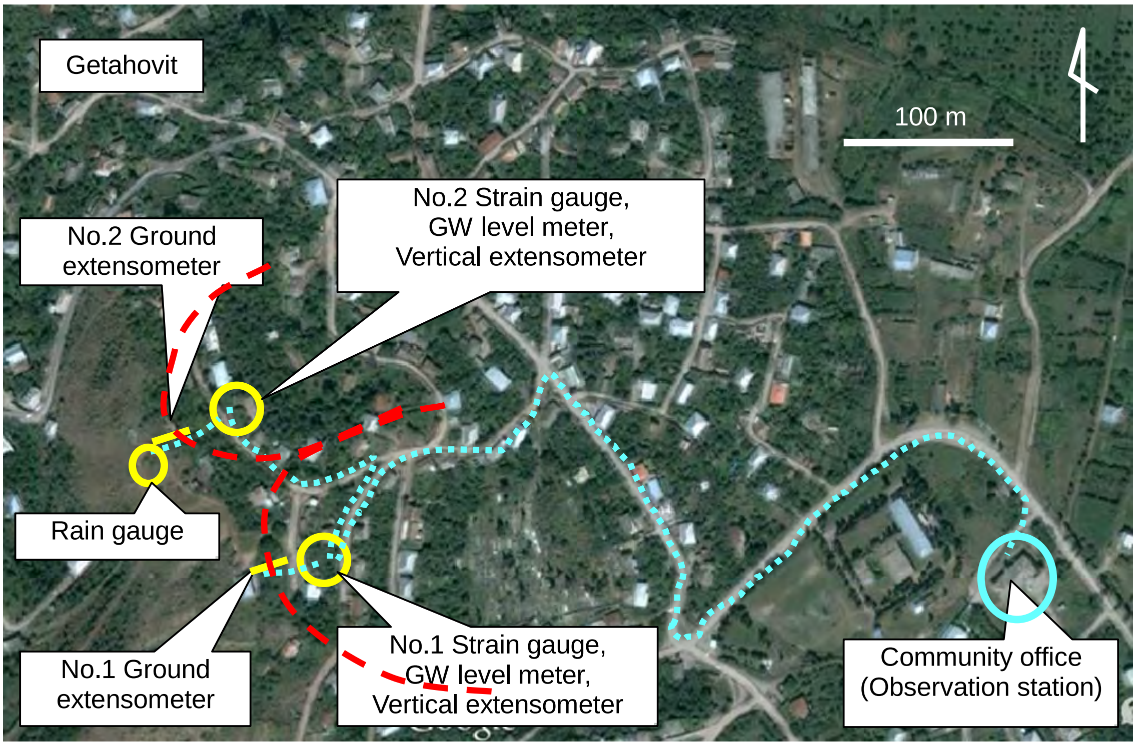
Arapi H1 and S3



Arapi H2 and S4

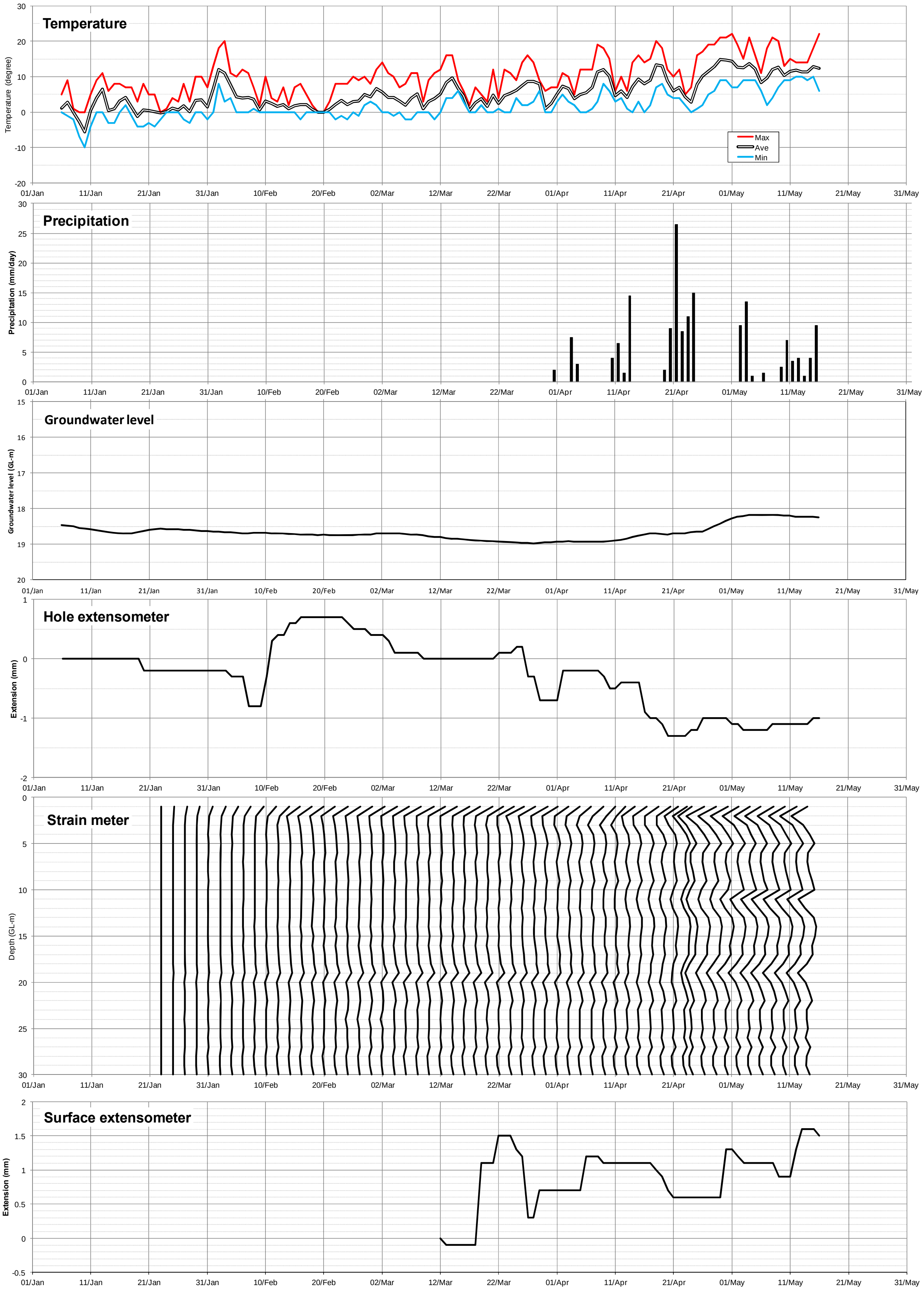


Attachment 8 Location of monitoring equipment installed in Getahovit site

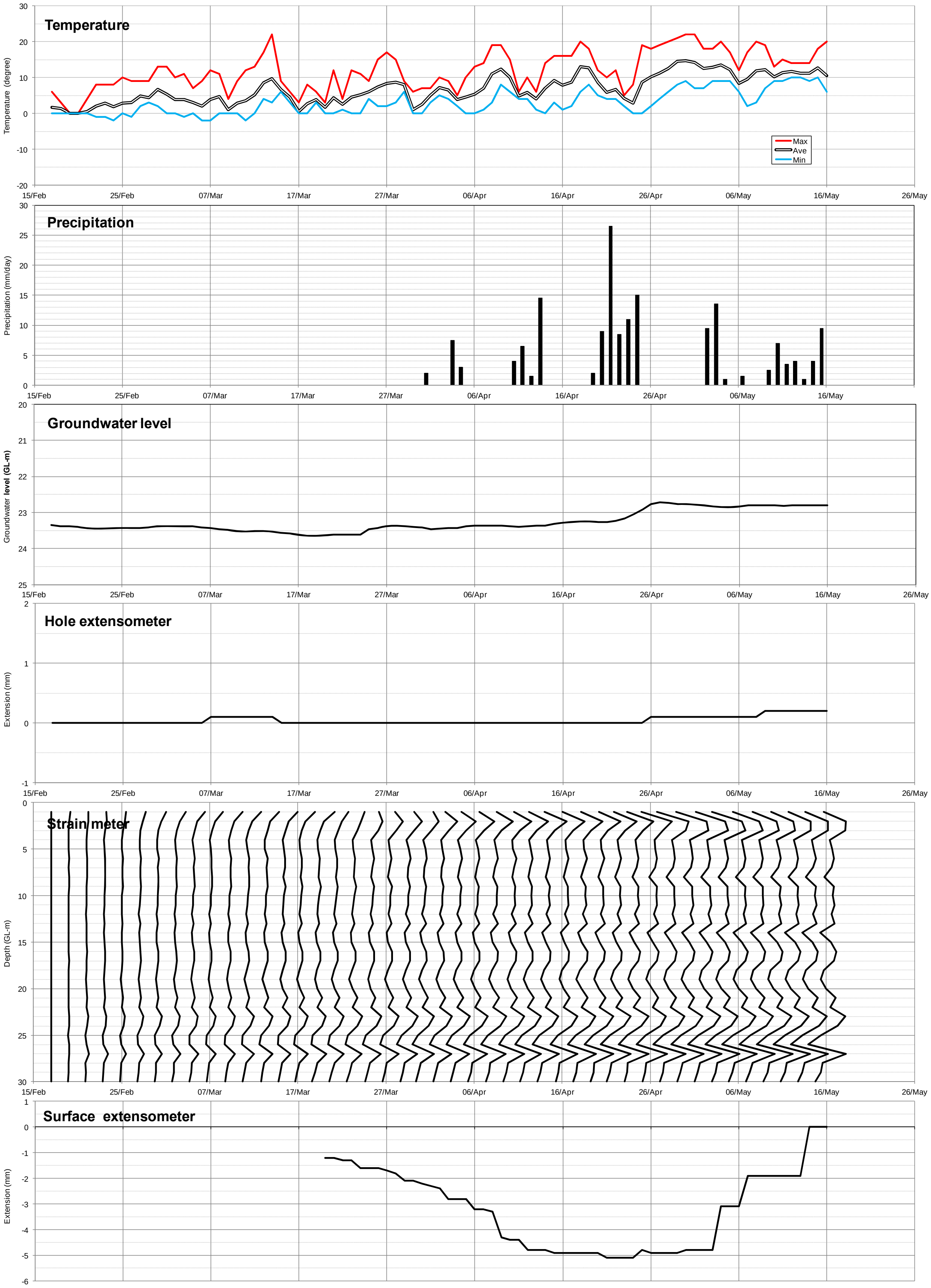


Attachment 9　Monitoring result at Getahovit site

Getahovit H1&S3



Getahovit H2&S4

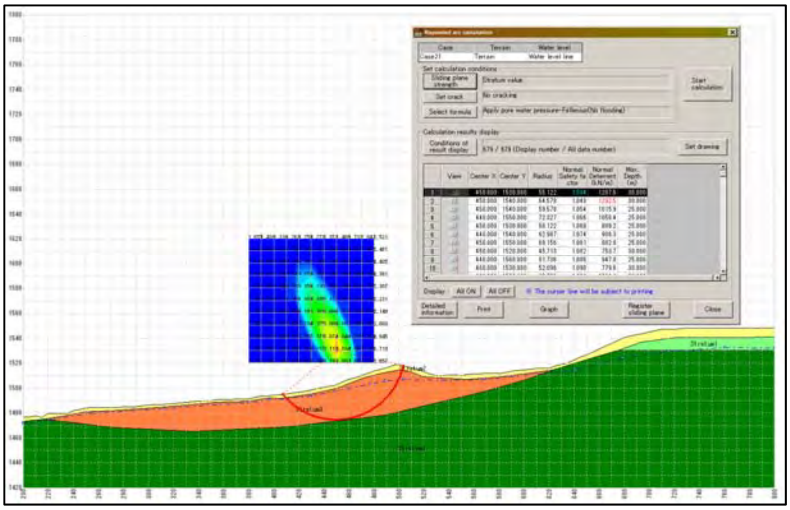


Attachment 10 Result of stability analysis for Arapi site

SA01

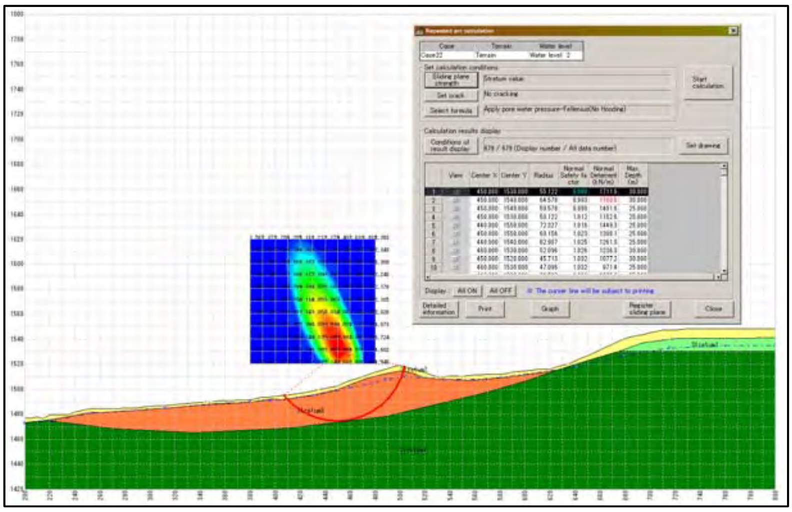
Case 1

GWL: at the present level



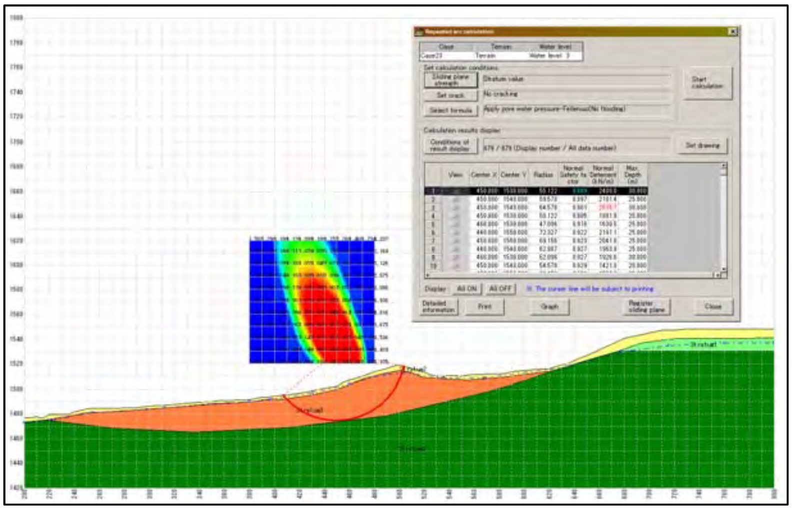
Case 2

GWL: at the upper portion of sliding mass



Case 3

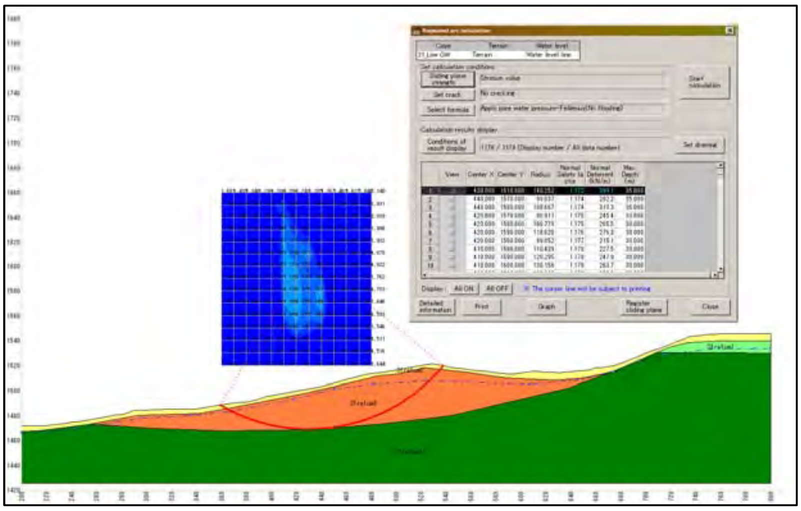
GWL: nearly at the ground surface



SA03

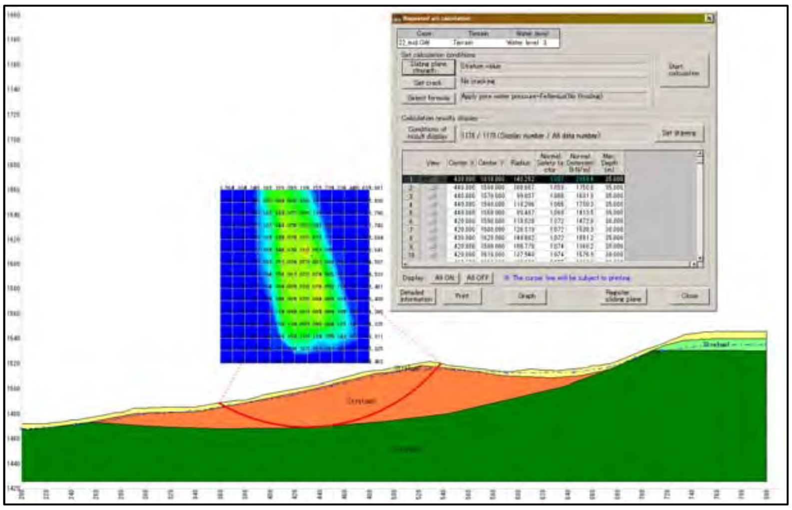
Case 1

GWL: at the present level



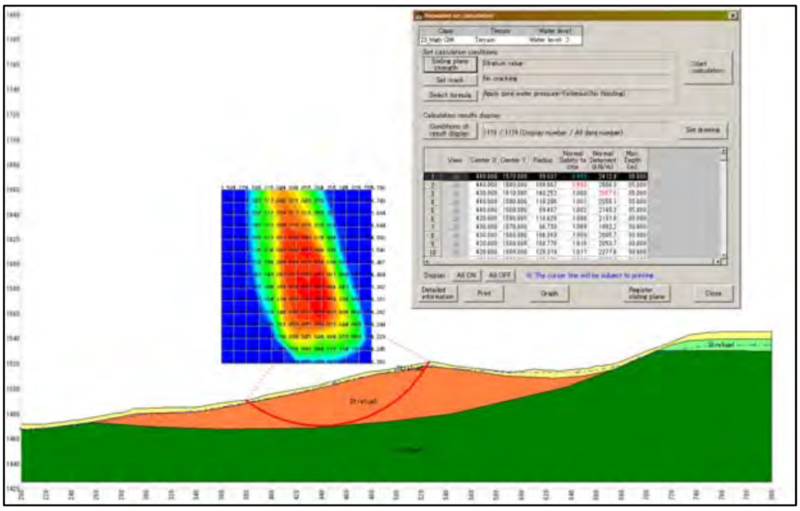
Case 2

GWL: at the upper portion of sliding mass



Case 3

GWL: nearly at the ground surface

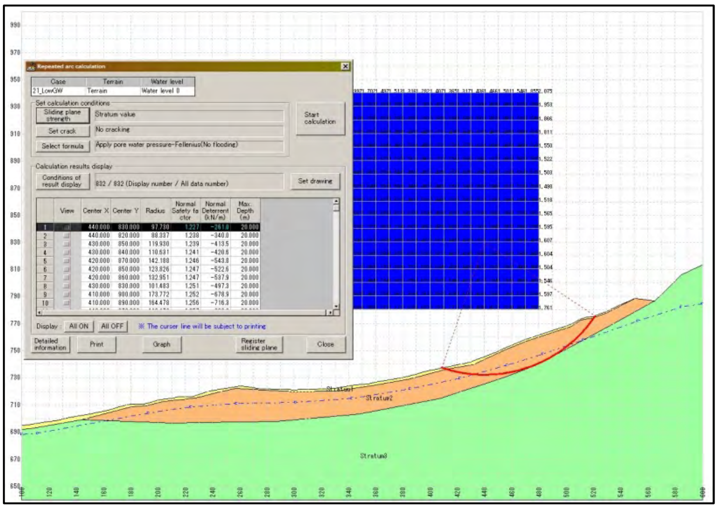


Attachment 11　Result of stability analysis for Getahovit site

SG01

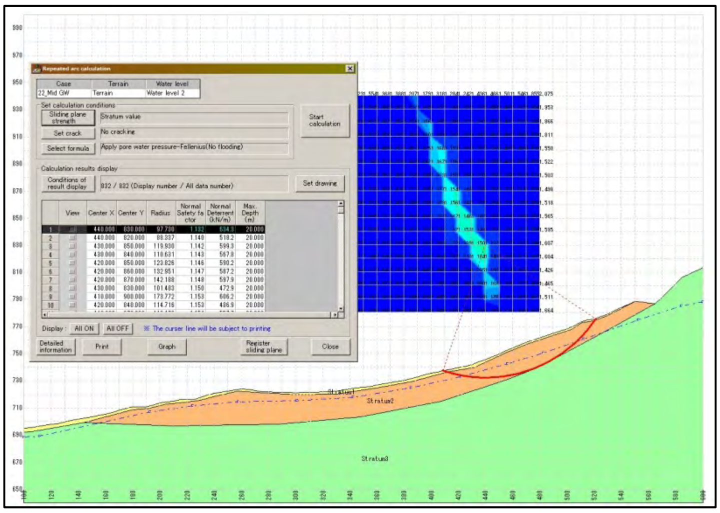
Case 1

GWL: at the present level



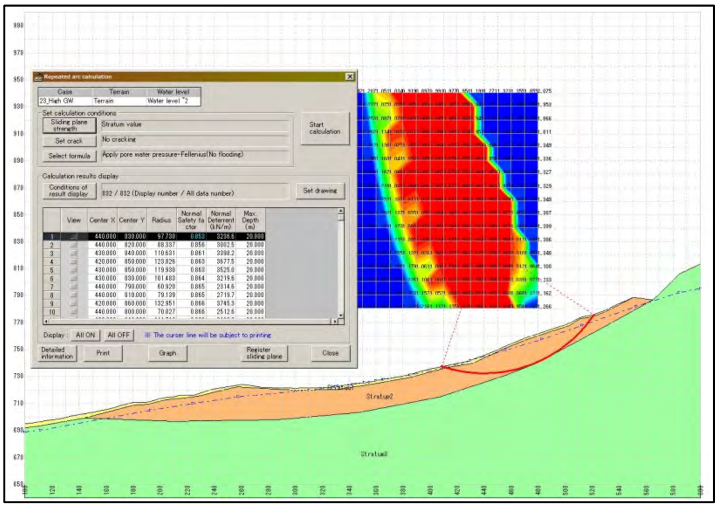
Case 2

GWL: at the upper portion of sliding mass



Case 3

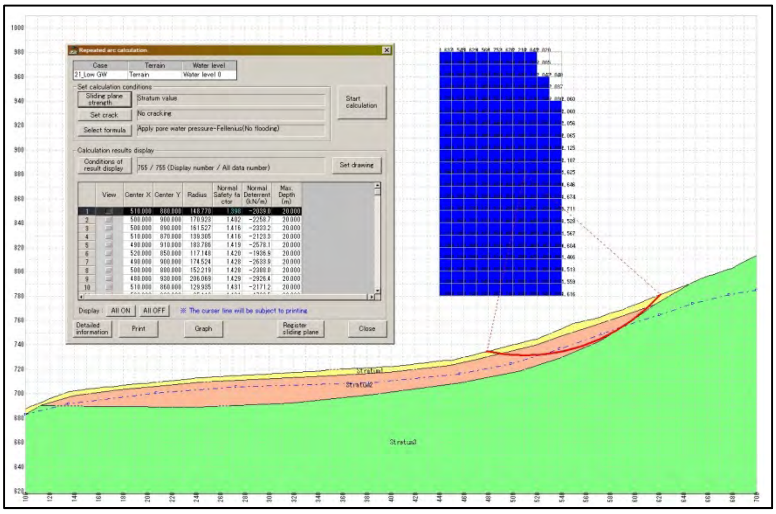
GWL: nearly at the ground surface



SG03

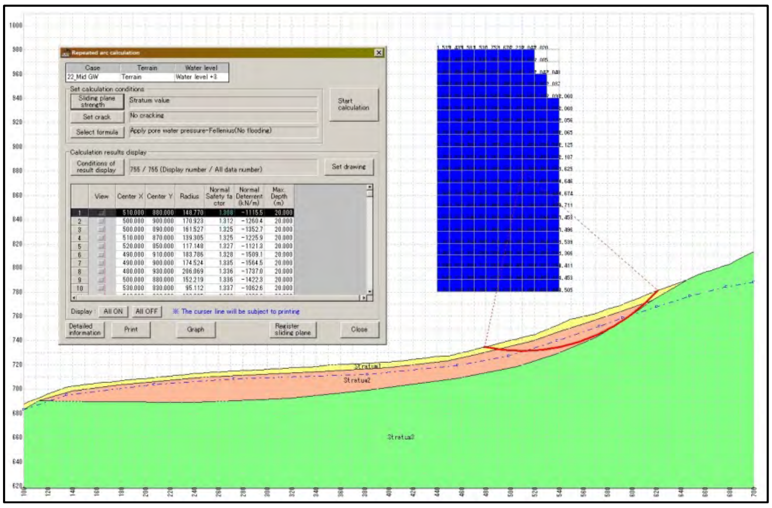
Case 1

GWL: at the present level



Case 2

GWL: at the upper portion of sliding mass



Case 3

GWL: nearly at the ground surface