Figure 1: Cartoon by Nate Fake for Nate's Rambling at www.nateflake.wordpress.com.

Mapping Risk Areas of Underground Power Cables

A Study of Underground Power Cables Extending From Nesjavellir Geothermal Power Plant in Iceland

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Abstract

Numerous factors need to be taken into consideration when designing and installing an underground power cable system. Efficient thermal dissipation in the soil surrounding the cable is critical in order to prevent high temperatures at cable jackets, causing an increased risk of thermal breakdown and a reduction in cable lifespan. Research has shown that the thermal conductivity of soil is impacted by the soil water content. There are various factors that affect the soil water content, such as various environmental variables causing the soil to dry up. Two underground power cables extend from Nesjavellir geothermal plant to Reykjavik, capital region, in Iceland. The purpose of this project is to map the risk areas for these two underground power cable systems extending from Nesjavellir power station to Reykjavik capital region. These risk areas are essentially drier areas or areas that tend to be more prone to becoming dry. In order to map the risk areas of cable failure we weighted different environmental variables that surround the cable. We produced maps weighing the relevant factors; land cover, elevation, and most importantly, soil type. The final results were a conclusive risk map including all the relevant environmental variables. An analysis of this risk map shows that the area between Nesjavellir power plant and Reykjavik capital region is relatively low risk, excluding a small high risk area close to the power plant. The cables extend through that area as overhead lines which is consistent with our risk assessment. Furthermore, Nesjavellir is a geothermal area which does not have favorable conditions for underground cables.

Introduction

Over the past few decades, world-wide usage of underground power cables, as opposed to landlines, has increased. Nonetheless, research on the different elements which impact subterranean cables is limited. Research has shown that there are several different important factors to consider in the design and installation of underground cables. Thermal conductivity of the surrounding material needs to allow for thermal dissipation from the cables. Restricted thermal dissipation can lead to high temperatures at the cable jacket, which will result in an increased risk of thermal breakdown of the underground cables and can reduce their lifespan considerably (Orradottir and Sveinbjornsson, 2009). Research has shown that decreased soil water content leads to decreased thermal conductivity (Krismundsson, 2007). Therefore it is important that the surrounding soil has sufficient water-holding properties so that the soil water content will not affect the thermal conductivity.

A knowledge of the various physical factors in Iceland which impact underground cables as distinct from surface electric transmission lines is limited, but vital in order to increase their efficiency and minimize failure risk in future power cables. Currently, the most important underground power lines in Iceland are those that extend from the geothermal power station, Nesjavellir, the second largest geothermal power station in Iceland. Nesjavellir, geothermal area, is located within the Hengill volcanic complex in southwest Iceland, Figure 5. As of now, there are two high voltage power cables, Nesjavalla-cable 1 and Nesjavalla-cable 2, that extend from the Nesjavellir power station to Reykjavik, the capital of Iceland. These power cables provide electricity for the greater Reykjavik area and therefore it is extremely important that these cables do not fail.

Various factors need to be considered when selecting the location of an underground power cable system. Previous research has shown that the main cause of cable failure is overheating which can be prevented by efficient thermal dissipation from the cable jacket. Inefficient thermal dissipation is caused by reduced thermal conductivity in a dried-out soil. As seen in Figure 2, several different factors need to be kept in mind when deciding where to place underground cables. It is important that not only the backfill material around the cable conducts heat efficiently but also the soil surrounding the entire system. Therefore it is important to know various properties of the area the cables extend through, such as the soil type, vegetation cover, elevation, and distance to water table. It is reasonable to assume that higher and more stable moisture content in the surrounding soil would be beneficial.

The purpose of this project is to map the risk areas for two underground power cable systems extending from Nesjavellir power station to Reykjavik capital region. An evaluation of the risk areas for the two current cables will be done with the goal of showing where the cables are most likely to fail. These maps could speed up the search of a cable failure, since they would most likely occur in the high risk areas. Furthermore, these maps could be used for future development of underground cables from Nesjavellir, aiding in the selection of where to place future cables.

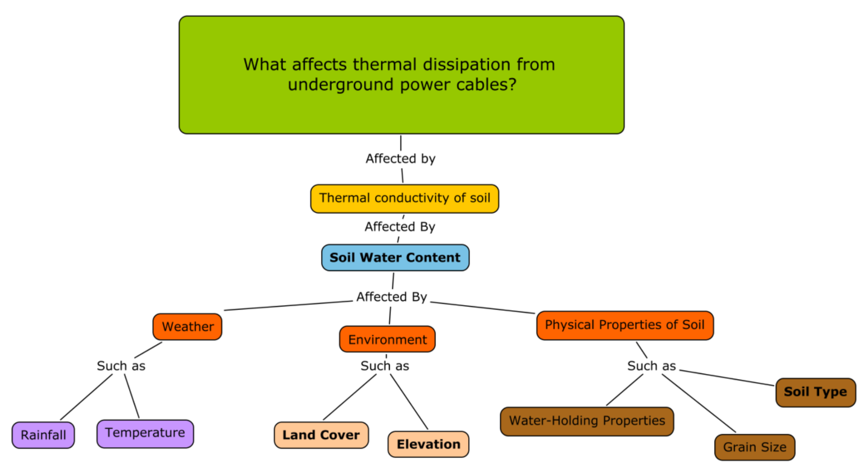

Figure 2: Concept map showing what affects thermal conductivity in soil.

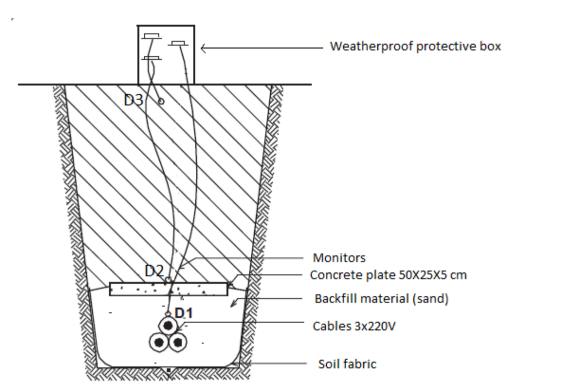

Figure 3: Cross section of underground cables showing the placement of monitoring devices (edit of Kristmundsson, 2004, Figure 2).

Figure 4: Nesjavellir geothermal power plant, Iceland (Gretar Ivarsson, 2006)

Results

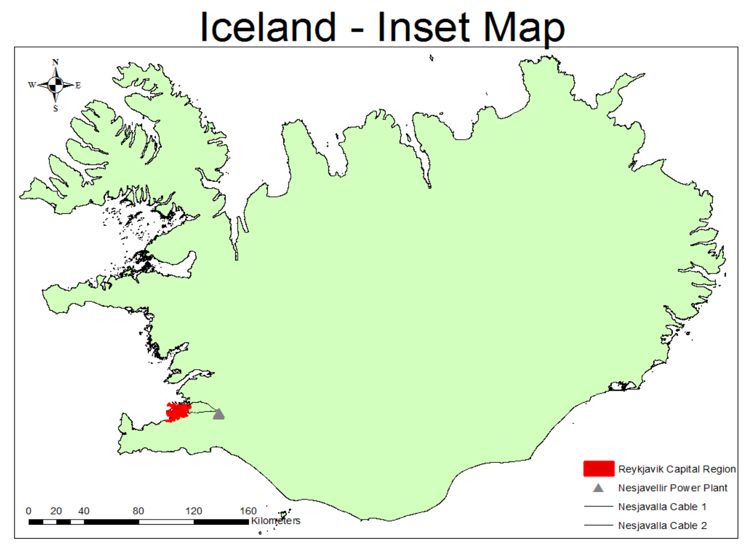

Figure 5: Location of area of interest in relation to Iceland.

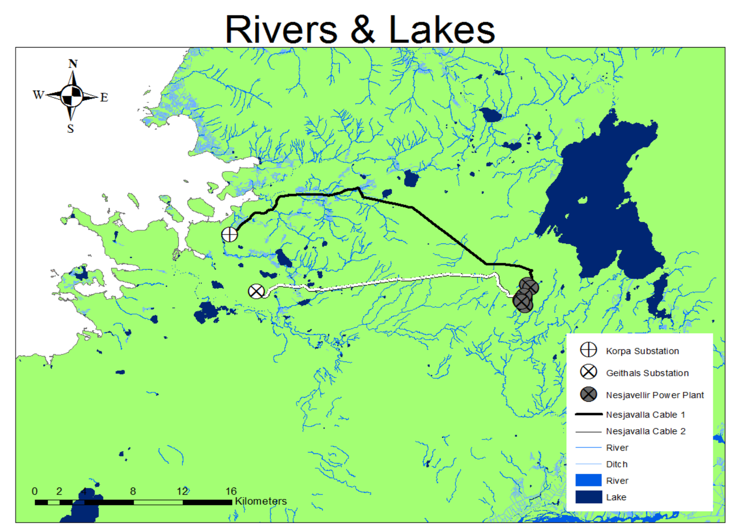

Figure 6: All bodies of water in the area of interest. While this variable could not be factored into the final map, it can affect an underground cable system.

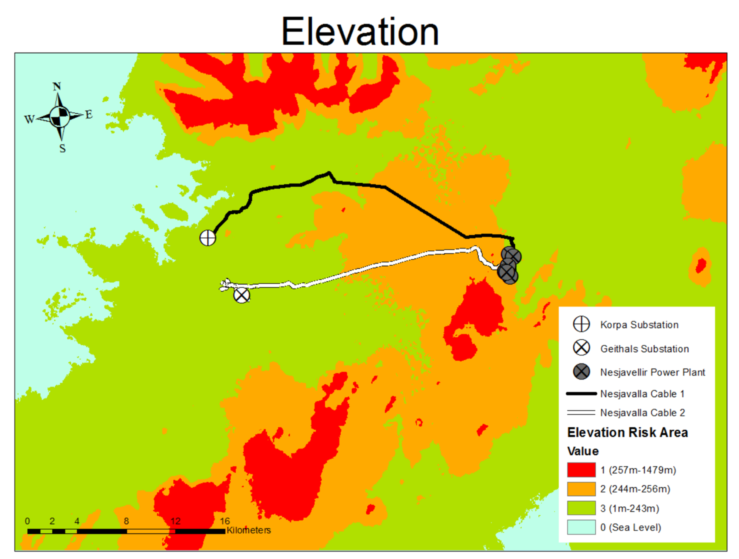

Figure 7: Elevation in the area of interest broken into four categories based on natural breaks in the elevation data. The higher the elevation, the higher the risk.

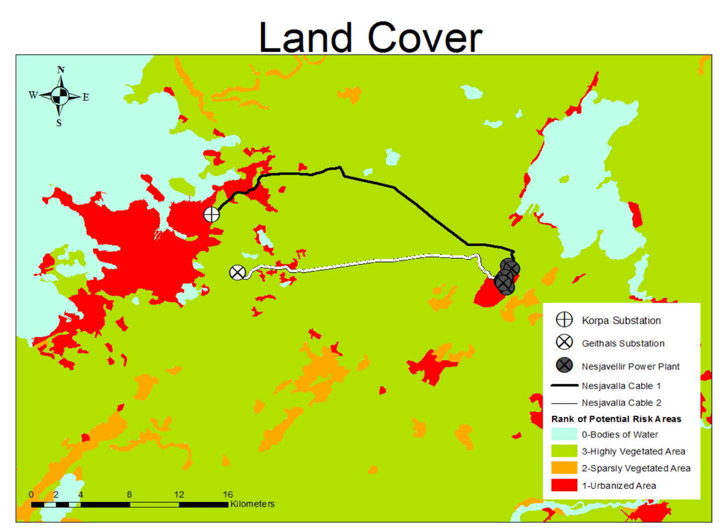

Figure 8: The different types of land cover in the area ranked by their risk of cable failure. The higher the vegetation, the lower the risk.

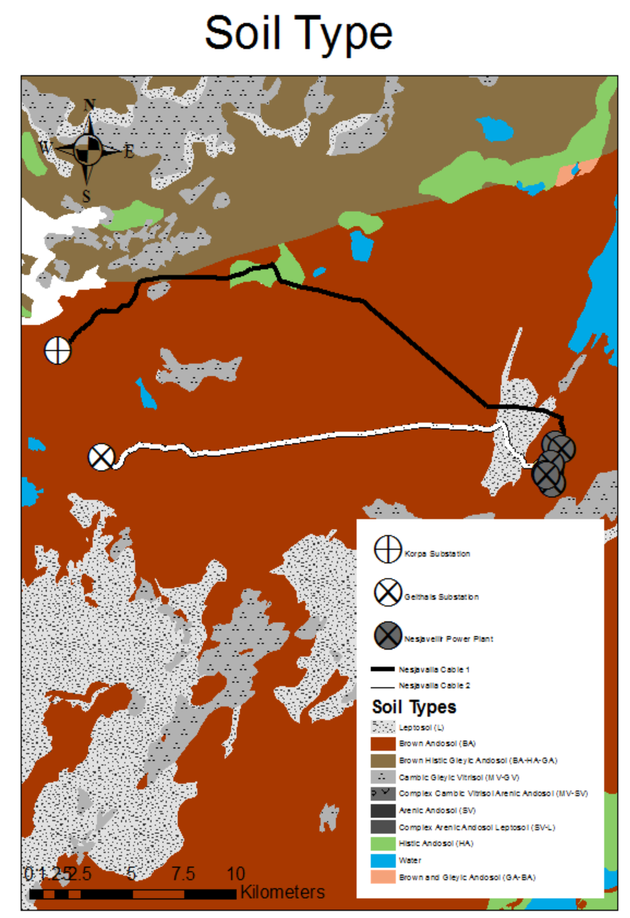

Figure 9.1: The different types of soil in the area of interest. Ranking provided by Arnalds (Arnalds, 2008, Table 1).

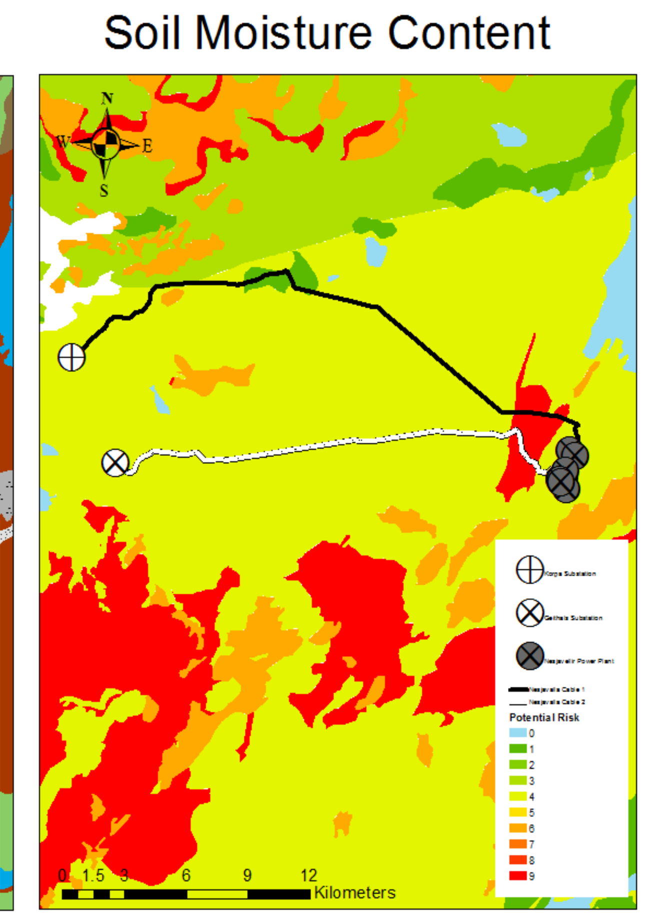

Figure 9.2: The different types of soils ranked based on their moisture content. Ranking provided be Arnalds (Arnalds, 2008, Table 1). The lower the moisture content, the higher the risk of cable failure.

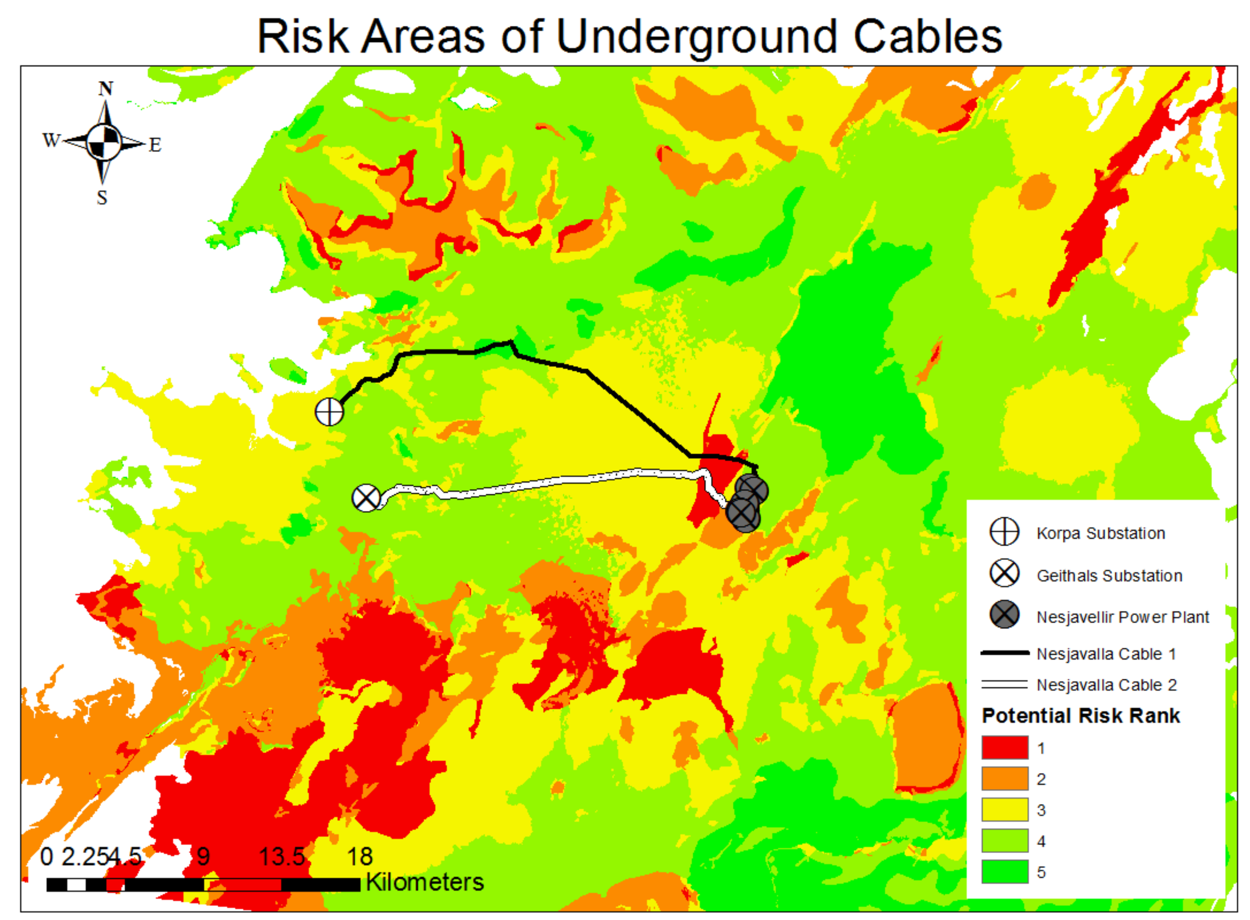

Figure 10: The sum of the soil type, elevation, and land cover risk maps. All the variables put together to give a total risk map for the area of interest. Based on previous research, we weighted the risk based on soil type, that is the soil moisture, the heaviest.

Methodology

Initially, we gathered all the data we needed from different sources in Iceland, including Reykjavik Energy and The Agricultural University of Iceland. In order to map the risk areas of cable failure we weighted different environmental variables that surround the cable. These variables include soil type, land cover, and elevation. We produced maps for each individual factor showing potential risk areas between Nesjavellir geothermal power station and Reykjavik. For all maps, we used a divergent color scheme in which green represented low risk areas and red represented higher risk areas. Furthermore, we produced a map showing water bodies in area of interest, that is between Nesjavellir power station and the capital Reykjavik.

Data Processing/Analysis:

River and Lake Map (Figure 6): The purpose of this map is to show the rivers and lakes in the area of interest. We did not include this in our layered risk map.

Elevation Map (Figure 7): We clipped an elevation raster for Iceland to the area surrounding the cables. We concluded that higher elevations would be of higher risk for underground cables because soil moisture is usually lower at higher elevations. Additionally, the installation of an underground cable system would be more difficult at greater elevations. We weighted the impact of elevation relatively lower than the other variables. We split the elevation into four rankings based on natural breaks.

Land Cover Map (Figure 8): We identified and labeled the different types of land cover in the area of the two cables. From our research, we concluded that higher vegetated area would have lower risk of cable failure. From that conclusion, we were able to rank each type of land cover, (1-low risk, 3- high risk).

Soil Type & Soil Moisture Maps (Figure 9): From the data, we were able to identify the different soil types in the area. Based on a soil description provided by Arnalds in his research article *Soils of Iceland,* we ranked each soil type based on their moisture content (Arnalds, 2008, Table 1). That is, the lower the moisture content the higher the risk of a cable failure, (1- low risk, 9-high risk).

Conclusive Risk Map (Figure 10): In order to determine the higher risk areas based on all the different variables, we layered a raster of each one of the maps together. First, we ranked each of our individual data sets data based on its risk level. We then converted our maps into raster format with their given values as the raster cell value. Finally, we added all of our raster together to get a final rank value, which is our total risk for each area weighting all variables.

Conclusion

From our research of previous studies, we were able to conclude that the main risk areas for underground cables are drier areas. This is because thermal conductivity is reduced in drier soil causing high temperatures at the cable jacket. Our objective was to map the areas where there would be a higher risk for drier soils in the areas where the cables extend through. We concluded that soil type, land cover, and elevation would be variables of interest to us. Even though we weighted different variables in order to make the final risk map, the sole most important factor is the soil type. We ranked each soil type based on their moisture content which is determined by the soil's water-holding capacity among other factors. Therefore the final risk map is quite similar to our map of soil moisture content.

The final result of this project is the map of the risk areas for underground cables extending from Nesjavellir geothermal power plant in Iceland. From the map, it seems like the underground cables start extending from Nesjavellir through a high risk area. Therefore, we decided to do further research on these two cables and discovered that these cables actually start of as overhead lines for the first few kilometers. It seems like that whoever designed these underground cable systems had the same conclusion as we did, of that area being a high risk area. An analysis of the map shows that the area contains few high risk areas apart from the one close to Nesjavellir power plant. Future installations of underground cables in the area could use this map to aid them in their selection of where to place the cables.

Future Research

Future research will mainly focus on further development of underground power cable systems. These developments should result in more efficient cables with a decreased risk of thermal breakdown and extended lifespan. Research like this will hopefully further understanding of the various factors affecting an underground power cable system and its efficiency. Advances in soil science and an increased understanding of soil physics, especially with regard to the various thermal properties, will be vital for this purpose.

Acknowledgements

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Data Sources

Data for these maps came from Reykjavik Energy, the Agricultural University of Iceland, and the National Land Survey of Iceland.

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Photo credit: Gretar Ivarsson, geologist at Nesjavellir for Wikipedia.

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