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Report 6

Input in managing strategies

Recommendations for the objects managed by the user partners in PCCH-Arctic

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ABSTRACT
This report presents input for managing strategies of selected objects of technical-industrial cultural heritage in Longyearbyen and Ny-Ålesund. In particular, the report provides results of condition survey of cableway trestles in Longyearbyen, assessment of natural hazard impacts on case study objects, recommendations for special case study objects, in addition to recommendations for monitoring and sources of data on climate projections.

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Cover image: Cableway trestles at the Line 5 in Endalen valley.

Image: © SINTEF AS, photographer: Anatoly O. Sinitsyn (mid-September 2022, processed picture).

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APPENDICES

1 Introduction

This report presents input and supportive information in management plans for several objects of technical industrial heritage in Longyearbyen and Ny-Ålesund, Svalbard. These objects served as case study objects in the PCCH-Arctic project [1]. List of the case study objects as it was defined in the beginning of project (2021) is presented in [2]. However, some of the objects were not analyzed as they were reconstructed by the owners during the project (as the White house and the airship mast in Ny-Ålesund), while some other objects were added into considerations. Depth of analysis also varies from object to object reflecting priorities in restoration set by the owners of the objects, project objectives, capabilities of the project, and the actual restoration activities that were taking place during the project.

This report presents results of risk assessment of natural hazards, detailed evaluations of permafrost degradation and performance of remediation solutions for selected objects, several particular recommendations (such as recommendations on snow management, input in monitoring, evaluation of risks and remediation for coastal erosion (cableway station in Hiorthhamn)).

Recommendations are based on several sources of information that were developed within the project, those include discussions on internal workshops, project reports, publications and master theses, some provisions (such as presented in Sect. 4.3.3) were not part of earlier deliverables and appear for the first time in this report. List of case study objects from [2] is presented in Table 1.

Table 1. List of the objects proposed for the case studies.

	Longyearbyen	**Object ID in Askeladden***
1.	System of the cableway trestles, 1907–1960 (*Taubanebukker*, Norwegian): a. Cable car line 1b (*Taubanelinje 1b*) b. Cable car line 2b (*Taubanelinje 2b*) c. Cable car line 3 (*Taubane 3)* d. Cable car line for mines 5 and 6 (*Taubane delstrekning gruve 5 og 6*)	 158657 158986 158619 87889
2.	The Titan crane, 1953 (*Titankrana*, Norwegian)	NA
3.	The old coal cableway centre in Longyearbyen, 1957 (*Taubanesentralen i Longyearbyen*)	87889-6
4.	Mine 2b, 1937 (*Gruve 2B*)	136716
5.	Mine 5, 1959 (*Gruve 5*)	87889-4
6.	The coal cableway station in Hiorthhamn, 1917 (*Taubanestasjonen i Hiorthhamn*)	93040-6
	Ny-Ålesund	
7.	The airship mast in Ny-Ålesund, 1926 (*Luftskipsmasta*)	158506-2
8.	The White house, 1919 (*Hvitt hus*)	159 781
9.	The Tronderheimen house, 1945 (*Trønderheimen*)	159 772
10.	The London houses, 1912/1950 (*Londonhusene*)	159807-1 159804-1 159806-1 159802-1
11.	The Green Harbour-house, 1909 (*Green Harbour-Huset*)	159759-1

Notes:

* – Askeladden [3], national heritage database in Norway.

NA – not applicable.

2 Condition of cableway trestles in Longyearbyen

2.1 Field survey

Conditions of 202 cableway trestles in Longyearbyen were surveyed during fieldwork that took place from August 30th to September 5th, 2021. It was a visual survey recording conditions of the objects and ground conditions around them. The survey did not include testing of timber, which would be useful for many of the objects, hence the survey was limited in its nature.

The survey included five lines with cableway trestles:

- Line 1b
- Line 2b
- Line 3
- Line 5-6
- Line 5
- Line 6

Lines 1a and 2a were at a later stage included in the analysis to obtain a more complete view that included analysis of the impacts of natural hazards, yet all cableway trestles are lost or removed from these lines up to the date.

All cable way trestles were photographed. The photographs included general views of the objects, as well as specific damages, and pictures are available at [4]. The "raw" data, i.e. information that was written in the field notes and results of consequent analysis ("initial" evaluation of PCCH-Arctic and evaluation in the light of NS-EN 16096 [5]) are presented in the Excel table [6].

For the "raw" data, Excel table [6] provides summary of observations on conditions of the objects, conditions of ground surface and some observations of natural hazards in the area around the objects.

The following is described in relation to conditions of the objects:

a. Position of the upper structure: vertical or tilted.
b. Position of the vertical foundation elements: vertical, "slightly tilted", "tilted", "heavily tilted".
c. Conditions of cross-bracing elements next to the ground surface.
d. Evaluation of whether structures settle in the terrain or not.

The following is described in relation to ground surface conditions and observations of natural hazards:

a. Conditions of terrain surface *around vertical members*, under and in vicinity (ca. 5 m) of the structure.
b. Morphological element (type of terrain, e.g. flat terrain, slope, etc.).
c. Notes on some of the most relevant natural hazards.
d. Other notes on natural hazards.

2.2 Initial evaluation

Based on the "raw" data, an *initial* evaluation of "situation" with cableway trestles was performed based on criteria that we called "Need in immediate restoration". We used seven categories, such as "Destroyed" and "Restored" (with no need in immediate restoration), and five nuanced categories, such as "Further analysis is needed", "Further analysis is needed/Needed", "Needed"; "Needed/Urgent" and "Urgent". A category "Absent" should also have been added in this list. Categories "Further analysis is needed/Needed" and "Needed/Urgent" were meant for intermediate situations.

In the following we present characteristics that looked to us relevant to suggested categories. **Urgent**: large tilt of the entire structure; large displacements of foundation elements, large settlements of the whole structure; potential danger due to HSE considerations (Health, Safety, and Environment). **Needed**: some displacements of foundations are observed; damages or ruptures of some elements, but structural performance visually maintained; presence of natural hazards, which may affect the structure or permafrost under the structure, for instance, presence of seasonal creek, which may cause surface erosion and may increase degradation of permafrost under the structure. **Further analysis is needed**: this category was typically used for the cases when situation was unclear – object looked visually in a good shape, yet should timber of its structural elements be rotten, a stricter category would be needed to be used. **Destroyed**: such situations are characterized by collapsed, capsized and structures destroyed by various natural hazards; this category was introduced with the view to attract attention that the object was actually "destroyed" so that restoring it could be suggested as an organic next step. Preliminary conclusions based on this simple framework were made at the time (2021–2022), yet as this methodology was simplistic and not standardised. For the latter limitations, the further assessment of the results of survey was performed in the *light* of the standard NS-EN 16096 [5].

2.3 Assessment based on NS-EN 16096

In the following we outline general settings and limitations of our assessment that was performed in the light of NS-EN 16096 [5].

a. First of all, we would like to note that the standard NS-EN 16096 [5] prescribes "visual observation, together – when necessary – with simple measures" as the means for evaluation of conditions. In our opinion, such means cause limitations as normally geotechnical and structural calculations are needed to evaluate and prognose stability of buildings and structures (from geotechnical and structural perspectives), especially in permafrost conditions. Stability may be affected by different natural hazards, and future magnitudes of the hazards may also be due to climate change. Such detailed calculations may support both, condition class, urgency class and remediation class. Hence, in our opinion, evaluations of these classes based NS-EN 16096 [5] have clear limitations and should be considered more like a qualitative advice.
b. Significant number of objects that had to be surveyed (approximately 200) in limited amount of time (approximately 5 days). This caused limitations on how much time we could devote to each object. Yet, we believe that an amount of information collected was quite sufficient to perform the subsequent analysis.
c. We have above noted that the analysis was performed "in the light" of the standard NS-EN 16096 [5]. This is because we were mostly focused on foundations of the objects and their overall stability and identification of the pace/significance of some of the natural hazards that may impact the objects.
d. Our choice to be focused on the stability of the objects, performance of their foundations and impacts of natural hazards are among the core issues defining overall stability of the objects.
e. There are other critical factors that are in the play, such as timber state in foundation elements and the upper structure, connection of foundation to the upper structure. Conditions of timber serves input in defining stability of the objects as well. Timber state was taken into account only when it was possible based on observations. For example, when ruptured foundation elements or cross-brace elements were exposed. Timber conditions inside of the load-bearing elements (which is normally done by invasive methods) was not assessed. Also, we did not explicitly assess the impacts of windstorms on the structures (an evaluation was done by Enevoldsen [6]).

f. Bearing in mind experimental character of our work, taken assumptions and limitations, we stress the suggestive nature of our results, but not as ultimate advice.
g. Future impacts of natural hazards on the objects were assessed by simple comparison whether an object is covered or not by hazards zones of several given hazards.

In the light of NS-EN 16096 [5], the Condition class (CC), the Urgency class (UC), and the Recommendation class (RC) were assigned for each cableway trestle. Data from the Excel table [6], and from selected hazards maps ([7, 8]) for Longyearbyen was used for the analysis.

NS-EN 16096 [5] requires to describe explicitly the methodology for classifying the condition. Such methodology is described in the following.

2.3.1 Assignment of Condition Class

In our evaluation, the CC was assigned based on overall stability of the objects, conditions of their foundations, and conditions of some other critical structural elements. We suggested attributes/situations that are relevant for different CC classes, those are presented in Table 2. In addition, for "border" cases when it was unclear which condition class to assign, we implied expert judgement rooted in structural and geotechnical engineering. In some cases, CC classes were adopted from previous evaluation that was done in 2013 by Store Norske (Riksantikvaren 2019). Such adoption was done when the objects or their foundations had minor visual symptoms corresponding to CC 1, but the actual condition of timber (should it been surveyed) might have changed the scoring. Such cases are marked with asterics ("*") in the Excel table [6]. 2013's evaluation was performed in terms of the TG classes (*Tilstandsgrad, condition level*). We performed translation of TG class from (Riksantikvaren 2019) to CC class according to NS-EN 16096 [5]. Despite being primitive, script for such translation is presented in Table 3.

Table 2. Methodology of PCCH-Arctic that was used for assigning condition class.

Condition	Relevant attributes
CC 0	No symptoms
CC 1 – Minor symptoms	CC 1 was not generally used due to concern in timber quality, which are based on the following considerations. Quality of timber (amount of rot) defines stability of the objects. "Youngest" cableway trestles as for 2025 are approximately 57 years old, these are the ones on the line from the Mine Nr. 6 which was prepared in 1964-1969. While the oldest objects are approximately 87 years old, these are the ones on the lines from the Mine 1b and 2b, which were in operation from 1939 and 1937, correspondently. However, it is known that significant rot of timber foundations in Svalbard was observed on already a 30-year old foundation [9]. Hence, more severe CC 2 may be recommended as a "minimal" requirement. Hypothetically, results of physical evaluation of timber quality and subsequent analysis (geotechnical and structural) may decrease CC 2 to the lower classes. Timber quality was evaluated on several timber trestles during the last 15 years (including the recent ArcticAlpine*Decay* project [10]), yet these results are not incorporated in the present assessment. Exceptions were made for the objects which showed no visual symptoms and for which CC 1 was assigned by the previous assessment [11].

<table>
<tr>
<td>CC 2 – Moderately strong symptoms</td>
<td>Such symptoms include slight tilt of foundations; tilted foundations, maximum two tilted foundations per object (examples are presented on Figure 1–Figure 2); rupture of cross-bracings (examples are presented on Figure 3–Figure 5).


Figure 1. Cableway post Nr. 15 on the Line 5-6, tilt of foundations due to solifluction (general view from the front).


Figure 2. Cableway post Nr. 15 on the Line 5-6, tilt of foundations due to solifluction (close look-up).</td>
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<tr><td></td><td>


Figure 3. Broken cross-bracing element at cableway trestle Nr. 36 at the Line 6 (general view).

Figure 4. Rupture of cross-bracing element at cableway trestle Nr. 25, Line 6.

Figure 5. Broken cross-bracing element at cableway trestle Nr. 36 at the Line 6 (close look-up).
</td></tr>
<tr><td>CC 3 – Major symptoms</td><td>
Such symptoms include the following:

- Tilted foundations, all four foundations per one object.
- Heavily tilted foundations, at least two per object (examples are presented on Figure 6–Figure 7).
- Ruptured vertical foundation members, at least one member per object (examples are presented on Figure 8–Figure 11).
- Tilt of the object, either due to a rupture of vertical foundation member (examples are presented on Figure 10–Figure 11), or due permafrost degradation under the object (examples are presented
</td></tr>
</table>

on Figure 12–Figure 13). Tilt and settlement of structure may happen simultaneously (examples are presented on Figure 12–Figure 13).

- Large settlements of structure into terrain (Figure 14), even if the structure looked intact (examples are presented on Figure 14–Figure 15, and interpretation of observations is presented on Figure 16) one may expect that cross-bracing elements would be broken in the result of settlement (examples are presented on Figure 17–Figure 18).

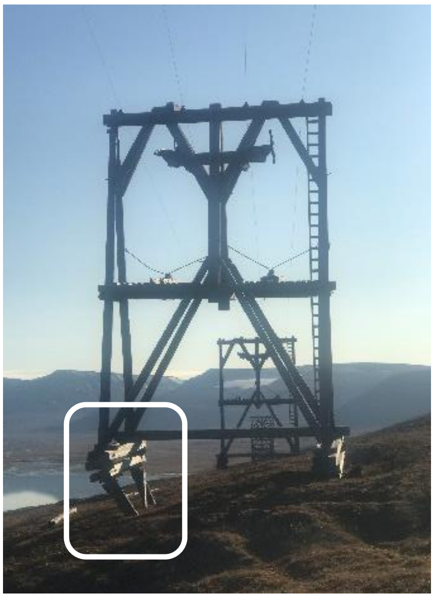

Figure 6. Heavy tilt of two foundations of the cableway post Nr. 17 on the Line 5-6.

Figure 7. Heavy tilt of two foundations of the cableway post Nr.22 on the Line 5-6.

Figure 8. Cableway post nr 22 on the Line 5-6, rupture of foundation element above the ground, presumably due to rot (general view from the front).

Figure 9. Cableway post nr 22 on the Line 5-6, rupture of foundation element above the ground, presumably due to rot (close lookup).

Figure 10. Tilt of the Cableway post nr. 16 on the Line 5-6 due to rapture rupture of foundation element (general view).

Figure 11. Tilt of the Cableway post nr. 16 on the Line 5-6 due to rapture of foundation element (close look-up).

Figure 12. Cableway post nr. 41 at the Line 5-6 – large vertical settlements and tilt due to degradation of permafrost (general view).

Figure 13. Cableway post nr. 41 at the Line 5-6 – large vertical settlements and uneven tilt (close look-up).

Figure 14. Settlement of terrain due to permafrost degradation and large uniform settlement of Cableway post Nr. 21 at the Line 6 into the permafrost. White line outlines settled area.

Figure 15. Cableway Nr. 18, Line 3 – terrain settlements under and around the structure. White line outlines settled area.

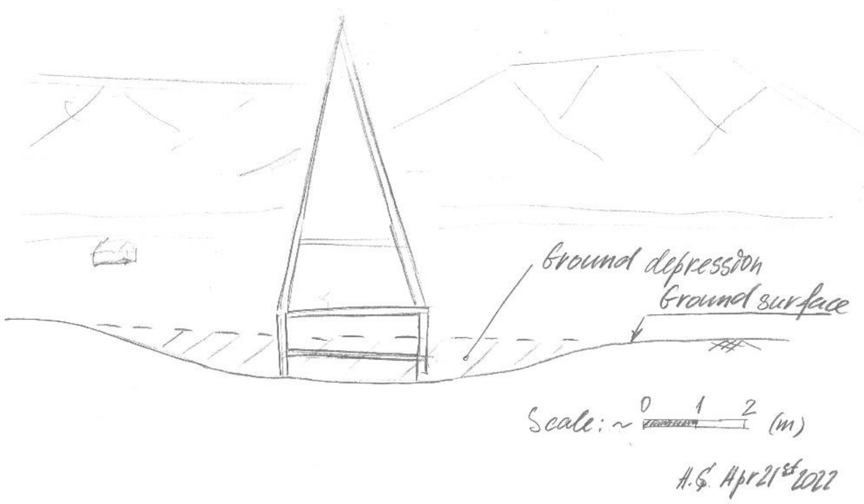

Figure 16. Illustration of permafrost degradation at the cableway trestle Nr 21, Line 6 (side view).

Figure 17. Cableway trestle Nr. 9, Line 6: massive terrain settlements under and around the structure and rupture of cross-bracing element. White line outlines settled area.

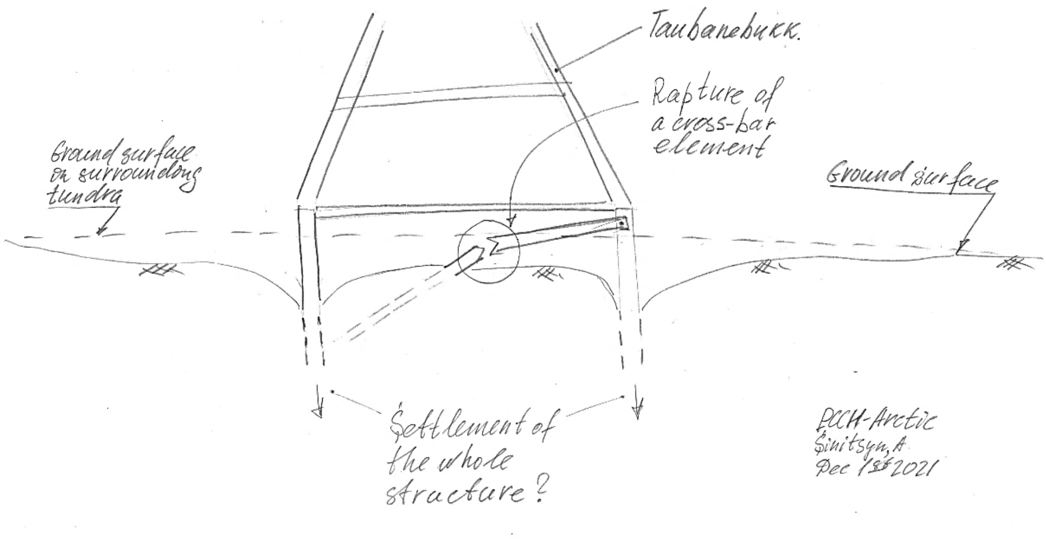

Figure 18. Proposed mechanism of rupturing cross-bracing elements due settlements of objects into permafrost.

Table 3. Correspondence of TG and CC classes used by PCCH-Arctic.

Correspondence of TG and CC classes used by PCCH-Arctic	
TG 1 – Ordinary need for restoration	CC 0 – no symptoms
TG 1 - Ordinary need for restoration	CC 1 – minor symptoms
TG 2 - Moderate need for restoration	CC2 – Moderately strong symptoms
TG 3 - Significant need for restoration	CC 3 – Major symptoms
TG 4 - Lost/Removed	CC 3 – Major symptoms. Comment: NSEN 16096 [5] defines that CC 3 also encompasses structure collapse and total functional failures.

2.3.2 Assignment of Urgency Class

For assigning the UC, following NS-EN 16096 [5] the departure point is largely rooted in the cause(s), and trigger(s) of the recorded condition, external actions, expected variations in external actions affecting the components, etc. Following this logic, we linked the UC class to the following:

- Observed and future probable impacts of relevant natural hazards.
- A need in further investigation.
- Urgency of measures.

Other factors that may influence risk assessment were not explicitly considered.

For probable impacts of natural hazards in connection to assigning the UC-class, we considered both, the impacts that have already happened (and hence, in many cases were observed by us) and probable future impacts.

For some of the natural hazards, such as landslides (different kinds) and snow avalanches, we suggest linking the probable future impacts and the UC based on probability of the hazards. For example, for design of civil infrastructure following TEK 17 handles safety (safety class for hazard) against certain types of natural hazards (such as landslides, snow avalanches, and flooding) as a function of consequences and biggest nominal yearly probability. Such an approach may be adopted in defining the UC.

It may be useful to mention that the impact of mentioned above natural hazards happens abruptly, i.e. when the hazard hits the object. As a primary tool, hazards maps can be used to assess the relevance of such hazards: if an object is located within a zone of a hazard, then it will probably experience a significant impact in case of an event. In general, one may expect that the higher the probability, the lower the potential impact is (i.e. smaller events happen more frequently). Detailed calculations of impacts of the hazards (such as landslides or snow avalanches) on specific objects may be used for further clarification of possible impacts on objects of cultural heritage. The latter, however, is clearly outside of the means prescribed by NS-EN 16096 [5].

Impacts of some other natural hazards (for example, permafrost degradation) happen in a different mode compared to landslides and snow avalanches. Impacts from these hazards happen at a very slow pace. Such impacts may also be determined based on probabilistic methods, yet the representation of the hazard itself will be different. This is because the use of hazard maps for permafrost degradation in relation to direct evaluation of stability of build objects on it is very challenging, if possible at all – the objects maybe stable even in challenging conditions. In many cases calculations based on detailed geocryological data is the only way to evaluate the stability of the objects. Again, such detailed analyses are clearly outside the means prescribed by NS-EN 16096 [5]. Hence, we had to root our evaluations on what we see in field, i.e. on indicators of permafrost degradation and the reaction of an object on these changes. The latter is not normally used in geotechnical engineering in evaluating structural health of objects. However, the surveyed objects of cultural heritage were not designed for permafrost conditions (hence one should not expect them to perform well), and they are not performing well at the present time (excessive settlements of many structures, numerous observations of ruptures foundations and other elements). This makes visual observations somewhat acceptable in defining, both UC and CC.

Similar considerations may be applicable to other types of natural hazards, such as coastal and riverine erosion.

In Table 4, we outline several considerations for assigning the UC-class based on 1) the safety consideration and probabilities used in TEK 17[12] and 2) some other considerations. These are preliminary considerations, and the incurring results should be used with caution or even as an exercise that contributes to the use of NS-EN 16096 including particularities of in permafrost areas.

Table 4. Considerations for assigning the UC values.

a. For landslides, snow avalanches and floods:
    1. UC 0 and UC 1 correspond to safety classes S1 with corresponding nominal yearly probability of 1/100 (slope hazards) and F1 with corresponding nominal yearly probability of 1/20 (flood) with assumption that consequences are small and *not critical* for the object. For example, we saw cases when cableway trestles were able to withstand the impacts of small landslides and snow avalanches (see examples on Figure 19–Figure 22).

Figure 19. Remains of old debris flow above Cableway post Nr. 9, Line 5.

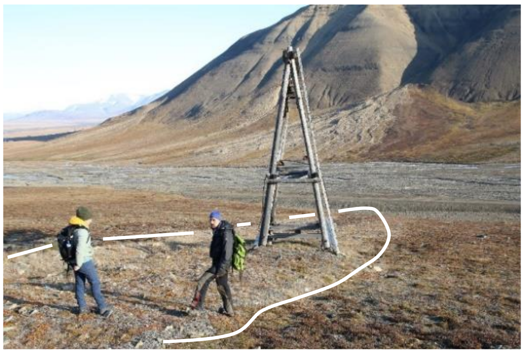

Figure 20. Remains of old debris flow at cableway trestle Nr. 9, Line 5. White line presents outline of debris flow.

Figure 21. Accumulation of rock debris at cableway trestle Nr. 5, Line 1b as an indicator of previous snow avalanche activity in the area. Despite impacts from snow avalanches and structural damages (one broken foundation) Cableway trestle Nr. 5 is still standing.

Figure 22. Ground surface between cableway trestles Nr. 5 and Nr. 4 (view towards Nr. 4) – former trail is partly covered with loose rock debris.

2. UC 2 correspond to safety classes S2 with corresponding nominal yearly probability of 1/1000 (slope hazards) and F2 with corresponding nominal yearly probability of 1/200 (flood) with assumption that consequences are middle and *critical* (large damage or collapse of object) for the object.
3. When it comes to safety classes S3 with nominal yearly probability of 1/5000 (slope hazards) and F3 with nominal yearly probability of 1/1000 (floods), we suggest that such situations should *not* correspond UC 3 as such probabilities are quite small (despite the consequences are big), hence one cannot call for "urgent and immediate" actions. Hence, we suggest that S3 and F3 should correspond to UC 2 or more milder class.

b. For permafrost degradation and solifluction, we do not present at this stage suggestions in the same way as for landslides, rockfalls and floods. We suggest that assigning UC-classes for such hazards may begin from a qualitative framework. On the second step, the reaction of the object on degrading permafrost should be evaluated.

In the first step, indicators of such hazards in the terrain should be considered. For permafrost, such indicators include features of thermokarst landscape (e.g. terrain settlements, see Table 6), for solifluction --- characteristic micro landscape (see Table 6). Also, in this step, performance of an object in given permafrost conditions (objects on permafrost may experience challenges even in the absence of climate change impacts) or/and on permafrost degradation should be assessed. Such reaction may take place in form settlement of the object into terrain, tilt of object, tilt for its foundations, rupture of its elements due to excessive settlements. These evaluations may be supported by geomorphological and geocryological (that should contain information of ground-ice content) maps of the area, future climate change projections, snow and drainage patterns.

For example, for permafrost degradation, we believe that field observations and expert judgement may be instrumental in defining the UC-class. For example, if we see that there are indicators of *significant* permafrost degradation (e.g. terrain settlements under the object), the object has structural damages (settlement of the entire object and broken cross-brace elements) then we prescribe "UC 3 – Urgent and immediate" time frame. This is because "urgent and immediate" seems to us to correspond to the next few months – 1-2 years, which in turn seems to be sensible for such situation. In other cases, terrain may exhibit no signs of intensive permafrost degradation (yet ground temperatures and the active layer may still rise), and the objects seem to handle well the ground conditions, then milder class "UC 2 – Intermediate term "may be then assigned.

Detailed suggestions for assigning UC in relation to permafrost degradation and solifluction are presented in Table 6.

On a second step, detailed evaluations of stability could be performed based on geotechnical and structural analysis that evaluates performance of particular objects in relation to specific site conditions. Again, such evaluations seems to be outside of the means prescribed by NS-EN 16096 [5].

c. It seems to be logical that UC may depend on CC. In general, CC 1 may correspond to UC 1, CC to CC 2, and CC 3 to UC 3. Yet, particularities may affect such relations.
d. If several natural hazards are present, the most severe UC class should be taken into account (UC 3).

Conceptualization of suggestions from Table 4 are presented in Table 5.

Table 5. Conceptualization of linkage between UC classes, probabilities and consequences of natural hazards.

UC class	Consequences of natural hazards	Landslides and snow avalanches: biggest nominal yearly probability	Flooding: biggest nominal yearly probability	Intensive occurrence of natural hazards by the object and high pace of subsequent morphological changes because of permafrost degradation and solifluction, based on observations observed
UC 0	?	?	?	Insignificant
UC 1	Small	1/1000	1/20	Low
UC 2	Middle, big	1/1000, 1/5000	1/200, 1/1000	Medium
UC 3	–	–	–	High

Table 6. Supportive information for assigning UC classes.

<table>
<tr><td>UC 0 – Long term</td><td>UC 0 was used only for restored objects.</td></tr>
<tr><td>UC 1 – Intermediate term</td><td>UC 1 class was not used. Such class deems to provide too delayed deadline for implementation of the measures. First of all, this is because of the high pace of natural hazards impacting the objects in permafrost settings, and indirectly because of the expectation that timber in many of the objects is sufficiently rotten. One may say with high confidence that both factors compromise structural stability.</td></tr>
<tr><td>UC 2 – Short term</td><td>UC 2 was assigned when there were indicators pointing out on medium rate of pace of geomorphological changes because of relevant natural hazards such as permafrost degradation, solifluction, erosion of the nearby riverbank or ravine. In such case the impacts from such hazards should be expected, and hence actions/measures need to be implemented in a foreseeable future, i.e. in a short term.

In contrast with temperate climate, permafrost-related hazards may have much faster paces. For example, permafrost degradation may lead to settlements of terrain or an object itself, both may have high rate that may, in turn, be dangerous for stability of an object. It is worth mentioning that objects of technical-industrial cultural heritage were probably never designed for various natural hazards (such as permafrost degradation). They were rather built based on experience and understanding of permafrost conditions by the builders, and climate change was not taken into design. This makes technical-industrial cultural heritage sensitive to various natural hazards.

The following several natural hazards and their indicators corresponding to UC 2 are presented:

• Permafrost degradation; conditions indicating permafrost degradation at the site:
o Moderate ground depression under the objects (examples are presented on Figure 14–Figure 17) as indicators of permafrost degradation by the object. The latter, however, may not be the case for the restored objects – ground depressions in such cases are thought to be attributed to compaction of backfill material (examples are presented on Figure 23–Figure 24).
o Moderate ground depressions around foundation members (example is presented on Figure 27–Figure 28).
o Presence of more lush vegetation ("greener grass") under and around the objects (example is presented on Figure 29–Figure 32). We interpret this observation as following: the cableway trestles capture snow underneath them. Snow provides insulation effect which leads to warmer ground surface. Such warmer microclimate is suitable for more lush vegetation that not would have survived otherwise. We do not see such vegetation in surrounding landscape, again it is present only under or in proximity (few meters) of the structures. At the same time, snow leads to warmer ground conditions that prevent evacuation of heat from the ground during winter, which leads to degradation of permafrost right under the structures and few meters around. Degradation of permafrost causes ground settlements under the structures that lead to water ponding from snow melt and after the snow melt. Ponding further accelerates permafrost degradation. Example of extensive ponding (that corresponds to UC 3) is presented on Figure 47.
o “Slide-like" settlements of sloping terrain. Such deformations were observed in several cases around the structures on a sloping terrain (example is presented on Figure 33–Figure 34). The proposed outlines of these features are presented in Figure 35. Mechanisms of such settlements are not fully clear. We suggest that this is caused by increased permafrost degradation (due to increased snow accumulation under the structure) and subsequent movement of the top layer of the ground.</td></tr>
</table>

- Pathways of surface water that runs under the object *some periods* (constantly running water will correspond to UC 3) during the year (example is presented on Figure 36–Figure 37).

- Moderate cases of frost heave: elevated terrain around structure along with the structure settling into terrain. We suggest to consider such situation as an indicator of frost heave that occurs due to probably thinner snow thickness by the object, example of such situation is presented in Figure 38–Figure 39, and interpretation is presented on Figure 46. Such cases were mostly observed in the Endalen valley where local wind conditions and topography seems to be responsible for frost heave. It also seems that the object itself affects snow distribution around it.
- Moderate cases of solifluction. Characteristic micro topography (with moderately "wavy" terrain) and tilted foundations of cableway trestles may serve as indicators of solifluction (examples are presented on Figure 41–Figure 44).
- Additional loads due to snow avalanche activity: accumulation of blocky material (normally delivered by slab avalanches) on the object (example is presented on Figure 45–Figure 46). Accumulation of blocky material may impose additional loads in the objects.

Figure 23. Ground depressions under cableway trestle Nr. 23 on the Line 1b (2021). This trestle was restored in 2007. Picture: © Snaprud Christensen, C.

Figure 24. Ground depressions under cableway trestle Nr. 23 on the Line 1b (2021). This trestle was restored in 2007. Picture: © Snaprud Christensen, C.

Figure 25. Ununiform ground settlements below recently restored cableway trestle Nr. 6 at the Line 5-6. One shall acknowledge that some uneven terrain below the object is due to the excavation activities.

Figure 26. Ununiform ground settlements below recently restored cableway trestle Nr. 6 at the Line 5-6. One shall acknowledge that some uneven terrain below the object is due to the excavation activities.

	 Figure 27. Depressions around vertical foundation elements at cableway trestle Nr. 19 at the Line 5-6.	 Figure 28. Depressions around vertical foundation elements at cableway trestle Nr. 20 at the Line 5-6.
	 Figure 29. More lush vegetation under cableway trestle Nr. 27 at the Line 6.	 Figure 30. More lush vegetation under cableway trestle Nr. 27 at the Line 6.
	 Figure 31. More lush vegetation under cableway trestle Nr. 27 at the Line 6.	 Figure 32. More lush vegetation under cableway trestle Nr. 6 at the Line 6.

Figure 33. "Slide-like" settlements of the ground around structures on a sloping terrain – Cableway post Nr. 19, Line 5-6 (general view). White line depicts "scar" of the "slide".

Figure 34. "Slide-like" settlements of the ground around structures on sloping terrain – Cableway post Nr. 19, Line 5-6 (close look-up). White line depicts "scar" of the "slide".

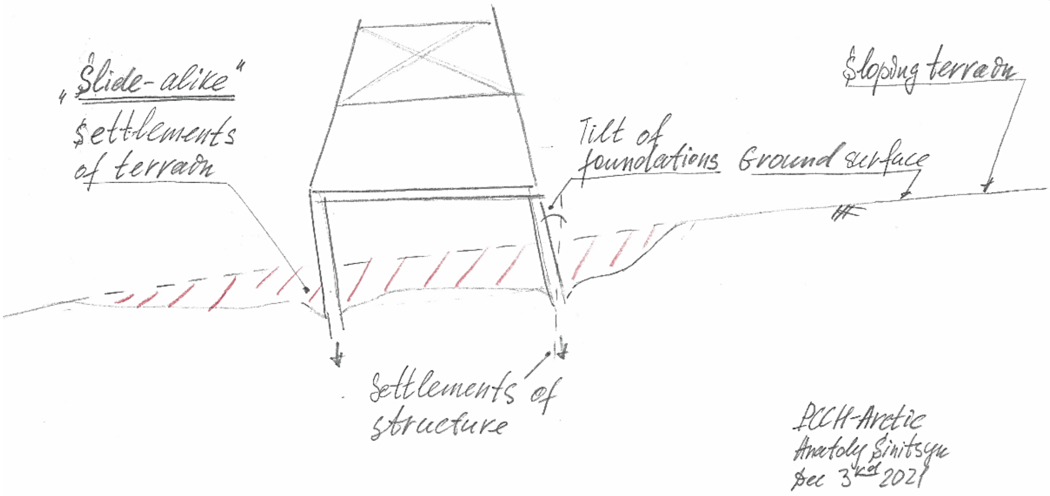

Figure 35. Sketch of proposed outline of the "slide-like" settlements of the ground around the structures on a sloping terrain.

Figure 36. Cableway post Nr. 15 on the Line3, seasonal creek running under the structure. Creek may cause both, surface erosion under the structure and increased degradation of permafrost. White rectangle depicts the creek.

Figure 37. Cableway post Nr. 15 on the Line 3, seasonal creek running under the structure (close look-up). White rectangle depicts the creek.

Figure 38. Cableway trestle Nr. 10, Line 5: ground under the structure is elevated in relation to surrounding tundra, while the structure seems to be settled into the terrain. White line presents outline of the elevated terrain.

Figure 39. Cableway trestle Nr. 16, Line 5: ground is elevated in relation to surrounding tundra. White line presents outline of the elevated terrain.

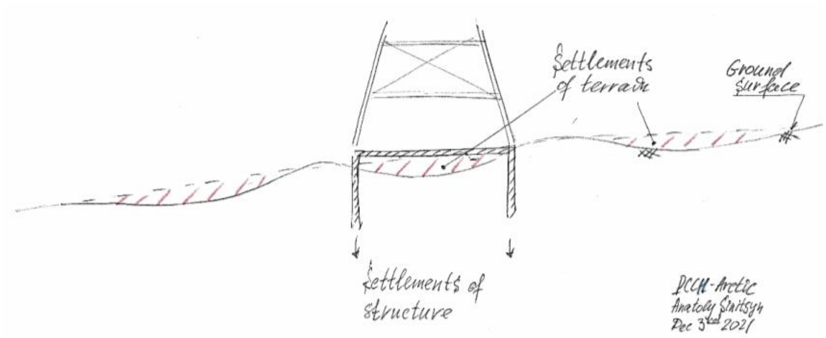

Figure 40. Sketch of proposed outline of the situation with elevated terrain and settled object.

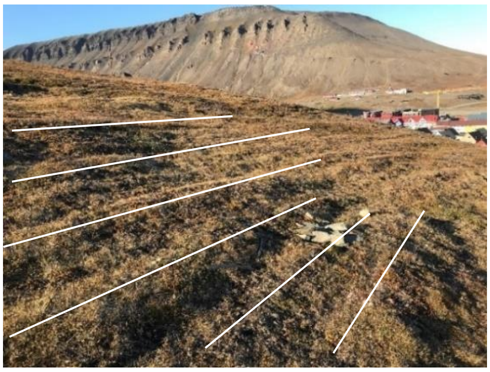

Figure 41. Solifluction above the cableway trestle Nr. 8 at the Line 5-6. White lines depict crests of "wavy" surface of the terrain that is typical for solifluction.

Figure 42. Cableway trestle Nr. 8 at the Line 5-6. This structure was affected by solifluction, and an attempt to stop this process was undertaken some years, see rusty metal poles.

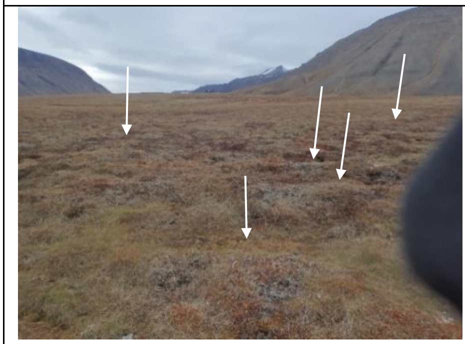

Figure 43. Solifluction above the Cableway trestle Nr. 17 at the Line 6. White arrows point of "dumps" on terrain surface that are typical for solifluction.

Figure 44. Heavy tilt of vertical foundation elements of the cableway trestle Nr. 17 at the Line 6. Tilt of foundation elements occurs due to action of solifluction.

Figure 45. Accumulation of rock debris at cableway trestle 10, Line 1b. Accumulated material around the structure is marked with ovals.

Figure 46. Close-up at accumulated material at cableway trestle Nr. 10, Line 1b.

<table>
<tr>
<td>UC 3 –
Urgent and
immediate</td>
<td>UC 3 was assigned when there were indicators pointing out on intensive occurrence of natural hazards by the object and high pace of subsequent morphological changes. The following were considered as indicators of such situations:
• Large ground depressions by the structure that were filled with water (ponding of water). In such conditions intensive permafrost degradation shall be expected (example is presented on Figure 47).
• Permafrost degradation caused by running water, in such cases intensive permafrost degradation may be expected, and as a result consequences for the object (example is presented on Figure 48).
• Terrain with pronounced solifluction (example is presented on Figure 51–Figure 52).
• High probabilities of large detrimental impacts of natural hazards, such as: 1) Proximity to steep or/and eroding slopes where landslides hypothetically may happen (example is presented on Figure 51–Figure 52); 2) Proximity of eroding river banks.

Figure 47. Close-up to ponding of water in ground depressions around a cableway post. Depressions are probably caused by degraded permafrost below the structure (cableway trestle Nr 8, Line 6). Ponding of water, in turn, leads to intensified degradation of permafrost.

Figure 48. Tilted cableway trestle in the situation when permafrost is affected by running surface water (cableway trestle Nr 10, Line 6). Running surface water intensifies degradation of permafrost. This case also presents an example of small creak meandering towards the object; this may cause partial undermining of foundation by the running water.</td>
</tr>
</table>

Figure 49. Terrain with pronounced solifluction by the cableway trestle Nr. 26.

Figure 50. Effects of solifluction on foundation of cableway trestle Nr. 26 at the Line 5-6: heavily tilted foundations.

Figure 51. Development of a ravine next to cableway trestle Nr. 36, Line 5-6. This development of ravine may lead to local slide of the slope supporting the trestle and subsequent collapse of it.

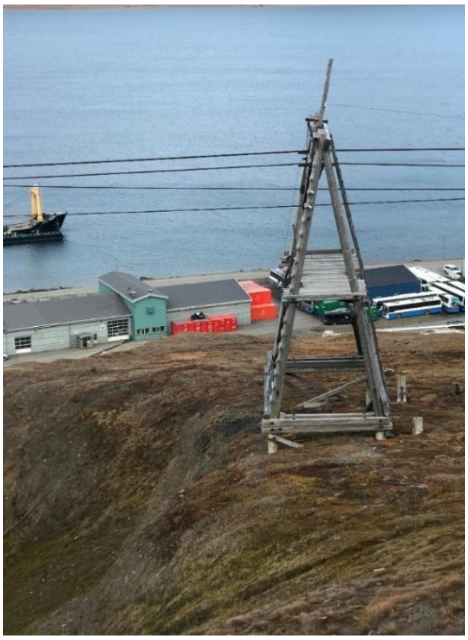

Figure 52. Cableway post Nr. 3 on the Line 3. Instability of adjacent slope and surface wash on it may affect stability of this post.

2.3.3 Assignment of Recommendation Class

An overall RC was assigned to each cableway trestle using [5]. RC was assigned based on overall stability of the objects, conditions of their foundations, cross-bracing elements, and probable/expected impacts of natural hazards. These "components" that were used to assign RC are critical and have the highest importance in the assessment of the overall recommendation class. At the same time some other components, such as quality of timber in visually intact foundation elements, were not explicitly taken into account. In some cases, specific recommended measures were outlined along with the RC class. Recommendations that were typically corresponding to different RC classes are presented in Table 7 (two first columns are from Table 3 in [5]).

Table 7. Recommendation classes and measured prescribed by PCCH-Arctic for cableway trestles.

Recommendation class (RC)	**Possible measures**	**Typical measures that were suggested by PCCH-Arctic for cableway trestles**
RC 0	No measures	–
RC 1	Maintenance/Preventive conservation	For trestles located in flat or gently sloping terrain: a. Filling up soil depression under the structure (compacted soil permitting outward drainage of water). b. Filling up ground depressions around foundation elements with compacted soil. Steep sloping and rocky terrain: a. Evaluation of timber quality in the active layer; possibly removal of rock-debris.
RC 2	Moderate repair and/or further investigation	In many cases, the RC 2 was used as "minimal" requirement because evaluation of timber quality deemed to be needed. The following measures may be suggested (in particular order): a. Measures from RC 1. b. Handling ground surface under the objects: ○ Handling flow of surface water. This concerns the cases when surface water appears in melting period and the cases when a flow is present throughout the summer. c. Further investigation: detailed condition survey of the object including evaluation of timber quality. Such survey should map damaged elements. d. Geotechnical and structural analysis of the object. Such analysis will answer a question whether replacement of entire foundation is needed or if only separate elements should be replaced. *We expect that replacing separate elements may be more typical operation at RC 2.*

		e. Eventual restoration. Comment: we leave it as an open question whether original elevations of timber trestles should be maintained during the restoration should trestles have settled in the terrain.
RC 3	Major intervention based on diagnosis	The following measures may be suggested (in particular order): a. Measures from RC 1 and RC 2. b. *We expect that replacing entire foundation would be a typical operation at RC 3.*

2.4 Results and discussion

Values for CC, UC and RC along are presented in Excel table [6] and also presented in Table 13 in Appendix 1. Summary of the results is presented in Table 8.

For the entire cableway system in Longyearbyen (lines Nr. 1a, 1b, 2a, 2b, 3, 5-6, and 6) the results show the following:

- Condition class (CC):
  - CC 0 – 9 cases
  - CC 1 – 10 cases
  - CC 2 – 59 cases
  - CC 3 – 91 cases
  - CC 3 Lost/Removed – 37 cases

  One can see that 91 objects or 54% of total number of still existing objects (lost and removed objects are excluded) are in the category "CC 3 – Major symptoms".

- Urgency class (UC):
  - UC 0 – 9 cases
  - UC 1 – 0 cases
  - UC 2 – 116 cases
  - UC 3 – 44 cases
  - 37 objects are in the class "CC 3 – Lost/Removed", hence no UC was assigned for them.

  One can see that 44 objects or 26 % of objects (lost and removed objects are excluded) are in the category "UC 3 – Urgent and immediate", which point out on pressing need of intervention.

- Recommendation class (RC):
  - RC 0 – 9 cases
  - RC 1 – 0 cases
  - RC 2 – 93 cases
  - RC 3 – 67 cases

One can see that 67 objects or 40 % of objects (lost and removed objects are excluded) are in the category "RC 3 – Major intervention based on diagnosis".

Overall, we see that for 2021 approximately 50% of the objects on the entire system require immediate intervention and such intervention will have a significant character, e.g. an entire foundation system would need to be redesigned and replaced.

Further, we have compared the obtained CCs for 2021 with the ones for 2013 to analyses temporal changes and to project development of conditions of cableway trestles in the future. CCs for 2013 were retrieved from [11]. We should note that detailed procedures that were used for assigning CC values presented in [11] were not identified by us, this constitutes a limitation for such comparison. Comparison (change in CCs values) is presented in Excel table [6] and in Table 9. The results show the following dynamics for the 8-year period from 2013 to 2021:

- 5 objects were lost, and 5 objects were restored (one should note that several objects were restored after 2021):
  - 3 objects were lost on the line Nr. 1b
  - 1 object lost on the line Nr. 2b
  - 1 object was (presumably (foundation remains but any structural elements are absent on the site) lost on the Nr. 5
- For 20 objects CC 1 has changed to CC 2.
- For 9 objects CC 1 has changed to CC 3.
- For 30 objects CC 2 has changed to CC 3.

Overall, conditions of 39 objects (classified with CC 1 and CC 2 in 2013) have changed to the most critical category "CC 3 – Major symptoms" from 2013 to 2021. This means that if pace of the change would remain the same, one may expect that conditions of all remaining objects will decrease to the worst category CC 3 in the next 30 year-period. If the rate of losing the objects will remain the same as in 2013–2021, 24 objects will be lost in the next 30-year period.

These predictions are probably conservative because one may expect that remaining strength "reserves" of load-bearing timber elements in the cableway trestles may decrease sharply at one point as many of them are already largely rotten. In addition, it may be expected that there will be further increase of impacts of natural hazards because they will be amplified by the ongoing climate change.

When it comes to the change of situation on particular lines of cableway trestles, we analysed the results in relation to the most critical situations, i.e. the cases classified with CC 3, UC 3 and RC 3 and also cases where the objects were lost (CC 3 "Lost/Removed"). Lost and removed object were excluded from the analysis for CC 3, UC 3 and RC 3 as they practically rarely are restored after being lost or removed. The results provide the following:

- For CC 3, we have analysed the percentage of CC3 cases on the line in 2013 and 2021, respectively (number of CC 3 related to the total number of objects on a line, lost and removed objects excluded):
  - Line Nr. 1b, percentage of CC 3 cases: 86% (2013) and 85% (2021).
  - Line Nr. 5-6, percentage of CC 3 cases: 53% and 79%.
  - Line Nr. 2b, percentage of CC 3 cases: 55% and 64%.
  - Line Nr. 5, percentage of CC 3 cases: 42% and 56%.
  - Line Nr. 6, percentage of CC 3 cases: 0% and 55%.
  - Line Nr. 3, percentage of CC 3 cases: 3% and 21%.

For 2021, line Nr. 1b has the highest percentage of CC 3 cases (85%), it followed by the lines Nr. 5-6 (79%) and 2b (64%), after which lines Nr. 5 and Nr. 6 are situated (56% and 55% respectively), with line 3 (21%) having the best conditions. Line Nr. 1b has the highest percentage of objects in most challenging conditions.

Interestingly, the most significant increase of CC 3 cases happened on the line Nr. 6 (+55%) which the "youngest" line (it was in operation in 1969-1987), which followed by the lines Nr. 5-6 (+25%), Nr. 3 (+18%), Nr. 5 (+14%), Nr. 2b (9%) and 1b (+1%).

- For UC 3, we have analysed the percentage of UC 3 cases on each of the lines for 2021 (number of CC 3 cases was related to total number of objects on a line, lost and removed objects were excluded), comparison with 2013 was not performed as UC 3 values for 2013 were not available in [11]. The following results were obtained:
    - Line Nr. 1b, percentage of UC 3 cases: 50%.
    - Line Nr. 2b, percentage of UC 3 cases: 45%.
    - Line Nr. 5, percentage of UC 3 cases: 44%.
    - Line Nr. 5-6, percentage of UC 3 cases: 33%.
    - Line Nr. 6, percentage of UC 3 cases: 15%.
    - Line Nr. 3, percentage of UC 3 cases: 5%.

  Line Nr. 1b has the highest percentage of objects in the category UC 3 (50%), where urgent and immediate interventions are needed, followed by the lines Nr. 2b and 5 (45% and 44%), line Nr. 5-6 (33%), line Nr. 6 (15%) and line Nr. 3 (5%).

- For RC 3, we have analysed the percentage of RC 3 cases on each of the lines for 2021 (number of RC 3 cases was related to total number of objects on a line, lost and removed objects were excluded), comparison with 2013 was not performed as RC 3 values for 2013 were not available in [10]. The following results were obtained:
    - Line Nr. 5-6, percentage of UC 3 cases: 58%.
    - Line Nr. 2b, percentage of UC 3 cases: 55%.
    - Line Nr. 5, percentage of UC 3 cases: 44%.
    - Line Nr. 1b, percentage of UC 3 cases: 40%.
    - Line Nr. 6, percentage of UC 3 cases: 38%.
    - Line Nr. 3, percentage of UC 3 cases: 18%.

  Line Nr. 5-6 has the highest percentage of objects in the category RC 3 (58%) where major interventions based on diagnosis are needed, it followed by the lines Nr. 2b and 5 (55% and 44%), line Nr. 1b (40%), line Nr. 6 (38%) and line Nr. 3 (18%).

Analysis shows that line Nr. 1b has the highest risk. Then, the lines Nr. 2b, 5-6 and 5 come (mentioned in no particular order), and lines Nr. 6 and Nr. 3 have the lowest risks.

Table 8. Summary of the results of PCCH-Arctic assessment for the system of cableway trestles in Longyearbyen.

Line Nr.	Years	CC0	CC1	CC2	CC3	CC3, % (CC3 /total number of cases except CC 3 L/R)	CC3 L/R	CC3 L/R, % (CC 3 L/R/total number of cases)	*Control, number of CCs*	UC0	UC1	UC2	UC 3	UC3, %	*Control, number of UCs*	RC0	RC1	RC2	RC3	RC3, %	*Control, number of RCs*
Taubanelinje 1a (159054)	2013-2021	0	0	0	0	0	11	–	11	0	0	0	0	–	–	0	0	0	0	–	–
Taubanelinje 1b (158657)	2013	1		2	20	86	1	4	24	–	–	–	–	–	–	–	–	–	–	–	–
	2021	1		2	17	85	4	17	24	1	0	9	10	50	20	1		11	8	40	20
Taubanelinje 2a (158987)	2013-2021	0	0	0	0	0	5	–	5	–	–	–	–	–	–	–	–	–	–	–	–
Taubanelinje 2b (158986)	2013		1	4	7	55	6	33	18	–	–	–	–	–	–	–	–	–	–	–	–
	2021	2		2	7	64	7	39	18	2	0	4	5	45	11	2	0	3	6	55	11
Taubanelinje 3 (158619)	2013	0	22	17	1	3	1	2	41	0	–	–	–	–	–	–	–	–	–	–	–
	2021	0	8	24	8	21	1	2	41	0	0	38	2	5	40	0	0	33	7	18	40
Taubanelinje G5-6 (87889)	2013	0	1	18	21	53	5	11	45	–	–	–	–	–	0	–	–	–	–	–	–
	2021	5	0	8	27	79	5	11	45	5	0	22	13	33	40	5	0	12	23	58	40
Taubanelinje G5 (87889)	2013	–	5	6	8	42	3	14	22	–	–	–	–	–	–	–	–	–	–	–	–
	2021	1	1	6	10	56	4	18	22	1	0	9	8	44	18	1	0	9	8	44	18

Taubanelinje G6 (87889)	**2013**	**–**	**11**	**26**	**3**		**0**	**0**	*40*	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
	2021	**0**	**1**	**17**	**22**	*55*	**0**	**0**	*40*	**0**	**0**	**34**	**6**	*15*	*40*	**0**	**0**	**25**	**15**	*38*	*40*
All cableway lines	Total for 2021	9	10	59	91	–	37	Sum for CC 0-CC 3 L/R	206	9	0	116	44	–	169	9	0	93	67	–	169
	Percentage of CCs to total number of cases (CC 3 L/R excluded), %	5	6	35	54	–	–	Sum for CC 1-CC 3 (CC 3 L/R excluded)	169	5	0	69	26	–	–	5	0	55	40	–	–

***: L/R – Lost/Removed**.

Table 9. Change of CCs from 2013 to 2021.

Line Nr.	Change in 2013 -- 2021														
	No change, classes remain to be the same in 2013 and 2021					Change in Condition class (CC)			Losses			Restoration			
	CC0	CC1	CC2	CC3	CC3 L/R	CC1→CC2	CC1→CC3	CC2→CC3	CC1→CC3 L/R	CC2→CC3 L/R	CC3→CC3 L/R	CC1→C 0	CC2→CC0	CC3→ CC0	*Control, number of CCs*
Taubanelinje 1a (159054)	–	–	–	–	11	–	–	–	`	–	–	–	–	–	**11**
Taubanelinje 1b (158657)	1		2	17	1	–	–	–	–	–	3	–	–	–	**24**
Taubanelinje 2a (158987)	–	–	–	–	5	–	–	–	–	–	–	–	–	–	**5**
Taubanelinje 2b (158986)	–	–	2	5	6	–	–	2	–	1	–	1	–	1	**18**
Taubanelinje 3 (158619)	–	8	12	1	1	12	2	5	–	–	–	–	–	–	**41**
Taubanelinje G5-6 (87889)	–	–	7	17	5	1	–	10	–	–	–	–	1	4	**45**
Taubanelinje G5 (87889)	–	1	4	7	3	2	2	1	1	–	–	–	1	–	**22**
Taubanelinje G6 (87889)	–	1	12	3	–	5	5	14	–	–	–	–	–	–	**40**
Number of cases	*1*	*10*	*39*	*50*	*32*	*20*	*9*	*32*	*1*	*1*	*3*	*1*	*2*	*5*	**206**
Total number of cases														*206*	

3 Impacts of natural hazards

3.1 Study objects and methodology

A risk assessment of impacts of natural hazards was performed [13] for the case study objects listed in Table 1 ([14]), the analysis was however extended to several other objects (both in Ny-Ålesund and Longyearbyen) to make it more complete. The analyzed objects are presented in Table 10 and Table 11 ([13]).

There are two versions of this risk assessment. The first version in presented in the report by Bekele and Sinitsyn [13], where the methodology and first version of assessment are given. The second version is presented in master thesis of Vehola [15], where results were also linked to an online GIS layer [16]. Second version of assessment ([15]) confirmed and clarified the results from the first version ([13]), and deviation between the results were rather minor.

Risk assessment [15] considered the impacts from several different natural hazards, and permafrost degradation was a "central" hazard among those. Further clarification of permafrost degradation (in the climate change perspective) can be based on simulations by Aga, Westermann *et al.* [17]. Simulations [17] present modeling of permafrost regime for cultural heritage objects in Adventdalen and Ny-Ålesund. Modeling is performed under the high emission scenario SSP5-8.5, which covers the period from the 1980s to 2100. In [17], 15 model scenarios characterized by different soil stratigraphies, drainage conditions and snow dynamics were simulated to represent the diverse conditions across Adventdalen and Ny-Ålesund. The results provide a data set which can be used to more precise evaluation of the risks (caused by permafrost degradation) to individual objects analyzed in [15]. Such more precise evaluation may also utilise the results (conditions of structures, drainage conditions, geomorphological conditions) of field inspection of cable way trestles in Longyearbyen that are presented in Excel table [6], while the data on snow conditions by cableway trestles in Adventdalen is presented in [18, 19].

Table 10. List of cultural heritage objects in Longyearbyen selected for risk assessment of impacts of natural hazards.

Heritage Object ID*	Heritage Object Name	Operational period (from [20])	Remark(s)
159054	Cable car line 1a (*Taubanelinje 1a*)	1906-1921	11 foundations
158657	Cable car line 1b (*Taubanelinje 1b*)	1939-1958	24 trestles (*bukker*) and 1 tightening station (*Strammestasjon*). Several objects around the mine entrance were not included in the analysis, yet findings for the closest to them *Bukk 1 – Taubanelinje 1* (ID 158657-1) would be in general applicable to those objects.
158987	Cable car line 2a (*Taubanelinje 2a*)	1921-1968	5 foundations (1 for machine house) at the Cable car line 2a were included in the analysis. Several objects around the mine entrance were not included in the analysis, yet findings for closest to them *Fundament maskinhus* (ID 136714-3) would be in general applicable to those objects.
158986	Cable car line 2b (*Taubanelinje 2b*)	1937-1968	18 trestles and 1 corner station (*Vinkelstasjon*)

158619	Cable car line 3 (*Taubanelinje 3*)	1937-1987	41 trestles and 1 tightening station
87889	Cable car line mine 5 (*Taubanelinje delstrekning gruve 5*)	1959-1972	23 trestles and 1 tightening station (does not exist at present time)
87889	Cable car line mine 6 (*Taubanelinje delstrekning gruve 6*)	1969-1987	40 trestles and 1 tightening station (*Strammestasjon Todalen*)
87889-6	The cable car center in Longyearbyen (*Taubanesentralen i Longyearbyen*)	-	-
93040-6	The cable car station in Hiorthhamn (*Taubanestasjonen i Hiorthhamn*)	-	-
NA	The Titan crane (*Titankrana*)	-	-
136713	Mine 1a (*Gruve 1a*)	-	-
136716	Mine 2b (*Gruve 2b*)	-	-
87889-4	Mine 5 (*Gruve 5*)	-	-
87889-3	Mine 6, the pit top North building (*Gruve 6, Daganlegget Bygning Nord*)	-	-
87889-8	Mine 6, the pit top East building (*Gruve 6, Daganlegget Bygning Aust*)	-	-
87889-9	Mine 6, the pit top South building (*Gruve 6, Daganlegget Bygning Sør*)	-	-
N/A	Mine 6, Gallery (*Gruve 6, Galleri*)	-	-
N/A	Mine 6, Mine entrance (*Gruve 6, Gruve inngang*)	-	-
87889-5	The angle station at Endalen (*Vinkelstasjon ved Endalen*)	-	-
146668-7	Building G in Hiorthhamn (*Boligbrakke G i Hiorthhamn*)	-	-

* – Heritage Object ID in Askeladden [3].

Table 11. List of cultural heritage objects and modern buildings in Ny-Ålesund selected for risk assessment of impacts of natural hazards.

Heritage Object ID*	Heritage Object/Modern Building Name
158506-2	The airship mast (*Luftskipsmasta*)
159759-1	The Green Harbour house (*Green Harbour-Huset*)
159781	The White house (*Hvitt hus*)
159772	The Tronderheimen house (*Trønderheimen*)
159807-1 159804-1 159806-1 159802-1	The London houses (*Londonhusene*)
159 756	The school (*Skolen*)
159 769	The telegraph (*Telegrafen*)
159793-1	The museum (*Museet*)
159761	Museum cabin, light green (*Museum/Museumshytta/hytte lysegrønn*)
159762-1	Veteran cabin, light blue (*Veteranhytta/hytte lyseblå*)
159763-1	Sysselbu
159764-1	Museum
159768	Amundsen villa (*Amundsenvillaen*)
159776-1	North Pole hotel (*Nordpolhotellet*)
159779-1	Yellow house (*Gult hus*)
159784	Blue house (*Blått hus*)
159795-1	The middle warehouse (*Mellageret*)
159796	Post office (*Posthuset*)
159801	The iron warehouse (*Jernlageret*)
159798-1	Sætra
159823-1	Boat house (*Båtnaust*), 1st operation period
159 820	Boat house (*Båtnaust*), before 1921
159 739	Boat house (*Båtnaust*), 1st operation period
159782-1	Mexico
159 785	Hospital (*Sykehuset/Skutergarasjen*)
159790-1	The community house (*Samfunnshuset*)
-	Saga
-	The old power station (*Gamle kraftstasjonen*)
-	The dog yard (*Hundegården*)
-	Doll house (*Dokkehus*)
-	Transformer house (*Transformatorhus*)

* – Heritage Object ID in Askeladden [3].

In the following we present the main points of the risk assessment and conclusions from [15]. This risk assessment of impacts of natural hazards is a "high-level" or "coarse" analysis with the aim to provide identification of objects exposed to the most risk and hence to provide possibility for prioritization of the objects for restoration. This analysis paves the foundation for a design of engineering solutions (such as foundations and protective structures) for specific objects. Such design should reply to the natural hazards that are most relevant to a specific case. A methodology of such detailed geotechnical analysis in case of *permafrost degradation* is presented in [21], and results of application of it to specific objects are presented in [22].

Methodology for the coarse analysis is presented in [13]. Methodology provides two types of analysis – qualitative and quantitative. The following presents introduction to this methodology from [13]. The methodology was realized in the PCCH-Arctic Risk Assessment Excel Tool.

> *Qualitative risk analysis focuses on evaluating the likelihood and impact of risks based on their potential severity and probability of occurrence. It relies on expert judgment and is subjective to some extent, as it involves assessing risks using a qualitative scale. This approach is often utilized when data is limited or when conducting a more intricate analysis is impractical. The outcome of qualitative risk analysis is typically a risk register or risk matrix that ranks risks based on their likelihood and potential impact.*
>
> *On the other hand, quantitative risk analysis involves a more comprehensive examination that employs numerical estimations to assess the probability and impact of risks. It relies on numerical data and is generally more objective than qualitative analysis. Quantitative risk analysis encompasses the identification and modelling of risks, simulation of scenarios to estimate the likelihood and impact of risks, and assessment of the overall risk exposure of a project. This approach provides a more accurate assessment of risks and aids in prioritizing risk mitigation strategies.*
>
> *A combination of qualitative and quantitative risk analysis approaches is often used to provide a more comprehensive assessment of risks. Qualitative risk analysis can help identify and prioritize risks that require further analysis, while quantitative analysis can provide a more detailed assessment of those risks. By combining the two approaches, project managers can develop effective risk mitigation strategies that address both the likelihood and potential impact of risks. Ultimately, the choice of risk analysis methodology depends on the specific needs and constraints of the project, as well as the availability of data and resources.*
>
> *For the purpose of the project, the qualitative risk analysis step is based on risk identification, assignment of probability and consequence classes (based on NS 5815) and generation of a risk matrix. The quantitative risk analysis step builds on the qualitative risk analysis by defining numerical class for the probabilities and consequences.* Figure 53 *shows an illustration of these two steps.* Each step is presented in detail in Bekele and Sinitsyn [13]. To quantify the expected consequence of a certain natural hazard on a cultural heritage, the concept of Heritage Loss (HL) was introduced based on inspiration from [23]. In the context of risk assessment for cultural heritage objects, heritage loss was defined as a quantitative estimate of the expected physical loss of a cultural heritage object due to the action of natural and anthropogenic hazards or a combination of such hazards [13].

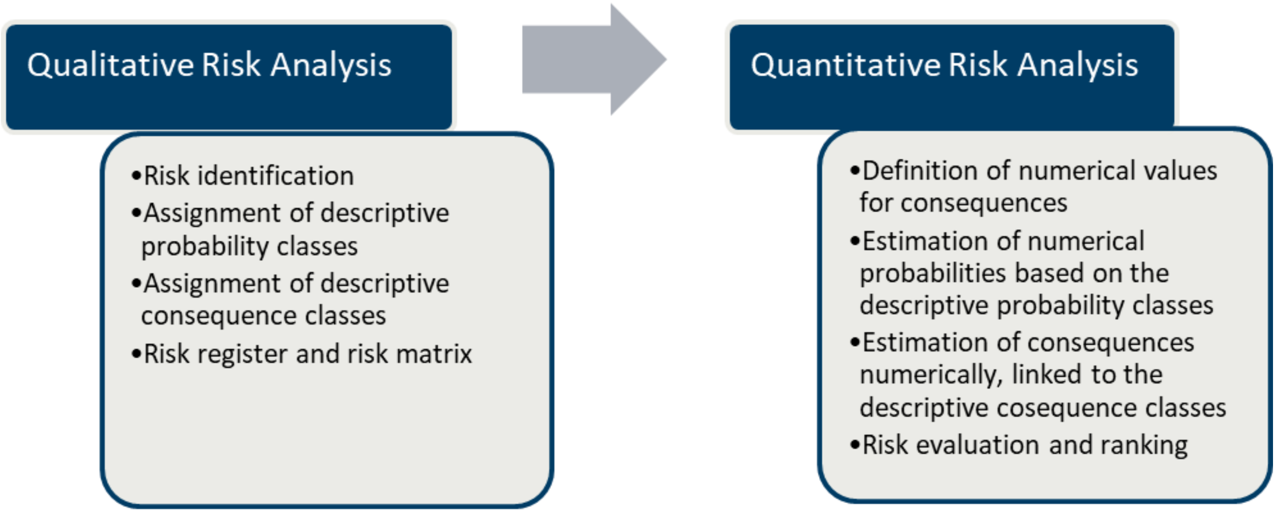

Figure 53. Qualitative and quantitative risk analysis steps and a link between the two from [4].

Risk assessment of impacts of natural hazards performed by Vehola [15] includes the following natural hazards: permafrost degradation, solifluction, landslides and debris flows, rockfalls, snow avalanches, coastal erosion, riverine flooding, surface erosion and gullying, and weathering.

3.2 Results for case study objects in Longyearbyen

Main conclusions for case study objects in Longyearbyen from [15] are presented below, cited text is written in *Italic.*

For the case study objects in Longyearbyen (including absent/destroyed ones), Cable car line 1b exhibits the highest exposure to the combined effects of natural hazards (Figure 54). Following Cable car line 1b in terms of aggregated risk exposure, several trestles on Cable car line 2b and entrance to the mine, as well as trestles on lines 5-6, 5, and 1a, are identified as significant points of exposure. Trestle Nr. 6 on Cable car line 1b (Taubanelinje 1b, Bukk Nr. 6) exhibits the highest average risk of Heritage Loss when considering the combined effects of hazards. Figure 55 displays the contributions made by the considered natural hazards to the aggregated risk of Heritage Loss for this cable car trestle. The figure reveals that snow avalanches and rockfalls pose the most significant risks to this specific object.

In addition to the analysis of individual cultural heritage (CH) objects, Vehola [15] *examined the Cable car lines (eight in total) to identify the primary hazards affecting each cable car line and determine the lines at the highest risk. The findings provide insights into the specific risks associated with each cable car line. For Cable car lines 1a, 1b, and 2b, snow avalanches were found to contribute the most to the overall risk of Heritage Loss, whereas for Cable car lines 3, 5, 5-6, and 6, permafrost degradation emerged as the most prevalent hazard. In the case of Cable car line 2a, shallow landslides contributed the most to the overall risk* *of Heritage Loss. As an example, for the most hazardous Cable car line 1b, the contribution of the natural hazards to the total risk of Heritage Loss is shown in* Figure 56*.*

Examining the contributing natural hazards reveals that snow avalanche and rockfall, followed by debris flow play the main role in the aggregated risk of Heritage Loss for Cable car line 1b. A detailed display of the results for each cable car line is presented in Appendix 3 in [15]*. Results of the level of risk for CH objects and cable car lines are summarized below.*

Aggregated Risk for:	Sum of Avg Risk of HL	Rank based on Avg Risk of HL
Taubanelinje 1b, Bukk Nr. 6 (158657-6)	87,64 %	1
Taubanelinje 2b, Bukk Nr. 2 (158986-2)	83,64 %	2
Taubanelinje 1b, Bukk Nr. 7 (158657-7)	82,29 %	3
Taubanelinje 1b, Bukk Nr. 1 (158657-1)	81,59 %	4
Taubanelinje G5-6, Bukk Nr. 33 (87889-42)	80,34 %	5
Taubanelinje G5-6, Bukk Nr. 38 (87889-47)	74,84 %	6
Taubanelinje G5-6, Bukk Nr. 32 (87889-41)	74,34 %	7
Taubanelinje 1b, Bukk Nr. 8 (158657-8)	73,29 %	8
Taubanelinje 2b, Bukk Nr. 3 (158986-3)	71,39 %	9
Taubanelinje 1b, Bukk Nr. 4 (158657-4)	70,42 %	10
Taubanelinje 2b, Bukk Nr. 1 (158986-1)	69,59 %	11
Taubanelinje 1b, Bukk Nr. 12 (158657-12)	69,44 %	12
Taubanelinje 1b, Bukk Nr. 2 (158657-2)	68,34 %	13
Taubanelinje 1b, Bukk Nr. 5 (158657-5)	67,82 %	14
Taubanelinje 1a, Foundation 9 (159054-9)	67,69 %	15
Taubanelinje 1a, Foundation 8 (159054-8)	67,69 %	15
Taubanelinje 1a, Foundation 6 (159054-6)	67,69 %	15
Taubanelinje 1a, Foundation 5 (159054-5)	67,69 %	15
Taubanelinje 1a, Foundation 7 (159054-7)	67,69 %	15
Taubanelinje 1b, Bukk Nr. 18 (158657-18)	67,02 %	16
Gruve2b (136716)	66,62 %	17
Taubanelinje G5-6, Bukk Nr. 9 (87889-17)	65,87 %	18
Taubanelinje G5-6, Bukk Nr. 30 (87889-39)	65,34 %	19
Taubanelinje G5, Bukk Nr. 1 (87889-78)	64,91 %	20
Taubanelinje 1b, Bukk Nr. 10 (158657-10)	64,84 %	21
Taubanelinje 1b, Bukk Nr. 19 (158657-19)	64,79 %	22
Taubanelinje 1b, Bukk Nr. 17 (158657-17)	64,79 %	22
Taubanelinje 1b, Bukk Nr. 20 (158657-20)	62,99 %	23
Taubanelinje G5, Bukk Nr. 10 (87889-69)	62,84 %	24
Taubanelinje 1b, Bukk Nr. 11 (158657-11)	62,09 %	25
Taubanelinje 1a, Foundation 4 (159054-4)	61,44 %	26
Taubanelinje G5, Bukk Nr. 2 (87889-77)	60,80 %	27
Taubanelinje 2b, Bukk Nr. 4 (158986-4)	60,64 %	28
Taubanelinje 1b, Bukk Nr. 13 (158657-13)	60,24 %	29
Taubanelinje 2b, Bukk Nr. 5 (158986-5)	60,09 %	30

Figure 54. The highest ranked CH objects in the Longyearbyen area in terms of aggregated average risk of Heritage Loss (referred as HL in the figure). Figure: [15].

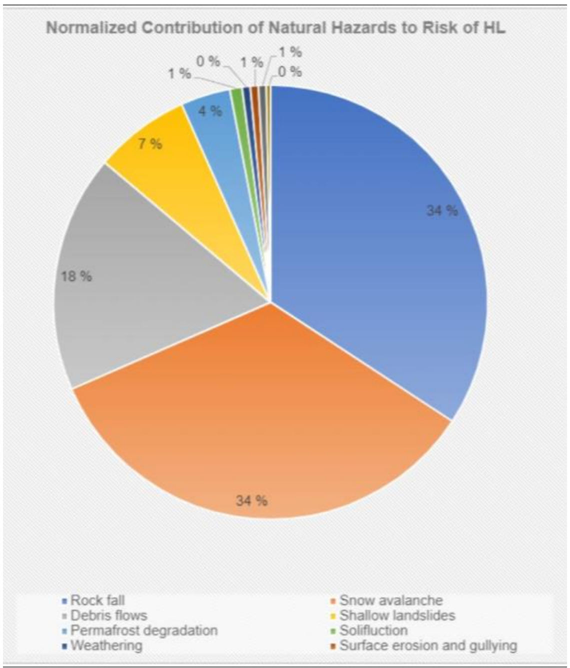

Figure 55. Aggregated risk of Heritage Loss (referred as HL in the figure) from natural hazards to the trestle nr. 6 on Cable car line 1b. Figure: [15].

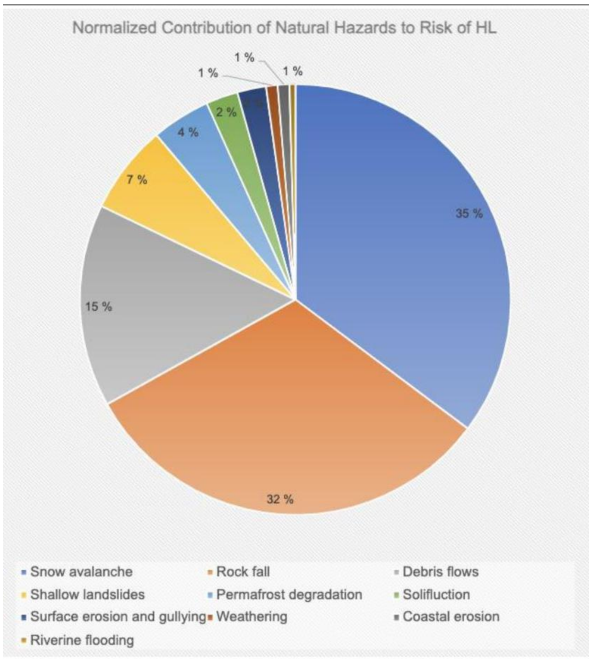

Figure 56. Aggregated average risk of Heritage Loss (referred as HL in the figure) for Cable car line 1b. Figure: [15].

The total scores and hazard distribution for each object were visualized in GIS [16]. The map shows detailed hazard evaluation for each studied heritage object near Longyearbyen (and Ny-Ålesund)*. The zoomed-out view shows overall hazard evaluation for each of the 8 cable car lines in Longyearbyen, with red indicating highest risk and yellow lower risk (*Figure 57 *and* Figure 58*). In addition, popup windows provide the information on the cable car line at question (the aggregated average total risk of Heritage Loss for that specific CH object; Rank within the Cable car line (for the CH objects being part of a Cable car line), Askeladden ID for more information; pie chart that shows the distribution of natural hazards, a picture of the CH object (if available)).*

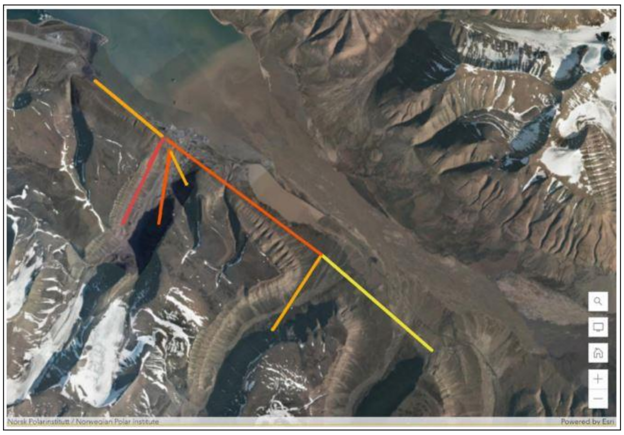

Figure 57. Zoomed-out overview of the cable car lines. The darker the colour, the higher the total risk, i.e. red colour indicating higher risk, yellow the least risk. Figure: [15].

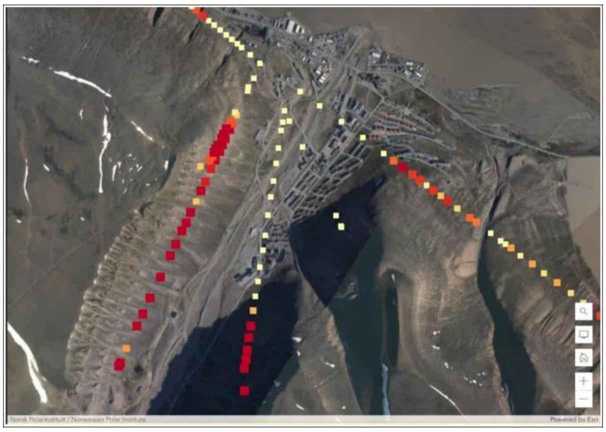

Figure 58. Zoomed-in overview of the cable car lines. The darker (redder) and the bigger the symbol of the object, the larger the risk. Figure: [15].

Table 12 *presents the distribution of CH objects in Longyearbyen based on the three threshold groups used for visualizing results in ArcGIS online* [15, 16]*. The table also includes information about the main natural hazards associated with each of the eight cable car lines. The analysis reveals that half of the CH objects in Longyearbyen are posed with relatively low level of total risk of Heritage Loss (below 30%). About one third are exposed to a medium level of risk (total risk between 30 and 60%), while 16% face a high level of total risk of Heritage Loss (above 60%). Regarding all CH objects, the main natural hazards identified are permafrost degradation, snow avalanches and rockfalls. Examining the cable car lines, it was revealed that permafrost degradation is the biggest contributor to overall risk for 50 % (4/8) of the cable car lines, whereas snow avalanches are the main hazard for 37.5 % (3/8) of the cable car lines.*

Table 12. Summary table for the total risk posed by the cable car lines and other CH objects in Longyearbyen. For the cable car lines the main natural hazards, contributing to the total risk, are also mentioned. Table: [15].

	Sum of average risk of Heritage Loss <30%	Sum of average risk of Heritage Loss 30-60%	Sum of average risk of Heritage Loss >60%	Main natural hazards of the Cable car line
Cable car line 1a (11 CH objects)	1 (9 %*)	4 (36 %)	**6** (55 %)	Snow avalanches (42 %**), Debris flows (23 %), Rock falls (17 %)
Cable car line 1b (25 CH objects)	2 (8 %)	7 (28 %)	**16** (64 %)	Snow avalanches (35 %), Rock falls (32 %), Debris flows (15 %)
Cable car line 2a (5 CH objects)	5 (100 %)	-	-	Shallow landslides (41 %), Permafrost degradation (15%), Debris flows (9%)
Cable car line 2b (19 CH objects)	12 (63 %)	2 (11 %)	**5** (26 %)	Snow avalanches (27 %), Rock falls (26 %), Debris flows (17 %)
Cable car line 3 (42 CH objects)	24 (57 %)	18 (43 %)	-	Permafrost degradation (26 %), Surface erosion & gullying (20 %), shallow landslides (14 %)
Cable car line 5-6 (47 CH objects)	13 (28 %)	28 (60 %)	**6** (13 %)	Permafrost degradation (22 %), shallow landslides (17 %), snow avalanches (17%)
Cable car line 5 (23 CH objects)	9 (39 %)	11 (48 %)	**3** (13 %)	Permafrost degradation (26 %), Rockfalls (19 %), debris flows (14 %)
Cable car line 6 (41 CH objects)	40 (98 %)	1 (2 %)	-	Permafrost degradation (32 %), Solifluction (20 %) Surface erosion & gullying (18 %)
Other objects in Longyearbyen (13 CH objects)	8 (62 %)	4 (31 %)	**1** (8%)	-
Total (226 CH objects)	114 (50%)	75 (33%)	**37** (16%)	-

*Percentage share of the total number of CH objects on that Cable car line/group.
** Contribution of the hazard to the total risk of Heritage Loss on that line.

Overall, it can be observed that Cable car line 1b faces the highest risk of Heritage Loss, with 16 out the 25 CH objects (64%) exposed to the highest identified level or risk. The primary hazards for Line 1b are snow avalanches, rockfalls and debris flows. Snow avalanches and rockfalls each contribute to approximately one-third of the overall the risk, while debris flows account for 15%. Shallow landslides and permafrost degradation also contribute to the total risk to some degree.

Following Cable car line 1b, Cable car line 1a demonstrates the second highest overall risk, with six out of 11 (55%) objects exposed to the highest level of risk. Snow avalanches pose the greatest threat for this line, followed by debris flows and rockfalls.

The majority of the objects on Cable car line 2b are exposed to low overall risk. However, the first five CH objects (26%) on the Cable car line, located on a steep slope, are exposed to the highest level of risk. Consequently, the primary contributors to the total risk for this line are snow avalanches, rockfalls and debris flows.

Cable car line 5-6, the longest line consisting of 47 CH objects, has significant proportion of the objects facing medium risk (60%). 6 objects (13%) are exposed to the highest level of risk. Among these objects, snow avalanches are the primary contributor to the total risk for four out of six objects. However, when considering the overall risk of the entire cable car line, permafrost degradation poses the most substantial risk. Shallow landslides and snow avalanches contribute equally to the overall risk of the line. Given the length and varying terrain of this line, the distribution of natural hazards is relatively mixed, with different hazards posing the main risk for different CH objects.

For Cable car line 5, permafrost degradation, rockfall and debris flow are the main hazards, accounting for around 64% of the total risk. Shallow landslides, snow avalanches and solifluction also pose a risk to some of the CH objects along the line. On this line, three out of 23 objects are exposed to the highest level of total risk.

Moving on to Cable car line 3, none of the objects face the highest level of risk, and the majority fall under the lowest level of overall risk. The main hazards for this line include permafrost degradation, surface erosion and gullying, and shallow landslides. Diverging form other cable car lines, weathering is considered a risk for some of the CH objects on this line, contributing to 10% of the total risk.

Cable car lines 6 and 2b experience relatively low levels of total risk, with no objects along these lines exposed to the highest level of risk. For Cable car line 2a, all objects have the lowest level of total risk, while for Cable car line 6, only one object faces a medium level of risk. The main hazards for Line 2b are shallow landslides, permafrost degradation, and debris flows. As for Line 6, permafrost degradation, solifluction, and surface erosion and gullying are the primary contributors to the overall risk.

Amongst other CH objects in Longyearbyen (a total of 13), one object, namely, the Mine entrance for Cable car line 2b, is exposed to the highest level of total risk. Similar to the Cable car trestles at high risk on that line, the main hazards for this object are rockfalls, debris flows and snow avalanches.

3.3 Results for case study objects in Ny-Ålesund

Main conclusions for case study objects in Ny-Ålesund from [15] are presented below, cited text is written in *Italic*. A risk ranking for CH objects in Ny-Ålesund is presented in Figure 59.

The air ship mast (Luftskipsmasta) was found to be the object with the highest aggregated risk of Heritage Loss. The aggregated risk for the objects in Ny-Ålesund is significantly lower compared to those observed for objects in Longyearbyen and it shows less variation amongst the different heritage objects.

The analysis highlights the significance of permafrost degradation as the primary natural hazard contributing to the risk of heritage objects in Ny-Ålesund (Figure 60). *For the CH objects located at the coastal area, coastal erosion is considered as the second biggest contributor to the overall risk.* As shown in Figure 8, all CH objects, except the Air ship mast (which has an overall risk of 36%), have a total average risk of over 30%.

Aggregated Risk for:	Sum of Avg Risk of HL	Rank based on Avg Risk of HL
Luftskipsmasta	36,04 %	1
Gamle kraftstasjonen	24,63 %	2
Båtnaust (22)	24,63 %	2
Båtnaust (24)	21,65 %	3
Båtnaust (23)	21,65 %	3
Jernlageret	17,06 %	4
Hundegården	17,06 %	4
Museum	15,92 %	5
Mellageret	15,92 %	5
Blått hus	15,92 %	5
Samfunsshuset	15,92 %	5
Mexico	15,92 %	5
Gult hus	15,92 %	5
Saga	15,92 %	5
Transformatorhus	15,92 %	5
Hvitt hus	15,92 %	5
Trønderheimen	15,92 %	5
Telegrafen	11,06 %	6
Veteranhytta/hytaa lyseblå	9,92 %	7
Green Harbour-Huset	9,92 %	7
Sysselbu	9,92 %	7
Meseet	9,92 %	7
Dokkehus	9,92 %	7
London 2	9,92 %	7
Skolen	9,92 %	7
London 3	9,92 %	7
London 1	9,92 %	7
Sætra	9,92 %	7
Nordpolhotellet	9,92 %	7
Posthuset	9,92 %	7
London 4	9,92 %	7
London husene	9,92 %	7
Amundsenvillaen	9,92 %	7
Sykehuset/Skutergarasjen	6,92 %	8
Museumshytta/hytte lysegrønn	4,20 %	9

Figure 59.Ranking of the CH objects in Ny-Ålesund in terms of the aggregated average risk of Heritage Loss. Figure: [15].

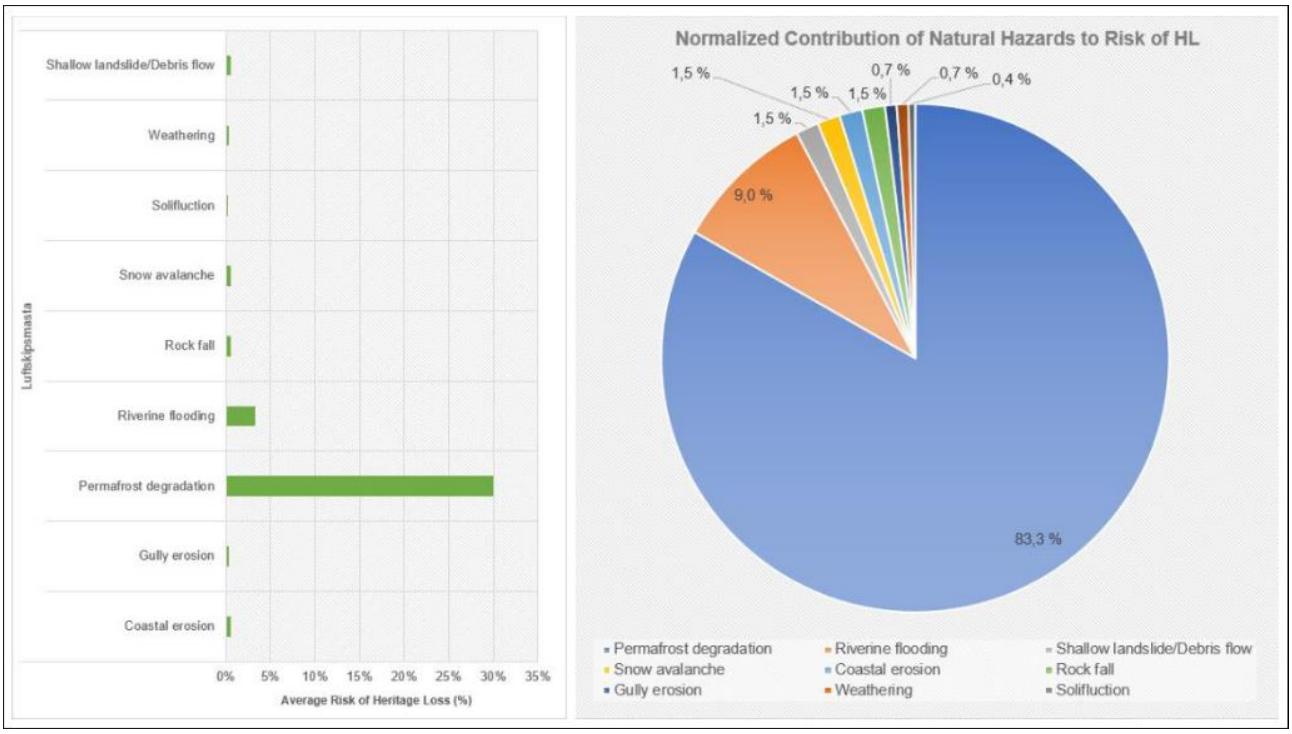

Figure 60. Contribution of different natural hazards to the risk of Heritage Loss for the Air ship mast. Figure: [15] .

3.4 Additional recommendations based on risk assessment of natural hazards

Restoration of individual objects should take into account a set of natural hazards that is relevant to that specific object. In other words, if one aims to safeguard a cable way trestle that is affected by both permafrost degradation and solifluction, then its foundation design (performed for restoration purposes) need to take both hazards into account. In support to such considerations, description of the hazards responsible for highest risks impacts on various case study objects in PCCH-Arctic in [15] (Ch. 7) should be considered.

Climate change may affect natural hazards, and hence the impacts from those on the objects of cultural heritage. Vehola [15] provides discussion on the changes of natural hazards (that are relevant to the PCCH-Arctic case study objects) in a warmer climate.

Prioritization of the objects of cultural heritage for restoration, in addition to historical and cultural significance of the object, may include considerations regarding its physical condition and vulnerability to damage or decay, its class as a symbol of the cultural identity of the local community, and its potential appeal to tourists and other visitors [15]. The latter is rooted in class and dilemmas in management of cultural heritage, which are presented in [24].

4 Recommendations for particular case study objects

4.1 Parametric analysis for cableway trestles

Evaluation of climate change impacts on cableway trestles in Longyearbyen is presented in [18]. This evaluation includes parametric analysis of settlements of cableway trestles as a function of soils type (sand, silt, clay), load (expressed via typical high/size of a trestle (defined as “small”, “medium”, and “tall”)), and climate change impacts on permafrost (expressed via changes of ground temperatures and active layer thickness). *Predicted by Enevoldsen [18] permafrost temperatures and the active layer thickness may seem to be somewhat on the “warmer” side, hence need to be used with a certain care.*

The results of these simulations show that the active layer thickness reaches depths from 1.5 m to 2 m in 2030–2050 depending on the ground conditions. The actual depth of foundations of cableway trestles is not known, however it may be assumed (based on the existing excavations) to be approximately 2 m. Predicted development of the active layer may place the timber trestles at danger as support from permafrost will be lost in the next decades. Simulations also predict that establishment (in case of restoration) of shallow authentic solutions will be challenging due to projected higher active layer thickness and warmer permafrost temperatures. Settlement analysis of authentic solution shows that settlement increase of 10 cm (which may be defined as the failure criteria) may be reached between 2040 and 2060 depending on soli type.

4.2 CryoGrid modeling of permafrost regime for cultural heritage objects in Adventdalen and Ny-Ålesund

The permafrost thermal regime in Adventdalen and Ny-Ålesund was modeled with the CryoGrid community model, and the results are presented in [17]. Modeling is performed under the high emission scenario SSP5-8.5 and covers the period from the 1980s to 2100. 15 model scenarios characterized by different soil stratigraphies, drainage conditions and snow dynamics were simulated to represent the diverse conditions across Adventdalen and Ny-Ålesund. Key conclusions from [17] are presented below, cited text is written in *Italic.*

The results show, that in the 2000s and 2010s, the simulated class of mean annual ground temperature and the active layer thickness are in the range of observed class in Adventdalen and Ny-Ålesund [25], however, the variation in mean annual ground temperatures highlight, that permafrost conditions might vary substantially depending on the soil stratigraphy, drainage conditions and snow cover.

Scenarios with high snowfall factors resulted in higher mean annual ground temperatures compared to model scenarios with little snow due to the insulating properties of the snow cover. Scenarios with blocky terrain and drained conditions exhibited greater active layer thickness increases due to faster warming and deeper thaw into the soil. Conversely, scenarios with an organic layer and undrained conditions showed a lower active layer thickness increase, which can be explained by the thermal buffer provided by the organic content and soil moisture. While some model scenarios already feature mean annual ground temperature between -1 ˚C and 0 ˚C nowadays, others reach the critical temperature range towards the end of the century. As the ground temperatures might have a strong impact on the stability of structures built on the permafrost, the conditions for each object should be evaluated separately and based on that, the best fitting model scenario should be selected to avoid an over- or underestimation of mean annual ground temperature and the active layer thickness.

4.3 Case study objects for detailed evaluations

Objects for detailed evaluation include Cableway trestles Nr. 6 and 34 on Line 5-6, Cableway trestle Nr. 32 on Line 3, the Cable car center, the Titan crane from Longyearbyen and Green Harbour House and Luftskipsmasta from Ny-Ålesund (Figure 61–Figure 68). These structures represent diverse foundation types and varying dimensions, which may enable us to transfer the findings to other objects in the study areas. The White house in Ny-Ålesund was restored in 2024 and the Air ship mast was restored in 2025 (both structures were placed on new pile foundations embedded in bedrock), hence these structures were not included in the analysis.

Figure 61. Cableway trestle Nr. 6, Line 5-6, Longyearbyen.

Figure 62. Cableway trestle Nr. 34, Line 5-6, Longyearbyen.

Figure 63. Cableway trestle Nr. 32, Line 3, Longyearbyen.

Figure 64. The old coal cableway centre in Longyearbyen.

Figure 65. The Titan crane, Longyearbyen.

Figure 66. Green Harbour House, Ny-Ålesund.

Figure 67. Foundation remains in Ny-London (2021), similar foundation type is believed to be used at Green Harbour House.

Figure 68. The air ship mast, Ny-Ålesund.

Report by Bekele and Sinitsyn [22] presents detailed and comprehensive understanding of potential climate-driven impacts on foundation stability of several case study objects in Longyearbyen and Ny-Ålesund. This report presents both, evaluation of permafrost degradation (expressed via changes of ground temperatures and the active layer thickness) and settlements of selected case study objects in warming climate. This analysis is based on high resolution SSP5-8.5 climate projection presented in [26]. Evaluation of permafrost degradation is performed by numerical simulations in Temp/W (Temp/W is a commonly used software package for civil engineering purposes). These simulations cover time span until 2070. Steady increase of permafrost temperature and active layer thickness is predicted in both settlements (Figure 69–Figure 72).

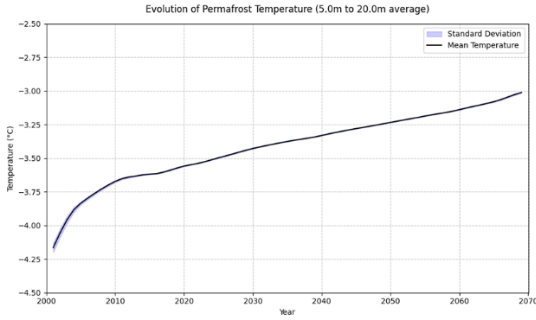

Figure 69. Evolution of average permafrost temperature in Longyearbyen. Figure: [22].

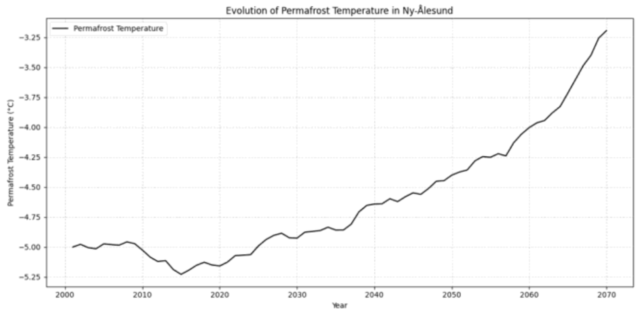

Figure 70. Evolution of average permafrost temperature in Ny-Ålesund. Figure: [22].

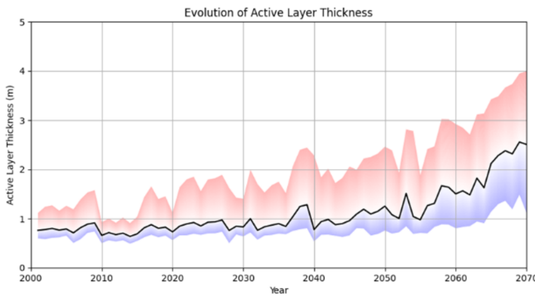

Figure 71. Evolution of active layer thickness in Longyearbyen. Figure: [22]. Pink and blue areas present upper and lower bound variations in the active layer thickness.

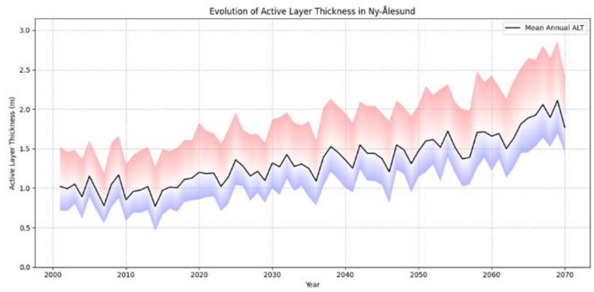

Figure 72. Evolution of active layer thickness in Ny-Ålesund. Figure: [22]. Pink and blue areas present upper and lower bound variations in the active layer thickness.

Evaluations [22] included calculation of settlements for _some_ of these case study objects under climate change conditions, two sources of settlements were considered – thaw settlement and creep settlement. These mechanisms represent the dominant processes affecting ground stability in permafrost regions under warming conditions. Details on the evaluation are presented in [22]. Results of evaluations and recommendations are presented in the sections below, cited text is written in *Italic.*

4.3.1 Stability of case study objects in Longyearbyen

*For the long-term performance of **Cableway trestle Nr. 6 (Line 5–6)**, total settlements of authentic shallow foundation reach significant class (approximately 10 cm) by 2070 (Figure 73). For restoration, one may assume to introduce new piles embedded 10 m into permafrost in 2026. The effective pile length gradually diminishes over time as the active layer thickness increases (Figure 74). Creep settlement of pile foundations remain relatively small for these new piles, reflecting the improved load transfer to deeper, colder layers. Consequently, total predicted settlement through 2070 remains noticeably lower than that of the shallow foundation, making pile retrofitting an attractive mitigation strategy if field investigations confirm suitable conditions for pile foundations.*

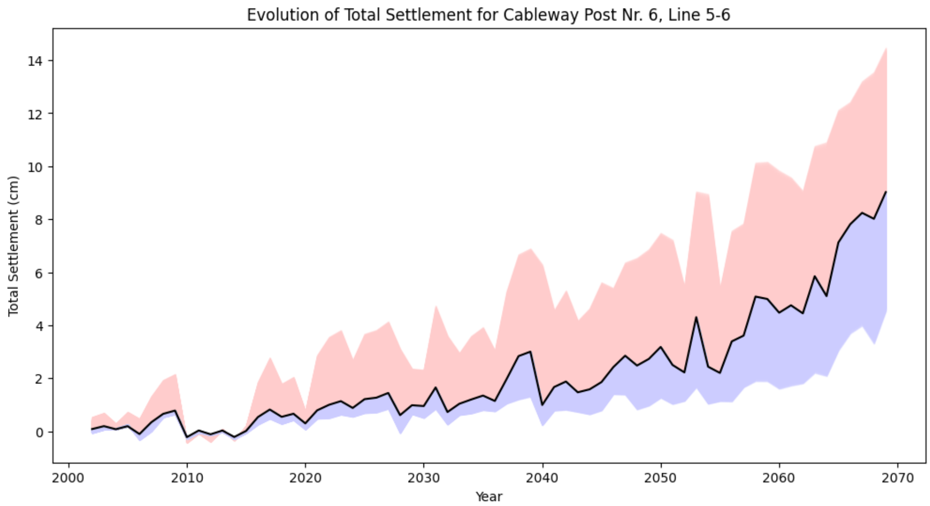

Figure 73. Evolution of total settlement (creep and thaw) for Cableway trestle Nr. 6, Line 5-6 from 2000 to 2070. Figure: [22]. Pink and blue areas present upper and lower bound variations in total settlements.

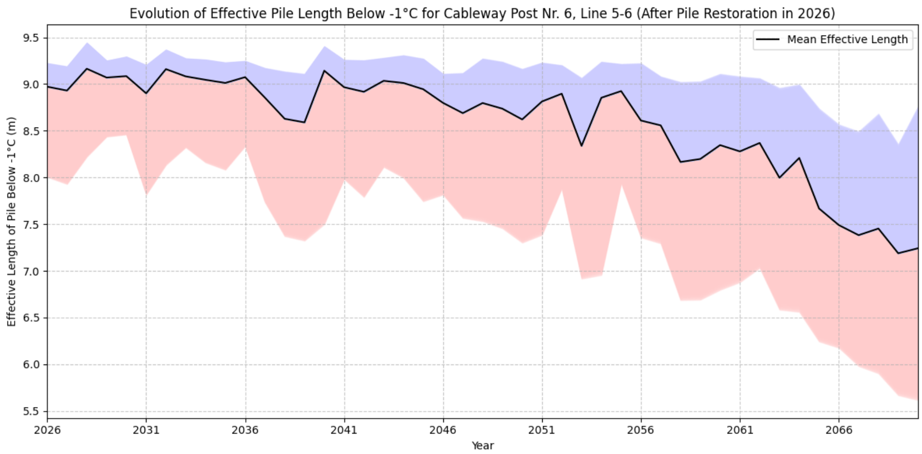

Figure 74. Evolution of effective pile length for Cableway trestle Nr. 6, Line 5-6 after assumed pile restoration in 2026. Figure: [22]. Pink and blue areas present upper and lower bound variations in effective length of piles.

Similar analyses were conducted for ***Cableway trestles Nr. 32 (Line 3)*** *and* ***Nr. 34 (Line 5–6)****. The summation of creep and thaw deformation is shown in Figure 75, suggesting that total settlement by 2070 could surpass practical serviceability limits for sensitive heritage structures. If these cableway trestles are restored using pile foundations in 2026 – mirroring the approach for Cableway trestle Nr. 6 (Line 5-6) – predicted settlements remain considerably lower (*Figure 76*). In these scenarios, deeper permafrost layers sustain the foundation loads more reliably, resulting in moderate creep rates and improved long-term stability.*

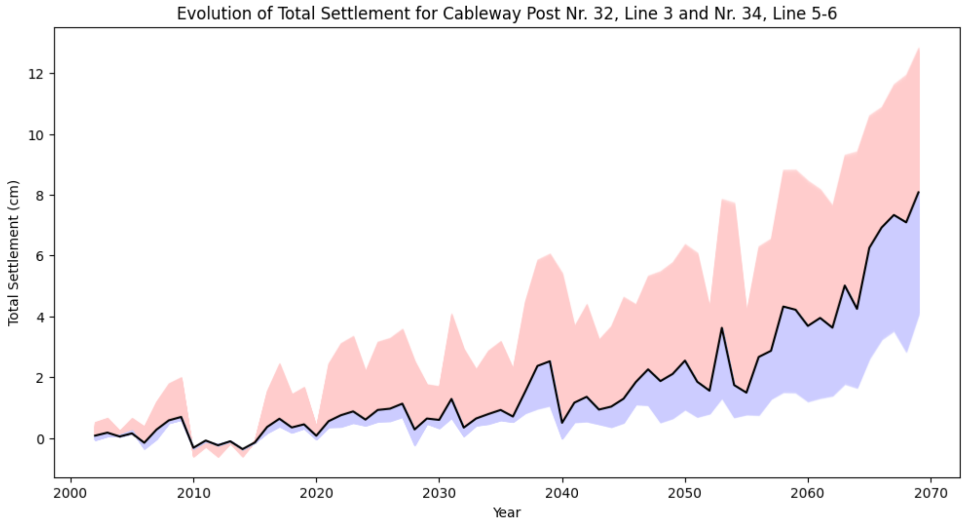

Figure 75. Evolution of total settlement (creep and thaw) for Cableway trestle Nr. 32, Line 3 and Nr. 34, Line 5-6. Figure: [22]. Blue and pick areas present upper and lower bound variations in total settlements.

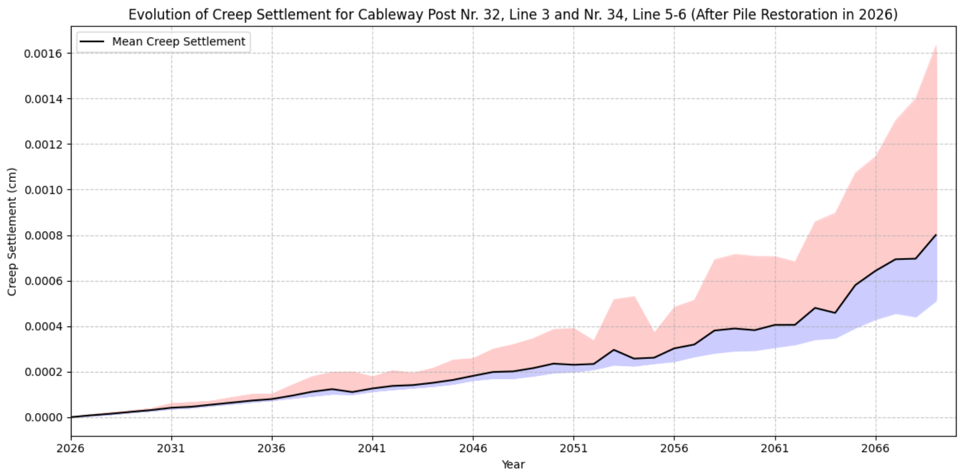

Figure 76. Evolution of creep settlements for Cableway trestle Nr. 32, Line 3 and Nr. 34, Line 5-6 after assumed pile restoration in 2026. Figure: [22]. Pink and blue areas present upper and lower bound variations in creep settlements.

The old coal cableway centre in Longyearbyen *is presumed to involve a combination of shallow and deeper support elements, and* ***the Titan crane is presumed*** *to have surface support elements. While detailed numerical settlement results were not obtained, the same warming trends as indicated by the thaw settlements presented in Figure 71 will influence both structures.* Progressive deepening of active layer (Figure 71) *may augment potential differential settlement, and any deeper foundation elements may experience higher creep rates if subjected to sustained loads considering the gradual warming of permafrost as predicted in Figure 69. For both the Cable car center and the Titan crane, routine ground-temperature measurements and active-layer monitoring are recommended to detect evolving permafrost conditions. Thermistor strings were installed by both structures in 2024. These installations provide measurements of permafrost* *temperatures to 5 m depth at the Cable car center, and down to 7 m depth at Titan crane. It is expected to have a full year of measurement in September 2025.*

It is important to note that proper drainage regime needs to be assured by objects in question to prevent increased permafrost degradation. This can be more challenging for cableway trestles located in boggy and flat terrain, while it is easier to establish drainage for the once located on more sloping terrain. Further, field observations show () extensive permafrost degradation specifically by singular cableway trestles. We assume that such extensive permafrost degradation is caused by snow that is entrapped by the structures. Much more lush vegetation, compared to surrounding tundra, was observed by timber trestles where extensive degradation was happening. Such lush vegetation also points out on warmer microclimate by the structures.

As the result of such degradation, excessive settlements () and/or failures of structural elements were observed (). To avoid further permafrost degradation, depressions around structural elements of cableway trestles need to be filled up with soil, ideally provide drainage of water away from the structures. A better option is to place structures on new foundation, for example by using technological solutions, such as piles ().

When it comes to the larger structures, drainage arrangements (culverts) do exist at some parts of the Cable car center, drainage arrangement can be recommended for Titan crane where a large puddle was observed (). Arrangement of drainage may also be useful at … where ponding of water was observed after heavy rain events (), yet one may assume that permafrost conditions at … are characterized by low ground ice content and high salinities, which limit possible thaw settlements due to permafrost degradation.

4.3.2 Stability of case study objects in Ny-Ålesund

In a similar way as for the evaluations for Longyearbyen, we start the settlement evaluations in Ny-Ålesund with estimation of the thaw settlements. The thaw settlements, unlike for Longyearbyen, are based on analytical calculations. Obtained active layer thicknesses are used as a basis for the thaw settlement calculations. The resulting thaw settlement predictions are shown in Figure 77. The predictions show that the thaw settlements could reach more than 5 cm by 2070. These results are then used as a basis to evaluate the total expected settlements of foundations in Ny-Ålesund.

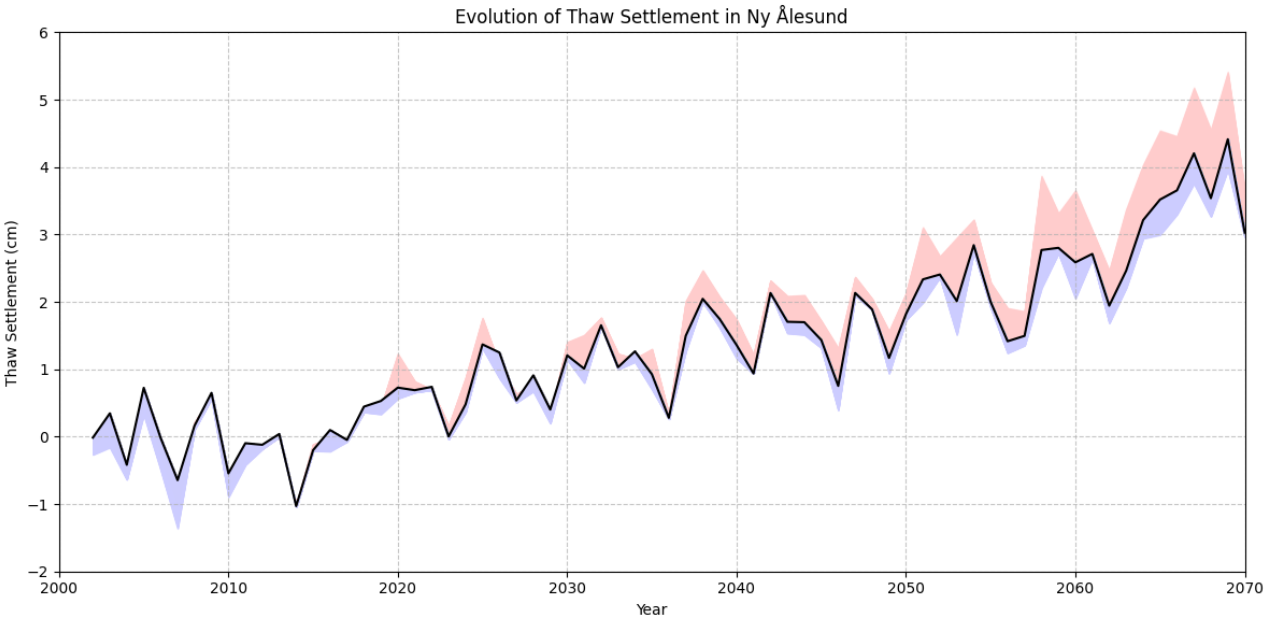

Figure 77: Predicted thaw settlements in Ny-Ålesund. Figure: [22]. Pink and blue areas present upper and lower bound variations in thaw settlements.

Green Harbour House *rests on a series of surface foundations (logs supporting a simple frame). By 2070, total settlement (Figure 78) begins to approach levels that, especially if uneven, might compromise the structure's alignment or functionality. Although these absolute class remain moderate, heritage structures in permafrost often have little tolerance for differential movement. Therefore, even a few centimeters of settlement can become problematic over time.*

Shallow rock lying at approximately 3 m depth was discovered at Green Harbour House during PCCH-Arctic field work in Ny-Ålesund in spring 2024 ([27]). This suggests considering using pile foundations when restoring Green Harbour House. At the same time, as the load from the house is small and the object itself is quite compact, it may be advised to keep the authentic foundation solution with introduction of minor modifications such as slightly deeper planks of the foundation "grill" (see Figure 67). The grill plate may also be made sufficiently rigid to allow its levelling by inserting new timber elements/stones underneath when deemed.

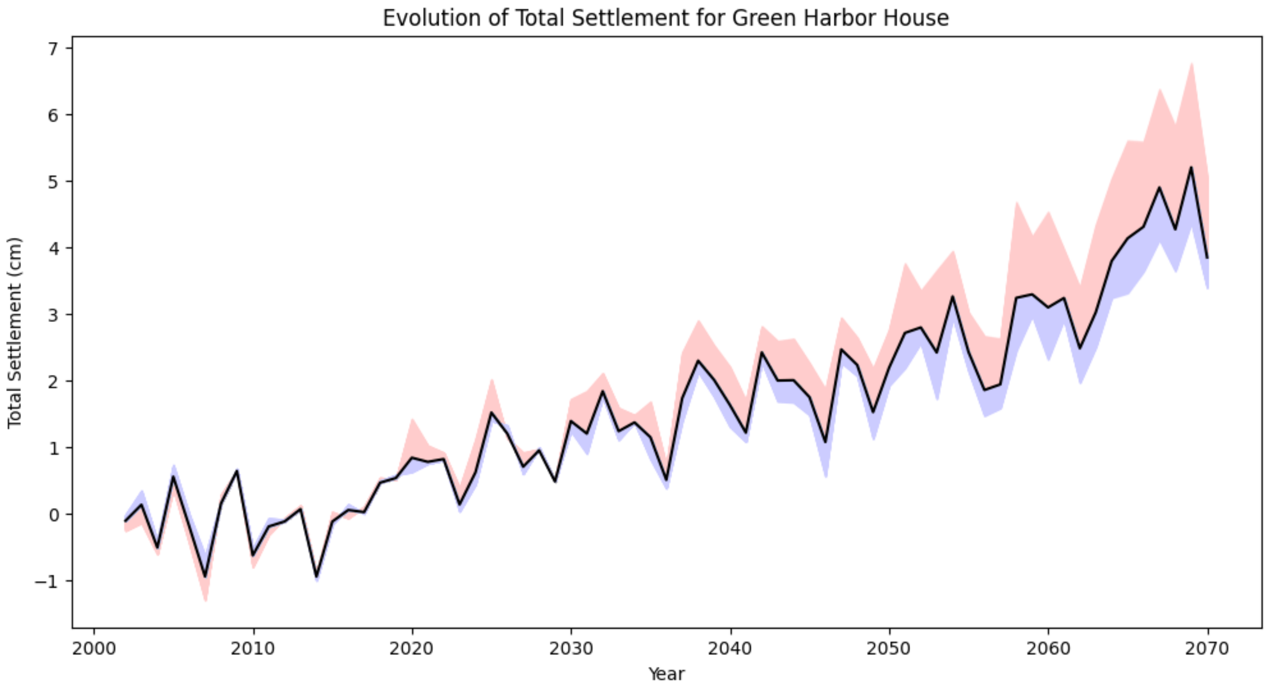

Figure 78: Evolution of total settlement for Green Harbour House. Figure: [22]. Pink and blue areas present upper and lower bound variations in total settlements.

Luftskipsmasta *is supported by shallow foundations and bears an estimated total weight of approximately 14 tons. Although specific creep settlement calculations are not shown here, the thaw settlement projections in Figure 77 apply similarly to this structure, and the added creep component could further elevate total long-term deformation. These predictions correlate with settlements of terrain at Luftskipsmasta that were observed in 2022 (*Figure 79*). Given the historical and symbolic significance of Luftskipsmasta, installing temperature/settlement monitoring instrumentation – such as ground-embedded thermistors and surveying markers – could provide early warnings of foundation distress.* In 2024 it became known that pile foundations installed in bedrock will be utilized when restoring Luftskipsmasta in 2025; the mast was successfully restored in 2025.

Figure 79. Terrain settlements (about 30-40 cm) around Luftskipsmasta (picture: 2022).

4.3.3 Additional remarks

It is important to establish proper drainage conditions to avoid increased permafrost degradation around the objects of cultural heritage. This is especially relevant to the buildings in Ny-Ålesund (Figure 80–Figure 82) and for the Titan crane (Figure 83), in both cases ponding of surface water was observed.

Figure 80. Flooding by the White House in Ny-Ålesund (April 2024), picture: ©Aga, J.

Figure 81. Flooding by Post office in Ny-Ålesund (April 2024), picture: ©Aga, J.

Figure 82. Flooding by Amundsen villa in Ny-Ålesund (April 2024), picture: ©Aga, J.

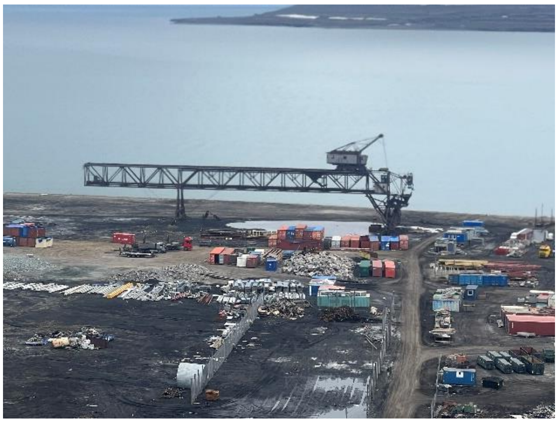

Figure 83. Flooding by the Titan crane (June 2023), picture: © SINTEF/Sinitsyn, A.O.

Simulations of permafrost response to snow conditions [28] point out on the need of avoiding snow storage (after ploughing) by the buildings in Ny-Ålesund. Another recommendation is related to the structure of timber “skirts” around historical buildings in Ny-Ålesund. One can see example of buildings with such shorts on Figure 84–Figure 85. We recommend that such “skirts” should be permeable for air flow. This will facilitate removal of heat from the ground during winter, hence contributing to preservation of permafrost. Such advice may be less relevant when buildings are resting on piles embedded in bedrock. Still, recommendations are relevant should unlithified permafrost be present above the bedrock surface. Degradation of unlithified permafrost may lead to ground depressions (magnitude of depressions will depend on ground ice content) beneath the buildings. Surface water may accumulate in such depressions, which in turn may further intensify degradation of permafrost.

Figure 84. "Skirt" by Museum (*Museum*) cabin in Ny-Ålesund (2021), picture: © SINTEF/Sinitsyn, A.O.

Figure 85. "Skirt" by Hospital (*Sykehuset/Skutergarasjen*) in Ny-Ålesund (2021), picture: © SINTEF/Sinitsyn, A.O.

In some cases (such as presented in Figure 86–Figure 87) when there is the gap between "skirt" and the ground surface installation a systems with mechanical circulation of cold air can be considered. Also, such systems may require additional openings in the "skirt". Such systems may also be considered for situations when openings already exist in the construction of a "skirt" (see examples on Figure 88–Figure 89). Such system also especially relevant to the buildings that are in use, i.e. where heat loss from the building into permafrost underneath occur.

Figure 86. Sysselbu house in Ny-Ålesund.

Figure 87. Mexico barack in Ny-Ålesund.

Figure 88. Telegrafen, Ny-Ålesund.

Figure 89. Opening is the "skirt" of Telegrafen, Ny-Ålesund. Such opening should be kept open during winter and closed during summer.

4.3.4 Special case – the Old cableway station in Hiorthhamn: evaluation of risk and suggestion of solutions for protection

4.3.4.1 Introduction

Hiorthhamn settlement is automatically protected, and it is a unique object that has a high conservation class as it is almost a complete mining facility from the beginning of 20th century, [29]. Flyen and Boro [29] point out that the risk imposed by the coastal erosion to the Old cableway station and some other objects in Hiorthhamn is extremely high for the year 2020, and this risk is unacceptable. It was recommended to apply temporal measures to mitigate the coastal erosion and to develop in the meanwhile a permanent solution.

Figure 90. The Old cableway station (Taubanestasjonen) in Hiorthhamn protected by temporal solution against coastal erosion (picture: 2024).

4.3.4.2 Coastal erosion in the area

The natural hazard of coastal erosion is normally characterized by the rates of coastal erosion, expressed in m/yr, where negative class indicate erosion. Nicu, Stalsberg *et al.* [30] investigated the position of 1.3 km of the Hiorthhamn shoreline and reported average erosion rates of -0.21 m/yr for the 92-year period and pointed out the needs in continued monitoring and sustainable management of cultural heritage at the site. The authors classify these rates as "very high". It is important to note that only two shoreline positions were analysed by the study, i.e. from 1927 and 2019. The latter leaves room to hypothesize that erosion rates in the last decades may be even higher than the reported long-term class. Such a situation may be possible due to longer periods of wave activity and possibly stronger wave climate in the last decades, yet such assumptions shall be clarified by a hydro-meteorological analysis. Indeed, the measurements performed in 2022, revealed even higher erosion rates in the period from 2011 to 2022 – -2.15 m/yr [31] (Figure 91). Also, accretion (accumulation) area was found in approximately 300 m towards north-west from the station (Figure 91). Distance from the cable to the crest of coastal bluff was 2 m as for 2020, [29].

Figure 91. Shoreline evolution from 2011 to 2022. Aerial picture: © TopoSvalbard, Figure: [31].

4.3.5 Managing coastal erosion at Hiorthhamn

One may suggest applying ISO risk assessment framework to coastal zone management for accommodating the uncertainties of climate change impacts, uncertainties due to limited data availability, the impacts with uncertain time frames, [32]. Such an approach provides for an objective decision-making process. Moreover, Rollason *et al.* [32] advocate "trigger-based" management responses (in contradiction to the "time-based" responses) for a better handling of uncertainties associated with the climate change impacts.

Following the methodology of [32] and using available data ([29, 30]), one may suggest the approaches for managing the situation at Hiorthhamn. To arrive to specific suggestions, one should perform screening of the key elements according to the methodology [32], such key elements are written in **bolt** below, and screening is performed under each of the elements.

Establishing the context:

- Shoreline at Hiorthhamn, at first approximation the study area of 1.3 km long ([30]).
- Geomorphological description – see Nicu *et al.* [30], and [33]. In particular, beach system in Sector 1 and Sector 2, and coastal bluff in Sector 3.
- Geomorphological units (the units are according to [34]): shore and shoreface (incl. coastal bluff when present), the nearshore (description of the nearshore is not presented herein).

- Nicu et al. [30] and Flyen and Boro [29] claim that the dominant coastal process in the area, i.e. coastal erosion is caused by storm waves, long-shore sediment transport, tidal currents. In addition, one may hypothesize that the area is represented (at least partly) by a cohesive shore, that may in turn be one of the reasons for permanent erosion at the site. A very narrow beach indicates that the shore in question may be cohesive. Investigations in the nearshore by Hiorthhamn point out on cohesive coastal type [31].

Objectives for Coastal Zone Management – safeguarding of the Old coal cableway station in Hiorthhamn.

Performance indicators – erosion rate of the shoreline (shore and shoreface zone), coastal erosion on the nearshore zone.

Risk identification – the Old coal cableway station in Hiorthhamn **is at risk** due to **beach erosion** (the principal source of risk) caused by waves, deficit in long-shore sediment transport, and tides. The object is characterized by the highest class of cultural and historical significance, [29]. For **time frame** – one should select **immediate** as for the year of 2021 (when the present assessment was initiated). The risk will be higher for a more distant time frame, for instance for 2050.

Risk analysis – the likelihood of the risk is "**almost certain**" (high possibility that the event will occur as the erosion rates are measured from historical data), and the consequences associated with coastal erosion at Hiorthhamn are **"catastrophic"** (irreversible loss of an area with the objects of highest conservation class), the risk at present time is "**extreme"** (intolerable). **"Extreme" risk** requires treatment as priority. This is an "unmitigated" risk as existing control measures are absent on the site.

Risk Evaluation – *tolerable* levels of risk *would be* from **"low" to "negligible"**, only temporal **control and mitigation measures** (revetment from crashed rock) **are present at the site**.

Risk Treatment Options – Baseline approaches:

- "Retreat" (cannot be acceptable)
- "Accommodate" (cannot be acceptable)
- "Protect" – could acceptable, two approaches may be suggested:
  - Temporary shoreline protection solution
  - Permanent shore protection solution

Temporary shoreline protection solution was suggested by Flyen and Boro [29]. Rock revetment constructed sometime between presumably 2021 and 2023 does not seem to be provide sufficient protection as it can be undermined by the waves with subsequent collapse.

A potential solution shall comply with cultural and historical contexts; it also may comply with the principles of sustainability. In this regard several solutions may be suggested; the solutions are:

- Temporal protection with geotextile bags that are filled with local soil (Figure 92**), colou**r of geotextile bags should modest to avoid dissonance with natural colour of the beach and the station building.
- Temporal protection (geotextile bags) combined with permanent solution, i.e. submerged breakwater (Figure 93).
- As system of submerged breakwaters. Such structures would be aimed at mitigation of wave action and creation of sheltered location. Submerged breakwaters would be preferrable from the historical perspective as they will not be visible (this outline is similar to the one in Figure 93).

- Groin (Figure 94). Goin may help capturing sediments (if there is enough of sediments) coming from the area above the station (i.e. the area where profiles a. and b. are located, see Figure 91), hence some accumulation of the material in front of the station may be achieved.
- Artificial beach, fed by soil from alluvial fan of the Telegrafdalen (Figure 95). This might even enable longshore transport to the station. This solution is based on the already mentioned observations of Antonello [31] that a spit (accumulative landform locate in few hundred meters to the west) is drifting towards the station with estimated speed of approximately 5 m per year. By creating artificial beach, one will introduce the landform that may appear in this location in some 50 years in the future. Such approach can be then classified as truly nature-based. It will also restore the original outline of the coastline, that will compline with antiquarian class. Groin may be a part of such solution.

In addition, one may foresee establishment of protection from debris flow that may hypothetically come from Telegrafdalen (Figure 97).

Another solution that at some point was under consideration is relocation of the Old cableway station on some several tens of meters inland. This solution has several challenges, from the historical perspective – function of the stion, i.e. connection to the sea will be lost. Also, area behind the station seems to be a boggy area that is sometime affected by surface flooding after rain events (Figure 97), these conditions may pose some technical challenges.

Some other technical options such as revetments, bulkheads, breakwaters seem to be less favourable from the cultural and historical points of view.

Figure 92. Example of revetment form geotextile bags (Svea, Svalbard).

Figure 93. Temporal protection (geotextile bags) combined with submerged breakwater.

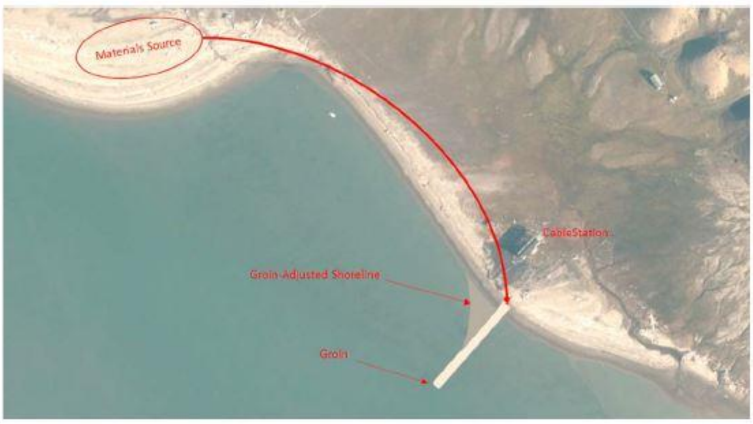

Figure 94. Groin for Hiorthhamn, Photo: © TopoSvalbard, figure: from [31].

Figure 95. Principal scheme for artificial beach. Photo: © TopoSvalbard.

Figure 96. Terrestrial flooding after severe rain event, early September 2023.

Figure 97. Debree flow that may hypothetically come from Telegrafdalen. Photo: © TopoSvalbard.

The costs of the measures – defining the cost estimates is outside of the scope of this Report.

Benefits of the measures – some of the benefits of suggested solutions are discussed in the above.

Trigger levels to implement the measures – trigger levels are already archived as crest of coastal bluff is in 2 m meters from the cultural heritage in question, [29].

One may suggest the following **necessary further steps:**

- Initiation of monitoring program (changes in nearshore bathymetry, morphology of coastal zone), hydrometeorological monitoring.
- Clarification of the coastal type, and corresponding coastal processes on the site.
- Better assessment of coastal dynamics at the site (erosion rates)
- Hydrometeorological (wave, climate, ice and other data) and lithodynamic (sediment transport) site characterization
- Investigations of stability of the nearshore profile: geotechnical and lithodynamic.
- Investigations of permafrost temperatures at the site.
- Design of permanent protective solutions based on advanced numerical tools.
- Assessment of impacts of global warming on wave climate and relative sea level rise.

5 Monitoring and side conditions

Assessment of conditions for structures of the cableway transport system in resented in [6], this assessment was performed in 2021. Along with conditions of structures, this table presents observations of the impacts and/or manifestation of different natural hazards close to the objects. One may suggest repeating such assessment each 5 years or so.

In Longyearbyen, permafrost temperatures are monitored at Titan crane, trestle Nr. 32 on the Line 5-6. In addition, monitoring is performed at the Old coal cableway centre and trestle Nr 6 on the Line 5-6 by the PermaRich project [35]. It is planned to measure permafrost temperatures by Luftskipsmasta and Green Harbour House in summer-autumn 2025. It can be recommended to continue monitoring of permafrost temperatures by these objects.

PCCH-Arctic had undertaken a trial to monitor vertical elevations of foundations of cableway trestles with DGPS. This experience did not provide expected results due to the challenges with resolution of data. It can still be recommended to pursue monitoring of vertical elevations, perhaps with the use of photogrammetry/drones.

Timber conditions at cableway trestles that served as case study objects in PCCH-Arctic project were surveyed by the ArcticAlpine*Decay* project [36], which enables more complete analysis of this objects.

6 Climate data for restoration and rehabilitation activities

Atmospheric warming is the largest factor that leads to degradation of permafrost. Despite the importance of local conditions (snow cover, drainage, ventilation of crawl space under the buildings), evaluations of permafrost degradation should be based on climate projections. In PCCH-Artic, climate projections were produced for the worst-case climate scenario SSP5-8.5. The outcome data sets have spatial resolution of 2.5 km. The data set was organized in a format that is usable for engineering purposes. The data set [26] is available for Longyearbyen and Ny-Ålesund.

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Appendix 1. Results of PCCH-Arctic assessment for the system of cableway trestles in Longyearbyen.

Table 13. Results of PCCH-Arctic assessment for the system of cableway trestles in Longyearbyen.

Object ID in Aksenladen	Name of object	Degree of condition (tilstandgrad; TG) according to the evaluation in 01.01.2013, The Directorate for Cultural Heritage (2019).	Interpretation of condition class (CC or TG) from Riksantikvaren (2019) based on NS-EN 16096-2012. Data as for 01.01.2013.	Condition class (CC) according to PCCH-Arctic (2021). Asterisk "*" denotes the cases when TG was taken as it was in 2013 (Riksantikvaren (2019)). In general, this was done when the objects or their foundations had minor visual symptoms corresponding to CC 1, but the actual condition of timber (should it been surveyed) might have changed the scoring.	Urgency class (UC) in 2021, evaluation of PCCH-Arctic	Recommendation class (RC) in 2021, evaluation of PCCH-Arctic
Taubanelinje 3 (158619)						
158619-1	Bukk nr 1	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-2	Bukk nr 2	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-3	Bukk nr 3	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-4	Bukk nr 4	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-5	Bukk nr 5	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-6	Bukk nr 6	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-7	Bukk nr 7	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation

158619-8	Bukk nr 8	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-9	Bukk nr 9	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-10	Bukk nr 10	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-11	Bukk nr 11	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation.
158619-12	Bukk nr 12	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-13	Bukk nr 13	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-42	Strammestasjon (Linje 3)	–	–	–	–	–
158619-14	Bukk nr 14	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-15	Bukk nr 15	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158619-16	Bukk nr 16	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-17	Bukk nr 17	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-18	Bukk nr 18	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-19	Bukk nr 19	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
158619-20	Bukk nr 20	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158619-21	Bukk nr 21	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Maintenance/Preventive conservation
158619-22	Bukk nr 22	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Maintenance/Preventive conservation
158619-23	Bukk nr 23	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-24	Bukk nr 24	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation

158619-25	Bukk nr 25	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-26	Bukk nr 26	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-27	Bukk nr 27	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-28	Bukk nr 28	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-29	Bukk nr 29	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-30	Bukk nr 30	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-31	Bukk nr 31	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis.
158619-32	Bukk nr 32	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-33	Bukk nr 33	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158619-34	Bukk nr 34	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-35	Bukk nr 35	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-36	Bukk nr 36	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158619-37	Bukk nr 37	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-38	Bukk nr 38	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
158619-39	Bukk nr 39	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158619-40	Bukk nr 40	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158619-41	Bukk nr 41	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
Taubanelinje 2b (158986)						
158986-19	Vinkelstasjon (Linje 2b)	–	–	–	–	–

158986-18	Bukk nr 18	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis.
158986-17	Bukk nr 17	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis.
158986-16	Bukk nr 16	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158986-15	Bukk nr 15	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158986-14	Bukk nr 14	TG 4 (Lost/Removed)	CC 3 (Lost/Removed), probably due to the river flood)	CC 3 (Lost/Removed), probably due to the river flood)	–	–
158986-13	Bukk nr 13	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 3 – Major intervention based on diagnosis.
158986-12	Bukk nr 12	TG 4 - Lost/Removed	CC 3 (Lost Removed)	CC 3 (Lost Removed)	–	–
158986-11	Bukk nr 11	TG 3 - Significant need for restoration	CC 3 – Major symptoms*	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158986-10	Bukk nr 10	TG 4 - Lost/Removed	CC 3 (Lost/Removed), removed due to urbanization)	CC 3 (Lost/Removed), removed due to urbanization)	–	–
158986-9	Bukk nr 9	TG 4 - Lost/Removed	CC 3 (Lost/Removed), removed due to urbanization)	CC 3 (Lost/Removed), removed due to urbanization)	–	–
158986-8	Bukk nr 8	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 0 – No symptoms	UC 0	RC 0
158986-7	Bukk nr 7	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 0 – No symptoms (assumed to be restored)	UC 0	RC 0
158986-6	Bukk nr 6	Not evaluated in Riksantikvaren (2019)	Not evaluated in Riksantikvaren (2019). Assumed to be CC 3	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis.
158986-5	Bukk nr 5	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis.
158986-4	Bukk nr 4	TG 4 - Lost/Removed	CC 3 (Lost/Removed), destroyed by snow avalanch	CC 3 (Lost/Removed, destroyed by snow avalanch)	–	–
158986-3	Bukk nr 3	TG 3 - Significant need for restoration	TG 3 - Significant need for restoration	CC 3 (Lost/Removed), destroyed by snow avalanch)	–	–

158986-2	Bukk nr 2	TG 4 - Lost/Removed	CC 3 (Lost/Removed), destroyed by snow avalanch	CC 3 (Lost/Removed), destroyed by snow avalanch	–	–
158986-1	Bukk nr 1	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate, assumption.	RC 3 – Major intervention based on diagnosis, assumption.
Taubanelinje 1b (158657)						
158657-24	Bukk nr 24	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-23	Bukk nr 23	TG 1 - Ordinary need for restoration	CC 0 – No symptoms	CC 0 – No symptoms	UC 0 – Long term	RC 0 – No measures
158657-22	Bukk nr 22	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	UC 0 – Long term	RC 0 – No measures
158657-21	Bukk nr 21	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 0 – Long term	RC 0 – No measures
158657-20	Bukk nr 20	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 0 – Long term	RC 0 – No measures
158657-19	Bukk nr 19	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 0 – Long term	RC 0 – No measures
158657-18	Bukk nr 18	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-17	Bukk nr 17	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 (Lost/Removed)	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-16	Bukk nr 16	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-15	Bukk nr 15	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-14	Bukk nr 14	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
158657-13	Bukk nr 13	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	–	–
158657-25	Strammestasjon - Taubanelinje 1b	–	–	–	–	–
158657-12	Bukk nr 12	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
158657-11	Bukk nr 11	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis

158657-10	Bukk nr 10	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
158657-9	Bukk nr 9	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 (Lost/Removed)	–	–
158657-8	Bukk nr 8	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-7	Bukk nr 7	TG 3 - Significant need for restoration	CC 3– Major symptoms	CC 3 (Lost/Removed)	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-6	Bukk nr 6	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
158657-5	Bukk nr 5	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
158657-4	Bukk nr 4	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
158657-3	Bukk nr 3	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
158657-2	Bukk nr 2	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
158657-1	Bukk nr 1	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
Taubanelinje G5-6 (87889)						
87889-11	Bukk nr 3	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-12	Bukk nr 4	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 0 – No symptoms	UC 0 – Long term	RC 0 – No measures
87889-13	Bukk nr 5	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 0 – No symptoms	UC 0 – Long term	RC 0 – No measures
87889-14	Bukk nr 6	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 0 – No symptoms	UC 0 – Long term	RC 0 – No measures
87889-15	Bukk nr 7	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 0 – No symptoms	UC 0 – Long term	RC 0 – No measures
87889-16	Bukk nr 8	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 0 – No symptoms, assumed to be restored	UC 0 – Long term	RC 0 – No measures
87889-17	Bukk nr 9	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation

87889-18	Bukk nr 10	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-19	Bukk nr 11	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-20	Bukk nr 12	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-21	Bukk nr 13	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-2	Strammestasjonen ved vanntårnet (Taubane delstrekning gruve 5 og 6)	–	–	–	–	–
87889-22	Bukk nr 15b	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-23	Bukk nr 15	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-24	Bukk nr 16	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-25	Bukk nr 17	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-26	Bukk nr 18	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-27	Bukk nr 19	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-28	Bukk nr 20	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-29	Bukk nr 21	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-30	Bukk nr 22	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-31	Bukk nr 23	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-32	Bukk nr 24	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-33	Bukk nr 25	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis

87889-34	Bukk nr 26	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-35	Bukk nr 27	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-36	Bukk nr 28c	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-37	Bukk nr 28b	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-10	Strammestasjonen sør for Isdammen (Taubane delstrekning gruve 5 og 6)	–	–	–	–	–
87889-38	Bukk nr 29	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-39	Bukk nr 30	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-40	Bukk nr 31	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-41	Bukk nr 32	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-42	Bukk nr 33	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-43	Bukk nr 34	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-44	Bukk nr 35	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-45	Bukk nr 36	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-46	Bukk nr 37	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-47	Bukk nr 38	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-48	Bukk nr 39	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-49	Bukk nr 40	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis

87889-50	Bukk nr 41	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-51	Bukk nr 42	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-52	Bukk nr 43	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-53	Bukk nr 44	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-54	Bukk nr 45	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-55	Bukk nr 46	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
Taubanelinje G5 (87889)						
87889-56	Bukk nr 23	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-57	Bukk nr 22	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-58	Bukk nr 21 (49)	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-59	Bukk nr 20	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-60	Bukk nr 19	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 -Major symptoms (Lost/Removed)		
87889-61	Bukk nr 18 (50)	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	–	–
87889-62	Bukk nr 17	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-63	Bukk nr 16	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 -Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-64	Bukk nr 15	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 -Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-65	Bukk nr 14	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 -Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-66	Bukk nr 13	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 0 – No symptoms, restored in 2022	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis

87889-67	Bukk nr 12	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC 0 – Long term	RC 0 – No measures
87889-68	Bukk nr 13	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-69	Bukk nr 10	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-70	Bukk nr 9	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-71	Bukk nr 8	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-72	Bukk nr 7	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-73	Strammestasjon - Taubane delstrekning gruve 5	–	–	–	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-74	Bukk nr 5	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-75	Bukk nr 4	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-76	Bukk nr 3	TG 4 - Lost/Removed	CC 3 (Lost/Removed)	CC 3 (Lost/Removed)	–	–
87889-77	Bukk nr 2	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	–	–
87889-78	Bukk nr 1	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
Taubanelinje G6 (87889)						
87889-79	Bukk 40	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-80	Bukk 39	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-81	Bukk 38	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-82	Bukk 37	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-83	Bukk 36	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-84	Bukk 35	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation

87889-85	Bukk 34	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-86	Bukk 33	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 1 – Minor symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-87	Bukk 32	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-88	Bukk 31	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-89	Bukk 30	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-90	Bukk 29	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-91	Bukk 28	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-92	Bukk 27	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-93	Bukk 26	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-94	Bukk 25	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-95	Bukk 24	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-96	Bukk 23	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-97	Bukk 22	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-98	Bukk 21	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-99	Bukk 20	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-100	Bukk 19	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-11	Strammestasjonen ved Todalen (Linje 6)	–	–	–	–	–
87889-101	Bukk 17	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis

87889-102	Bukk 16	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-103	Bukk 15	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-104	Bukk 14	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-105	Bukk 13	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-106	Bukk 12b	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-107	Bukk 12	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-108	Bukk 11	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-109	Bukk 10	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 3 – Major symptoms	UC 3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-110	Bukk 9	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-111	Bukk 8	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 3 – Urgent and immidiate	RC 3 – Major intervention based on diagnosis
87889-112	Bukk 7	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 3 – Major symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-113	Bukk 6	TG 1 - Ordinary need for restoration	CC 1 – Minor symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-114	Bukk 5	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-115	Bukk 4	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-116	Bukk 3	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation
87889-117	Bukk 2	TG 3 - Significant need for restoration	CC 3 – Major symptoms	CC 3 – Major symptoms*	UC 2 – Short term	RC 3 – Major intervention based on diagnosis
87889-118	Bukk 1	TG 2 - Moderate need for restoration	CC 2 – Moderately strong symptoms	CC 2 – Moderately strong symptoms	UC 2 – Short term	RC 2 – Moderate repair under and/or further investigation