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Construction in Mountainous Regions

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1.0 Executive Summary

1.1 Introduction

This paper has been compiled with the assistance of a diverse group of personnel with a broad range of experience of Construction projects in Mountainous regions from an Insurance perspective. The group has endeavored from the outset to keep this working paper focused on the key types of projects associated with working in the mountainous regions.

We have sought to look at types of projects located globally in some of the most challenging locations with respect to technical and natural catastrophes and not just the stereotypical snow topped, glacier rugged mountainous terrain type schemes.

Picture 1- **The Jungfrau Railway, Switzerland**. (Source: Rocky road to the project of the century).

1.2 Construction in Mountainous regions.

One of the most debated aspects for the working group was which projects should be considered for this paper and detailing the associated exposures. We hope the reader finds the following sections a useful reference point for Construction and Engineering Underwriters, who may be assessing such risks, whilst giving consideration to the potential consequences and risk exposures during construction of these types of projects. Generally the types of projects we researched are typically the small to mid - size in value in terms of cost and generally less than 250 million USD in value. There are some projects that are up to a few billion US Dollars in value but these are not the norm.

The effect of technology and the desire of mankind mean that these projects in mountainous regions are certainly more challenging and should not be underestimated from a risk perspective, particularly with the effects of climate change and natural perils. Projects in mountainous regions often require specialist mechanical equipment systems, complex construction plant and often innovative temporary works to facilitate the construction of the permanent works.

This paper aims to summarize the exposures and examples of typical projects that Underwriters could be presented with. However, it is not always possible to cover all aspects of these projects in detail.

2.0 Definition of Mountainous regions

Mountains are very diverse landforms and from research it appears that there is inconsistency in the definition, description and analysis of them. The criteria used to define them includes elevation, volume or size, relative relief, steepness, ruggedness, spacing and continuity. A mountain could be considered as ‘any part of a land mass which projects conspicuously above its surroundings.’ Or another definition used is ‘a natural elevation of the earth surface rising more or less abruptly from the surrounding level and attaining an elevation which, relative to adjacent elevation. However this doesn’t aid in distinguishing a mountainous area.

The UNEP (United Nations Environmental Program) details that 24% of the Earths land mass is mountainous. It states that a landmass may be considered a mountain if it meets any of the following criteria:

- An elevation of 300 metres- if that elevation gain occurs within 7 kilometres;
- An elevation of 1,000 metres - with a slope of 5 degrees or more;
- An elevation of 1,500 metres with a slope of 2 degrees or more;
- An elevation of 2,500 metres.

Picture 2- **Mountains of the world** (Source: Wikipedia).

2.1 Types of Mountains:

Mountains were formed by slow but gigantic movements of the earth's crust. Sometimes the crust has folded and buckled, sometimes it breaks into huge blocks.

There are **five** basic types of mountains:

2.1.1 Fold Mountains (Folded Mountains): These are the most common type of mountain. The world’s largest mountain ranges are generally from this formation and this includes Himalayan Mountains in Asia, the Alps in Europe, Andes in South America, Rockies in North America and Urals in Russia.

2.1.2 Fault-block Mountains (Block Mountains): These Mountains form when faults or cracks in the earth's crust force some materials or blocks of rock up and others down. This includes the Sierra Nevada Mountains in NA and the Harz in Germany.

2.1.3 Dome Mountains: Dome Mountains are the result of a great amount of melted rock (magma) pushing its way up under the earth crust. Without actually erupting onto the surface, the magma pushes up overlaying rock layers.

2.1.4 Volcanic Mountains: Volcanic Mountains are formed when molten rock (magma) deep within the earth, erupts, and piles upon the surface.

2.1.5 Plateau Mountains: Plateau Mountains were formed by erosion, these large flat areas have been pushed above sea level by forces within the Earth. The mountains in New Zealand are examples of Plateau mountains

Mountains cover approximately a 1/5th of the earths land surface. This could include individual mountains or more commonly, a group of chain of mountain ranges.

Most geologically young mountain rages are associated with either the Pacific Ring of Fire or the Alpide Belt, as shown below in picture 4. Mountain ranges outside these two systems include the Arctic Cordillera, the Urals, the Appalachians, the Scandinavian Mountains, the Altai Mountains and the Hijaz Mountains.

Picture 3- Pacific Ring of Fire- is a major area in the basic of the Pacific Ocean where many earthquakes and volcanic eruptions occur. It is the most active seismic region in the world. (Source Wikipedia).

The Alpide Belt shown below is the next most seismically active region in the world. This includes the Himalayas along with the European ranges.

Picture 4- The Alpide Belt or the Alpide – Himalayan orogenic belt stretching from Atlantic Java in Sumatra. (Source: Wikipedia).

3.0 Construction projects in Mountainous regions

3.1 Which types of projects we will discuss

There are many types of construction projects that could be presented to Construction and Engineering Underwriters during their day to day roles on a global basis. Some of these projects are often encountered in urban areas, of which some of these project types have been detailed in previous IMIA working group papers.

Of the typical Infrastructure construction projects discussed ranging from roads, bridges, tunnels, sky bridges, recreational attractions in the tourist regions, railways, hydro schemes, dams, pipeline irrigation networks, utility and power systems, ski lifts, resorts. It was decided that the following projects are unique to mountainous regions on the following:-

- Ski Stations and Tourist attractions incorporating transport systems
- Railways
- Power and Mobile Transmission systems
- Avalanche protections schemes
- Retaining walls and slope protection
- Hydropower and Dam projects
- Utilities and Pipelines
- The use of specialist plant and equipment such as Helicopters

3.1.1 Ski stations and Tourist attractions incorporating transport systems

Picture 5- Zugspitze – One of the highest building sites in germany at 4767M above Sea level with a Sum insured of 50 million Euro and 22 Million Euro Delay in Start up cover with an Indemnity period of 18 Months. (Source: www.zugspitze.de).

3.1.2 Railways

Picture 6- The Stoosbahnen Railway project in Switzerland opened in 2017**.**

The project took 5 years to be built at a cost of 42 million CHF and is the steepest funicular with a gradient of 110% and raises to a height of 774 meters. (Source Modernnet.com)

3.1.3 Power and Mobile overhead Transmission systems

Picture 7- Installation of Power transmission courtesy of Heliswiss International
(Source www.heliswissinternational.com).

These types of projects are usually carried out in varied terrain with remote access. Please also refer to IMIA working paper Construction of Transmission and Distribution Lines WGP 069/10.

3.1.4 Avalanche protection structures

Picture 8- Structural avalanche protection of an operational substation for a 1 in 10 year event and also for Snow drift protection, Fijotdalur, Iceland
(Source: www.verkis.com).

Avalanche-dams either divert, delay or stop avalanches. Dams are cheaper than the abovementioned supporting structures, but they require a large area and they change the natural scenery.

Picture 9- Example of an avalanche dam (Source: www.fiegel-tiefbau.at).

3.1.5 Retaining Walls and slope protection.

Picture 10- Rock fill walls as the one above are easy to erect, they adapt easily to potential settlements of the soil without cracking, they allow water to seep through without dangerously accumulating at the back and they additionally allow the vegetation to grow covering them up. (Source www.maccaferri.com).

Picture 11- Jet grouting/ Micro piles to stabilize a slope
(Source: http://www.veicopal.it/product/micropali/)

3.1.6 Hydros and Dams

The Lintahl project in Switzerland was the largest construction proejct in Switzerland and involved the construction of a 1000 Mega Watt (MW) Hydro scheme. The Logistics and planning involved to deliver such a scheme were immense.

Picture 12- Linthal project – Switzerland (Source www.myswitzerland.com).

3.1.7 Pipelines/utilities

The Trans Anatolian Pipeline which is 1805 Kilometres long with a cost of 8.5Bn USD in value is being constructed to export Azerbaijani gas to Europe. At its highest location it is 2700 metres above sea level.

Picture 13- Tanap Pipeline Albania - 1.8 meter Diameter Gas Pipeline (Source: LinkedIn).

3.1.8 Specialist Plant and equipment such as Helicopters for Logistics

Picture 14- Example of a construction Tower crane assembly
(Source: www.heliswissinternational.com)

3.2 Projects that have been covered previously and will not form part of this paper.

The following topics have been covered thoroughly in other IMIA papers and refer readers to the following as required.

1. Access Roads in Project Insurance (IMIA – WGP 46 and 84)
2. Engineering Insurance Exposures related to the Construction of Roads (IMIA – WGP 46)

3. Tunneling and Tunnel Boring Machines (IMIA WGP 60)
4. Renewable Energy and General Power Plants (Various WGP''s)
5. CECR (Civil Engineering Completed Risks) IMIA WGP Paper 72 (11)
6. Roads and Bridges (IMIA WGP 48 (2006) and 55 (2008)

4.0. Exposure associated with Mountains.

High mountain environments are one the most complex and sensitive ecosystems on the Earth, climate change has influenced considerably the natural processes in high mountains over the world in recent times. 140 million people live at altitude above 2,500 Metres and in mountainous regions are facing potentially a harsher climate due to the natural changes and hazards of these environments mainly in Andes, Central Asia and Africa.

The majority of disasters are triggered by hydro-meteorological hazards, including drought, floods, extreme temperatures and rainfall-related landslides, debris-flows, lake outbursts; all of which are likely to increase under a changing climate.

- Large-scale hazards: earthquakes, droughts, eruptions and hurricanes
- Small-scale hazards: mass movements of water, snow, ice, soil and rock

Dangerous natural processes include avalanches, debris flows, floods, landslides, rock falls and other disastrous mass movements of soil and rocks. In mountainous regions these processes coud easily lead to harm to humans, destruction of property and ecological damage. As humans pursue safety, we seek to mitigate, to control or to remove and control them by systematic planning and intuitive measures.

4.1 Natural Catastrophes (Nat-Cat)

In mountainous regions we can have the following Nat-Cat exposures:

- Earthquake
- Droughts
- Volcanic eruptions
- Hurricanes/ Storms
- Ice and snow

4.2 Earthquakes

Earthquakes in mountainous areas can cause significant damage. They can severely devastate structures, triggering landslides and avalanches and change the topography of land entirely. Earthquakes cannot be predicted, only probabalized. Many mountain ranges around the world experience earthquakes (such as the Himalayas and the western edge of North and South America).

The size of a dangerous process is described by physical parameters such as intensity, magnitude, duration, energy, pressure, height, volume and impact. The danger increases with the frequency of the dangerous process during a given period. Earthquakes are rated on the Richter scale – (see Appendix A)

Every assessment of danger therefore requires investigation of the probability of occurrence and the frequency of the dangerous process. In terms of succession and duration of dangerous processes, events are commonly distinguished as continuous or episodic; these can be further divided into single or repeating and periodic or sporadic events:

• ***Continuous processes*** are geomorphologic processes in mountains, such as creeping of rock and loose material.
• **A *single process*** is generally a large event in a period of a millennium, such as a major flood or earthquake

Picture 15- Landslides triggered by earthquake (Source: https://phys.org/news/2015-11-earthquakes-role-future-landslides.html)

Picture 16- Earthquake – South Island, New Zealand.Huge Fault developed (Source: https://www.inverse.com/article/24156-new-zealand-earthquake-fault-line-drone-footage)

4.3 Droughts

Picture 17- Drought causing erosion and deforestation.
(Source: http://www.viewsnews.net/2017/03/22/record-heat-vanishing-ice-droughts-pushing-planet-uncharted-territory/).

Droughts are a lack of water leading to unusually low levels of precipitation, soil mositure, river or groundwater levels or water for use by the public and industry. Droughts occur in high as well as low rainfall areas. It is a condition relative to some long-term average condition of balance between rainfall and evapotranspiration in a particular area, a condition often perceived as Normal. Yet average rainfall does not provide an adequate statistical measure of rainfall characteristics in a given region especially in the drier areas. Drought is a creeping phenomenen making an accurate prediction of either its onset of end of is a difficult task. To most observers, it seems to start with the delay in the timing(or failure) of the rains. Problems and impacts of having droughts are lack of water, lack of precipitation, lack of soil moisture causing erosion.

4.4 Volcanic Eruptions

Worldwide, around 550 volcanoes are classed as being active. Every year, between 50 and 65 of them erupt. Volcanic eruptions can cause earthquakes, fast floods, mud slides, and rock falls. Lava can travel very far and burn, bury or damage anything in its path, including people, houses, and trees. The large amount of dust and ash can cause roofs to fall, makes it hard to breathe, and is normally very smelly. The ground around the volcano is not secure and can cause big earthquakes. More than 90% of all earthquakes occur in regions where large tectonic plates meet.

4.4.1 Negative effects of volcanic eruptions:

- Eruptions occurring close to human settlements may spill and destroy lives and property causing people often have to be evacuated
- Ash discharged very high into the stratosphere can have negative consequences on the ozone layer
- Landscapes and natural sceneries can be destroyed

- Ash and mud can mix with rain and melting snow, forming lahars. Lahars are mudflows flowing at very fast pace

4.4.2 Positive effects of volcanoes include:

- Different types of erupting volcanoes provide extraordinary scenery, so beautiful and natural that they attract tourists to the area, bringing in some economic value
- Places close to volcanic activities tend to have higher potential for geothermal energy which can be an advantage to the towns and cities
- Some ash and lava breakdown become soils that are rich in nutrients and become good areas for crop planting activities.

Volcanoes have the Volcanic Explosivity Index (VEI) to measure intensity. (See Appendix A)

Picture 18- Mount Sinabung, Jakarta, Indonesia erupted. Volcanic ash spewed more than one mile into the sky,killing at least 15 people as hot ash of about 700 degrees celsius raced down the mountains slopes. Those affected were within 3 kilometre radius of the volcano.
(Source: http://eschooltoday.com/volcanoes/effects-of-volcanic-eruptions.html).

Picture 19- Mount Ontake Eruption
(Source: http://www.dailymail.co.uk/news/article-2772458/More-30-hikers-dead-near-Japanese-volcano-erupted-without-warning-spewing-eight-inch-blanket-ash.html).

4.5 Hurricanes/ Tornadoes/ Storms

Hurricanes are powerful tropical weather systems with clear circulation and winds of 74 miles per hour (119 km/h) or higher. When hurricanes move onto land, they sweep the ocean inward. They can cause tornadoes and make heavy rains and floods. Hurricanes are grouped into categories based on the wind speed so the stronger the wind speed, the higher the category. Most damage caused by hurricanes is from flooding, not the strong winds.

Mountains can cause change in the track of a hurricane as they can disrupt the centre of a hurricane's circulation, which may then reform on the other side of the mountains away from the trajectory of the hurricane's track prior to crossing the mountains.

All areas – from coastal and sound counties to the mountains have been impacted by hurricanes in the past 20 years. Heavy winds, tornadoes, strong thunderstorms, flooding, storm surge and landslides can all be caused by hurricanes causing tragic damage.

The windstorm hazard in mountainous areas may be subject to extreme small-scale changes due to topographical features like river valleys. Storms also can cause river flooding, rock slides, a sudden drop in temperature and hail; the main danger is being struck by lightening.

Tornadoes have the Fujita Scale and the TORRO scale to measure their ferocity. Hurricanes are rated on the Saffir-Simpson scale. (See Appendix A)

4.6 Ice and Snow

4.6.1 Ice

Ice storms form when a layer of warm air gets sandwiched between two layers of cold air above and below. Snow forms in the upper cold zone, which then melts as it falls through the warm region. When it hits the cold ground at the surface, however, it freezes instantly on whatever it lands on—forming a solid coating of glaze ice. This ice can accumulate to a thickness of several centimetres, adding a huge amount of weight to trees, power lines or buildings.

Meteorologists are pretty good at predicting when an ice storm is on its way, but like many types of natural disaster they vary dramatically in intensity. A meteorologist and electric utility industry professional have developed an index for rating ice storms. The Sperry-Piltz Ice Accumulation Index or SPIA Index (See Appendix A) and classifies ice storms based on the ice amount they accumulate, their wind speeds, and the damage that they cause.

Generally, heavy accumulations of ice can bring down trees and topple utility poles and communication towers. Ice can disrupt communications and power for days while utility companies repair extensive damage.

4.6.2 Snow

Snow refers to forms of ice crystals that precipitate from the atmosphere (usually from clouds) and undergo changes on the Earth's surface. It pertains to frozen crystalline water throughout its life cycle, starting when, under suitable conditions, the ice crystals form in the atmosphere, increase to millimeter size, precipitate and accumulate on surfaces, then metamorphose in place, and ultimately melt, slide or sublimate away.

Major snow-prone areas include the Polar Regions, the upper half of the Northern Hemisphere and mountainous regions worldwide with sufficient moisture and cold temperatures. In the Southern Hemisphere, snow is confined primarily to mountainous areas, apart from Antarctica.

In the mountains, heavy snow can also lead to avalanches. The cost of snow removal, repairing damages, and the loss of business can have severe economic and delay implications on construction projects.

4.6.3. Avalanches

An avalanche (also called a snow slide) is a rapid flow of snow down a sloping surface. After initiation, avalanches usually accelerate rapidly and grow in mass and volume as they entrain more snow.

The load on the snowpack may be only due to gravity, in which case failure may result either from weakening in the snowpack or increased load due to precipitation. Avalanches initiated by this process are known as spontaneous avalanches. Avalanches can also be triggered by other loading conditions such as human or biologically related activities. Seismic activity may also trigger the failure in the snowpack and avalanches.

Although primarily composed of flowing snow and air, large avalanches have the capability to entrain ice, rocks, trees, and other surficial material. However, they are distinct from mudslides which have greater fluidity, rock slides which are often ice free collapses during an icefall. Avalanches are not rare or random events and are endemic to any mountain range that accumulates a standing snowpack. Avalanches are most common during winter or spring but glacier movements may cause ice and snow avalanches at any time of year. In mountainous terrain, avalanches are among the most serious objective natural hazards to life and property, with their destructive capability resulting from their potential to carry enormous masses of snow at high speeds.

Picture 20- Avalanche causing a damage to an existing road
(Source: https://www.conserve-energy-future.com/types-causes-effects-of-avalanches.php).

Picture 21- Avalanche damage
(Source: http://www.icdo.org/en/disasters/natural-disasters/avalanches/).

4.6.4 **Mitigation**

There are several means to protect a construction site from avalanches. According to the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (www.wsl.ch), avalanche protection distinguishes between structural, planning and temporary measures. All approaches are important, but choosing and combining the right ones is the key to safety and economic viability.

Temporary measures are manmade activations of avalanches due to blasting. The goal of controlled blasting is to temporary protect areas of rupture, avalanche paths and *dispositional* areas as well as to avoid major avalanches. Avalanche galleries or tunnels are the protection measures for roads and railways. Avalanches simply run over those structures without impairing the traffic.

Planning measures, especially with avalanche exposure maps are an important instrument. Those maps show the exposure and the intensity of avalanches in a specific area. Those maps are the basis when it comes to the planning process of an infrastructure project but Underwriters should note there maybe an increased Third party Liability.

Picture 22- Example of an avalanche exposure map.
(Source: https://www.wsl.ch/de/schnee-und-eis/lawinen/lawinenschutz/raumplanerische-massnahmen.html).

The colours indicated the higher potential for damage – Underwriters should consider this as often existing property is sometimes required to be covered.

4.7 Political risk

Historically, countries national borders are frequently following natural orographic contours.
These areas could be the scene of potential frictions between different populations living either side of the border and as well within one same side.
Disputes may arise for several reasons, sometimes deeply rooted in history or for ethnical, religious, cultural, economic reasons and so forth.
In some cases, contrasts may trigger war-like situations backed from neighboring states.
Clearly, situations as above may have an impact on access roads, the supply of materials and cause a threat to the materials in storage.
It is important therefore to be aware of the exposure determined by these circumstances at underwriting assessment stage, in order to adequately address the topic in the policy with adequate terms and/or exclusions.

5.0 Technical exposures associated with Construction projects in Mountainous regions

Introduction

All the types of projects the paper has focused on will face similar challenges compared to standard environments, with aggravated conditions and with additional very specific logistical and methodology for respective mountains. Furthermore Health and Safety procedures are considered part of the project principal and main contractor responsibilities and enforced adequately in line with regulatory procedures

5.1 Factors which increase construction exposure in mountains

5.1.1 Weather- Permafrost

Permafrost is subsurface material, which shows temperatures below 0°C for a period longer than one year. Besides the large-scale distribution in subarctic and arctic lowlands, permafrost occurrences also exist on a smaller scale in mid-latitude high mountains like the Alps.

In the high mountains permafrost exists both in bedrock and in loose material (debris slopes, moraines, soil). Under permafrost conditions fissures and cracks in bedrock and cavities in loose material are normally filled with ice. With increasing ice content, the inner cohesion of loose material can be extremely reduced so that it becomes plastic by stress. Debris accumulations then start to move down-valley. Geomorphologic forms resulting from this movement are called "rock glaciers". They are the most striking signs for permafrost occurrences in the high mountains.

Picture 23- View into the catchment of the Riedgletscher (Matter Valley)
(Source: https://www.uni-giessen.de/fbz/fb07/fachgebiete/geographie/personal/ProfRuhe/prof-dlorenz-king/forschungsprojekte/akn-arbeitskreis-klima-und-naturgefahren/arbeitsgruppe-polargebiete-hochgebirge/dauerfrostboeden-permafrost).

The altitudinal belt of high mountain permafrost is situated below the glaciated areas. While continuous permafrost occurrences are restricted to the highest non-glaciated regions in the Alps, the belt of discontinuous or patchy mountain permafrost shows a larger vertical extent with a strong dependence on aspect. Individual permafrost bodies even occur as islands below the timberline in favoured locations.

Whether a permafrost body can form and persist in the ground depends on the surface radiation balance, the mean annual air temperature and the winter snow depth and snow cover duration. Consequently, climate changes affect the permafrost distribution. Altogether an increase of slope instabilities caused by permafrost retreat has to be expected resulting in rock falls, slumps or debris flows that often reach the valley bottom threatening settlement areas and infrastructures.

5.1.2 Glacial Water also due to snow melting

Floods due to intensive precipitation and/or snow melting can cause material damage and even fatalities on construction sites. It can also affect site logistics in remote locations

To keep losses to a minimum, hazard maps, forecasts, protective structures and optimally coordinated responses to emergencies are necessary. The overall goal is to avoid damage by not building in at-risk areas and providing more open space around waterways.

Water drainage systems should be sized to cope with the excess of water coming from the snow melting. If these measures are not sufficient, new protective structures need to be build. This requires hazard maps with data of mountain water flows, bedload volumes and snowpack.

Picture 24- Increased flows in river near Chitral, Pakistan due to snow melt can have devastating effect in remote locations. (Source. www.dawn.com).

5.1.3 Cold weather working- Concrete casting in cold weather

A frequent aspect to which constructions in mountainous areas are exposed is the cold weather. This is important because water contained in concrete admixtures may freeze if temperatures fall at 0°C or below. This could happen despite the reaction of setting and hardening of concrete which develops heat (exothermic reaction). Should water in the concrete ice, it will increase of volume, causing significant damage if the strength of the concrete at that time is below 2n/mm².

Picture 25- Linthal Project Switzerland – State of the art Concrete batching plant with features to facilitate winter working conditions including Avalanche blasting equipment triggered when snow built up to trigger levels.

5.1.4 Rock falls and Landslides

Exposure/Challenge:
Similar to the above-mentioned exposures, rock fall and landslides can be an exposure for material damage or fatalities on construction sites. I.e. 6 to 8% of Switzerland's surface area is unstable ground – mainly in the pre-alpine and alpine regions. Hillslope debris flows and landslides occur suddenly, can be predicted only to a limited extent and often move at high speeds, which makes them a serious threat to valley inhabitants. Given that they unleash such colossal forces, protective structures and safety measures often face technical difficulties or are simply too expensive. Hillslope debris flows are formed when soil on hillsides becomes waterlogged during heavy rain and effectively liquefies. This debris pose a serious threat to buildings, roads and railway lines. In shallow landslides, the top layer of earth moves and slides down; these landslides contain less water than hillslope debris flows.

Climate change could exacerbate these risks further: melting glaciers and thawing permafrost release rocks and boulders from their icy grip. If heavy rainfall increases as predicted, hillslope debris flows and shallow landslides could occur more frequently.
(https://www.wsl.ch/en/natural-hazards/rockfalls-and-landslides.html)

Picture 26- Rock fall
(Source: https://www.wsl.ch/en/natural-hazards/rockfalls-and-landslides/rockfall.html).

Mitigation:
"The forest is often the best and most cost-effective form of protection (Protection forest) against rock falls." (https://www.wsl.ch/en/natural-hazards/rockfalls-and-landslides/rockfall.html)
However, it is not realistic to wait for a forest to grow before an infrastructure project can be build. Protective fences, rock fall galleries or dams are the more suitable, though less effective methods, to mitigate rock fall scenarios.

Picture 27- Slope protection being fully utilized
(Source: https://www.wsl.ch/de/naturgefahren/steinschlag-und-rutschung.html).

"Plants reinforce steep and unstable slopes with their root systems, thereby helping to reduce the risk of landslides." (https://www.wsl.ch/en/natural-hazards/rockfalls-and-landslides/rockfall.html) Same as above, this can only be a longtime measurement. Due to the unforeseeable and unpredictable nature of landslides, other mitigation measurements, especially for roads and railroad construction projects are hard to realize. Therefore, the best way to avoid an infrastructure project loss is to "avoid building near steep slopes, close to mountain edges, near drainage ways or natural erosion valleys." (http://www.weatherwizkids.com/?page_id=1326).

Additional methods for geotechnical improvement of potentially unstable slopes in mountain areas include the traditional ones known in the geotechnical industry.
These are, in particular, rock fill walls, gravity walls, metal nets with anchors, but also sheet pile walls and diaphragm walls.
In this respect it is always advisable to make sure that the geotechnical intervention has been designed and reviewed by a geotechnical engineer, as opposed to be left to the judgement of the onsite personnel.

Further detail with regards to landslide and landslide mitigation is covered in section 5.8.

5.2 Third party interface

Picture 28- Avalanche protection constructed over an operational road
(Source: www.Atmb.com). Construction of a complex system of defense against rock fall and avalanches in Northern Italy. In the distance to the top of the picture it can be noted the construction of additional metal net barriers with similar purposes.

5.3 Difficulty of access/ harsh terrain/ Steep slopes up to mountain walls and slopes stability

Exposure/Challenge:
Some mountainous areas are difficult to access due to remoteness, lack of access roads, steep slopes or slope stability. Building access roads is not always possible, i.e. for environmental or economic reasons.

Picture 29- Access to work site being formed in very steep terrain
(Source: https://mutually.com/diy/manstuff/2017/07/24/these-tough-jobs-havent-deterred-men-from-taking-up-a-challenge/16/).

5.4 Property taken into use

Picture 30. Linthal 2015 Project, Cable lift system mountain (L) and valley (R) stations (Source Zürich Insurance**)**

Insurers should establish from the outset what coverage is being afforded to systems such as the cable car system which is built to facilitate the project.

5.5 Specialist Contractors plant and equipment

A possible way of getting equipment and material to a remote or difficult to access area is the use of specialist contractors, i.e. heavy load helicopters.

Some helicopters can carry loads up to 5 metric tons and are still able to operate with an extreme high precision and accuracy. Power lines for example can be placed into the pre-installed bolts.

Heavy load helicopters are typically used construction and assembly of cranes, power lines, especially the towers, ski stations or downtown for the lifting of air condition units. Helicopters cannot operate in heavy windy, foggy, rainy or snowy conditions.

Particular elements to be considered in mountain environments when carrying out a project can include, potentially lack of oxygen depending on the height, remoteness of some areas with difficulty of access. This can be exacerbated during the bad weather seasons

Risks

- exceeding max weight capacity of equipment having to abandon load and consequence of doing so and this requires a separate insurance and liability cover
- Equipment overturning
- Heavy water floods inclusive for the combined effect of snow melting and rain
- Pollution

5.6 Account for seasonal restrictions in respect of potential Delay in Start Up (DSU)

Projects located in mountainous regions may be subject to significant delays if the onset of a winter period delayed the rectification of an indemnifiable event. We have been made aware of pipeline projects at high altitudes where access to the site was not possible for up to 4 months in a calendar year.

5.7 Social and Economic factors

In addition to environmental concerns, social-economic factors need to be considered since many key infrastructure projects have a considerable impact on the local population. Large dam and transportation (road and rail) projects have forced millions of people from their land in the past decade.

In addition to the obvious loss of land, the adverse impact is compounded when the affected people belong to indigenous groups with a close relationship to the land - it represents a distinct culture, customs and traditions that are unique. Those displaced by reservoirs are only the most visible victims of large dams. Access to clean water and other natural sources have been lost. Those living downstream suffer from hydrological changes.

In a paper published by the World Health Organization (WHO), authors investigate the effects of large dam projects on human communities through time and conclude *"One of the most critical factors is the enforcement of the mitigation and resettlement plans, as defined at the feasibility stage, by international lending institutions. The withdrawal of these institutions, under external pressures, can strongly undermine the implementation of more equitable policies. Finally, some groups may also take advantage of the high visibility and stakes of a large dam project to propel or impose their own agenda, distorting the understanding of the issues at stake or increasing the complexity and difficulty of their resolution".*

From a project perspective, these additional challenges can lead to considerable project delays and much higher costs that need to be factored at inception. Cause for concern also rises on account of bad publicity, corruption and lack of corporate social responsibility.

5.8 Landslides & Slope Stability

5.8.1 Landslide features and causes

A landslide, also known as a landslip or mudslide is a form of mass wasting that includes a wide range of ground movements, such as rock falls, sliding, toppling, deep failure of slopes and shallow debris flows. Although the action of gravity is the primary driving force for a landslide to occur, there are other contributing factors affecting the original slope stability.

Typically, pre-conditional factors build up specific sub-surface conditions that make the slope area prone to failure; this can include weaker sub surface strata within a ground mass, increased water table or pressures; whereas the actual landslide often requires a trigger before being released. Landslides should not be confused with mudflows, which is a form of mass wasting involving very to extremely rapid flow of debris that has become partially or fully liquefied by the addition of significant amounts of water to the source material.

Landslides occur when the slope changes from a stable to an unstable condition. A change in the stability of a slope can be caused by a number of factors, acting together or alone.

Natural causes of landslides include:

- groundwater (pore water) pressure change acting to destabilize the slope
- loss or absence of vertical vegetative structure, soil nutrients, and soil structure (e.g. after a wildfire – a fire in forests lasting for 3–4 days)
- erosion of the toe of a slope by rivers or ocean waves
- weakening of a slope through saturation by snow melting, glaciers melting, or heavy rain
- erosion of an exposed slope face via natural weather actions
- earthquakes adding loads to barely stable slope
- earthquake-caused liquefaction destabilizing slopes
- volcanic eruptions
- non favorable orientation of faults or discontinuities within the soil or rock mass

Picture 31- Bored Piling shafts to support a road side where slope instability is manifesting (Source: http://www.bertoia.it/lavorazioni/pali-trivellati-per-fondazioni-e-consolidamento-terreni**)**

Picture 32- Unfavorable orientation of bedding planes within rock mass adjacent to a national road. (Source: M. Allan)

Man-made causes of landslides can include:

- deliberate deforestation/ vegetation removal leading to change in soil characteristics and water content of the soil mass
- deliberate removal of the toe of slopes through excavation, or re-profiling works
- change in imposed loading on a slope, for example through earthworks fill activities, or building or structure construction.
- Change in water regime of the soil mass though drainage of upper areas ducted towards a slope that was previously marginal stable, or change in run off characteristics of an area.

Prior to development, slope stability in mountainous areas, posed the same hazard, but the consequence of this hazard was significantly less due to the limited insurable assets present.

In many cases, the development within mountainous areas can aggravate the hazard that is present, leading to an increase of risk. As part of the assessment process, these hazards should be identified, assessed, and mitigated to an acceptable level.

5.8.2 Historic Slope Movement

Land movement may not be a short term phenomena; land slips may be occurring over long periods of time, and evidence of this can be identified without major site investigation, examples include:

- Trees and vegetation growing at angles other than vertical indicate possible longer term ground movement
- Ridges and terraces within slopes can indicate previous failures.
- Tension cracks at crests or upper areas of slopes can indicate movement of the slope.

As noted above, slope behaviour is often visible prior to works commencing, however further intrusive investigation may detail exact ground conditions and be able to identify weak strata that could pose a stability risk. Key concerns are areas in marginal stability, where any minor change in the slope loading or condition may precipitate or accelerate slope movement.

5.8.3 Land Slide Risk Mitigation & Management

As explained during the previous sections, landslides pose a significant hazard, and thus should be subject to serious risk assessment, and subsequent mitigation actions. These can include:

- Site investigation and survey of area during project planning and concept stage to establish degree of geotechnical and topographical risks that a project will face.
- Where possible, access routes and works areas should be located/ routed, as far as practicable, to avoid areas of higher risk. Risk avoidance is normally preferable to mitigation actions.
- Areas with weak sub surface layers and potential fluctuations of ground water may pose increased risk.
- Once location and routes are finalized, detailed site investigation should be undertaken.
- Evidence of past slope movements should be established. Evidence can be found in vegetation (larger bushes and trees growing in an irregular pattern over longer periods of time); tension cracking on slopes, and slumping of toes of slopes. These features can indicate that substantial slope stabilization measures may be required to secure the area against future movement.
- Physical protection measures can also be implemented; these can include Slope stabilization actions this may comprise of a programme of rock bolting, debris/ fall arrest netting, face protection shotcrete, rock scaling, deflection structures; or set aside of sterile/ run off areas for sections that are known to suffer rock falls or avalanche.


Picture 33 & 34- Vegetation growing at different angles / Tension Cracking on slope (Source: M. Allan).

- Once established, these hard actions should be managed in conjunction with development of slope management plan

- Regular (depending on findings of initial survey) inspections and geophysical monitoring. This can include a combination of all or some of the following:

- Rope access physical inspections
- Installation of grout bridges and monitoring targets to identify localized ongoing movements
- Wider scale terrain monitoring to identify local and wider ground movements
- Regular patrols to identify increased slope movement / rock fall incidents
- Proactive and re-active inspections – for example following heavy rain, snow or extreme temperature fluctuations.

- Reporting back of findings, and recommendations with regards to ongoing maintenance works such as scaling, placement of slope stability measures such as rock bolts, rock fall arrest netting, and water run off management techniques.

- Documented inspection and maintenance activity.

5.8.4 Example of slope Protection methods:

An interesting example of slope protection following erosion from atmospheric events is provided by geotechnical specialized contractors. In order to allow for the slope to revegetate while at same time stabilizing it from further erosion, a geomat polymer matrix reinforced with a steel wire mesh can be implemented as per the pictures below

Picture 35- Reinforced polymer geomat with steel wire mesh close view
(Source: Unknown)

Picture 36 & 37- Use of steel netting to protect and stabilize loose slopes
(Source: Unknown)

5.8.5 Slope Management - Project Example

During construction of motorway in south Eastern Europe, an existing road had to be kept open and tolls levied prior to full opening of the motorway. In the early stages of the works, the existing road suffered a major rock fall event that closed the road for a significant length of time. Following the re-opening of the road the project then implemented a number of slope protection structures and implemented a structured slope management policy, where a full inspection, survey and corresponding slope stability works were undertaken. Inspections were undertaken on a bi-annual basis, with maintenance works being carried out on the basis of the prior inspection. Intermediate inspections were carried out after any significant rain or snow events; and daily patrols were also undertaken by the toll road operator to ensure satisfactory operation of the systems, and that no major slope movements were noted. Following implementation of this system, other than planned closures for inspection and maintenance the road remained open for the entire duration of the project without incident.

5.8.6 Practicalities to Consider

The mitigation actions noted above are best practice, however they all require a degree of investment and potentially on-going maintenance and survey costs.

For roads and accesses that are funded by tolls or other payments, then the cost of the mitigation can be (should be!) built into the financial model; or projects with high capital costs, then so called enabling or safeguarding works can be built into the budget. For temporary access tracks that may only be used for a short period of time during part of a construction project, for example access to temporary adits/ access shafts or work areas, then significant slope stability actions beyond basic site clearance are not likely to justify significant outlay. However with the project's risk management strategy an action plan should be developed to outline actions to be taken in the event of slope movement.

When assessing new projects, the above considerations should be taken into account; the proposed actions to mitigate the exposure should be considered proportionate to the severity of the risk, and thus reasonably practicable.

6.0 Insurance Coverage and underwriting considerations

This is another key section of the paper as it can be seen from the previous sections that construction in mountainous regions gives the (Re)Insurers greater exposure and with this there must be considerations given to the consequences following a loss and the entitlements afforded to them under the policy. Underwriters also need to take into consideration that projects in mountainous regions are likely to be requiring higher limits due to the remoteness, complexity,

6.1 Policy Wording

Policy wording, scope of cover and contract certainty are core aspects of insurance. The policy is a legally binding agreement between contract parties and will be recognized and enforced when it comes to court. This is why insurers need to be clear on the cover provided and will try to ensure that there is not unambiguous wording in place.

6.2 Location of Risk

The location/country of risk does not only determine the type of insurance as explained previously, but also, and especially for projects in remote parts of the world, requires special consideration regarding applicable Law and Jurisdiction as well as seat of Arbitration.

6.3 Policy Limits

It should be clarified if policy limits apply combined or on policy sections, per event or in the aggregate. Sublimits sometimes are included or are in addition/on top of the sum insured.

Typicall extensions sublimits are listed A mix of monetary and percentage limitation is common.

- Removal of Debris

- Expediting Expenses
- Automatic Increase (%)
- Surrounding Property
- Offsite Storage
- Professional Fees
- Fire Fighting Expenses
- Public Authorities
- Loss of Drawings
- Repeat tests

6.4 Third Party Liability

Third Party Liability (TPL) coverage has evolved over time from traditional (Munich Re) wording language to much broader (manuscript wording) coverage. Contractual obligations and underwriter's comfort level will determine the limits for TPL coverage.

Also please reference:

- IMIA Work Group Paper 40 (05) – EAR/CAR Third Party Liability – Existing and Surrounding Property

6.4.1 Cross Liability

A construction policy is typically a multi-insured policy and covers the interests of the owner, contractors, subcontractors and others. However, Section 2 will not respond to claims between two or more insureds covered by the same policy. To resolve this, cover for cross liability will be agreed upon (Munich Re endorsement 002 or similar).

6.5 Advanced Loss of Profit / Delay in Start-Up

Advanced Loss of Profit (ALoP) and Delay in Start-Up (DSU) provide coverage for the financial consequences of delay to the completion of a construction project following physical loss or damage caused by an insured peril.

Owners and Financiers require protection of their investments in projects. Accordingly, this coverage is only beneficial to owners and financing parties.

The ALop/DSU sum insured is depending on the type of project. For a power pant this will likely be the income from power sales, for a cable car (like the new Zugspitze cable car, which was the destination of the 2017 IMIA conference site visit) it will be the volume of ticket sales.

Both type of projects, hydro power and cable car, may also serve as examples for seasonal impact on ALoP/DSU. Seasonal fluctuation can result in low/high water levels or reduced/increased number of passengers during the year.

It is recommended to utilize the LEG (London Engineering Group) DSU Worksheet (available through the IMIA webpage) to establish the DSU sum insured properly.
Generally, underwriters should be extremely cautious in providing ALoP/DSU coverage, as even small material damage losses can result into huge DSU losses.

A most recent and market known example for an extensive ALoP/DSU loss is the Hidroituango hydro power project in Colombia. The loss happened in May 2018 and is still under investigation. However, the impact is being discussed in the market and expected to be in the three digit million US dollars.

Therefore, monitoring is key to ALoP/DSU cover. Insurers' own Risk Engineers and/or experts of specialized companies should be involved in order to provide risk engineering, to track project progress and to identify deviations from the original construction schedule.

6.5.1 Contingent Business Interruption

Contingent Business Interruption (CBI) is a cover extension that reimburses lost profits resulting from an interruption of business at the premises of a customer or supplier. Coverage is usually triggered by an off-site event - physical damage to customers' or suppliers' property. The type of coverage can either be named perils or even all risks. There is usually a higher sublimit for named customers or suppliers than for unnamed.

In the same context, there are other cover extensions, e.g. utility service interruption, interdependency, lack of ingress or egress, civil or military authority, and further more.

- **"Suppliers:** The insurance by this Section is extended to include Delay or Interruption arising from physical loss or damage to.
- **"Utilities:** The insurance by this Section is extended to include Delay or Interruption from failure of any utility supply upon which the Project may be dependent, arising from physical loss or damage as a result of fire, lightning, explosion, aircraft or articles dropped therefrom or from storm, tempest, flood, water damage, subsidence, collapse and earthquake."
- **"Ingress/Egress:** The insurance by this Section is extended to include Delay or Interruption when as a result of a peril not excluded by Section 1 of this Contract of Insurance, ingress to or egress from the Project Site is prevented or impeded."
- **"Interruption by civil or military authority**: The insurance by this Section is extended to include Delay or Interruption when caused, or contributed to, by reason of any order or action of a civil or military authority, as a result of physical loss or damage by a peril not excluded by Section 1 of this Contract of Insurance whether or not the Property Insured is also physically lost or damaged."

  Underwriters should be aware that these cover extensions could well result in a large CBI claim from a relatively small material damage event.

6.6 Definitions

The definitions section of a policy will typically provide necessary explanations on insurance terms.

6.6.1 Event

If coverage is defined "per event" there has to be a definition of "event" incorporated in order to clarify the underwriting intent.

A Typical manuscript wording for a 72 hours clause:

"Any physical loss or damage to the Property Insured, arising during any one period of 72 hours caused by storm, tempest, flood, hurricane or cyclone, water damage, earthquake, or tsunami shall be deemed to be one loss for the purposes of this Section.

The Insured shall select the time from which any such period shall commence, but no two selected periods shall overlap."

6.7 Cover extensions

6.7.1 Maintenance

Traditionally, Visits Maintenance (Munich Re endorsement 003 or similar) and Extended Maintenance (Munich Re endorsement 004 or similar) were provided for typically up to 24 month.

Nowadays, Guarantee Maintenance (Munich Re endorsement 201 or similar) and longer maintenance periods are seen more frequently.

Whereas Extended Maintenance requires that "loss or damage was caused on the site during the construction period", this limitation does not apply to Guarantee Maintenance which therefore provides much broader cover.

6.7.2 Strike, Riot and Civil Commotion (SRCC)

A loss example for SRCC is the Taliban in Afghanistan destroying recently installed Transmission lines.
Whilst standard CAR policies exclude SRCC this is not necessarily the case within manuscript wordings. It should be kept in mind that SRCC is automatically covered on a full value basis with an unlimited number of reinstatements unless otherwise excluded.
For details, please reference:

- IMIA Work Group Paper 90 (15) - Strike, Riot and Civil Commotion (SRCC) Risks in Engineering Insurance.

6.7.3 Existing Property / Surrounding Property

"Existing Property" (Munich Re endorsement 119 or similar) is commonly defined as "property on site, belonging to or held in care, custody or control by the principal or contractor", i.e. part of Section 1. In contrast, "Surrounding Property" is understood to be property of third parties. Both will typically be provided with a reasonable sublimit in relation to the total sum insured.

Also please reference:

- IMIA Work Group Paper 40 (05) – EAR/CAR Third Party Liability – Existing and Surrounding Property

6.7.4 Off-Site Storage

Due to location and characteristic of logistics in mountainous areas, off-site storage will be required for many construction projects (Munich Re endorsement 013 or similar):

"Section I of the Policy shall be extended to cover loss of or damage to property insured in offsite storage within the territorial limits as stated. The Insurers will not indemnify the Insured for loss or damage caused by the neglect of generally accepted loss prevention measures for warehouses or storage units."

Such measures include protection against theft, fire and rain/flood. Ideally, cover should be limited by territory, per storage unit and per occurrence.

6.7.3 Access Roads

It is common to include access roads within the cover of project policies. The main concern with access roads is their provisional nature, which means less investment in their design and construction resulting in lack of quality. In addition to material damage, there is potentially significant ALoP/DSU exposure resulting from access roads. It is therefore recommended to limit cover for (temporary) access roads.
For further information on this subject please refer to:

- IMIA Work Group Paper 87 (14) - Access Roads in Project Insurance

6.7.4 Inland Transit

Section 1 is often extended "to cover loss of or damage to the insured property whilst in transit to the contract site other than on waterways or by air". This type of cover extension, known as Inland Transit, should be limited by territory and maximum amount payable (per conveyance).

6.7.5 Property Taken into use

For some projects involving cable cars we have seen that the cable car once installed and commissioned is then used to facilitate the transport of e.g. construction machinery.
Underwriters should be aware of this and, for the sake of clarity, adopt the wording accordingly. Further, project policies typically provide all risks coverage and it is probably not the intention of underwriters to insure the operational risk of a cable car, especially not including Machinery Breakdown.

6.7.6 Liquidated Damages

EPC Contractors and subcontractors may be exposed to large penalties in the form of Liquidated Damages (LDs). An LD Cover can improve the financial stability of the EPC contractor and subcontractors backing up their contractual liabilities.
For further information, please reference

- IMIA Work Group Paper 77 (12) - Entrepreneurial Risks
- IMIA Guest Presentation 08 (08) - Liquidated Damages

6.7.7 Sue and Labour or Betterment

Should a project suffer slope instability, how does one go about recovering the situation? This may depend on the area that has been affected; a section of works that is not on the critical path of the project, or does not directly influence any revenue activities, may allow a solution to be found without undertaking significant temporary stabilization works.

Incidents located on critical access routes, or on areas of works that are on the critical path, would need timely interventions in order to minimize disruption to the works programme.

In the event of a landslide, it is likely that more significant stabilizing works will be required than originally envisaged. Should this landslide be the result of pre-existing condition i.e. weak layer within the slope, then it could be argued that the remedial works were always required.

Works in relation to sue and labour should be expected to be short term, and undertaken immediately to prevent further deterioration of the area or situation. This can include, excavation to remove destabilizing material at the crest or near the top of the landslide area, placement of fill to retain the slope mass, and drainage works to remove ground water, duct surface or rain water away from the unstable area, and also to reduce pore water pressures within the strata. These should be temporary works to stabilize the situation, and allow other works to continue whilst a permanent solution is found.

It is not appropriate to present a robust installation that is expected to be in place permanently, as a “sue and labour” claim. However the success of this will depend on how precise the insurance contract wording is.

6.8 Cover Restrictions

For many construction projects in mountainous areas it will be required to apply "warranties" or "special conditions" to limit the insurer's exposure.

6.8.1 Earthquake: warranty concerning structures in earthquake zones (Munich Re endorsement 008 or similar)

6.8.2 Flood and Inundation: special conditions concerning safety measures with respect to precipitation, flood and inundation (Munich Re 110 or similar)

6.8.3 Construction Material: warranty concerning construction material (Munich Re endorsement 109 or similar)

6.8.4 Construction Plant, Equipment and Machinery: warranty concerning construction plant, equipment and machinery (Munich Re endorsement 108 or similar)

6.8.5 Camps and Stores: warranty concerning camps and stores (Munich Re endorsement 107 or similar)

6.8.6 Schedule: special conditions concerning the construction and/or erection time schedule (Munich Re endorsement 005 or similar)

6.8.7 Sections: warranty concerning sections (Munich Re endorsement 106 or similar)

6.9 Cover Exclusions

6.9.1 Defects: Not only the definition of physical loss or damage is important, but also the distinction from defects. The most common clauses for the purpose of defect exclusion are the London Engineering Group (LEG) Clauses 1 to 3 for manuscript wordings and Endorsements 115/CAR and 200/EAR for use with Munich Re policy forms.

6.9.2 Removal of Debris from Landslides: (Munich Re endorsement 111 or similar)

6.9.3 Overtopping of Cofferdam: Cofferdam construction is typically done within a short timeframe and under difficult conditions, e.g. in a riverbed without dewatering. Further, cofferdams are temporary structures only and designed as such for a defined flood return period. Failure of this structure has often resulted in flooding of the project itself and overtopping was a frequent root cause.

6.10 General Exclusions

Project policies typically exclude:

- War
- Terrorism
- Sanctions
- Nuclear Risks
- Cyber
- Willful Act, Reckless Act
- Retained Liability / Deductibles

6.11 Probable Maximum Loss (PML) assessment is critical to successful underwriting

PML assessment is critical to successful underwriting. One element is Scope of Cover Considerations. Therefore, the wording always has to be taken into account for PML assessment. The ultimate exposure under the policy may well be restricted by sublimits or increased by policy wording extensions.
The following is a list of common policy extensions, which should be part of the PML considerations:

- Removal of Debris
- Expediting Expenses
- Professionals Fees
- Escalation Clause
- Contractor's Plant and Equipment
- Existing Property
- Third Party Liability (TPL)

Please also make reference to :-

- IMIA Work Group Paper 9-28 (93) - New Aspects of PML Estimation in CAR and EAR Insurance, and
- IMIA Work Group Paper 19 (02) - Possible Maximum Loss Assessment of Civil Engineering Projects

7.0 Examples of Actual claims in Mountainous regions

The aim of this section is to highlight some of the issues and claims that have been realised from projects ongoing in mountainous regions. We have not had any success in sourcing openly available information on claims involving Railways/Cable cars and recreational projects.

7.1 Claim Example 1: South American Gas Pipeline claim in Mountainous terrain (Source: Charles Taylor Adjusting)

7.1.1 The project details

One of the highest gas pipelines at above 5000 metres above sea level was being installed in a mountainous range in South America. The route was from the gas fields to the east of the mountains and heading to the Pacific coast to a new Gas plant was being constructed. An extremely difficult terrain for construction activity by all standards.

Pictures 38 & 39- Typical Gas pipe line route (Source: Charles Taylor Adjusting)

7.1.2 Details of the Incident

The trench was excavated and the pipe sections were installed and each section was Hydrostatically pressure tested as the pipeline construction and installation progressed seqentially. All appeared to be in order following after succesful Hydrostatic testing of the complete pipeline. However, when the 'pig' was sent through the line for final weld testing, it became stuck at a number of locations due to deformity in the pipeline. On investgation, of the installed pipeline at the higher elevations along the terrain, required remobilization of machinery and equipment to remove the back fill, and locate the exact locations of deformation and sagging of the pipeline. At these locations, pipe bedding and surround non conforming material such as large stones had been left in the sand forming the bed of the pipeline. The weight of the

Picture 40- Pipe in trench (Source: Charles Taylor Adjusting).

water caused the pipe sections to deform due to uneven loading from these non compliant backfill materials.

7.1.3 The consequences of this incident

- The damage occured at an altitude of 5,000 metre above seal level. The air was too thin for any helicopters to transport new pipe sections to the required locations
- Due to the difficult mountainous terrain and extreme weather experienced at such high altitude, The remobilization of Contractors equipment and machinery to carry out the removal of backfill, cutting of damaged pipes and re-welding was a muliple of the original project cost by a factor of 3 to 4 times.
- The need o conduct repeat hydrostatic and other testing required significant additional costs and time.
- Salvage issues due to high cost of disposal.
- Time required to reolve delayed the project by several months.

7.1.4 Policy considerations:

- Different sections damaged at various locations. Discussion on the number of events and applicable deductibles was not straight forward especially as the deductible amount was quite high.
- Debris removal and Salvage costs
- Expediting expenses, Repeat Tests (welding, coating, Non Destructive Testing)
- Pipeline consruction methodology – Possiby too long sections, winter working scenario,
- Design – defective workmanship? Work left in an incomplete state for a long period on steep slopes.
- Lack of access – winter working conditions.

7.2 Claim example 2 - Damage to a Hydro power project by flooding and landslide in Pakistan. (Source: Hamid Mukhtar & Co. (Pvt) Ltd.)

7.2.1 The project details

A 130 MW Hydro Power Project was being constucted in Pakistan.

7.2.2 Details of the Incident

The project site encountered a 1 in 80 years flood due to unprecedented rainfalls in the catchment areas in July 2010. This flood water breached and overtopped the cofferdam at the Weir and washed it away. The Flood water entered the 5 km long Tunnel under construction, exiting with such a powerful force which triggered a massive land slide towards the Power house and main camp/stores located at a lower elevation

Picture 41 & 42- Flood and Landslide Debris before and after (Source:Hamid Mukhtar & Co. (Pvt) Ltd.)

7.2.3 The consequences of this incident

- Several fatalities were reported from burial under the debris from the landlside
- Severe damage to the Insured contract work including plant and machinery resulting in claim of USD 30 million. DSU was not covered.
- 2 years delay due to inaccessibility which was only by Foot for two years only.
- The main camp office site was completely destroyed
- The project design facility had to be removed to a new as the current location was prone to more land sliding in future.

Picture 43 & 44- Flood and Debris following flood (Source: Hamid Mukhtar & Co. (Pvt) Ltd.).

7.2.4 Policy Considerations

- Selection of wrong location for main camp and stores,
- Proper land-slide protections should have been carried out.
- Munich Re clause 110 for safety precautions not followed to the spirit or sufficient
- Changes in weather patterns led to an unprecedented flood of intensity more than the 80 years recorded history.
- The access to the weir was employer's responsibility which created massive project delays due to controversies/disputes.

7.3 Change in river course causing damage to a Hydro Power project in Pakistan

7.3.1 The project details

A 17 MW Hydro Power Project located in the mountainous north of Pakistan suffered damage to contract works due to change in river course.

7.3.2 Details of the Incident

During heavy rainfall in August 2013 in the catchment areas, a land-slide occurred upstream of the project resulting in a stock of wooden logs to fall into the Ranolia River. These logs caried to the project site with immense force and the flow of river was blocked at a culvert prior to the Weir site which changed the flow pattern of the river unexpectedly. The obstruction caused widening of river and erosion/destruction of contract work, project roads, retaining walls, bridges and culverts.

Pictures 45, 46, 47 & 48- Pictures of the event (Source: Hamid Mukhtar & Co. (Pvt) Ltd).

7.3.3 The consequences of this incident

- The claim amounted to USD 13 million under a standard Munich Re CAR cover.
- Damages to Roads and Bridges

- Construction site inundated with water

7.3.4 Policy Considerations

- Land-slide did not directly impact the project site. It was a remote event generating an unforeseen incident of heavy logs getting into the river.
- Despite adequate safety precautions taken, MRe endorsement 110 fully complied. Very unusual event occurring upstream of the project site.
- Can a change in river course be predicted?
- Monitoring of upsteam conditions of a project site

7.4 Volcanic Eruption causing damage to OCP Pipeline Ecuador 2002 (Source: Charles Taylor Adjusting)

7.4.1 The project details

The OCP Pipeline (Oleoducto de crudos pesados or heavy crude oil pipeline) in Ecuador was damaged due to the eruption of Reventador volcano in 2002, 93 km east of Quito which damaged the equipment and the OCP pipeline itself during construction. The pipeline was almost ready to be buried.

7.4.2 Details of the Incident

Picture 49- Consequence of event (Source: Charles Taylor Adjusting).

It is very unusual for a volcanic eruption during a construction project and for this to cause damage. The eruption changed the profile of the landscape making the original design/route no longer viable.

7.3.3 The consequences of this incident

- The route for the pipeline would now pass across an area where ash has just been deposited and therefore likely to be unstable.
- A fast-tracked re-assessment of the alignment and design of the OCP as the pipeline was already welded up in preparation for its burial was damaged by the impact of the debris flow was necessary. (Ref. www.hydroconsult.com/art/news/B_T_N.pdf)

7.3.4 Policy Considerations

- The rerouting of the away from the volcanic material brings into question policy issues over repair/reinstatement. Has part of the works been "abandoned".
- The insured would argue that they are still going to end up with a pipeline with the same capability. Why should they be penalized if the pipeline has to follow a different route and be longer?
- To accommodate the longer route it might have been necessary to add additional features (extra compression stations) – is it reasonable that these form part of the claim?

7.5 Cable stayed Bridge project in Columbia

7.5.1 The project details

A Cable stayed bridge was being built on national Route W40 between Bogota and Villavicencio. The 446 metre span bridge was being built at a height of 280 metres above a ravine and was well advanced stage of construction. The works were being undertaken in particularly mountainous terrain.

Picture 50: View of bridge prior to incident (Source: BBC news).

7.5.2 Details of the Incident

On 15th Jan 2018 part of the bridge partially collapsed and at least 10 construction workers were fatally wounded and several other workers injured. The Deck and Pylon associated on the right hand side of the above picture failed dramatically. The failure of the bridge was subject to media coverage.

Picture 51- View of bridge after the incident (Source: BBC News).

7.5.3 The consequences of this incident

Obviously the loss of life is probably the biggest issue associated with this event.The actual extent of the implications and quantum however, it is clear that a significant loss has occured on the project and one that will take several years to review and resolve going forward. In early July 2018, it was reported on BBC news that the remaining structure and Tower crane were to be demolished by explosives as part of the next steps following the incident.

7.5.4 Policy Considerations

Due to the very limited information and sensitivity of such a claim we are unable to make too many comments but certainly if the project had a Delay in Start up coverage then it could lead to a significant time delay on the project. Policy for Removal of Debris, Increased cost of working and other standard Contractors All Risk coverage could lead to a very large claim in deed.

8. 0 Conclusions

This has been a challenging paper in many ways during the research and discussion phase. The difficulty has been to encapsulate the wide range of Construction projects that are likely to be encountered in mountainous terrains. As one would expect the exposures of projects undertaken in such locations can be subject to a wide range of natural hazards and extreme weather events which sometimes can be very unseasonal indeed.

Construction in these remote locations also requires experienced companies with proven management to ensure that extensive planning, managing and logistical interfaces are coordinated safely and successfully. However, as these locations are remote and generally in restricted locations, it becomes more costly and longer duration periods are required to build such schemes. Ultimately, Underwriters must satisfy themselves that the Insurance exposures in such an environment are assessed carefully and commensurate with the terms and conditions offered.

As can be seen from some of the sample claims, when an event does occur the costs and delays associated of reinstating the project to the same condition prior to the event. These costs can be significantly higher particularly if the site works are in the final stages and the project has started to demobilize requiring it to go back to resolve and investigate the issues.

Appendix A – Nat Cat References

1. **Munich Re Hazard map**

2. **Richter Scale**

3. Volcano Scale

VEI Chart (Source: https://volcanoes.usgs.gov/vsc/glossary/vei.html)

4. Hurricane Scale

5. Sperry – Pilitz ice Scale

SPIA Index Chart (Source: https://medium.com/looking-up/ice-damage-index-76968ff5e392)

6. World Permafrost Distribution

Source: http://arhivach.org/thread/356081/

Appendix B – High Level Underwriting review checklist

Risk Information
A sufficient level of risk information will strongly influence Underwriter's decision in writing a risk or not. Below you will find a list of key considerations regarding risk information requirements.

Technical Information
- Project overview/presentation
- Project description
- Type of project (e.g. Hydro: Run-of-River, Pump-Storage,…)
- Detailed scope of works
- New, refurbishment or upgrading
- Technology proven or unproven, prototype technology/design
- Technical key data (e.g. power, annual energy production, discharge, shape, height, length,…)
- Design criteria (foundations, structural design, …)
- Plans and drawings (layout, cross sections, profiles, elevations, …)
- Construction method statement (including temporary structures, cofferdams, dewatering, slope protection,…)
- Construction materials
- Key equipment data (turbines, generators, transformers …), manufacturers, values, lead times,…
- Reference list of CPE/CPM (including values and key data), new/used
- Existing property, value, protection/preservation
- Loss experience (with similar projects)

Project Parties
- Organizational chart
- Policyholder (OCIP, CCIP)
- Project Manager
- Main contractor
- List of contractors and subcontractors
- Contractor's and subcontractor's experience and reference projects
- Selection of subcontractors, process (size, turnover, local presence, experience,…)
- Project personnel qualification and experience
- Insured Parties, including Professionals (Architects, Designers, Engineers,…) and Lenders
- Contractual obligations

Project Financials
- Key financials
- Total contract value
- Breakdown of values
- List of equipment/machinery (CPE/M) including values
- ALoP/DSU sum insured, debt service or fixed cost, etc.
- DSU Worksheet (IMIA / London Engineering Group)

Project Location

- Site address, geographical coordinates
- linear project (roads, railways, pipelines,…) or single site
- Site layout plan
- Geology, geotechnical reports and recommendations, including type and size of foundations
- Geomorphology (folds, river basins, flood areas)
- Weather data, statistics, return periods, severity, seasonal differences
- Natural hazards exposure (earthquake, volcanoes, flood/inundation, wind/storm, hail, blizzards, avalanches, landslides, rock falls, snow, ice, extreme cold,…), NatCat event history
- Neighborhood, existing property, surrounding property
- Offsite storage/ laydown area
- Geographical area, remoteness
- Access roads, inland transit
- Site security, (public) access
- Political situation, social and environmental impact

Project Period

- Project time schedule, bar chart
- Critical path of the project
- Seasonal impacts (weather, …)
- Exposure related to different construction phases
- Hot testing period

Project Management

- Insured's risk management strategy and risk-awareness
- Technical expertise, training of (local) staff
- Site security, access control, protection from theft, etc.
- Fire protection/prevention systems/procedures
- Flood protection, elevation
- Risk mitigation, exposure control, precautionary measures, contingency plan, redundancies, availability of spare parts
- Risk monitoring, risk surveys/inspections, risk engineering reports/progress reports including