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Geology and hydrogeology of Jadar spring area with regard to export of drinking water (Jaðar)

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GEOLOGY AND HYDROGEOLOGY OF JADAR SPRING AREA WITH REGARD TO EXPORT OF DRINKING WATER

Thorspring Inc has asked Orkustofnun (National Energy Authority of Iceland) for an evaluation of the Jadar spring area with regard to bottling of drinking water for export. The Jadar spring area is within the wider Heidmörk lava field which forms the upland and recharge area for Jadar and other springs near its northwestern boundary. We therefore include a general description of the catchment as a whole.

1. Location of source and characteristics of Thorspring borehole.

Near Jadar SE of Reykjavík copious springs emerge at the edge of a recent lava flow within a fault zone. Two groups of boreholes have been drilled upwards from the springs to tap the spring water underground rather than at the spring orifices. The more southwesterly group is called Jadar.

Drinking water for the Reykjavík area is supplied from boreholes within the Heidmörk park at a rate of about 0.7 m^3/s. The Jadar boreholes have a yielding capacity of about 590 l/s. The water is very pure and for the Water Works no treatment of it is required. One of the boreholes of the Jadar group numbered V-11 now called Thorspring borehole (THB) is used as a source for the water bottling and is defined as follows:

THB is 13.1 m deep. It is cased to 11.5 m depth. It is located at 86.2 m above sea level. Its static water level fluctuates between 79.5 and 80 m a.s.l. The distance from the natural main spring to the borehole is around 300 m. The borehole has a maximum yield of about 40 l/s at a drawdown of 1.5 m. The water from this well is used solely for bottling.

The boreholes in the Jadar area were drilled with a hammer drill. Nevertheless, as the holes are shallow, lithological logs could be made on the basis of rate of penetration, rock pieces and cuttings. The lithological log of THB is shown in Fig.5. It penetrates a single lava flow down to 12 m and 1 m deep into gravel below it. Water inflow is from 6.5 m depth down to the bottom of the hole.

The borehole was drilld by the Iceland Drilling Company. Its design and pumping constructions comply with regulations and laws pertinent to water supplies in Iceland.

Fig. 1 shows the location of THB within the Heidmörk area on a map with a scale 1:25.000. Fig. 2 is from the same map showing the sources north of it. THB and other boreholes now tap these sources about 150-300 m upstream in the groundwater reservoir. The ground water level falls off to the north to 73 m at Lake Ellidavatn. The Heidmörk area is part of a nature reserve which extends up to the Bláfjöll mountains in the SE. Heidmörk itself is a park reserved for reforestation and outdoor recreation. A 150 hectares area around Jadar is fenced off against unauthorized entry. The entire catchment of the spring area is under strict rules to protect the ground water.

2. Geology and hydrogeology of the surrounding terrain

The Heidmörk area is located a few km NW of the zone of active volcanism. Piles of subglacially formed volcanic breccias occur in the higher ground to the SE (Fig. 3 and 4). During ice free periods lavas have spread over the area. Thus in postglacial time lavas have overflowed the southeastern part of Heidmörk.

The bedrock of Heidmörk consists of interglacial and postglacial lava flows (Fig.3). The interglacial lavas are inferred to be of Eemian age, i.e. from the last interglaciation. These are fresh olivine rich basalts consisting of thin flow units with scoriaceous boundaries in between. Glacial mud has seeped into vugs, fractures and cavities and somewhat reduced the high primary permeability of the rock. The postglacial lavas have an extremely rubbly surface and are highly permeable and practically all the precipitation is infiltrated to the groundwater. The youngest lava flow was erupted some 1000 years ago. It has thin soil but a thick carpet of moss. The lava which extends up to Bláfjöll in the SE has an extremely rough surface and is therefore naturally protected from outside traffic.

The interglacial lavas carry on the surface some morainic deposits that are thickest in lows and on gentle slopes. They were smeared on the surface by a glacier that moved towards NW from the mountain range of the central Reykjanes peninsula. The morainic deposits date from the last glaciation. They are poorly permeable. In the Jadar spring area a layer of lake sediment and gravel overlies the moraine.

Heidmörk is traversed from NE to SW by an active fault swarm. The fault scarps are fresh with throws of up to 40 m. Extensional fissures with opening of up to 1/2-1 m are seen. The Jadar area lies near the middle of the fault swarm which is about 6 km wide (Fig. 3). The rock permeability is greatly enhanced by the faults and fractures. They intersect the interglacial lava, but have not affected the postglacial flow.

The aquifers are mainly interglacial lava but nearest to the source area the postglacial lava extends below the groundwater table.

A map showing the undisturbed groundwater level around THB is presented in Fig. 6. The water level is seen to drop by about 11 m over a distance of 0.5 km from the SE towards THB and the lake Ellidavatn in the west where a number of springs emerge on the shore. Fig. 7 shows the effect of pumping at a rate of up to 520 l/s. Rather than tapping the springs directly the water is pumped from wells a short distance upstream from them. Pumping is kept at a rate lower than could possibly reverse the groundwater flow and cause ingress of lake or river water towards the wellfield.

The aquifer in the Jadar (THB) area occurs at shallow depth. The feed zones are firstly the lower part of the postglacial lava flow and its underlying gravel, and secondly fissures in the basal interglacial lava. The shallow nature of the Jadar aquifer brings with it small fluctuations in chemical constituents and pH of the water. These do not affect the direct use of the water for consumption.

It is known from deeper drilling in the surroundings of Jadar that the groundwater reservoir reaches to at least 300-400 m depth. The groundwater catchment is part of an extensive groundwater reservoir which depth is not known. Permeability is provided essentially by scoriaceous inter-lava partings and faults. Recharge is mainly from the lava covered high ground and mountains to the SE where precipitation is in the range 2000-3000 mm/y (Fig. 3).

Fig. 8 shows the result of a resistivity survey of Reykjavík and surroundings. A zone of high resistivity lies east of Reykjavík, in the area of young open fractures. The high resistivity zone reaches at least 750 m below sea level and correlates with an area of near zero geothermal gradient (Fig.9). Both is taken to indicate the existence of an extensive cold aquifer. A borehole 7 km SW of THB has confirmed 5°C to about 650 m below sea level.

3. Description of the Jadar wellfield with regard to sources of contamination.

The Jadar area is situated at 80-90 m above sea level 1 km east of Lake Ellidavatn (75,5 m above sea level). The ground is partly moraine covered interglacial basalt cut by several faults with SW-NE trend and partly a rubbly postglacial lava flow. The soil is thin and discontinuous and the vegetation is mainly of heath and shrub type. The postglacial lava is overgrown predominantly with moss. Roads and walking paths pass southeast of the wellfield. They are used mainly during the summer by people enjoying the nature of the park. The nearest permanent dwellings are at Ellidavatn (residence of park warden) 1.2 km west of the wellfield and the farm Vatnsendi northwest of Lake Ellidavatn about 2 km distant, both downslope from THB with regard to groundwater flow. Highway 1 passes about 1500 m NE of THB, also outside the groundwater catchment of this well. The well field around THB is fenced off and proof against unauthorized entry. Also the park as a whole is fenced off to keep out domestic animals. THB is farthest southeast among the production wells, and therefore also farthest upstream with regard to groundwater flow (Fig.6).

The Heidmörk park is reserved for outdoor life, reforestation and last but not least as a supplier of abundant ground water for Reykjavík and the neighbouring communities. Apart from a skiing area on the NW-slope of Bláfjöll 12 km to the SE, there is no landuse at present upstream from THB that could contaminate the groundwater. No land use is planned in the future. During times of rapid snow melting water may accumulate temporarily in ponds and seep into the permeable ground to mix with the groundwater at near surface level.

4. Rate of flow and identity of source and borehole water

The rate of flow from the spring area north of THB is on average 1000 l/s. Of this about 500 l/s are captured by boreholes for the Reykjavík Water Works 150-300 m distant upstream. Another 500 l/s bypass and still emerge in the natural springs. Pumping tests of THB yielded ~ 40 l/s at 1.5 m drawdown of the water level in the borehole. The identity of the spring- and borehole water is manifested firstly by the rate of flow of the springs decreasing correspondingly to the rate of pumping from the boreholes and secondly the water chemistry of the borehole water is the same within fluctuation limits as that of the spring water.

5. Temperature of the aquifer.

Measurements of temperature of THB water show a variation between 3.6°C (winter) and 4°C (summer).

6. Water chemistry and hydrogeology and the nature of the terrain

The surroundings of Reykjavík can be roughly divided in three hydrogeologically different regions:

1) Esja - Mosfellssveit zone: Pliocene - Pleistocene rocks with a rather low permeability and not very much affected by recent fissure zones. A high rate of surface runoff and a low discharge of perennial springs (each of the order 1 - 10 l/s). Numerous small groundwater

basins, with marked seasonal variations. Mostly unconfined aquifers. Precipitation probably 1,000 - 2,500 mm/a but the infiltration ratio is low.

2) Reykjavík border zone, stretching from Mosfellssveit to Hafnarfjördur: Pliocene rocks with a rather low permeability, covered by relatively thin Pleistocene rocks with a markedly higher permeability. Strongly fissured in SW - NE direction. Surface runoff restricted and infiltration considerable. Few springs but some in excess of 10 l/s. Seasonal variations probably less marked. A composite groundwater basin with some subbasins. Mostly confined aquifers. Precipitation near to or less than 1,000 mm/a.

3) The Reykjanes peninsula: Pleistocene rocks with a very high permeability, strongly fissured. Hardly any surficial runoff. Discharge in many marginal and seashore springs in excess of 100 l/s. A continous groundwater basin although divided in subbasins. Semi-confined aquifers. Two main outlet areas, one in Heidmörk and the other at Straumsvík, both with a total discharge of near to 5,000 l/s or more. Seasonal variations observed on some surficial springs, as well in discharge as temperature. Precipitation probably 1,000 - 4,000 mm/a, with a very high ratio of infiltration.

The groundwater in any distinct area has its own chemical characteristics. A considerable part of the chemical contents is of marine origin, from seaspray and salt particles, carried to the groundwater with the precipitation. Most chemical components in this marine factor show a clear correlation to the chloride content. The concentration values can therefore be corrected for the marine component with a simple subtraction. The remaining concentrations are then the result of the reactions between the groundwater and the rocks in the aquifers under the prevailing hydrogeological conditions. The corrected chemistry is thus indicative of the hydrogeological nature of the aquifers. In deep and confined aquifers the water is undersaturated with regard to carbon dioxide (total dissolved carbon), due to reactions with the rocks, and the pH is correspondingly high (near to ~9). In equilibrium with the atmosphere, the water usually acquires pH near to 7.5. The groundwater in the Reykjavík border zone is rather typical for water from deeply fissured, not very permeable basaltic rocks in Iceland: A high pH (>9), but magnesium and potassium, when corrected for the marine component in the precipitation, are virtually depleted, the corrected contents of sodium and calcium are rather high (5-10 ppm). In the Esja - Mosfellssveit zone the water is typical for rather shallow aquifers with a considerable constituent from high mountains: A rather low pH (7-7.5), low overall chemistry (calcium (corrected) near to 4 ppm, sodium (corrected) 1 - 4 ppm) but yet the corrected values for magnesium and potassium are higher than in the fissured area (0.3-1 ppm resp. 0-0.2 ppm).

With the same corrections, the chemistry in the Reykjanes peninsula area, inclusive the Heidmörk area around THB, can be interpreted as typical for deep, semiconfined aquifers, the pH being rather high (up to 9), the corrected values for magnesium are low (0.2-0.6 ppm), sodium and calcium not very high (2-6 ppm resp. 2.5-4 ppm) and potassium rather low (0.2 ppm). In Heidmörk the corrected sodium content is relatively high (near to 5 ppm) and the magnesium content relatively low (0.2-0.3 ppm) indicating a relatively great depth of circulation and a high degree of confinity.

The chloride values decrease from the coast (13 - 18 ppm in groundwater) and are as low as 10 ppm on the borders of the interglacial Mosfellsheidi shield volcano. On the other side of the Reykjanes peninsula, in Ölfus, springs with contents of only 8 ppm chloride are found, which drain the higher central parts of the peninsula. The chloride content in the Heidmörk area is close to 10 ppm, which indicates that a considerable part of the water must be drawn from the central parts of the Reykjanes peninsula, the drainage basin probably stretching up to the mountain cluster of Bláfjöll.

A similar conclusion can be drawn from the sulphate contents, when corrigated for the marine factor. It is around 3 ppm in the fissured border zone, near to Reykjavík, but around 2.5 ppm in the Esja zone. In the Heidmörk area it is still lower or around 2.0 ppm. These low values can be explained by a relatively high altitude for the place of precipitation, in view of the country-wide distribution of sulphate in groundwater. The most probable area would again be the Bláfjöll mountain cluster.

Summarily, the available chemical and hydrogeological evidence indicates, that the groundwater present in the THB area - and for that purpose in the whole Heidmörk area - is from a deep, semiconfined aquifer with an extension far into the uninhabitated, mountainous Reykjanes peninsula, probably as far as to the mountains of Bláfjöll.

Chemical analyses of the groundwater from the well THB indicate, that the water essentially originates from this extensive reservoir and from a semiconfined aquifer. The chloride content is rather but not exceptionally high, perhaps indicating a relatively high ratio of water from the Heidmörk area proper as compared with the contribution from the higher mountains. The relatively high sulfate content, as well as the contents of anions of the main constituents, are probably indicative of the same source, especially in view of the more dense vegetation cover in that lower area, resulting in a higher content of carbonate (dissolved carbon) and correspondingly in an increase of the mineral contents.

List of Figures

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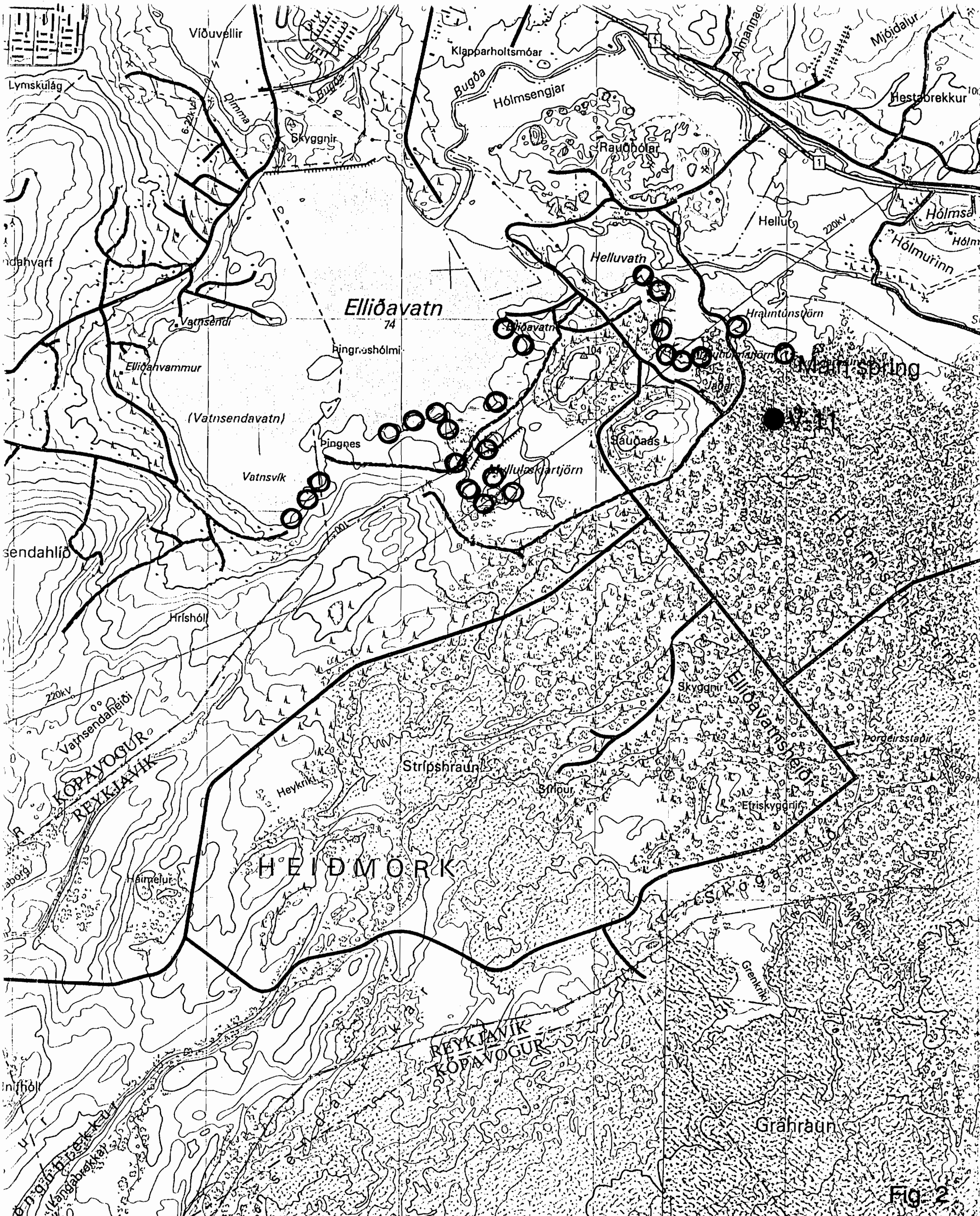

Víðuvellir
Klapparholtsmóar
Lymskulág
Bugða
Hólmsengjar
Hestabrekkur
Skyggnir
Rauðhólar
Hellur
Hólmsá
Hólmurinn
Helluvatn
Elliðavatn
74
Vatnsendi
Hrauntúnstjörn
Þingnesshólmi
Elliðavatn
Elliðavammur
Main spring
V-11
(Vatnsendavatn)
Rauðaás
Þingnes
Vatnsvík
Hrísholl
220kV
Vatnsendaheiði
KÓPAVOGUR
REYKJAVÍK
Strípshraun
Heykriki
Skyggnir
Elliðavatnsheiði
Þorgeirsstaðir
HEIÐMÖRK
Efriskyggnir
Hálmelur
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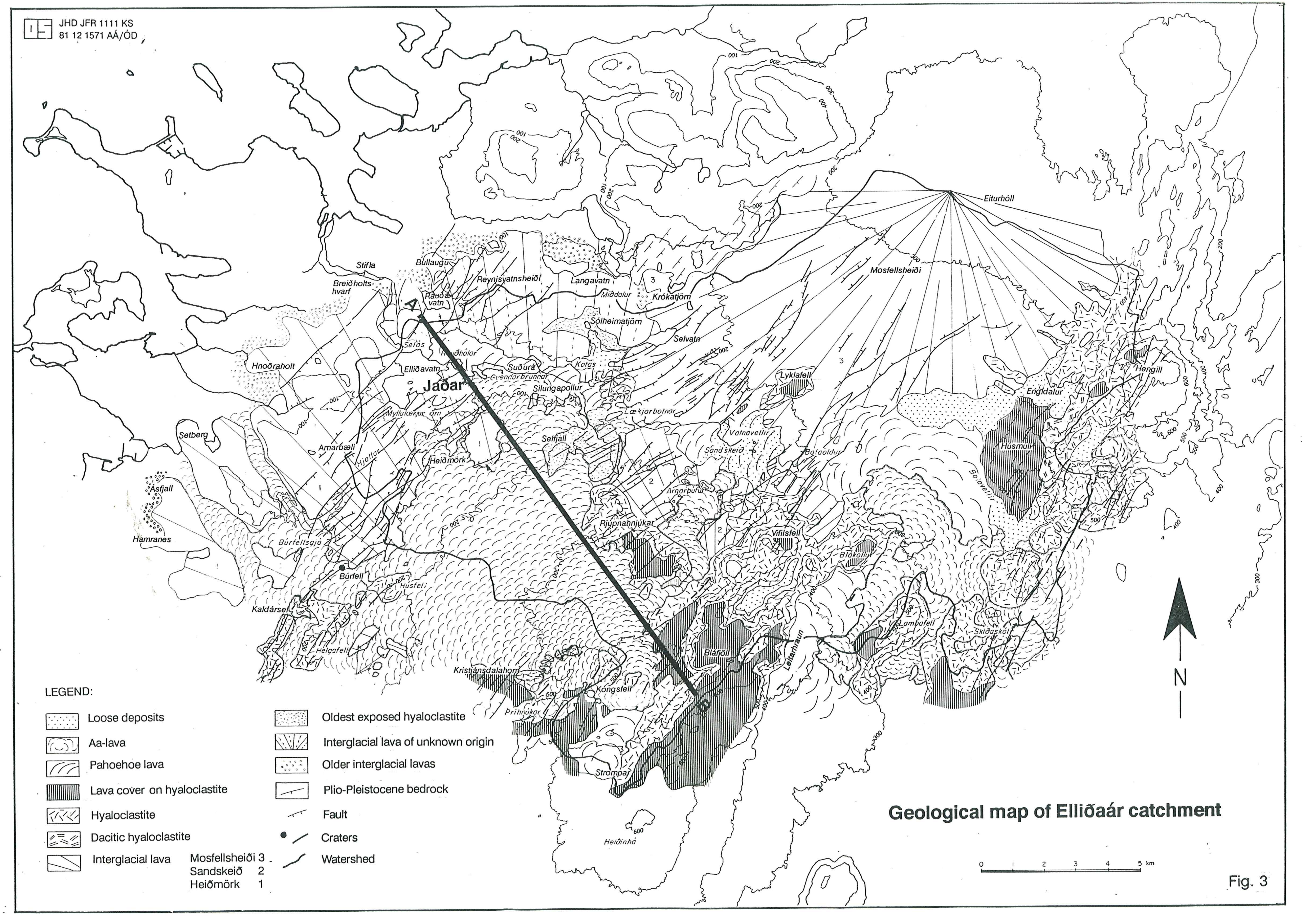
KÓPAVOGUR
Gráhraun
Langabrekka

Fig. 2



Geological map of Elliðaár catchment

Fig. 3

JHD JFR 1111 KS
90.06.0284 Gyða

Geological section across Heidmörk

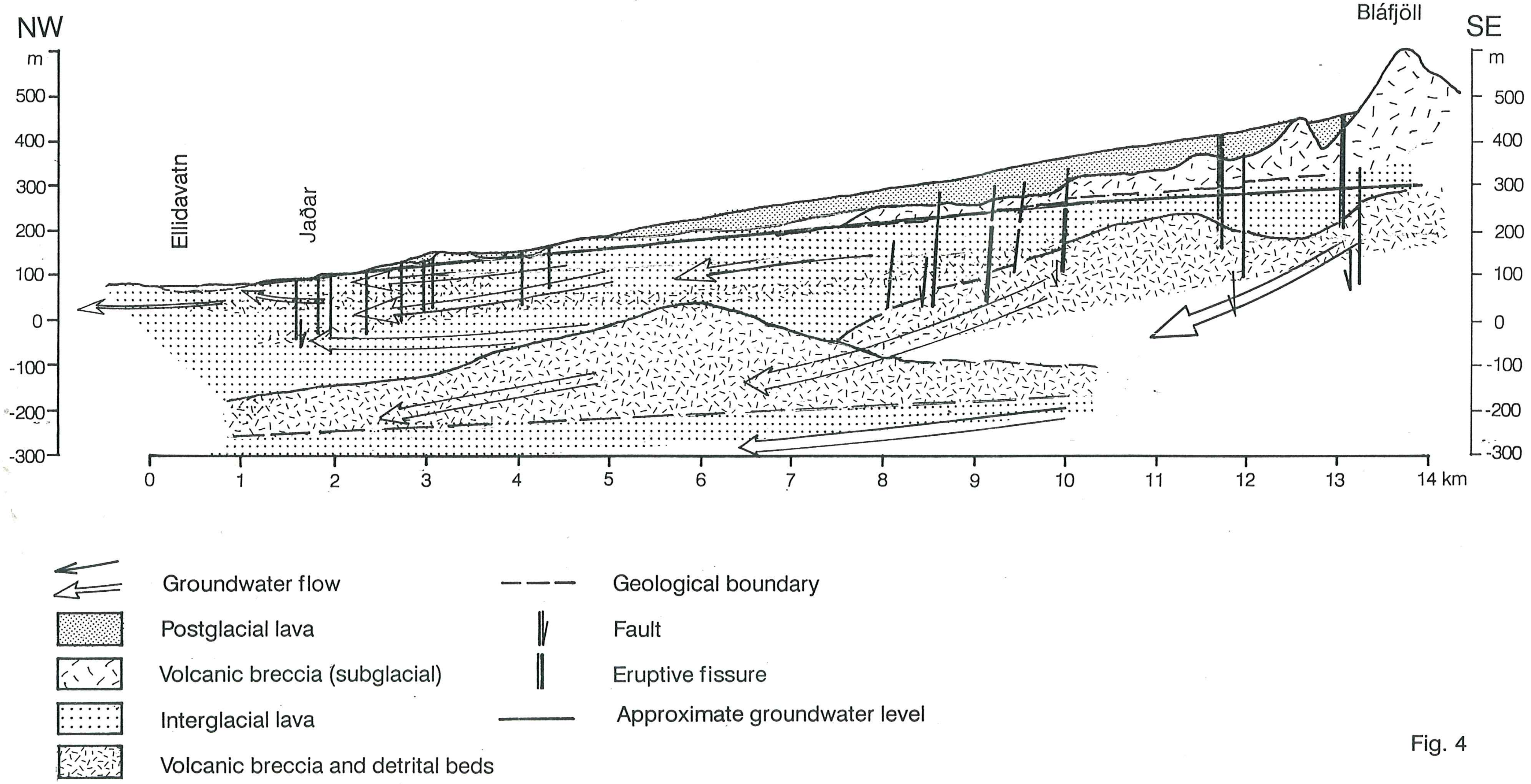


Fig. 4

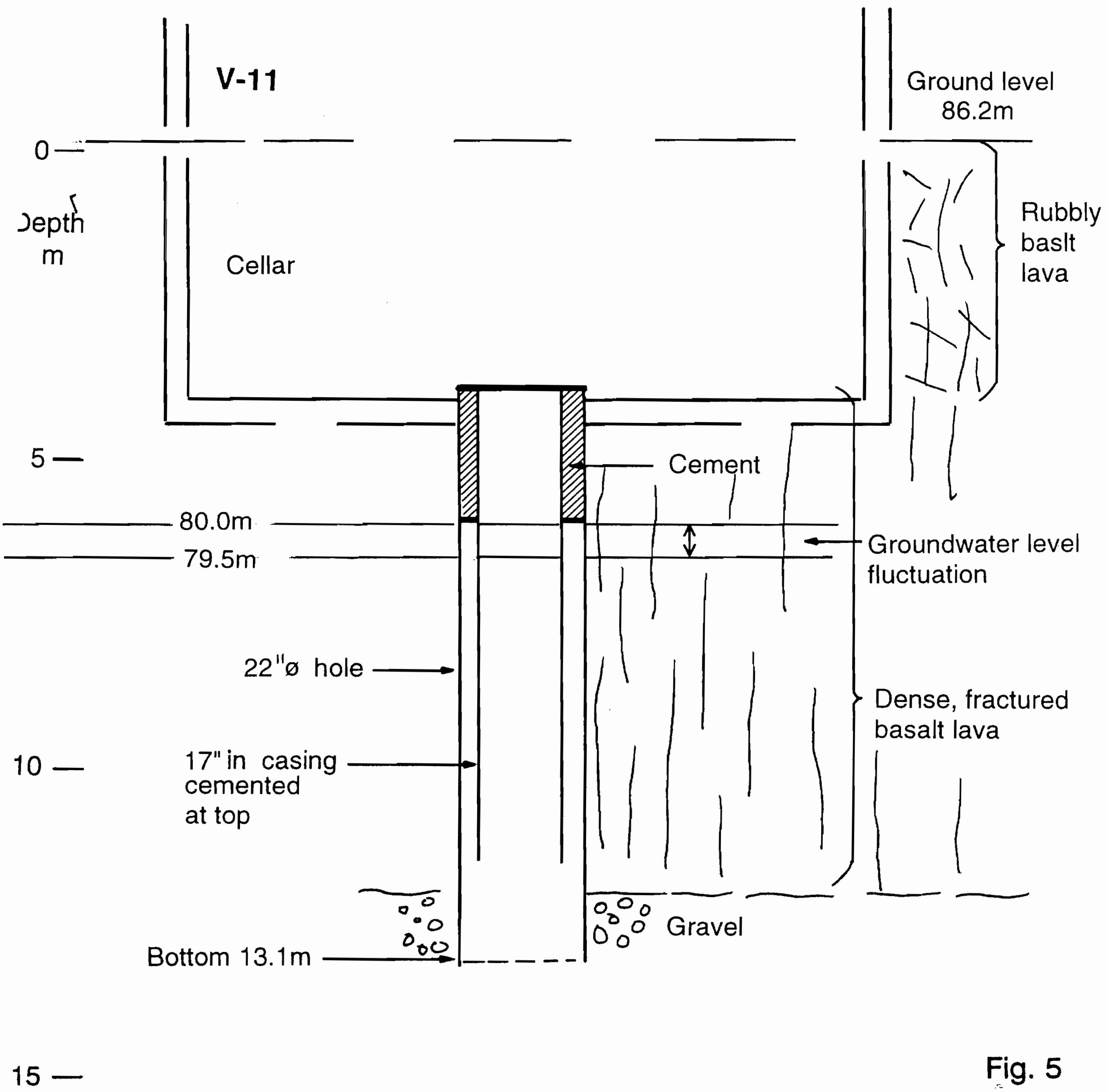
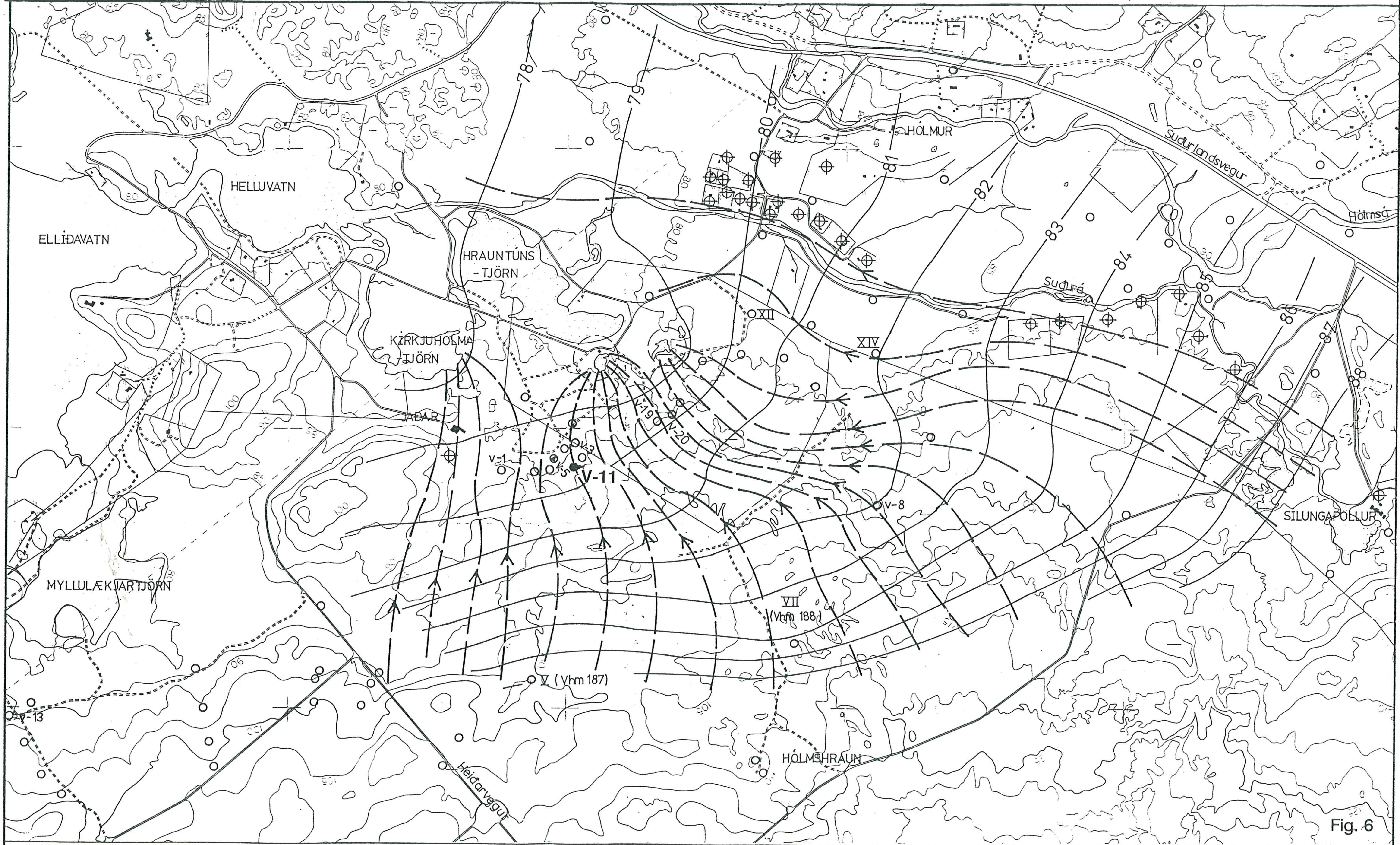

V-11
Ground level
86.2m
0
Depth
m
Cellar
Rubbly
baslt
lava
5
Cement
80.0m
79.5m
Groundwater level
fluctuation
22"ø hole
Dense, fractured
basalt lava
10
17" in casing
cemented
at top
Gravel
Bottom 13.1m
15

Fig. 5



GRUNNKORT: FORVERK h/f OG SKIPULAGSSTJÓRI RÍKISINS.
HÆÐ: HÆÐARMERKI REYKJAVÍKUR
HÆÐARLÍNUMISMUNUR 5 m.

SKÝRINGAR:
○ BORHOLA.
⊕ ROTÞRÓ.
—— REIKNUÐ JAFNHÆÐARLÍNA GRUNNVATNS.
→— STRAUMLÍNA.
RENNSLI MILLI HVERRA TVEGGJA STRAUMLÍNA ER 50 l/s.

MYND: 2.3

MÆLIKVARÐI: 1:10.000

0 200 400 600 800 1000 m

VATNSVEITA REYKJAVÍKUR
VATNSBÓLANEFND.

FLÆÐINET LÍKANS.
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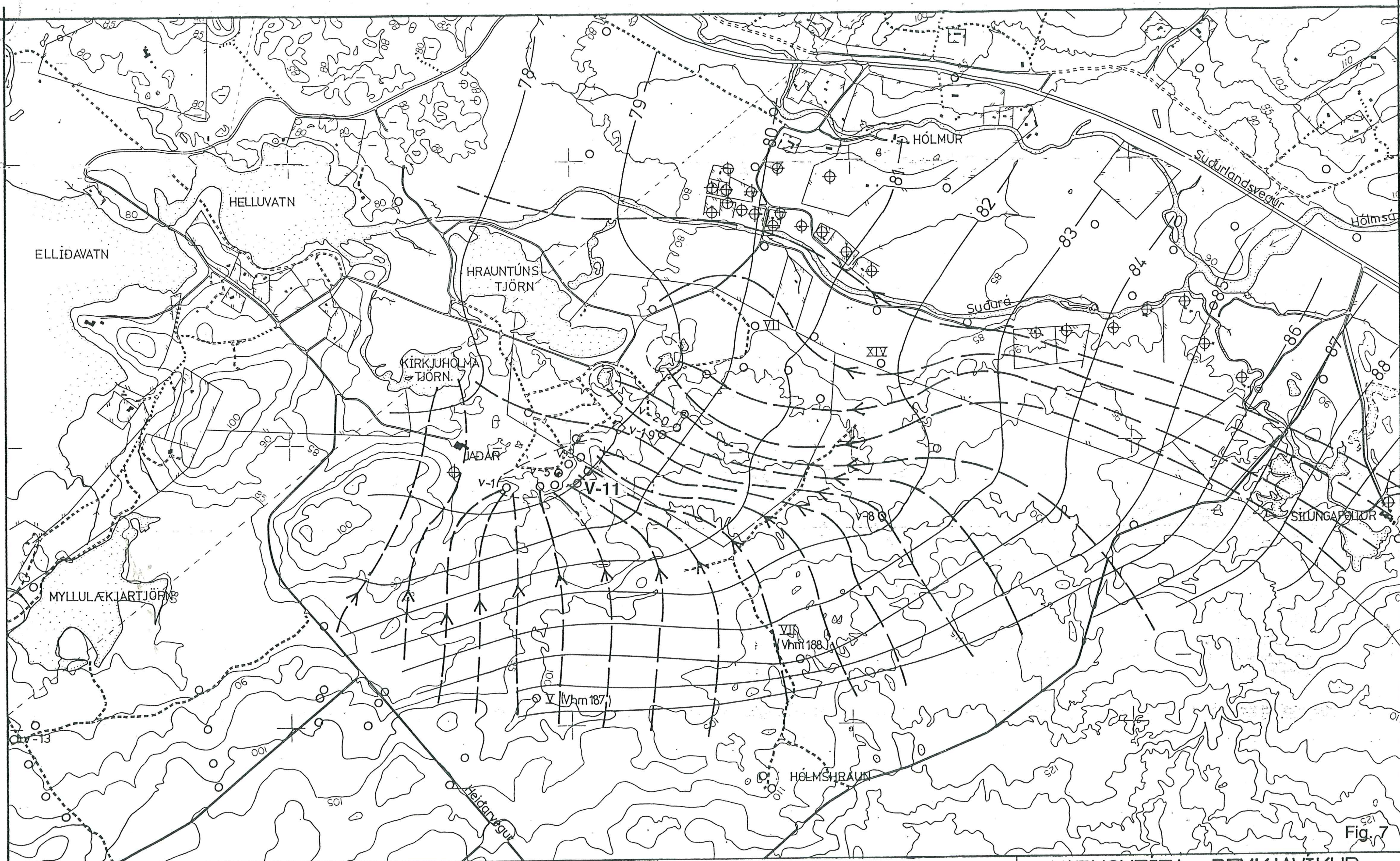
1909 INNTAK 230 l/s

Reikn: AI
Teikn: SG
Dags: 19831003

OS.95.10.0475 KS



GRUNNKORT: FORVERK h/f OG
SKÍPULAGSSTJÓRÍ RÍKISINS.
HÆÐ: HÆÐARMERKÍ REYKJAVÍKUR
HÆÐARLÍNUMÍSMUNUR 5m.

SKÝRINGAR:
- O BORHOLA.
- ⊕ ROTÞRÓ.
- ——— REÍKNUÐ JAFNHÆÐARLÍNA GRUNNVATNS
- —> STRAUMLÍNA.

RENNSLÍ MÍLLÍ HVERRA TVEGGJA STRAUMLÍNA ER 50 l/s.

MYND: 2.4

MÆLÍKVARÐÍ: 10.000

0 200 400 600 800 1000 m

VATNSVEÍTA REYKJAVÍKUR
VATNSBÓLANEFND.

FLÆÐÍNET LÍKANS.

VATNSTAKA: JAÐARSSVÆÐÍ 520 l/s.
SJÁLFRENNSLÍ 200 l/s.

Reikn: AI.
Teikn: SG.
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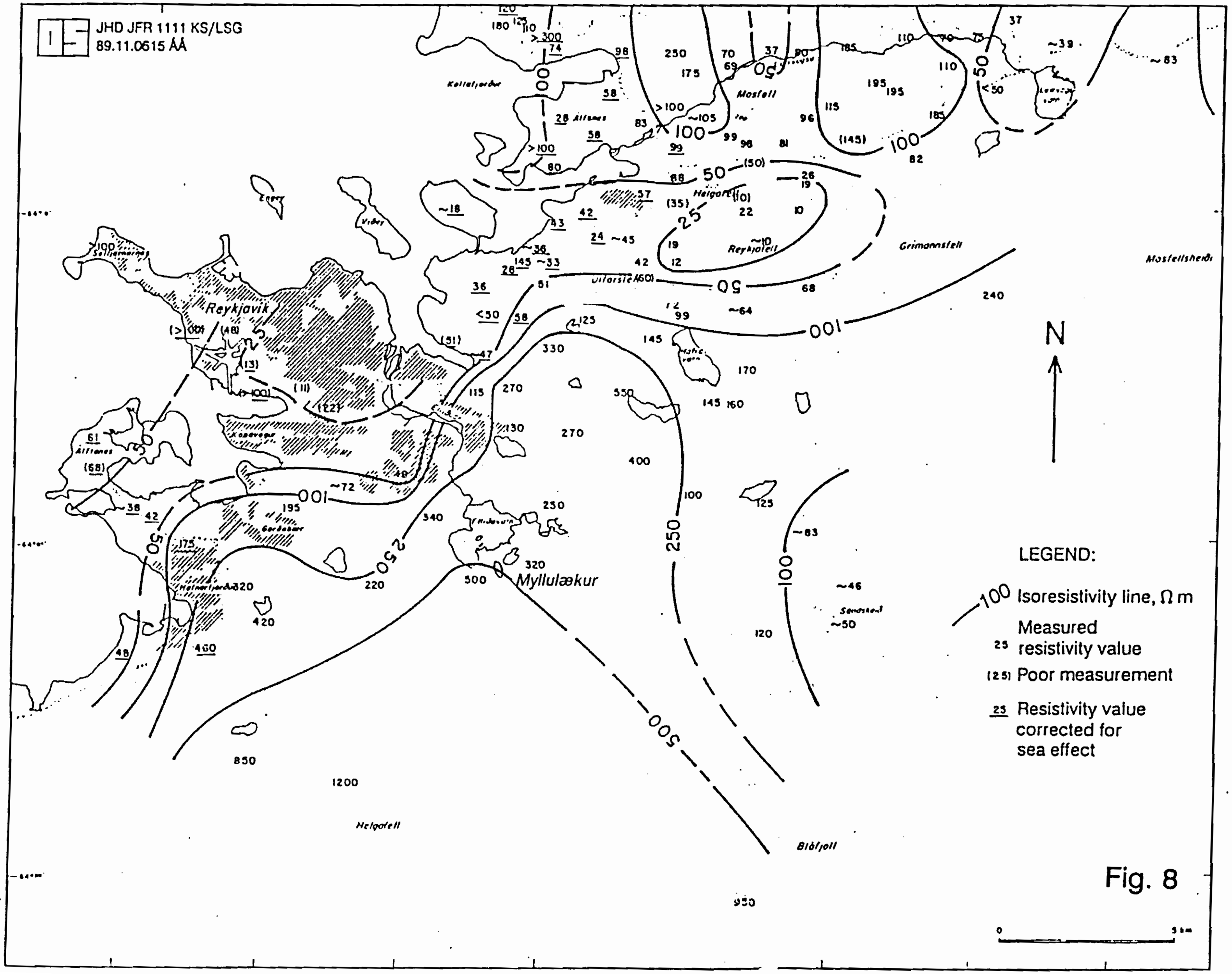
JHD JFR 1111 KS/LSG
89.11.0615 ÅÁ
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Mosfell
Helgafell
Reykjafell
Grimannsfell
Mosfellsheiði
Myllulækur
Helgafell
Bláfjöll
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LEGEND:
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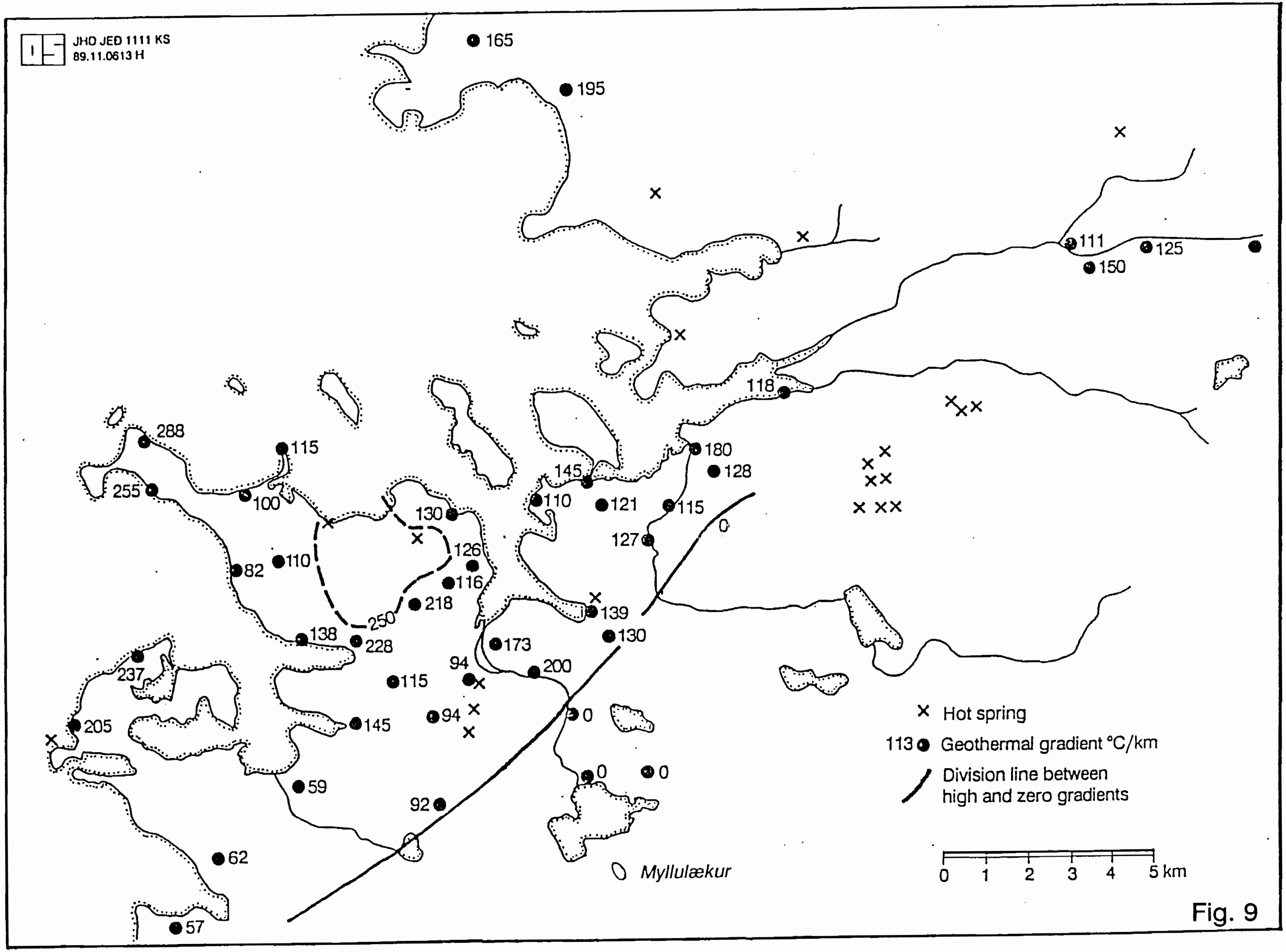
25 Measured resistivity value
(25) Poor measurement
25 Resistivity value corrected for sea effect
0
5 km

Fig. 8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116
218
139
250
138
228
173
130
237
94
200
115
94
0
205
145
0
0
59
92
62
Myllulækur
57
Hot spring
113 Geothermal gradient °C/km
Division line between
high and zero gradients
0
1
2
3
4
5 km

Fig. 9