K178+550滑坡加宽侧以桥代路

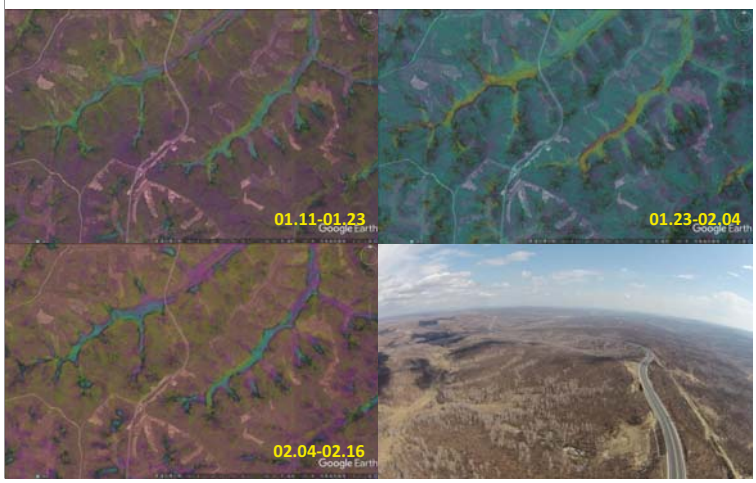
Using bridge to instead original road near K178 + 550 landslide

K177+550滑坡虽经抗滑桩支挡，旧滑坡前缘出现新滑坡

set anti-slide pile(17*24m, DIS 3m), the second creep landslide occur ahead

滑坡路段2017.01.11-02.16时段SAR干涉图

SAR interferogram (2017.01.11- 2017.02.16)



Conclusion-Landslide in Embankments

- Because of climate warming and artificial disturbance, the permafrost degradation there is serious.
- The water accumulation and distribution again along geological soil interface.
- In some place(impermeable layer beneath), from spring, thawing water form sliding surface and landslide.
- Landslide movement has characteristics of seasonal and annual periodicity.
- The slip rate and movement of landslides are controlled by both the thawing process of permafrost and the geological soil interface condition.

3.2路堑边坡涎流冰 Icing in excavation section

3.1.1 Landslide caused by icing

Background

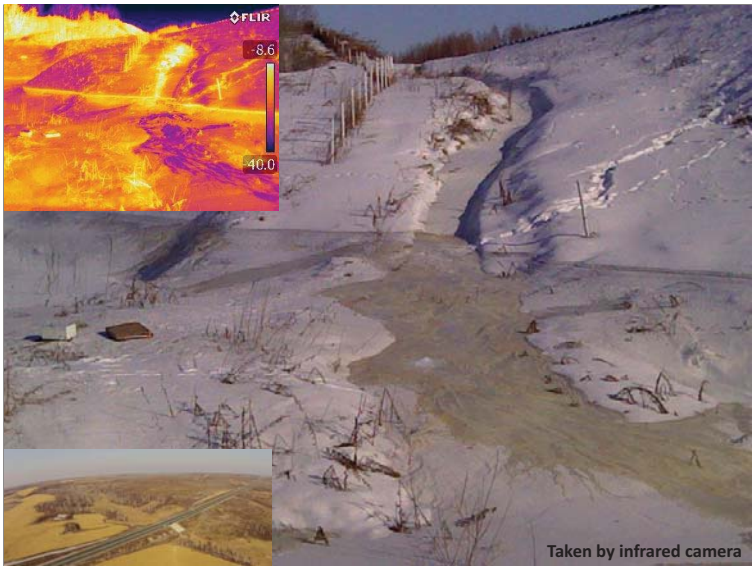
Highway cutting slope(560m):

- The highway is Extension Project.
- In 2009 fall, mechanical excavation.
- In Feb.2010, Icing occurrence.


Aufeis on the cutting slope (2010.03)


The Location of cutting slope (photo from Google earth)


The cutting slope after excavated (2009.09)

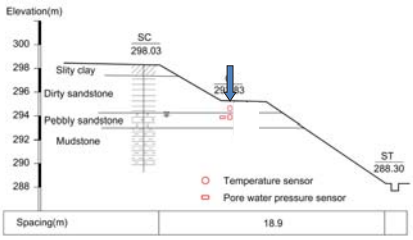


Method

Monitoring(2011~2015):

- At the second floor of the slope, near the toe of the slope, four drilling borehole(space,40m).
- Soil temperature, water content, pore water pressure for 5 years.

Geological profile of left cutting slope in K161 + 860 section

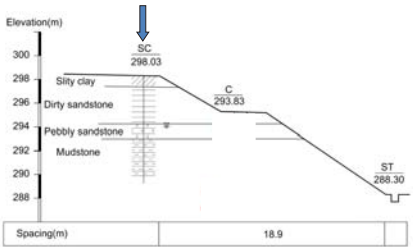


Method

Drilling exploration(2010.07):

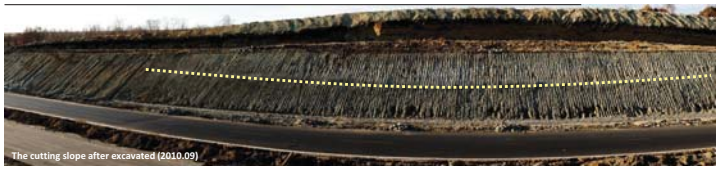
- At the top of the hill.
- Soil samples was conducted particle analysis and penetration tests.
- Different soil layer is very important for icing here.

Geological profile of left cutting slope in K161 + 860 section



Soil physical indicators in monitoring section of the slope

Layer	Category	Rock types	Thickness (m)	Permeability coefficient (cm / s)
1	Quaternary loose layer	silty clay	0.8~1.0	3.84×10^{-5}
2	Quaternary loose layer	muddy sandstone	2.5~3.0	6.49×10^{-5}
3	Tertiary sandstones	pebbly sandstone	1.0~1.2	2.11×10^{-5}
4	Cretaceous mudstone	mudstone	>5	2.09×10^{-5}

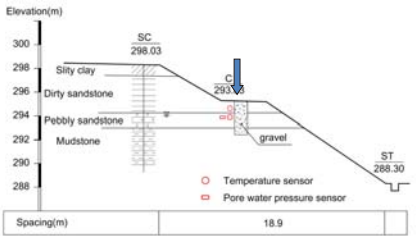


Measure

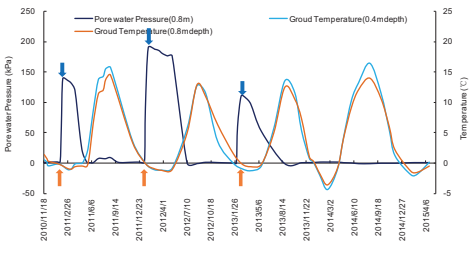
Gravel ditch(W0.8m,D3.5m):

- At the second floor of the slope.
- A ditch was backfilled by gravel (2.0m depth) and geotextile(1.5m depth).
- Catchment and derangement.

Geological profile of left cutting slope in K161 + 860 section



Results & Discussion



Signal of icing :

- Icing is related to soil PWP around here. The signal of it is a sudden increasing of soil PWP accompanied by soil temperature dropped to 0 ℃.(frozen front)

Icing cycles:

- Occurrence, bigger, smaller, disappearance...

Conclusion- Icing

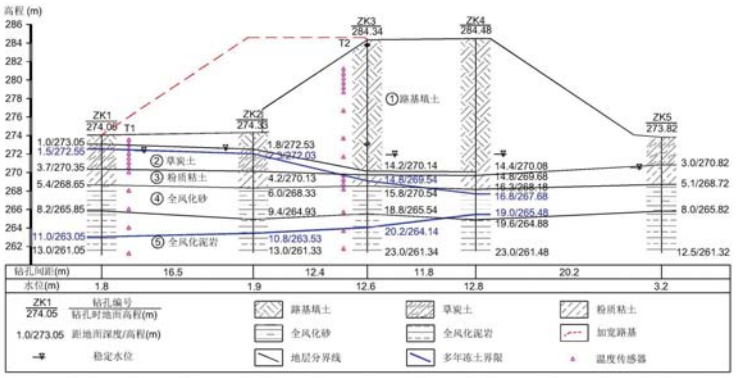
- Icing here is caused by slope excavation which not only destroy the balance of underground water, but also change the condition of permafrost around here.
- The water accumulation and distribution again along geological soil interface.
- In some place, in winter, the water out flew pressured by upper frozen front and beneath impermeable layer.
- Using Gravel Ditch on the slope could solve this icing problem.
- Icing could erosion the slope surface and lead to landslide in spring.

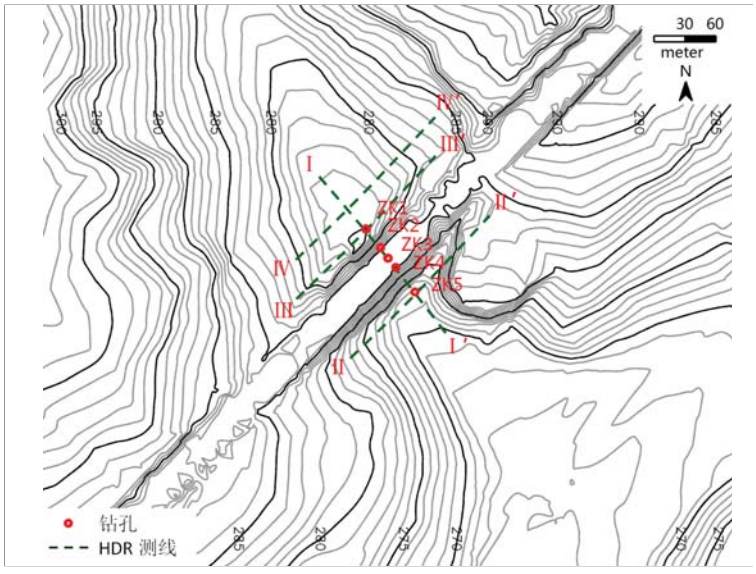
3.3 冻土退化导致地基沉降及工程对策

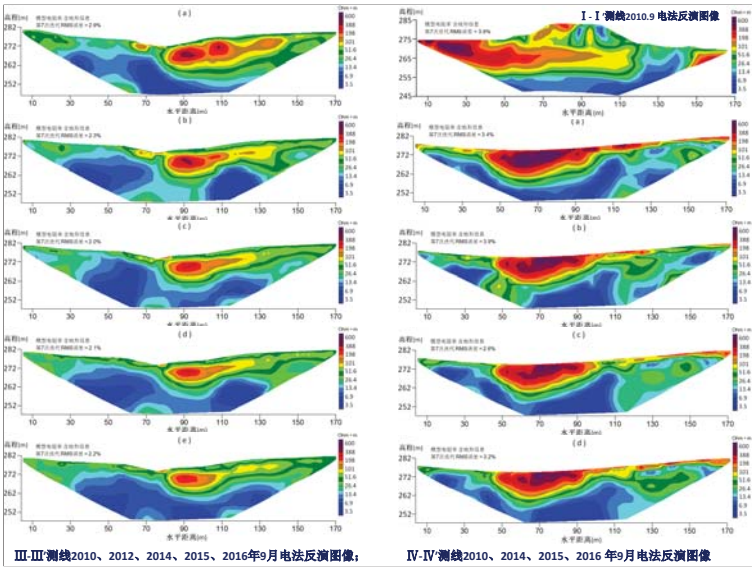
Foundation settlement caused by PF Degradation and Engineering Countermeasures

K161+440断面监测孔布置、地质剖面示意图

Monitoring hole layout, geological profile diagram

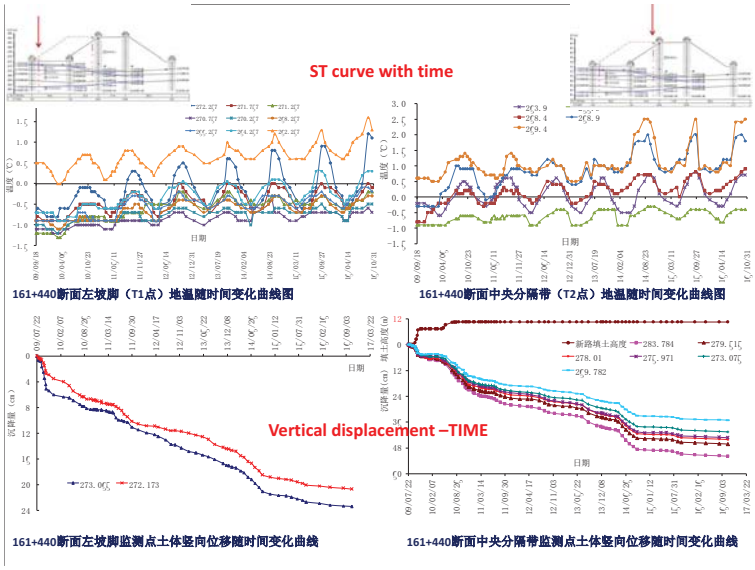






Ⅲ-Ⅲ'测线2010、2012、2014、2015、2016年9月电法反演图像；

Ⅳ-Ⅳ'测线2010、2014、2015、2016 年9月电法反演图像



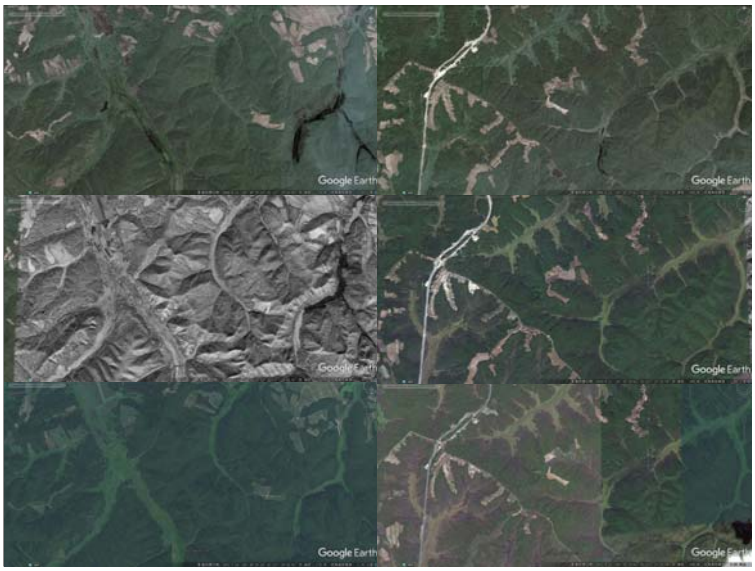
4.多年冻土退化引发的环境地质问题

其他环境地质问题
（研究区）

Other environmental geological issues
（ *study area* ）

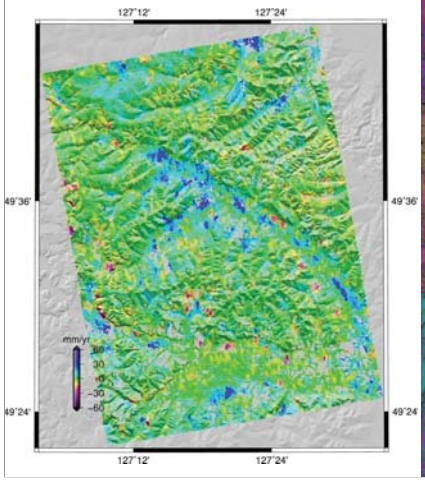
4.1 冻土退化的证据——水文地质条件变化

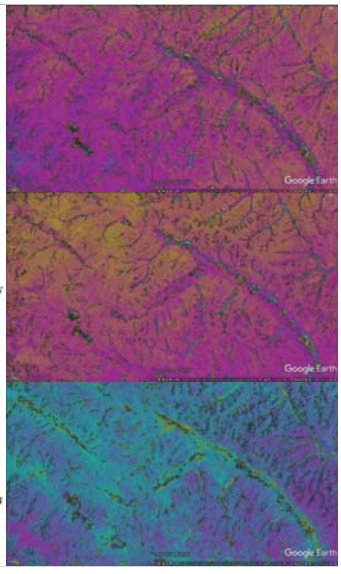
Evidence of PF Degradation - Variation of Hydrogeology Condition



4.2 地貌变化

Geomorphology changes





4.3 地表植物种类变化

Changes in surface plant species

4.4 可燃冰与温室气体排放