LP-2017-003

Landsvirkjun Power

# Mtsketa-Stepantsminda-Larsi International Road Alternative Alignment of KM132-KM135 Devdoraki Mudflow Section

## Preliminary Design Report

Prepared for
Roads Department of the Ministry of Regional Development and Infrastructure of Georgia

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# Key Page

Landsvirkjun Power

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**Abstract:** This Preliminary Design Report presents a preliminary design for a road tunnel to bypass the Devdoraki mudflow section of the Mtskheta-Stepanstminda-Larsi Road KM132-KM135. The report sets the basis for a Design-Build contract for construction of the road tunnel and associated structures. The preliminary design presented has carefully considered construction cost and safety of road users with the aim of arriving at an optimum solution.

**Keywords:** Feasibility Study, Georgia, Road, Tunnel, Mudflow

**Approvals and Revision History**

| Status / Revision | Date | Reason for Issue | Prepared by | Project Manager Approval |
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# Executive Summary

Mtsketa-Stepantsminda-Larsi International Road passes over the Caucasus Mountain Range and connects the capital Tbilisi with the Gudauri ski resort, the Kazbegi district and with the Russian Federation. In addition to general traffic in the area, the road is an important international transit route. Approximately 3 km from the border to Russia, the road has in recent years repeatedly been hit by mudflows from the Devdoraki Glacier on north slopes of the Kazbek Mountain.

This Preliminary Design Report is part of:

> *Design-Build and Take-Over of Alternative Alignment of KM132-KM135 (Devdoraki Mudflow Section) of Mtsketa-Stepantsminda-Larsi (Border of Russian Federation) International Road bidding documents.*

In the Preliminary Design, the recommended alternative from the Feasibility Study has been further reviewed, improved, and detailed, considering results of the geological investigations, further developed design criteria, environmental, social issues, and other relevant matters.

The Preliminary Design Report is not intended to reflect a complete final design for the project. It shall be used as a preliminary design to evaluate relevant and necessary components to successfully bid on a full design and construction of the project.

The report presents the baseline data used to prepare the preliminary design followed by a description of the design requirements for the preparation of the tunnel and road elements included in the project. Requirements for construction methodology and schedule are discussed and finally presentation of cost and risk analysis for the project.

Available traffic data has been analyzed and a traffic prognosis prepared. Even if the available data series extends only over 2 years, an increase in traffic is significant. With reasonable assessment of future increase it is recommended to design the tunnel for annual average traffic of more than 4000 vehicles per day. This results in a tunnel profile (cross section) as shown below.

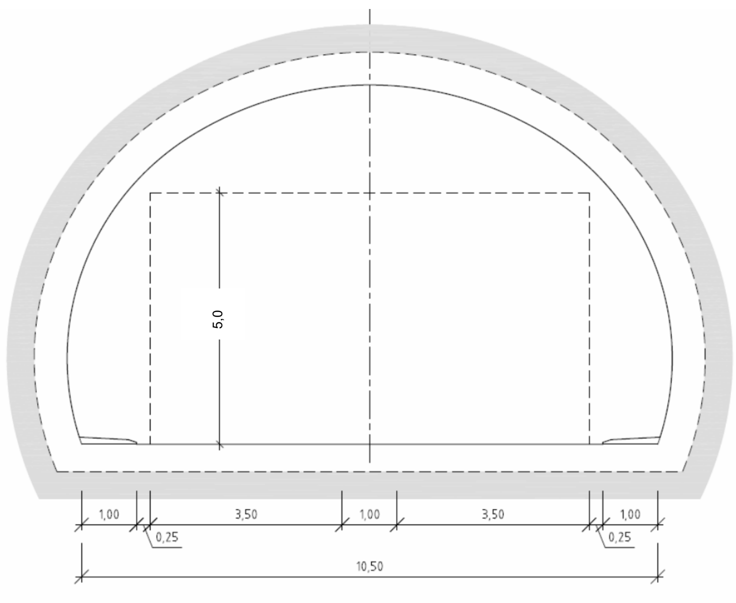



*Figure 1.* Recommended tunnel profile *(dimensions in meters).*

Starting from the south, the preliminary design includes the following: From the existing E117 alignment, a new approximately 100 m long road with 3-4% slope downwards. On this ramp approximately 55 m long reinforced concrete tunnel portal is constructed. The tunnel, approximately 1.2 km long, has a constant 5% slope from the south portal down towards the north. At the north end of the tunnel there is an approximately 20 m long reinforced concrete portal constructed on an engineered fill, which is approximately 4 m high at the portal. From the north portal a new approximately 600 m long ramp, sloping 6% down from the portal, shall connect the tunnel to the existing E117 road alignment. A new permanent access to the Dariali power station shall be constructed from the north end of the ramp.

The tunnel proposed tunnel is to be constructed in close proximity to the recently commissioned Dariali hydropower station. The road tunnel will intersect an abandoned section of access tunnel to the Dariali underground powerhouse, which must be sealed off from the road tunnel with a concrete plug. The road tunnel will also cross the Dariali tailrace tunnel at some distance. The road embankment will close the current access road to the power station and a new access road must be provided. The embankment fill will be adjacent to a transmission line tower which may have to be lifted.

# 1 Introduction

## 1.1 Project Description

In December 2016, the Roads Department of the Ministry of Infrastructure and Regional Development of Georgia retained Landsvirkjun Power of Iceland to prepare a Feasibility Study for alternative alignment of the highway in the Devdoraki Mudflow section in Kazbegi District of Georgia. The work is executed in accordance with Terms of Reference of the contract and accepted bid corresponding to "*Simplified Electronic Bidding for Procurement of Services related to Preparation of Feasibility Study and Conceptual Design for Construction of Alternative Alignment of KM132-KM135 of Mtskheta-Stepantsminda-Larsi (Border of Russian federation) International Road".*

Mtsketa-Stepantsminda-Larsi International Road passes over the Caucasus Mountain Range and connects the capital Tbilisi with the Gudauri ski resort, the Kazbegi district and with the Russian Federation. In addition to general traffic, transit trucks from Turkey, Armenia, Azerbaijan and Georgia use this route to access Russia, Kazakhstan, Ukraine, Belarus and other countries. Approximately 3 km from the border to Russia is the Devdoraki mudflow section which in recent years has repeatedly been hit by mudflows from the Devdoraki Glacier on north slopes of the Kazbek Mountain, see Figure 3 and Figure 4.

During the past few years, mudflows have closed the road repeatedly:

In May-June 2014 for one month.
In August 2014 for 10 days.
In June-July 2016 for 14 days.

The road is essential for international transit companies, local residents and tourists. Additionally, the traffic on the road is expected to rise significantly in the coming years. Therefore, a safe alternative alignment of the road is needed.

Alternative road alignments for the KM132-KM135 Mudflow Section of the road have been studied in a Feasibility Study to find an optimum alignment in terms of cost and safety. Three alternatives were evaluated with respect to technical, environmental, economic- and social aspects. Following the completion of the Feasibility Study, the Roads Department has decided to pursue an implementation of the construction of the most feasible alternative from the Feasibility Study.

This preliminary design does not cover any sections of the road other than the specified section KM132-KM135.

## 1.2 Study area

The study area is located in the Dariali valley, near the recently commissioned Dariali Hydropower Plant, see Figure 2 and Figure 3. The Dariali Gorge is at the east base of Mount Kazbek, pierced by the river Tergi which runs along the valley.

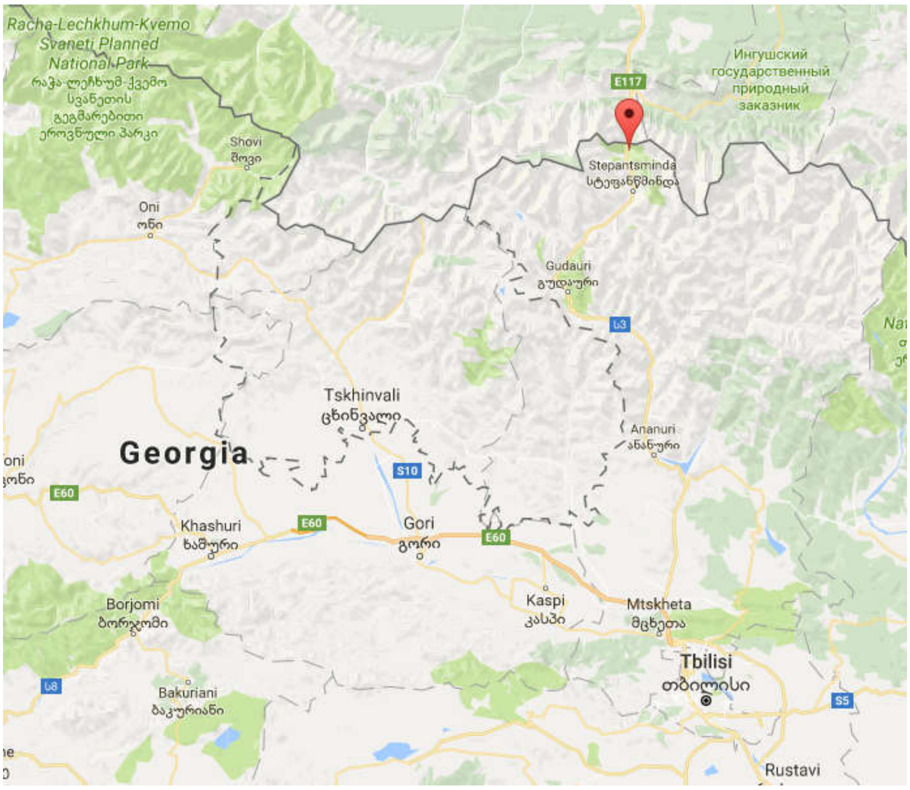



*Figure 2. Map showing the study area (Google Maps, 2016).*

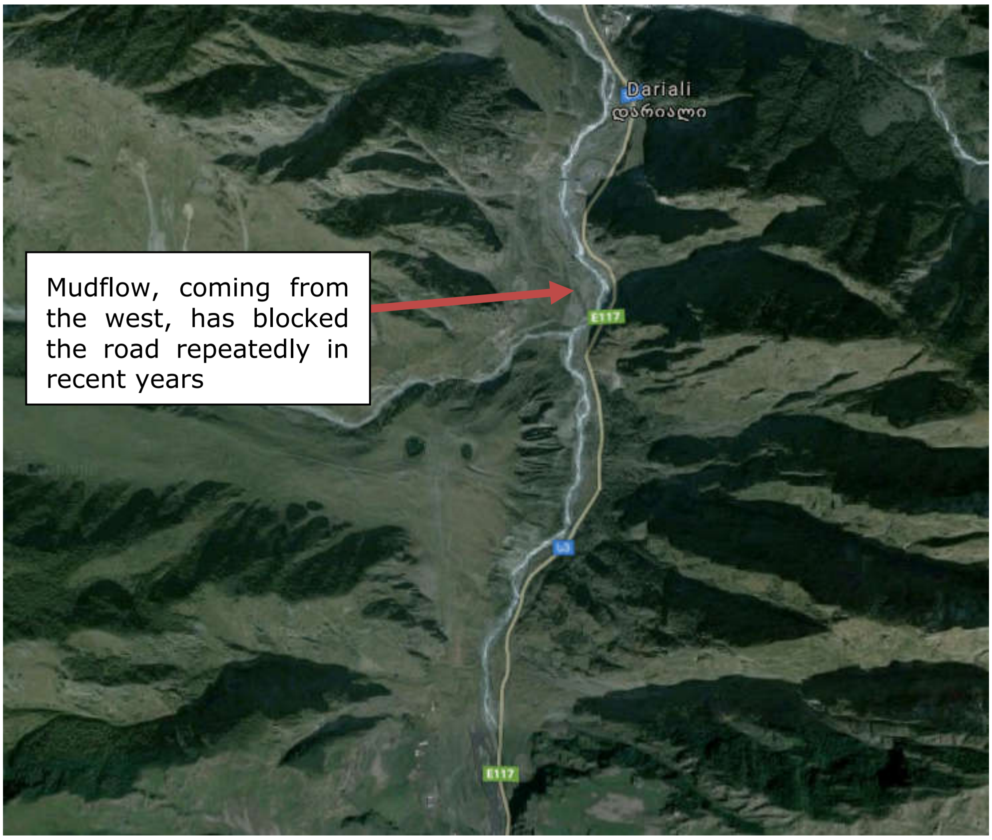
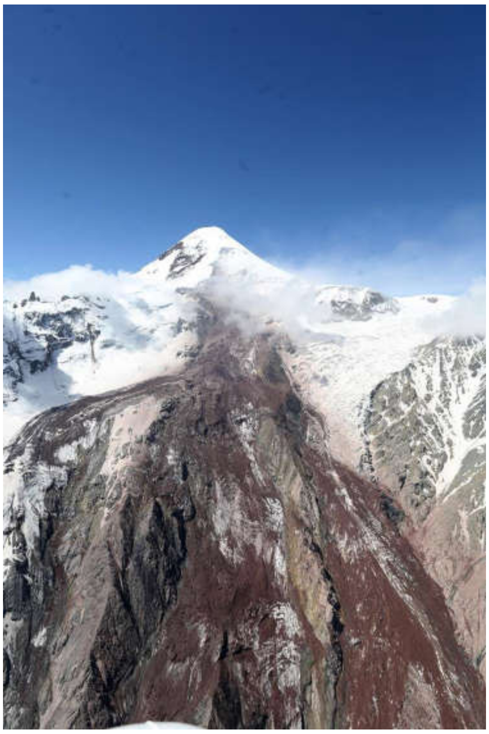



*Figure 3. Arial photo showing the study area and landslide direction (Google Maps, 2016).*



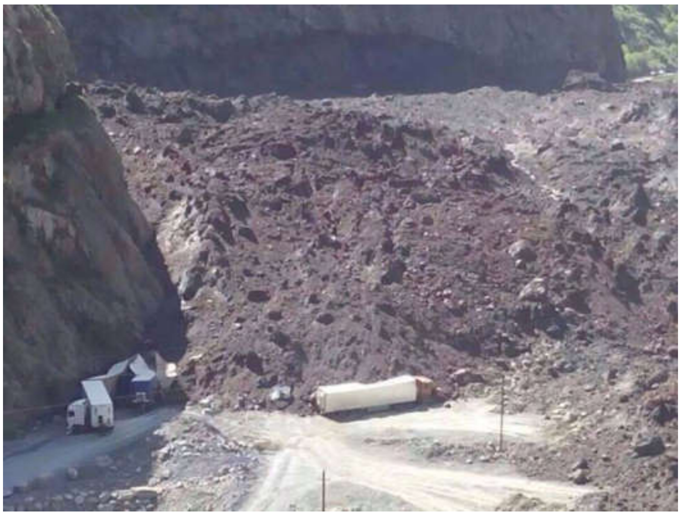


*Figure 4. Landslides from Mt. Kazbek which closed the valley in 2014 (AGU Blogosphere, 2016).*

## 1.3 Scope

The high risk of mudflows/landslides is the main reason why this project is under consideration. The mudflow material has repeatedly destroyed the road and dammed the river, creating an upstream lake in an uncontrolled manner. Such a mudflow embankment can burst, potentially flooding the downstream area in a catastrophic way. This scenario must be taken into consideration for the alternative alignment analysis. Other environmental risk factors considered are rockfalls, snow avalanches and river floods.

Time is also a determining factor in this project due to the probability of yet another landslide in the summer of 2017. The Roads Department of Georgia strives to advance the project as fast as possible, while not compromising safety and quality.

The road is classified as part of the International E-road network and has the number E117. The E-route network follows European design standards that should be applied unless there are exceptional circumstances. The Eurocode standards, supplemented by other applicable international standards, form design criteria for the Preliminary Design.

# 2 Baseline Data

## 2.1 Importance of the road

The E117 road is an A class road in the international E-road network, which has a numbering system assigned by the United Nations Economic Commission for Europe (UNECE). It runs for 1050 km from Mineralnye Vody in Russia, through Georgia into Armenia where it stops in Megri, at the border to Iran.

The road is essential for traffic in the Dariali valley and to the Georgia-Russia border crossing. There is heavy traffic on the road throughout the year, including large number of trucks transporting goods to and from Russia. During the tourist season the traffic increases significantly. If the road closes, alternative transportation routes will increase the travel time by at least one day, leading to great economical losses. The road needs to be open for traffic during construction of the tunnel, which means that preliminary roadwork is needed.

Continuous access to the 108 MW Dariali hydropower station (Dariali HPP) and other power stations in the area is essential for operation, service and maintenance of these facilities.

## 2.2 Traffic data

Traffic data on the road from Pasanauri through Stepantsminda to Larsi have been received from the Client, see Table 1.

It is not known where exactly the traffic is counted. Therefore, it is unclear if this traffic volume is representative for the traffic in the Dariali valley. Traffic data was also retrieved from the Georgian National Tourism Administration. It shows the number of arrivals through the Kazbegi border crossing (Appendix A).

*Table 1. Traffic data on the road from Pasanauri through Stepantsminda to Larsi (Road Department).*

| | Cars | Mini Buses<15, Pickups | Buses &Trucks | Trailers & > 3 axles | Sum |
|---|---|---|---|---|---|
| **April 2016** | 1.930 | 71 | 85 | 124 | **2.210** |
| **July 2016** | 3.075 | 74 | 162 | 155 | **3.466** |
| **Okt. 2016** | 2.515 | 408 | 352 | 74 | **3.349** |
| **AADT 2016** | **2.507** | **184** | **199** | **118** | **3.008** |

| | Cars | Mini Buses<15, Pickups | Buses &Trucks | Trailers & > 3 axles | Sum |
|---|---|---|---|---|---|
| **April 2015** | 1.764 | 64 | 78 | 113 | **2.020** |
| **July 2015** | 2.594 | 138 | 51 | 168 | **2.951** |
| **Okt. 2015** | 2.525 | 134 | 105 | 300 | **3.064** |
| **AADT 2015** | **2.294** | **112** | **78** | **194** | **2.678** |

| Change between 2015 & 2016 | Cars | Mini Buses<15, Pickups | Buses &Trucks | Trailers & > 3 axles | Sum |
|---|---|---|---|---|---|
| **April** | 9% | 9% | 9% | 10% | **9%** |
| **July** | 19% | -47% | 217% | -8% | **17%** |
| **Okt.** | 0% | 205% | 235% | -75% | **9%** |
| **AADT** | **9%** | **64%** | **156%** | **-39%** | **12%** |

Table 1 indicates considerable increase in traffic between the years 2015 and 2016. It is considered unlikely that such large increase will continue for many years. Preferably, the forecast should be based on long-term data, such as 10 years.

Table 1 shows also large variations for larger vehicles, which are unexplained. A possible partly explanation could be construction activities in the valley. Since the volume of heavy vehicles is low in relation to the total traffic, it should not have a large effect on traffic projections.

The number of arrivals through the Kazbegi border have been increasing steadily for the last years, see *Table 2* (also see Appendix A).

*Table 2: Daily average arrivals on the Kazbegi border crossing (no. of people).*

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Arrivals | 485 | 1101 | 1921 | 1918 | 2490 | 2553 |
| Increase | 333% | 127% | 74,5% | -0,2% | 29,8% | 2,5% |

## 2.3 Traffic projections

The estimated annual average daily traffic (AADT) design value, based on the traffic data given, is determined according to the ratio between AADT and annual summer daily traffic (ASDT). The result is a design value of 3078 vehicles per day, see Table 4. This is used as basis for future traffic projections.

In the design standards for tunnels in the Trans-European Road Network, 15 years projected traffic is the value for determining the design traffic volume. Table 3 shows a 15-year prediction using various annual percentage increase in traffic volume.

*Table 3. 15-year traffic projection.*

| | Various rates of increase in traffic | | | | |
|---|---|---|---|---|---|
| **AADT design** | 1% | 1,5% | 2% | 3% | 5% |
| 3078 | 3573 | 3848 | 4142 | 4795 | 6398 |

Values for 10- and 20-year projection are calculated for comparison purposes, see Table 4.

*Table 4. 10- and 20-year traffic projection*

| | Various rates of change in traffic | | | | |
|---|---|---|---|---|---|
| **Projection** | 1% | 1,5% | 2% | 3% | 5% |
| 10 years | 3400 | 3572 | 3752 | 4136 | 5013 |
| 20 years | 3755 | 4145 | 4573 | 5559 | 8166 |

The projections all have in common that they surpass 4000 vehicles per day at a relatively low rate of increase in traffic. This is very important for the design criteria concerning the type of road designed and various important elements of the tunnel design.

Predicting future increase in arrivals based on the data from the Georgian National Tourism Administration is difficult to use since the changes fluctuate significantly from 2011 to 2016. This data also refers to number of people and not number of vehicles.

Based on the preceding discussion, it is recommended to design the tunnel for more than 4000 vehicles per day.

## 2.4 Geology

### 2.4.1 General

The rock mass is represented by the following main lithological varieties:

- clay slate with thin siltstones and sandstone bands;
- slate with thin siltstone bands;
- gray, fine arkosic sandstones;
- quartzite;
- greenish tuff sandstone;
- striate greenish and grayish hornstones;
- diabases;

Attached in Appendix B is a Geological Report of the area.

### 2.4.2 Engineering geological assessment

The following has been concluded in the geological assessment based on experience from Dariali HPP and the Geological Report from GeoEngineering (GeoEngineering Ltd., 2016) :

1. Squeezing rock is considered very unlikely in the tunneling areas.
2. The slate formations can be regarded as moderately strong, uniaxial compressive strength in the order of 50 MPa. In the slate there are diabase dikes. There are also 0.2 – 0.5 m thick bands of schist and some sandstone-siltstone layers with moderate strength.
3. The granitic formations are protrusions through the slates during a time when the slate may have been softer (shale). The granitic formation may be regarded as stronger rock than the slate formations.
4. There is a distinctive cleavage in the slate formation with cleavage spacing of 1 cm typically. There is also cleavage in the granitic formations.
5. There may be zones of crushed rock at the boundaries between the granite and the slate formations. Quartzite are also present in the contact zones. The contact zones may be considered to be up to 30 m wide.
6. High stresses are considered unlikely to cause difficulties during tunneling.
7. Expected water inflow into the tunnel during construction is generally considered to be small. Some inflow may be expected near the southern portal since there are some water springs in the general vicinity.

8. There are no major faults or discontinuities on the tunnel route. There is however a number of minor fractures and smaller faults.
9. The joint system, even if generally considered favorable for the tunnel alignment, will potentially result in formation of blocks in the tunnel roof. The blocks will in general be bigger in the granitic formations, approximately 0.5 - 1 m and smaller in the slates, approximately 0.3 – 0.5m.

### 2.4.3 Excavation experience from the Dariali HPP

The rock formations in the proposed road tunnel consist of sheeted granitoids in the north and black slates in the south with diabase dyke intrusions crossing perpendicular on the tunnel, see Figure 5.

As part of construction of the Dariali HPP access tunnel, tailrace tunnel, underground powerhouse, cable tunnel and headrace tunnel have been constructed in the general area of the proposed road tunnel. Figure 5 shows a geological map of the area. The Dariali access tunnel is 5.5 m wide, 6 m high and the tailrace tunnel is 5 m wide and 5 m high. The powerhouse is 13.5 m wide, 70 m long and up to 30 m high. The cable tunnel and headrace tunnel are circular with 5.5 m diameter.

The excavation work on the access and tailrace tunnels progressed well through generally competent rock. Rock stress measurements were conducted in the headrace tunnel upstream of the powerhouse and the results were as expected, low and moderate level compared to the overlying rock mass. Average drill and blast tunneling progress was about 150-180 m/month and up to 10 m/day. The tunnels were dry and rock conditions fairly good. Only near the powerhouse cavern, some water inflow was encountered. No squeezing of the rock mass or rock bursting was encountered. Some lineaments were intersected in the cable and headrace tunnel and these will also be intersected by the road tunnel. Most of the lineaments are minor and caused no problems during excavation. However, one lineament intersected by the powerhouse needed extra rock support.

The foliation and lineaments in the project area are more or less vertical and oriented almost perpendicular to the road tunnel alignment, which is favorable for the tunnel construction.

Rock support in the access tunnel consisted of continuous shotcrete in the tunnel crown and down to the spring line and minimal rock bolting during the excavation period.After the excavation was finished, sprayed concrete layer with steel fibers was applied on the ceiling and walls; the quantities were some 1 $m^3$ of shotcrete per linear meter of tunnel. In the powerhouse cavern, systematic rock bolting and reinforced sprayed concrete was applied on the ceiling and upper part of the walls, shotcrete thickness was 10 to 15 cm.

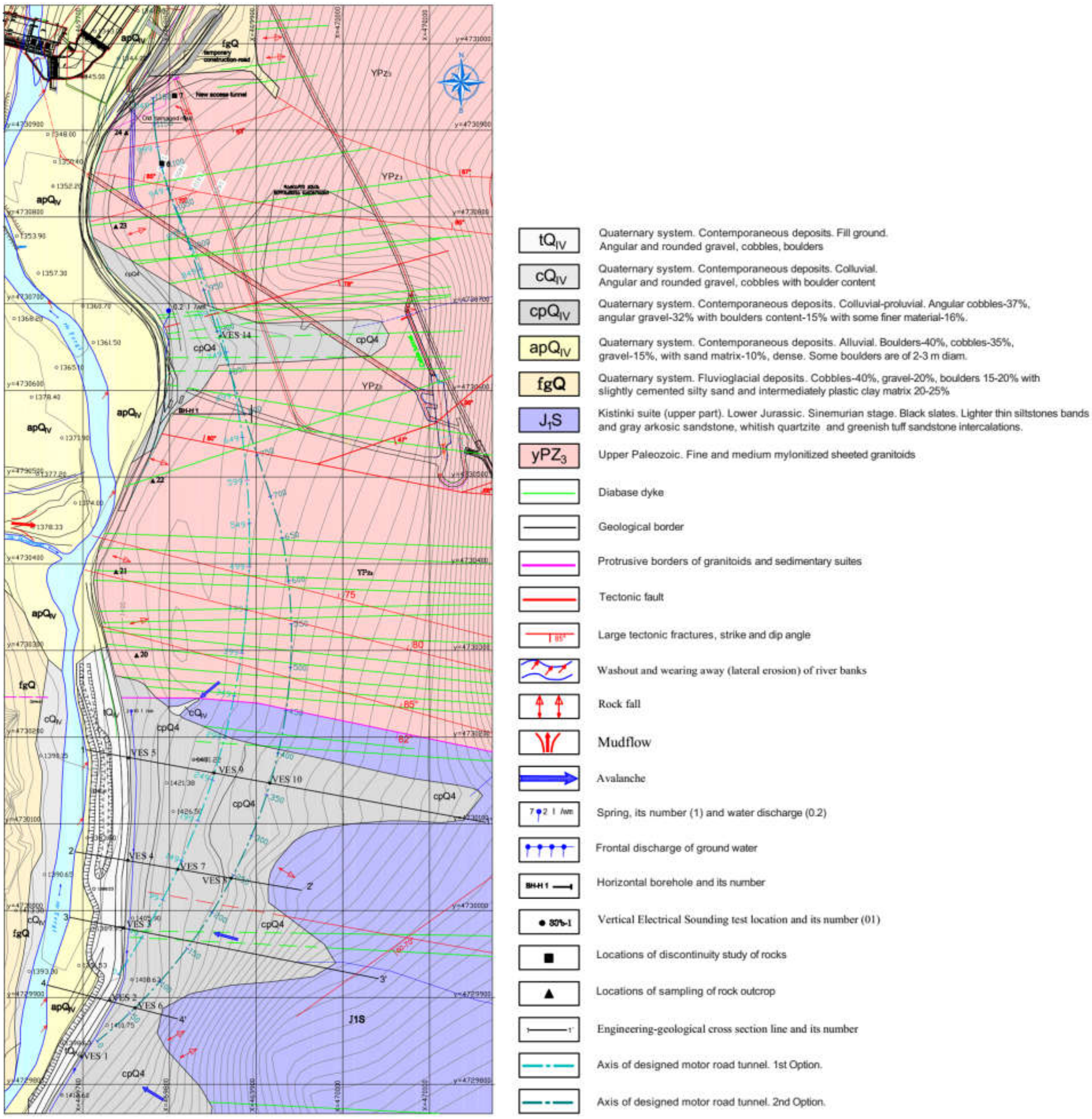


*Figure 5. Geological map of the area. (GeoEngineering Ltd., 2016).*

## 2.5 Seismicity

The project is situated in the Caucasus Mountain Range. It is one of the most seismically active regions in Alpine-Himalayan collision belt. The main seismic-tectonic feature is the junction between Arabian and Eurasian plates. Peak ground acceleration with 10% probability of exceedance in 50 years is estimated as 2.4-3.2 m/s2 (0.24-0.33g).

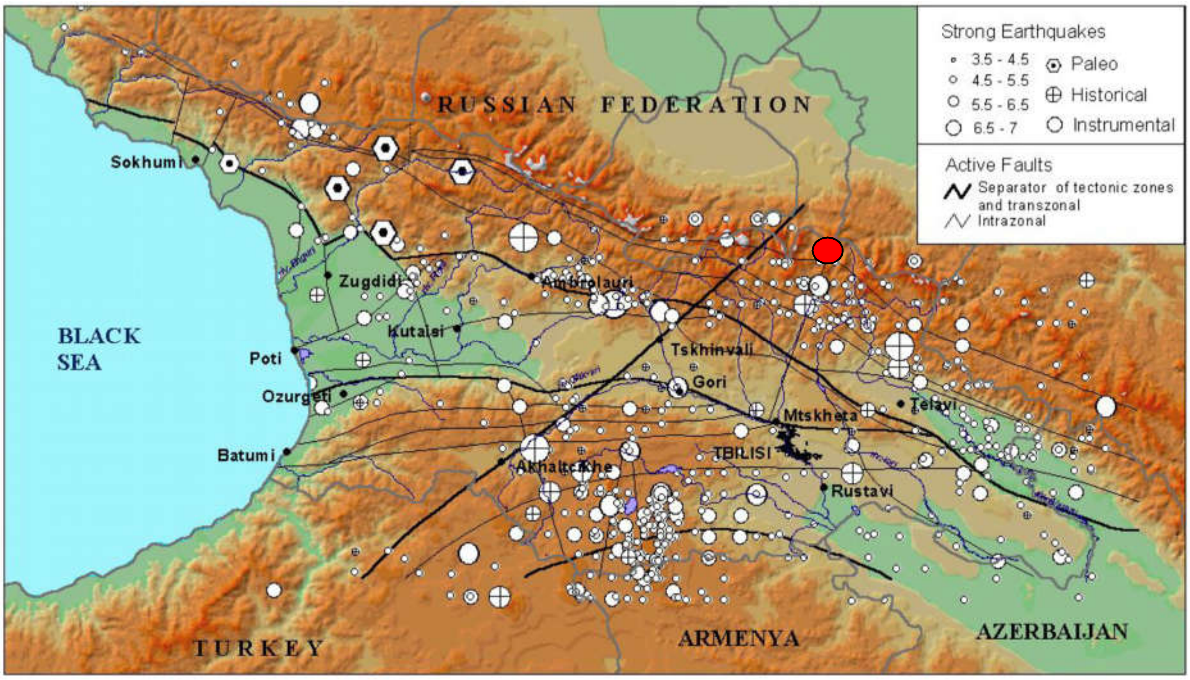



*Figure 6. Map of seismicity and active faults of Georgia, red dot shows the area (Godoladze, 2003).*

Seismic hazard at the Dariali area may be judged by the stipulations of the Construction Norms and Rules – "Antiseismic Construction'' (PN 01.01-09) for the communities in the Kazbegi district and are presented in Table 5.

*Table 5. Seismic hazards.*

| Community | Seismic coefficient | Intensity MSK64 scale |
|---|---|---|
| Stepantsminda | a=0,41g | 9 |
| Tsdo | a=0,39g | 9 |
| Gveleti | a=0,38g | 9 |

Based on data and calculations a seismic coefficient of a=0,45g is preliminarily recommended for design of the road alternatives.

## 2.6 Weather - Climate and meteorological conditions

There is a moderate humid climate in Kazbegi municipality lower zone (up to 2000 m a.s.l.), with relatively dry, cold winters and long, cool summers. Stable snow cover lasts ca 3-4 moths.

Moderate humid climate is in the 2000-2600 m elevation zone, with relative dry, cold winters and short summers. Average temperature of above 10°C lasts 1-3 months, above 5°C – 4-5 months. The temperature of the warmest month is 10-14°C. Mountain-gorge winds are dominant. There are west winds in the upper zone. Precipitation amounts to 1000-1200 mm annually. Stable snow cover during 5-7 months.

There is a moderate humid climate in the 2600-3600 m elevation zone. No real summer, average temperature in January -11 -15°C. In July below 10°C overall.

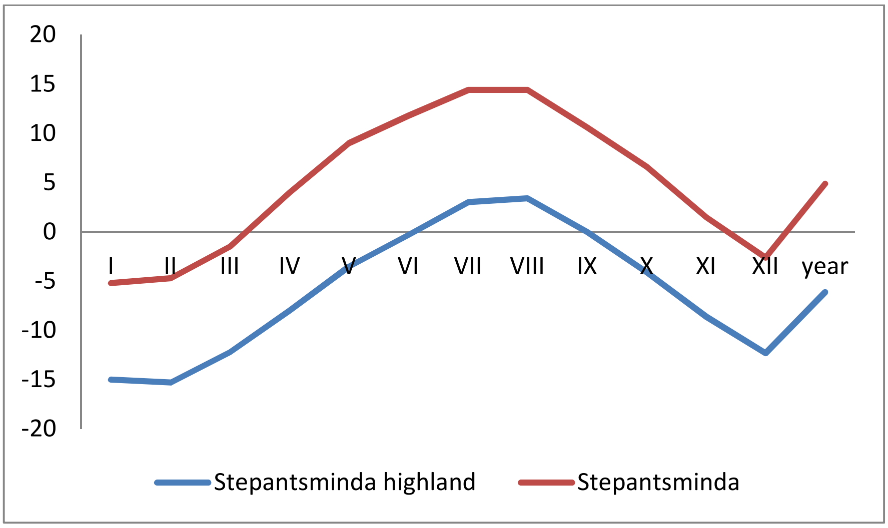
A highland, moderate humid climate above 3600 m, eternal snow cover and glaciers. Average temperature in winter is -13 -16 °C, in summer – above-zero temperatures. Precipitations mainly in the form of snow.

Tergi River basin up to the project section is located at the Caucasus range northern slope, which is open to the Russian lowland; therefore, northern cold Arctic air masses enter here without being hindered. Consequently, winter weather is severe and summers are relatively cool.

One of the main factors for forming the prevailing climatic conditions is the air temperature, average monthly and annual values (according to long-observed data by meteorological stations (m/s), located prior to the project section in the Tergi River basin) of which are given in the *Table 6*.

*Table 6. Average monthly and annual air temperatures, t°C.*

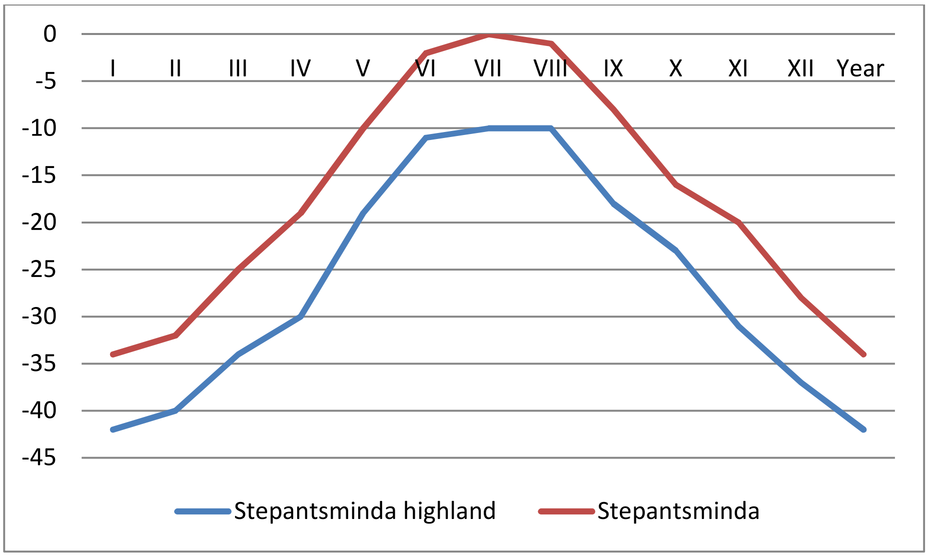
| Meteo station | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | -15,0 | -15,3 | -12,2 | -8,0 | -3,5 | -0,3 | 3,0 | 3,4 | 0,0 | -4,1 | -8,6 | -12,3 | -6,1 |
| Stepantsminda | -5,2 | -4,7 | -1,5 | 4,0 | 9,0 | 11,8 | 14,4 | 14,4 | 10,6 | 6,6 | 1,5 | -2,6 | 4,9 |




The absolute maximum air temperature of the region is recorded in Stepantsminda settlement and equals 32°C. Absolute maximum air temperatures, based on long-observed data by meteorological stations, located in the Tergi River basin are given below, in *Table 7*.

*Table 7. Absolute maximum air temperatures, t°C.*

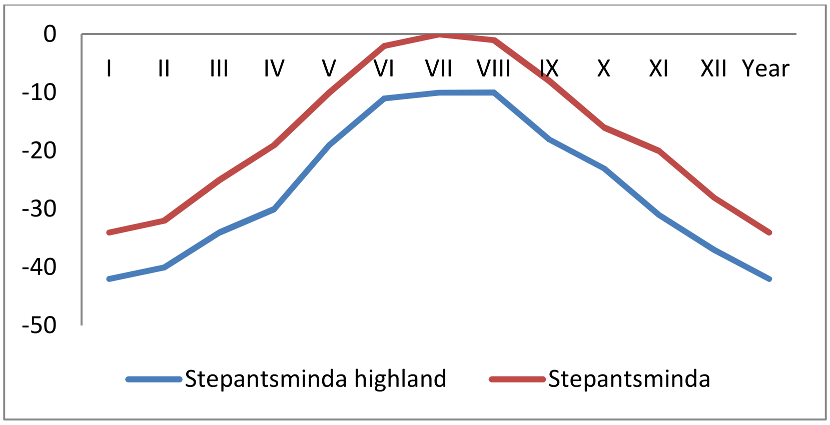
| Meteo station | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | 1 | 3 | 5 | 9 | 10 | 11 | 16 | 16 | 14 | 12 | 8 | 4 | 16 |
| Stepantsminda | 13 | 14 | 20 | 23 | 26 | 29 | 32 | 32 | 30 | 27 | 22 | 18 | 32 |




The absolute minimum temperature is measured at Stepantsminda highland meteo-station and is equal to -42°C. Absolute minimum air temperatures, based on long-observed data by meteorological stations, are given in Table 8.

*Table 8. Absolute maximum air temperatures, t°C.*

| Meteo station | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | -42 | -40 | -34 | -30 | -19 | -11 | -10 | -10 | -18 | -23 | -31 | -37 | -42 |
| Stepantsminda | -34 | -32 | -25 | -19 | -10 | -2 | 0 | -1 | -8 | -16 | -20 | -28 | -34 |



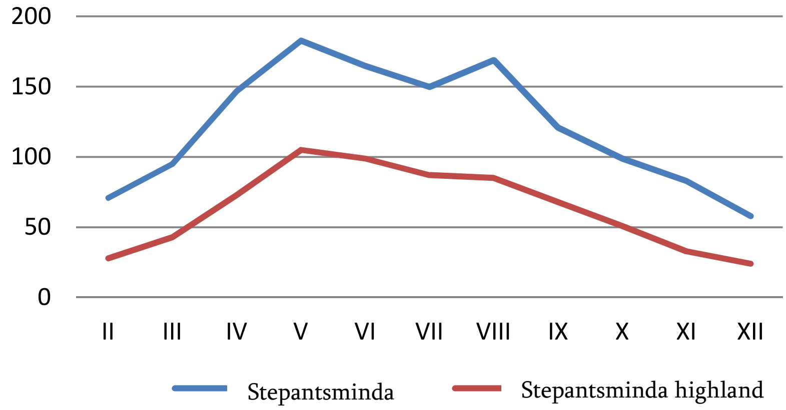

As the tables and diagrams show, the warmest month at the road tunnel location is August, and the coldest – January.

Annual value of precipitations in the survey area depends on hypsometric development of the Tergi River basin; therefore, highest values of precipitations are measured at the stations, located at higher points. Also note that annual movement of precipitations is characterized by maximums in warm periods of the year (IV-X) and minimums – in the cold period (XI-III).

Average month precipitation and total annual values, based on long-observed data by the meteorological stations, are given in *Table 9*.

*Table 9. Average month precipitation and total annual values, mm.*

| Meteo station | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | 63 | 71 | 95 | 147 | 183 | 165 | 150 | 169 | 121 | 99 | 83 | 58 | 1404 |
| Stepantsminda | 22 | 28 | 43 | 73 | 105 | 99 | 87 | 85 | 68 | 51 | 33 | 24 | 718 |



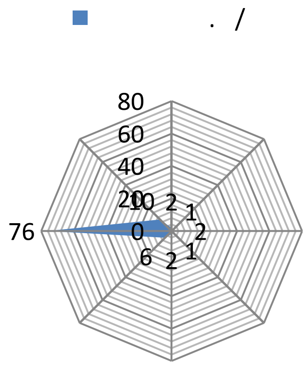

The 24-hours' rate of atmospheric precipitations in the survey region is quite high. The maximum daily precipitation was measured in Stepantsminda on 1.09.1965 and amounted to 111 mm.

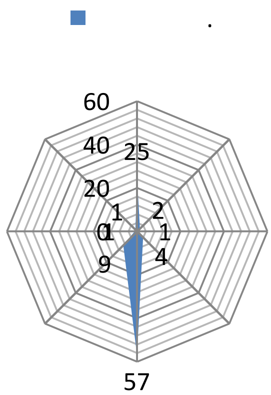
Winds from all directions blow in the survey area, though at relatively low points of Tergi River Gorge (m/s Stepantsminda) prevail South winds, at Stepantsminda highland m/s- West winds, and at the Jvari Pass- NE and SW winds.

Repeatability of wind directions and numbers of calms as a percentage of annual, based on long-observed data by the meteorological stations, are given in *Table 10*.

*Table 10. Repeatability of wind directions, and numbers of calms as a percentage of annual.*

| Meteo station | N | NE | E | SE | S | SW | W | NW | Calm |
|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | 2 | 1 | 2 | 1 | 2 | 6 | 76 | 10 | 38 |
| Stepantsminda | 25 | 2 | 1 | 4 | 57 | 9 | 1 | 1 | 30 |



The maximum value of average annual wind velocities is measured at the Stepantsminda highland weather station.

Average month and annual wind velocities, based on long-observed data by the same meteorological stations, are given in Table 11.

*Table 11. Average monthly and annual wind velocities, m/sec.*

| Meteo station | Vane height, m | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stepantsminda highland | 11 | 7,0 | 7,5 | 7,4 | 7,0 | 6,1 | 4,8 | 5,0 | 5,4 | 6,4 | 7,1 | 6,6 | 6,8 | 6,4 |
| Stepantsminda | 9 | 2,6 | 2,6 | 2,4 | 2,0 | 1,6 | 1,5 | 1,4 | 1,6 | 1,7 | 2,0 | 2,2 | 2,5 | 2,0 |

## 2.7 Environmental hazards

### 2.7.1 Floods

Starting on the northern slopes of Mount Zilgakokh (3856 m), at 3400 m above sea level on the Caucasus Ridge, the Tergi River joins the Caspian Sea north of Agrakhan Peninsula in the territory of Russian Federation. The length from the river source to the project site, southern tunnel entrance, is approximately 50 km with a general elevation difference of roughly 1680 m and average declination about 34 ‰. Watershed of the Tergi River is around 780 km$^2$.

The riverbed meanders moderately and branches in wide places. By the project location, the river flows in one deeply embedded riverbed through the Dariali Gorge. The current depth varies from the source downwards from 0,5 to 1,5 m, its width - from 8-10 m to 15-20 m, and the flow velocity - from 1-1,5 m/s to 1,8- 2,3 m/s. The riverbed bottom in narrow places is uneven, rocky and stopped by large stones/rocks, and in wide places, it is sandy-gravelly.

Water in the river is accumulated by glacier melting, snow, rain and groundwater. Its water regime is characterized by spring-summer floods and instable low water levels in different periods of the year. The spring-summer floods, caused by snow, glacier melting and rains reaches it's maximum in July and ends in September. Minimal water levels are observed in February.

A method of analogy was used to estimate floods with various return periods at the tunnel location. Perennial observations of Kazbegi (Stepantsminda) Hydrological Watch Point were used as an analogy. The observations cover the periods from 1928 to 1940 and from 1953 to 1990. The results are presented in Table 12.

*Table 12. Estimated floods in the Tergi River at the proposed tunnel location.*

| Flood event | Q (m3/s) |
|---|---|
| Average Annual Flood | 24.7 |
| 10-year flood | 245 |
| 100-year flood | 450 |
| 200-year flood | 515 |
| 1000-year flood | 660 |

### 2.7.2 Landslides and mudflows

From Russian border to Stepantsminda town, the road route runs through the narrow rocky corridor of Dariali gorge. Devdorak (Amal) River joins Tergi River from the left. Devdorak valley is of glacial origin and is characterized by mudflows. Over the centuries catastrophic mudflow runoffs occurred in the valley (1776, 1832), which caused significant damage to the population living downstream on the river Tergi.

Due to the catastrophic mudflows from Devdorak valley in recent years, Dariali gorge was closed several times, causing significant material damage to the country and, unfortunately also loss of lives. In August 2007, the road was blocked for 2 months, in May and June of 2014 - for 1 month, in August of 2014 – for 10 days, and in June 2016 -for 14 days. Based on historical events it is clear that the area is prone to mudflows and the risk for future mudflow events is inevitable.

### 2.7.3 Rock falls and snow avalanches

The existing road runs along very steep mountains. In some areas there is significant rock debris originating on the steep mountain slopes.

Snow can accumulate in gullies and on slopes which are inclined 30-45°. Below such areas there is risk of snow avalanches.

This must be considered in the design of the portal areas and adjacent roads.

## 2.8 Biological data

### 2.8.1 Flora and Vegetation

The project area is located in the geo-botanical district of the gorge. Structure of its vegetation cover is quite different from vegetation of other regions of Georgia. The forest belt of the gorge is represented by birch and pine forests preserved in form of small parcels and fragments, at elevations from 1000 m to 1600-1850 m above sea level. Groves of forest are of various age and are characterized by a low density, it is often sparse. Aspen (Populus tremula), hornbeam (Carpinus Caucasia), sessile oak (Quercus petraea) and other species are mixed in the forests.  Most common bushes are: Caucasian honeysuckle (Lonicera caucasica), hackberry (Padus racemosa), wayfarer (Viburnum lantana) and other species. Herbaceous cover is dominated by Poaceae and sedges (Carex).

Birch forests are represented by three species of birch: silver birch (Betula pendula), Litwinow's Birch (Betula litwinowii) and endemic black birch (Betula radeana); They are mainly common on northern and north-western slopes, which are mixed with rowans (Sorbus caucasigena).

Vegetation cover of the project area is quite poor. Rocky slope of the northern portal of the proposed tunnel is represented by several units of Pine trees *(Pinus sosnowskyi)* and Litwinow's Birch (Betula litwinowii).

*Figure 7. View of the area selected for the arrangement of northern portal.*

The southern portal of the proposed tunnel and the project corridor of the access road are relatively important in terms of vegetation cover. The slope, where the tunnel portal and access road will be constructed, is represented by the following plant species: Pine *(Pinus Kochiana)*, Litwinow's Birch *(Betula litwinowii)*, poplar *(Populus tremula)*, Common Juniper *(Juniperus depressa)*, rowans *(Sorbus caucasigena*), Raspberry *(Rubus idaeus),* spirea *(Spiraea hypericifolia)* and Buckthorn *(Hippophae rhamnoides)*.

*Figure 8. Project corridor of access road to the southern portal*

### 2.8.2 Fauna

Studies within the project area have been carried out in January, due to which we have no comprehensive information about the species of fauna inhabiting there. Considering this, results of studies conducted in summer for Dariali HPP project have been used.

On the territory of northern portal of the proposed tunnel and access road (where Dariali substation and entrance portal of transportation tunnel are located) following species have been observed: Lake frog

*(Pelophylax ridibundus)* and Caucasian lizards *(Darevskia caucasica).* Following species have been recorded near Tergi: white wagtail *(Motacila alba),* grey wagtail *(Motacila cinerea)* and Blackbird *(Turdus merula).*

Adjacent to southern portal, near Gveleti bridge, on the right bank of Tergi River following species have been recorded: Fox (*Vulpe vulpes*), Rock marten (*Martes foina*); as for the small mammals, holes of voles have been observed on measows. Presumably secondary meadow holes can belong to only 2 species of voles: Daghestanian (Microtus daghestanica) or common (Microtus arvalis) voles. Near piles of stone, Chionimys *gud* may be revealed, though it is difficult to record them without catching. Holes are also observed in bushes, which may belong to Forest mice (*Sylvaemus fulvipectus S. uralensis*) or bush voles (*Microtus majori*). Following species of birds have been recorded: common buzzard (*Buteo buteo),* Common Kestrel *(Falco tinunculus),* red-footed falcon (*Falco vespertinus),* red-billed chough *(Pyrrhocorax pyrrhocorax),* raven *(Corvus corax),* jays (*Garrulus glandarius),* common red-backed shrike (*Lanius collurio),* blackbird *(Turdus merula),* mountain Pipit (*Anthus spinoletta),* black redstart *(Phoenicurus ochruros),* white wagtail *(Motacilla alba),* yellow wagtail *(Motacilla flava),* grey wagtail (*Motacilla cinerea),* field sparrow *(Passer montanus).*

At different stages of monitoring, no large mammals and red list species have been recorded within the project area.

### 2.8.3 **Fish Fauna**

Generally the upstream reaches of Tergi River are represented by rheophil fish fauna. 6 species of fish are common there: Brook trout, barbell, gudgeon, minnow Oriental, Caucasian chub, loach Terek. Only brook trout (included in the Red List status - VU) is observed within the project section of Tergi River. Based on the survey results it is determined that the Trout reproduction area less represented within the project section, as the river flow is quite strong there and it is not favorable for reproduction.

### 2.8.4 **Protected Areas**

Kazbegi protected territories are distributed discontinuously and their common area sums in 8707 ha. Kazbegi State Park is entirely high-mountainous. Its lowest point is at 1400 m above the sea level.

Kazbegi State Park is situated in Stepantsminda municipality, Tergi River basin, at the north slopes of the Main Caucasian Ridge. The lower mark of its area is at 1400 m above the sea level, and the higher-within the range of 3300-4100 m. Creation of Kazbegi State Park aims to the highland ecosystem protection.

Its terrain is complicated, mountainous and heavily fragmented. In Dariali Gorge and also south to it, wherever Tergi River has formed deep canyons, the gorge walls are highly demonstrative in terms of local geology. Basalt partitions and lava layers are clearly observable on the rocks.

Kazbegi State Park vegetation is quite diverse. It is situated exactly in the part of Kazbegi floristic district of the Great Caucasus which is characterized by richness of endemic species. 1347 plant species are distributed in this floristic district, 26 % of which are endemic plants. Alpine, subalpine, xerophytes and plants of many other ecological groups are distributed here.

Kazbegi State Park forests are located at steep slopes. 105 bark wood species are distributed here, though most common species are: Litvinov birch, Sosnovski pine, junipers, cranberries. It should be noted that a quite large array of sea buckthorn, which is rather rarely met in Georgia, can be found in Stepantsminda vicinity; also Caucasian rhododendron is met here; eastern beech and high land oak are widespread in relatively large areas.

Presence of various plant species is a rich fauna signification; here in Kazbegi State Park are distributed such species from the Georgia Red List, as the East Caucasian Gabion, chamois, wolf, forest marten and others. Here in the Preserve is the environment for birds of prey, such as mountain eagle we can meet here, vulture, bearded vulture and others. Also noteworthy Caucasian black grouse and Caucasian Snow cock.

## 2.9 Human data

### 2.9.1 Demographic situation

According to 2016, number of population of Mtskheta-Mtianeti region is 94.2 thousands persons that is 2.3% of total amount of population of Georgia. Density is 18,3 persons for per km$^2$.

In accordance with the self-governing units, majority of population is lives in Mtskheta municipality, while the least number of population is observed in Kazbegi municipality.

Number of population in Mtskhet-Mtianeti region in 2006-2016 is presented in Table 13.

*Table 13. Population in Mtskhet-Mtianeti region in 2006-2016 (thousands of people)*

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015** | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Georgia | 4,401.3 | 4,394.7 | 4,382.1 | 4,385.4 | 4,436.4 | 4,469.2 | 4,497.6 | 4,483.8 | 4,490.5 | 3,713.7 | 3,720.4 |
| Mtskheta Mtianeti | 124.5 | 124.1 | 105.2 | 105.2 | 108.8 | 109.3 | 109.7 | 108.9 | 108.8 | 94.5 | 94.2 |
| Kazbegi municipality | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 3.8 | 3.8 |

**Note:** in 2008 territories of Mtskheta municipality were transferred to Tbilisi. In this regard number of population reduced about by 20.000.

According to data of 2015, population of Stepantsminda town is 1,2 thousands individuals, while their number in rural settlements is 2.5 thousands. As to the data of 2014, natural change on the territory of Kazbegi municipality is 15 units, including: Stepantsminda town -1, in the entire municipality – 16.

Site of the design tunnel is located in the adjoining territory of Gveleti village, which belongs to Stepantsminda town in terms of administrative viewpoint.

### 2.9.2 National and Ethnic Composition

In Kazbegi municipality 97% of population are Georgians, 2,5% -Ossetians, 0,3% - Russians, 0,1% - Armenians. Georgian nationalities prevail in 22 villages, while Ossetians prevail in 3 villages.

Ethno group of Georgian – Mokhevians reside in the municipality. They mostly live in the territory of historical Khevi or Kazbegi municipality, as well as in the villages of the neighboring North Ossetia and in Vladikavkaz. Mokhevians speak Mokhevian dialect of Georgian language.

### 2.9.3 Employment

Majority of Kazbegi municipality population (58-60%) are self-employed, they are residing in villages, they have their own agricultural lands and private farms. Considering the fact that Kazbegi municipality is characterized by small amount of lands, income of the population is extremely low and insufficient.

The main source of livelihood of the local population is manufacturing and selling of agricultural products. In recent years', number of visitors has significantly increased and subsequently, tourist infrastructure (guest houses and service sector) is being intensively developed as well.

Considerable amount of locals used to be employed on the HPP construction works in Dariali valley, where about 120 locals are employed on permanent jobs at present.

### 2.9.4 Economics

Agriculture and tourism are main fields of economics in Kazbegi municipality. In recent years' energy sector is actively developed, in particular, three HPPs have been put into operation – Dariali HPP, Larsi HPP and Kazbegi HPP. This is significant for employment of locals and increase of revenues in the local budget.

Agricultural land area is about 81.712 ha in Kazbegi municipality, majority of them are pastures and grasslands, just small areas are used for growing of agricultural crops. From agricultural fields, cattle-breeding, namely sheep-breeding, is more or less developed in the municipality. From crops, potato is noteworthy that is basically used for private usage and just minority of population use this product for commercial purposes.

### 2.9.5 Technical Facilities

Transport vehicle is the only mean of movement in Kazbegi municipality. Mtskheta-Stepantsminda-Larsi highway of international importance runs on the territory of the municipality. Length of local roads of the municipality is 160 km.

It should be noted that, location of the design tunnel is a narrow rocky gorge, where several linear structures are observed, as well as military road of Georgia (design tunnel is its part), north-south gas pipelines, electrical transmission lines and Silknet communication cable.

### 2.9.6 Land Use and Ownership

As already mentioned, Kazbegi Municipality suffers from the lack of land plots and agricultural lands are owned by the local population. Pastures, areas of Forest Fund and Kazbegi National Park are in the state ownership.

6 land plots are located within the project impact zone, including 5 land plots, registered in the Public Registry, and one is not registered, including: project affected land plots, including:

1. "Energy" LTD -32351 m$^2$ – I/C 740116036;
2. "Energy" LTD - 11994 m$^2$ - I/C 740116035;
3. JSC "Dariali Energy:"- 106 m$^2$ - I/C 740116034;
4. Gugua Marsagishvili - 600 m$^2$- 740115003;
5. JSC "Dariali Energy:"- 17322 m$^2$ - I/C 740115016;
6. JSC "Dariali Energy:"- 5176 m$^2$ - I/C 74011501;1
7. Unregistered land plot - about 600 m$^2$

Prior to the start of the construction works, Resettlement Action Plan will be developed and land acquisition will be carried out in accordance with the legislation of Georgia and environmental and social policy of International Finance Organizations.

### 2.9.7 Touristic Potential

There is a great resource for ski tourism development in Mtskheta-Mtianeti. Two touristic products dominate:

- Resort places (Ananuri, Pasanauri, Sioni, Stepantsminda, Tskhvarichamia, Bazaleti Lake);
- Winter resort (Pasanauri, Gudauri);

Gudauri should be singled out related to the tourism development in the region.

There are so-called 'Discovery Tourism" and "Cultural Tourism"(getting familiar with natural and historical monuments) in Mtskheta-Mtianeti, as well as ski tourism, etc.

In total there are 5 resorts and 25 vacation destinations in the region. In Dusheti and Stepantsminda municipalities there are balneologic -climatic and climatic-balneologic resorts

There are 37 touristic-resort facilities in Mtskheta-Mtianeti. 12 hotels, 20 guest-houses and 7 rest homes operate throughout the year. There are following hotels of international standards: "Mtskheta Palace", "Gudauri", "Stepantsminda", "Truso", "Hotel 7", "Ozone", "Shamo", "Jvris Ugheltekhili (Jvari pass)", Panorama", Gudauri Alpine Hut", etc.

### 2.9.8 Cultural Heritage and Archaeology

Kazbegi Municipality is distinguished with numerous and diverse cultural heritage monument, including:

- Gergeti Trinity Church (XIV);
- Sno Fortress (XVI);
- Arshi Fortress (XVI);
- Sioni Church (IX-X);
- Betlemi Cave (VIII-XII);
- Kazbegi Kari Church(XVII-XIX);
- Akhaltsikhe Church by John the Baptist;
- Virgin Mary Church (IX );
- St. George Church in Garbani village (IX-X );
- Basilica Church in Fkheli village (IX);
- St. Archangel Church in Truso Grorge (X-XI);

Near the project tunnel location, on the left bank of Tergi River, Dariali Fortress is located. It is the last point on the northern border of Georgia. According to Georgian history, the first fortress here was built by Vakhtang Gorgasali (V century), but the current fortress is built much more earlier. Considering the fact that the project tunnel construction will be provided only on the right bank of the river, in about 800 m from the historical monument, the impact is not expected.

In addition, "Red" church, niche of John the Baptist on the left bank of Tergi River (adjacent to Gveleti village) and the Church by John the Baptist on the right bank of Tergi river are located within the project area region. It should be noted that all these monuments are located in significant distance from the construction site.

According to visual audit of the project areas and literary sources, there are no visible historical or architectural monuments directly within the project impact zone. Considering the relief and local conditions of the project areas, the risk of identification of any archaeological monuments is at minimum.

# 3 Preliminary Design

## 3.1 Introduction

Quantities and costs contained in this preliminary design report shall be considered preliminary and for general information only and may change in the final design.

The Preliminary Design Report involves the following:

- Tunnel excavation and rock support using drilling and blasting methodology
- Road construction including access ramps to the tunnel
- Tunnel portals, underground technical room and other concrete structures
- Drainage systems for road, access ramps and tunnel
- Electrical systems, ventilation, utilities and equipment for furnishing of tunnel and roads.

Individual component of the project is described in more detail below.

Preliminary design drawings are presented in the Appendix A. The drawings are not intended for construction and must be studied together with the preliminary design report for a cohesive picture of the project preliminary design.

The Road is in total 1920 m, roughly 1200 m inside the tunnel and the rest are roads leading up to it. It is designed for an annual average daily traffic (AADT) of 4000 – 6000 vehicles with a design speed of 80 km/h. It connects with the existing road in accordance with design standards.

If the traffic is less than 4000 vehicles per day, the recommended road standards could be lowered. The traffic analyses predictions should be checked in the final design.

## 3.2 Tunnel and roads

### 3.2.1 Design codes and standards

The Tunnel and Road shall be designed according European standards, and shall conform to the European Agreement on Main International Traffic Arteries. Traffic and fire safety shall be according to Eurocode or similar standards.

The Preliminary Design follows Norwegian road and tunnel standards and handbooks, which are similar to European standards:

- Håndbok N100 Veg- og gateutforming
- Håndbok N200 Vegbygging
- Håndbok N500 Vegtunneler
- Handbook no. 021 Road Tunnels from the Norwegian Public Roads Administration (2004)

All design requirements and other details should be reevaluated by the Contractor and his Designer in the final design.

In the preliminary design the Indicative Design Working Time is based on “EN 1990:2002 - Basic og structural design“ and „NS-EN 1990:2002+ NA2008“. The design working time for the road south of the tunnel is set to 50 years, for the road north of the tunnel to 10 years, 100 years for the tunnel and 50 years for the water and frost support in the tunnel. To increase the lifetime of the road north of the tunnel portal, additional erosion protection is required at the foot of the road embankment. This can be done at a later stage of the project whenever funds are available.

### 3.2.2 General design criteria

The following design requirements have been used in the preliminary design:

*Road:*

- Minimum horizontal curve shall be 300 m with transitional curves at minimum 140 m.
- Stopping distance visibility shall be at least 145m, down to 108 in the tunnel depending on the gradient.
- Lane width will be 3,5 m with a 1,0 m median. Shoulder width is 1,0 m. Total width 10,0 m.
- Gradients shall be ≤6% wherever possible.
- Minimum vertical curvature shall be 4400 m for high points and 2100 m for low points.

*Tunnel:*

- Total width 10,5 m between walls.
- Free height 5,0 m over lanes (requirement from the Georgian Road Department).
- One-sided transverse slope minimum 3%.
- Gradients shall be ≤5%.
- Mechanical ventilation shall be provided

Recommended tunnel profile, with excavated cross sectional area of approximately 75,8 m$^2$, is shown Figure 9. More detailed cross-section is presented in the drawings in Appendix A.

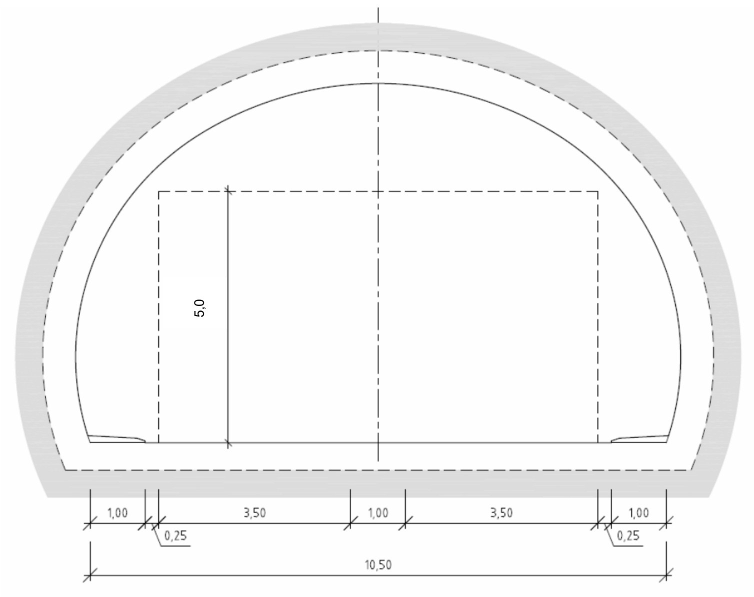



*Figure 9. Tunnel profile (dimensions in meters).*

Starting from the south, the preliminary design includes the following: From the existing E117 alignment, a new approximately 100 m long road with 3-4% slope downwards. On this ramp approximately 55 m long reinforced concrete tunnel portal is constructed. The tunnel, approximately 1.2 km long, has a constant 5% slope from the south portal down towards the north. At the north end of the tunnel there is an approximately 20 m long reinforced concrete portal constructed on an engineered fill, which is approximately 4 m high at the portal. From the north portal a new approximately 550 m long ramp, sloping 6% down from the portal, shall connect the tunnel to the existing E117 road alignment. A new permanent access to the Dariali power station shall be constructed from the north end of the ramp.

Geological findings around the south portal area show thick talus material in the proposed portal location in the Feasibility Study, therefore the portal has been moved approximately 100 m further south to lower surface excavation and support cost around the south portal area.

Drawings in Appendix A show an overview of the proposed alternative.

*Ramps:*

On both sides of the tunnel, ramps have to be constructed due to the elevation difference of the tunnel entrance and the existing road. In the preliminary design the north ramp is 576 m long and the south ramp will be approx. 100 m long.

The embankment fills that the ramps consist of, the subgrade, is constructed from the material excavated from the tunnel, provided that the material is deemed appropriate and after it has been crushed and sieved to the desired composition.

- Ramps have sides with slope 1:1,5 in the preliminary design.
- Subbase and base course shall be consistent with design standards with regards to available material

*Lay-bys in tunnel:*

Lay-bys are required every 375 meters (see Figure 24 in electrical chapter), with a tolerance of 50 m in either direction. Lay-bys make it possible to park vehicles out of traffic in case of emergencies.

Each lay-by should be designed as follows:

- Lane-width of 3 m.
- Length of 30 m.
- Transitions of 30 m in both directions.
- Not more than 250 m from tunnel entrances to the first lay-by.

Lay-bys shall be designed with other constructions in mind, e.g. technical rooms.

*Tunnel pavement:*

Safety standards and regulations do not specify directly if tunnels should be paved with concrete or asphalt. Fire safety standards do not specify this in detail and this should always be evaluated by the designer. There is a possibility of a big mudflow damming the river and at the same time a 10-year flood could occur. If the dam is higher than the southern tunnel portal the water will eventually run through the tunnel. It is therefore recommended that the tunnel should have a concrete paved road surface. The concrete can handle more erosion from the flood and will limit the closing time of the tunnel. The cost of concrete surface is a more expensive that asphalt but cost saving will be generated through maintenance.

*Erosion protection (rip-rap):*

Rip-rap (erosion protection) is required for erosion protection on the ramp side and over the Dariali HEP tailrace penstocks and Larsi HEP penstocks. The rip-rap shall be strong durable non frost susceptible rock selected from required excavations or from other approved sources (e.g. borrow areas or other sources as approved). The rip-rap shall be clean, free from debris and soil, fractures and cracks. Rip-rap shall be generally cubical with the maximum dimension not greater than 2,5 times the smallest one. Each stone shall be placed separately in the rip-rap zone with each stone interlocking with the abutting ones, so as to provide a stable zone. The largest size stones shall be placed at the surface, with their largest dimension perpendicular to the slope.

*Figure 10. North portal proposed in the preliminary design, looking south.*

The road geometry is designed with a traffic capacity projection of 15-20 years. The real total amount of traffic using the road effects the working life of the road constructions. Unforeseen circumstances that could increase traffic flow will therefore lower the working life of the construction.

### 3.2.3 Geological conditions

Geology of the area is presented in Appendix B (GeoEngineering Ltd., 2016).

Based on the available geological information and experience from excavation of various tunnels and the powerhouse cavern of the Dariali HPP, the rock in the area is generally of good quality and well suited for tunneling. There is however limited experience using Drill and Blast (D&B) excavation method in the black slate which is expected in the southern section of the tunnel. The headrace tunnel in Dariali HPP was excavated using a TBM machine, which gives a smoother tunnel profile and needs less rock support than the D&B excavation method.

The direction of diabase dikes and faults is perpendicular to the tunnel which is favorable. The rock stress will not be homogenous in the tunnel because the tunnel is located parallel to the valley. The steep slopes on the surface on one side of the valley will give less overburden and rock stress.

Rock quality assessment, based on the excavation experience from the Dariali HPP and the geological report is presented in Table 14.

*Table 14. Estimated rock quality.*

| Rock support class | Q-value | Estimated percentage [%] | Length [m] |
|---|---|---|---|
| A/B | 10-100 | 80 | 944 |
| C | 4-10 | 10 | 118 |
| D | 1-4 | 6 | 71 |
| E | 0,1-1 | 3 | 35 |
| F | 0,01-0,1 | 1 | 12 |
| G | <0,01 | 0 | 0 |
| Total | - | 100 | 1180 |

Overburden along the proposed tunnel is acceptable. The minimum overburden is estimated about 30 meters. However, this needs to be confirmed by more surveying.

The optimum location of the portals depends on geotechnical conditions in the area. The thickness of the talus needs to be confirmed with more geotechnical investigations.

### 3.2.4 Rock support

The rock support shall be based on the Q-system for rock mass classification. It shall provide permanent stability of the rock mass. The rock support estimate in the preliminary design is based on the Norwegian standards and practices for road tunnels. The figure below shows the permanent rock support that shall be used in a tunnel according to rock quality.

*Table 15. Permanent rock support according to rock quality.*

| **Rock Mass Class** | **Rock Mass Conditions (Q-value [(1)])** | **Rock Support Class (Permanent Rock Support)** |
|---|---|---|
| **A/B** | Low-jointed rock mass<br>Average joint spacing > 1m<br>Q = 10-100 | **Rock Support Class I**<br>- Spot bolting<br>- Reinforced sprayed concrete B35 E700, thickness 80 mm in crown and walls down to max 2 m above tunnel invert. |
| **C** | Moderately jointed rock mass<br>Average joint spacing 0.3 – 1 m<br>Q = 4 - 10 | **Rock Support Class II**<br>- Systematic bolting (c/c 2m), end-anchored. Pre-tensioned, fully grouted rock bolts.<br>- Reinforced sprayed concrete B35 E700, thickness 80 mm, in crown and walls down to tunnel invert. |
| **D** | Heavily jointed rock mass or stratified schistose rock mass. Average joint spacing < 0.3 m<br>Q = 1 - 4 | **Rock Support Class III**<br>- Reinforced sprayed concrete B35 E1000, thickness 100 mm or more<br>- Systematic bolting (c/c 1.5 m), end-anchored fully grouted rock bolts as permanent support |

| | | |
|---|---|---|
| **E** | Very poor rock mass quality<br>Q = 0.1 - 1 | **Rock Support Class IV**<br>- Spiling bolts when Q < 0.2, Ø25 mm, max c/c 300mm<br>- Reinforced sprayed concrete B35 E1000, thickness 150 mm<br>- Systematic bolting c/c 1.5 m, fully grouted rock bolts<br>- Reinforced ribs of sprayed concrete, Q < 0.2, rib dimension E30/6x rebar Ø20 mm, c/c 2-3 m between ribs, bolted systematically c/c 1.5 m, 3 – 4 long rock bolts (2)<br>Decide if cast in place invert slab is necessary |
| **F** | Extremely poor rock mass<br>Q < 0.01 – 0.1 | **Rock Support Class V**<br>- Forepoling (3), c/c 200 – 300 mm, Ø32 mm or self-boring stud bolts<br>- Reinforced sprayed concrete B35 E1000, thickness 150 – 250 mm<br>- Systematic bolting, c/c 1.5m, fully grouted rock bolts, c/c 1.0 - 1.5<br>- Reinforced ribs of sprayed concrete, rib dimension D60/6+4x rebar Ø20 mm, c/c 1.5 – 2 m between ribs, bolted systematically c/c 1.0 m, 3 – 6 m long rock bolts (2)<br>- Decide if cast-in-place invert slab is necessary<br>- Cast-in-place reinforced invert slab with rise-to-span ratio min. 10% of the span of the tunnel |
| **G** | Exceptionally poor rock mass<br>Q < 0.01 | **Rock Support Class VI**<br>- Special evaluation of excavation and rock support |

(1) Q-values are given for uniaxial compressive strength UCS = 100 MPa.

(2) Requirements to materials, methods, and solutions are described in "Teknologirapport nr. 2538: Arbeider foran stuff og stabilitetssikkring I vegtunneler" (Technology repport No. 2538: Works ahead of the tunnel face and rock support in road tunnels). Avalible in Norwegian only.

(3) Forepoling, also known as tube umbrella, is an application used to strengthen tunnel roof in broken rock conditions. Drilling system consists of casing tubes which are drilled through the overburden as an umbrella and filled with grouting.

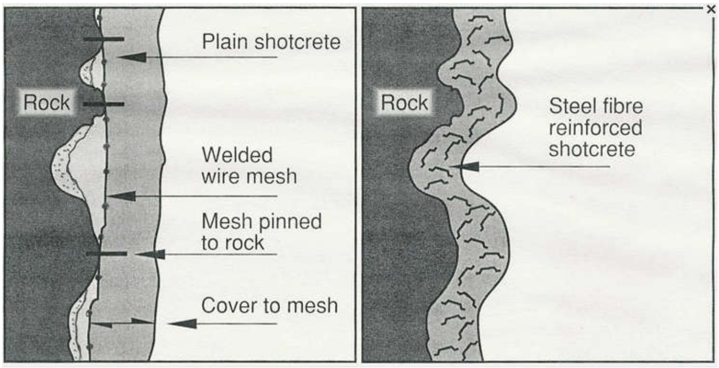



*Figure 11. Fibre reinforced shotcrete (sprayed concrete) limits the voids and shadows.*

Figure 12 shows reinforced ribs of sprayed concrete which are used as rock support arcs when tunneling through poor rock mass quality.

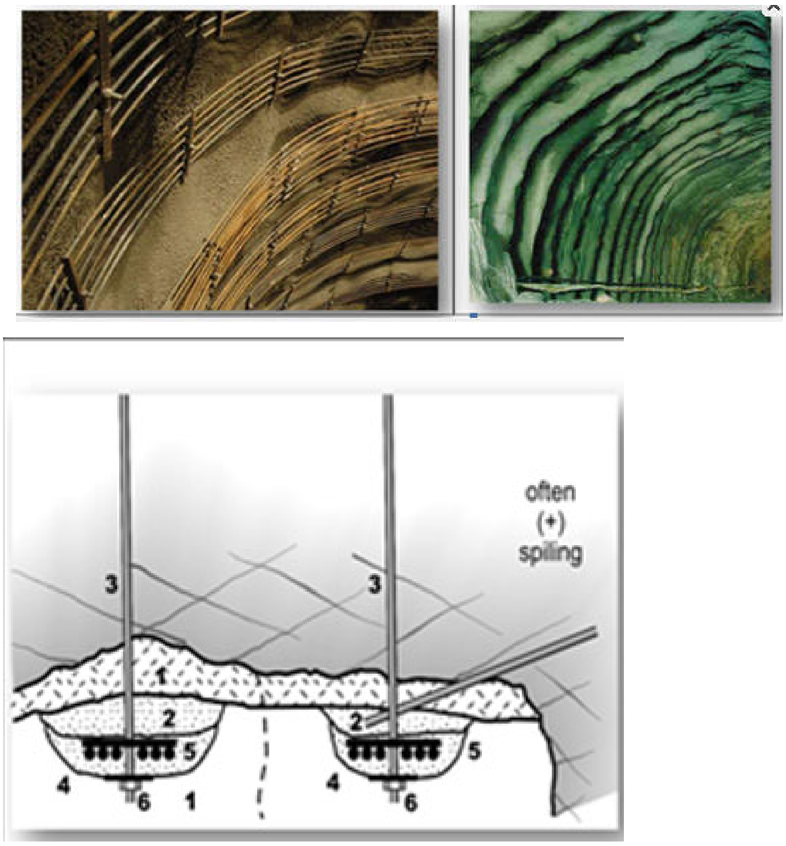



*Figure 12. Reinforced ribs of sprayed concrete.*

### 3.2.5 Existing structures

#### *3.2.5.1 Dariali Power Station*

A new access road has to be constructed to the Dariali HEP.

The preliminary design proposes a tunnel that will intersect the old access tunnel of the Dariali HPP and cross over the Dariali HPP tailrace tunnel. Figure 13 and Figure 14 below show the cross section of the old access tunnel and tailrace tunnel of the Dariali Power Station. The vertical clearance between the new road tunnel and the tailrace tunnel is no less than 10-12 meters.

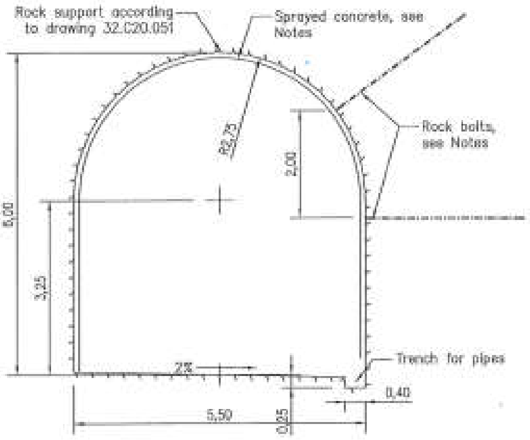



*Figure 13. Old access tunnel cross section.*

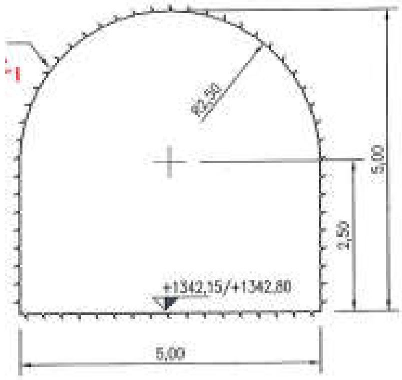



*Figure 14. Tailrace tunnel cross section.*

Since the road tunnel will be located approximately 200 m from the headrace tunnel, the water pressure is not expected to effect the road tunnel but it has to be considered in the design. Furthermore, there is no water pressure in the tailrace tunnel.

The figure below shows the transmission lone toper near the propose road. In the preliminary design it is suggested to build a retaining wall around it.

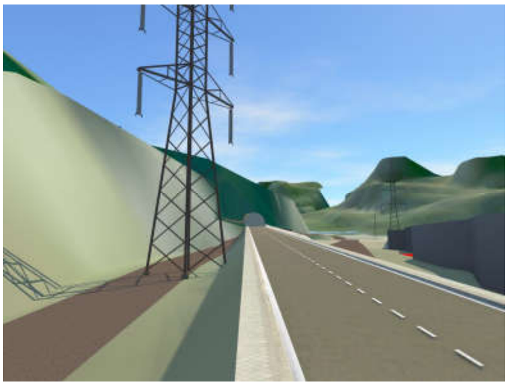


*Figure 15. In the preliminary design it is suggested to build a retaining wall around the transmission line tower. The Contractor has to evaluate with the Owner if the tower should be moved in the final design.*

### *3.2.5.2 Larsi HEP*

Final design has to take into consideration the Larsi HEP penstock in the design of the new road embankment. The penstock must be protected against erosion and the structural integrity has to be evaluated.

*Figure 16. Larsi penstock alongside the existing road.*

### *3.2.6 Excavation*

The surface and underground excavation is together approximately 200.000 $m^3$ (excavated loose material). D&B method is considered best suited for the excavation due to the shape of the cross section and a relatively short tunnel length. Blasting restrictions are imposed during the construction of the road tunnel when blasting above the tailrace tunnel. A vibration limit is stated in the specifications in the area around the Dariali powerhouse and limited pullout when excavating over the tailrace tunnel.

Most of the excavated rock surface and underground material will be used in road fillings and some driven to spoil areas.

To shorten the excavation time, the new road tunnel can possibly be excavated from the old access tunnel by removal of an existing concrete plug at the tunnel portal during construction. This should be looked at in the final design.

There is ample space for construction of the portals and this alternative has minimum effect on the existing road while some temporary relocation of it is required near the portal areas. During the construction period, the traffic on E117 will have to be diverted away from the construction area both at the south and north end of the tunnel.

A drainage system shall be designed to prevent water inflow and leakage into the Dariali Power station during construction and operation of the tunnel. This can be done by building a concrete plug in the old access tunnel and making a grout curtain around it. Such a plug is necessary also as a physical barrier between the road tunnel and the power station.

### *3.2.7 Water and frost protection*

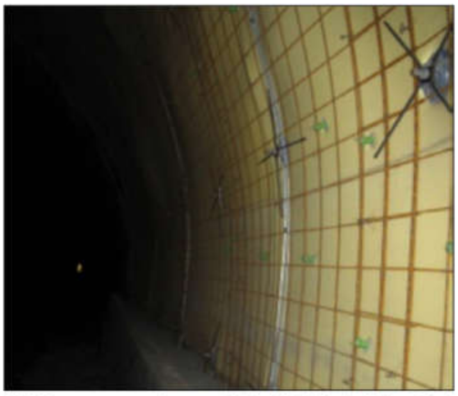
Road tunnels and portals must be protected against water and ice formation. This is normally done by erecting a lining which directs water to the tunnel walls and into the drainage system. If frost exceeds given limits a thermally insulated lining is installed. The choice of frost insulation system is based on traffic volume (tunnel category), design traffic speed, tunnel length and standard, aesthetics, frost level, maintenance requirements and financial aspects. Example of water proofing and frost insulation is shown in the figures below.

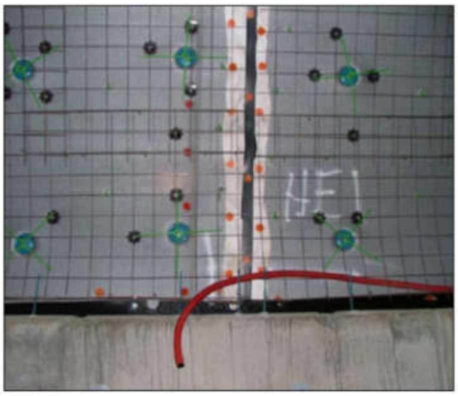
The water and frost protection shall be detail designed according to Eurocode or similar standards.

For the Preliminary Design, Norwegian handbook N500 and R510 were used. It is assumed that approximately 600 m of tunnel needs to be water and frost protected, 300 m from each end of the tunnel portals. Final length and dimensions shall be designed by the Contractor taking into account the climate in the area.

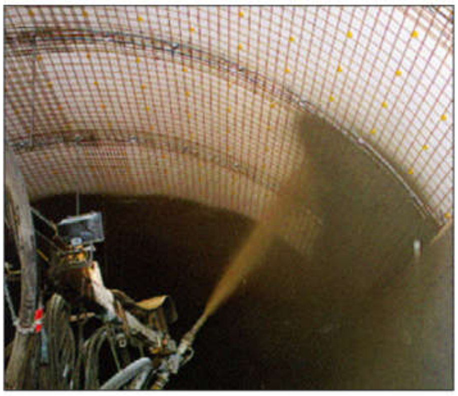
According to Norwegian handbook N500 (2016) tunnel portals also need to be constructed with water and frost protection.


*Layout of traditional Norwegian tunnel lining system with two options. A: shield system with thermally insulating pre-cast concrete elements. B: shield system with PE sheets (after NPRA 2012).*





***PE above concrete elements (H.Buvik, NPRA) (Mona Lindstrøm,NPRA)***
*The details include an expansion joint, reinforcement mesh, structural reinforcement and plastic coils for control of distance between PE-foam mat and the reinforcement.*



*Fire protection of PE-foam with sprayed concrete (NPRA)*

*Protection details (H.Buvik, NPRA)*

## 3.3 Environmental Hazards

### 3.3.1 Tergi River flooding

A method of analogy was used to calculate the design values of the average annual flow rates and the maximum annual flow rates of the Tergi River at the design section of headworks for the Dariali HPP project. These values were used to evaluate flooding conditions by the proposed road tunnel location. Perennial observations of Kazbegi (Stepantsminda) Hydrological Watch Point were used as an analogy. The observations cover the periods from 1928 to 1940 and from 1953 to 1990 (See further description of the methodology in the Dariali HPP feasibility report).

At the south tunnel portal, the Tergi riverbed is approximately 25 m wide with average longitudinal slope about 4,4%. Based on the uneven and rocky riverbed, the manning´s roughness is assumed to be 0,07. Estimated flood water elevations based on the above assumptions are presented in Table 16. At the north tunnel portal, the overflow structure on the Tergi river is designed to have a maximum water level elevation of 1344.

*Table 16. Estimated flood flows and elevations on the Tergi River at the southern and northern tunnel portals.*

| | | South Portal | | |
|---|---|---|---|---|
| | | River bottom elevation | 1396 m.s.l | |
| **Flood event** | **Q (m3/s)** | **Velocity (m/s)** | **Depth (m)** | **Elevation (m.s.l)** |
| Average Annual | 24.7 | 1.8 | 0.5 | 1396.5 |
| 10 yr. | 245 | 4.1 | 1.9 | 1397.9 |
| 100 yr. | 450 | 5.0 | 2.7 | 1398.7 |
| 200 yr. | 515 | 5.2 | 2.9 | 1398.9 |
| 1000 yr. | 660 | 5.6 | 3.4 | 1399.4 |

*Impacts of extreme floods in the Tergi River on tunnel*

The overflow structure of the Larsi HPP is designed to have a maximum water lever elevation of 1344. The tunnel portals elevations are 1351 m.s.l at the northern entrance and 1410 m.s.l at the southern entrance. The Tergi river water levels are estimated to rise up to 1339.2 and 1344 in the respective locations during the 1000-year event and therefore it is considered unlikely that flood in the Tergi river will affect the construction or operations of the tunnel.

The road profile, elevations, materials, and armoring shall be designed to minimize risk for failure of road and tunnel infrastructure. The report „Dariali Hydroelectric project, Feasibility study report dated September 2011" has to be reviewed further for information on river flooding estimates and design structures to withstand flooding up to the 1000-year event.

*Impacts of large mudfloods from the Amali River on tunnel*

River bottom elevation at the confluence of the Amali and the Tergi Rivers is at about 1374 m.s.l. The southern tunnel entrance is located approximately 600 meters south at an elevation of 1410 m.s.l. The mudflood height would have to be more than 30 meters to start impacting the tunnel entrance. Once that happens, the river would start flowing into the tunnel, and discharge into the river downstream of the mudflood. Even though insufficient information is available to evaluate the likelihood of such extreme mudflood event to occur, the tunnel has been designed to withstand some flooding due to river flows.

The following preliminary estimates of flood flows in the tunnel are provided:

*Table 17. Tunnel flooding from Tergi river if river valley is blocked by a > 20 m high mudflow*

| | **Discharge ($m^3/s$)** | **Velocity (m/s)** | **Normal Flow Depth (m)** |
|---|---|---|---|
| Average Annual Flood | 24.7 | 5.8 | 0.4 |
| Average June/July Flood | 56.7 | 7.9 | 0.7 |
| Average Maximum Annual Flood | 137 | 10.9 | 1.2 |
| 10 year flood | 245 | 13.4 | 1.7 |
| 100 year flood | 450 | 16.3 | 2.6 |
| 200 year flood | 515 | 16.9 | 2.9 |
| 1000 year flood | 660 | 18.23 | 3.4 |

The only mitigation done in the preliminary design against tunnel flood is elevation of the technical room and electrical equipment. This is to minimize repairing cost, cleaning and to speed up the re-opening of the tunnel. Other mitigation shall be evaluated in the final design.

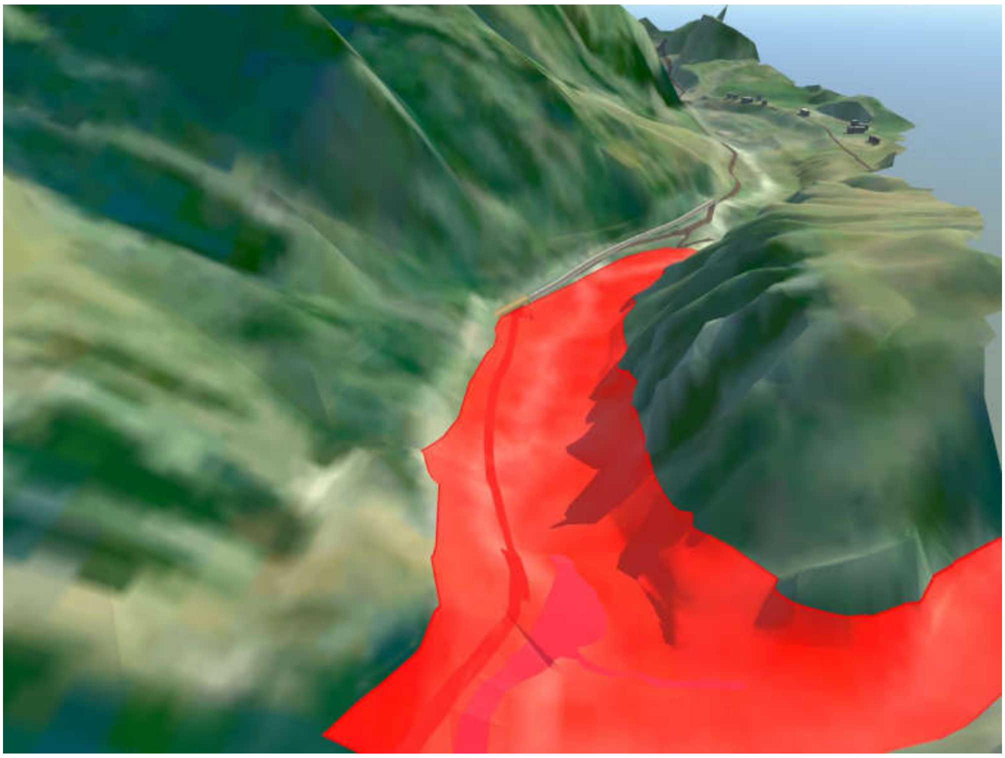


*Figure 17. Looking south. Estimated flood area after the landslide in 2014 (based on photos). The south portal is above the flood line in the preliminary design. The final location of the south portal shall be reevaluated in the final design.*

The cross-sections in Appendix A show the calculated water level for 10-year and 100-year flood.

### 3.3.2 Rock fall

Geodynamic conditions in the road tunnel area are significant, particularly in the portal areas. In this regard, steep inclination of rocky slopes on the top of both portals should be highlighted. Special attention should be drawn to the North portal, which will be situated at the foot of the high and steep slope. Prior to the construction it will be necessary to clean the slope from loose boulders and use protective nets or other means, both during tunnel construction and operation phases. At the south portal the situation is similar, above which old rocky debris is accumulated in the eroding ravine. Most of the accumulated material consists of large boulders. Surface layer of the debris is loose and experiences movement in time, which leads to the need of implementation of major protection measures.

At the south portal, dry ravines located above it, bear certain risks, where temporary water flows run through them during heavy rain and snow melt. It will be necessary to regulate and strengthen the riverbeds and valleys of these ravines in order to protect the tunnel portal during the construction and operation periods.

In addition, from upper part of the slope infiltrated water constantly flows from proalluvial-colluvial soils, which are accumulated at the bottom of these ravines. The total of infiltrated water is about 10 l/sec. It is required to provide capturing of these sources and organized removal from the tunnel portal. The exact location of the south portal must be re-evaluated in the final design.

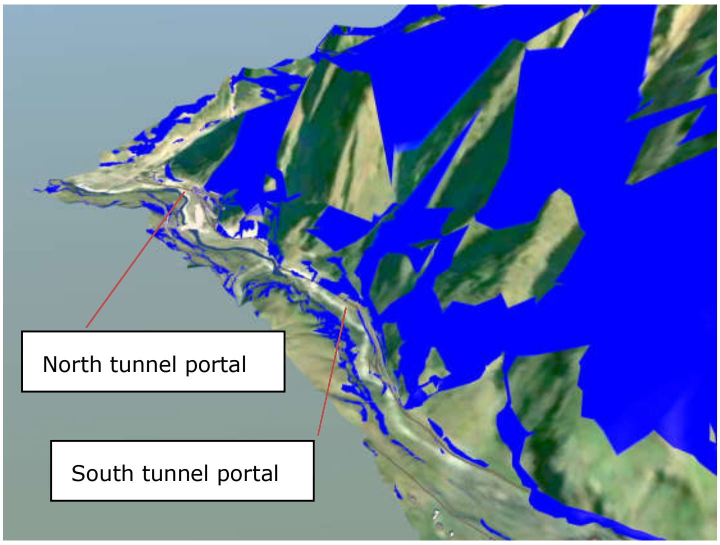



*Figure 18. View of the south portal. The slopes marked blue are 30°-45° angle slopes which are more likely to trigger snow avalanches. This needs to be evaluated in the final design.*

## 3.4 Tunnel portals and structures

### 3.4.1 General

Structural work for the project comprises of delivering and installing reinforcement and delivering and casting concrete for the following structures:

› Tunnel portal structures
› Foundation for tunnel portals
› Retaining wall by an existing electrical mast
› Foundation for retaining wall
› Service room inside the tunnel

An estimated amount of nearly 1000 $m^3$ of structural concrete is required.

### 3.4.2 Design codes and standards

All structures shall be designed according to the following Eurocode standards:

› EN 1990: Basis of structural design
› EN 1991-1-1: Actions on structures: Densities, self-weight, imposed loads for buildings.
› EN 1991-1-3: Actions on structures: Snow loads.
› EN 1991-1-4: Actions on structures: Wind loads.

› EN 1991-1-5: Actions on structures: Thermal actions.

› EN 1991-1-7: Actions on structures: Accidental actions.

› EN 1991-2: Actions on structures: Traffic loads on bridges.

› EN 1992-1-1: Design of concrete structures: General rules, and rules for building.

› EN 1992-2: Design of concrete structures: Reinforced and pre-stressed concrete bridges.

› EN 1997-1: Geotechnical design: General rules.

### *3.4.3* Proposed design for portals and structures

*Portal structures*

Portal structures shall be constructed at each side of the tunnel. The portal structures are necessary in order to provide a stable entryway and minimize risk of rock slides, avalanches or tunnel collapse at the entrances. The north portal is set to be approx. 20 m long with the sidewall closer to the mountain approximately 4 meters longer than the other. The south portal is set to be approximately 55 m long. The length of the portal is due to the risk of rock fall from the surrounding mountain and scree. Geometry of the portals shall follow the tunnel cross section, see Figure 19 and Figure 20.

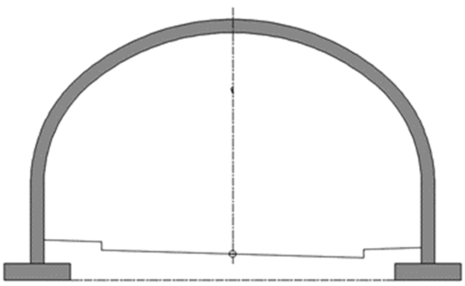


*Figure 19. Portal cross section*

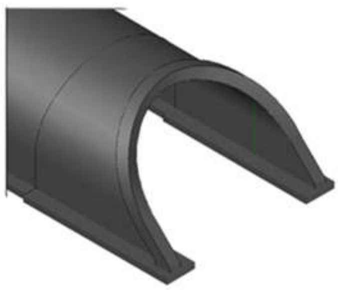


*Figure 20. Portal*

Prior to the foundation work for portals, excavation shall be conducted to establish foundations in an acceptable depth, or beneath the depth of the frost active layers. If during the foundation works, a solid bedrock cannot be reached, a well compacted suitable layer shall be used as the supporting layer beneath the concrete foundation.

Examination and determination of the load on the tunnel entrance structures due to rock fall, avalanches and mudflows has not been included in the preliminary design and should be taken into consideration prior to completing the design of the tunnel portals.

Constrictions in the tunnels geometry, portal entrances and exits shall be considered to withstand shear forces due to flowing water as a consequence of the Tergi river flowing into the tunnel due to a mudflow downstream.

*Retaining wall*

On north side of the tunnel, a 320-meter-long ramp shall be constructed due to the elevation difference of the tunnel entrance and the existing road. A retaining wall shall be constructed around an existing electrical mast, due to the elevation difference of the mast foundation and the road and to protect the mast. The wall shall be approximately 10 meters long and approx. 1-2 meters high.

Prior to the foundation work the retaining wall, excavation shall be conducted to establish foundations beneath the depth of the frost active layers. If during the foundation works, a solid bedrock cannot be reached, a well compacted suitable layer is to be used as the supporting layer beneath the concrete foundation.

The retaining wall shall be an in-situ casted concrete wall which shall support the loading from the traffic on the road. A drainage pipe shall be placed beside its foundation, on the earth side (road side) of the wall (see Figure 21).

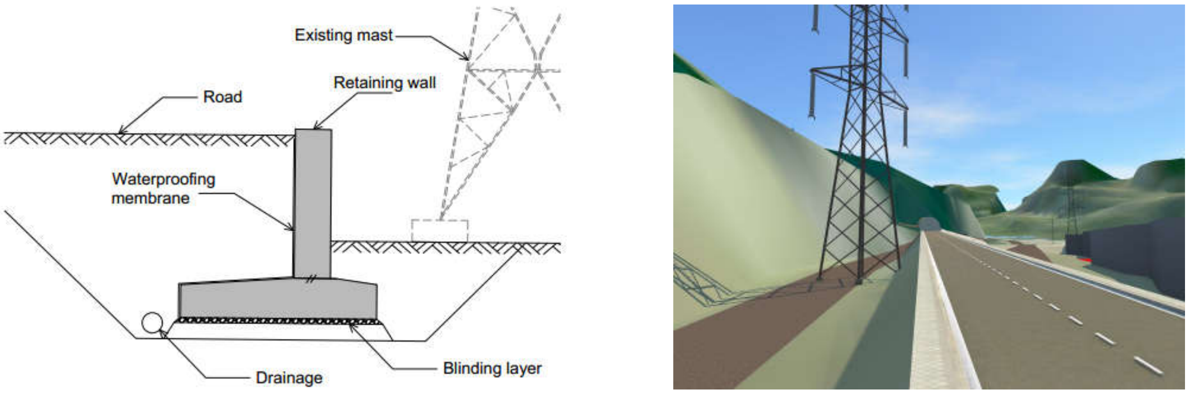



*Figure 21. Schematic look at retaining wall section*

*Technical room inside tunnel*

A service room shall be located approximately midway inside the tunnel. The service room shall be placed inside the tunnel at a lay-by and shall be approximately 6 m wide, 8 m long, and 2,6 m high and shall have two sections (see figure 9).

The service room shall be a concrete casted construction, placed higher than the road profile inside the tunnel, to protect the room in case of flooding in the tunnel. It shall have enough space to be equipped with all necessary technical installations.

When casting walls and plates for technical room up against the bed rock, depending on the situation, the contractor can use only single sided formwork where appropriate. This shall be accepted by the Project Manager prior to casting.

Floor finish inside the technical room shall be according to requirements for technical rooms.

On the figures below the placement of technical room and basic geometry is shown.

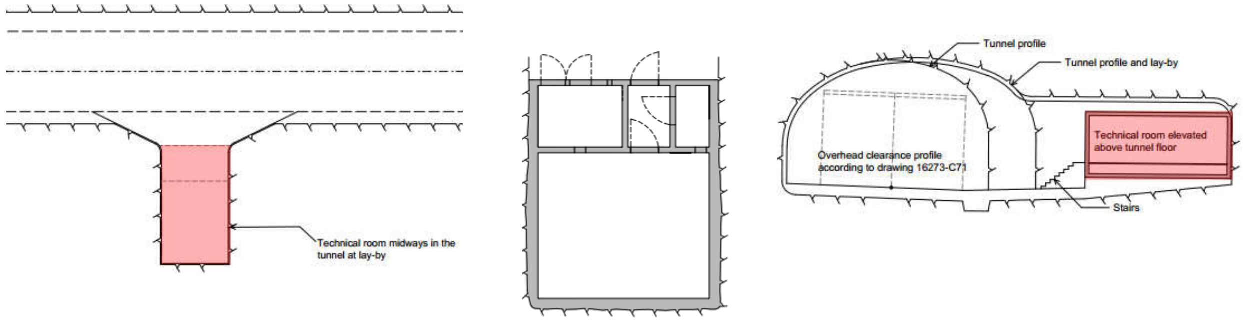



*Figure 22.Example service room layout (red)*

## *3.5* Construction considerations for concrete structures

The following information regarding the construction of the structures was assumed during the preliminary design of the structures:

- Classification of all concrete types of the individual structural parts including information on environmental class, minimum strength class, exposure class, minimum cover and maximum aggregate size is to be selected according to European standards.
- Types, design and durability of formwork for casting of the service room inside the tunnel, the portals and the retaining wall is to be accepted by the client prior to the start of the project.
- Method for casting and vibration of all concrete structures and the selected trimming and profiling procedure must be described in the contractor's casting program and submitted to supervision for approval.
- The concrete shall be cast and processed in such a way that the surface is tight, uniform in colour and texture, and free of cracks.
- Earth covered concrete surfaces (support walls backside and parts of tunnel entrance structures) shall be covered with waterproofing materials. These materials shall be an epoxy based primer beneath a bitumen material.
- Use of fibre-reinforced concrete is not allowed.

## 3.6 Drainage

### 3.6.1 General

Water leakages in the tunnel and runoff from the ramps and roads leading up to the tunnel need to be collected and discharged safely to the Tergi river. Drainage system for the tunnel and for the roads leading up to the tunnel is included in the preliminary design. Other piped supply systems, such as water supply and sewer collection are not anticipated as part of this project. Handling of water during construction time is also discussed in this chapter along with design criteria for tunnel due to possible flooding of the Tergi river.

### 3.6.2 Design standards and rules

All pipe networks shall be designed according to European standards or similar.

### *3.6.3* Proposed design for drainage

*Tunnel drain system*

Water leakages in the tunnel shall be collected and conveyed out of the tunnel via pipe system that is placed at a frost free depth. Frost free depth shall be determined based on local environmental conditions and local design standards but no less than 1 meter or by using insulation boards.

Drain pipes shall be placed along each side of the tunnel to collect leakage water from rock. Leakages in walls and crown are collected by lining which directs water to drain pipes. Drain pipe diameter in the preliminary design are assumed to be DN100mm based on expected leakage in tunnel of 0.14 l/s/meter.

The Contractor shall study the geological report and seek information from construction reports from the construction of the tunnels at the Dariali HPP to confirm leakage rates. Once the construction of the tunnel is completed, it is required to map the locations of wet and dry stretches and measure discharge rates and incorporate on-site information into the final design. Need for additional drain pipes along wetter sections of the tunnel should be considered. Minimum size of drain pipes shall be 100mm.

A separate collection system shall be designed to carry water from drain system and from surface water from road such as washwater, leakage water from section where lining is not used, surface water, and incidental spills. Inlets shall be installed and integrated into the road system every 80 meters to collect this water and connect to the collection pipe. Drain pipe system shall also be connected to the collection pipe at intervals no longer than 80 meters.

Manholes shall be installed for access and cleaning of collection pipe. Distance between manholes shall not exceed 80 meters. Minimum diameter for collection pipe shall be 150mm but pipe size is assumed to be DN400mm at 5% slope with a total capacity of around 740 l/s. Pipe shall be designed to have sufficient capacity to convey all drainage from the entire length of the tunnel. Pipe shall be accommodated in a drainage trench sufficiently deep enough to protect against frost and allow for placement of pipe bedding material. The width of the trench shall be at least 1.5 time that of the nominal diameter of the pipe.

Treatment of discharge water from tunnel shall follow local or national requirements or permits for stormwater treatment prior to discharge to waterbodies. Review of local and national standards for stormwater treatment and design an appropriate water quality treatment system that meets those standards shall have to be implemented prior to final design. At a minimum, the outfall pipe shall be equipped with an oil separator and sediment tank to be sized for the design discharge.

Construction of the drainage and collection system shall take place after excavation of the tunnel. Separate drainage plan needs to be designed during construction.

*Road drainage system*

All runoff from roads shall be collected into a drainage system and drained away from roads and tunnel entrances wherever necessary to ensure no road runoff drains into tunnels or ponds against the roadway. All surface water runoff shall be led away from road into culverts or towards ground that slopes away from the road.

Drainage system shall be either a closed pipe system with curb and gutter and inlets collecting stormwater and discharging to the nearest outfall location or an open channel system with shoulders and ditches discharging to the nearest outfall location. All open channel systems and discharge points shall be designed and protected with appropriately designed lining to eliminate soil and vegetation erosion.

Pipe and/or ditch sizes shall be determined based on subcatchments and rainfall quantities in approach area. Rainfall quantities shall be based on local or national standards and shall be no less than 10-year recurrence interval. Minimum pipe size shall be 200mm.

The preliminary design provides ditches along the ramps on both north and south sides with one DN400 concrete culvert on either side of the tunnel. Culverts shall be used to drain all closed depressions as a result of the construction of the ramps leading up to the tunnel. Any additional culverts that are found to be necessary in the hydrological study shall be provided in the final design. Culverts shall be designed to convey runoff from a storm with no less than 10-year recurrence interval. Minimum pipe size to be 400mm.

*Water supply for fire safety*

Water supply for fire extinguishing needs shall be provided in and around the tunnel. The Norwegian standards call for fire hydrants near the portals and inside at intervals not to exceed 250 m. However, if the water supply is not available it shall be ensured that sufficient water is provided by other means, for example using a tanker. For the preliminary design, it has been assumed that the tunnel manager shall provide for a tanker on standby as an alternative level of water supply for fire protection for the tunnel operations.

## 3.7 Construction considerations for drainage system

*Construction time dewatering*

During construction, contractor shall design, furnish, operate, maintain and dismantle all the temporary dewatering facilities required to remove/divert water of every origin (precipitation, natural surface flow or groundwater seepage, contractors use, etc.) from construction activities, working areas on the surface as well as underground.

*Treatment of discharge water from dewatering activities*

No water containing harmful matter shall be allowed to pollute creeks, rivers, groundwater, etc. The Contractor shall provide, settlement ponds and other measures to ensure that potentially contaminated or polluted matter from the execution of the Works is nowhere released into creeks, rivers, or the ground, all according to the Contractor’s approved HSE Plan, cf. 1.6, Health, Safety and Environment (HSE).

*Protect temporary structures during construction from river flooding*

The Contractor shall also, as applicable, design, furnish, maintain, and remove river diversions and protect the construction activities, working areas on the surface as well as underground against possible floods.

## 3.8 Electrical

### 3.8.1 General

EU minimum safety requirements for tunnels ensure that they are adequate for the volume of traffic and have guidelines to emergency exits and lights to prevent them from becoming death traps in an accident. EU law or Directives sets minimum safety requirements for tunnels, including measures to evacuate the tunnels on foot through possible escape tunnels out to safety.

The Dariali tunnel is over 1000-meter long. Therefore, a technical room shall be placed accordingly where a control panel is situated with other technical equipment and cooling plant installed.

Floods are to be expected in the Dariali road tunnel of up to 1,2-1,5m that may occur occasionally from the Tergi river after a mudflow from the surrounding mountains. Because of this all electrical cabinets shall stand on a platform and the height of platform shall be accordingly.

### 3.8.2 Design standards and rules

Detail design of electrical engineering and safety shall be according to European standards or similar. For the preliminary design norwegian standard Hb-N500 from 2016 and the EU directives were used.

The tunnel is of Class C, for 4-8 thousand cars pr. month, according to Norwegian standard Hb-N500.

Please note that EU member countries are required to adopt the EU directive 2004/54 on road tunnel safety and they shall meet the new standards of safety in road tunnels by 30$^{th}$ of April 2014. The Directive applies to all tunnels exceeding 500 m on the Trans European Road Network (TERN). The EU countries have until April 2019 to comply with the EU Directive.

All equipment shall be CE approved. In addition, the manufacturer or their agent shall confirm, that the equipment conforms with the specified requirements. All cables shall be according to classification standard.

All equipment shall be connected to continuous power (UPS) and here below is a list of possible equipment's:

- Surveillance, control
- Flashing red stop signal
- Priority lighting See Section 1003.6 in Norwegian handbook 021
- Escape route lighting
- Emergency telephone
- Service signs
- Emergency Exit signs
- Communication and broadcasting equipment

### *3.8.3* Proposed design criteria for electrical works

*Information on equipment tolerance*

The atmosphere in tunnels is corrosive. This is due to the condensation of water from warm, moist air and salt. Water in the tunnel space can be mildly acidic due to nitrous acid and nitric acid from nitrogen oxides in the exhaust. All equipment, cables and lighting should be accordingly insulated and corrosion protected. Platforms, profiles and bolts for fastening of all equipment's shall be of corrosive tolerated materiel.

The level of armoring for selected equipment is:

- Fan motors IP 55
- All sensors IP 65
- Electric cabinets, emergency lighting, and internally illuminated signs IP 66
- Light fittings IP 65, nipples on light fittings IP 66

- Junction boxes and nipples in the tunnel room IP 66
- Junction boxes and nipples in the shoulder and pavement IP 68.

*Tunnel safety*

The EU Directives, to a certain level, is prescriptive on technology. Automatic incident detection for tunnels monitored from control centers is being required in the new Directive and is mandatory for tunnels over 3 km.

The tunnels in this project is about 1,1 km. The Norwegian standard recommends to use red lights at the entrance of tunnel to allow to stop all traffic in case of an accident. Other controls and safety features can be added like measuring humidity, temperature in air and on the road, wind speed and CO/NO in the tunnels.

*Tunnel lighting and safety*

According to the Norwegian standard all road tunnels longer than 100m shall have lighting. Technically, a tunnel is divided into an entry zone, a transition zone and an inner zone, see Figure 23 here below, see also drawing in Appendix A.

Entrance and exit lighting have to be adjusted throughout the day to make entering and exiting the tunnel as safe as possible. At night time, the entrance/exit system is turned off and the internal lighting may be dimmed according to the project. The best control can be achieved controlling entrance/exit lighting with a luminance photometer, for a real time adjustment of the luminous flux according to the outside lighting level.

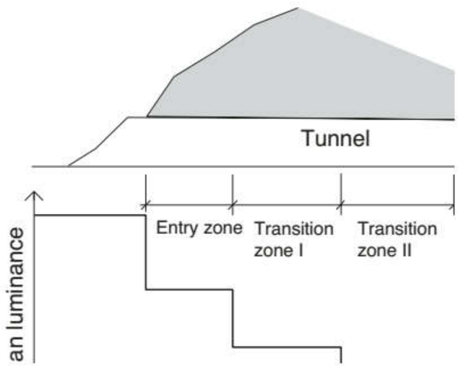



*Figure 23. Tunnel transition zones*

*Table 18. Length of transition zones for specific speed limits*

| Speed limit (km/h) | Entry zone length (m) | Transition zone length (m) | |
|---|---|---|---|
| | | I | II |
| 50 | 40 | 70 | 70 |
| 60 | 50 | 80 | 80 |
| 70 | 60 | 100 | 100 |
| 80 | 70 | 110 | 110 |
| 90 | 75 | 120 | 120 |

The adaptation of the eye is subject to a time delay. The gradual reduction in luminance implied to assist in the adaptation of the eyes, which is dependent on the driving speed. Table 18 shows the length of the entry zone and transition zone as a function of speed. Table 19 gives the requirements of the lowest mean luminance level of the various lighting zones as a function of traffic volume defined as AADT(10) and the speed limit in the tunnel.

Emergency lighting or priority lighting is determined by every fourth or fifth light continuing to operate for about 1 hour following a power breakdown.

Best practice is to increase the light level when entering the tunnel for the first 150 m in both ends and decrease the light level in between by 1/3 to ¼. Lighting in lay-bys and turning points needs special illumination.

*Table 19. Lowest mean luminance level of various lighting zones*

| AADT (10) | < 2 500 | 2 500 - 5 000 | | 5 000 - 7 500 | | > 7 500 |
|---|---|---|---|---|---|---|
| Zone / Speed limit | - | 50 km/h | 80 km/h | 50 km/h | 80 km/h | - |
| Entry zone | 50 cd/m² | 1.50 % | 3.00 % | 2.5 % | 5.0 % | 5.0 % |
| Transition zone I | 10 cd/m² | 0.30 % | 0.60 % | 0.5 % | 1.0 % | 1.0 % |
| Transition zone II | 2 cd/m² | 0.06 % | 0.12 % | 0.1 % | 0.2 % | 0.2 % |
| Inner zone day | 0.5 cd/m² | 2 cd/m² | 2 cd/m² | 2 cd/m² | 2 cd/m² | 4 cd/m² |
| Inner zone night | 0.5 cd/m² | 1 cd/m² | 1 cd/m² | 1 cd/m² | 1 cd/m² | 2 cd/m² |

*Other safety equipment*

UPS is mandatory to help with evacuation in case of an accident or power loss. Additionally, good marking of guidance signs to lead the way to safety is required. A telephone booth every 375m along with a fire extinguisher placed in a box on the wall every 125m in regular distances is required.

Lay-bys and equipment required for tunnel of category C are listed on Figure 24 and Figure 25.

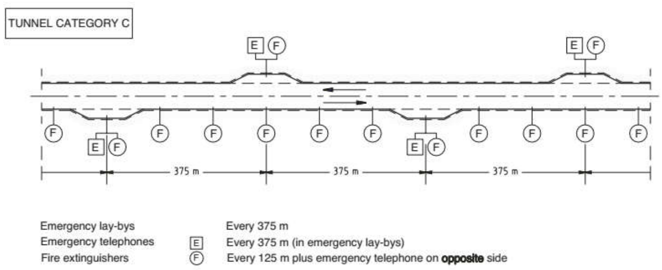



*Figure 24. Placement requirements of tunnel furniture.*

Technical equipment must be located in a separate niche. An extra emergency lay-by or technical room must be installed in a tunnel of more than 1km. in length, see Figure 25.

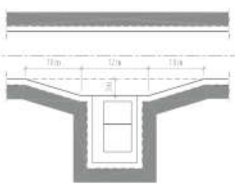


*Figure 25. Example of a technical room in a tunnel.*

Here below we have table from Norwegian standard on safety equipment in tunnels from 2016.

*Table 20. Safety equipment in tunnels.*

| EQUIPMENT | TUNNEL CATEGORY | | | | | |
|---|---|---|---|---|---|---|
| ● Obligatory<br>◷ Evaluated | A | B | C | D | E | F |
| Emergency lay-bys | | ● | ● | ● | ● | ● |
| Turning points | | ● | ● | ● | | |
| Escape possibility by foot | | | ◷ | ● | ● | ● |
| Power supply, lighting and ventilation | Designed accoring to standard | | | | | |
| Emergency power supply | ● | ● | ● | ● | ● | ● |
| Emergency exit lighting | ● | ● | ● | ● | ● | ● |
| Emergency Exit sign | ● | ● | ● | ● | ● | ● |
| Emergency telephone | ● | ● | ● | ● | ● | ● |
| Fire extinguishers | ● | ● | ● | ● | ● | ● |
| Water for fire extinguishing | | ● | ● | ● | ● | ● |
| Flashing red stop signal | | ● | ● | ● | ● | ● |
| Remote controlled barriers | | ◷ | ● | ● | ● | ● |
| Changeable signs | | ◷ | ◷ | ◷ | ◷ | ◷ |
| Lane signals | | | | | ◷ | ◷ |
| CCTV surveillance | | ◷ | ◷ | ◷ | ◷ | ◷ |
| Communication and broadcasting equipment | ● | ● | ● | ● | ● | ● |
| Mobile telephone | | ◷ | ◷ | ◷ | ◷ | ◷ |
| Height control barrier | ● | ● | ● | ● | ● | ● |

## 3.9 Ventilation

### 3.9.1 General

Ventilation system shall be installed in tunnels with length over 1000 m when cars per day is > 1000. The design shall be based on measurements and calculation of pollution levels after drilling is completed. The system shall be dimensioned for fire and for expected pollution level, 10 years following the opening of the tunnel (AADT(10)).

### 3.9.2 Design standards and rules

The ventilation design shall be according the European standards or similar.

The preliminary design for the ventilation systems engineering and safety was estimated according to Norwegian standard Hb-N500 from 2016 and the EU directives.

### *3.9.3* Proposed design standards for electrical works

By longitudinal ventilation increases the pollution level in the tunnels length direction. By dimensioning required fresh-air capacity, account shall be taken to the background concentration of NO2 by the tunnel opening, see Figure 9.1 in the Hb-N500.

The air quality shall be monitored with measurement equipment for CO and measurement equipment for NO2 (or NO).

With a normal mixture of exhaust gases, it is only necessary to determine the level of permissible concentration of carbon monoxide (CO-gas) and nitrogen dioxide (NO2 gas). The concentration of the other toxic gases does not present a health hazard if a sufficient dilution of CO and $NO_2$ gases is achieved. In order to attain sufficient control of gas concentration in the tunnel, measuring instruments should be installed in the middle of the tunnel and at both ends.

Threshold concentrations of gasses and particles are given in table 9.2 in Hb-N500.

In case of a tunnel over 1000m a technical room shall be placed accordingly where control panel is situated with other technical equipment and ventilation system installed.

*Figure 26. Tunnel designed and build by Eurocode standards.*

## 3.10 Fire and Safety

### 3.10.1 General

The first priority for fire design of all tunnels is to ensure their safety. Taking preventive actions against critical events that may endanger human life, the environment and the tunnel structure is by far the most effective way to ensure its safety.

Additionally, in the event of fire the objective of fire safety design is to reduce the consequences of eventual fires.

### 3.10.2 Design standards and criteria for fire safety in tunnels

This tunnel falls into to tunnel category C according to the Norwegian tunnel handbook [Vegdirektoratet, 2016]. The category is based on traffic volume and the tunnel's length. The Norwegian tunnel handbook meets the requirements of the EU standards and adds extra requirements based on experience from Norway.

Load bearing structures and cave/tunnel reinforcement should be designed for the design fire and have good fire resistance. Asphalt and cement as a road surface shall be considered equal with respect to fire safety. All materials covering the cave's surface are assumed to be non-flammable, use of flammable materials is subject to the handbook's restrictions.

This preliminary design is based on the Norwegian tunnel handbook.

The Design shall be according to the following standards as referenced in this chapter:

- EN 54: Fire detection and fire alarm systems.
- EN 12101-3: Smoke and heat control systems - Part 3: Specification for powered smoke and heat exhaust ventilators.
- EN 1838: Lighting application - Emergency lighting.
- EN 50172: Emergency escape lighting systems.
- EN 62034: Automatic test system for battery powered emergency escape lighting.
- ISO 3864-1: Graphical symbols -- Safety colours and safety signs -- Part 1: Design principles for safety signs and safety markings.
- EN 60598-2-22: Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting.
- EN ISO 7010: Graphical symbols - Safety colours and safety signs - Registered safety signs.
- ISO 16069:2004: Graphical symbols -- Safety signs -- Safety way guidance systems (SWGS).
- ISO 17398:2004: Safety colours and safety signs -- Classification, performance and durability of safety signs.

### *3.10.3* Proposed design standards fire design of tunnels

Heat, smoke and toxic chemicals from fires can damage a tunnel's structure and result in loss of lives. Damage to structure and installation is generally caused by the heat from the fire but heat is rarely a cause of death in tunnel fires. Smoke lowers visibility that impedes evacuation and with prolonged exposure leads to toxicity.

The main consequences to be mindful of are; fatalities, economic losses related to reconstruction, traffic rerouting due to tunnel closure after a fire and potential environmental damage.

Many events and various faults can lead to a fire in a tunnel but the majority of them are caused by electrical or mechanical defects in the vehicles themselves. Electrical malfunction and motor or brake overheating for example. Most large fires are caused by accidents and the probability of a serious fire is greater in heavy goods vehicles than in passenger cars.

Smoke and heat produced by the fire moves with the slope of the tunnel so emergency response services should be available from lower ground at the tunnel's north entrance.

*Fire suppression systems*

Fire suppression systems can be used to prevent local fires from developing into severe fires. For example, fixed suppression systems in technical rooms, or fixed suppression systems located in the traffic tubes. It is not required to use a fire suppression system but it should be considered as part of the fire safety design.

Automatic fire detection and alarm systems, in accordance with EN 54 and recommendations from local building authority, should also be considered as part of the fire safety design but are not required. The alarm signal could be automatically submitted to an approved emergency dispatch center.

*Emergency escape*

The requirements in the Norwegian tunnel handbook for emergency exit to a safe place, e.g. into a separate escape tunnel, apply for tunnel in class D (number of vehicles per lane > 4000), and for tunnels longer than 10 km in tunnel class C. Recommended distance between each emergency exit is 500 m.

Because the tunnel is only 1.1 km long and in class C, it is not necessary to offer a special escape exit. It is therefore expected that the escape route will be through tunnel portals on each end of the tunnel.

*Smoke ventilation system*

Ventilation and smoke control in case of fire is considered to be primordial. Smoke ventilation in tunnels with greater slope than 2% has to be calculated with the final dimensions of the tunnel, as part of the fire safety design. The required information is air volume and velocities or simply the design objectives that must be based on the selected design fire. Requirements are stated to prevent smoke from penetrating into the escape routes and ensure clear access for rescue staff.

*Table 21. Fire size for tunnel length over 1 km (greater slope than 2%).*

| Tunnel class | Length | HRR | curve | Time (minutes) | Minimum air speed |
|---|---|---|---|---|---|
| A | > 1,0 km | 50 MW | HC | 60 | 3,0 m/s |
| B | > 1,0 km | 50 MW | HC | 60 | 3,0 m/s |
| C | > 1,0 km | 50 MW | HC | 60 | 3,0 m/s |
| D | < 2,0 km<br>> 2,0 km | 50 MW<br>100 MW | HC<br>HC | 60<br>60 | 3,0 m/s<br>4,5 m/s |
| E | > 1,0 km | 50 MW | HC | 60 | 3,0 m/s |
| F | < 2,0 km<br>> 2,0 km | 50 MW<br>100 MW | HC<br>HC | 60<br>60 | 3,0 m/s<br>4,5 m/s |

The minimum air speed for smoke ventilation is 3,0 m/s for category C.

See the graph below for requirements for smoke ventilation for a 50 MW fire, ΔP = 0 Pa.

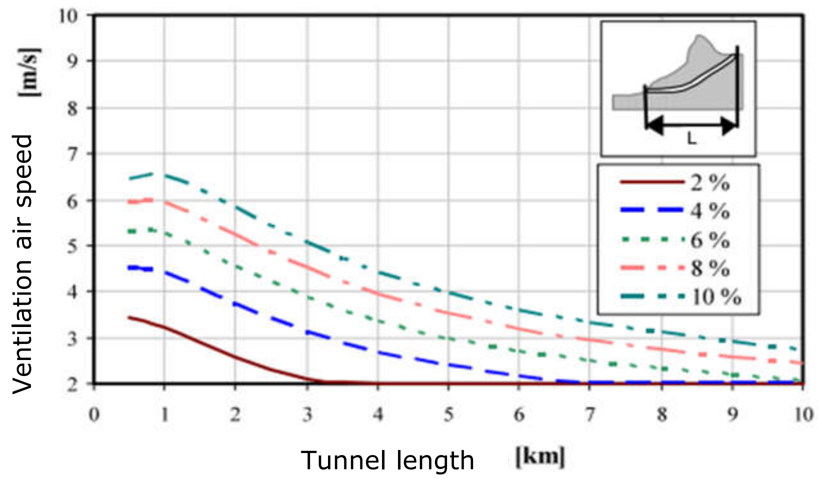



*Figure 27. Smoke ventilation air speed requirements according to Hb-N500*

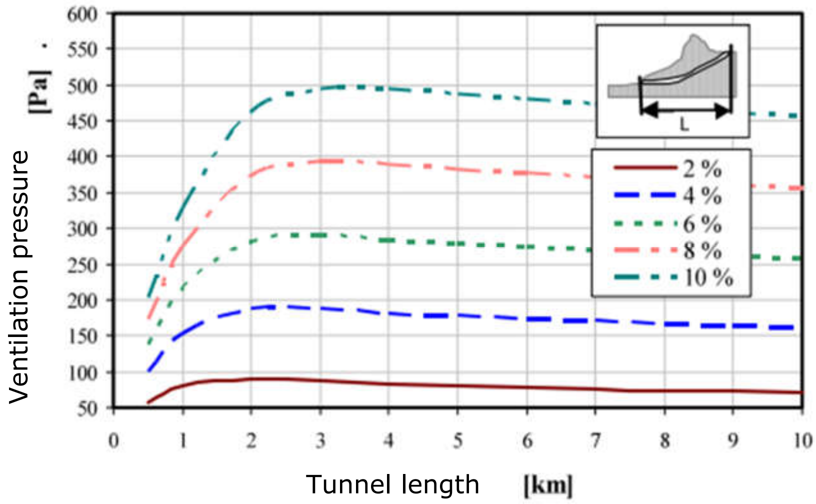



*Figure 28. Smoke ventilation pressure requirements according to Hb-N500*

Generally natural smoke ventilation is sufficient in tunnels where the gradient exceeds 2% throughout the tunnel. Various factors can affect airflow through the tunnel and has to be calculated according to the final design.

If the results show that mechanical ventilators are necessary despite the gradient the fire rating of the ventilators should be in accordance to EN 12101-3 and the calculated results.

*Water supply*

Water supply should be accessible in the event of fire to be used in firefighting or suppression. Water in sufficient supply and pressure is unavailable at the site so must be secured by other means, a reservoir for example or a water tanker. Method of availability, volume and pressure of the water is to be decided according to a performance based design.

*Technical emergency installations*

Emergency stations should be placed at the tunnel's openings and with regular intervals throughout the tunnel never exceeding 125 m between two stations. At every 3 station there should be enough room to stop a car at the station without slowing traffic down.

The stations are to be equipped with an emergency phone and two 6 kg ABC powder fire extinguishers. The fire extinguishers should be connected to an alarm that alerts the control center if an extinguisher is removed. Emergency stations at the openings should additionally be equipped with an emergency control panel.

They are to be located no further than 300 m from the entrance but no closer than 100 m to ensure enough room for evacuation and smoke ventilation. The boom should be able to close manually and has to be long enough to block its half of road but not the outgoing traffic.

Loudspeaker alarm system and surveillance cameras, although not required, should be considered as an added safety feature as part of the fire safety design.

*Emergency escape lighting*

The tunnel must have an emergency escape lighting system. The emergency lighting system shall be designed and installed according to EN 1838, EN 50172, EN 62034, ISO 3864-1, EN 60598-2-22, EN ISO 7010 and ISO 16069:2004. Classification of the signs shall be according to ISO 17398:2004. The guidance system shall be along the entire length of the tunnel and all escape routes.

Emergency lighting shall be minimum 1 lux in the centerline of an escape route. The system should light for 60 minutes in case of a power failure. Manual call points, first aid kits, portable fire extinguishers and fire alarm control panel should also have 5 lux lighting.

*Electric cables*

Cables which are to be used in the tunnel should be classified based on their requirements in accordance to Norwegian tunnel handbook.

Electric cables pose a potential fire risk and should be buried wherever possible. Cables in open ducts that do not serve critical functions shall be halogen free and satisfy the requirements of the following standards: IEC 60332-1-2, IEC 60332-3-24, IEC 60754-1, IEC 60754-2, IEC 61034-2.

Cables in open ducts that serve critical functions to fire safety should be fire-proof cables and satisfy all previous requirements in addition to IEC 60331.

*Fire department*

In the preliminary design for fire safety it is assumed that the access for the fire department is available from the tunnel's north entrance. If no fire departments are available from the north the existing road has to be kept open and accessible or other fire safety measures have to be considered.

The catastrophic mudflows from the Devdoraki valley causing closure of the road for long periods of time, seriously harm the country's economy. There are significant safety risks for passengers and personnel, employed by the infrastructure facilities existing in the valley.

According to the surveys, carried out in Devdoraki river valley by National Environmental Agency LEPL of the Ministry of Environment and Natural Resources Protection of Georgia, actually, there are no preventive measures against mudflow process and the only way to minimize expected hazards is to select relatively safe alternative of road section project implementation.

## *3.11 Environmental considerations*

### 3.11.1 General

Portals of the proposed tunnel and corridors of access roads will be located outside the borders of the national park. The major part of the tunnel will pass under the protected areas, under the great depths.

Prior to the construction works, it will be necessary to cut approximately 22 pine trees and 35 Litwinow's Birch trees. There is no vegetation cover within the corridor of access road to the tunnel portal. Therefore, no impact is expected there.

According to the design solution proposed within the feasibility study, for the arrangement of the construction site approximately 125 pine trees, 115 Litwinow's Birch trees, 40 Poplar, 15 Juniper, 7 rowans and Raspberry, buckthorn and spirea bushes will be cut.

Additional study of vegetation cover shall be carried out prior to the construction, after the construction project is prepared and it will be possible to define the exact number of trees to be cut.

It should be noted that based on the botanical study conducted within the project influence zone, no Red List species have been found there

The Contractor shall review and conclude in his bid “Environmental Mitigation Plan” and “Environmental Monitoring Plan” presented in Appendix C and D. The Contractor shall review the and conclude in his bid „Resettlement Action Plan “.

### 3.11.2 Environmental Mitigation Plan

Environmental mitigation measures involve:

- Impact avoidance/prevention;
- Impact reduction;
- Impact mitigation;
- Damage compensation;

Impact can be avoided and risks reduced using best construction and operation practices. Designed project considers some measures of mitigation. However, as not every impact can be avoided, a plan of mitigation measures for every phase is worked out to ensure maximum environmental safety of the project.

The environmental mitigation plan consists of a “live” document, which is to be amended and corrected on the basis of monitoring/observation data. In case of any changes in work procedures, corresponding amendments are to be made in the mitigation measures plan. Owner's representative should be responsible for environmental monitoring and management. Throughout the construction phase, responsibility on environmental management is shared between the Owner and Contractor.

In Appendix C the Environmental Mitigation Plan is presented for both construction phase and operation phase.

### 3.11.3 Environmental Monitoring Plan

The aim of environment monitoring is:

- Verification of potential impact assessment;
- Control/ensure compliance with environmental and safety law and standards;
- Control risks and ecological/social impact;
- Provide public/stakeholders with corresponding information;
- Determine effectiveness of mitigation measures and correct them if necessary;
- Control environmental impact and risks during construction and operation of the road;

Monitoring involves visual observation and measurement (as needed) techniques. The monitoring plan considers monitoring parameters, monitoring time and frequency, collection and analysis of monitoring data. Monitoring frames depend on significance of anticipated impact and risks.

In Appendix D the Environmental Monitoring Plan is presented for both construction phase and operation phase.

# 4 Construction Methodology

## *4.1 Introduction*

This section describes how the preliminary design outlined in previous chapters of this report could be constructed.

The methodology ultimately deployed for the construction of the tunnel would be determined by the organization appointed to undertake these works. The methods adopted may therefore differ from the indicative method presented in this document.

The construction methodology is based around standard, industry good practice construction methods and techniques that are likely to be used by a competent and experienced contractor. The construction methodology has considered working space requirements to ensure that the tunnel could be built safely and unnecessary constraints are not placed on the construction methods likely to be adopted.

A preliminary construction schedule has been developed based upon the construction methodology presented in this section. An overall target of the planned construction schedule is to minimise the total construction time and to bring the tunnel into operation as soon as possible.

The works necessary to complete the tunnel-project can be subdivided into a number of elements which when planned holistically could be constructed in a logical and safe manner. The Service Levels and informative Bill of Quantities in the bidding documents are based on the similar project schedule.

The main elements of the project are listed below:

- Site facilities, installations and services
- Preliminary completion
    a. Surface works (excavation, fills and preliminary roadwork)
    b. Drilling and grouting (tunnel works)
    c. Rock reinforcement and sprayed concrete
    d. Piping
- Water and frost protection
- Concrete structures
- Road works (tunnel pavement and road ramp completion)
- Furnishing of tunnel and roads
- Demobilization

## 4.2 Site facilities, installations and services

Access to the site is already available through existing roads, which connects the area to the main highways in Georgia. The distance from the capital Tbilisi to the proposed site is approximately 160 km. The main potential harbours for import of equipment and machinery lie on the east coast of the Black Sea (Batumi or Poti), with transport distance of some 530 km to the site.

Site compounds would be established at the commencement of the works and would remain throughout the construction phase. The layout of construction compounds needs careful consideration to ensure a safe, secure and efficient base for operation and associated construction activities.

The main site compound could be located near the existing Dariali power station, and would contain offices, plant maintenance facilities, materials testing laboratory, recycling, medical and welfare facilities. The location shall be defined and proposed by the Contractor.

The compound shall contain sufficient offices and facilities to support the tunnelling activities to be undertaken. The site has to utilise the excavation material, and shall therefore have a storage area at the compound to provide easy utilisation of the on-site segments.

The Contractor shall define and propose all construction power. The Dariali HEP substation is near the north portal. The power supply for the tunnelling work is foreseen to be on 10 kV into the tunnels with transformers moved as the tunnelling work advances.

A concrete plant should be set up near the Kristinka river close to the main site compound.

## 4.3 Preliminary completion

### 4.3.1 Earth works (surface excavation, underground excavation, fills and preliminary roadwork)

The removal and disposal of topsoil and surplus and unsuitable material would be carried out prior to any filling work. The topsoil, vegetation and trees are to be disposed to spoil areas.

All access roads, and connections to existing roads should be considered prior to starting any filling work. The Contractor shall maintain the traffic through the valley throughout construction of the tunnel and roads. All connection roads and construction roads shall be permanent gravel roads. Construction and preliminary roads required by the contractors to execute the Works shall be planned, designed and constructed individually.

The filling work should begin by finding filling material for construction of a new access road to the Dariali HEP. Then construction of the tunnel approach ramps on both sides of the tunnel. Construction of a retaining wall around the existing mast at the power station, should be constructed alongside the filling work. Any drainage system alongside the ramps and retaining wall would be constructed at this stage in the project.

Work concerning construction of rip-rap protection, should be considered alongside the filling work since the base of the rip-rap needs to be excavated below the filling.

Tunnel excavation can commence after construction filling ramps are finished, following the excavation completion of the fills and preliminary roadwork.

*Table 22. Following table show the estimated volumes of excavation and roadworks.*

| | **Theoretical volume solid cubic [m3]** | **Loose cubic [m3]** |
|---|---|---|
| TOPSOIL | 4000 | 4600 |
| SURFACE EXCAVATION | 17500 | 21875 |
| FILLS AND ROADWORK + other fillings (excluding concrete and asphalt) | 170500 | |
| UNDERGROUND EXCAVATION | 98000 | 176400 |

The excavation method recommended is Drill and Blast. Excavation of the tunnel would be carried out from both ends of the tunnel. This requires two separate unites for excavation and installation of tunnel reinforcement in the tunnel and all it's necessary equipment.

Drilling and grouting is estimated near the tunnel portals and could be some places inside the tunnel.

The preliminary design assumes that the material from the tunnel excavation is be used on site for fillings and ramps. All unnecessary material would be removed from the site by road and driven to spoil areas.

In correlation with the excavation the tunnel shall be reinforced as specified in the above sections.

### 4.3.2 Piping and subgrade in tunnel

Blasting of drainage ditch should be done parallel to the main excavation. After excavation piping and subgrade are installed in the tunnel. The Contractor should evaluate where the high-voltage cable should be located in the tunnel.

The subgrade inside the tunnel can thereafter be carried out once the piping work is completed.

### 4.3.3 Portals

The concrete structures in this project are the north and south portals, and the technical room inside the tunnel. The concrete retaining wall would already be constructed in the preliminary completion.

After preliminary completion of the tunnel is finished the portal construction can start. The casting of the portals would be conducted at both sides simultaneously to minimise construction time.

The construction and casting of the portals foundation would be carried out prior to all other concrete works. The setup of formwork for the portals themselves shall be carried out in such a way that access to the tunnel itself is possible. This requires special formwork that would be designed by the contractor and approved by the Project Manager.

Following the casting of the portals, which is conducted in sections, all membrane and sprayed concrete work is to be established.

The commence of casting the technical room inside the tunnel shall be following the portals. The foundation/flooring of the room will be casted, followed by the walls and the ceiling.

### 4.3.4 Water and frost support

Water and frost support can commence following the preliminary completion and should then be installed as specified in the tunnel and portals.

#### 4.3.5 Road works

Roadworks outside the tunnel can commence following the preliminary completion. The work inside the portals and tunnel can commence following the completion of the W&F insulation and concrete structures.

The concrete pavement construction in the tunnel and portals will be carried out in segments and will follow the completion of each tunnel profile segment.

The laying of concrete pavement is to be conducted followed by the finishing of the concrete surface, with joints and sealants.

### 4.4 Furnishing

All furnishing work inside the tunnel and outside, shall be commenced following the completion of the road work. This includes all technical equipment and utilities according to specifications.

### 4.5 Demobilization

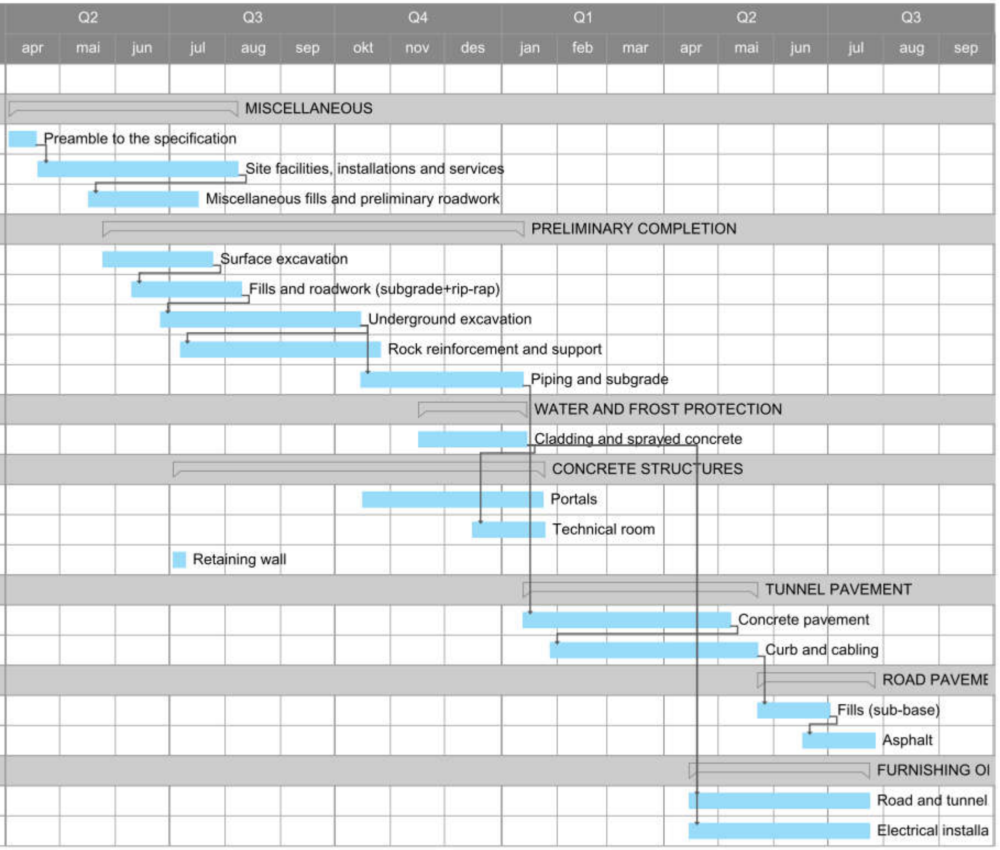
Following the completion of the construction, testing and commissioning activities, all construction facilities (offices, workshops, material stockpiling areas waste facilities etc.) would be removed and the land would be reinstated to its previous condition.

### 4.6 Construction schedule

A construction schedule has been prepared for the project. The schedule is divided into the main construction items according to the different project stages. All major activities and milestones are listed.

Construction schedule:

| | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | | | | |
| 2 | MISCELLANEOUS | 127d | 03.04.17 | 07.08.17 |
| 3 | Preamble to the specification | 15d | 03.04.17 | 17.04.17 |
| 4 | Site facilities, installations and services | 111d | 19.04.17 | 07.08.17 |
| 5 | Miscellaneous fills and preliminary roadwork | 61d | 17.05.17 | 16.07.17 |
| 6 | PRELIMINARY COMPLETION | 233d | 25.05.17 | 12.01.18 |
| 7 | Surface excavation | 61d | 25.05.17 | 24.07.17 |
| 8 | Fills and roadwork (subgrade+rip-rap) | 61d | 10.06.17 | 09.08.17 |
| 9 | Underground excavation | 111d | 26.06.17 | 14.10.17 |
| 10 | Rock reinforcement and support | 111d | 07.07.17 | 25.10.17 |
| 11 | Piping and subgrade | 90d | 15.10.17 | 12.01.18 |
| 12 | WATER AND FROST PROTECTION | 60d | 16.11.17 | 14.01.18 |
| 13 | Cladding and sprayed concrete | 60d | 16.11.17 | 14.01.18 |
| 14 | CONCRETE STRUCTURES | 206d | 03.07.17 | 24.01.18 |
| 15 | Portals | 100d | 16.10.17 | 23.01.18 |
| 16 | Technical room | 40d | 16.12.17 | 24.01.18 |
| 17 | Retaining wall | 7d | 03.07.17 | 09.07.17 |
| 18 | TUNNEL PAVEMENT | 130d | 13.01.18 | 22.05.18 |
| 19 | Concrete pavement | 115d | 13.01.18 | 07.05.18 |
| 20 | Curb and cabling | 115d | 28.01.18 | 22.05.18 |
| 21 | ROAD PAVEMENT COMPLETION | 65d | 23.05.18 | 26.07.18 |
| 22 | Fills (sub-base) | 40d | 23.05.18 | 01.07.18 |
| 23 | Asphalt | 40d | 17.06.18 | 26.07.18 |
| 24 | FURNISHING OF TUNNEL AND ROAD | 100d | 15.04.18 | 23.07.18 |
| 25 | Road and tunnel furniture | 100d | 15.04.18 | 23.07.18 |
| 26 | Electrical installation | 100d | 15.04.18 | 23.07.18 |



According to the construction schedule shown, it is concluded that the duration of the preliminary work is about 7,5 months. The completion of the project would be concluded in approx. 16 months. It should be noted that this is a tight construction schedule and requires good planning of the works to be implemented and achieved.

Some basic criteria must be met to achieve this schedule:

- Continuous progress of the work.
- An average progress of the excavation has been assumed at least 25 m per week from each side.
- Design and manufacturing of the electromechanical equipment must be contracted in sufficient time, to ensure timely installation synchronized with the tunnel opening.
- All contractors must be capable and experienced in the work assigned to them.

# 5 Conclusion and recommendations

The preliminary design has shown that this road alignment can be designed and built in such a way that it evades the hazardous mudflow section of last years.

For the final design some technical issues need to be considered by the Contractor, for example:

- River flood height during large mudflows and mitigations in the design
- Clearance to existing powerlines needs to be checked.
- Area for preliminary access roads needs to be verified with landowners
- New access to Dariali HPP need to be agreed with Dariali Energy
- Monitoring of blasting vibrations and special blast design near existing underground structures
- Consultations with owners of Dariali HPP and Larsi HPP concerning buried penstocks near the road embankment north of tunnel portal.
- Depth to bedrock in the alluvial fan at the south end of the tunnel
- Geological investigation of the south portal to determine the type of material in the alluvial fan.
- Avalanches and rock fall and effect on tunnel portal length
- Verification of spoil area for excavated soil and rock
- Ventilation needs to be calculated by the designer
- Location of the nearest fire departm3qent and their access to the tunnel during fire.
- Water and frost protection in tunnel and portals
- Emergency power supply for lights in tunnel
- Proximity of concrete plant due to potential closure of Gudauri Pass

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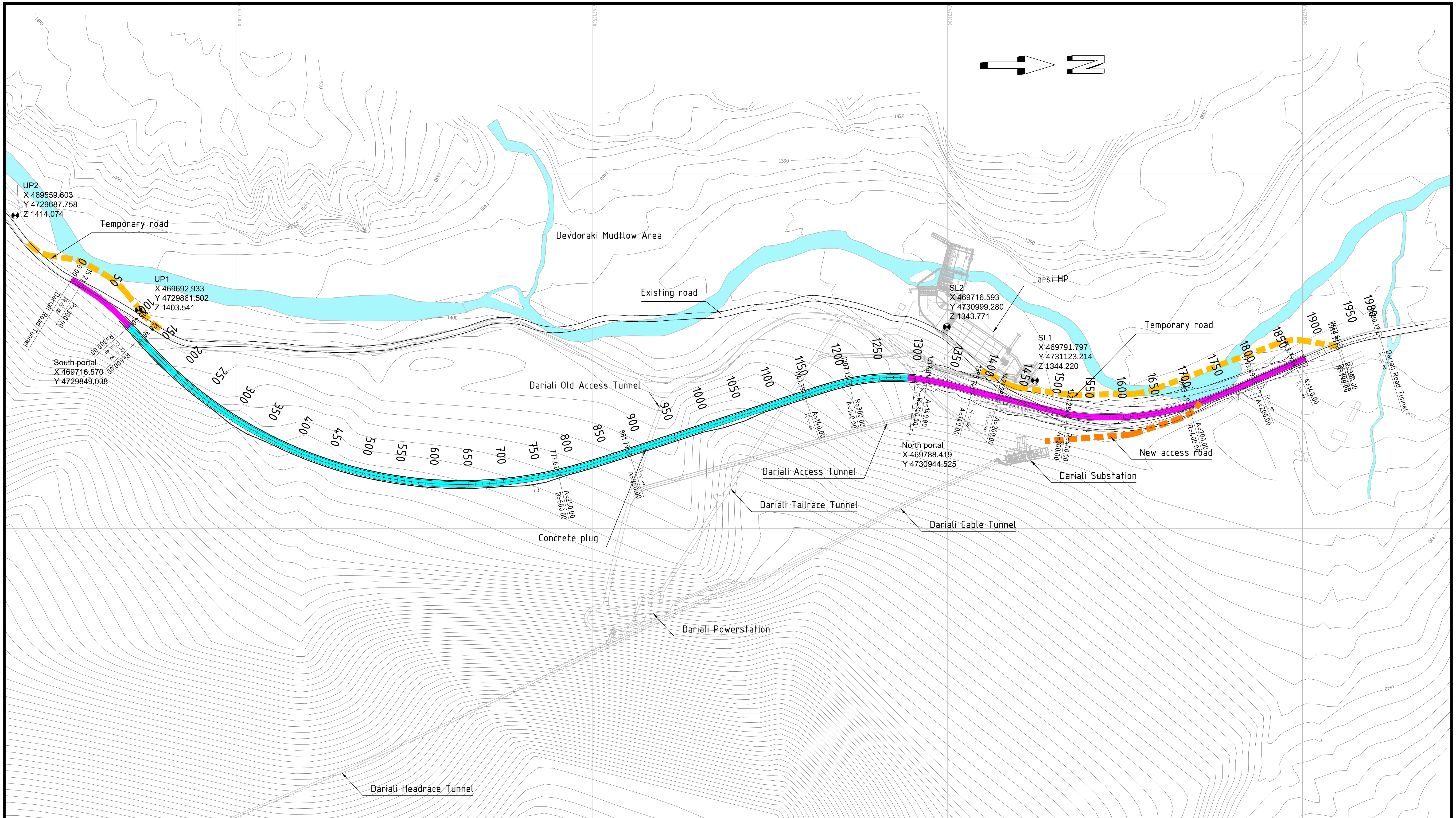
# Appendices

Appendix A – Preliminary Design Drawings
Appendix B – Geological Report
Appendix C – Environmental Mitigation Plan
Appendix D – Environmental Monitoring Plan

## Appendix A – Preliminary Design Drawings




Tunnel

Roads and fillings

New access road to Dariali HEP

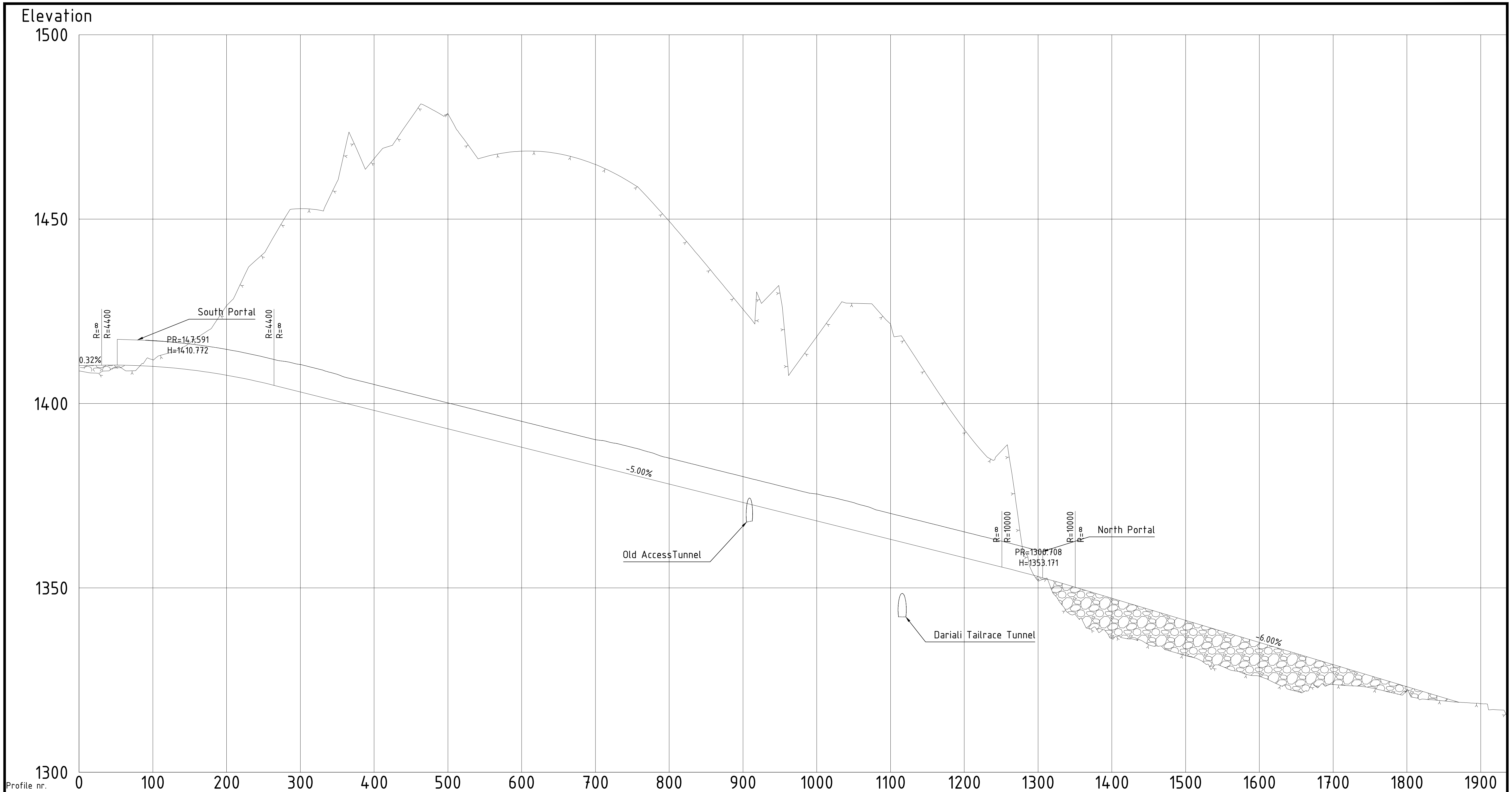
Temporary roads

NOT FOR CONSTRUCTION

1:2500 0 50 100 150 200 250 m

Note: The alignment of the river is based on GIS data that may be out of date.

| | | | |
|---|---|---|---|
| damkveTi: EMPLOYER: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA | konsultanti: CONSULTANT: Landsvirkjun Power | gzis dasaxeleba: ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117 | naxazis dasaxeleba: DRAWING TITLE: Tunnel and Roadworks – Plan overview |
| proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section | qvekonsultanti: SUBCONSULTANT: Geoengineering – Gamma Consulting | damtkicda: APPROVED: BS; TariRi: DATE: 16.02.2017; daaproeqta: DESIGNED: SAT; daxaza: DRAWN: SAT; Seamowma: CHECKED: GJ; cvlil. REV.: A; aRwera DESCRIPTION: Tender drawing; TariRi DATE: 16.02.2017 | naxazis #: DRAWING No.: C71.001; masStabi: SCALE: 1:2500; naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1 |




Horizontal curve: L 15.21 | R 300.00 | L 22.98 | R 600.00 | A 250.00 | L 260.01 | A 140.00 | R 300.00 | A 140.00 | L 38.14 | A 200.00 | R 400.00 | A 200.00 | L 60.31 | A 140.00 | R 300.0

| Profile nr. | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Profile height | 1410.07 | 1407.68 | 1403.16 | 1398.16 | 1393.17 | 1388.17 | 1383.18 | 1378.18 | 1373.19 | 1368.19 | 1363.20 | 1358.20 | 1353.09 | 1347.22 | 1341.22 | 1335.23 | 1329.23 | 1323.24 |
| Terrain height | 1410.07 | 1407.68 | 1403.16 | 1398.16 | 1393.17 | 1388.17 | 1383.18 | 1378.18 | 1373.19 | 1368.19 | 1363.20 | 1358.20 | 1353.09 | 1347.22 | 1341.22 | 1335.23 | 1329.23 | 1323.24 |

NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis
EMPLOYER: saministros saavtomobilo gzebis departamenti
ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – Longitudinal section

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

damtkicda: / APPROVED: BS
TariRi: / DATE:
daaproeqta: / DESIGNED: SAT
daxaza: / DRAWN: SAT
Seamowma: / CHECKED: GJ

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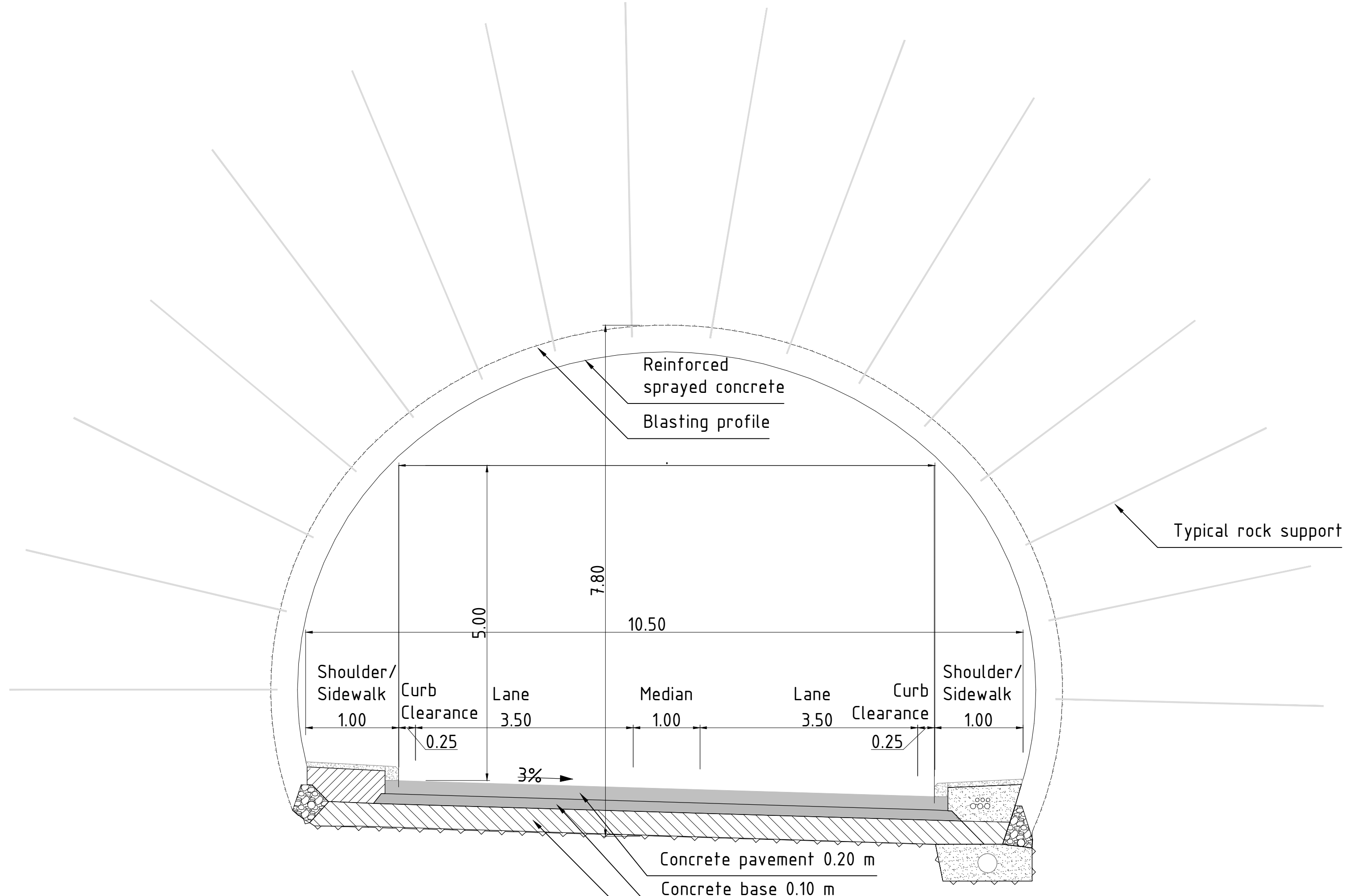
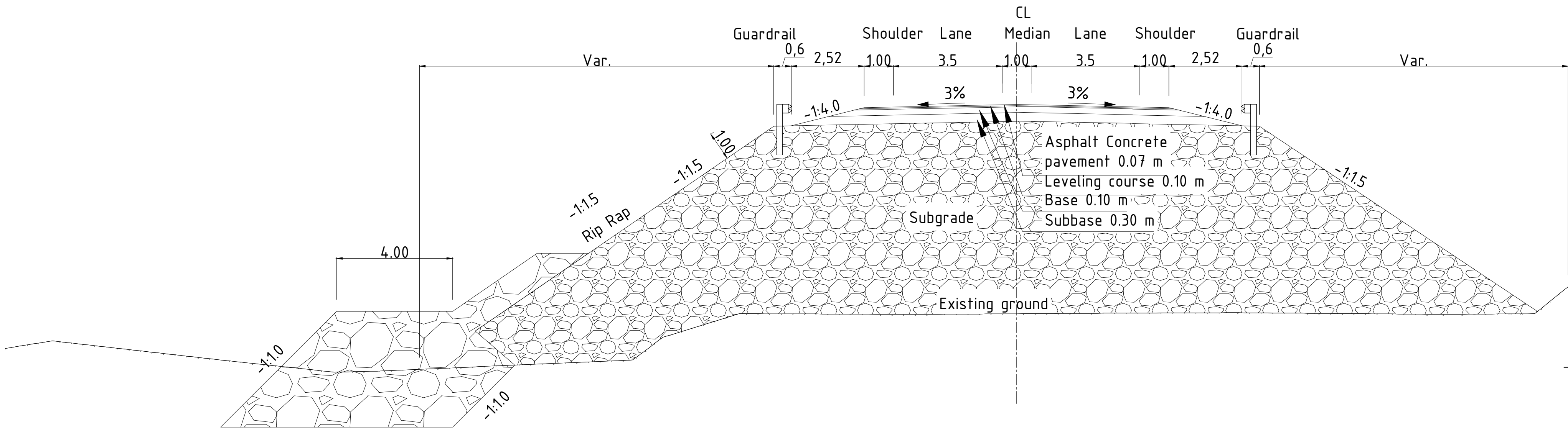


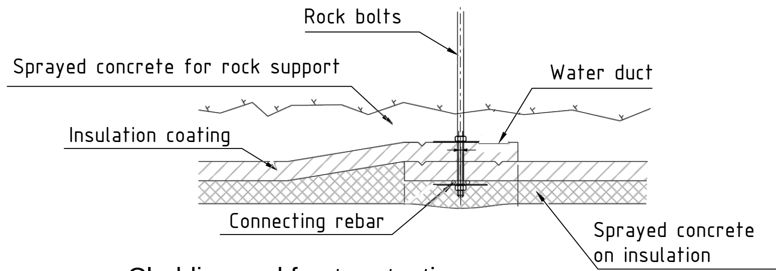

Tunnel cross section

1:50 0 1 2 3 4 5 m




Road cross section with guardrails

1:100 0 1 2 3 4 5 10 m




Cladding and frost protection

1:10 0 0.1 0.2 0.3 0.4 0.5 1 m

NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road –E117

naxazis dasaxeleba:
DRAWING TITLE: Roadworks and Tunnel – Cross sections

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

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| daaproeqta: DESIGNED: SAT | daxaza: DRAWN: SAT | Seamowma: CHECKED: GJ | |

| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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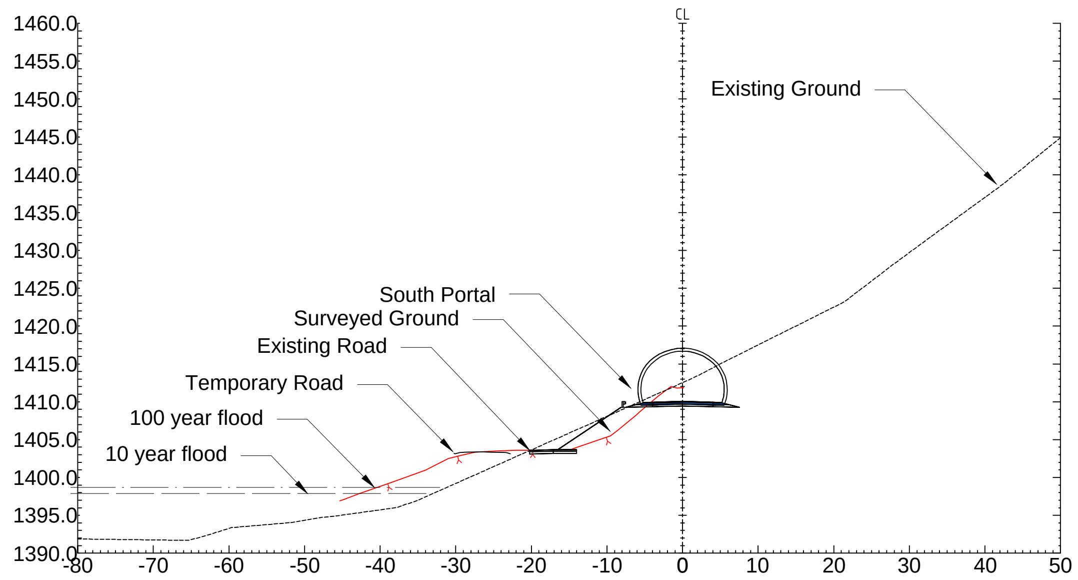
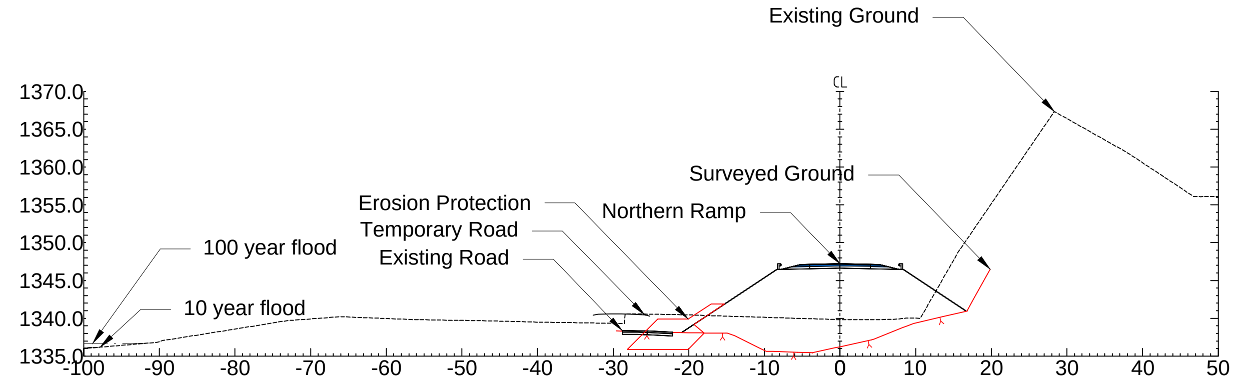
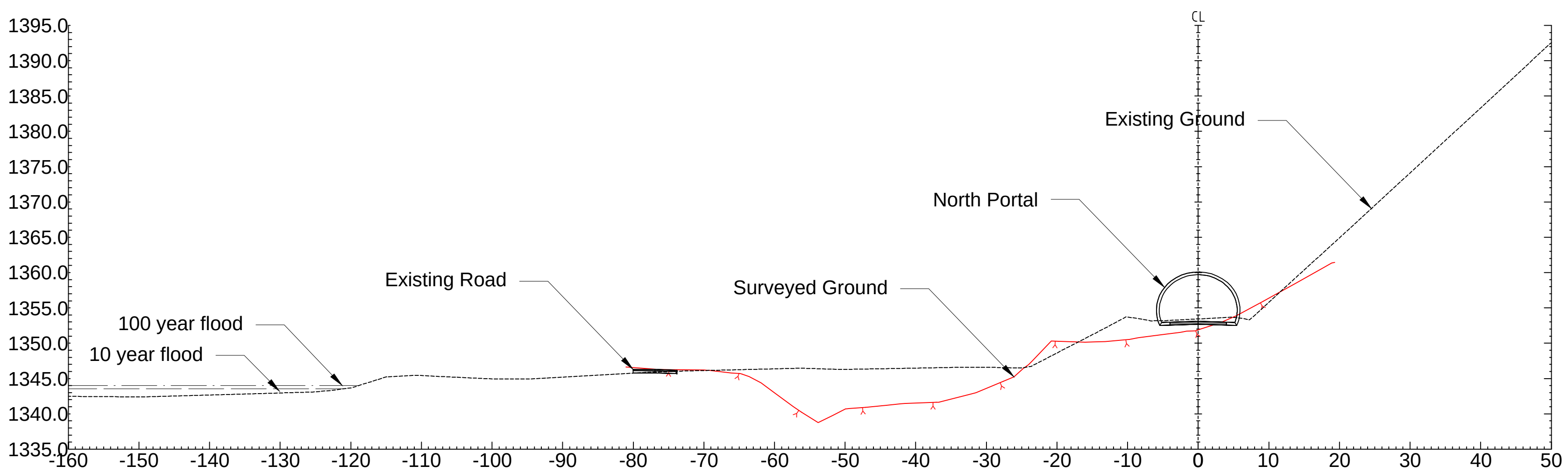


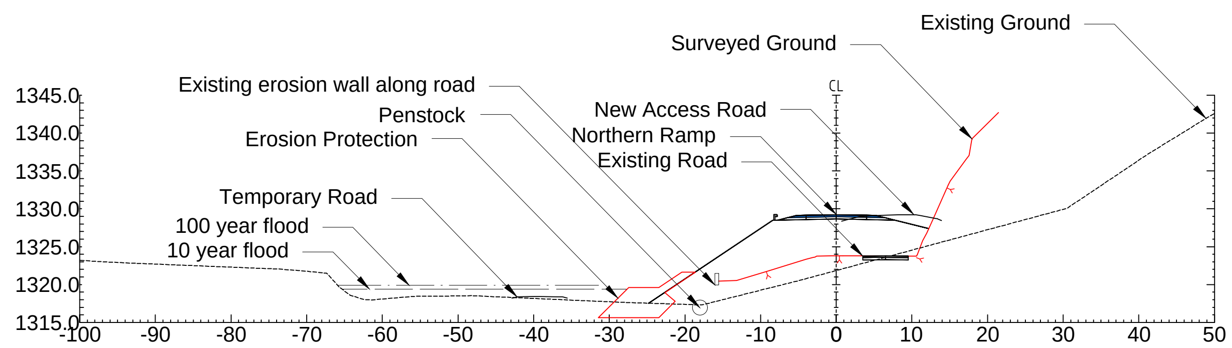

1 Section - South portal
St.100 1:500




3 Section - Northern ramp
St.1400 1:500




2 Section - North portal
St.1300 1.500




4 Section - Northern ramp
St.1700 1:500

NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti: / CONSULTANT: Landsvirkjun Power

gzis dasaxeleba: / ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba: / DRAWING TITLE: Tunnel and Roadworks – Cross sections – 2

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti: / SUBCONSULTANT: Geoengineering – Gamma Consulting

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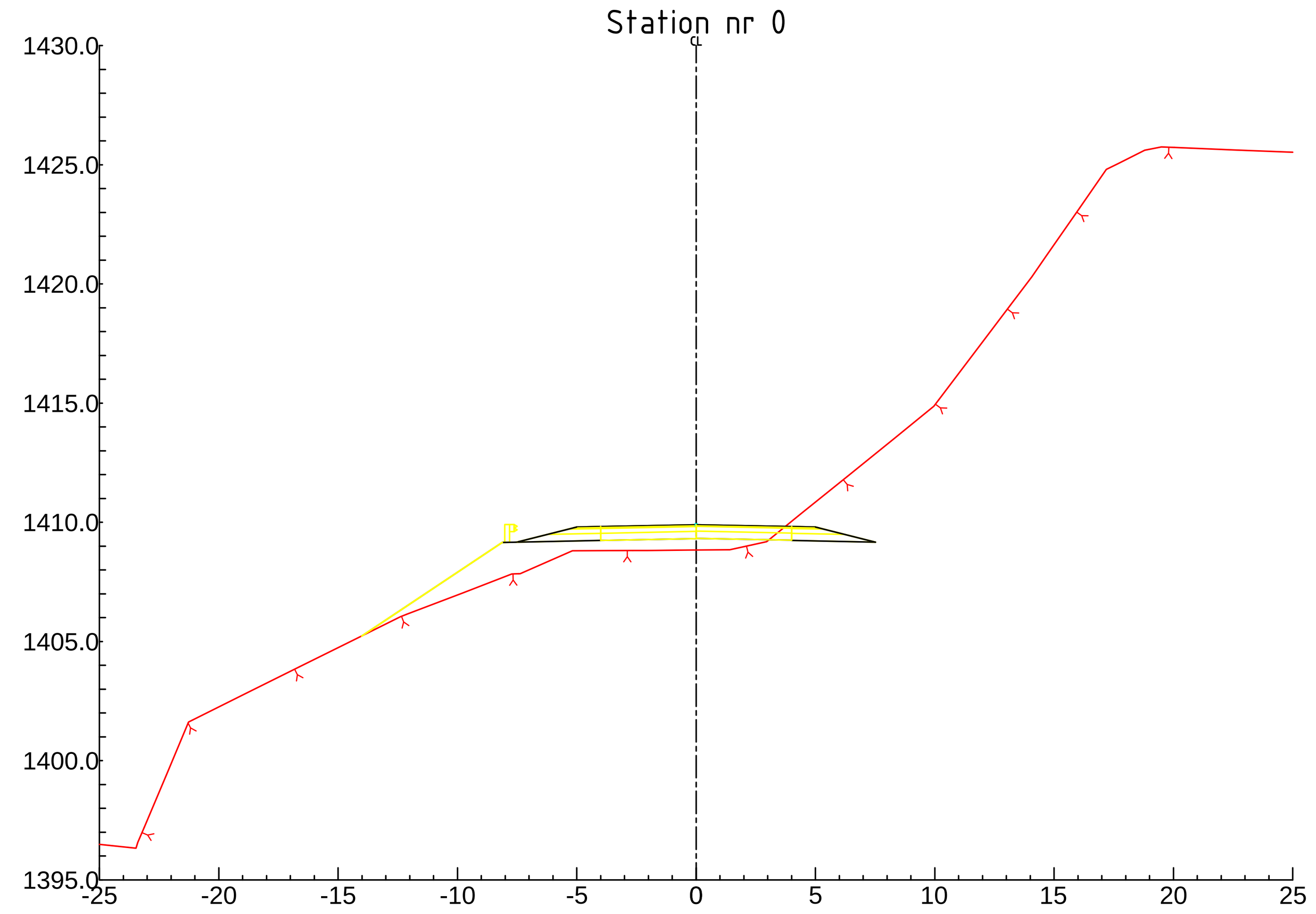


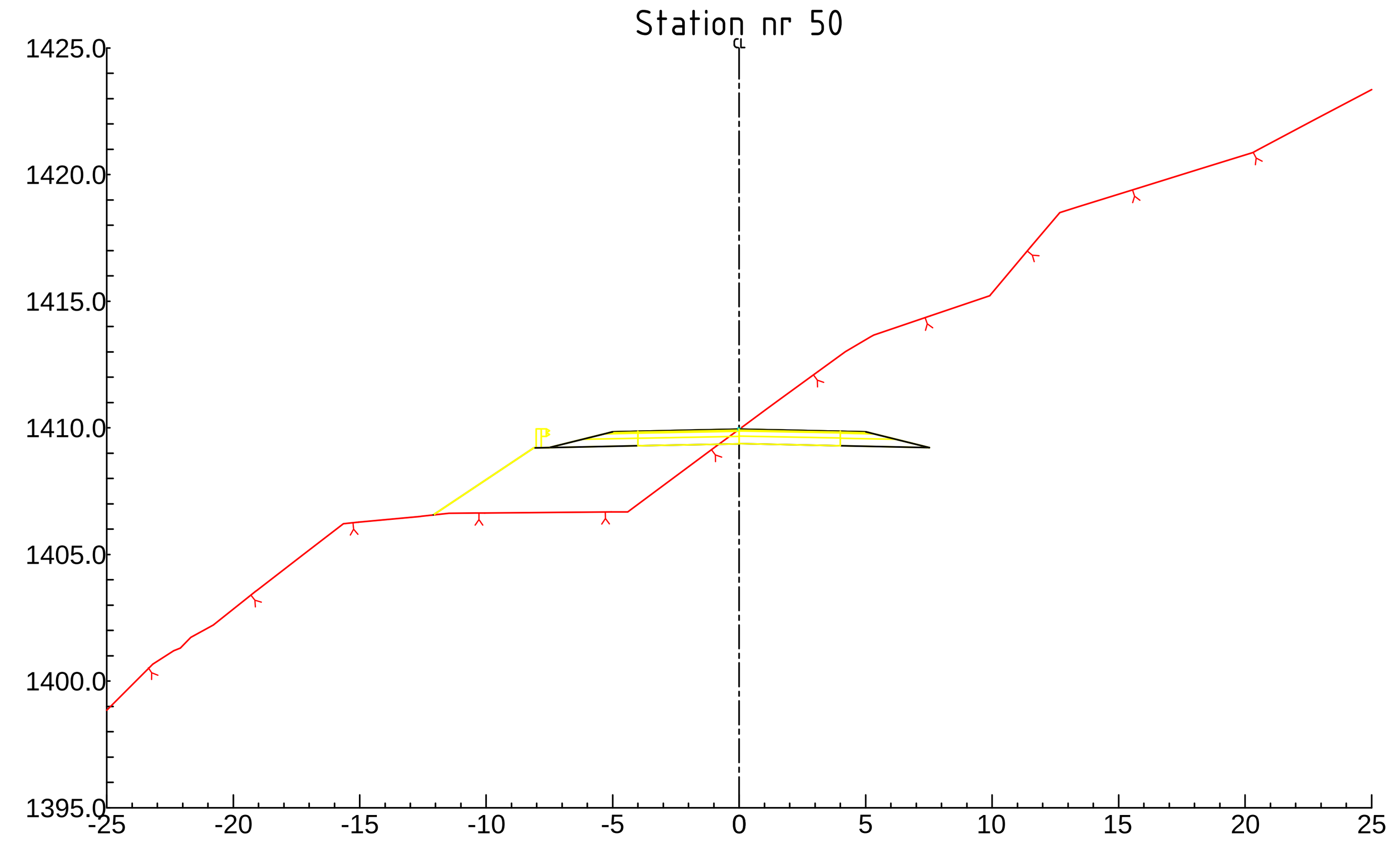


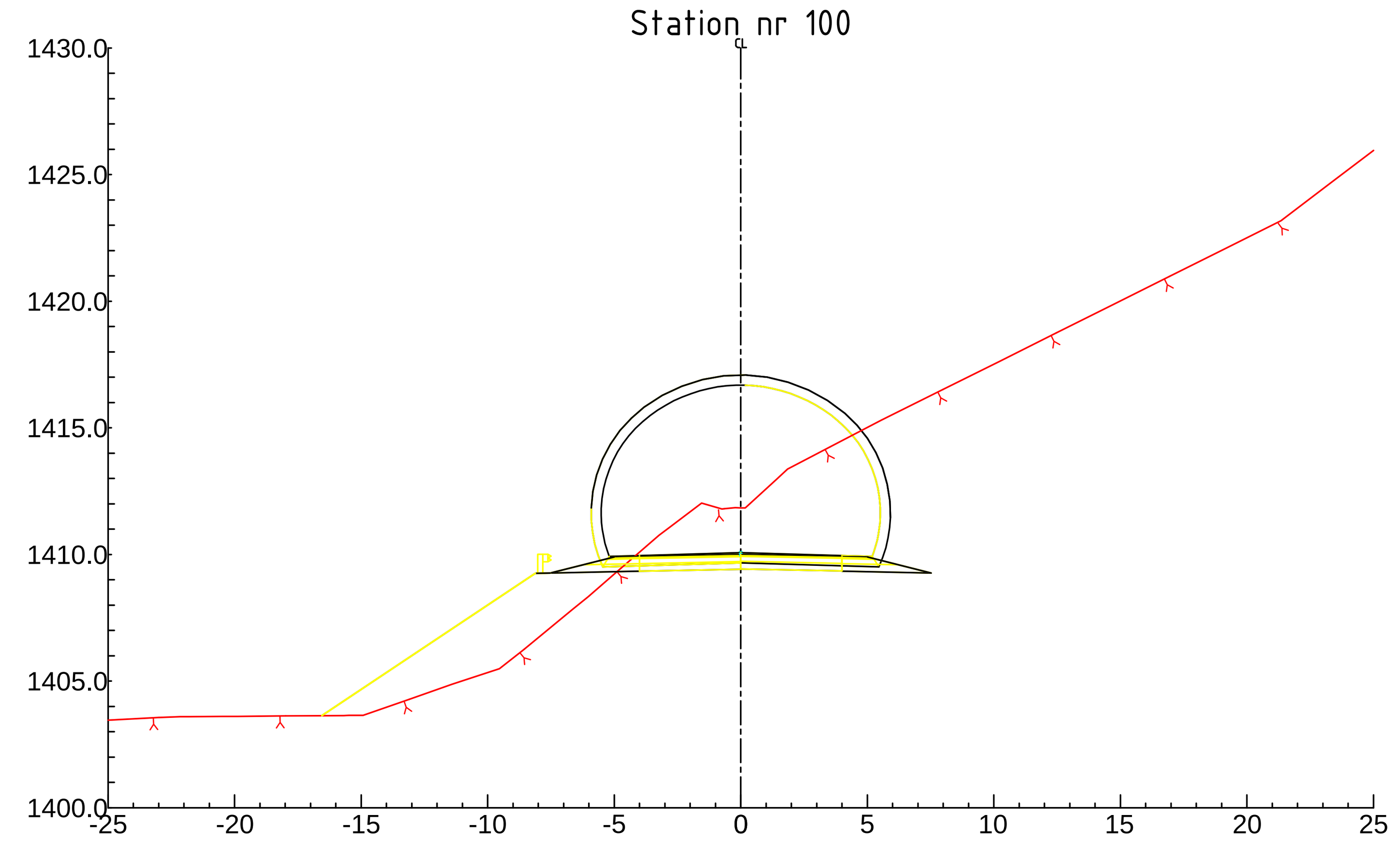


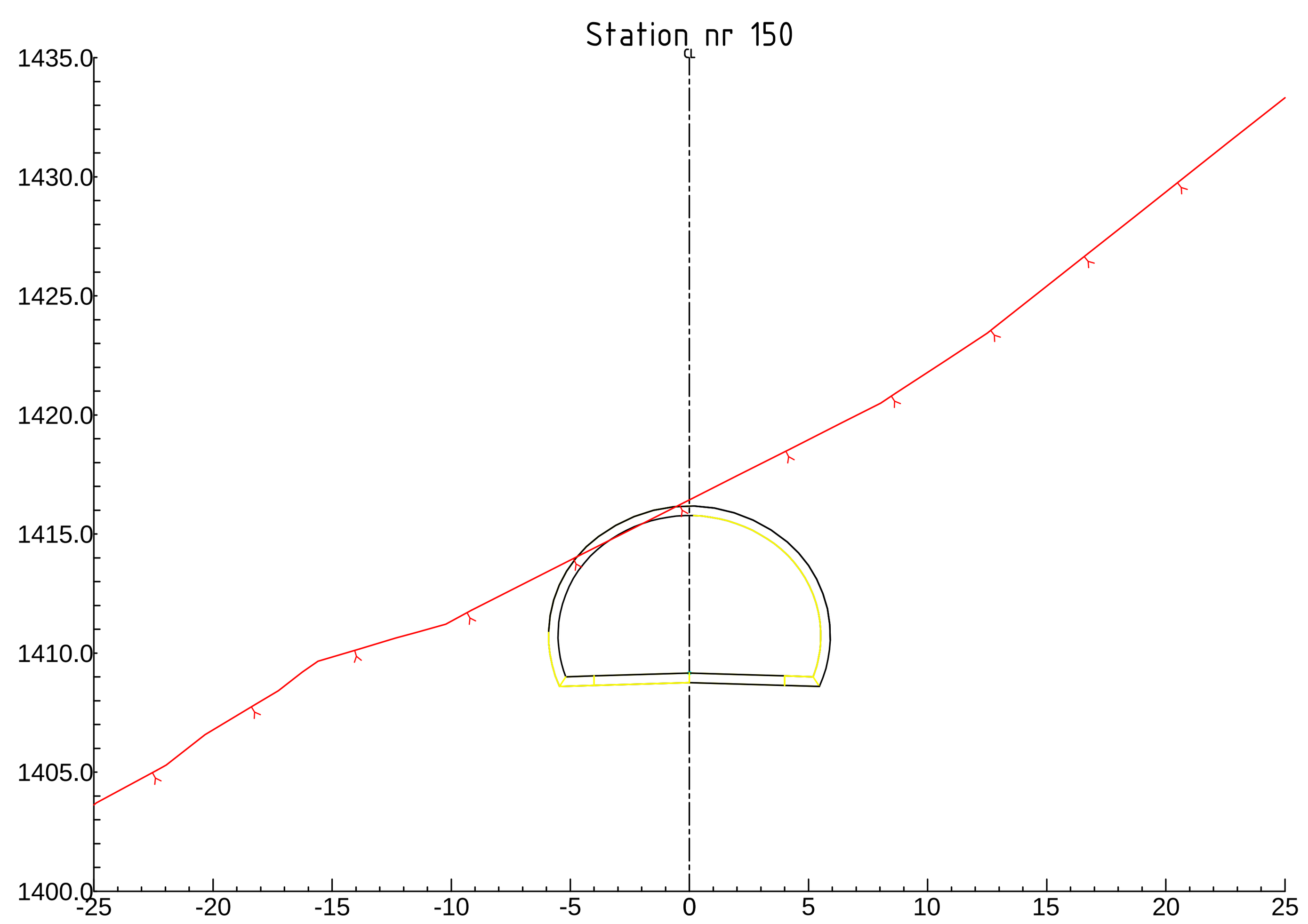


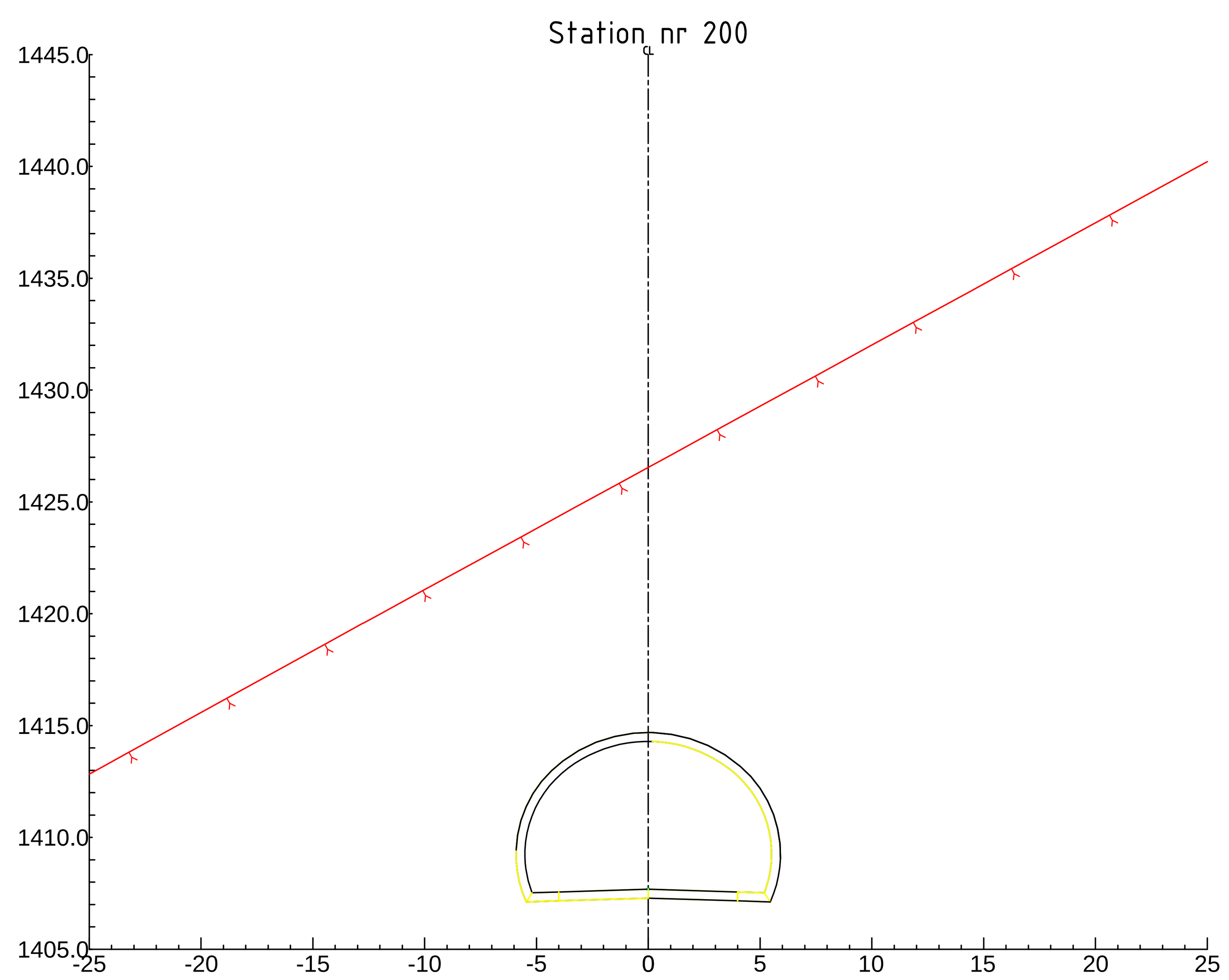


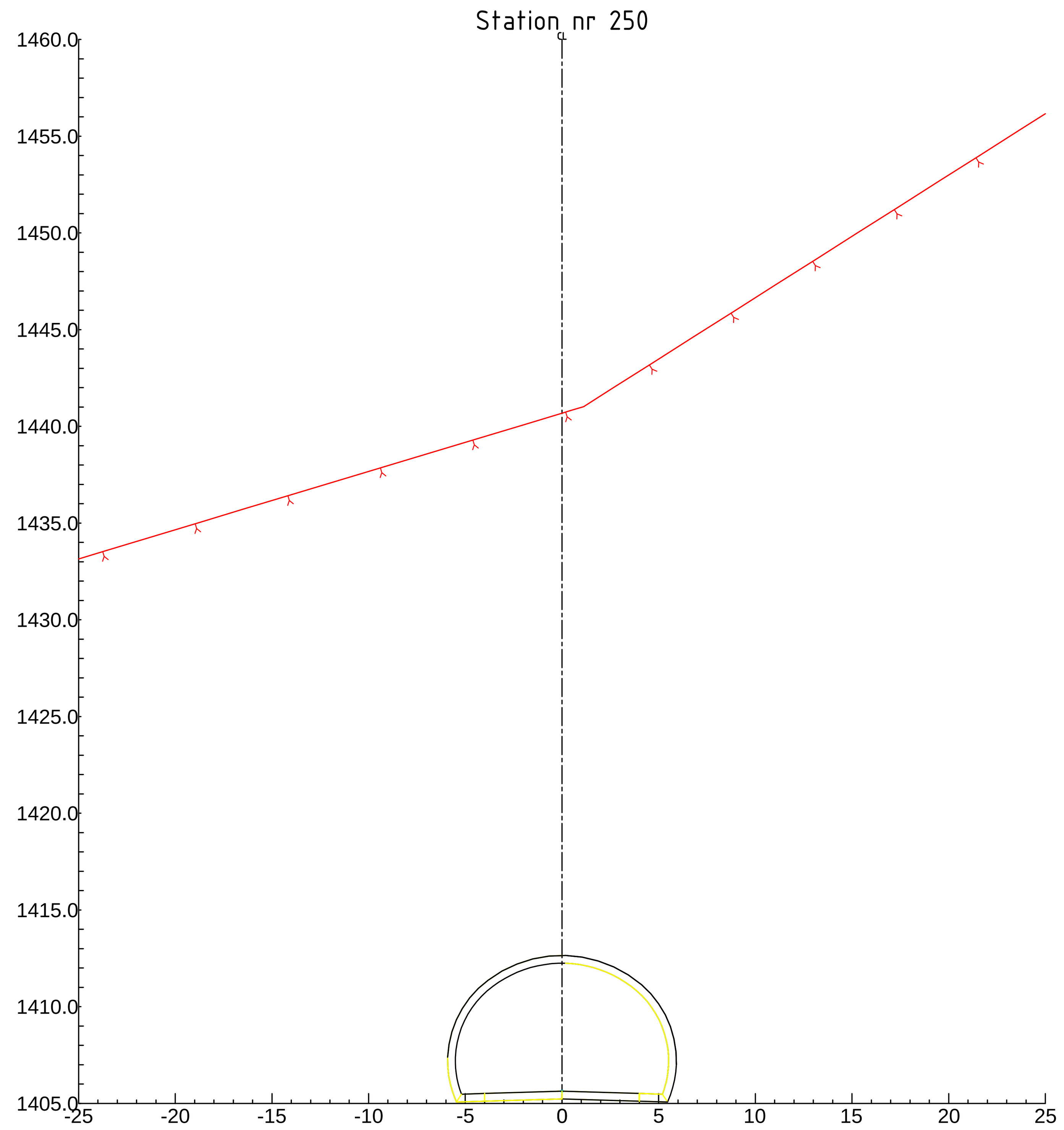


NOT FOR CONSTRUCTION

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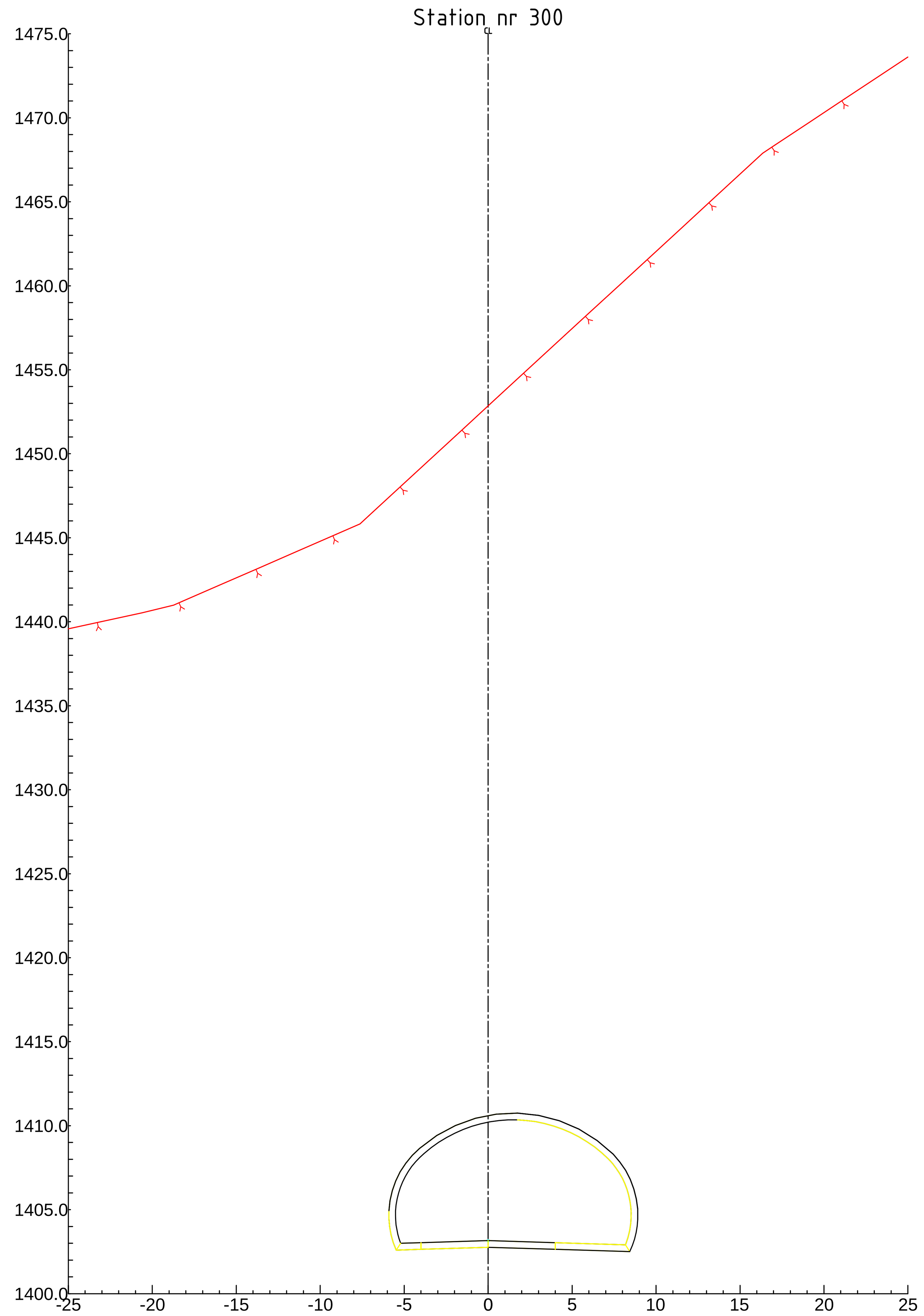


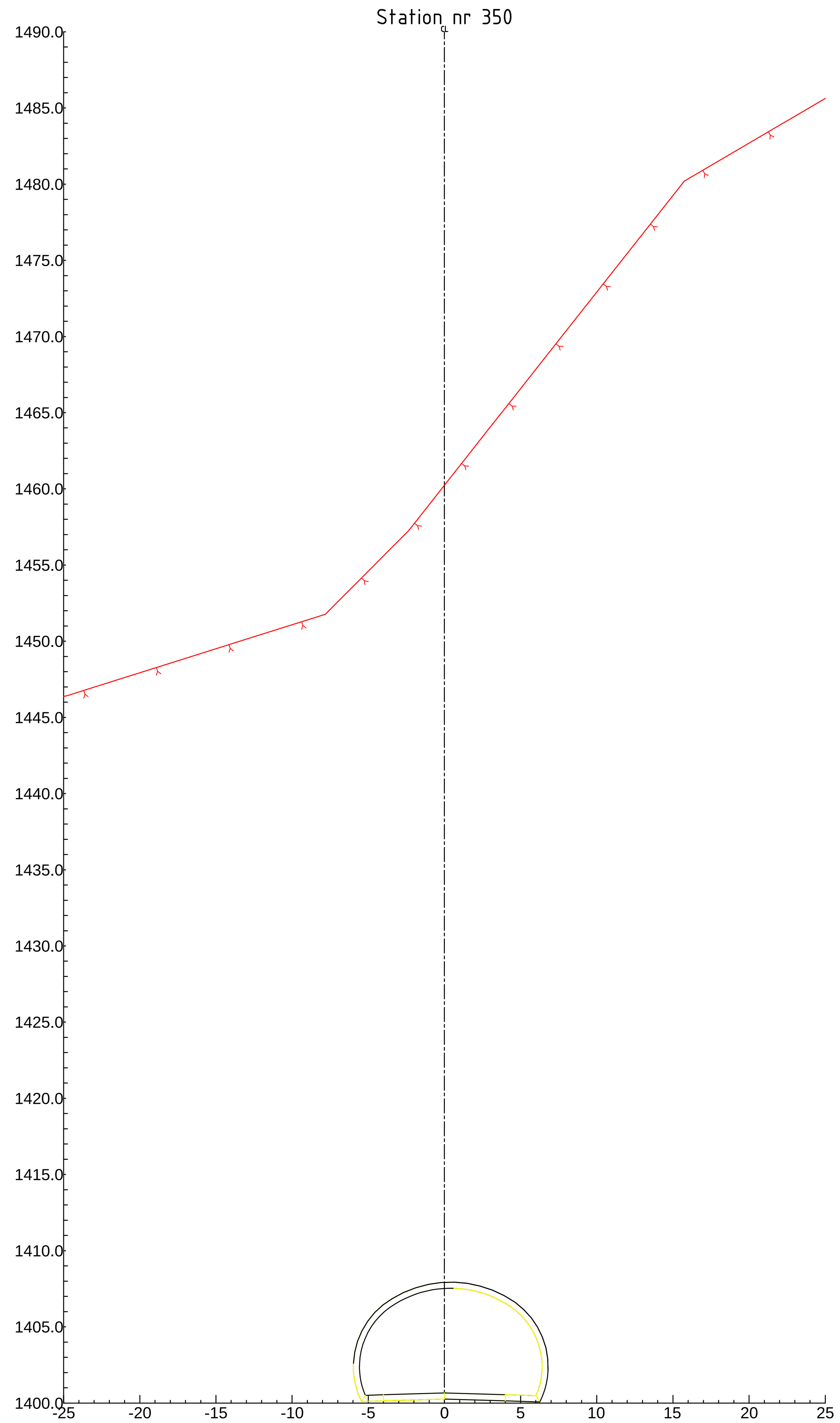


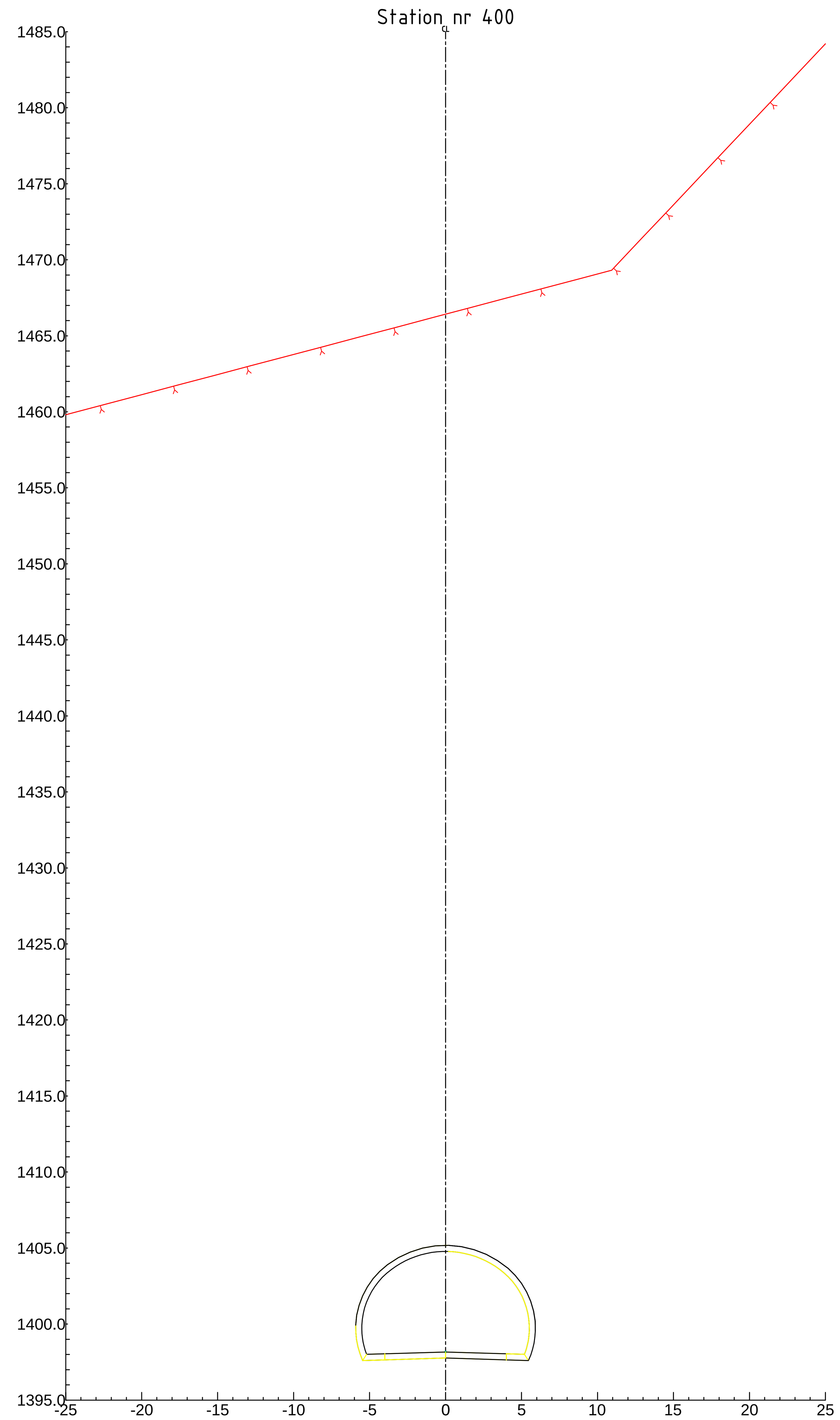


NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 300 – 400

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

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| damtkicda: APPROVED: BS | TariRi: DATE: 16.02.2017 | |
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| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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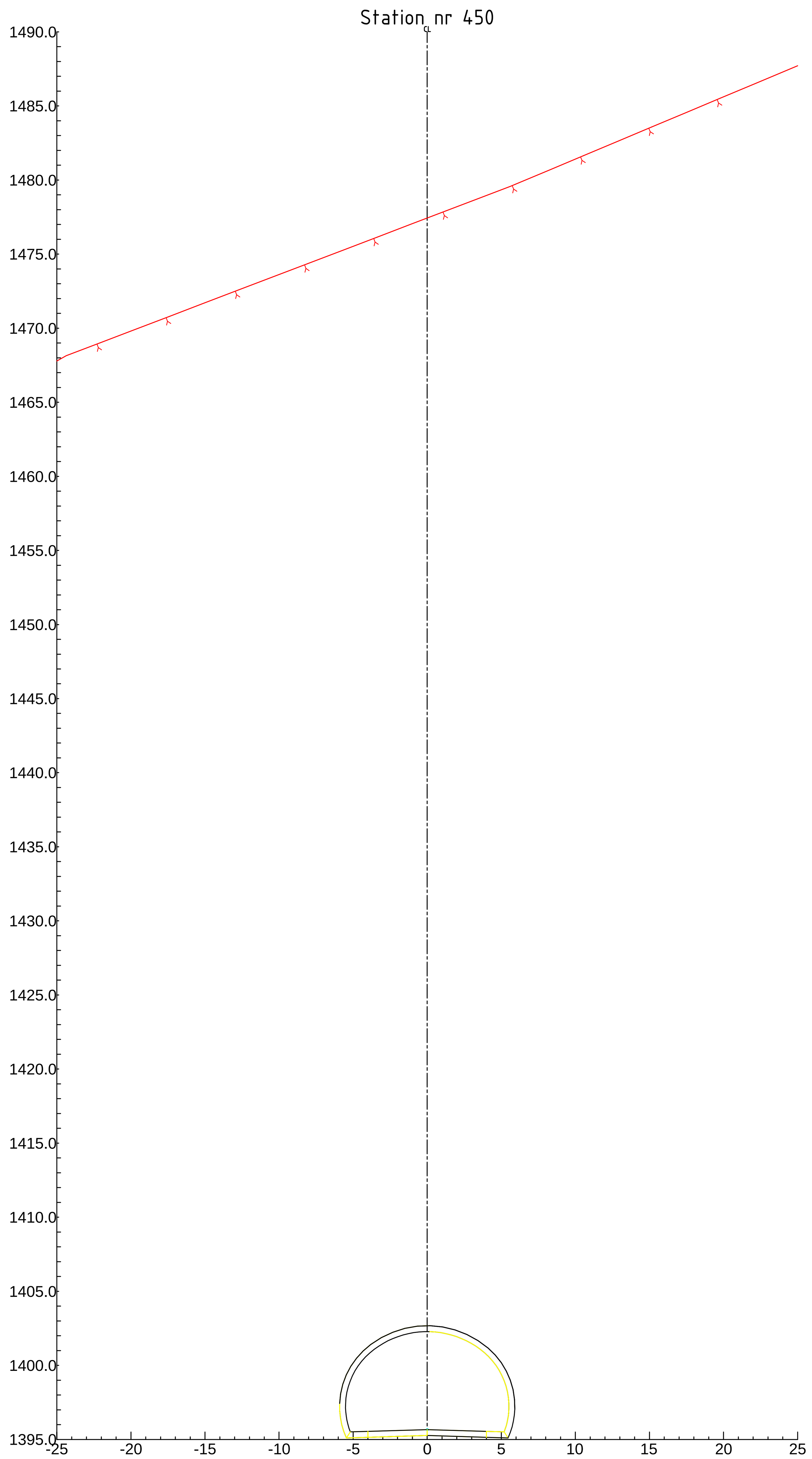


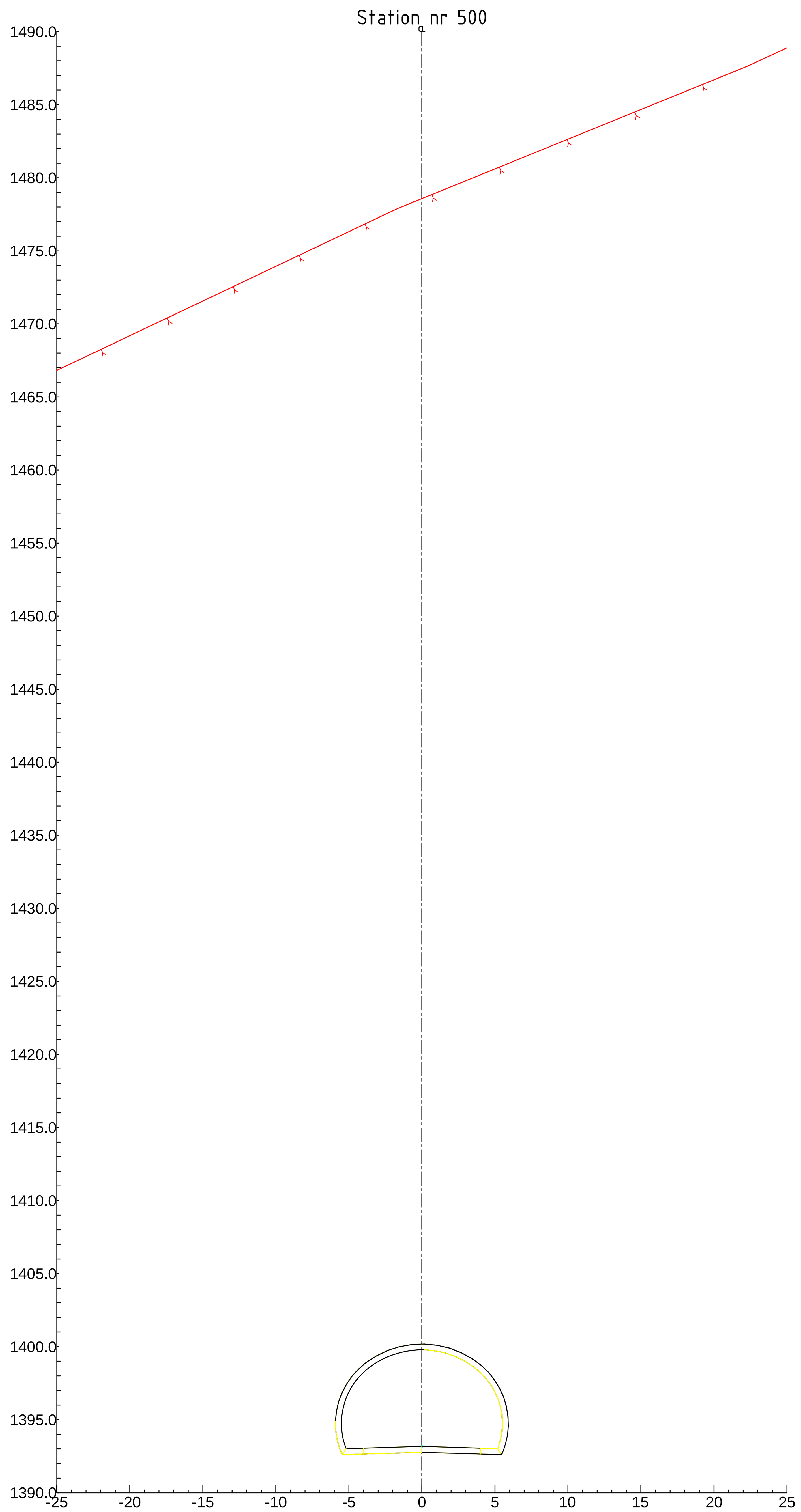


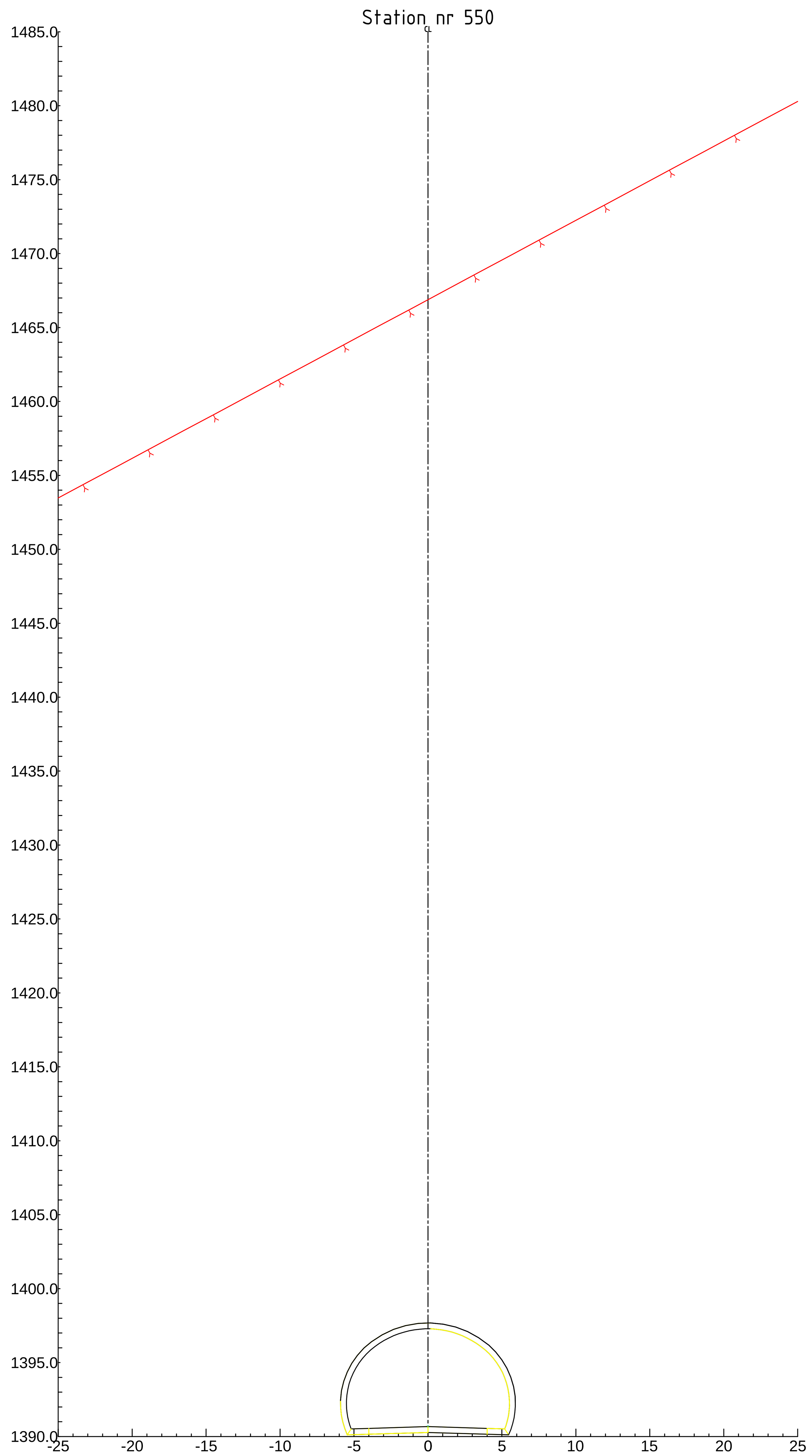


NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 450 – 550

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

| damtkicda: APPROVED: BS | | TariRi: DATE: 16.02.2017 |
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| daaproeqta: DESIGNED: SAT | daxaza: DRAWN: SAT | Seamowma: CHECKED: GJ |

| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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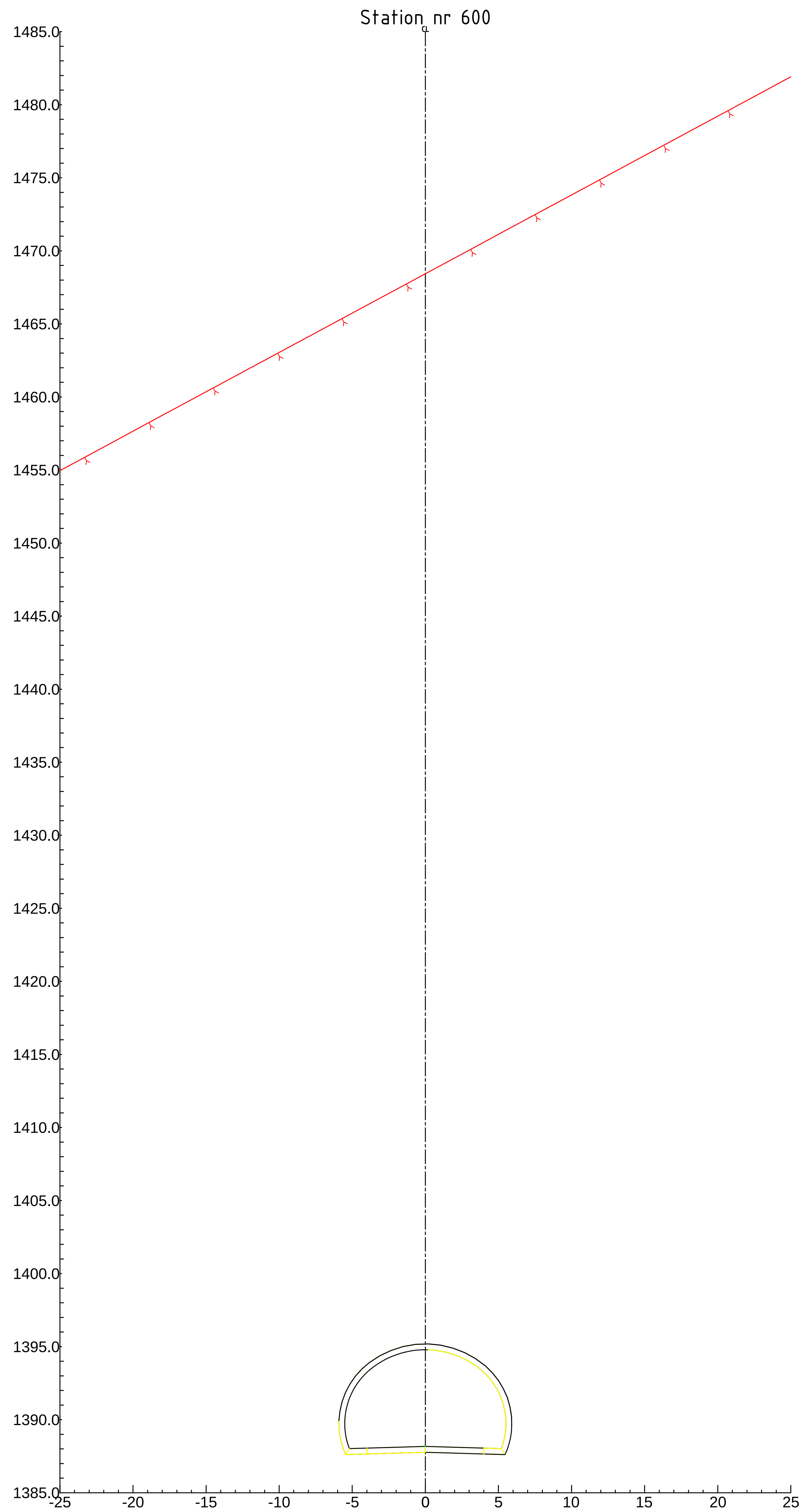


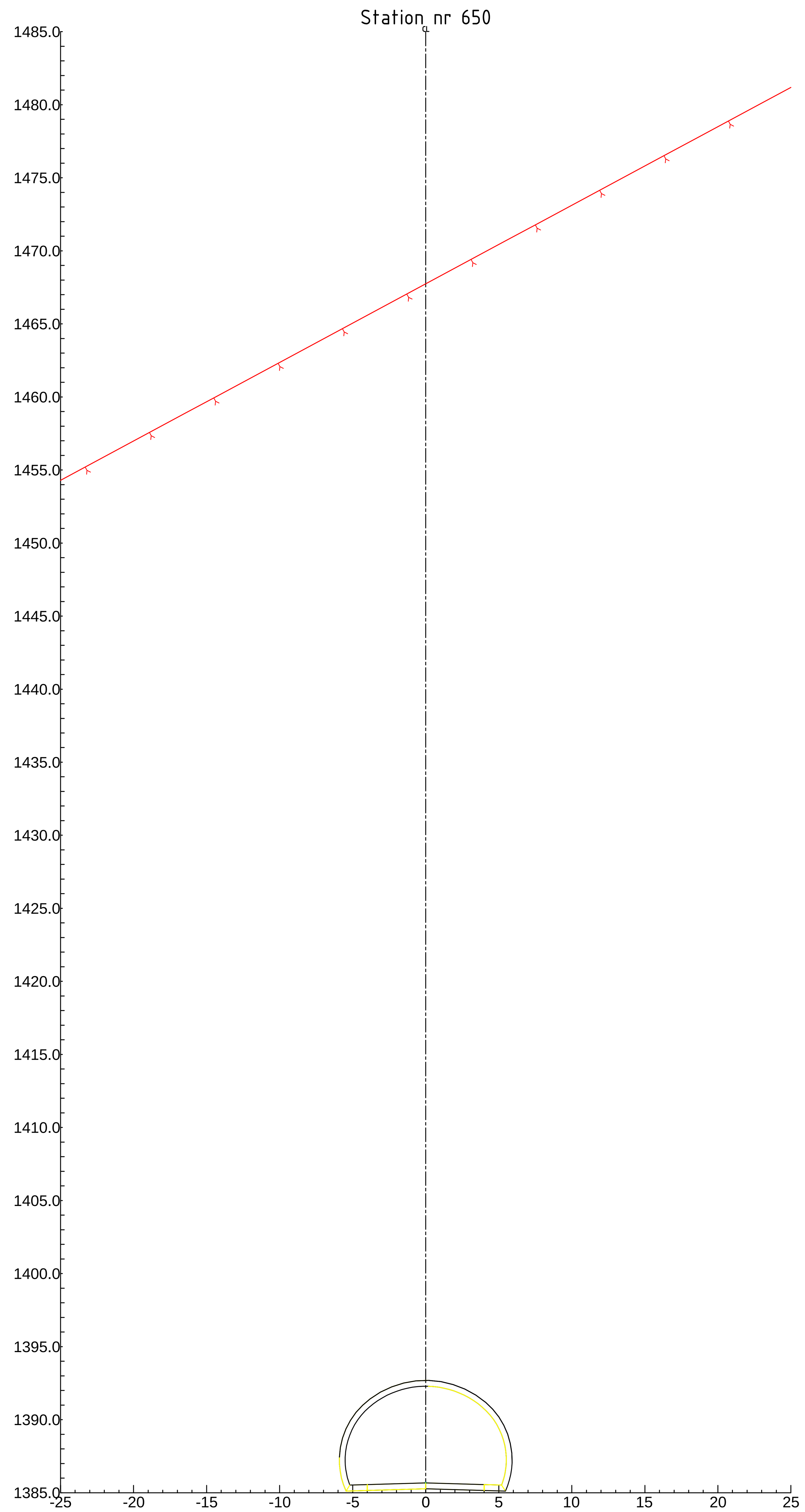


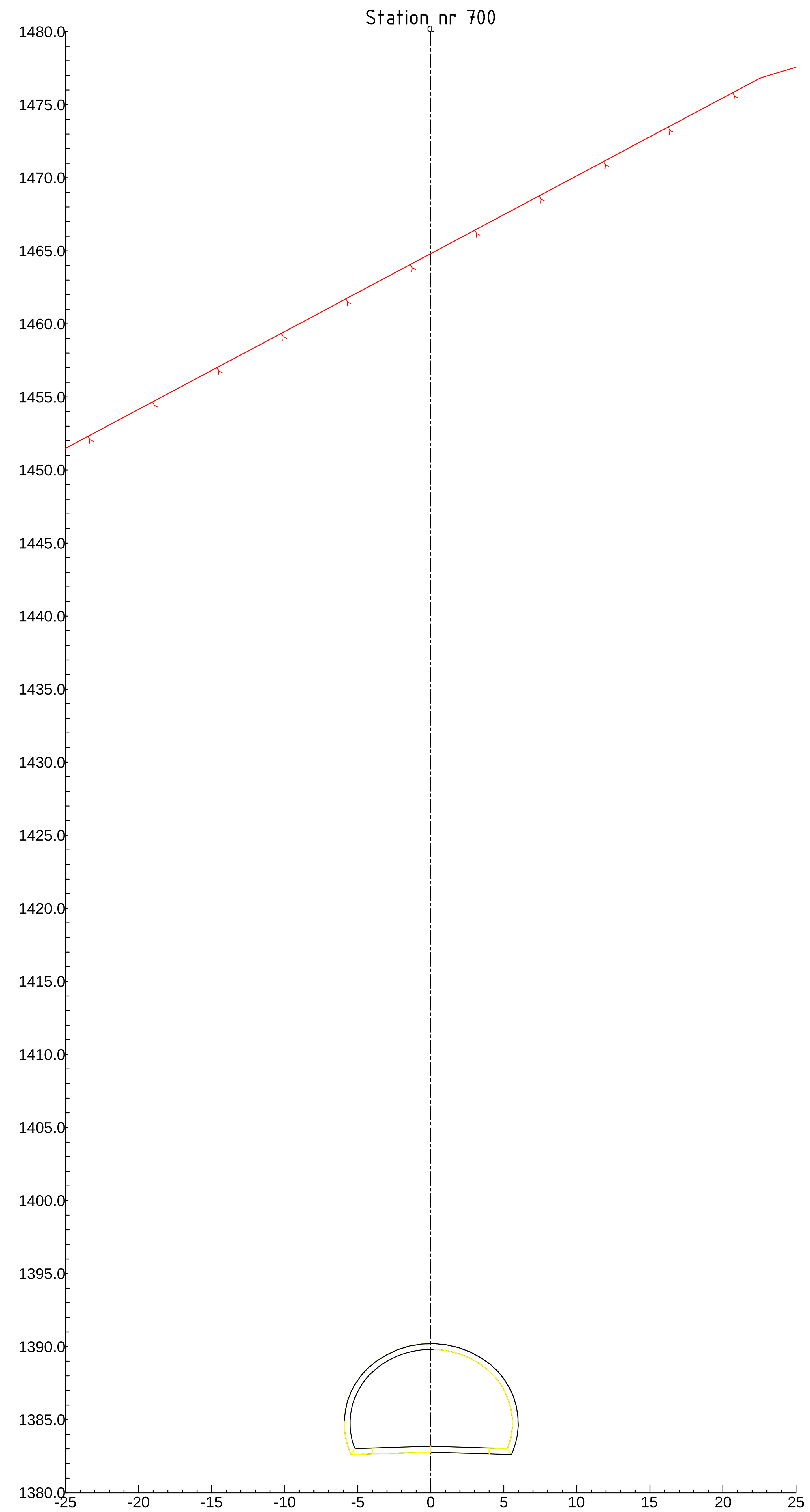


NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti: / CONSULTANT: Landsvirkjun Power

gzis dasaxeleba: / ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba: / DRAWING TITLE: Tunnel and Roadworks – St. 600 – 700

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti: / SUBCONSULTANT: Geoengineering – Gamma Consulting

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| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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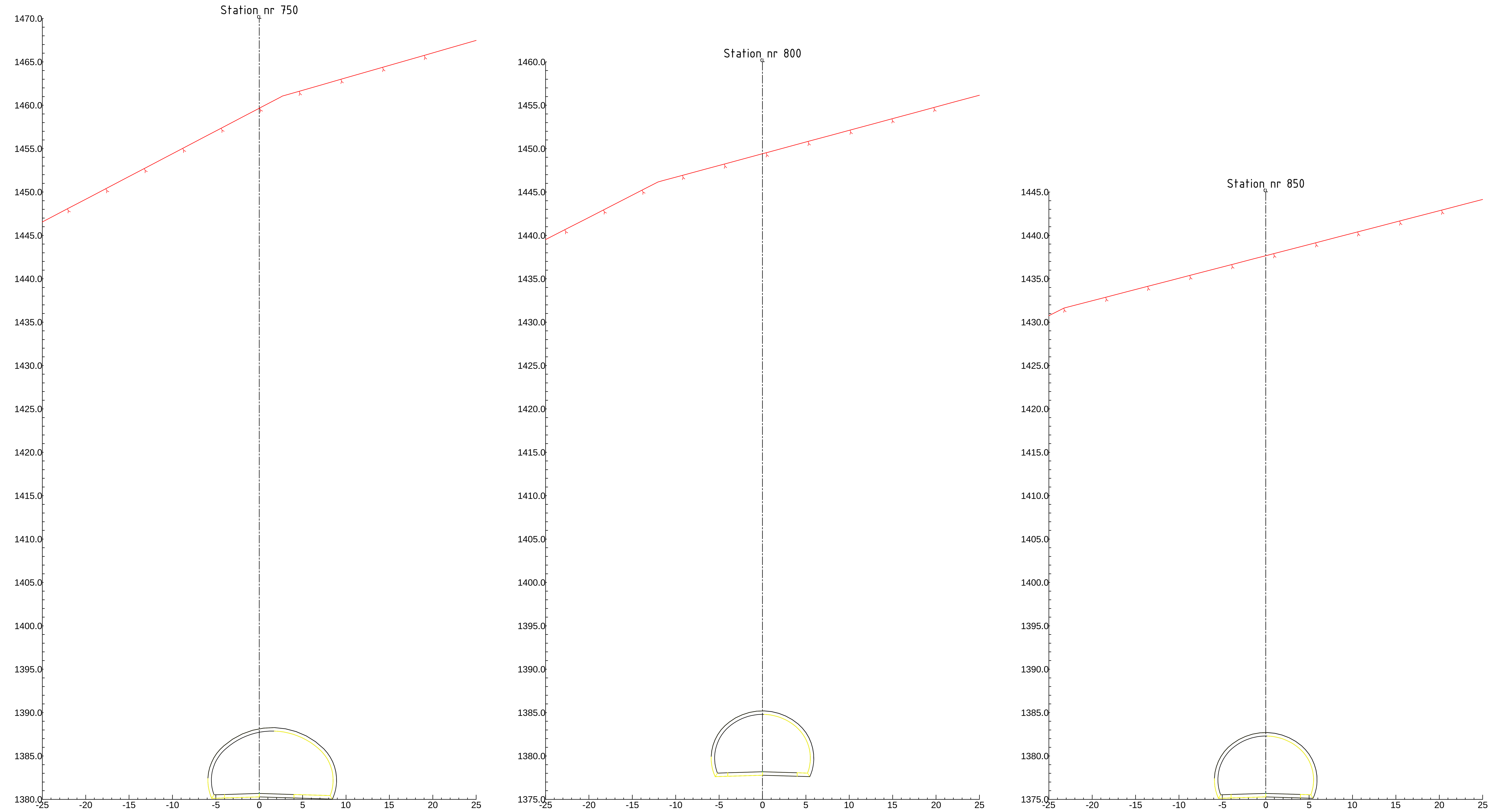


NOT FOR CONSTRUCTION

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|---|---|---|---|
| damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti<br>EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA | konsultanti:<br>CONSULTANT: Landsvirkjun Power | gzis dasaxeleba:<br>ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117 | naxazis dasaxeleba:<br>DRAWING TITLE: Tunnel and Roadworks – St. 750 – 850 |
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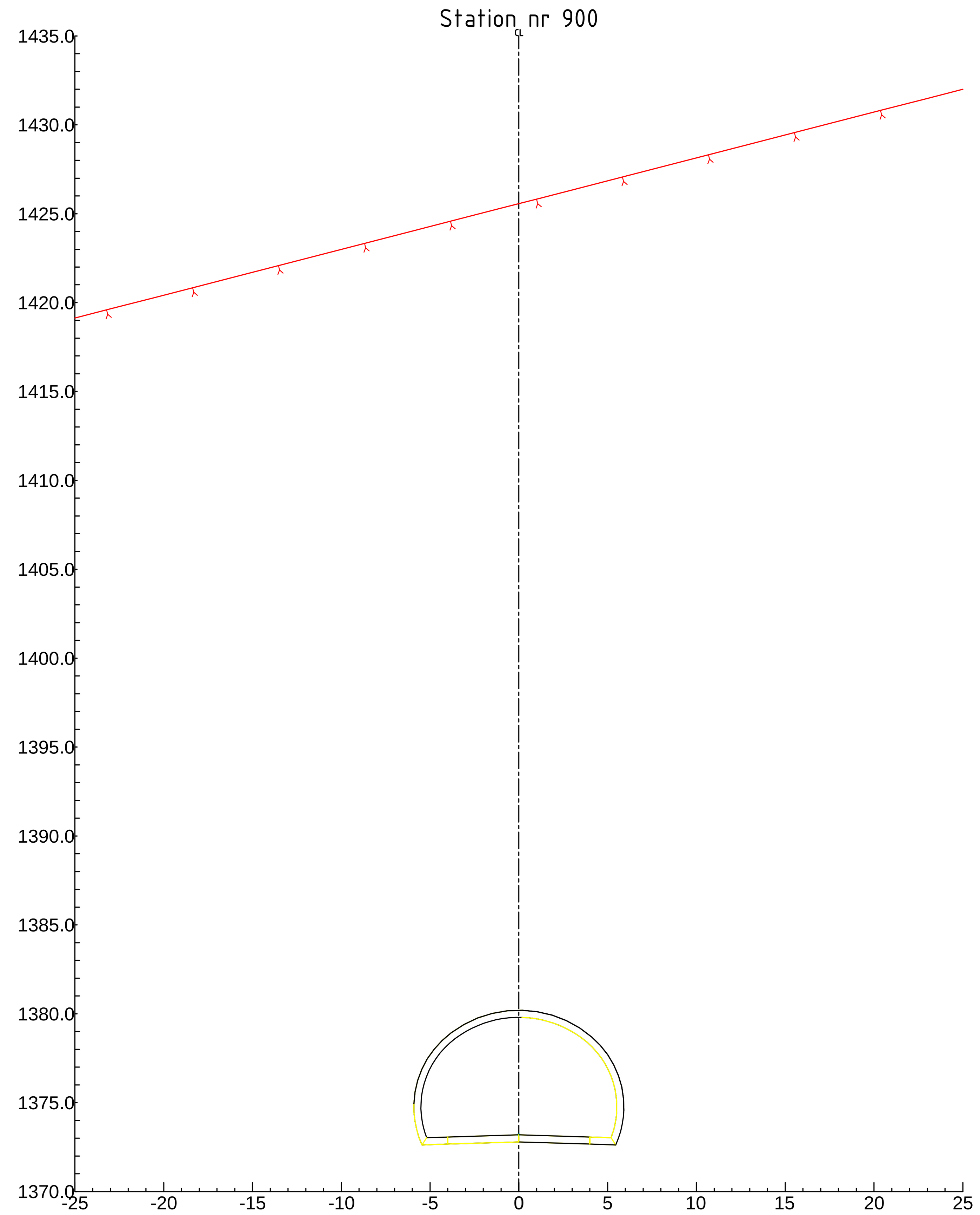


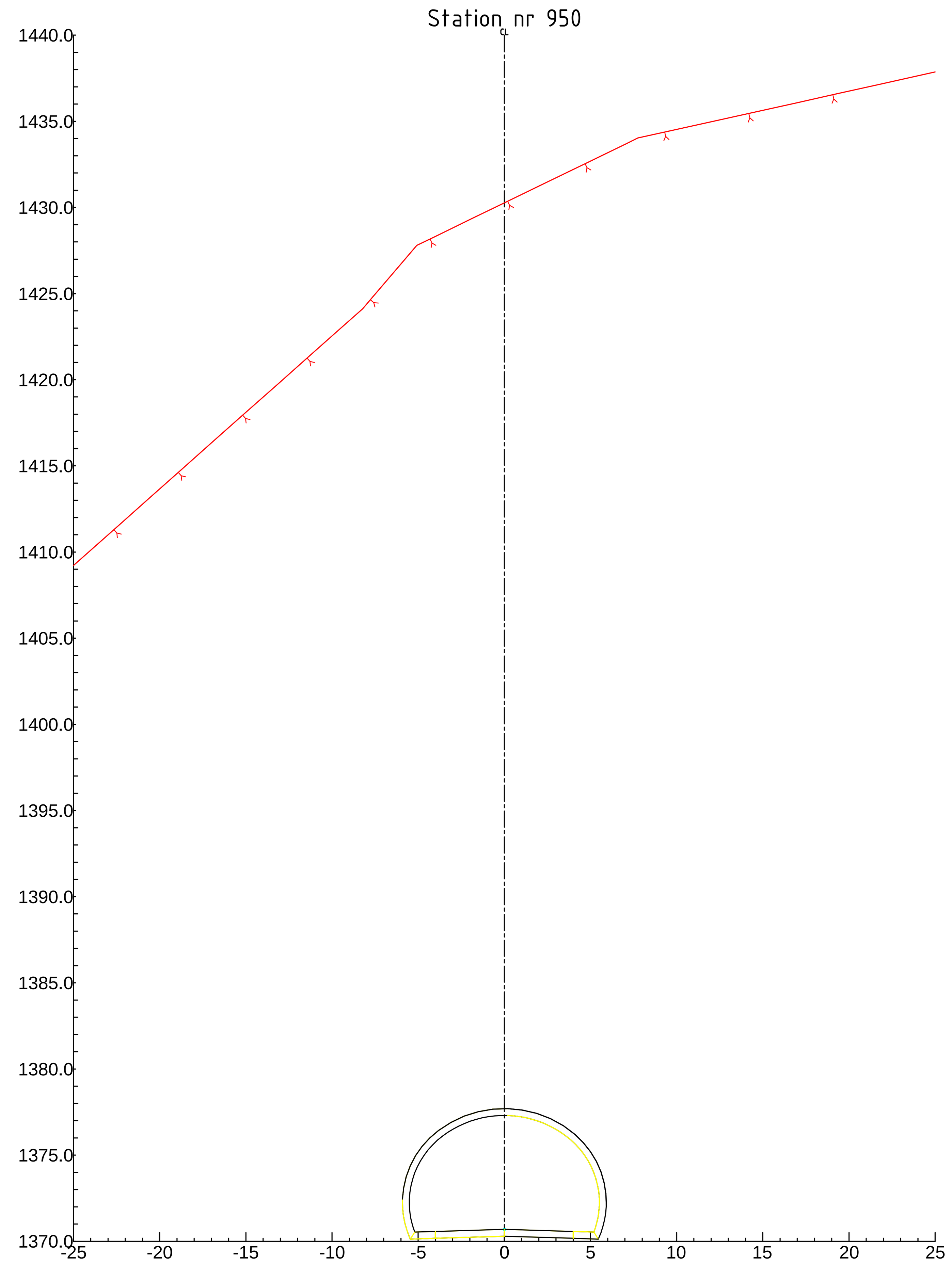


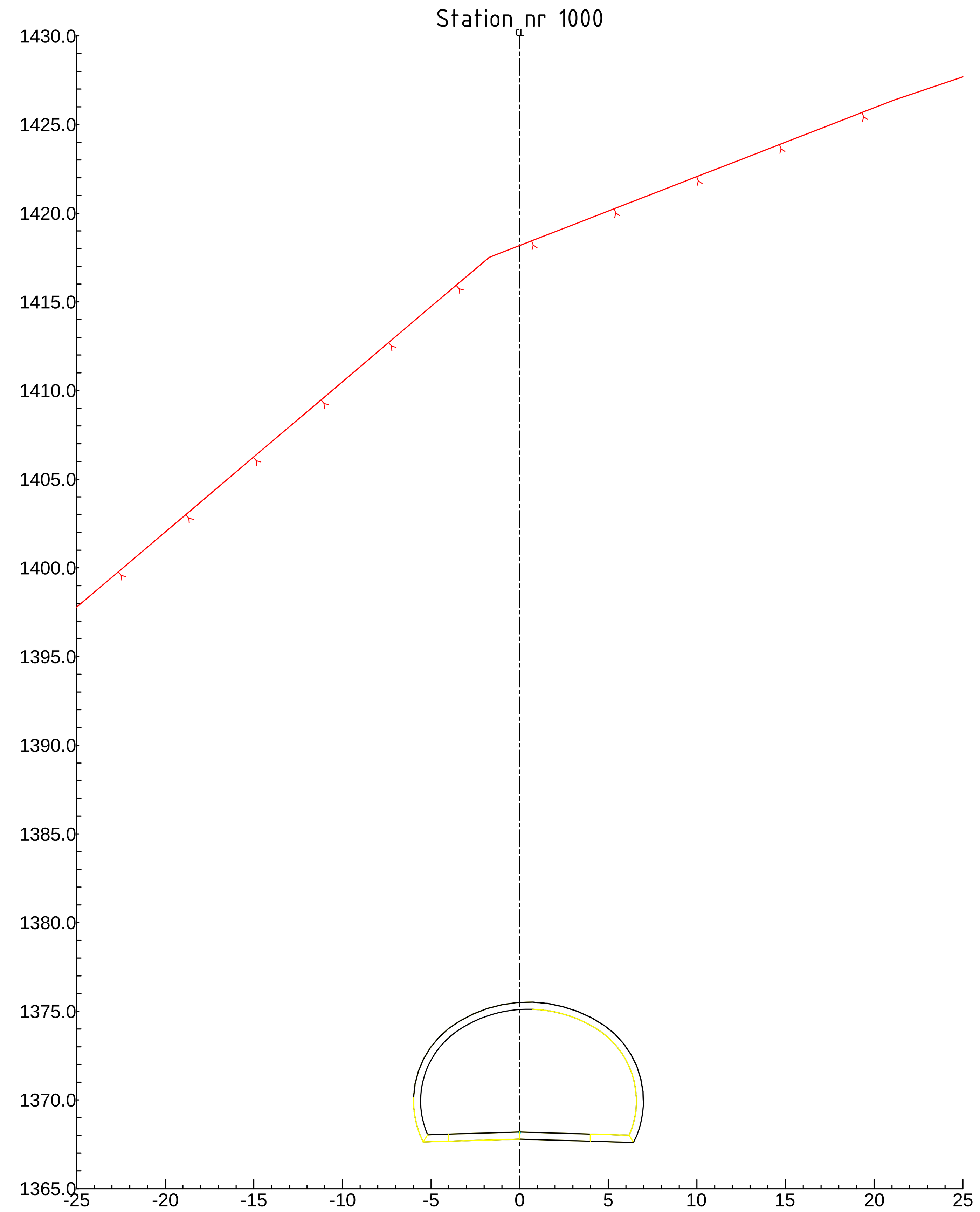


NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 900 – 1000

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

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|---|---|---|---|
| damtkicda: APPROVED: BS | | TariRi: DATE: 16.02.2017 | |
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| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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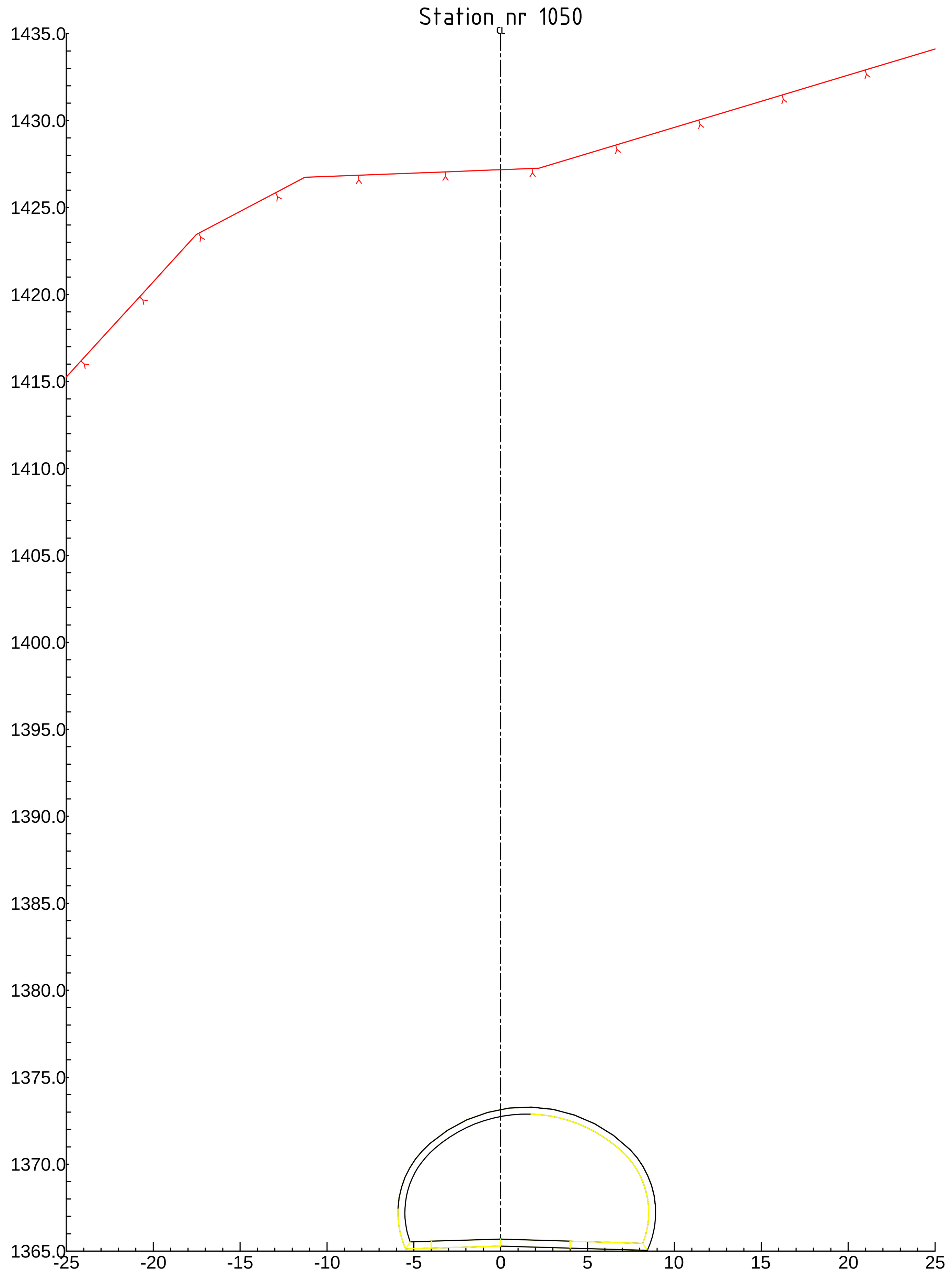


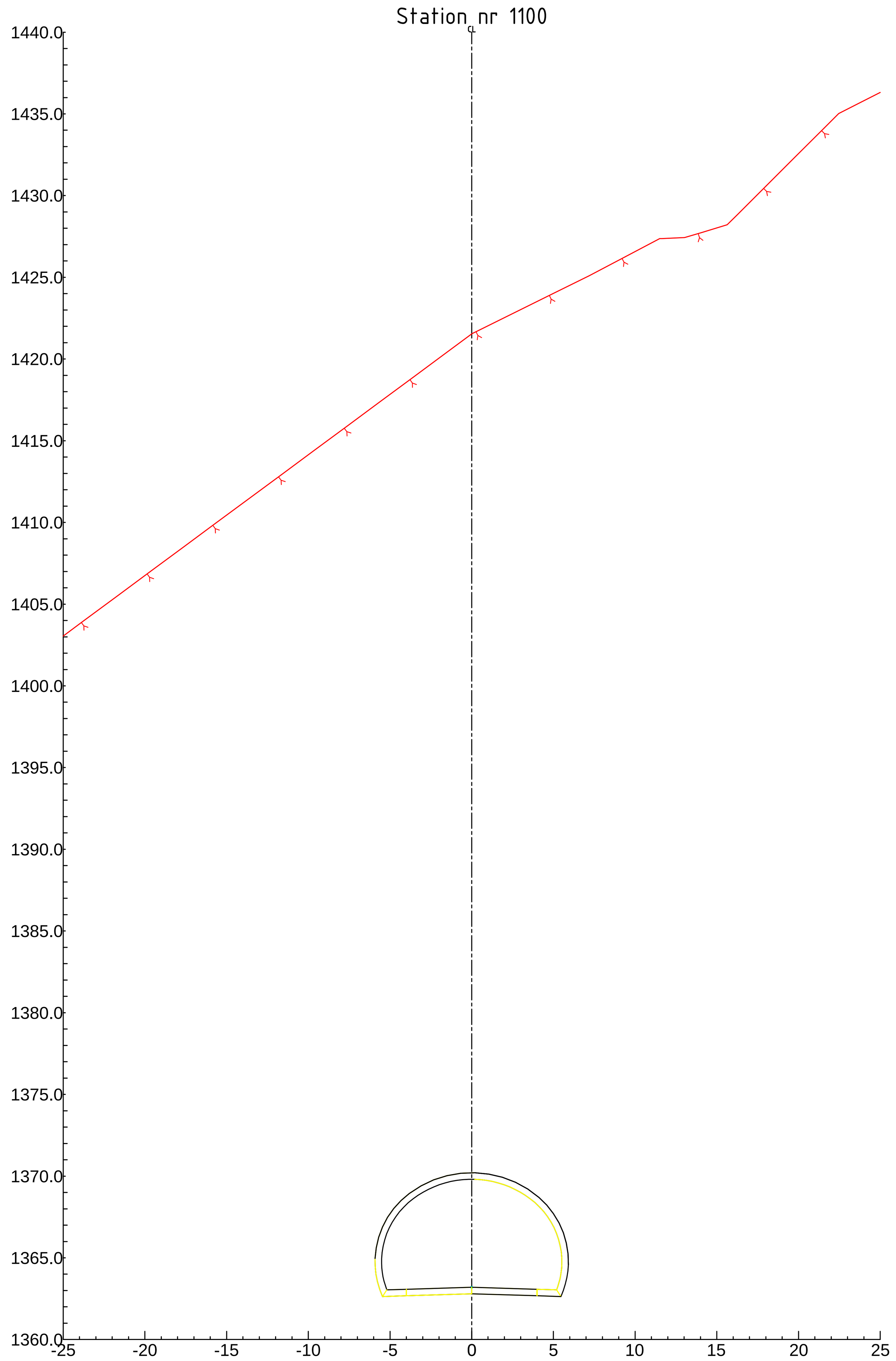


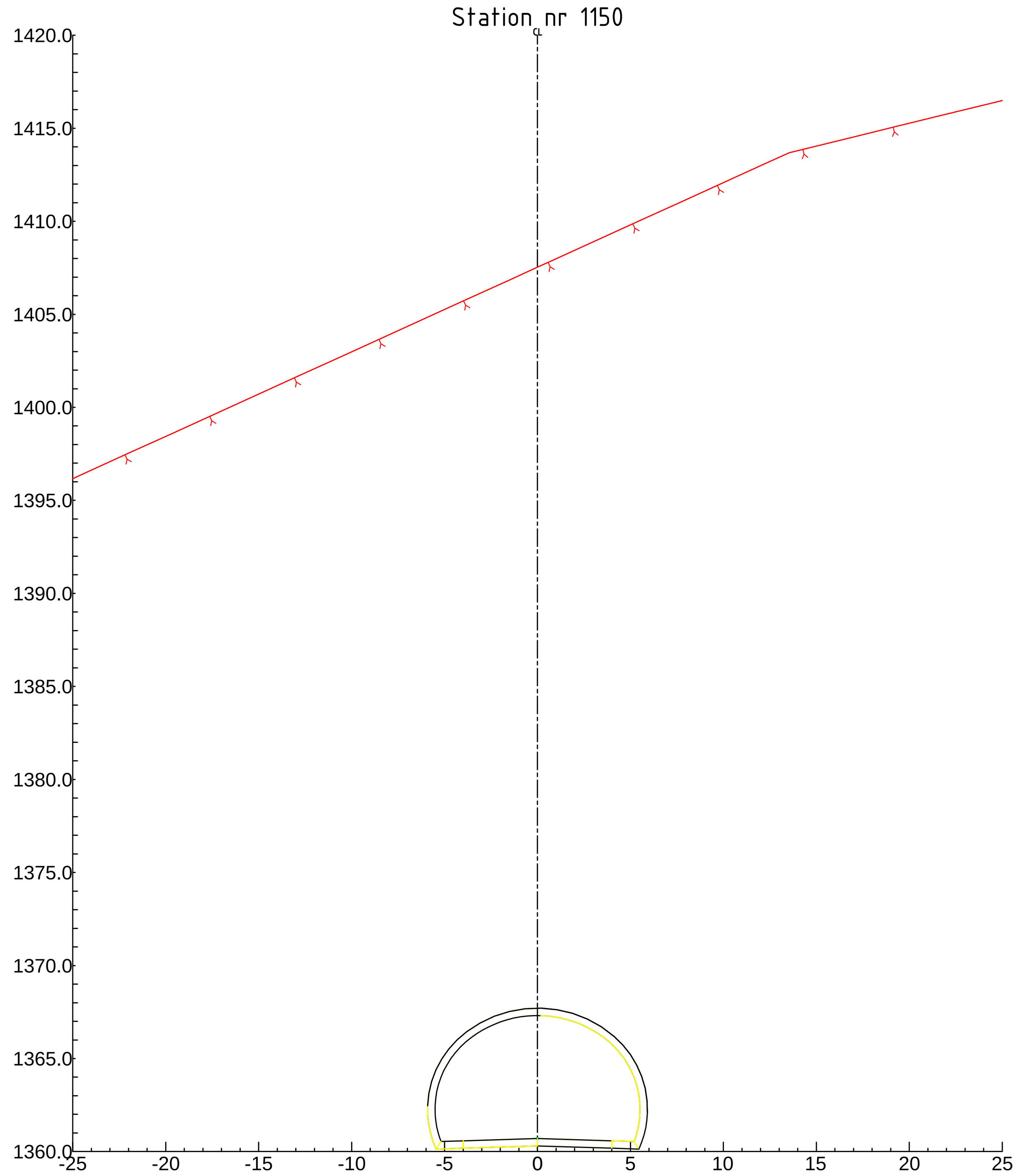


NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 1050 – 1150

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

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| | | | cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |

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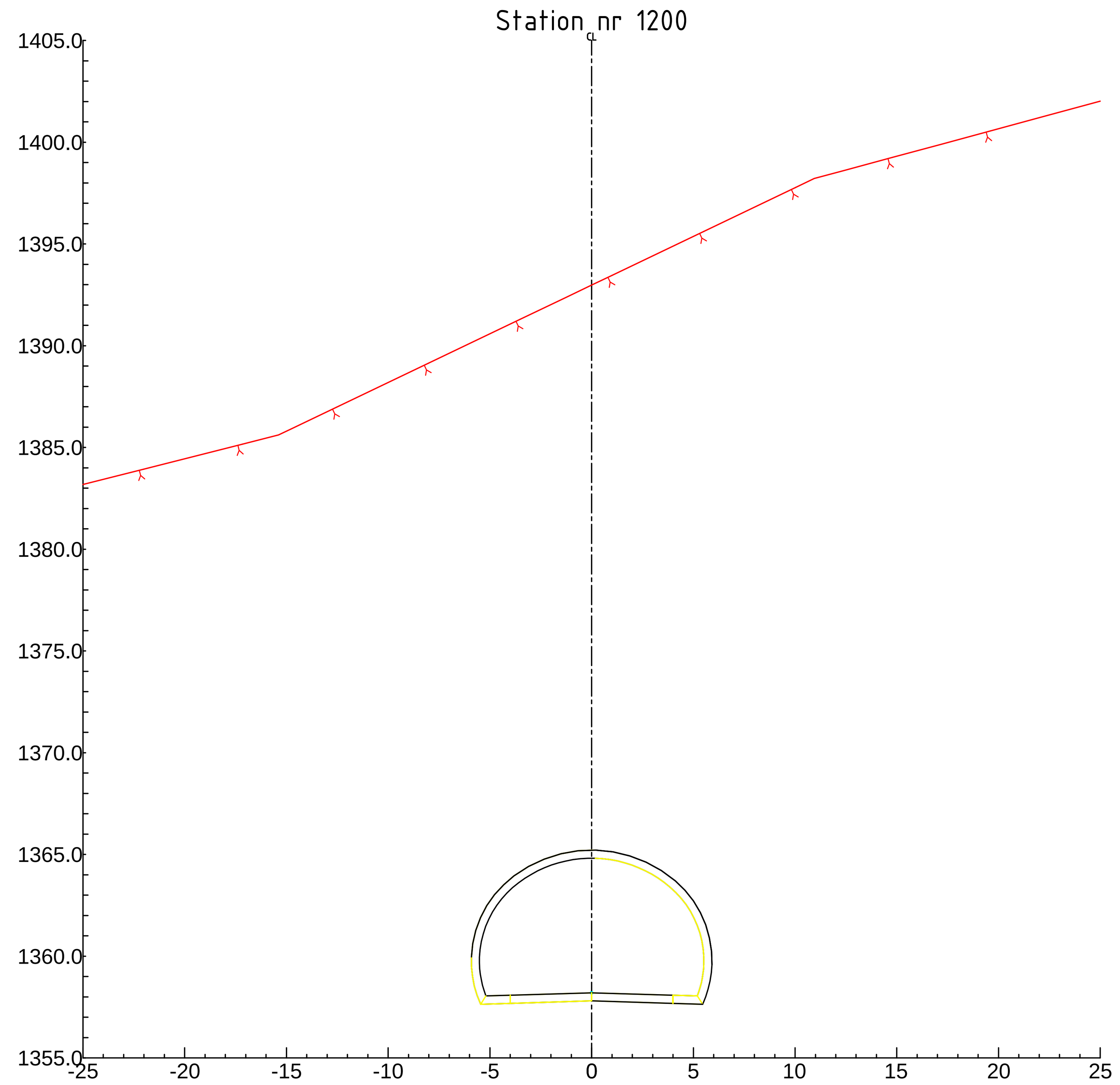
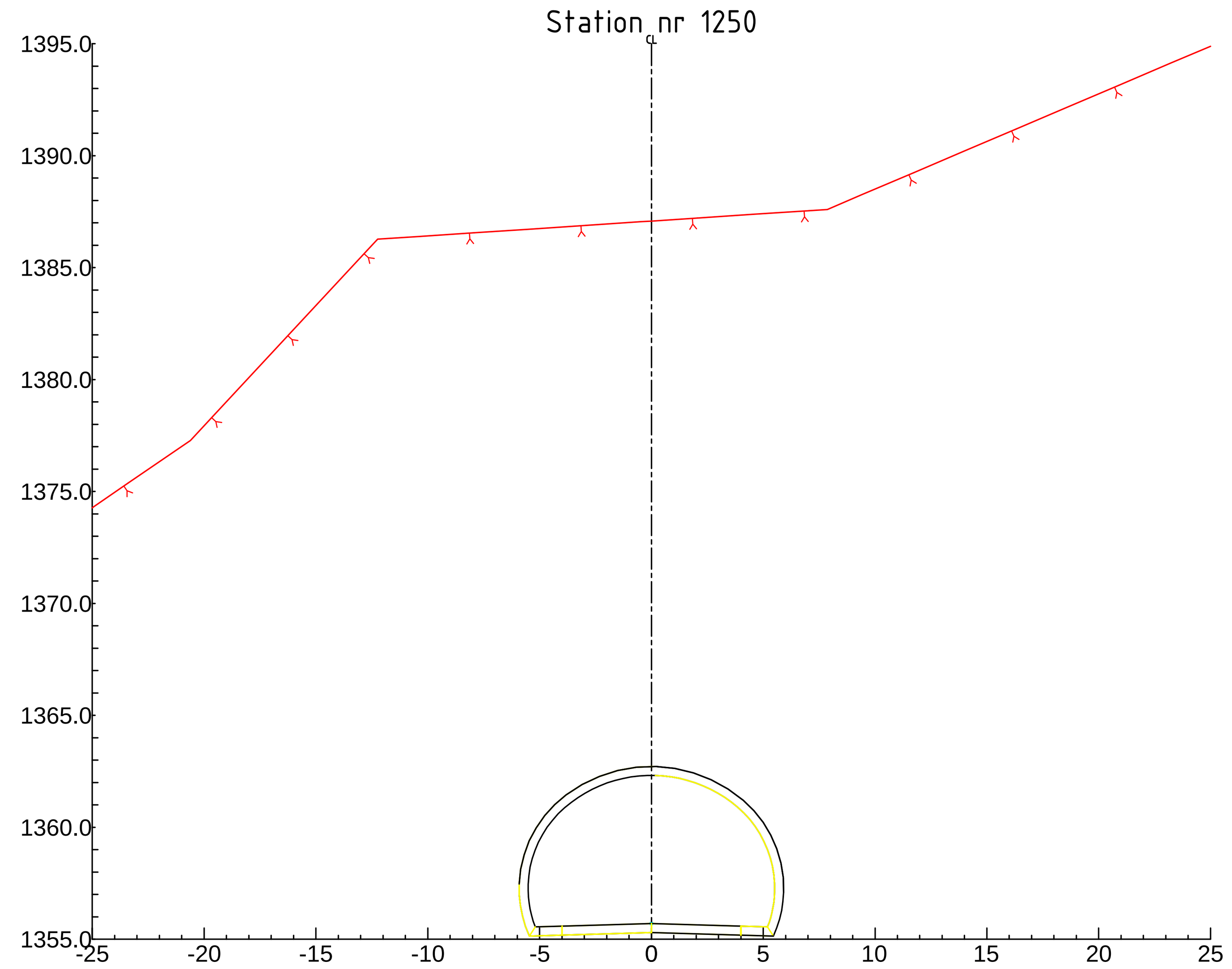
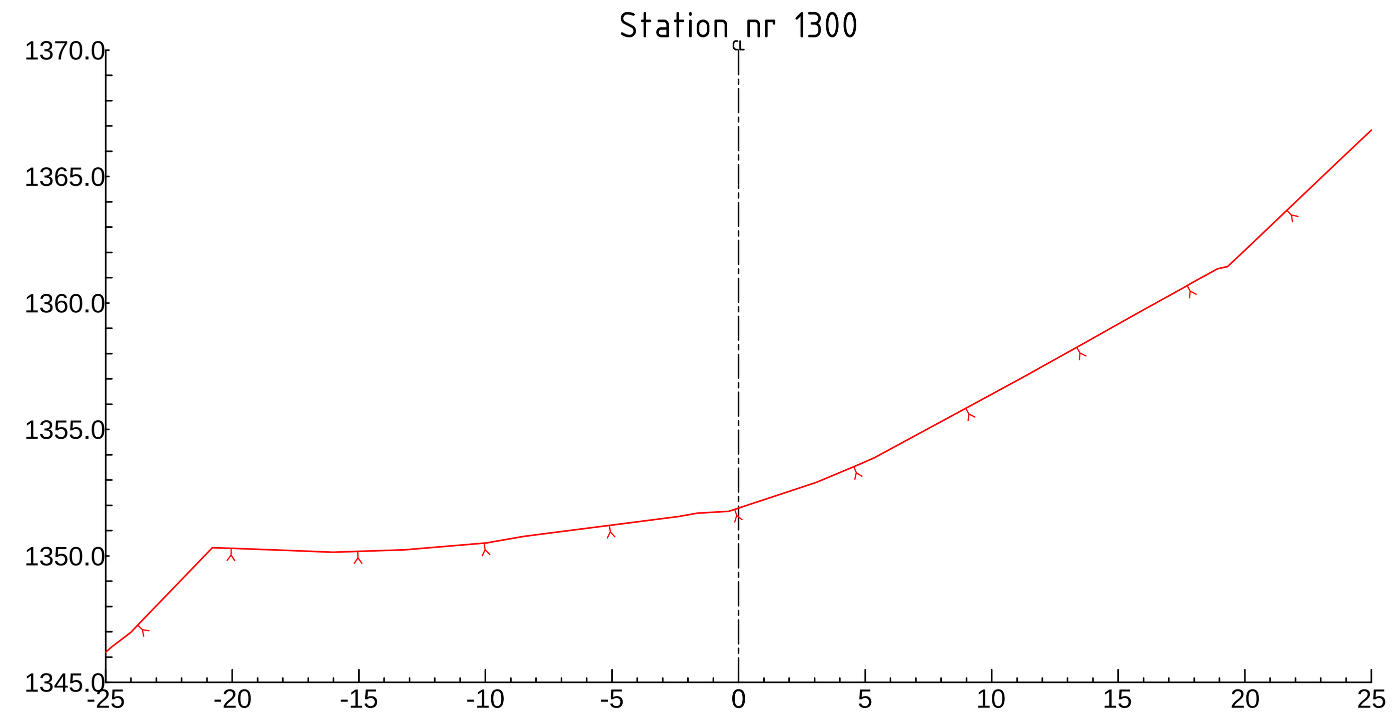
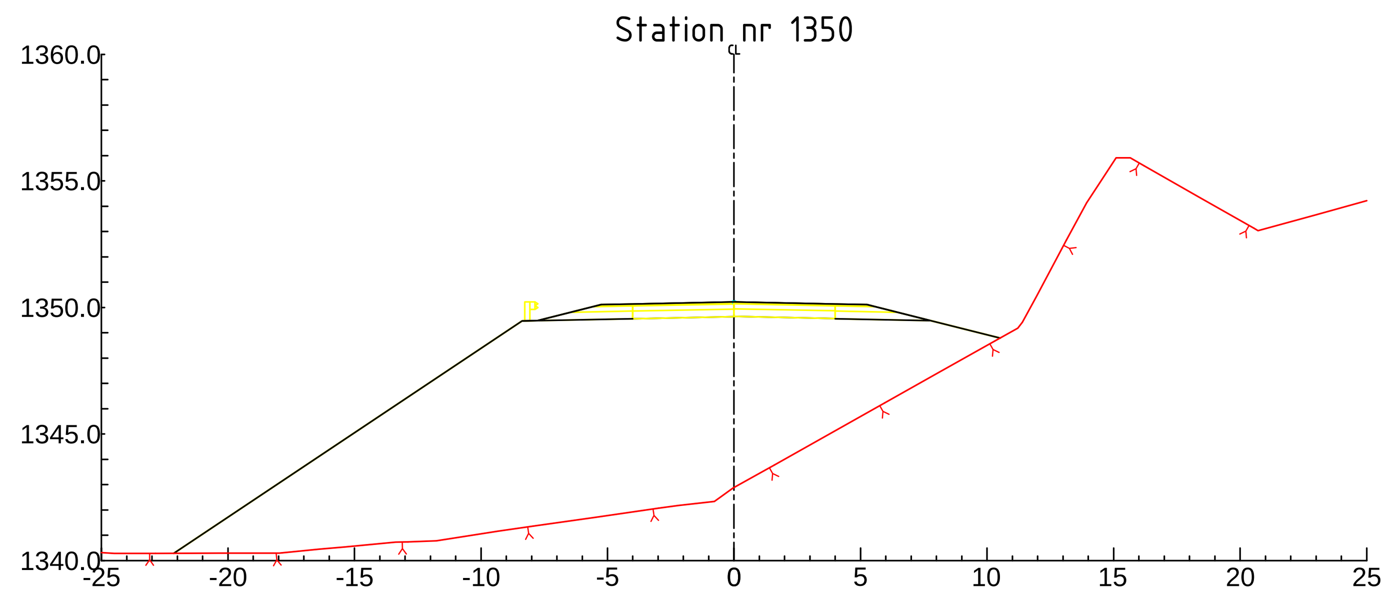
masStabi: SCALE: 1:250

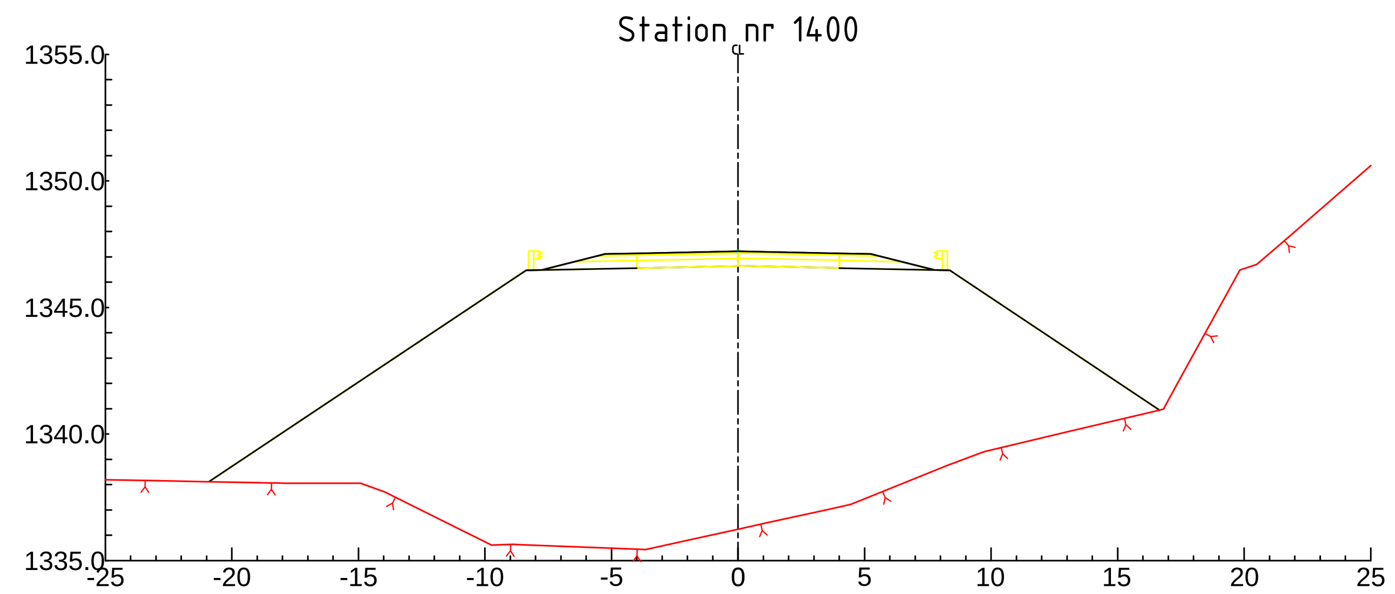
naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1

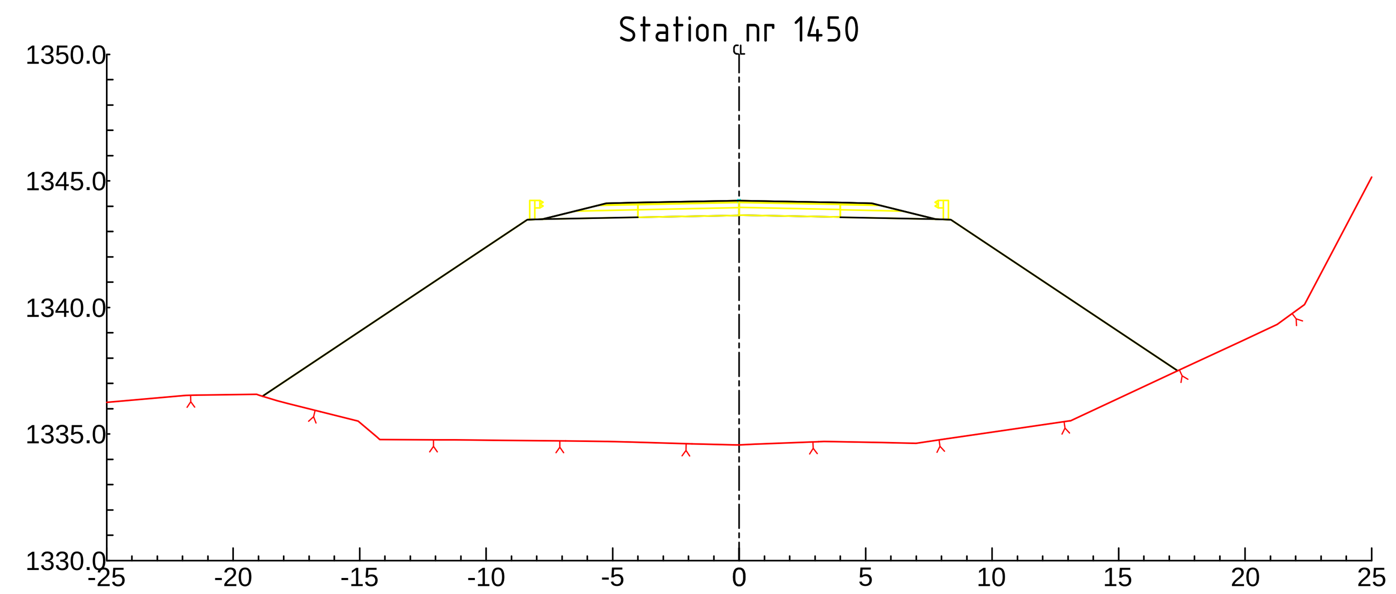



NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 1200 – 1450

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

| damtkicda: APPROVED: BS | | TariRi: DATE: 16.02.2017 |
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| daaproeqta: DESIGNED: SAT | daxaza: DRAWN: SAT | Semowmda: CHECKED: GJ |

| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
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| A | Tender drawing | 16.02.2017 |

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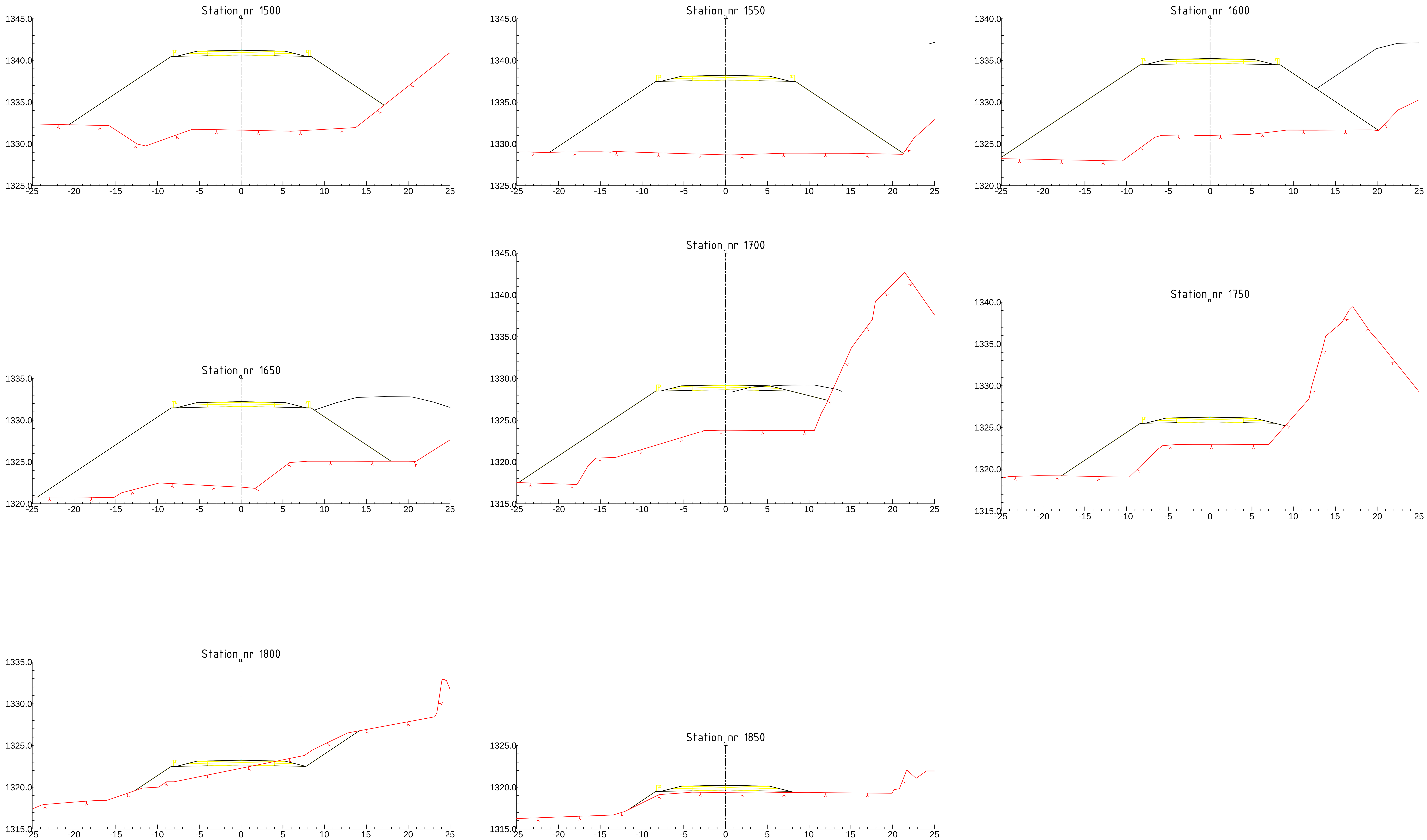
masStabi: SCALE: 1:250

naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1






damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Tunnel and Roadworks – St. 1500 – 1850

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

| damtkicda: APPROVED: BS | TariRi: DATE: 16.02.2017 | | | |
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| | | | A | Tender drawing | 16.02.2017 |
| | | | cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |

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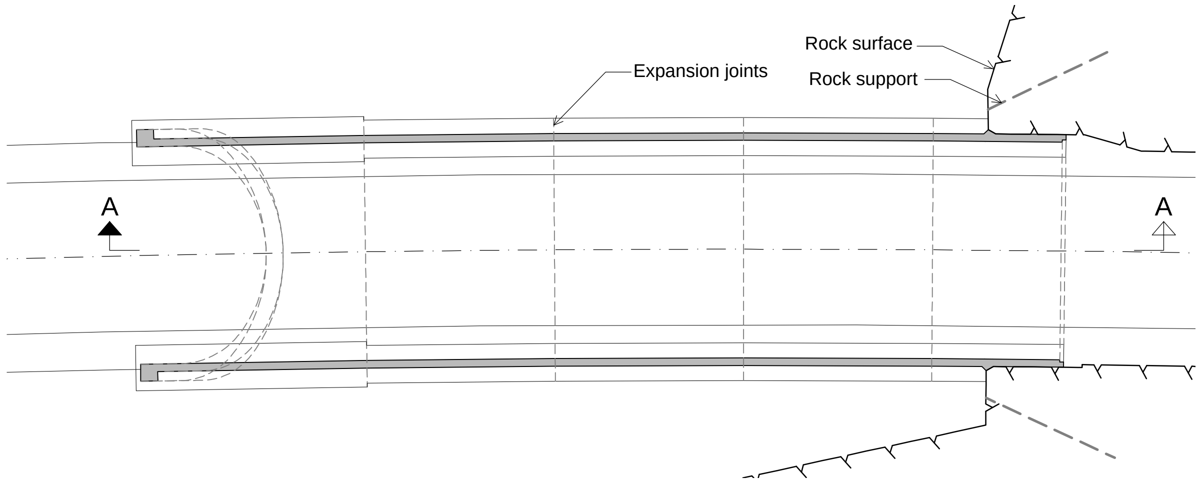
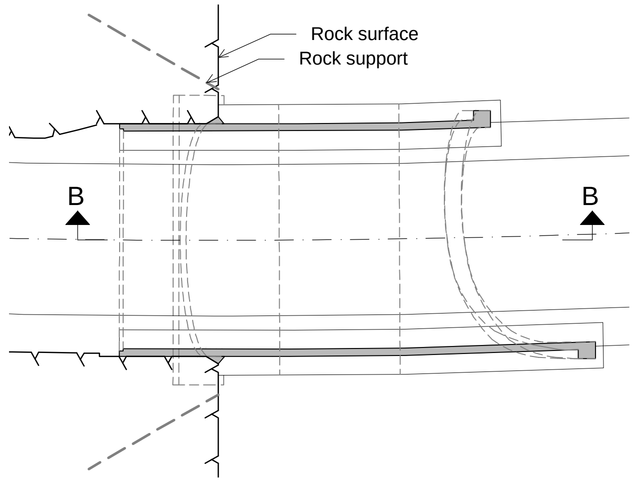
masStabi: SCALE: 1:250

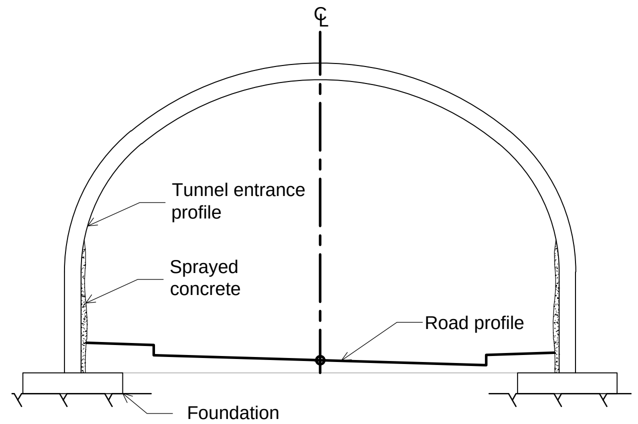
naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1



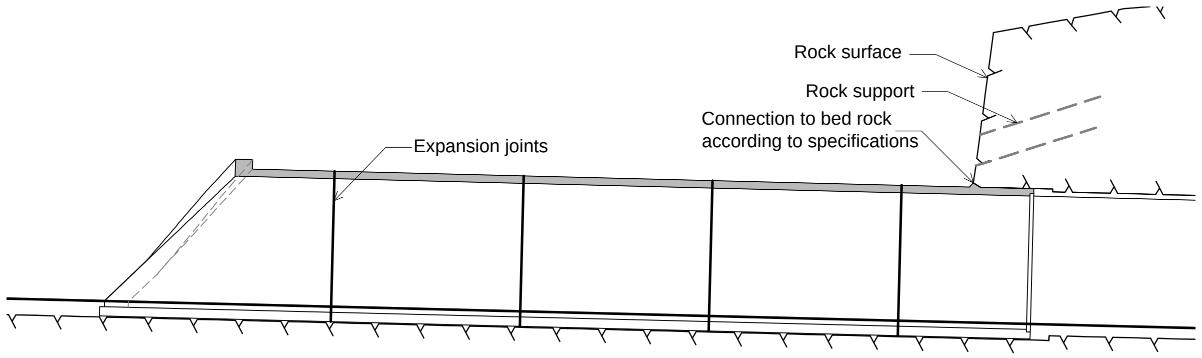

South portal



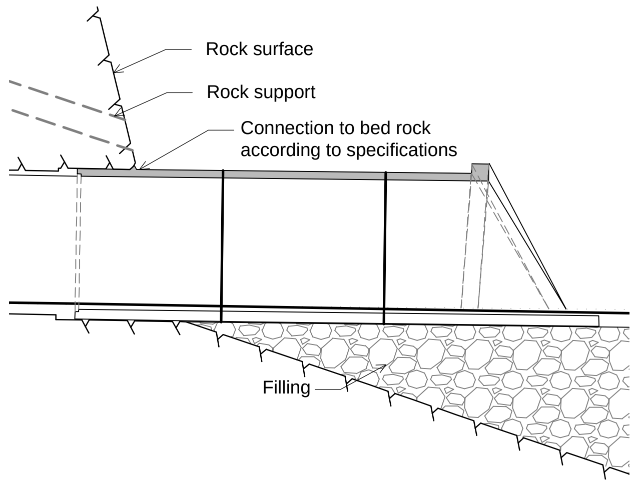

North portal



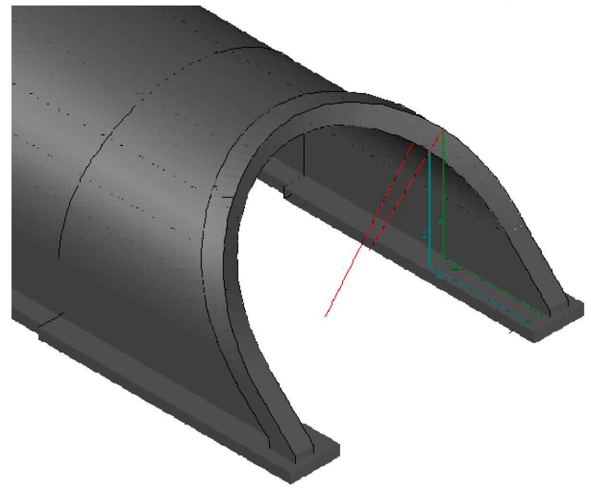

Cross section portal structure



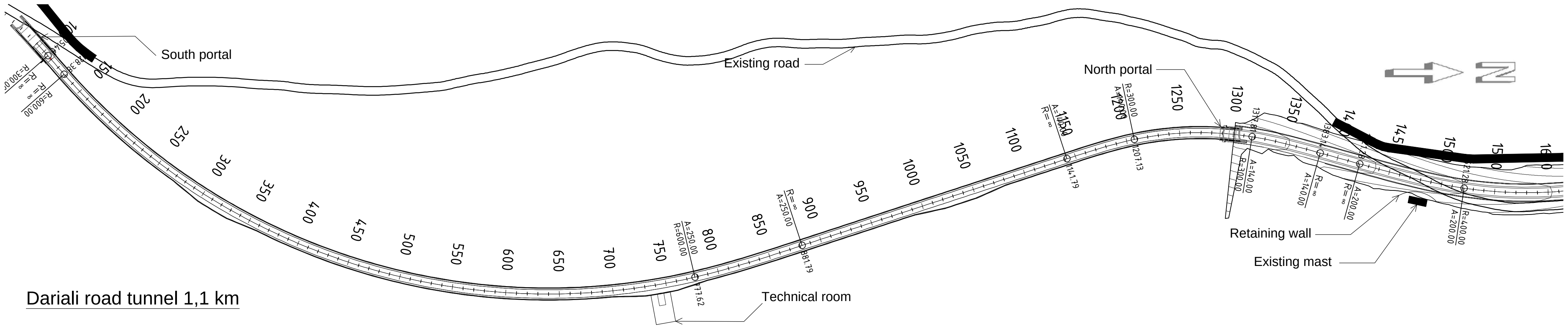

South portal A-A



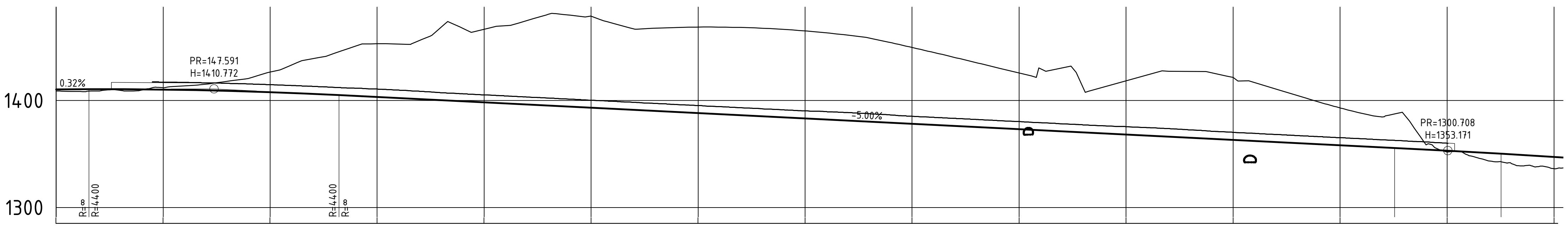

North portal B-B



South portal - overview




Dariali road tunnel 1,1 km




NOTE:

Concrete structures will be as described in design report.

Tunnel entrance structures
South side - 55 m long approx.
North side - 20 m long approx.

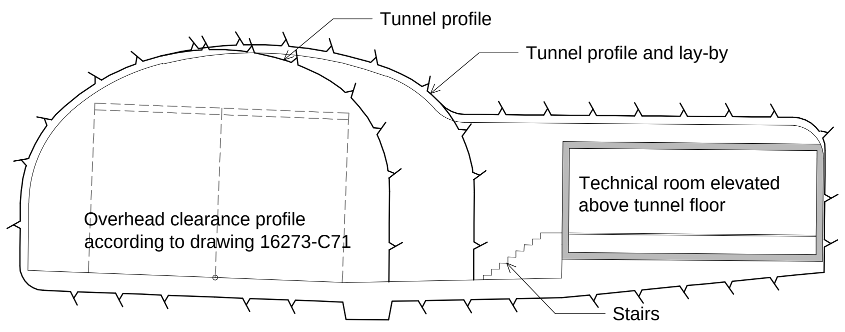
Portal structure cross section same as the tunnel cross section

REFERENCE

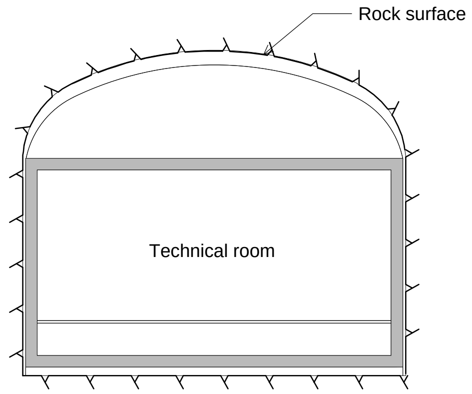
C50-002 - Technical room and retaining wall
C71-001/002/003 - Roadworks and tunnel
M20-001 - Drainage structures
E20-001 - Electrical and safety equipment

NOT FOR CONSTRUCTION

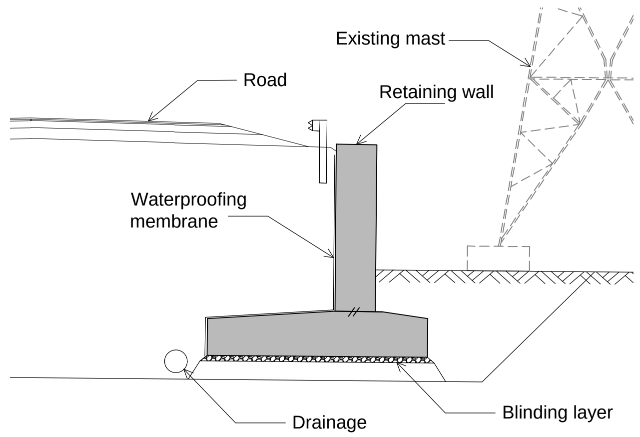
| | | | |
|---|---|---|---|
| damkveTi: EMPLOYER: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA | konsultanti: CONSULTANT: Landsvirkjun Power | gzis dasaxeleba: ROAD TITLE: Mtskheta-Stepantsminda-Larsi Road – E117 | naxazis dasaxeleba: DRAWING TITLE: Concrete structures / Tunnel portal structures |
| proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section | qvekonsultanti: SUBCONSULTANT: Geoengineering – Gamma consulting | damtkicda: APPROVED: BS; TariRi: DATE: 16.02.2017; daaproeqta: DESIGNED: DTG; daxaza: DRAWN: DTG; Seamowma: CHECKED: GPJ; cvlil. REV.: A; aRwera DESCRIPTION: Tender drawing; TariRi DATE: 16.02.2017 | naxazis #: DRAWING No.: C50.001; masStabi: SCALE: Varies; naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1 |



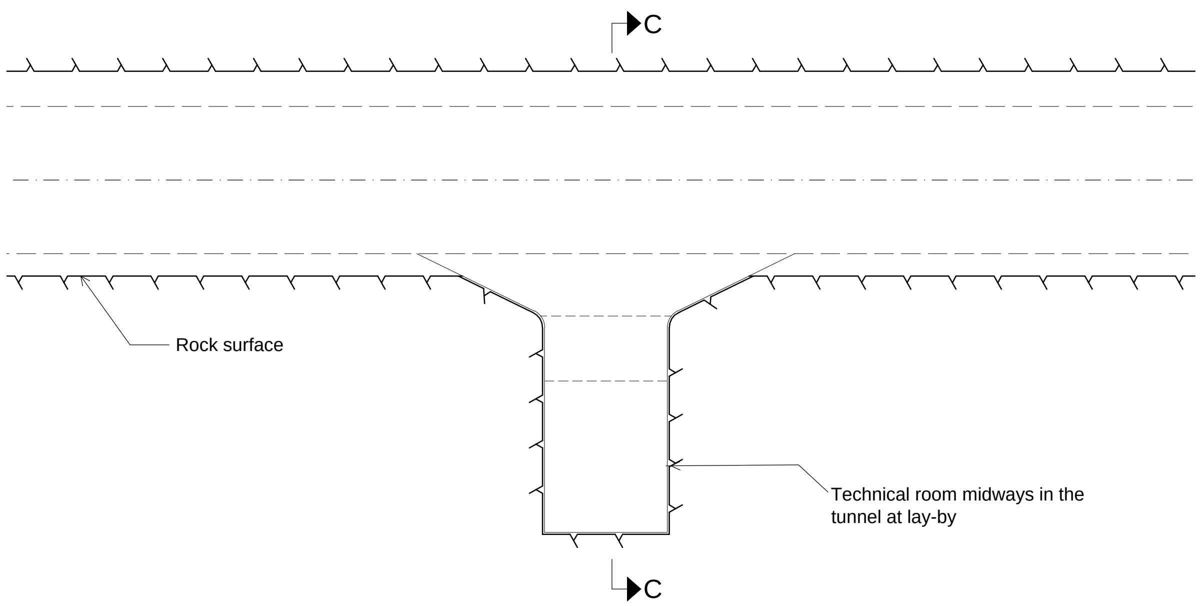

Technical room - cross section C-C



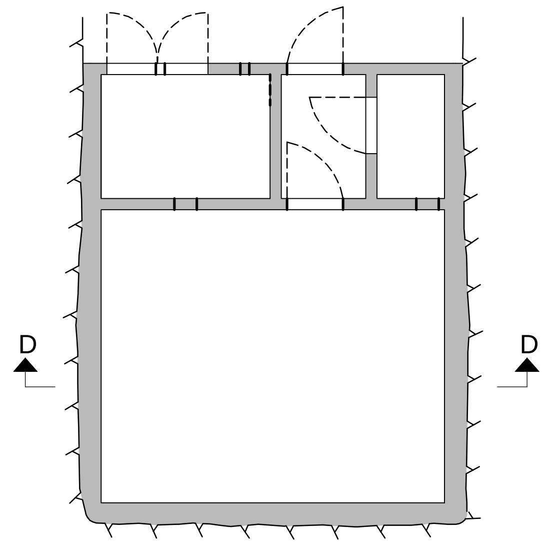

Technical room - cross section D-D



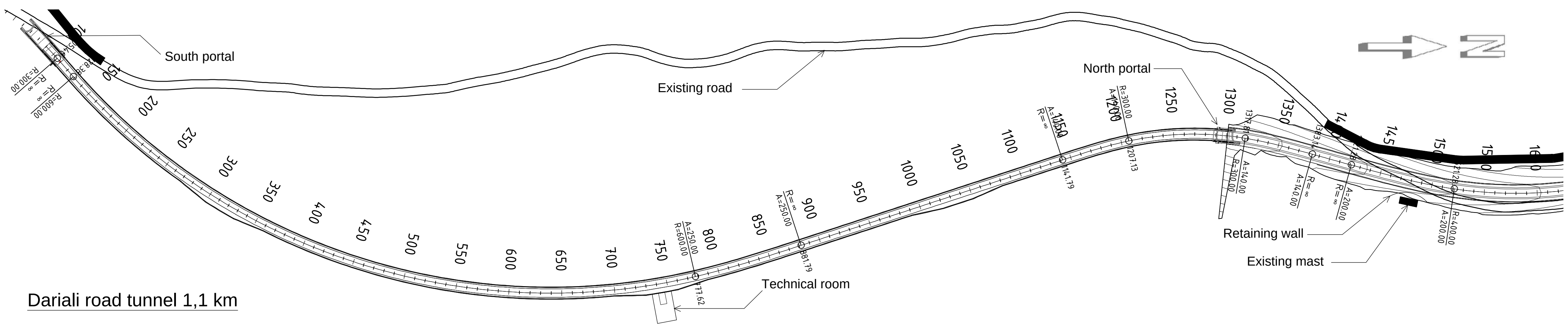

Retaining wall around mast




Technical room




Technical room - example of layout




Dariali road tunnel 1,1 km

NOTE:

Concrete structures will be as described in design report.

Technical room will be placed midway in the tunnel at the lay-by.
Retaining wall shall be constructed around existing mast for protection.

REFERENCE

C50-001 - Concrete structures / Tunnel portals
C71-001/002/003 - Roadworks and tunnel
M20-001 - Drainage structures
E20-001 - Electrical and safety equipment

NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis
EMPLOYER: saministros saavtomobilo gzebis departamenti
ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti:
CONSULTANT: Landsvirkjun Power

gzis dasaxeleba:
ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117

naxazis dasaxeleba:
DRAWING TITLE: Concrete structures / Tech room – retaining wall

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti:
SUBCONSULTANT: Geoengineering – Gamma Consulting

| damtkicda: APPROVED: BS | TariRi: DATE: 16.02.2017 | | | |
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| | | | A | Tender drawing | 16.02.2017 |
| | | | cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |

naxazis #: DRAWING No.: C50.002
masStabi: SCALE: Varies
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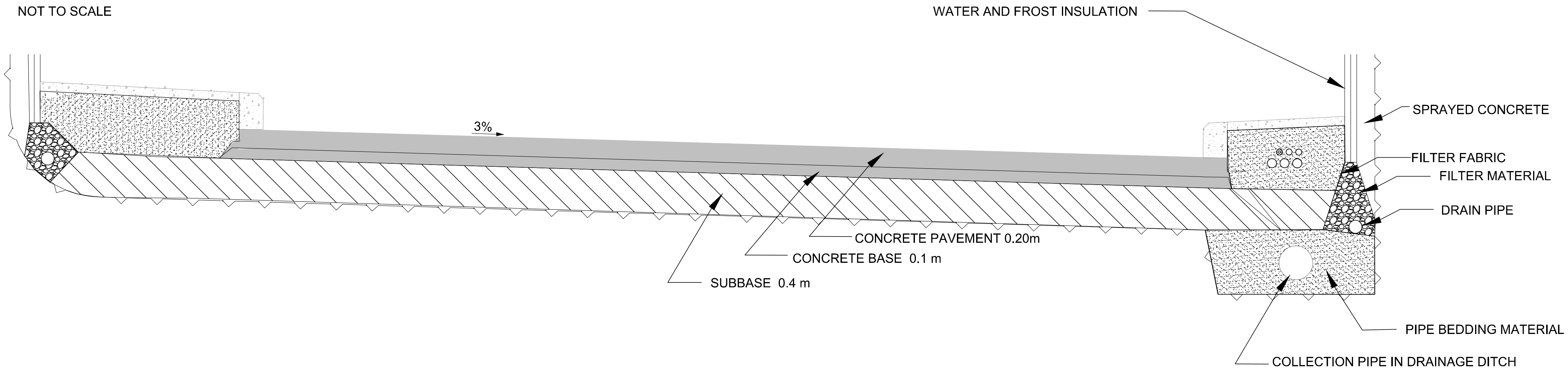
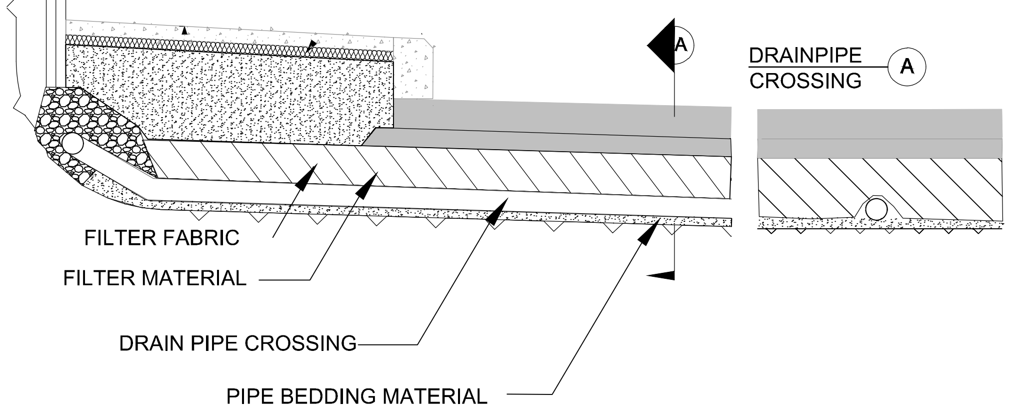
## TYPICAL CROSS SECTION FOR TUNNEL DRAINAGE

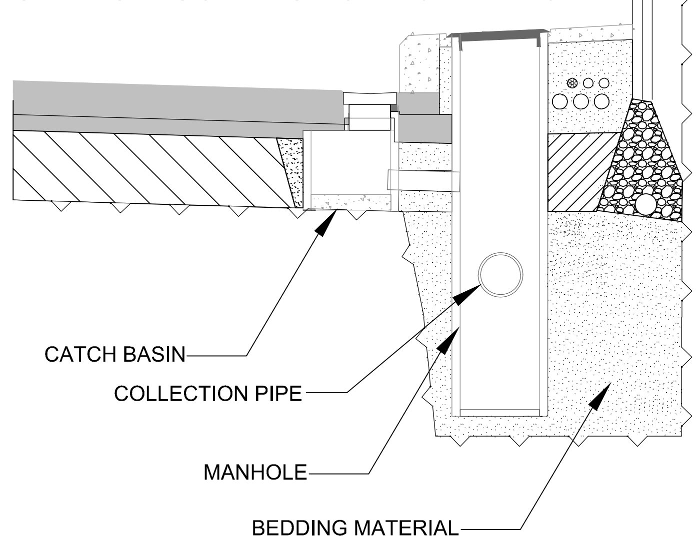
NOT TO SCALE




## DRAINPIPE CROSSING




## CATCH BASIN CONNECTION TO MANHOLE




REFERENCE

C71-001/002/003 – Roadworks and tunnel
E20-001 – Technical equipment

NOT FOR CONSTRUCTION

damkveTi: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti
EMPLOYER: ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA

konsultanti: / CONSULTANT: Landsvirkjun Power

gzis dasaxeleba: / ROAD TITLE: Mtskheta-Stepantsminda-Larsi Road – E117

naxazis dasaxeleba: / DRAWING TITLE: Drainage and utility systems

proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section

qvekonsultanti: / SUBCONSULTANT: Geoengineering – Gamma Consulting

| damtkicda: APPROVED: BS | | TariRi: DATE: 16.02.2017 | | | |
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naxazis #: / DRAWING No.: M20.001

masStabi: / SCALE: Not to scale

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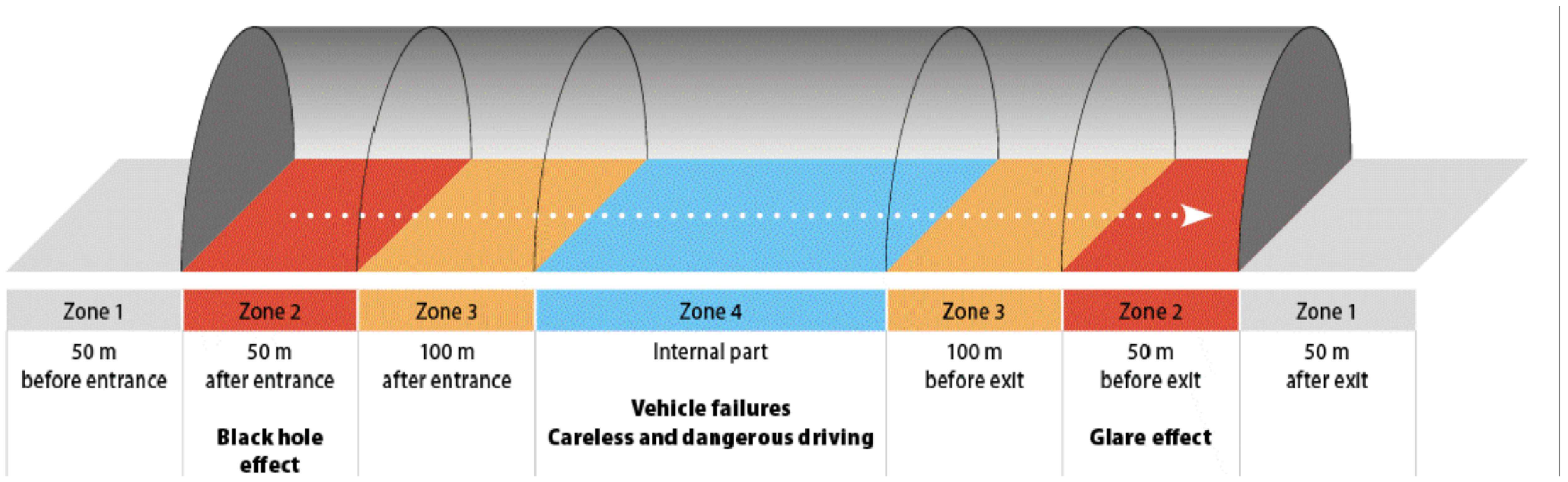
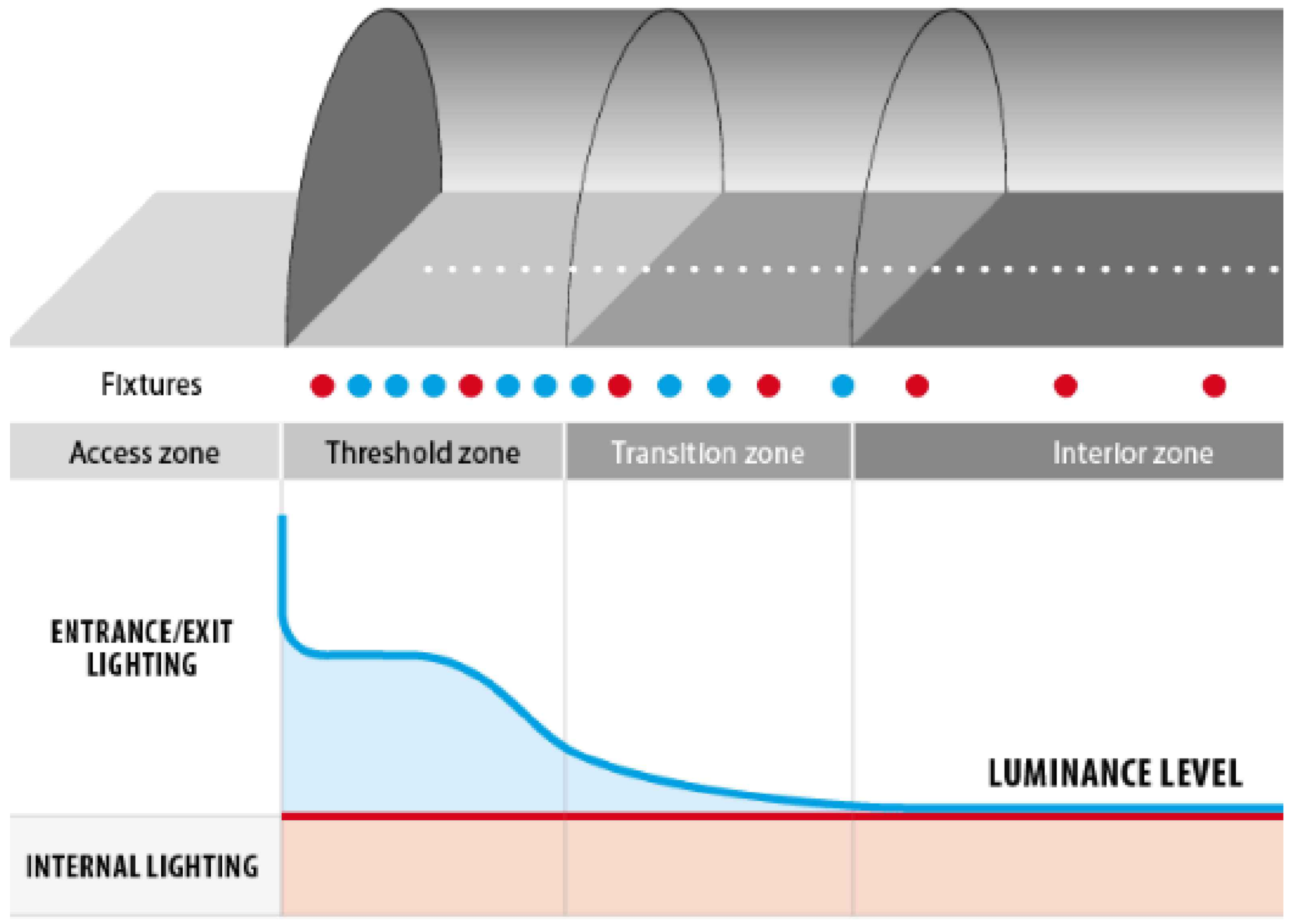
Below showing section of zones in tunnels

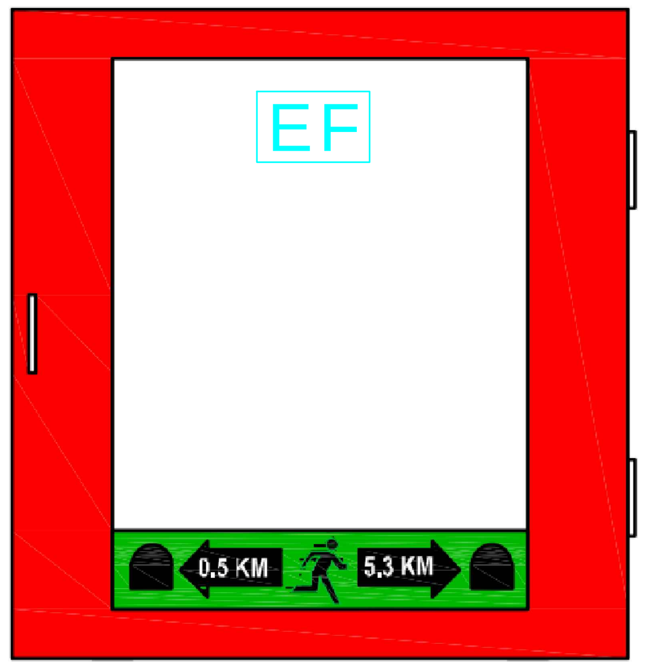



Escape distance sign placed on every emergency telephone

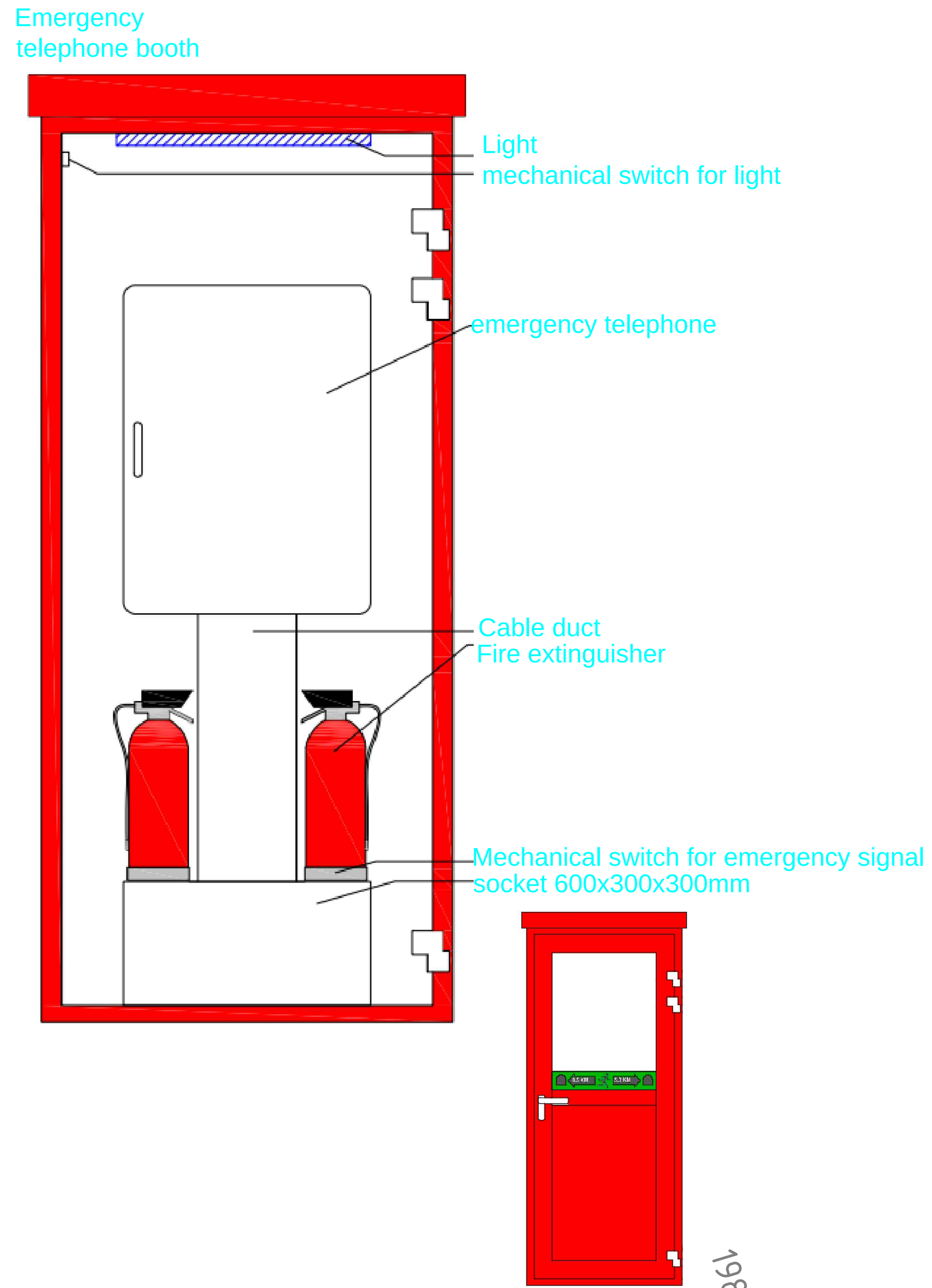
The graphic below shows a typical layout of the tunnel luminaires according to the light levels required in each tunnel zone.
This picture is showing zones at the entrance and into the interior zone and this applies in both ends of the tunnel.

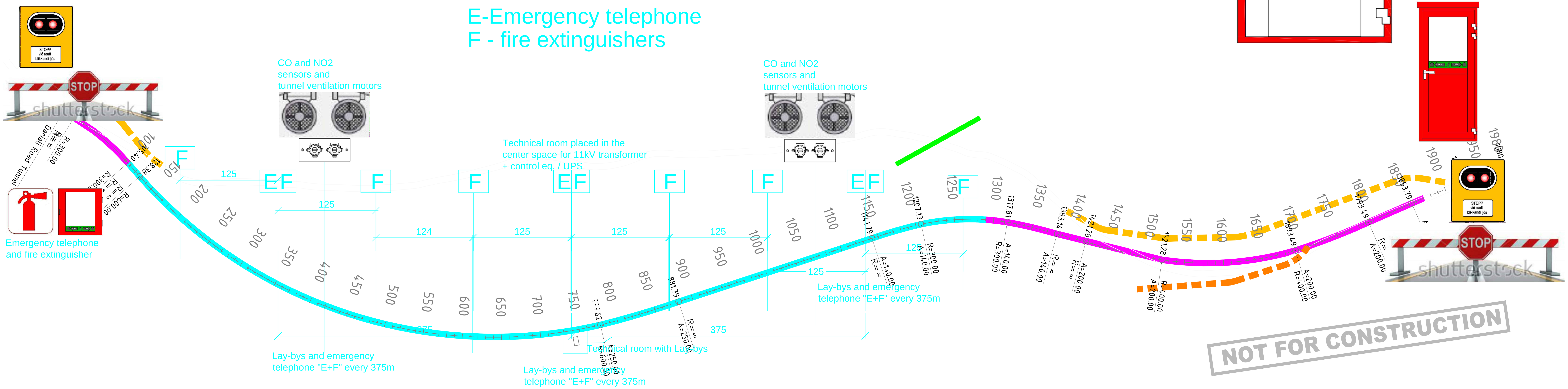



Emergency box on wall about 800x800mm
fire extinguisher "F" - Emergency telephone "E"




E-Emergency telephone
F - fire extinguishers




| | | | |
|---|---|---|---|
| damkveTi: EMPLOYER: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA | konsultanti: CONSULTANT: Landsvirkjun Power | gzis dasaxeleba: ROAD TITLE: Mtskheta-Stepantsminda-Larsi Road - E117 | naxazis dasaxeleba: DRAWING TITLE: Electrical and safety equipment |
| proeqti / PROJECT: Alternative alignment og KM132 - KM135 - Devdoraki mudflow section | qvekonsultanti: SUBCONSULTANT: Geoengineering - Gamma Consulting | damtkicda: APPROVED: BS; TariRi: DATE: 16.02.2017; daaproeqta: DESIGNED: SVE; daxaza: DRAWN: SVE; Seamowma: CHECKED: AOI; cvlil. REV.: A; aRwera DESCRIPTION: Tender drawing; TariRi DATE: 16.02.2017 | naxazis #: DRAWING No.: E20.001; masStabi: SCALE: Not to scale; naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1 |

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| 2 | 469853 | 4731078 |
| 3 | 469782 | 4730943 |
| 4 | 469753 | 4730960 |
| 5 | 469815 | 4731083 |
| 6 | 469695 | 4730958 |
| 7 | 469736 | 4730941 |
| 8 | 469683 | 4730839 |
| 9 | 469654 | 4730863 |
| 10 | 469691 | 4729960 |
| 11 | 469730 | 4729952 |
| 12 | 469708 | 4729886 |
| 13 | 469660 | 4729839 |
| 14 | 469660 | 4729894 |
| 15 | 469624 | 4729766 |
| 16 | 469642 | 4729762 |
| 17 | 469597 | 4729714 |
| 18 | 469547 | 4729681 |
| 19 | 469507 | 4729638 |
| 20 | 469494 | 4729650 |
| 21 | 469565 | 4729718 |
| 22 | 469463 | 4729345 |
| 23 | 469545 | 4729319 |
| 24 | 469520 | 4729211 |
| 25 | 469483 | 4729135 |
| 26 | 469418 | 4729129 |
| 27 | 469401 | 4729170 |
| 28 | 469394 | 4729254 |
| 29 | 469341 | 4729142 |
| 30 | 469364 | 4729100 |
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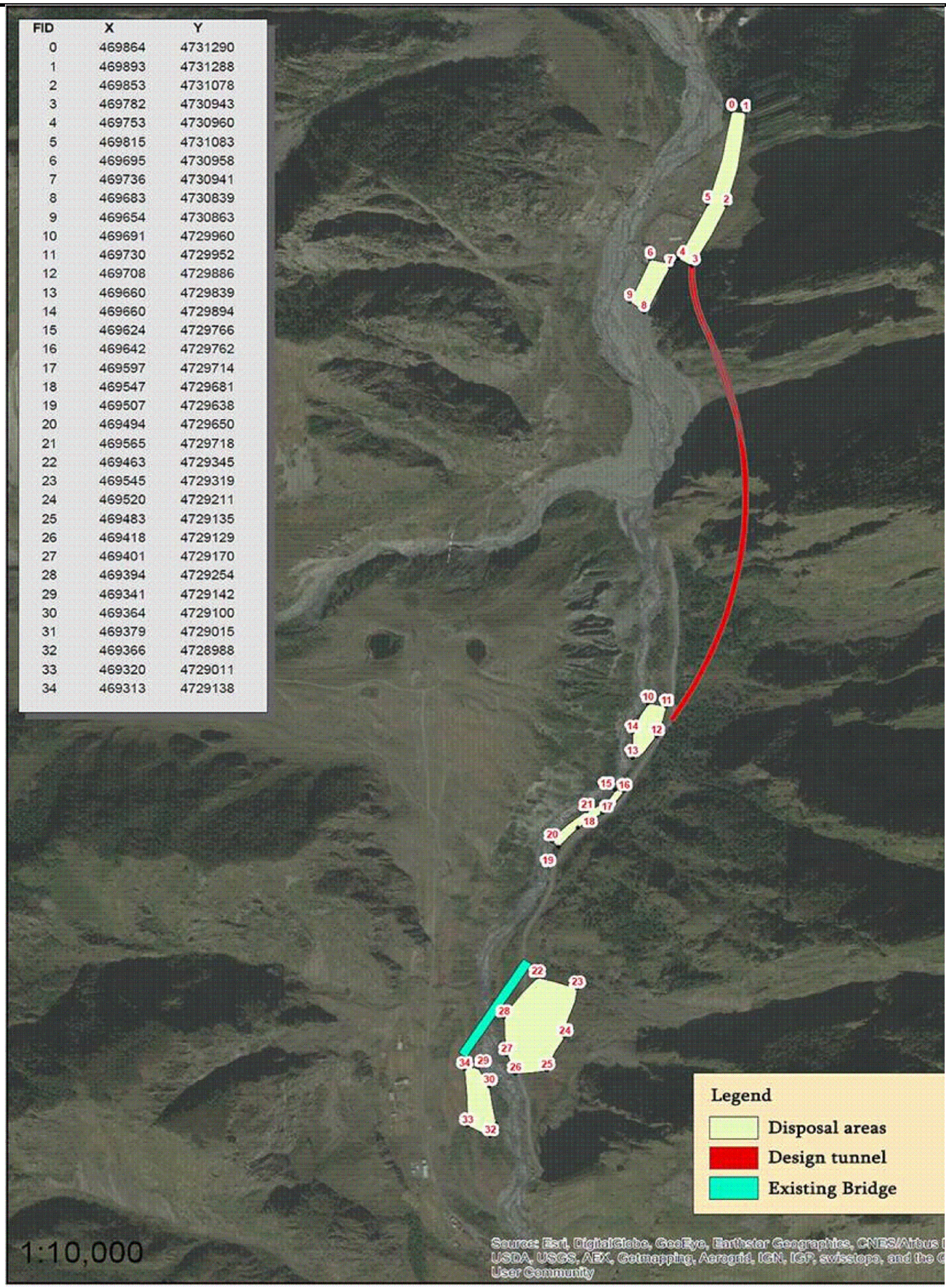


NOT FOR CONSTRUCTION

| | | | |
|---|---|---|---|
| damkveTi: EMPLOYER: saqarTvelos regionaluri ganviTarebisa da infrastruqturis saministros saavtomobilo gzebis departamenti<br>ROADS DEPARTMENT OF THE MINISTRY OF REGIONAL DEVELOPMENT AND INFRASTRUCTURE OF GEORGIA | konsultanti: CONSULTANT: Landsvirkjun Power | gzis dasaxeleba: ROAD TITLE: Mtskheta–Stepantsminda–Larsi Road – E117 | naxazis dasaxeleba: DRAWING TITLE: Tunnel and Roadworks – Spoil areas |
| proeqti / PROJECT: Alternative alignment of KM132 – KM135 – Devdoraki mudflow section | qvekonsultanti: SUBCONSULTANT: | damtkicda: APPROVED: BS<br>TariRi: DATE: 16.2.2017<br>daaproeqta: DESIGNED: Gamma<br>daxaza: DRAWN: Gamma<br>Seamowma: CHECKED: Gamma | naxazis #: DRAWING No.: C21.001<br>masStabi: SCALE: 1:10000<br>naxazis originaluri zoma: ORIGINAL DRAWING SIZE: A1 |

| cvlil. REV. | aRwera DESCRIPTION | TariRi DATE |
|---|---|---|
| A | Tender drawing | 16.2.2017 |

## Appendix B – Geological Report

## Appendix C – Environmental Mitigation Plan

### Construction Phase

| Receptor/Impact | Impact | Mitigation Measures | Characteristics |
|---|---|---|---|
| Inorganic dust emission in ambient air<br><br>**significance:**<br>low | • Dust generated due to earth works;<br>• Dust generated due to transportation operations;<br>• Dust generated during loading-unloading materials and waste. | • Ensure proper working conditions of machinery;<br>• Ensure that vehicle's speed is optimal (especially on earth roads);<br>• Provide preventive measures to avoid excessive dust emission during earth-works and handling of building materials (e.g. prohibition of material dropping from height during loading/unloading);<br>• Carry out measures for suppression of dust emission as needed (e.g. water work area);<br>• Equip personnel with proper protecting equipment (masks-respirators) as needed;<br>• Instruct personnel before works are launched;<br>• Register and respond to complaints whenever occur | **Residual Impact significance and likelihood:** very low<br>**Responsible for implementation of mitigation measures:** Construction contractor<br>**Monitoring:** Maintenance check-up of machinery**;** Drivers' inspection during transportation operation<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>Personnel individual protection means expenses;<br>No additional expenses |
| Emission of combustion products in ambient air<br><br>**significance:**<br>low | • Exhaust gases from vehicles, building machinery;<br>• Welding aerosols | • Ensure proper working conditions of machinery;<br>• Ensure that vehicle's speed and route is optimal;<br>• Ensure vehicle motors are turned off, or run at idle speed, when they are in use.<br>• Instruct personnel before works are launched;<br>• Register and respond to complaints whenever occur. | **Residual Impact significance and likelihood:** very low<br>**Responsible for implementation of mitigation measures:** Construction contractor<br>**Monitoring:** Maintenance check-up of machinery**;**<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>No additional expenses |
| Noise propagation in working zone<br><br>Level: | • Noise and vibration caused by vehicles and equipment; | • Ensure proper working conditions of machinery;<br>• Equip personnel with proper protecting equipment (hearing-protectors) as needed;<br>• Execute "noisy" works, including blasting during the daytime; | **Residual Impact significance** low - average<br>**Responsible for implementation of mitigation measures:** Construction contractor |

| | | | |
|---|---|---|---|
| Varies from average to high impact | • Noise and vibration caused by works related to blasting. | • Register and respond to complaints whenever occur. | **Monitoring:** Technical check-up of machinery<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>Personnel individual protection means expenses;<br>No additional expenses |
| Noise Propagation on the borders of residential zone (village Gveleti, Monastery complex)<br><br>**significance:**<br>low | | • Ensure proper working conditions of machinery<br>• Execute “noisy” works, including blasting during the daytime;<br>• Instruct personnel before works are launched;<br>• Register and respond to complaints whenever occur. | **Residual Impact significance:** very low<br>**Responsible for implementation of mitigation measures:** Construction contractor<br>**Monitoring:** Technical check-up of machinery<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>No additional expenses |
| Soil stability and destruction of fertile layer<br><br>**significance:**<br>very low | • Soil stability and destruction, fertile soil layer damage risk during the construction works. | • Follow safety norms introduced for the works;<br>• Strict protection of construction site borders in order to avoid damaging of topsoil layer;<br>• Provide protective works as needed;<br>• Remove fertile soil layer (if necessary) and temporarily stockpile topsoil till reused for recultivation;<br>• Instruct personnel before works;<br>• Register all potential risks on time and ensure prompt response | **Residual Impact significance** very low<br>**Responsible for implementation of mitigation measures:** Construction contractor<br>**Monitoring:** current observation<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>Cost of protective works depends on volume of work and market prices |
| Ground/soil contamination | • Soil pollution by waste | • Ensure proper working conditions of machinery to avoid fuel/oil spilling. Proper management of the fuel/oil materials; | **Significance of residual impact:** very low<br>**Responsible for implementation of mitigation measures** Construction contractor |

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| **significance:**<br>low | • Soil pollution due to fuel/oil spilling | • Proper waste management; including separation and reusing as possible; placement of useless waste in special containers and disposal off site;<br>• Localize and clean spilt fuel/oil;<br>• Instruct personnel before works<br>• Provide corresponding equipment (containers, spill collection implements, etc.);<br>• Remove all potential pollutants when works are finished. | **Monitoring:** Technical checkup of machinery;<br>Waste management plan accomplishment control; Visual control of soil conditions;<br>**Responsible for monitoring:** Department of Roads<br>**Expenses for implementation of mitigation measures:**<br>No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>Technique and inventory expenses in case of fuel/oil spillage |
| Risk of potential dangerous geological processes<br><br>**significance:**<br>May vary from medium to high impact | • Activation - development of erosion and rock fall processes during the preparation of tunnel portals | • Remove active landslide formations from upper parts of slopes and arrange corresponding gradient angle, ensuring stability;<br>• Removal of stones and boulders posing risk in terms of rockfall from the upper slopes of the construction sites.<br>• Drain surface- and ground- water so that prevent extra-watering lower of slopes;<br>• Direct storm water and slope runoffs from roadside ditches to Tergi River and its tributaries;<br>• Recultivate and landscape construction area. | **Significance of residual impact:** low<br>**Responsible for implementation of mitigation measures** Construction contractor<br>**Monitoring:** current observation<br>**Responsible for monitoring:** Department of Roads<br>**Monitoring expenses:** No additional expenses<br>**Expenses for implementation of mitigation measures:**<br>Must be considered in design documentation |
| Pollution of surface water (River Tergi)<br><br>**Significance:**<br>medium | • Contamination during earth works;<br>• Contamination due to wrong management of solid and liquid waste;<br>• Pollution in case of improper | • Ensure proper working conditions of machinery to avoid fuel/oil spilling<br>• During car maintenance on site, if necessary, location must be selected away from water object<br>• Proper management of materials;<br>• Ensure proper waste management, including separation and reuse as possible, store waste not appropriate for reuse in special containers and move out of the territory by the licensed Contractor; | **Significance of residual impact:** low<br>**Responsible for implementation of mitigation measures:** Construction contractor<br>**Monitoring:** technical check-up and control of water treatment facility and other machinery and equipment; waste management plan accomplishment control; visual control of soil and waste water condition<br>**Responsible for monitoring:** Department of Roads |

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| | management of drainage water from tunnels;<br>• Contamination as a result of fuel/oil spillage | • Treatment of drainage waters generated during the tunneling works through sedimentation ponds;<br>• Arranging of settling pond for drainage water during tunnel construction process;<br>• Arrange waste water sedimentation tank of corresponding capacity on construction camp territory;<br>• Localize and clean spilt fuel/oil;<br>• Instruct personnel before commencement of works;<br>• Equip with corresponding technical means and inventory (containers, spillage collecting means and etc.,)<br>• Remove all potential contamination materials after work completion and conduct recultivation of the area. | **Monitoring expenses:** No additional expenses<br><br>**Expenses for implementation of mitigation measures:**<br>Expenses of technical means and inventory to eliminate pollution due to fuel/oil spillage. Sedimentation tank expenses, which is not connected with considerable financial expenses. |
| Change of ground water flow<br><br>**significance:**<br>very low | • Crossing of water-containing horizon and violation of ground water regime during tunneling process | • Due to the characteristics of the activity exact determination of this kind of impact is difficult, correspondingly specific mitigation measures on this stage is not existing; | **Significance of residual waste:** very low<br><br>**Responsible for implementation of mitigation measures:** not considered<br><br>**Monitoring:** not foreseen<br><br>**Responsible for monitoring:** Department of Roads |
| Pollution of ground water<br><br>**significance:**<br>low | • Quality deterioration with polluted surface water or soil;<br>• During construction works(especially during earth works) as a result of fuel/oil spillage | • Implement all the measures to prevent contamination of surface water (see corresponding clause);<br>• Implementation of the measures to avoid soil quality contamination (see corresponding clause);<br>• To follow all the possible safety rules during underground construction works in order to prevent ground water pollution | **Significance of residual waste:** very low<br><br>**Responsible for implementation of mitigation measures:** Construction Contractor<br><br>**Monitoring:** Technical check-up of machinery; Waste management plan accomplishment control; Visual control of soil and water conditions;<br><br>**Responsible for monitoring:** Department of Roads<br><br>**Monitoring expenses:** No additional expenses<br><br>**Expenses for implementation of mitigation measures:**<br>Expenses of technical means and inventory to eliminate pollution due to fuel/oil spillage. Sedimentation tank expenses, which is not connected with considerable financial expenses. |

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| Impact on vegetation cover<br><br>**Significance:**<br>very low | • Direct impact on vegetation cover<br>• Indirect impact - dust, emission | • Control traffic routes and construction site borders to minimize risk of vegetation cover damage at the adjacent territory of construction site<br>• Personnel instruction before work commencement about protection of vegetation cover;<br>• Cutting of wood must be accomplished by authorized supervision of Ministry of Environment and Natural Resources<br>• Wherever protected species are found, they shall be extracted in compliance with Georgian Law on Georgian Red List and Red Book, paragraph 24, clause 1, sub-clause 'v', what shall be done in agreement to the Ministry of Environment Protection and Natural Resources<br>• Implement measures in order to prevent pollution of ambient air and soil quality (see corresponding clauses);<br>• Prior to the construction works, the area selected for the arrangement of southern portal of the tunnel must be agreed with the "National Agency for Protected Areas; | **Residual Impact significance** very low<br><br>**Responsible for implementation of mitigation measures:** Construction Contractor<br><br>**Monitoring:** Control of roads and work site borders; Technical check-up of machinery;<br><br>**Responsible for monitoring:** Department of Roads<br><br>**Monitoring expenses:** No additional expenses |
| Impact on Fauna<br><br>**Significance:**<br>medium | • Movement of construction machinery/transpo rt and people temporary disturbance of local fauna during construction works (direct impact - collision – indirect impact dust emission) | • Control traffic routes and construction site borders;<br>• Define optimal vehicle speed to minimize dust emission;<br>• Prohibit machinery horning to minimize fauna disturbance;<br>• Ensure proper working conditions of machinery to reduce noise/vibration;<br>• It is recommended to fence working sites during earth works to avoid falling of small mammals in ditches;<br>• Instruct personnel before starting works | **Residual Impact significance** low<br><br>**Responsible for implementation of mitigation measures:** Construction Contractor<br><br>**Monitoring:** waste management control; equipment proper operation control;<br><br>**Responsible for monitoring:** Department of Roads<br><br>**Monitoring expenses:** No additional expenses<br><br>**Responsible for implementation of mitigation measures:** during earth works expenses required for fencing, which is not connected with important financial expenses.<br>Other measures are not connected with additional expenses |
| Impact on Ichthyofauna | • Deterioration of surface water quality during | • Prevention of water pollution through ensuring proper management of waste and wastewater; | **Residual Impact significance:** very low<br><br>**Responsible for implementation of mitigation measures:** Construction Contractor |

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| **Significance:**<br>Very low | earth works and construction period | • Caution during working in close vicinity of water object in order to prevent water turbidity. | **Monitoring:** waste management control; equipment proper operation control; |
| | | | **Responsible for monitoring:** Department of Roads |
| | | | **Monitoring implementation expenses:** No additional expenses |
| | | | **Expenses for implementation of mitigation measures:** No additional expenses |

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| Waste<br><br>**Significance:** medium | • Construction waste<br>• Domestic waste | • Some part of the waste rock (approximately 30 000 m3) generated during the tunneling process will be used for the arrangement of embankments at northern and southern portals, the other part will be used in the form of aggregate for concrete production and the rest part will be disposed at spoil areas (layout schemes of spoil grounds are given in Appendix G);<br>• Earth fill surface recultivation works after storage of waste rock material<br>• Deliver scrap metal to corresponding company<br>• Waste wood not fitting for local use will be handed over to local population as firewood.<br>• Domestic waste from the construction camp should be disposed of at Stepantsminda landfill. Domestic waste from construction grounds should be landfilled locally;<br>• Explosive materials waste should be moved out by adequately licensed contractor;<br>• Special storage facility shall be provided at the camp site for temporary storage of hazardous waste. Construction grounds shall be provided with adequately labeled watertight containers.<br>• Properly trained personnel (environmental manager) shall be assigned for waste management operations. They should be periodically trained and tested.<br>• Hazardous waste from construction camp shall be removed by adequately licensed contractor.<br>• Waste water from construction camp territory must be discharged in surface water only after treatment | **Residual Impact significance:** low |

**Operation phase**

| Receptor/impact | Impact description | Mitigation measures | Description |
|---|---|---|---|
| Risks of hazardous geodynamic processes | • Activation of erosion, rock fall and mudflow processes on the neighboring territories of tunnels and within the corridor of access road at the north portal | • Control of technical functionality of protective structures and implementation of proper adjustment measures if necessary;<br>• Control of technical functionality and scheduled services (cleaning) of drainage systems at the tunnel portals and through the corridors of access roads at the north portal;<br>• Vegetation protection on the road neighboring slopes with the purpose of rock stabilization;<br>• Signing memorandum with LEPL National Environmental Agency about immediate informing in case of activation of debris flows in Devdorak River Valley. | **Responsible for mitigation measures:** Roads Department of Georgia<br>**Monitoring:** Monitoring technical functionality of protective structures and geodynamic processes<br>**Responsible for monitoring:** Roads Department of Georgia |
| Waste | • Scattered waste along the highway and waste accumulated in service facilities; | • Ensure awareness of population and passengers and providing information about proper waste management measures;<br>• Informing population and passengers about fines for pollution;<br>• To use special banners on the roads, where information about fines for pollution will be presented. | **Responsible for mitigation measures:** Roads Department of Georgia<br>**Monitoring:** monitoring on scattering wastes from transport moving on the highway<br>**Responsible for monitoring:** Roads Department of Georgia |
| Health and safety of passengers | • Risk of traffic accidents | • Installation of corresponding road signs within the road and tunnel borders;<br>• Permanent monitoring over technical functionality of the road surface and other consistent infrastructure (road signs, etc) and in case of damage, implementation of corresponding rehabilitation/renovation works. | **Responsible for mitigation measures:** Road Department<br>**Monitoring:** Control over protection of permissible speeds and traffic rules.<br>**Responsible for monitoring:** Road Department |
| Traffic movement safety | • Fire;<br>• Damage to tunnel; | • Control of technical functionality of emergency lighting system, firefighting means, communication means within the tunnel and in case of necessity, carry out corrective measures;<br>• Existence of warning signs and evacuation direction indicating signs; | **Responsible for mitigation measures:** Road Department<br>**Monitoring:** Control of technical means, considered for minimization of emergency risks.<br>**Responsible for monitoring:** Road Department |

## Appendix D – Environmental Monitoring Plan

### Monitoring Plan – Preparatory and Construction Phases

| Object/Action of Monitoring | Control/Sampling Point | Technique | Frequency/Time | Target | Responsible for Monitoring |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| Air (emission of dust and exhaust gases) | • Construction site;<br>• Construction site access roads;<br>• Nearest receptor (village Gveleti, Monastery complex) | • Visual control<br>• Technical check-up of machinery<br>• Instrumental measurement | • During earth works and regularly in dry weather<br>• Technical check-up of machinery before works<br>• During intensive transportation in dry weather<br>• Technical check-up of machinery – daily prior to the construction works<br>• Measurement of dust concentration in air - in case of grievance. | • Ensure compliance with the ambient air quality standards applicable in the country<br>• Minimize population disturbance<br>• Ensure personnel's safety<br>• Minimize flora and fauna disturbance | • Construction Contractor<br>• Department of Roads |
| Noise and vibration | • Construction site<br>• Nearest receptor (village Gveleti, Monastery complex) | • Control conditions of buildings (to find damages caused by vibration)<br>• Technical check-up of machinery and vehicles<br>• Instrumental measurement in case of grievance. | • Technical check-up of machinery and vehicles every day, before commencement of works;<br>• Instrumental measurement in case of grievance. | • Ensure compliance with health and safety norms<br>• Provide personnel with comfortable working conditions<br>• Maintain buildings and facilities<br>• Minimize fauna/population disturbance | • Construction Contractor<br>• Department of Roads |
| Soil | • Construction areas<br>• Material and waste storage areas | • Regular control, supervision<br>• Technical checkup of machinery<br>• Lab control | • Regular inspection;<br>• Inspection after completion of works.<br>• Laboratory analysis – in case of contaminant spillage | • Preserve soil stability and quality | • Construction Contractor<br>• Department of Roads |
| Water | • Construction sites<br>• Construction camps | • Visual control<br>• Technical check-up of machinery and vehicles | • During preparation of construction sites, especially after rain/snow.<br>• During construction works; | • Ensure protection of water quality | • Construction Contractor<br>• Department of Roads |

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| | | • Solid waste management control<br>• Waste water management control<br>• Provide laboratory analysis as needed | • During transportation/storage of solid waste;<br>• Technical check-up before work commencement;<br>• Laboratory analysis to be carried out quarterly; | • Minimize potential impact on fish fauna due to water contamination | |
| Vegetation cover | • Area adjacent to the southern portal of the project tunnel | • Visual control | • Quantitative and qualitative inspection of vegetation cover before commencement of works;<br>• Unplanned control during construction works<br>• Inspection and reinstatement of vegetation cover after completion of works | • Preserve Vegetation cover<br>• | • Construction Contractor<br>• Department of Roads |
| Waste | • Construction area and/or its adjacent territory<br>• Waste storage areas | • Visual control of the territory<br>• Waste management control | • Regularly, especially in windy weather | • Preserve soil and water quality | • Construction Contractor<br>• Department of Roads |
| Occupational safety | • Construction camps and construction sites | • Inspection<br>• Availability of personal protection equipment | • Regular control during works | • Ensure compliance with health and safety norms<br>• Avoid/minimize traumatism | • Construction Contractor – H&S Officer<br>• Department of Roads |

**Operation Phase**

| Control object | Control/sampling point | Method | Frequency/period | Goal | Responsible |
|---|---|---|---|---|---|
| Engineering-geodynamic processes, technical functionality of protective structures. | • Tunnel portals and perimeter of access road | • Visual inspection;<br>• Engineering-geological survey if necessary;<br>• Signing memorandum with LEPL National Environmental Agency about immediate informing in case of activation of debris flows in Devdorak River Valley | • Twice a year – in spring and autumn; | • Protection of road infrastructure from damage; providing safety of passengers. | • Technical Supervision and Monitoring Division of Roads Department of Georgia |
| Waste | • Tunnel and roadside tunnel | • Visual inspection of the territory | • Occasionally | • Prevention of environmental pollution by waste | • Roads Department of Georgia |
| Safety of passengers | • Tunnel and entire length of the road | • Visual inspection;<br>• Providing road signs along the perimeter and control of their functionality;<br>• Control of technical condition of the road surface; | • Several times in a year | • Providing safety of passengers throughout the highway | • Technical Supervision and Monitoring Division of Roads Department of Georgia |
| Emergency risks | • Tunnel | • Control of technical functionality of emergency lightning system, fire protection equipment and communication systems within the tunnel | • Occasionally | • Minimization of emergency risks | • Technical Supervision and Monitoring Division of Roads Department of Georgia |

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