

Mtkvari HPP Georgíu

Aðalfundur Jarðgangafélags Íslands

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2022-11-24

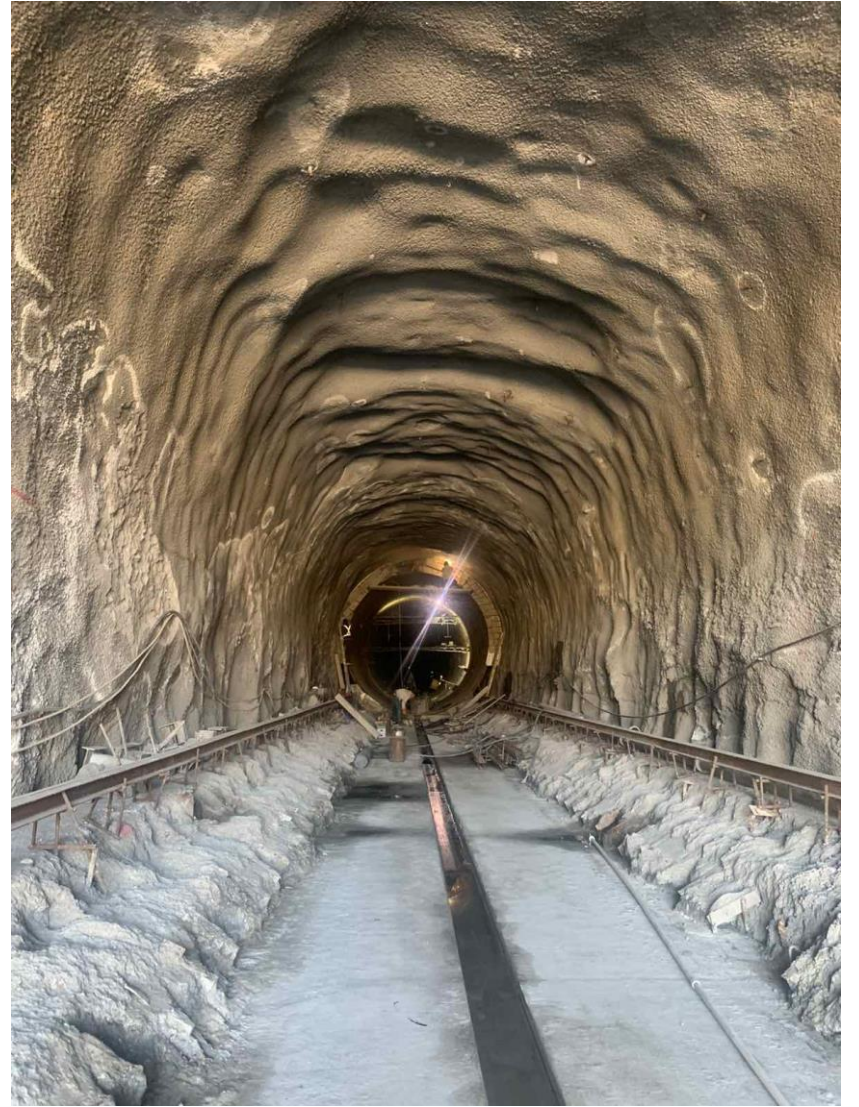
Mtkvari HPP

- Landsvirkjun Power
 - Verkefnisstýring og sérfræðiráðgjöf
- Verkís
 - FEM módel og rýni
 - Deilihönnun
- Mannvit
 - FEM módel og rýni



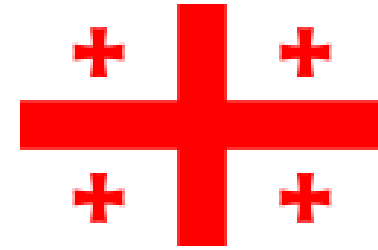
Yfirlit kynningar

- Staðsetning og yfirlit Mtkvari HPP
- Aðkoma ráðgjafa á Íslandi
- Helstu verkefni okkar
- Stæðnivandamál í aðrennslisgöngum

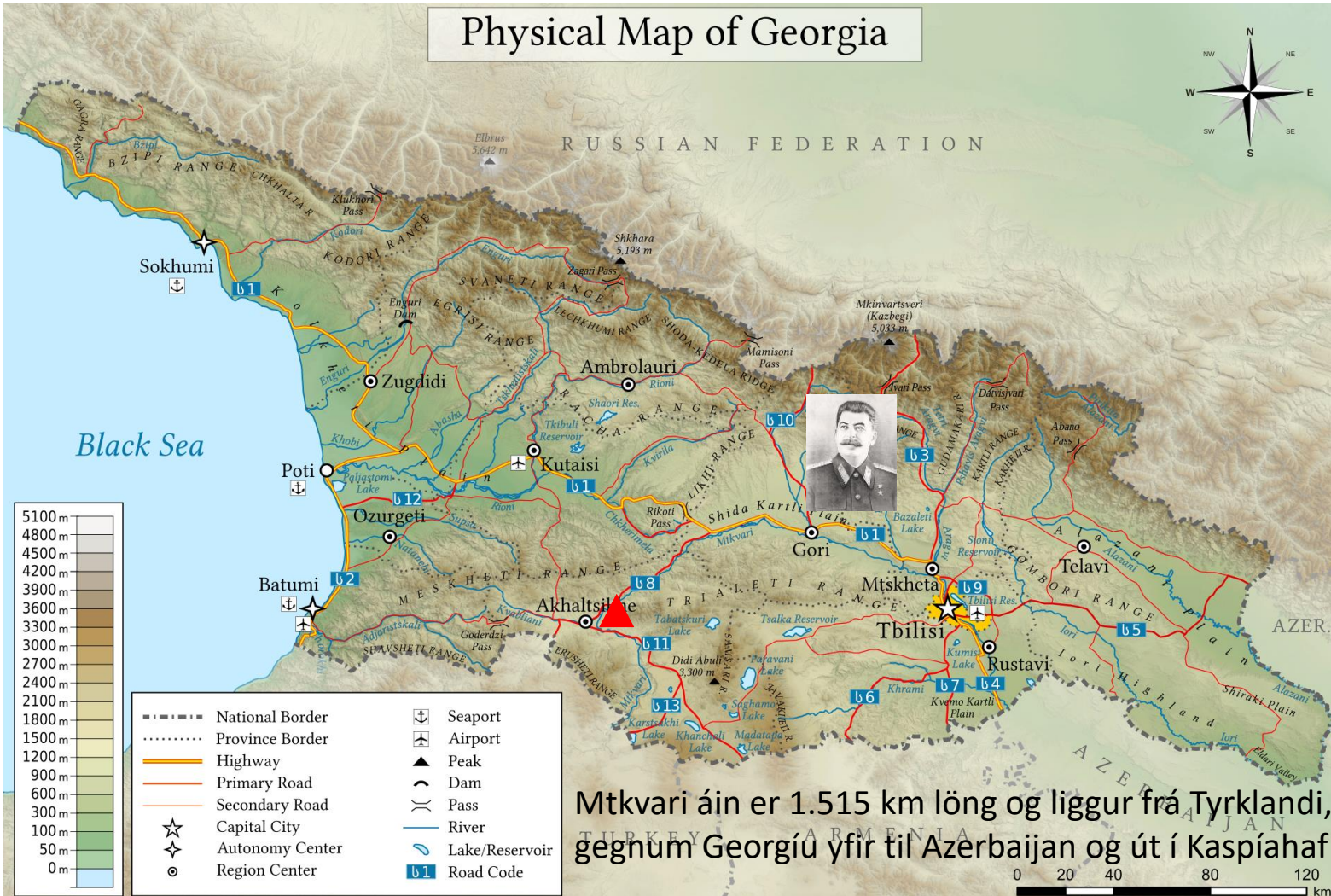


Georgía

Flatarmál: 69.700 km²
 Íbúafjöldi: 3,7 milljónir
 Tungumál: Georgíska
 Trú: 88,1% Kristni



Physical Map of Georgia



Mtkvari áin er 1.515 km löng og liggur frá Tyrklandi, gegnum Georgíu yfir til Azerbaijan og út í Kaspíahaf



Grátlegt tap gegn Georgíu



Mtkvari HPP

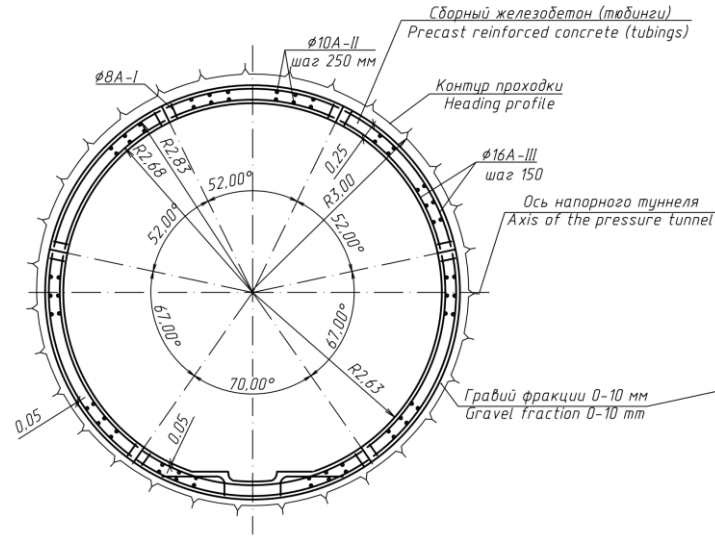
Aðrennslisgöng 9,6 km



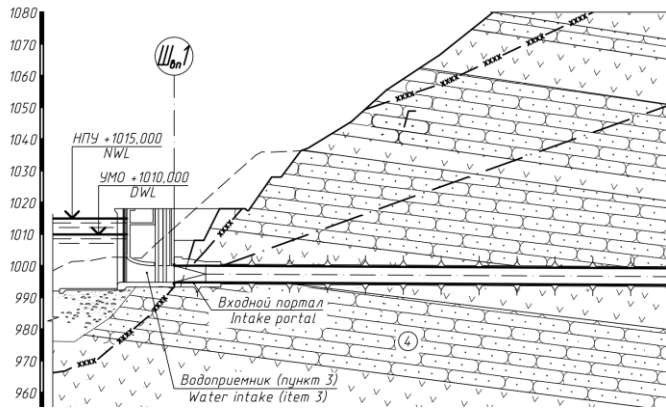
Mtkvari HPP

Verkís og LVP komu að frumhönnun 2008.
 Deilihannað af Ukrhydroproject PJSC (UHP).
 Framkvæmdir hófust ~2010 en stöðvuðust.
 Haldið áfram 2015 eftir að nýir eigendur komu að verkefninu, Mtkvari Hesi LLC (GCF).
 Við komum aftur að verkinu í byrjun árs 2021.
 Stucky er ráðgjafi verkkaupa og annast eftirlit.
 Verktakafyrirtækið Peri sér um framkvæmdir.

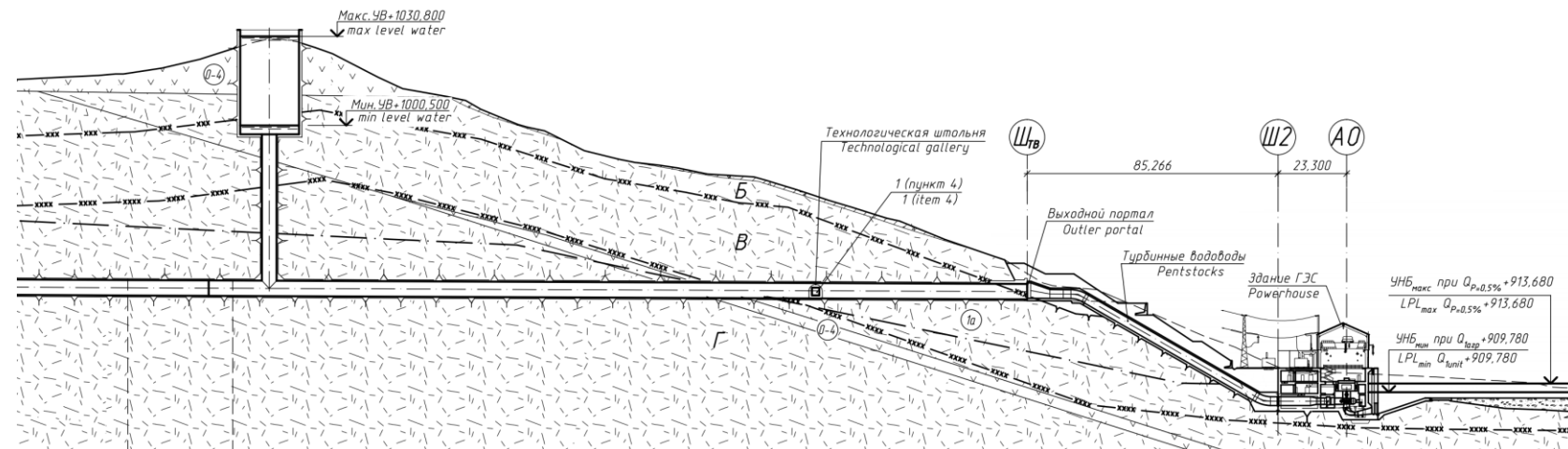
Tun 1
Type 1



| | |
|----------------------|------------------------|
| Uppsett afl: | 53 MW |
| Orkuframleiðsla: | 251 GWh |
| Hönnunarrennsli: | 63,8 m ³ /s |
| Fallhæð: | 105,2 m |
| Aðrennslisgöng: | |
| Vinnsla: | TBM |
| Lengd: | 9,6 km |
| Ø _{borað} : | 6,0 m |
| Ø _{innan} : | 5,26 m |
| Stálfóðring: | 300 m |



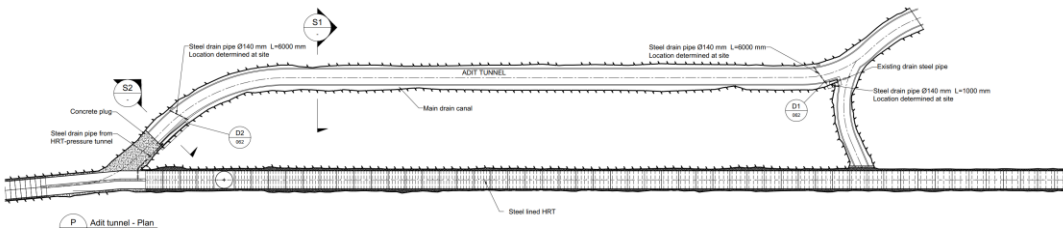
Продольный профиль по оси напорного туннеля от ПК 91 до ПК 96+22.366
 Longitudinal profile along axis of the pressure tunnel from Sta.91 to Sta.96+22.366



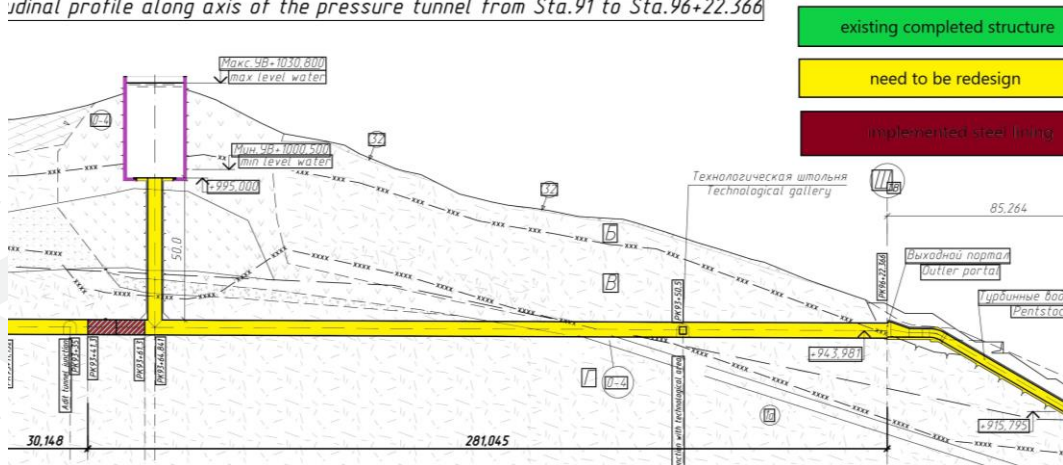
УНБ_{max} при Q_{p-0.5%} +913.680
 LPL_{max} Q_{p-0.5%} +913.680
 УНБ_{min} при Q_{сп} +909.780
 LPL_{min} Q_{сп} +909.780



Helstu verkefni



Longitudinal profile along axis of the pressure tunnel from Sta.91 to Sta.96+22.366



- Skoðun á stæðni aðrennslisganga
- Hönnun á heilfóðrun ganganna á krítískum stöðum
- Endurskoðun á hönnun
 - stálfóðringar og þrýstipípur
 - steyputappi og heilfóðrun gatnamóta við aðkomugöng
 - steypufóðrun/hækkun á sveiflutanki
 - sveiflugreining í vatnsvegum (e. transient analysis)

Mtkvari HPP – TBM

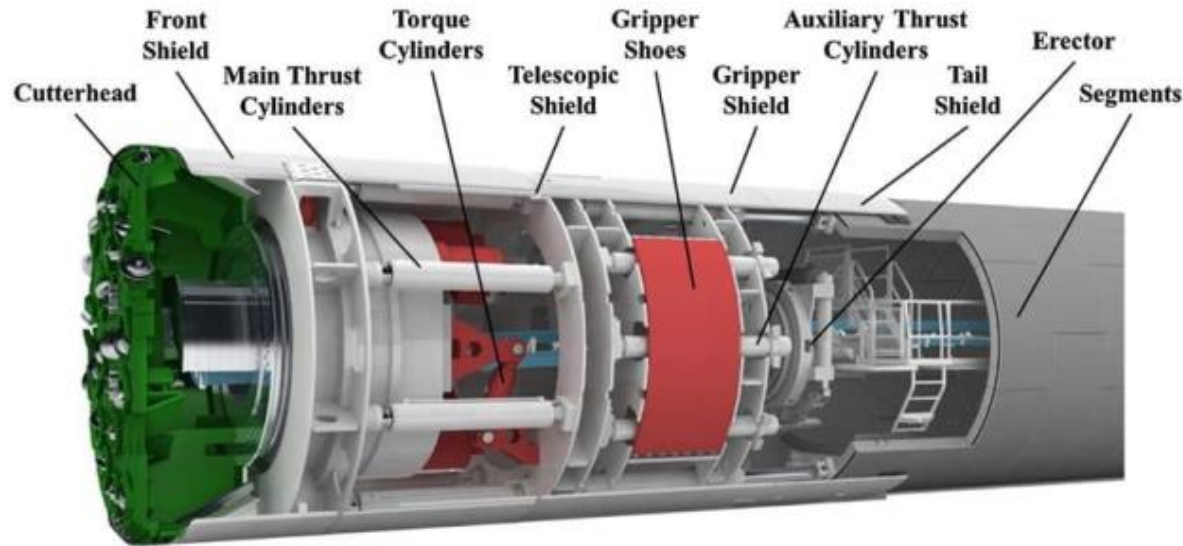
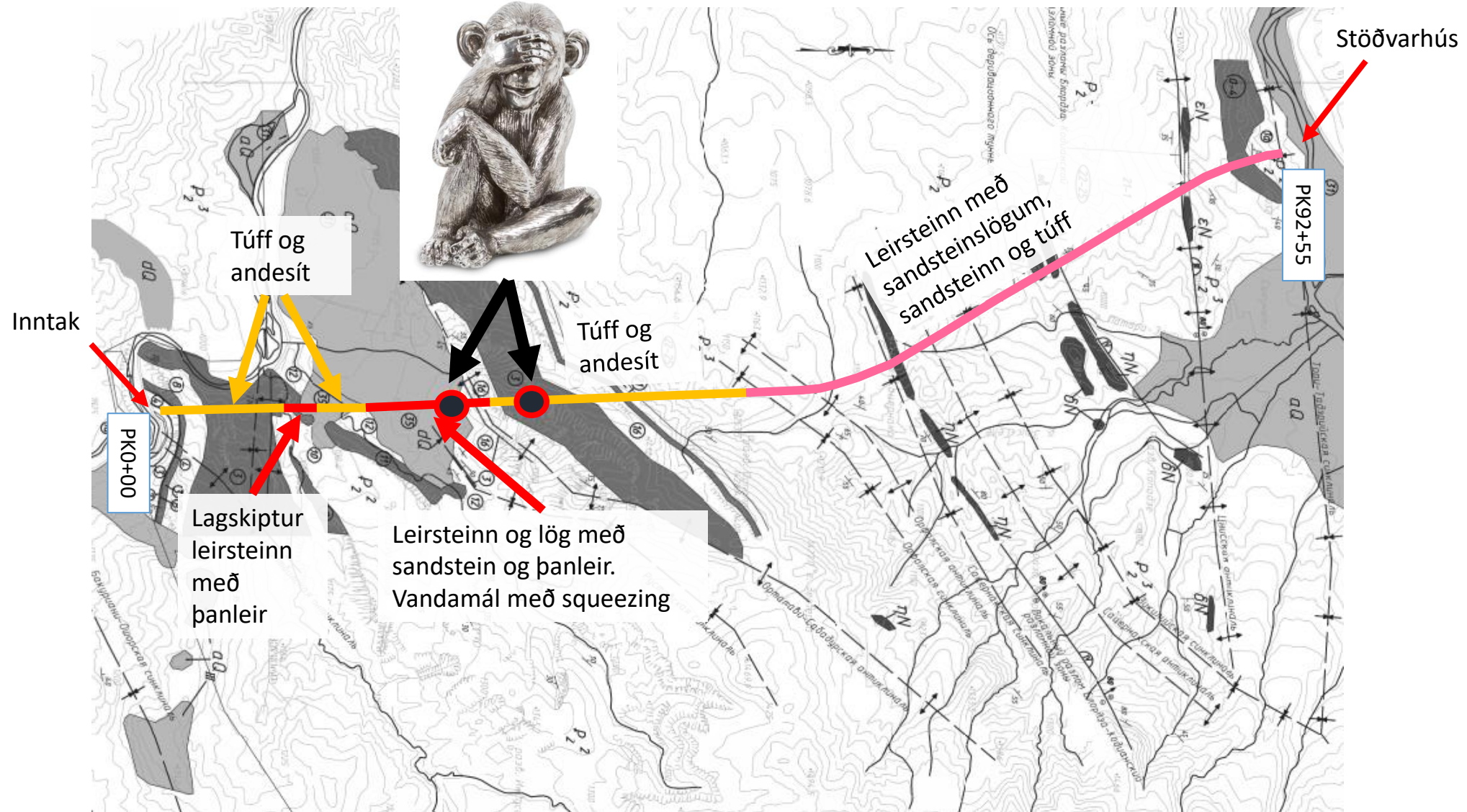


Table 1. Dimensions of TBM used in Mtkvari HRT.

| | | | |
|--|------------------------------------|--------------|-----------|
| Cutterhead | Bore diameter | 6020 | mm |
| Shield | Diameter front shield | 5940 | mm |
| | Length front shield | 1770 | mm |
| | Diameter telescopic shield (outer) | 5940 | mm |
| | Length telescopic shield (outer) | 2770 | mm |
| | Diameter gripper shield | 5930 | mm |
| | Length gripper shield | 4490 | mm |
| | Diameter tailskin | 5930 | mm |
| | Length tailskin | 2250 | mm |
| Total length from cutterhead to concrete lining | | 11280 | mm |
| Concrete lining | Outer diameter | 5760 | mm |
| | Inner diameter | 5260 | mm |
| Total gap width from tunnel diameter to concrete lining | | 130 | mm |
| Total gap width from tailskin to concrete lining | | 85 | mm |

Figure 1. Overview of a TBM tunneling rig, similar to the rig used in Mtkvari HPP.

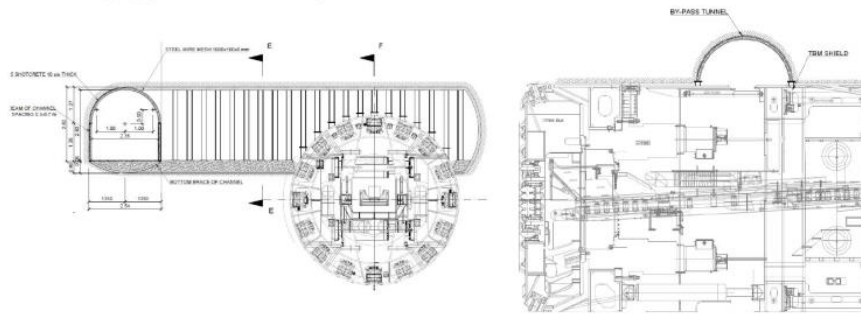
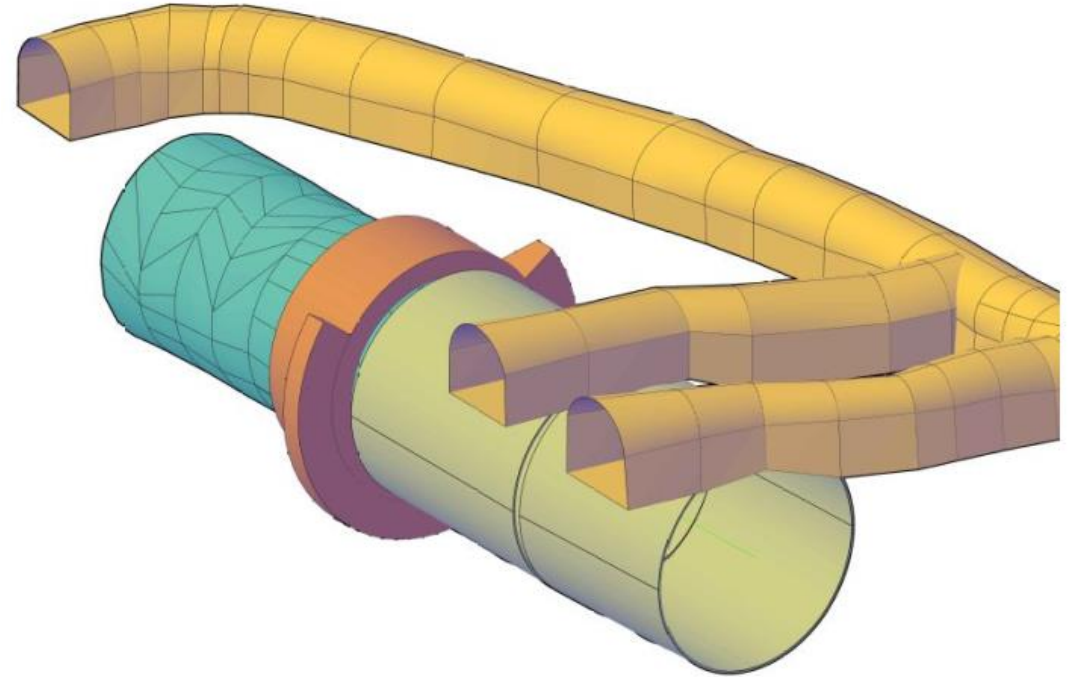
Jarðfræði á gangaleið



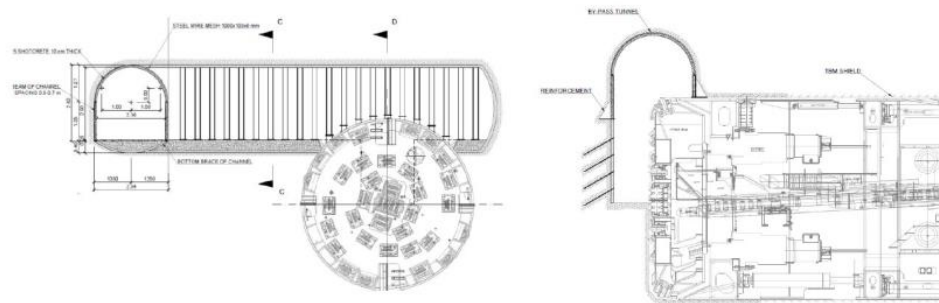
Hrun á gangaleið



a) By-pass towards the Telescope:



b) By-pass towards the Cutting-wheel:



Útreikningar á hugsanlegu squeezing

- Aðferð Hoek og Merino, 2000.

$$\sigma_{cm} = (0.0034m_i^{0.8})\sigma_{ci}\{1.029 + 0.025e^{(-0.1m_i)}\}^{GSI}$$

| Chainage m | Tunnel depth m | Vertical stress p_o MPa | Intact strength σ_{ci} MPa | Constant m_i | Geological Strength Index GSI | Rock mass strength σ_{cm} MPa | Strength/stress σ_{cm}/p_o | Percentage strain ϵ |
|------------|----------------|---------------------------|-----------------------------------|----------------|-------------------------------|--------------------------------------|-----------------------------------|------------------------------|
| 6865 | 100 | 2.6 | 25 | 10 | 20 | 1.01 | 0.39 | 1.33 |

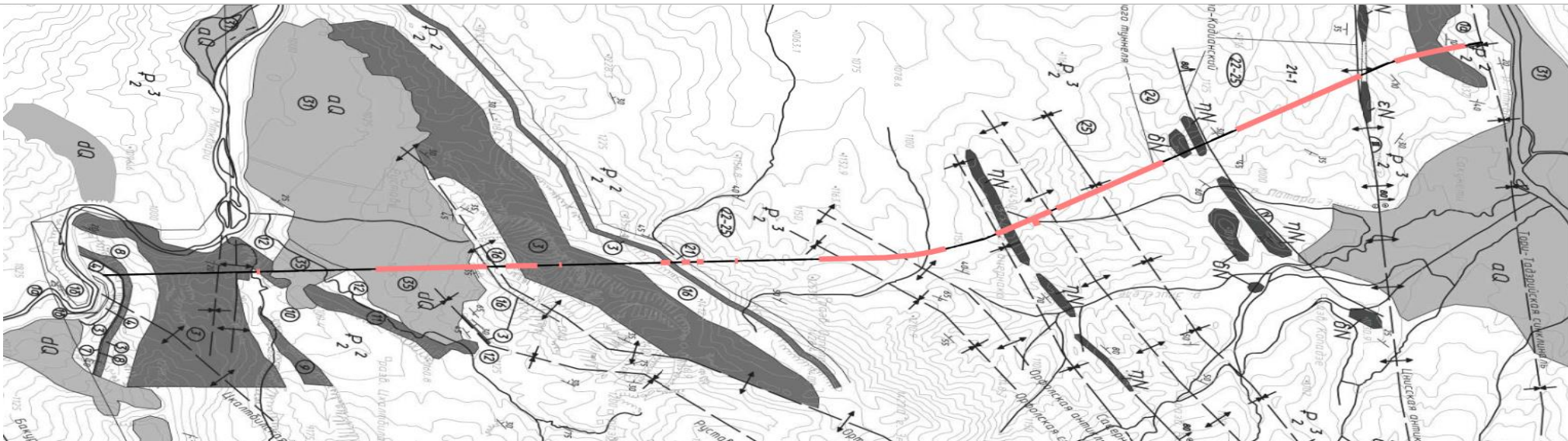
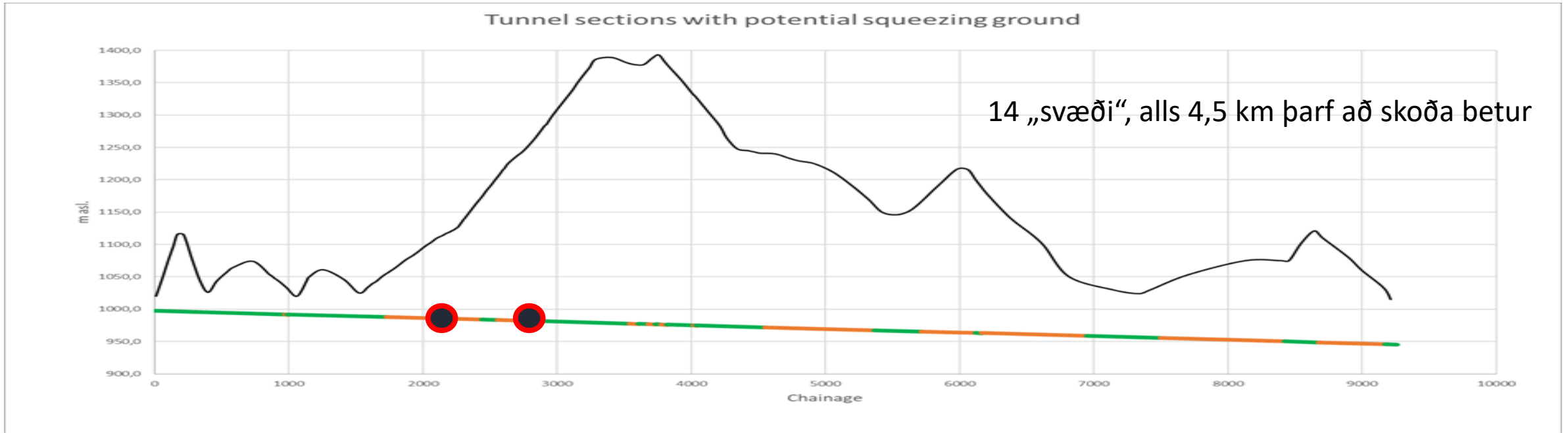
$$\epsilon = 100 \times \left(0.002 - 0.0025 \frac{p_i}{p_o} \right) \frac{\sigma_{cm}}{p_o} \left(\frac{2.4 p_i - 2}{p_o} \right) \text{ for } p_i = 0$$

- Áætlað hlutfall af strain fyrir hvert svæði, notast við as-built gögn frá verktaka.
- Gangasvæði með strain yfir 2,5% skoðuð nánar með RS2 frá Rocscience.

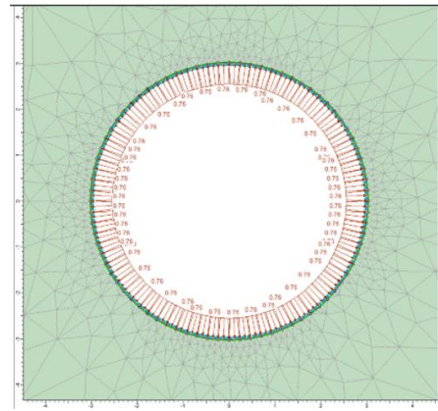
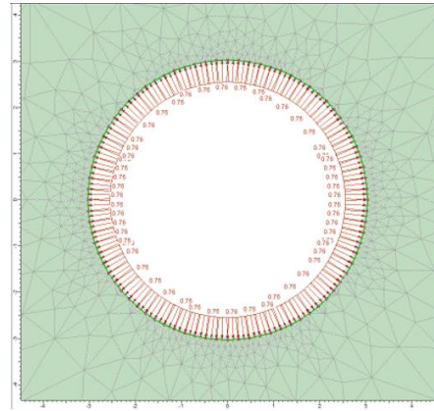
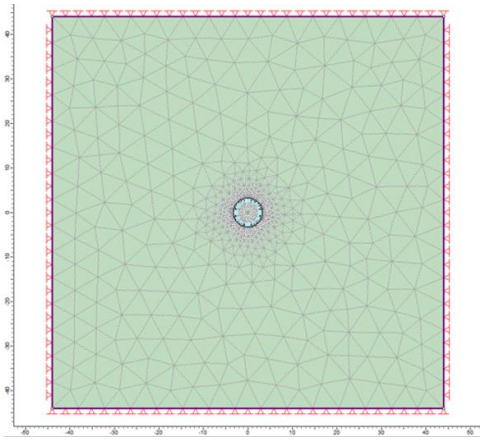
Dæmi úr reikniskjali

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|----|----------|------------------------|----------|------|--------|---|---------|--------------|--------------|--------------|-------------|-----------------|-----------------|----------|----|-----|-----|--------------------|-----------------|-------------------|
| 1 | Num | Report no | Chainage | | | | Section | | | | | | | | | | | | | |
| 2 | Analysis | | From | to | Length | | Middle | Tunnel crown | Terrain elev | Tunnel depth | Unit weight | Vertical stress | Intact strength | Hardness | mi | RMR | GSI | Rock mass strength | Strength/stress | Percentage strain |
| 3 | | 66 Tuff | 0 | 28 | 28 | | 14 | 997,6 | 1020 | 22,4 | 2,32 | 0,52 | 46,7 | 3,97 | 13 | 49 | 44 | 5,8 | 11,1 | 0,002 |
| 4 | | 65 Andesite | 22 | 95 | 73 | | 59 | 997,1 | 1046 | 48,932 | 2,4 | 1,17 | 74,8 | 3,64 | 25 | | 50 | 15,4 | 13,7 | 0,001 |
| 5 | | 64 Andesite | 95 | 114 | 19 | | 105 | 997,0 | 1075 | 78,0384 | 2,38 | 1,88 | 67,25 | | 25 | | 60 | 18,8 | 10,7 | 0,002 |
| 6 | | 64 Andesite | 114 | 171 | 57 | | 143 | 996,6 | 1097 | 100,3576 | 2,38 | 2,39 | 67,25 | | 25 | | 60 | 18,8 | 7,9 | 0,003 |
| 7 | | 64 Sandstone | 171 | 178 | 7 | | 175 | 996,6 | 1116 | 119,3968 | 2,25 | 2,69 | 64,31 | | 15 | | 60 | 14,7 | 5,4 | 0,007 |
| 8 | | 63 Sandstone | 178 | 262 | 84 | | 220 | 996,1 | 1115 | 118,8672 | 2,33 | 2,77 | 67,33 | | 15 | | 55 | 13,0 | 4,6 | 0,009 |
| 9 | | 62 Sandstone | 262 | 310 | 48 | | 286 | 995,9 | 1075 | 79,136 | 2,47 | 1,95 | 110,79 | 9,3 | 15 | | 45 | 15,2 | 7,3 | 0,003 |
| 10 | | 62 Andesite | 310 | 382 | 72 | | 346 | 995,5 | 1042 | 46,5392 | 2,43 | 1,13 | 76,27 | 6,48 | 25 | | 45 | 13,5 | 11,5 | 0,001 |
| 11 | | 62 Sandstone | 382 | 423 | 41 | | 403 | 995,2 | 1026 | 30,7688 | 2,33 | 0,72 | 107,99 | 9,18 | 15 | | 45 | 14,8 | 20,6 | 0,000 |
| 12 | | 61 Sandstone | 423 | 507 | 84 | | 465 | 994,8 | 1043 | 48,2392 | 2,34 | 1,13 | 56,66 | 4,81 | 15 | | 40 | 6,5 | 5,7 | 0,008 |
| 13 | | 61 Sandstone/andesite | 507 | 573 | 66 | | 540 | 994,4 | 1057 | 62,6088 | 2,31 | 1,45 | 64,86 | 5,51 | 15 | | 60 | 14,8 | 10,3 | 0,002 |
| 14 | | 61 Andesite | 573 | 615 | 42 | | 594 | 994,2 | 1065 | 70,844 | 2,63 | 1,79 | 92,18 | 7,83 | 25 | | 60 | 25,8 | 14,3 | 0,001 |
| 15 | | 60 Andesite | 615 | 859 | 244 | | 737 | 992,8 | 1074 | 81,2104 | 2,39 | 1,94 | 97,25 | 5,85 | 25 | | 75 | 43,0 | 22,7 | 0,000 |
| 16 | | 59 Andesite | 859 | 865 | 6 | | 862 | 992,8 | 1053 | 60,244 | 2,51 | 1,51 | 114,47 | 6,87 | 25 | | 75 | 50,6 | 33,4 | 0,000 |
| 17 | | 59 Andesite | 865 | 881 | 16 | | 873 | 992,7 | 1052 | 59,3336 | 2,51 | 1,49 | 114,47 | 6,87 | 25 | | 40 | 17,4 | 11,6 | 0,001 |
| 18 | | 59 Tuff | 881 | 897 | 16 | | 889 | 992,6 | 1049 | 56,4232 | 2,35 | 1,33 | 57,46 | 4,415 | 13 | | 40 | 6,2 | 4,6 | 0,009 |
| 19 | | 59 Sandstone/argillite | 897 | 977 | 80 | | 937 | 992,1 | 1042 | 49,8712 | 2,46 | 1,23 | 12,13 | 2,42 | 10 | | 40 | 1,2 | 0,5 | 0,222 |
| 20 | 1 | 59 Argillite | 977 | 999 | 22 | | 988 | 992,0 | 1033 | 40,9944 | 2,29 | 0,94 | 4,24 | 1,33 | 4 | | 30 | 0,2 | 0,1 | 6,299 |
| 21 | | 59 Argillite | 999 | 1130 | 131 | | 1065 | 991,3 | 1020 | 28,728 | 2,43 | 0,70 | 28,356 | | 3 | 4 | 35 | 1,4 | 2,0 | 0,050 |
| 22 | | 58 Sandstone/argillite | 1130 | 1145 | 15 | | 1138 | 991,2 | 1044 | 52,812 | 2,43 | 1,28 | 28,356 | | 3 | 10 | 40 | 2,7 | 2,2 | 0,044 |
| 23 | | 58 Sandstone | 1145 | 1156 | 11 | | 1151 | 991,1 | 1049 | 57,8736 | 2,31 | 1,34 | 35,5 | 2,19 | 17 | | 40 | 4,4 | 3,2 | 0,019 |
| 24 | | 58 Andesite | 1156 | 1356 | 200 | | 1256 | 990,0 | 1061 | 70,9936 | 2,52 | 1,79 | 127 | 7,6 | 25 | | 50 | 26,2 | 14,6 | 0,001 |
| 25 | | 57 Andesite | 1356 | 1470 | 114 | | 1413 | 989,4 | 1046 | 56,632 | 2,57 | 1,46 | 97,83 | 5,87 | 25 | | 45 | 17,3 | 11,8 | 0,001 |
| 26 | | 56 Andesite | 1470 | 1582 | 112 | | 1526 | 988,7 | 1025 | 36,2592 | 2,37 | 0,86 | 42,01 | 3,97 | 25 | | 60 | 11,7 | 13,6 | 0,001 |
| 27 | | 56 Sandstone50/tuff30 | 1582 | 1604 | 22 | | 1593 | 988,6 | 1034 | 45,3824 | 2,35 | 1,07 | 22,11 | 3,42 | 15 | | 40 | 2,6 | 2,4 | 0,035 |
| 28 | | 55 Tuff40/sandstone40 | 1604 | 1643 | 39 | | 1624 | 988,4 | 1039 | 50,6008 | 2,4 | 1,21 | 11,53 | 2,35 | 15 | | 40 | 1,3 | 1,7 | 0,168 |
| 29 | | 55 Argillite | 1643 | 1669 | 26 | | 1656 | 988,3 | 1043 | 54,7464 | 2,3 | 1,26 | 8,1 | 1,91 | 4 | | 40 | 0,5 | 0,4 | 1,269 |
| 30 | | 55 Tuff40/sandstone40 | 1669 | 1735 | 66 | | 1702 | 997,9 | 1051 | 63,116 | 2,31 | 1,46 | 15,5 | 2,79 | 15 | | 40 | 1,8 | 1,2 | 0,132 |
| 31 | | 55 Argillite | 1735 | 1758 | 23 | | 1747 | 987,8 | 1057 | 69,2448 | 2,34 | 1,62 | 7,12 | 1,75 | 4 | | 30 | 0,3 | 0,1 | 6,656 |
| 32 | | 54 Argillite | 1758 | 1851 | 93 | | 1805 | 987,2 | 1065 | 77,7656 | 2,30 | 1,79 | 2,71 | 0,93 | 4 | | 25 | 0,1 | 0,7 | 87,522 |
| 33 | | 54 Argillite | 1851 | 1895 | 44 | | 1873 | 997,0 | 1076 | 89,012 | 2,25 | 2,00 | 2,19 | 0,93 | 4 | | 20 | 0,1 | 0,0 | 262,968 |
| 34 | | 54 Argillite | 1895 | 1962 | 67 | | 1929 | 986,6 | 1083 | 96,3872 | 2,25 | 2,17 | 2,41 | 0,95 | 4 | | 15 | 0,0 | 0,0 | 398,221 |
| 35 | | 53 Argillite/clay | 1962 | 1988 | 26 | | 1975 | 986,5 | 1090 | 103,5328 | 2,26 | 2,34 | 3,58 | 1,21 | 4 | | 15 | 0,1 | 0,0 | 210,110 |
| 36 | | 53 Argillite like clay | 1988 | 2022 | 34 | | 2005 | 986,3 | 1095 | 108,7232 | 2,25 | 2,45 | 3,01 | 0,77 | 4 | | 15 | 0,1 | 0,0 | 325,596 |
| 37 | | 53 Argillite | 2022 | 2056 | 34 | | 2039 | 986,1 | 1100 | 113,9136 | 2,43 | 2,77 | 3,89 | 1,27 | 4 | | 15 | 0,1 | 0,0 | 249,060 |
| 38 | | 53 Argillite like clay | 2056 | 2070 | 14 | | 2063 | 986,0 | 1103 | 116,992 | 2,29 | 2,68 | 1,61 | 0,79 | 4 | | 15 | 0,0 | 0,0 | 1361,983 |
| 39 | | 52 Argillite like clay | 2070 | 2081 | 11 | | 2076 | 985,9 | 1105 | 119,0536 | 2,04 | 2,43 | 1,57 | 0,77 | 4 | | 10 | 0,0 | 0,0 | 1841,189 |
| 40 | | 52 Tuff microfragment | 2081 | 2135 | 54 | | 2108 | 985,6 | 1110 | 124,356 | 2,23 | 2,77 | 4,82 | 1,43 | 4 | | 10 | 0,1 | 0,0 | 254,684 |
| 41 | | 52 Argillite like clay | 2135 | 2146 | 11 | | 2141 | 985,6 | 1113 | 127,4176 | 2,42 | 3,08 | 13,24 | 2,5 | 4 | | 10 | 0,2 | 0,0 | 41,753 |
| 42 | 3 | 51 Sandstone | 2147 | 2156 | 9 | | 2152 | 985,5 | 1114 | 128,4736 | 2,38 | 3,06 | 18,12 | | 17 | | 7 | 0,7 | 0,2 | 3,335 |
| 43 | 4 | 51 Argillite like clay | 2156 | 2195 | 39 | | 2176 | 985,3 | 1117 | 131,692 | 2,16 | 2,84 | 0,41 | | 4 | | 10 | 0,0 | 0,0 | 9,627 |
| 44 | | 50 Tuff | 2195 | 2207 | 12 | | 2201 | 985,2 | 1119 | 133,7592 | 2,17 | 2,90 | 7,6 | 1,85 | 13 | 39 | 34 | 0,7 | 0,2 | 3,81 |
| 45 | 5 | 50 Tuff | 2207 | 2208 | 1 | | 2208 | 985,2 | 1120 | 134,7648 | 2,17 | 2,92 | 7,6 | 1,85 | 13 | 32 | 27 | 0,5 | 0,2 | 6,32 |
| 46 | 4 | 50 Argillite like clay | 2208 | 2229 | 21 | | 2219 | 985,1 | 1121 | 135,8824 | 2,21 | 3,00 | 2,01 | 0,78 | 4 | 10 | 10 | 0,0 | 0,0 | 1717,40 |
| 47 | 5 | 50 Tuff | 2229 | 2245 | 16 | | 2237 | 985,0 | 1123 | 137,972 | 2,17 | 2,99 | 7,85 | 1,88 | 13 | 29 | 24 | 0,5 | 0,1 | 7,67 |
| 48 | 6 | 50 Argillite | 2245 | 2256 | 11 | | 2251 | 985,0 | 1125 | 140,0336 | 2,36 | 3,30 | 7 | 1,2 | 13 | 28 | 23 | 0,4 | 0,1 | 12,62 |
| 49 | | 50 Argillite | 2256 | 2261 | 5 | | 2259 | 984,9 | 1126 | 141,0616 | 2,38 | 3,36 | 9,71 | 2,12 | 4 | | 20 | 0,2 | 0,0 | 37,59 |

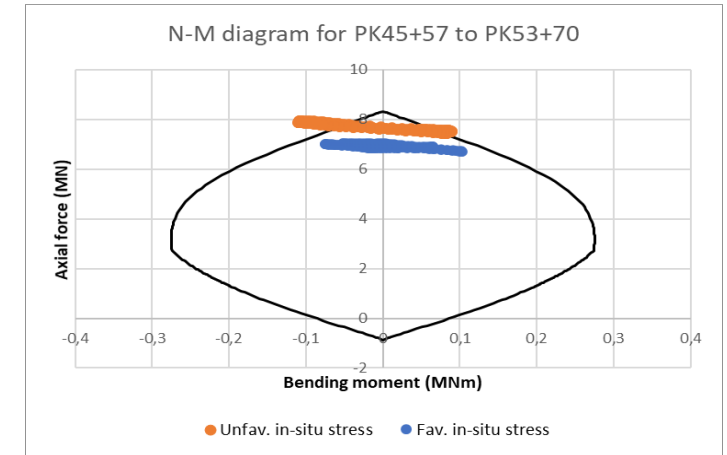
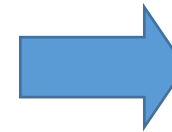
Svæði sem þurfa nánari skoðun



Mismunandi stig í tölulegri greiningu



Túlkun



Reiknað fyrir tvö spennistig, hagstætt og óhagstætt

Hagstætt: $\sigma_{h \max} > \sigma_{h \min} > \sigma_v$

Óhagstætt: Miðað við gögn frá World stress map

Niðurstöður tölulegra greininga

- Jarðfræðilegar aðstæður mun verri en áætlað í útboðsgögnum, með mikið af leirstein með lágan styrk og þanleir.
- Squeezing meira en áætlað var.
- Reiknað fyrir “hagstætt” og „óhagstætt“ spennustig í berggrunni.
- Hagstætt = 566 m sem þarf að styrkja betur.
- Óhagstætt = 1.512 m sem þarf að styrkja betur.
- Augljóslega þörf á auka styrkingum til að tryggja að þau haldi.
- Mælt með að mæla bergspennur til að fá nákvæmari niðurstöður þar sem þær hafa mikil áhrif á niðurstöður.



Hagstæðar og óhagstæðar aðstæður

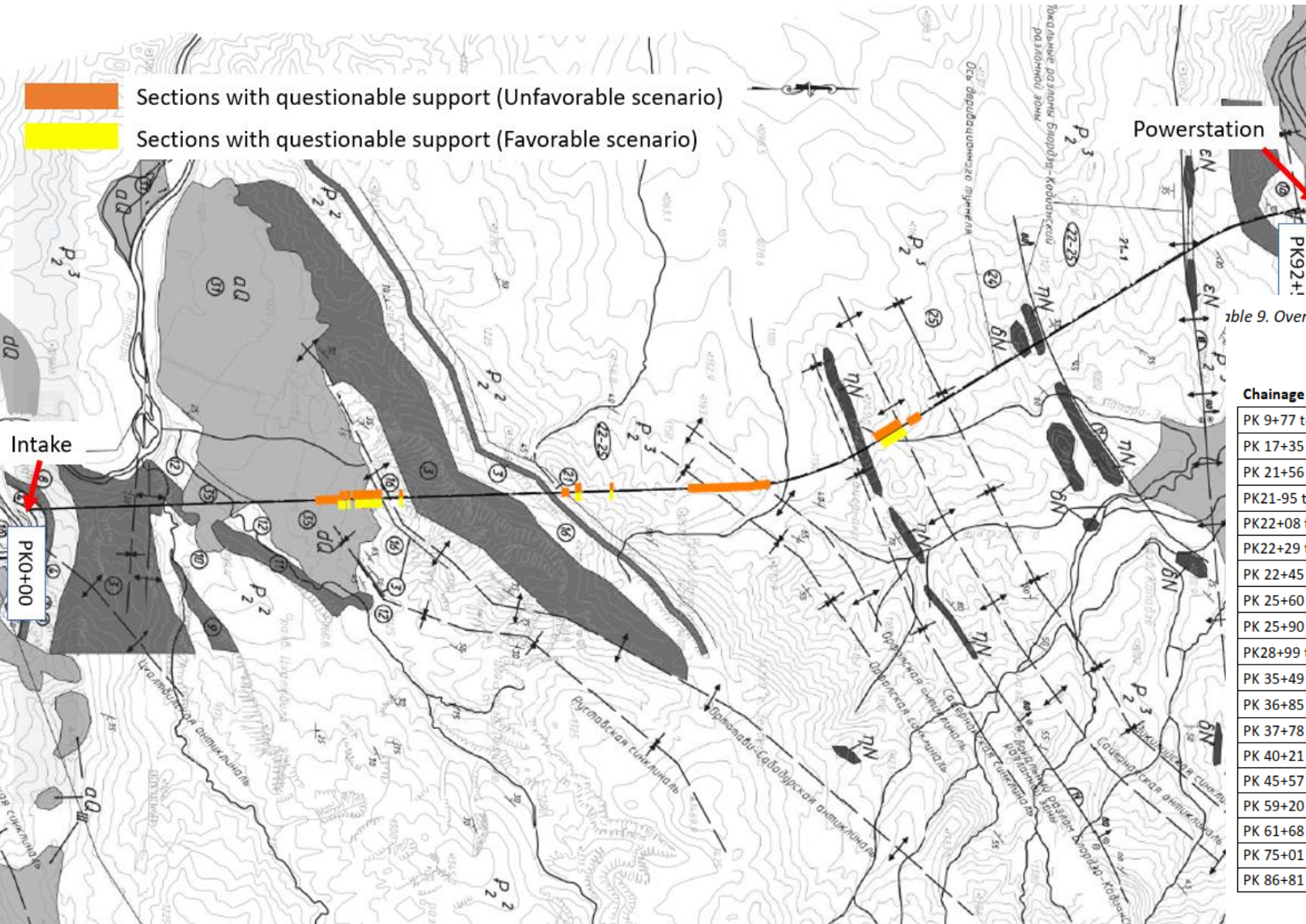
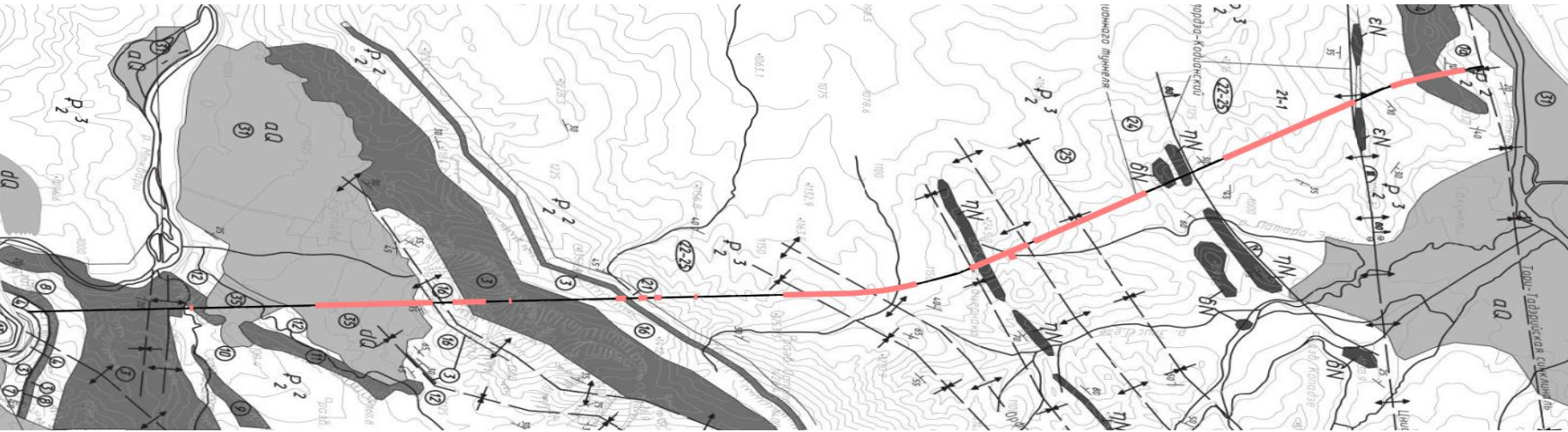


Table 9. Overview of questionable tunnel sections in unfavorable and favorable scenarios.

| Chainage | Rock mass Type | Section length m | Unfavorable scenario | Favorable scenario |
|--------------------------------|---------------------|------------------|----------------------|--------------------|
| | | | Questionable m | Questionable m |
| PK 9+77 to 9+99 | Argillite | 22 | - | - |
| PK 17+35 to 21+56 | Argillite | 421 | 168 | 12 |
| PK 21+56 to 21+95 | Argillite-like clay | 39 | 39 | 39 |
| PK21-95 to 22+08 | Tuff | 13 | 13 | - |
| PK22+08 to 22+29 | Argillite-like clay | 21 | 21 | 21 |
| PK22+29 to 22+45 | Tuff | 16 | 16 | - |
| PK 22+45 to 24+44 | Argillite | 199 | 199 | 183 |
| PK 25+60 to 25+90 | Argillite | 26 | 30 | 26 |
| PK 25+90 to 27+65 | Tuff | 175 | - | - |
| PK28+99 to 29+23 | Argillite | 24 | 24 | 24 |
| PK 35+49 to 36+12 | Tuff | 63 | - | - |
| PK 36+85 to 37+39 | Tuff | 54 | 54 | - |
| PK 37+78 to 38+26 | Tuff | 48 | 48 | 48 |
| PK 40+21 to 40+45 | Argillite | 24 | 24 | 24 |
| PK 45+57 to 51+27 | Argillite | 570 | 570 | - |
| PK 59+20 to 61+30 | Argillite | 210 | 210 | 189 |
| PK 61+68 to 62+64 | Argillite | 96 | 96 | - |
| PK 75+01 to 84+27 | Argillite | 926 | - | - |
| PK 86+81 to 91+50 | Argillite | 469 | - | - |
| Total tunnel length (m) | | | 1.512 | 566 |

Mtkvari HPP



Aðferð Hoek og Merino: 4,5 km

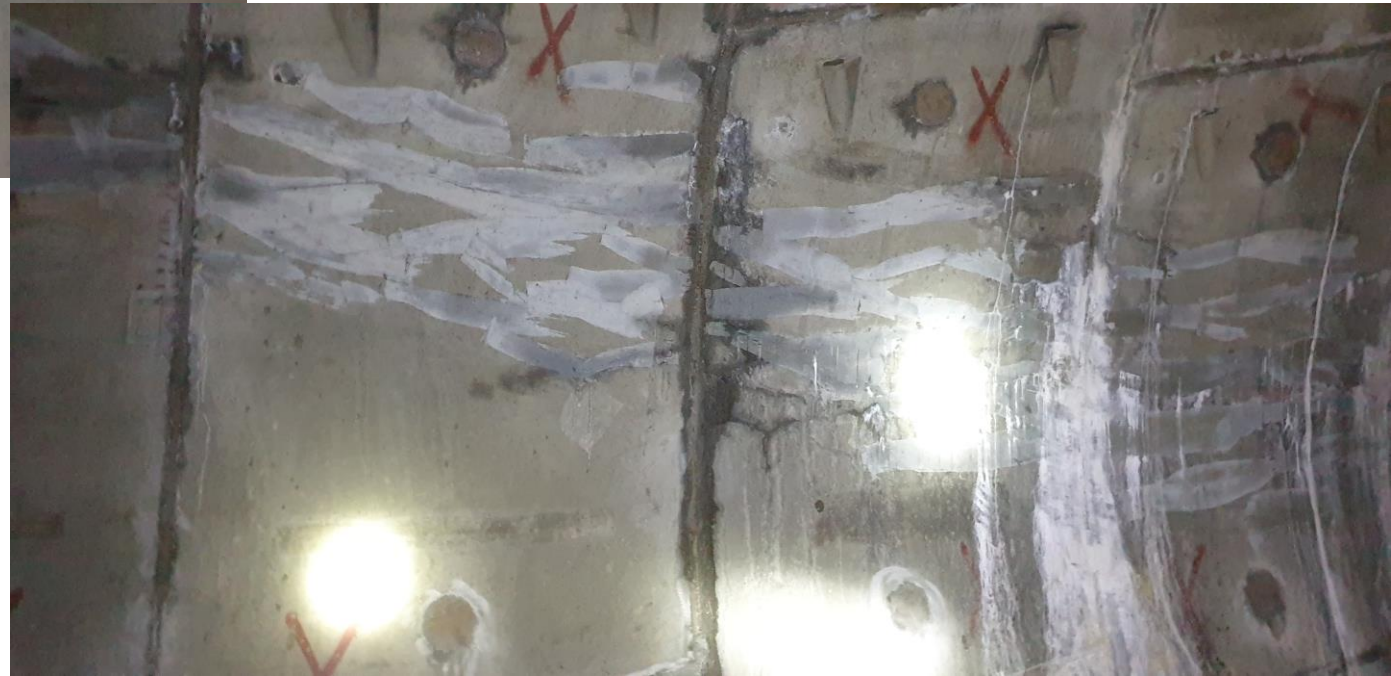


Töluleg greining:
 Óhagstæðar aðstæður: 1,5 km
 Hagstæðar aðstæður: 0,5 km

Sprungur í steypufóðringu



Sprungur áberandi í steypufóðringu kl. 2 og 10



Sprungur í steypufóðringu

Töluleg greining

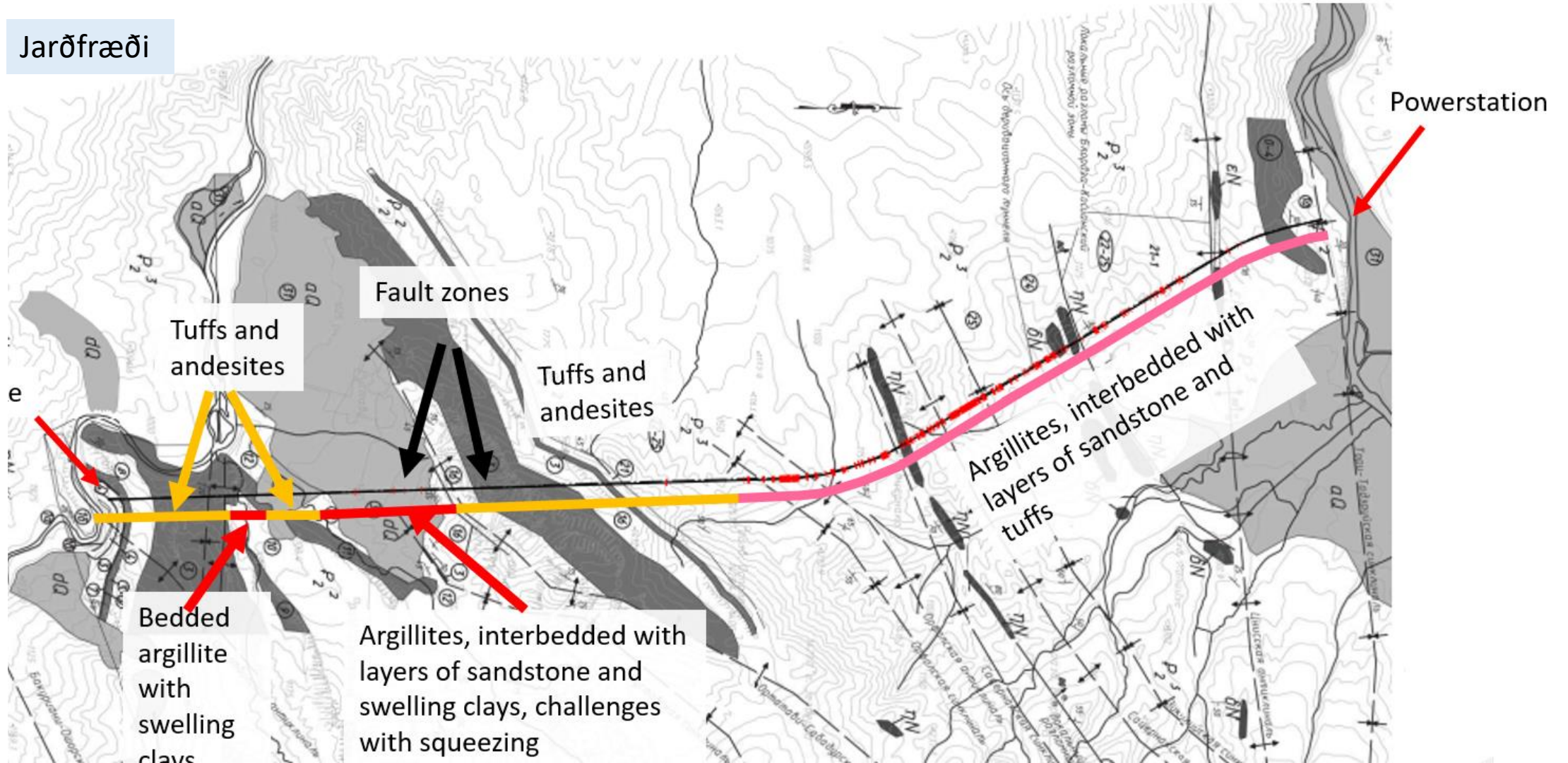


Aðferð Hoek og Merino

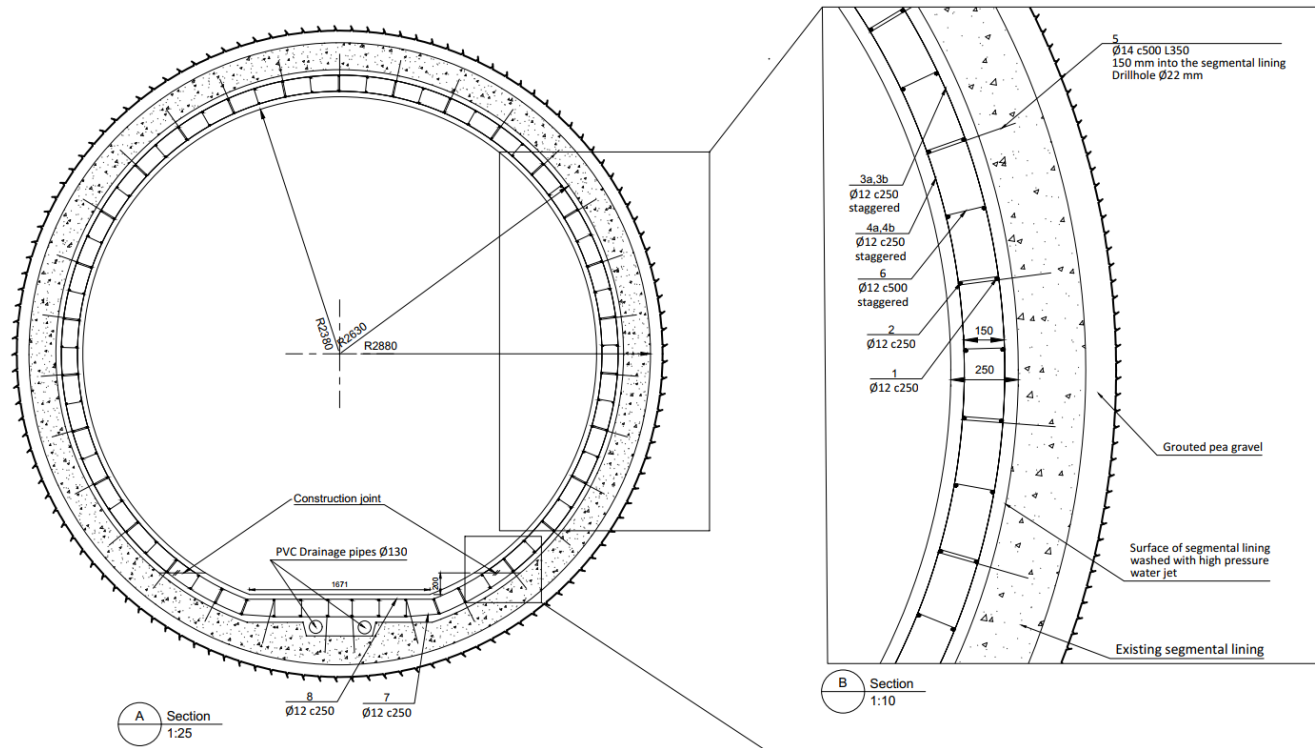


Sprungur í steypufóðringu

Jarðfræði



Teikning af sniði og mynd



Takk fyrir mig



Heilindi
Metnaður
Frumkvæði