(2)第３回現地調査時ミニセミナー

Colombia

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Advisor for Strengthening for ANLA Institutional Capacity on the Tunnel Sector

Introduction of Japanese Practices for Environmental Management in Tunnel Construction Projects

12 March 2018

Team Leader
Ichizuru ISHIMOTO

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Japan and Colombia

- Similar tectonics location along the Pacific Ring of Fire

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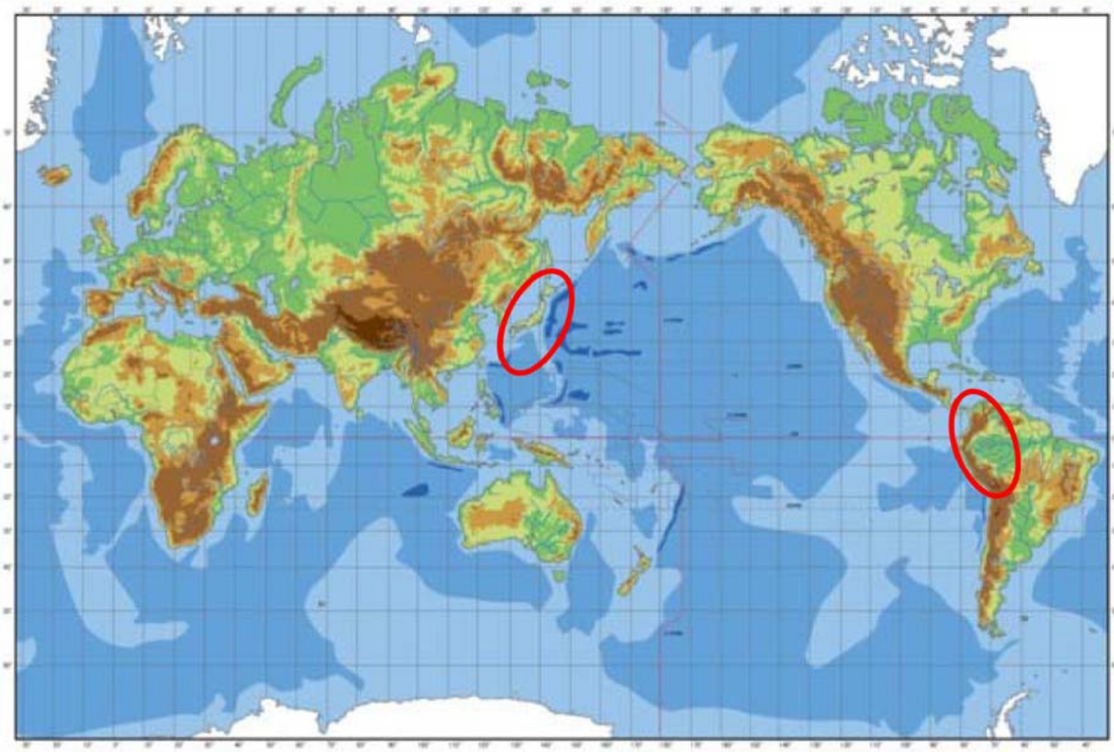
Japan and Colombia



Japan and Colombia

- Both countries are covered by **mountainous areas**

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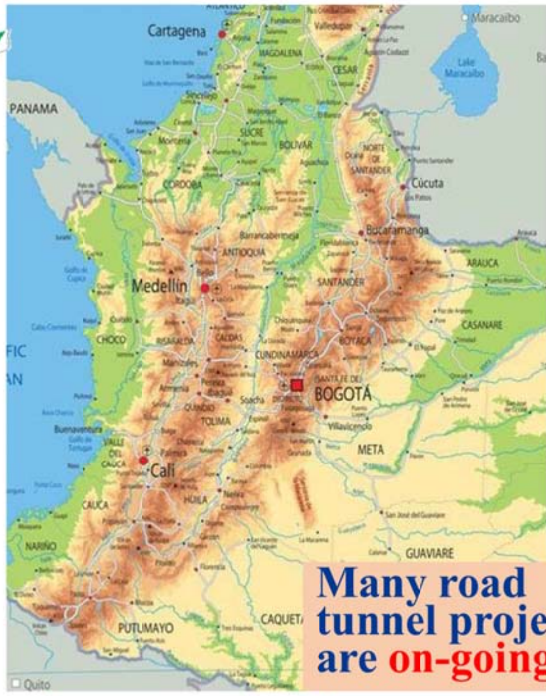
Japan and Colombia

Many road tunnels have been built

Express Network in Japan



Many road tunnel projects are on-going

- National Road Network **passing mountainous areas**

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General EIA Process and Procedure in Japan

12th March 2018

Environmental Engineer

Shinji TANAKA

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General EIA Process and Procedure in Japan

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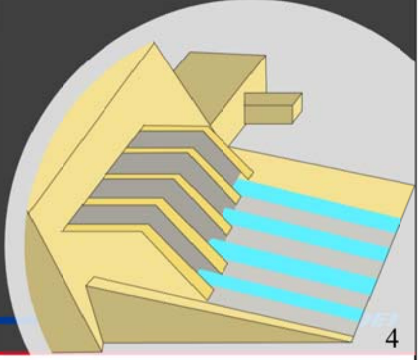
1.Projects required EIA study

- Projects subject to the national law
  (Environmental Impact Assessment Act No.81 1997)
  - 13 Categories (Road, River ,Railway, Airport, Waste disposal.....)
- Only large scale project
  - e.g. National road project 4 lanes or more, and 10km or longer

	Road	River	Railway	Airport	Power Plant	Waste disposal	Landfill and Reclamation	Land readjustment (6types of land development)	Total
On-going	9	3	2	1	186	1	4	2	208
Completed	85	7	18	9	136	7	16	21	299
Aborted	12	1	2	1	44	0	3	7	70
Total	106	11	22	11	366	8	23	30	577

As of March 2017 / Source: MoEJ,



1.Projects required EIA study

- Projects subject to the prefectural/municipal ordinance
  - Smaller project and including many categories restricted by the municipal ordinance
  - e.g.

  Tokyo Metropolitan :
  Skyscraper,
  Shopping center,
  Wholesale Market

  Kawasaki city : Apartment building
  Nagano prefecture : Development of the villa area

2.EIA Process in Japan

- Primary Environmental Impact Consideration (PEIC)

  (PEIC is defined in Environmental Impact Assessment Act)

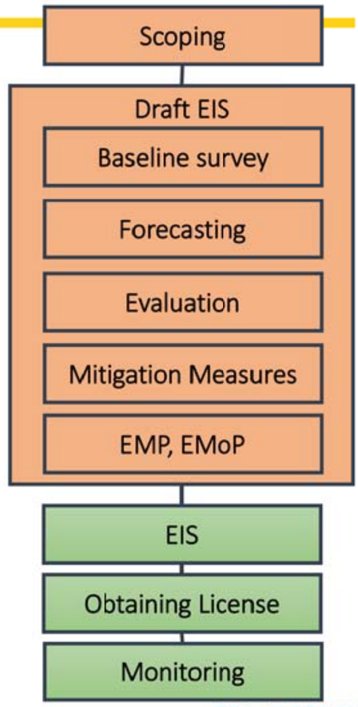
  Primary Environmental Impact Consideration enables environmental consideration at the early stage.

  Alternative plans on a project location, scale and others are compared.

PEIC stage is corresponding to the DAA stage in Colombia.

2.EIA Process in Japan

❑ EIA Process



- Scoping

  To select the evaluation items and to determine the assessment method in a more site-oriented way

  Project proponent will prepares "Scoping Document" that describes the assessment method

  (survey, forecast and evaluation methods)

- Implementation of EIA

  After the Scoping, the project proponent implements survey, forecast and evaluation of the environmental impacts in accordance with the evaluation items and methods decided through the scoping procedure.

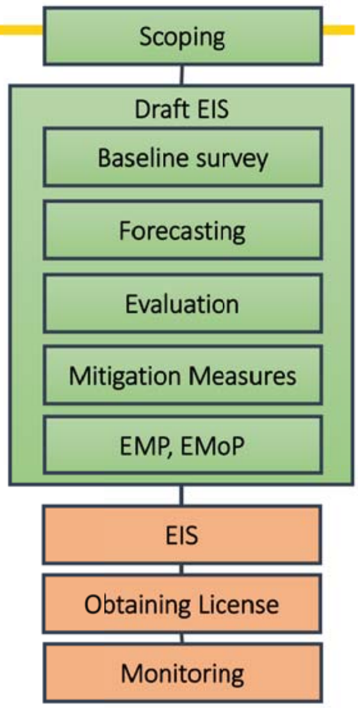
- Draft Environmental Impact Statement

  The project proponent prepares a Draft Environmental Impact Statement (DEIS) and sends it to the prefectural governor and the municipal mayors.

  (To continue)

2.EIA Process in Japan

❑ EIA Process



- Environmental Impact Statement

  After the procedure for the Draft EIS is completed, the project proponent examines the opinions of the prefectural governor and the public about the Draft EIS, reviews it and makes the EIS.

- Project license

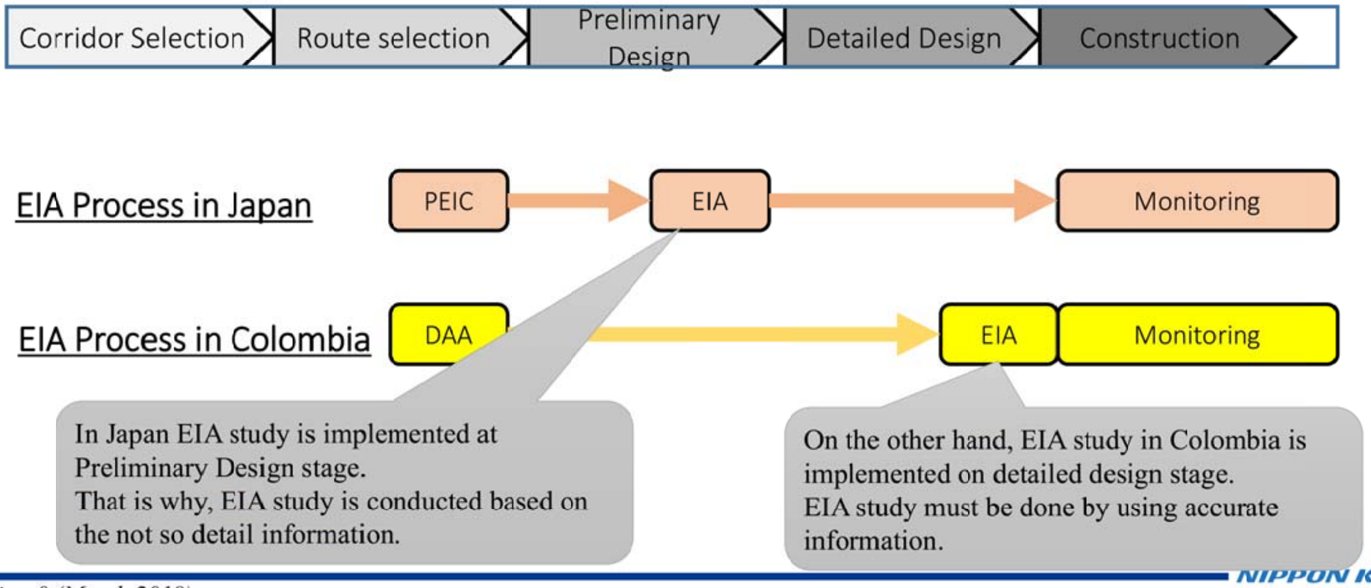
  The project-related Minister give approval to a project. (In Japan, minister of Environment do not give license.)

- Impact Mitigation Reporting

  After the procedure for the EIS is completed and the construction is started, a follow-up survey is conducted in order to monitor environmental conditions at the construction and operation stages.

3.Comparison of EIA system with Colombia

Progress of the Road Project



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4.EIA guideline of Road Project in Japan

There are sector-specific EIA guidelines which are issued by institution of project licensor. In Japan, Consultant of the project proponent must use those guidelines.

- ❑ Responsible institution of road project

  Environmental Impact Assessment Technique for road project was issued by National Institute for Land and Infrastructure Management(NILIM) under jurisdiction of Ministry of Land, Infrastructure, Transport and Tourism(MLIT) that is licensor of road project

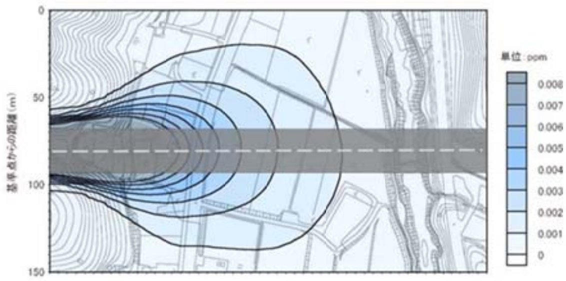
4.EIA guideline of Road Project in Japan

❑ Contents of the guideline

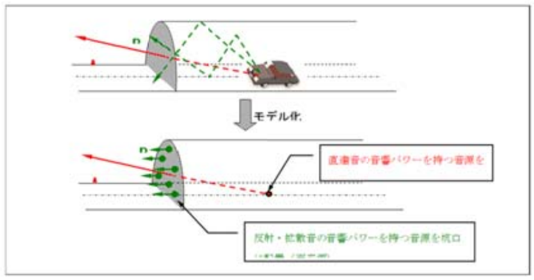
Evaluation Items : Air pollution, Noise ,Vibration, Water quality, Geology, Landscape, Fauna, Flora, Ecosystem.....

Analysis (Forecast): Based on the information of Preliminary Design Stage

Mitigation : Typical mitigation measures are contained



Forecasting air quality in tunnel portal based on the Guideline



Road Tunnel Noise Mode based on the Guideline

5.Conclusion

❑ Timing of the EIA study

Japanese EIA study is implemented on more upstream of the project stage than Colombia. In Colombia, it is necessary to implement accurate study corresponding with project stage.

❑ Effect of the guideline

Guideline could homogenise the EIA report prepared by different user and could keep technical level of the EIA study. As a result of this, it also can simplify reviewing process of personnel in authority.

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Japanese Practices related to Tunnel Geology

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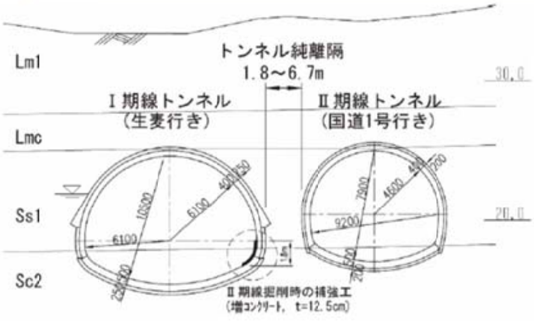
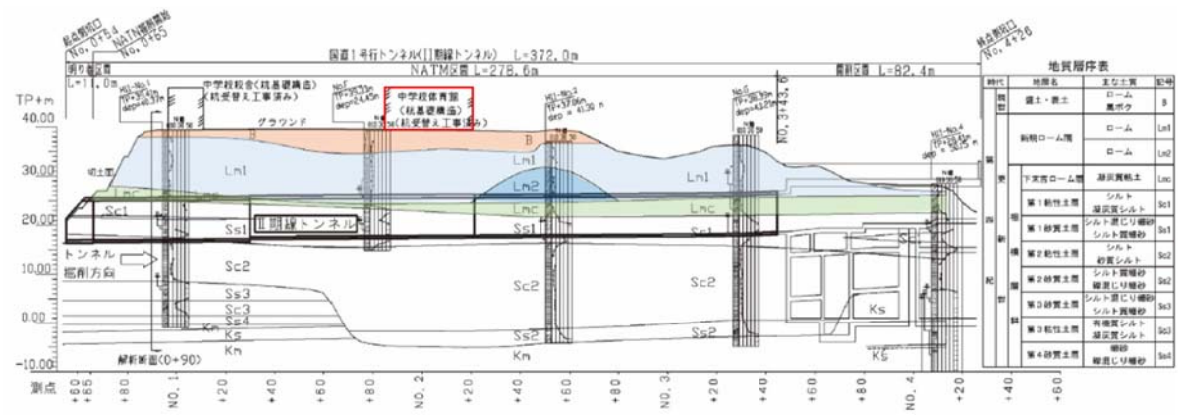
Practice 1 Kishitani Namamugi Tunnel



- Road Tunnel near Tokyo, Japan
- Const. Period 2011 – 2017
- 1,250m in total, Width 12m & 9m
- Const. Method NATM
- Volcanic Ash Loam, Low N values
- Important building above the tunnel

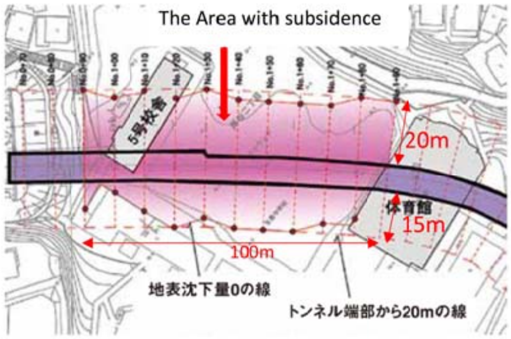


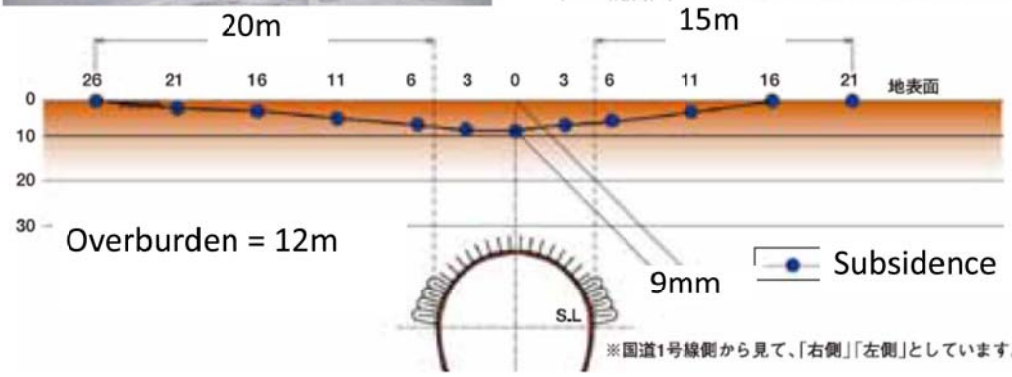
Practice 1 Kishitani Namamugi Tunnel

Before the construction,

- Identify one of the risks, subsurface subsidence
- Detailed geological survey, evaluation of the expected deformation by 2D FDM.
- Plan the construction method, Determine Support type (H200@1m), Early closure of lining concrete (t=25cm)
- Preparing monitoring plan during construction

Practice 1 Kishitani Namamugi Tunnel





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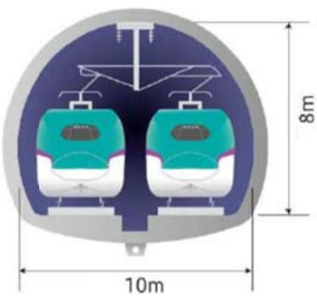
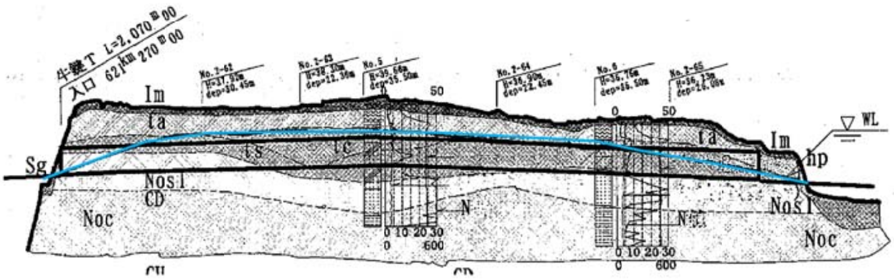
Practice 2 Ushikagi Tunnel

- Highspeed Railway Tunnel in Aomori, Japan
- Const. Period 2009 – 2012
- 2.1km in total, Width 10m
- Const. Method: NATM
- Geo: Volcanic Ash Loam, Low N values
- Thin Overburden (8-10m)





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Mini-Seminar on 13th March 2018

Practice 2 Ushikagi Tunnel

Before the construction,

- Detailed geological survey
- Subsidence was estimated by 2DFEM
- Plan the construction method, NATM
- Auxiliary Method (Soil improvement, Fore piling, Lowering ground water are applied to selected section)
- Preparing monitoring plan during construction

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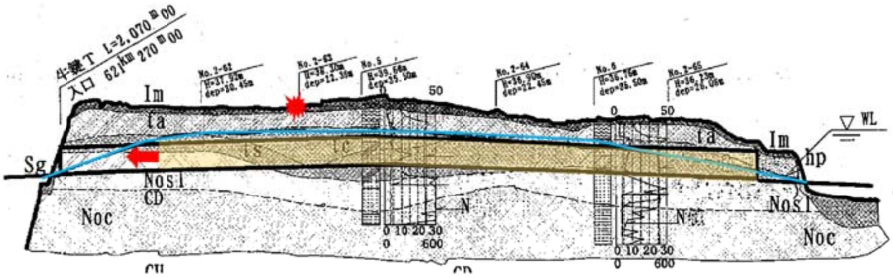
Practice 2 Ushikagi Tunnel

- Large sized Collapse had happened during construction

W20m x L60m x D10m

Practice 2 Ushikagi Tunnel

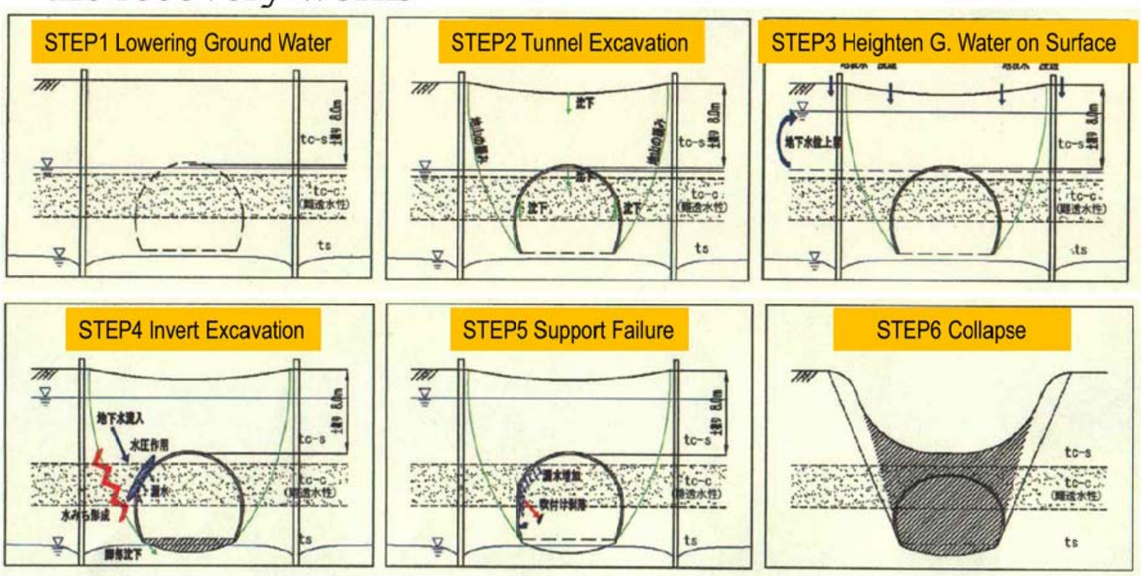


Remaining 210m of excavation to End Portal,

- 22:00PM :Confirmed the water inflow increasing
- 23:00-23:30PM :Lining concrete fallen, Breaking Sound, Workers evacuation
- 2:00AM : End of the collapse

Practice 2 Ushikagi Tunnel

- Heighten G.W.L because of Paddy field was the main cause
- Open cut method was applied for the section collapsed for the recovery works



Practice 3 Kurio Bypass Tunnel

National Road passing above TN portal

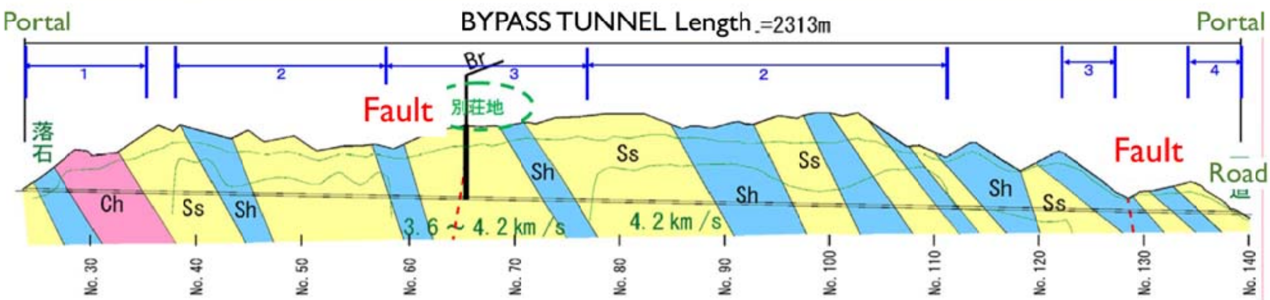
- Road Tunnel in Kyoto, Japan
- Const. Period 2009 – 2012
- 2.3km in total, Width 10m
- Const. Method: NATM
- Geo: Shale, Sandstone
- National Road passing above the tunnel portal

Practice 3 Kurio Bypass Tunnel

Before the construction,

- Identified geological risks for the construction works

Section No.	Identified Risks
1	Tunnel Face Collapse (E Wave Velocity-Low), Support Failure, Rock Fall (Near B.P.)
2	Tunnel Face Collapse & Support Failure in the Sh (Shale) sections
3	Large amount of water inflow at Fault passing sections
4	Subsurface Subsidence of National road on tunnel portal

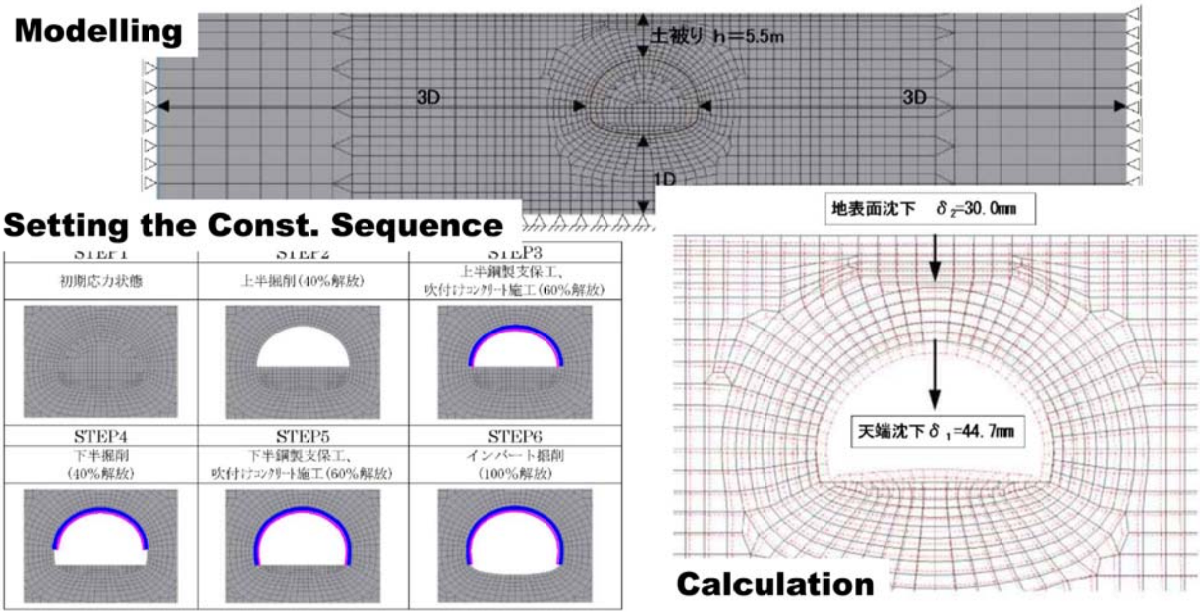


Practice 3 Kurio Bypass Tunnel

- Evaluate the risks and emergency action plan was established
- For the section of portal under the national road, the predicted subsidence was estimated by 2DFEM
- Pipe Roof Method and Fore Polling Method were applied as the Auxiliary Method
- Monitoring Plan and Emergency Action Plan during construction was prepared

Practice 3 Kurio Bypass Tunnel

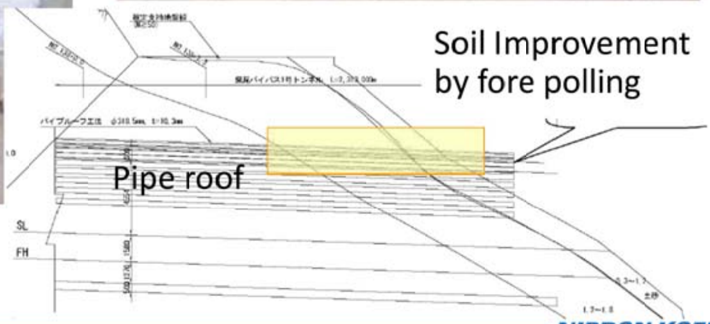
- 2D FEM was conducted for estimating the subsidence



Practice 3 Kurio Bypass Tunnel

Auxiliary Method

National Road above TN portal



Soil Improvement by fore polling

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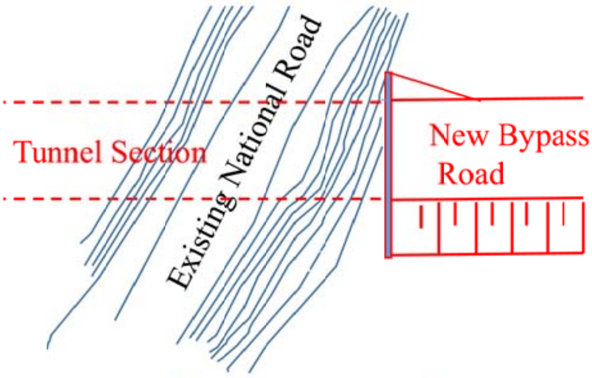
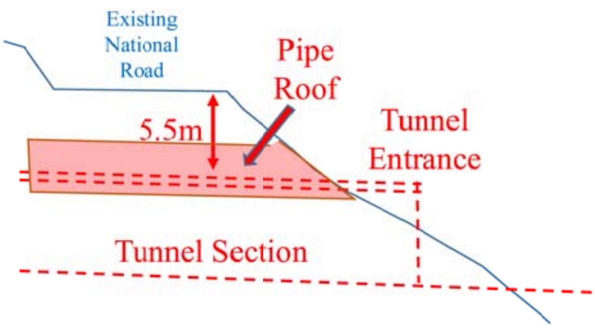
Practice 3 Kurio Bypass Tunnel

Monitoring Plan





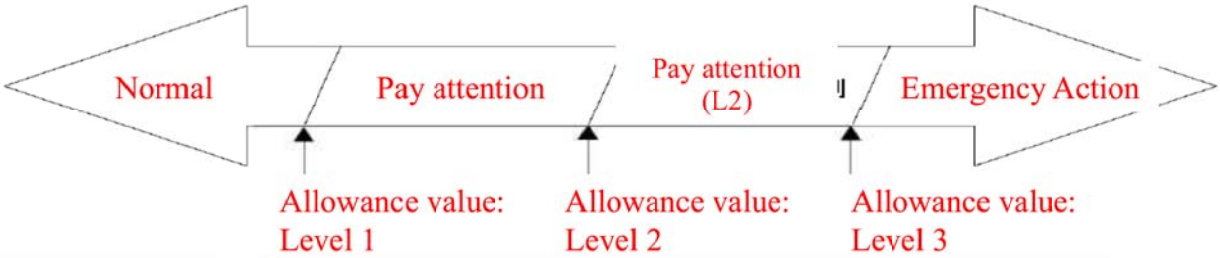
To keep safety of the traffic is Essential

Purpose of monitoring (Deformation)

To keep safety of the existing traffic on National Road

Practice 3 Kurio Bypass Tunnel

➢ Basic concept of Safety Management Plan



Level 0: Normal	➢ Normal construction management
Level 1: Pay Attention	➢ Increasing frequency of monitoring ➢ Safety Instruction to workers
Level 2: Pay Attention(L2)	➢ Increasing frequency of monitoring ➢ Study on cause of deformation, prediction of future behavior ➢ Study on measures and application
Level 3: Emergency Action	➢ Terminate the work, discussion between stakeholders ➢ Study on cause of deformation, prediction of future behavior ➢ Study on measures and application

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Practice 3 Kurio Bypass Tunnel

➢ Monitoring Item : Deformation of Tunnel

➢ Method (equipment) : Total Station with automatic target recognition, CCTV

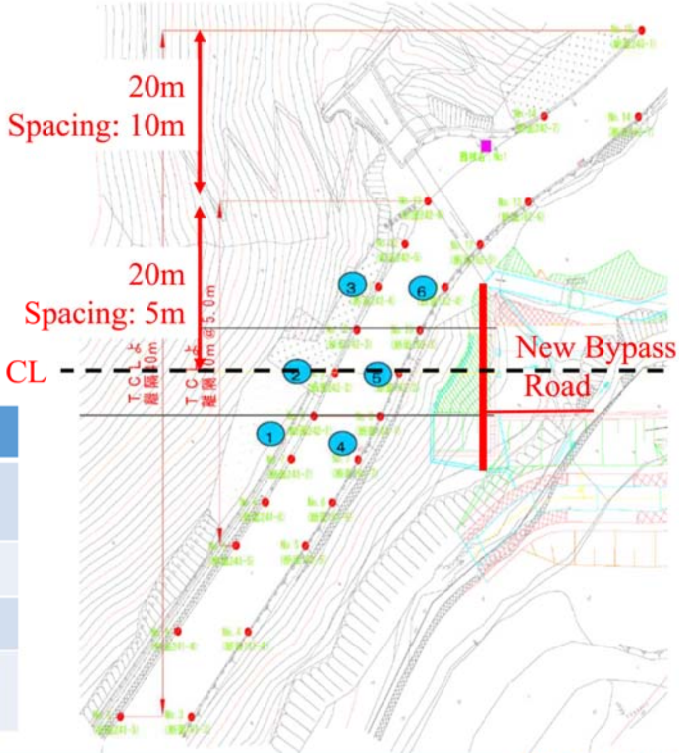
➢ Allowance values

Management Level	Allowance value (mm)	Remarks
I	15	50% of Level III
II	22	75% of Level II
III	30	From Japanese Road Maintenance Standard

Practice 3 Kurio Bypass Tunnel

➢ Location and Plan

Target: 26 nos.



➢ Period and Frequency

Period	Frequency
Before construction ~ beginning of the construction	1 time / day
During construction	2 times /day
After construction*	1 time / day
* Monitoring can be terminated after confirming the stable results	

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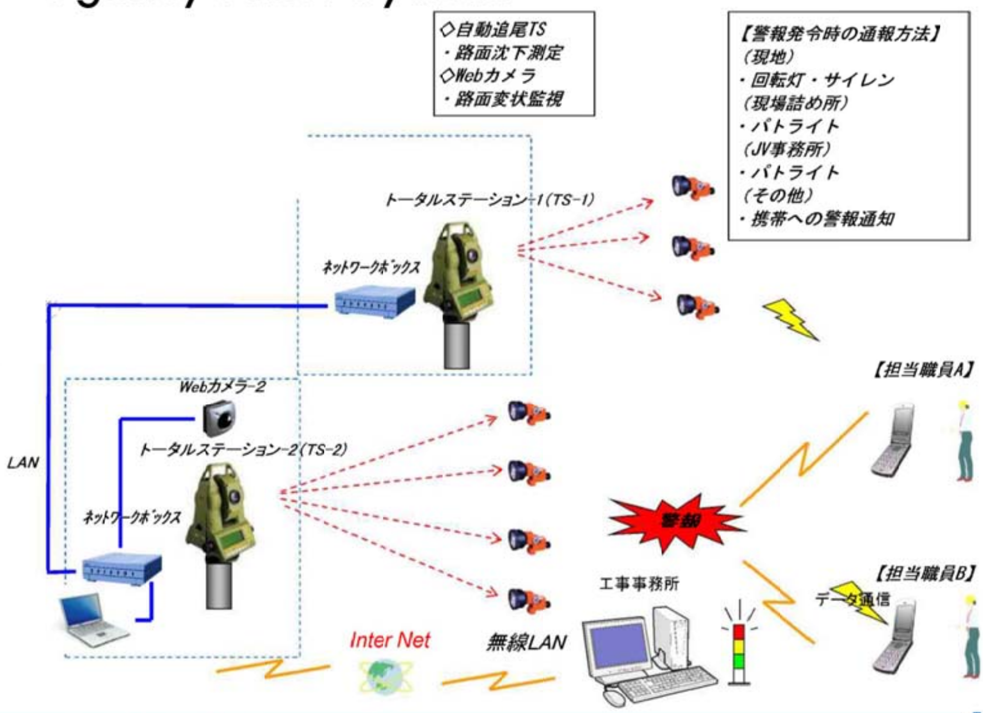
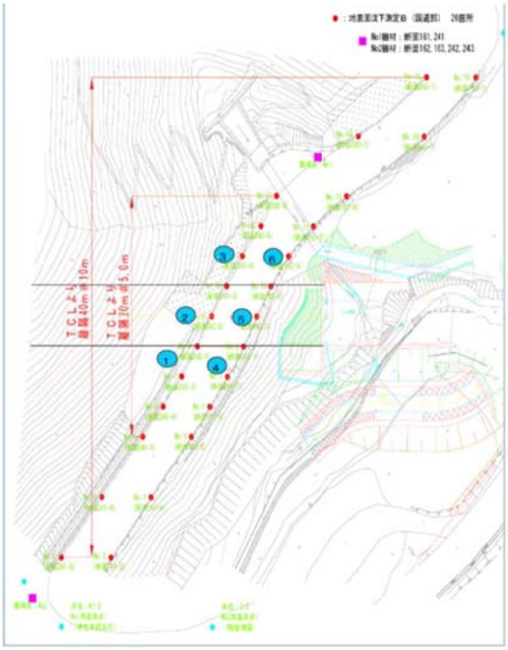
Practice 3 Kurio Bypass Tunnel

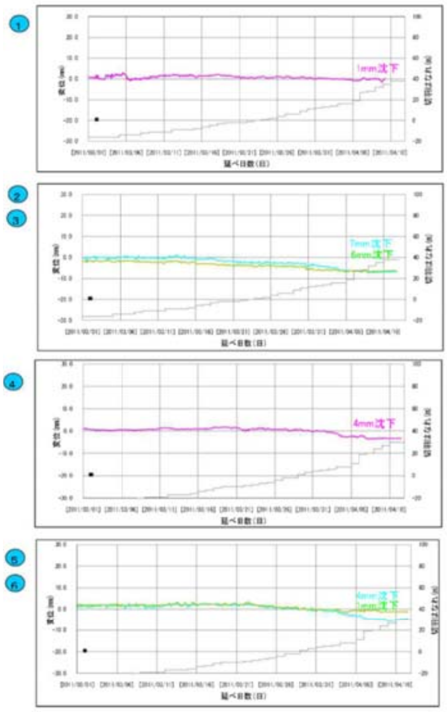
➢ Emergency Alert System



Practice 3 Kurio Bypass Tunnel

Monitoring Plan and Results

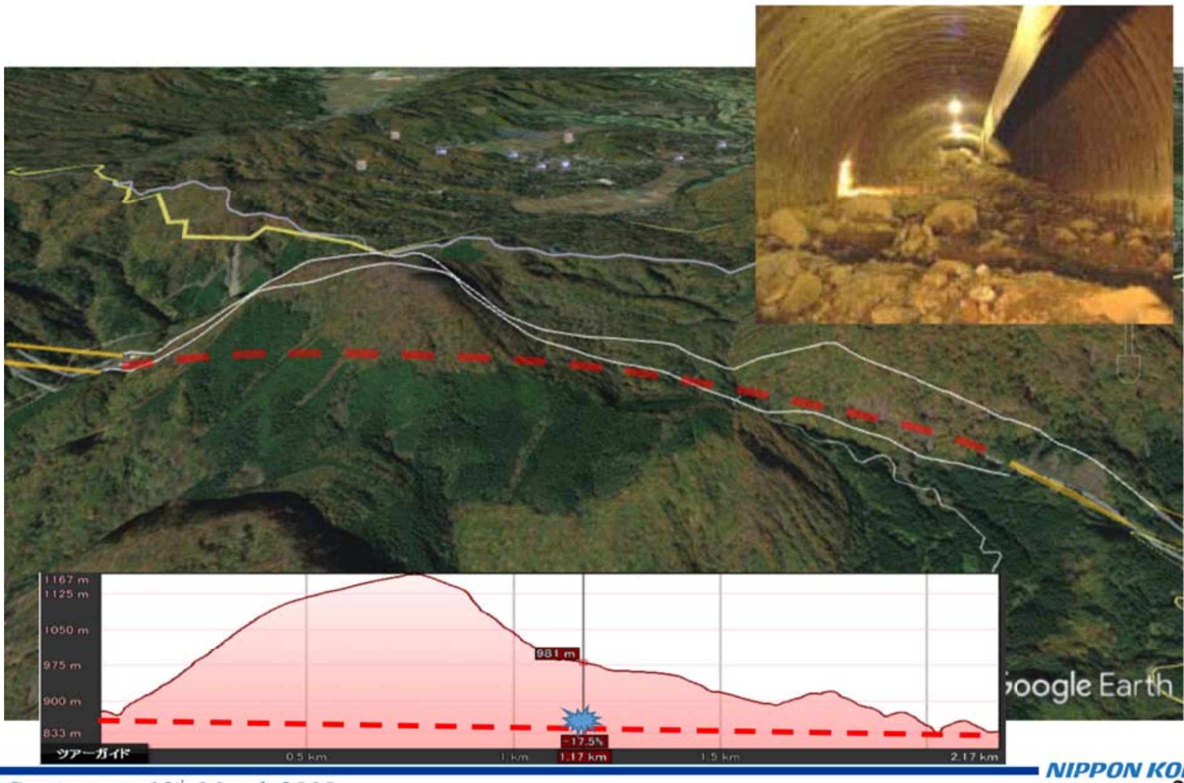




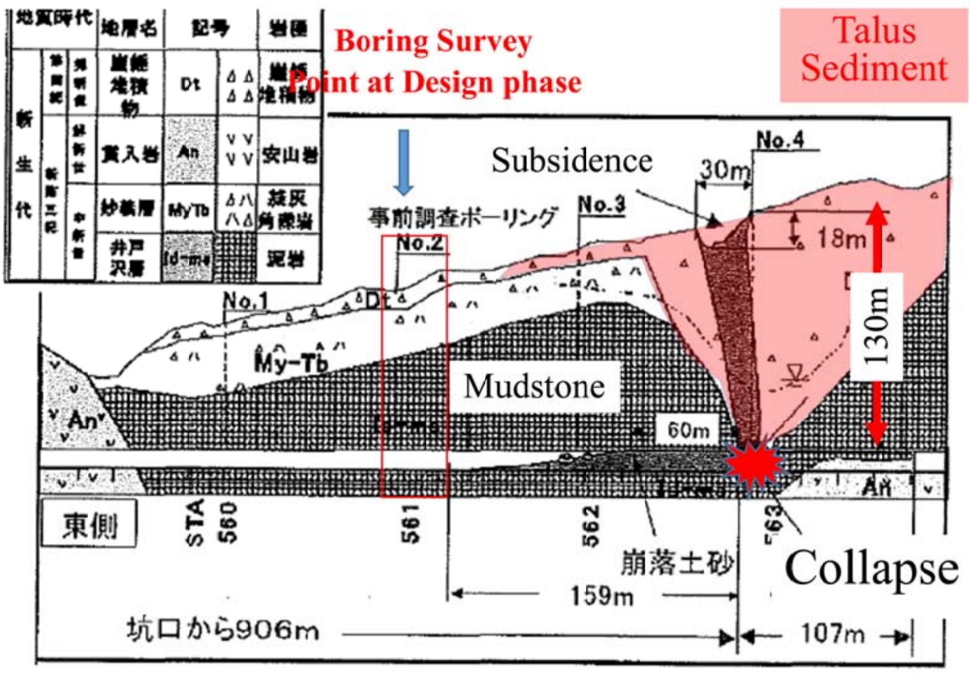
Practice 4 Nikkureyama Tunnel

- Highway Tunnel in Gunma, Japan
- Const. Period 2007 – 2011
- 2.1km in total, Width 10m
- Const. Method: NATM
- Geo: Mudstone, Talus sediment
- Overburden 130m

Practice 4 Nikkureyama Tunnel

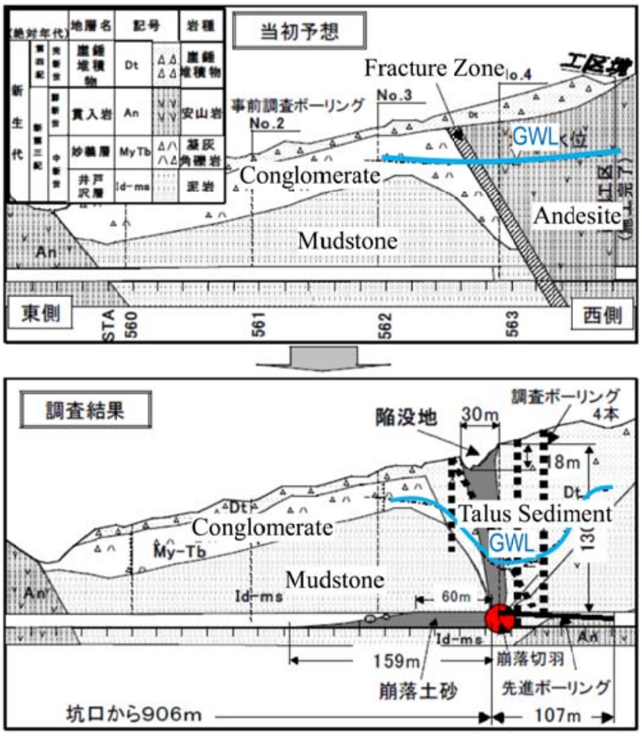


Practice 4 Nikkureyama Tunnel



Practice 4 Nikkureyama Tunnel

- The Cause: Existing of Talus sediment and High G.W.L.
- The large Talus sediment was not identified before construction



Other Serious Incidents

Fukuoka Metro Tunnel

- Railway Tunnel, NATM

Source: Asahi.com

W27m x L30m x D15m

Source: MLIT Report

Consideration

High Risk Geological Condition;

- Unconsolidated Soil, Rock Stratum
- Thin Overburden
- High Groundwater Pressure

Cause of the accidents

- Wrong Assumption of geological condition before construction
- Over-reliance on technology

Consideration

For Decreasing the risks

- Careful consideration before planning of Geo Investigation
- Careful observation and consideration based on obtaining results
- Careful study, estimation of the behavior of the ground
- Appropriate auxiliary method

Geological Uncertainty remains definitely

- Monitoring and safety management
- Emergency action plan

Colombia

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Advisor for Strengthening for ANLA Institutional Capacity on the Tunnel Sector

Japanese Practices related to Hydrogeology

12 March 2018

Hydrogeology Engineer
Masako TERAMOTO

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Today's Presentation

- Introduce Japanese successful case on Environmental Impact Study for Hydro-Environmental risks due to Tunnel Construction Project.
- Hydro-Environmental study includes Hydrogeology as well as Geology, Hydrology and Water Quality.

Hydro-Environmental Study and Analysis

Case : "K Tunnel" in Japan

NIPPON KOEI

Revision 0 (March 2018)

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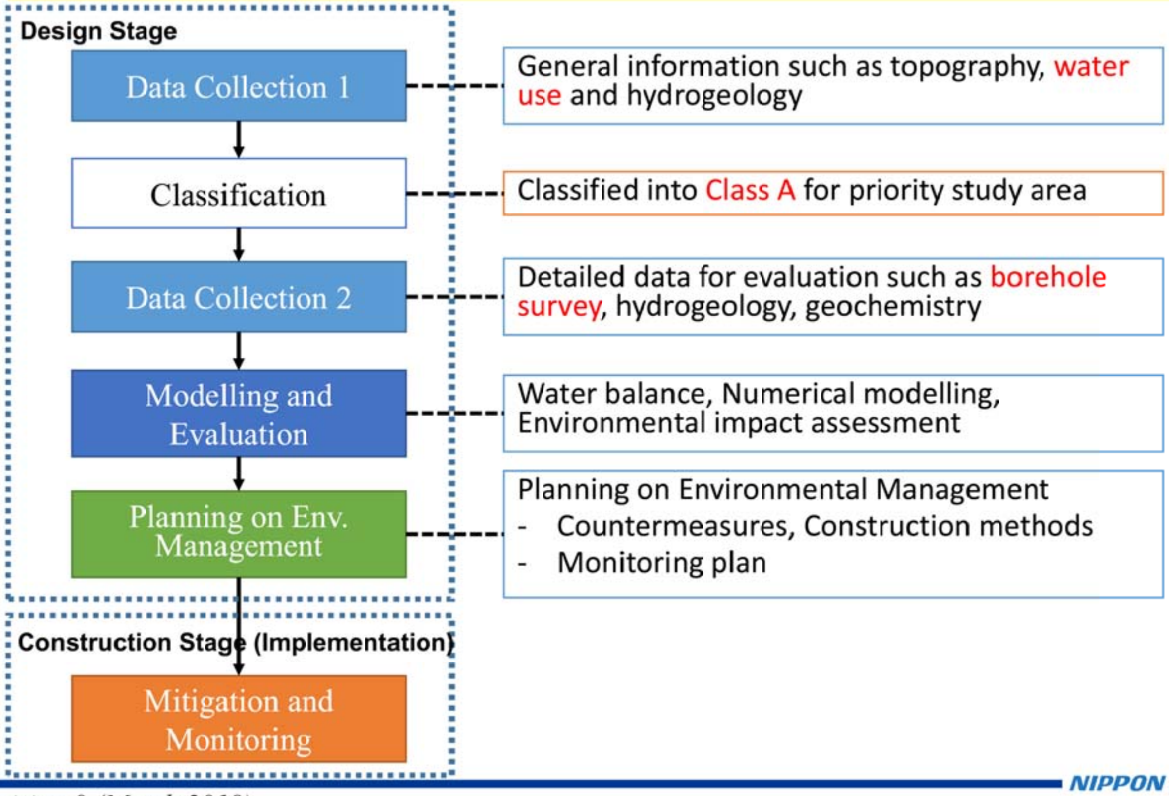
1. Environmental Concerns in "K Tunnel" Project
2. Method of Hydro-Environmental Study and Analysis
3. Data Collection
4. Numerical flow analysis and Impact assessment
5. Conclusion

1. Environmental Concerns in "K Tunnel" Project

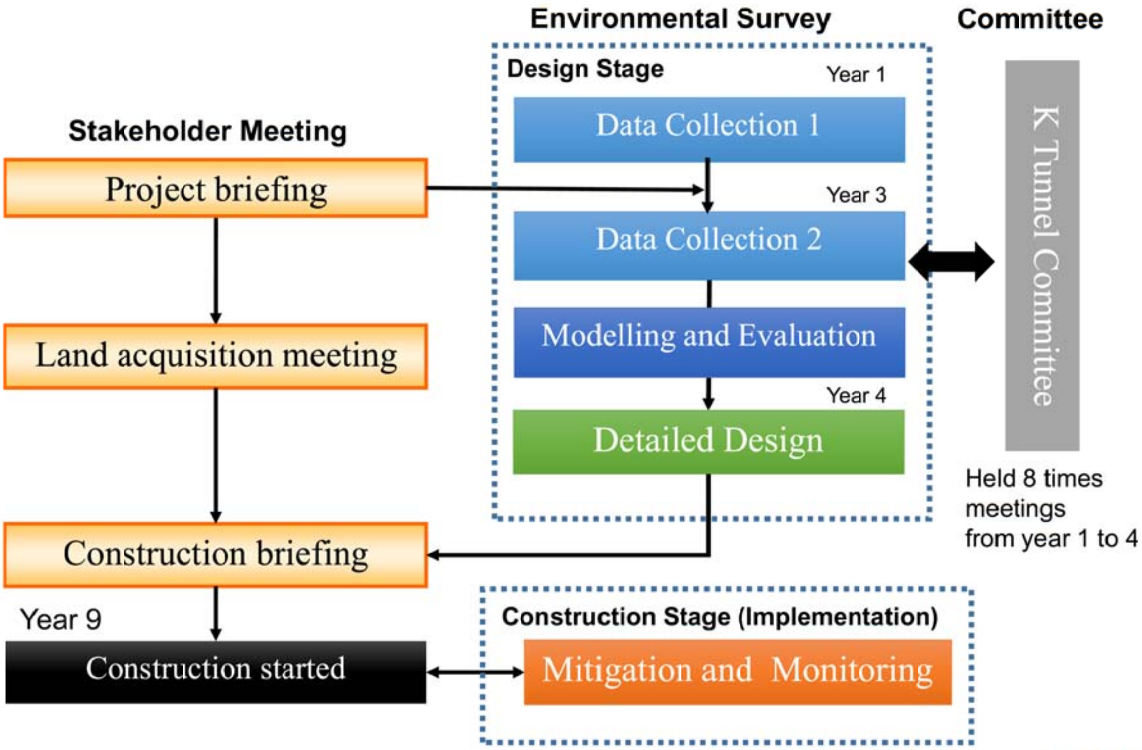
"K Tunnel" construction was planned under an alluvial fan where abundant groundwater is stored and used by residents and agriculture. Therefore, there were some concerns about the environmental risks on the existing groundwater resources during the tunnel construction.

2. Method of Hydro-Environmental Study and Analysis

1.Procedure of Hydro-Environmental Study for EIA



2. Project Workflow - Study and Stakeholder Meeting



3. Identification of Area of Influence and Classification of Investigation Method

I. Impact on Hydrological Environment

High Risk

1) Impact on **water wells** located in alluvial fan around the tunnel
>> Depletion, groundwater decline

2) Impact on **surface water** around the tunnel
>>Depletion, discharge reduction, influence on fauna and flora

Low Risk

3) Impact on the water supply resource
4) Land subsidence

II. Impact on Tunnel Construction

High Risk

1) Encounter confined groundwater inflows from faults
2) Encounter confined groundwater inflows from alluvial deposit and land movement

※ I and II are two sides of the same coin → Efficient construction method and mitigation measures are needed to manage those risks

4.Flow of Hydro-Environmental Study (Design stage)

Data Collecting 1 and 2

① Hydrological survey
- Hydrological environment survey
- Water budget survey
- Hydrogeological survey

① Hydrological survey

Collect necessary hydrological information and build the model for infiltration flow simulation

Modelling and Evaluation

② Numerical flow analysis
- Modelling of current situation
- Simulation after construction completed

③Impact assessment
- permissible level of groundwater decline
- Results comparison

② Numerical flow analysis
③ Impact assessment

Assess the impact on environment quantitatively by use of groundwater simulation

Planning Environmental Management

④ Mitigation measures
- Environmental consideration
- Secure tunnel construction

④ Construction method discussion

Based on the results of impact assessment, proper and environment-friendly construction method, as well as the design and construction plan will be discussed

5.Flow of Hydro-Environmental Study (Construction stage)

Monitoring

① Hydrological monitoring

- Groundwater level, river flow, water quality

Update analysis and re-evaluation

② Update numerical flow analysis

- Re-analysis if construction method and schedule changed
- Model revision for reflecting the actual water level change

③ Well survey

- Confirm the location of screening and pump

④ Impact assessment

- Monitoring results evaluation
- Relationship between well structure and groundwater level

Reflect to plan

⑤ Reflect to construction and compensation

- Information of setting water tight section
- Information of water well compensation

① Hydrological monitoring

Monitoring of hydrological environment during construction

② Update Numerical flow analysis

Re-analysis if construction method and schedule are revised. Improve and update the model by use of monitoring data.

③ Water well survey

Well structure information

④ Impact assessment

Impact assessment based on monitoring data

Evaluate the relationship between well structure and groundwater level

⑤ Reflect to construction and compensation

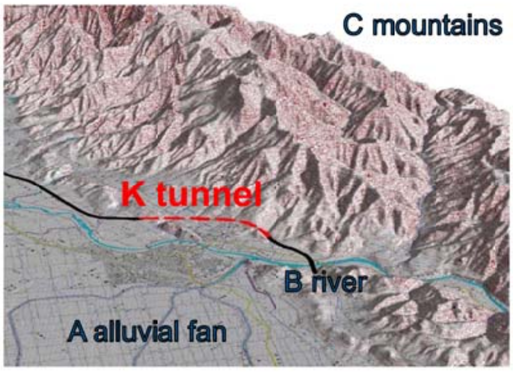
Information of setting water tight section.
Information of water well compensation.

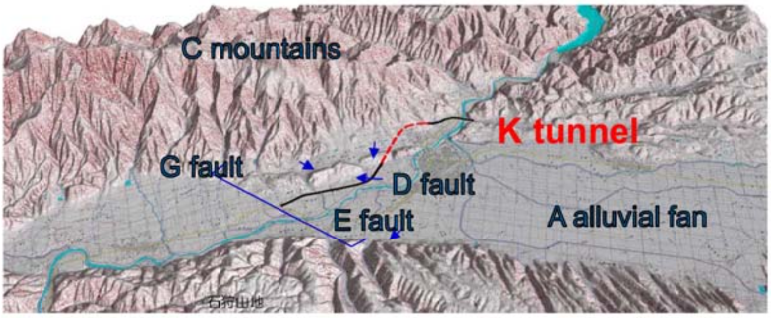
3.Data Collection

1. Topography (1/2)

【Overview of topography】

- A alluvial fan with plenty of groundwater
- Hill area is used for resort land and farmland
- K Tunnel passes through the "D fault"
- Alluvial area is surrounded by active faults (E and G)



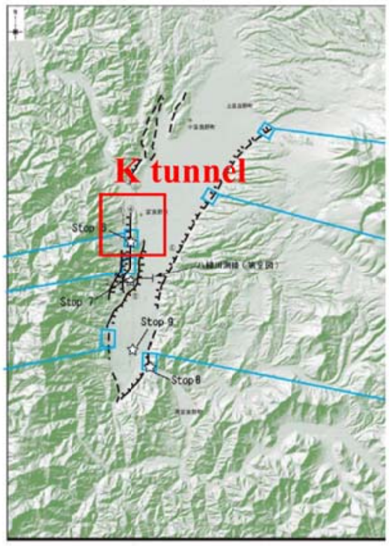


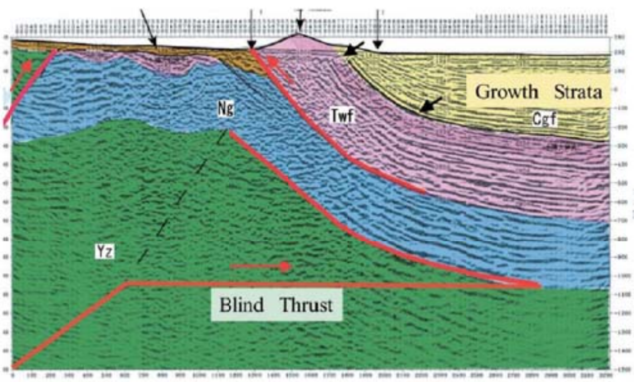
Bird's eye view

Advisor for Strengthening for ANLA Institutional Capacity on the Tunnel Sector

1. Topography (2/2)

【Reflection seismic survey for D Fault】
The reflection seismic survey results show that the boundary of geologic stratum are easy to be defined, and the geological composition and structure are distinctly different between the river side and mountain side of fault.

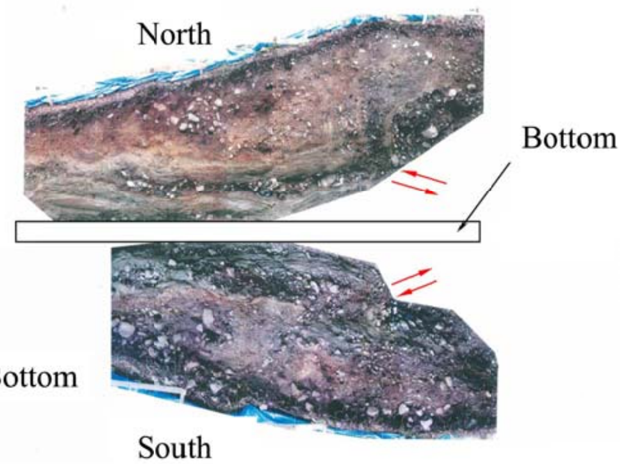


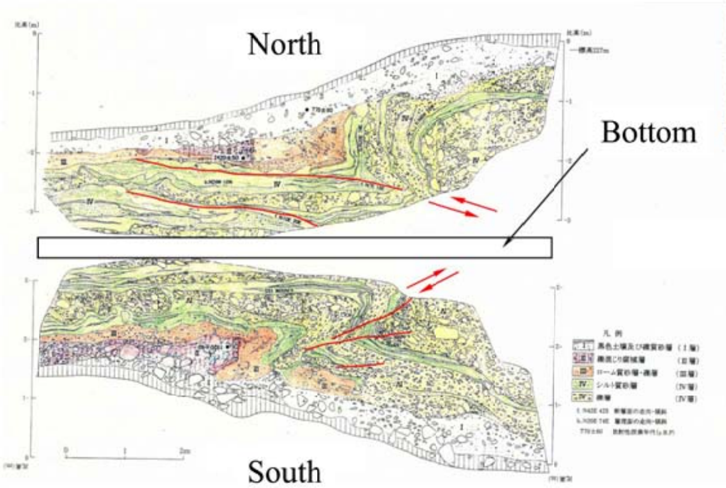


Cross section of Reflection Seismic

2. Geology - faults

- The activity cycle of D Fault is about 8,000 years, and the latest activity is about 1,600 years ago.
(Yeas to next activity: 8000-1600=5400 years)





Trench Survey

2. Geology - boring survey

Hygh Permeability

Quaternary: Alluvial deposits

Quaternary: Alluvial deposits

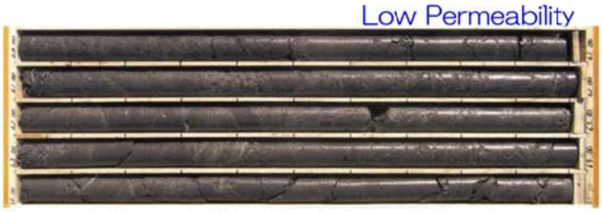
Quaternary: Alluvial deposits

High Permeability

Fractures

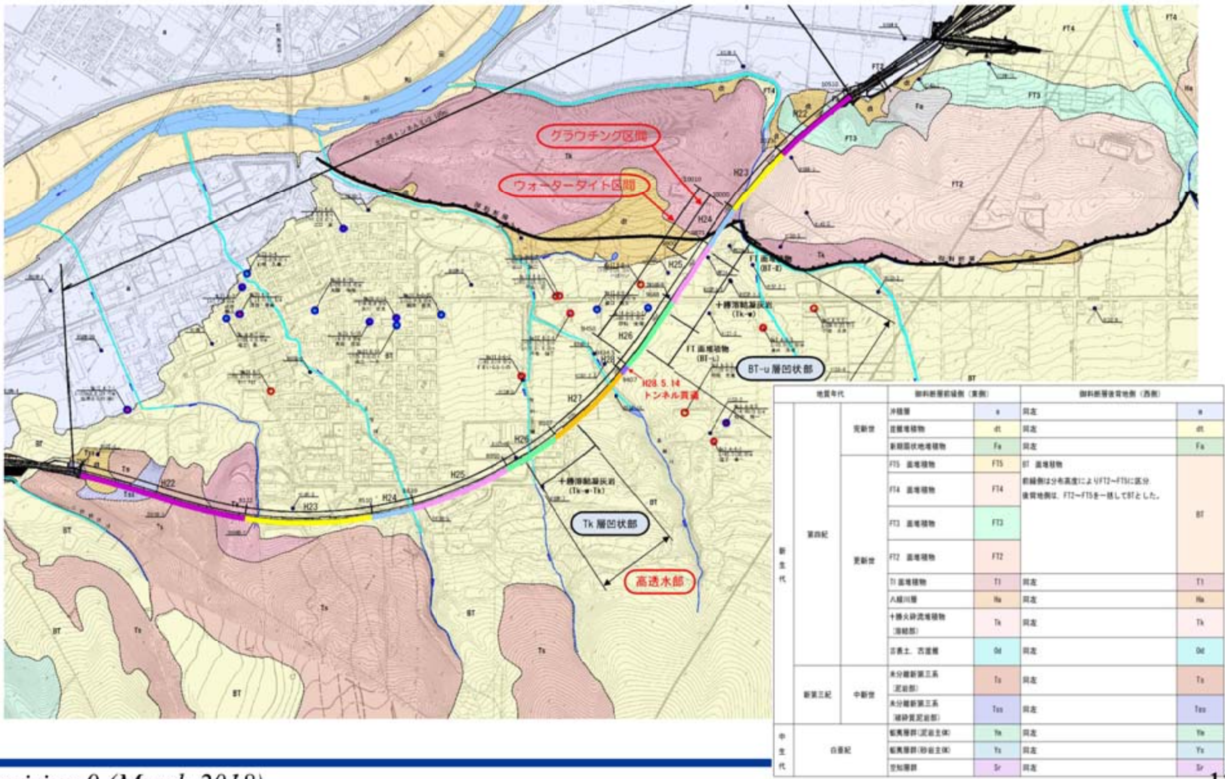
Quaternary: Pyroclastic flow

Low Permeability

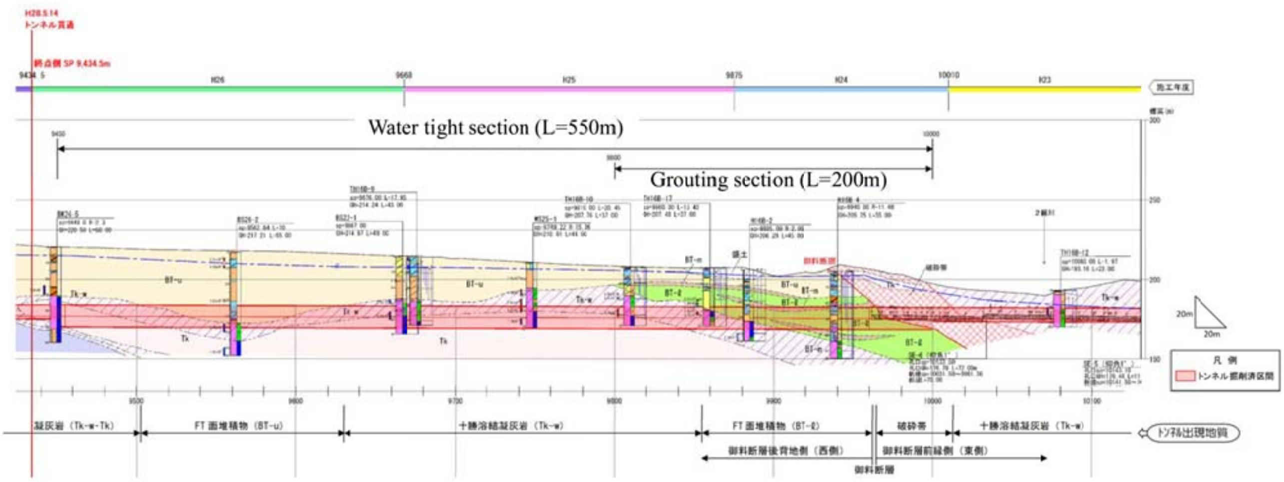


Basement : Tertiary Mudstone

2. Geology – planimetric study



2. Geology – profile study

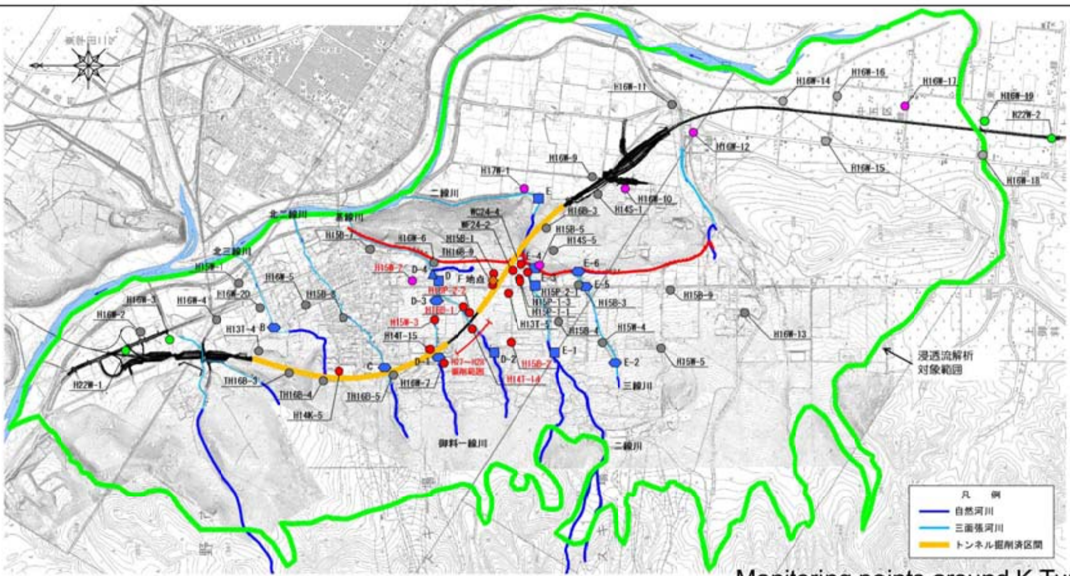


Cross section of Tunnel Profile

3. Hydrology – planimetric study

Hydrological monitoring has been carried out to investigate the influence of tunnel Excavation.

(1) River flow rate; (2) Groundwater level; (3) Soil water; (4) Water quality



Monitoring points around K Tunnel

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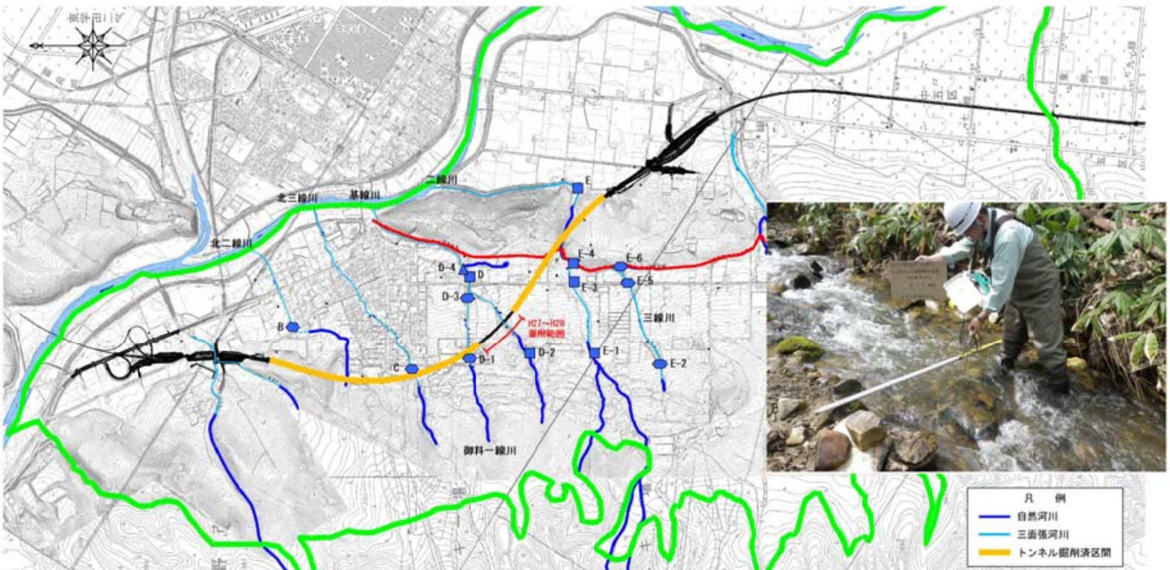
3. Hydrology - river flow rate monitoring

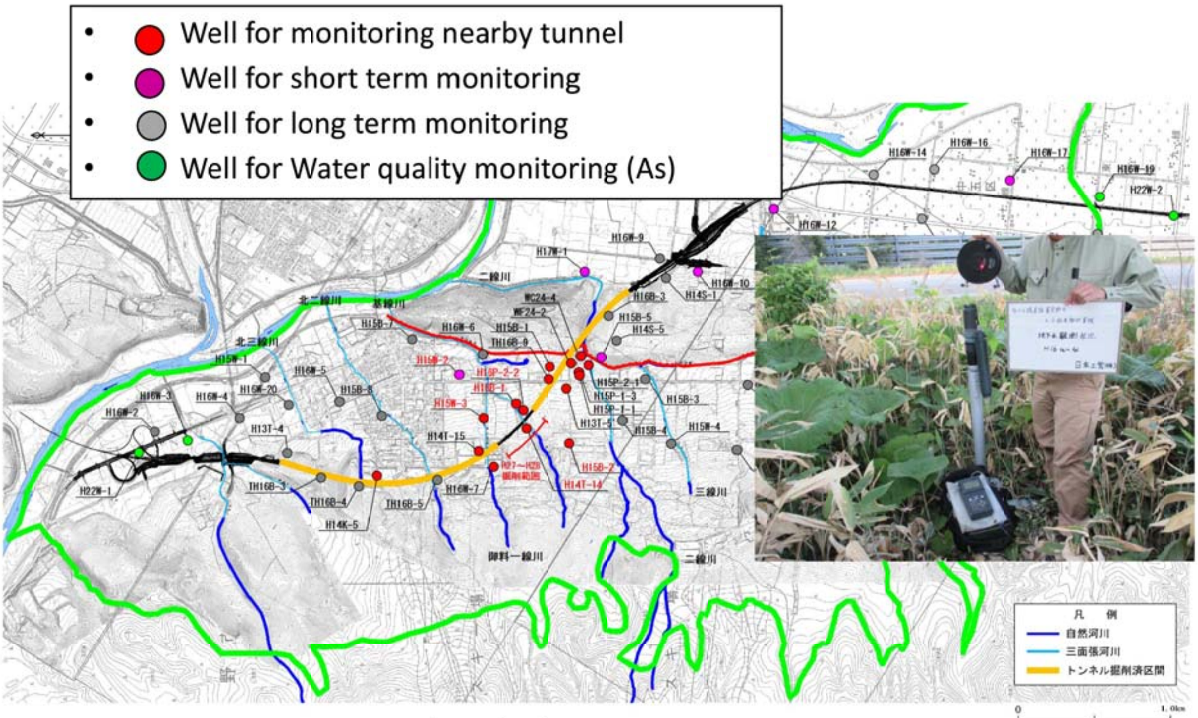
14 stations for 6 streams. Monitoring once per month for 1 year.



River flow rate observation points

4. Hydrogeology - groundwater monitoring (1/2)

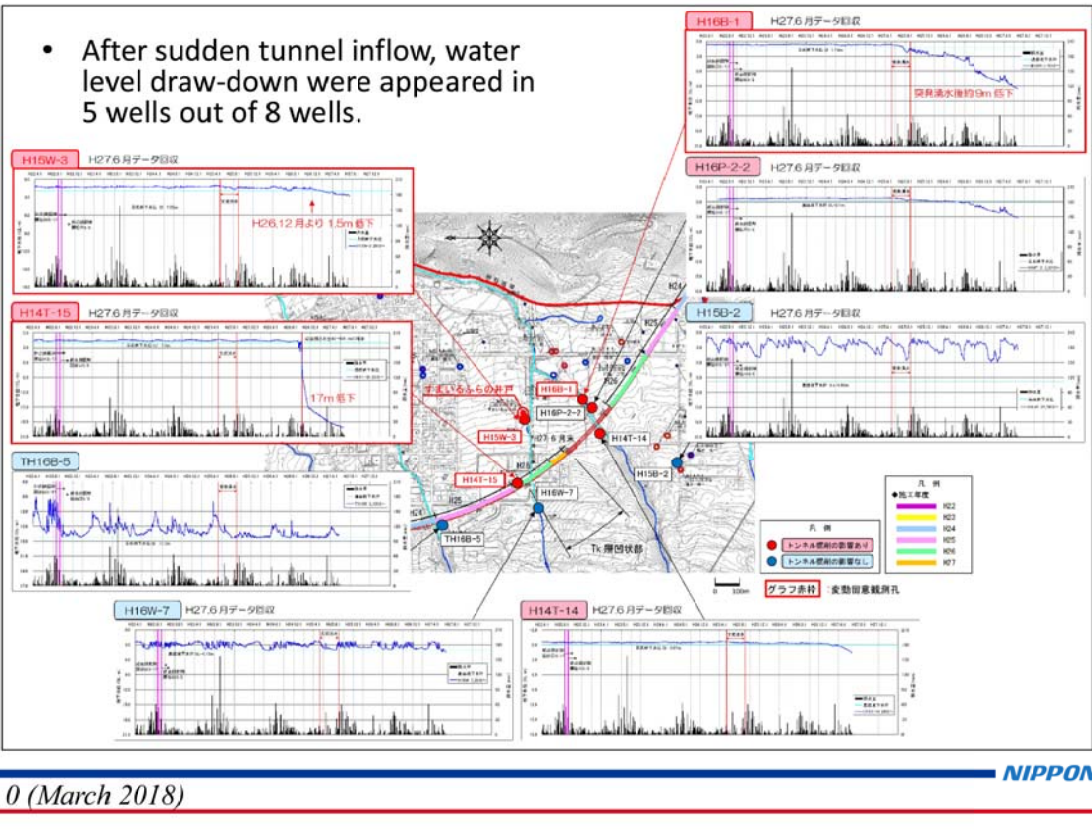
- Well for monitoring nearby tunnel
- Well for short term monitoring
- Well for long term monitoring
- Well for Water quality monitoring (As)



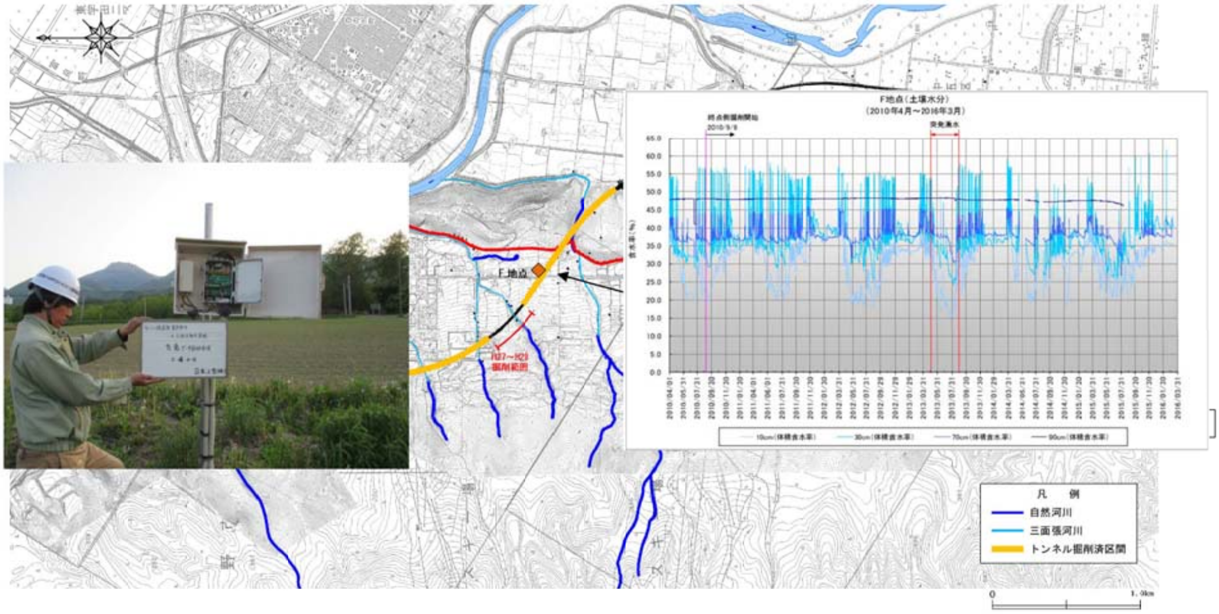
Groundwater level monitoring points

4. Hydrogeology - groundwater monitoring (2/2)

- After sudden tunnel inflow, water level draw-down were appeared in 5 wells out of 8 wells.



4. Hydrogeology – surface water level monitoring



Soil water monitoring results

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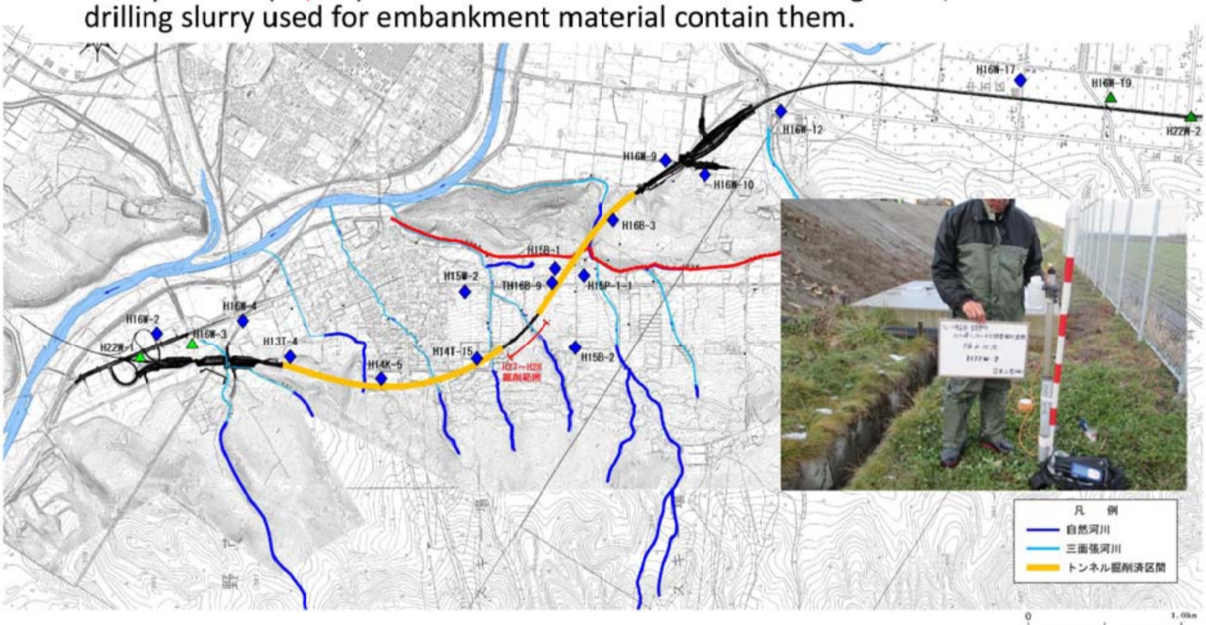
5. Water quality – survey and monitoring

- Water quality monitoring has been carried out to collect necessary information used for evaluation of influence of groundwater level decline on water quality.
- Heavy metals (As, Pb) started to be measured as monitoring items, because of the drilling slurry used for embankment material contain them.



Water quality monitoring points

4. Numerical flow analysis and Impact assessment

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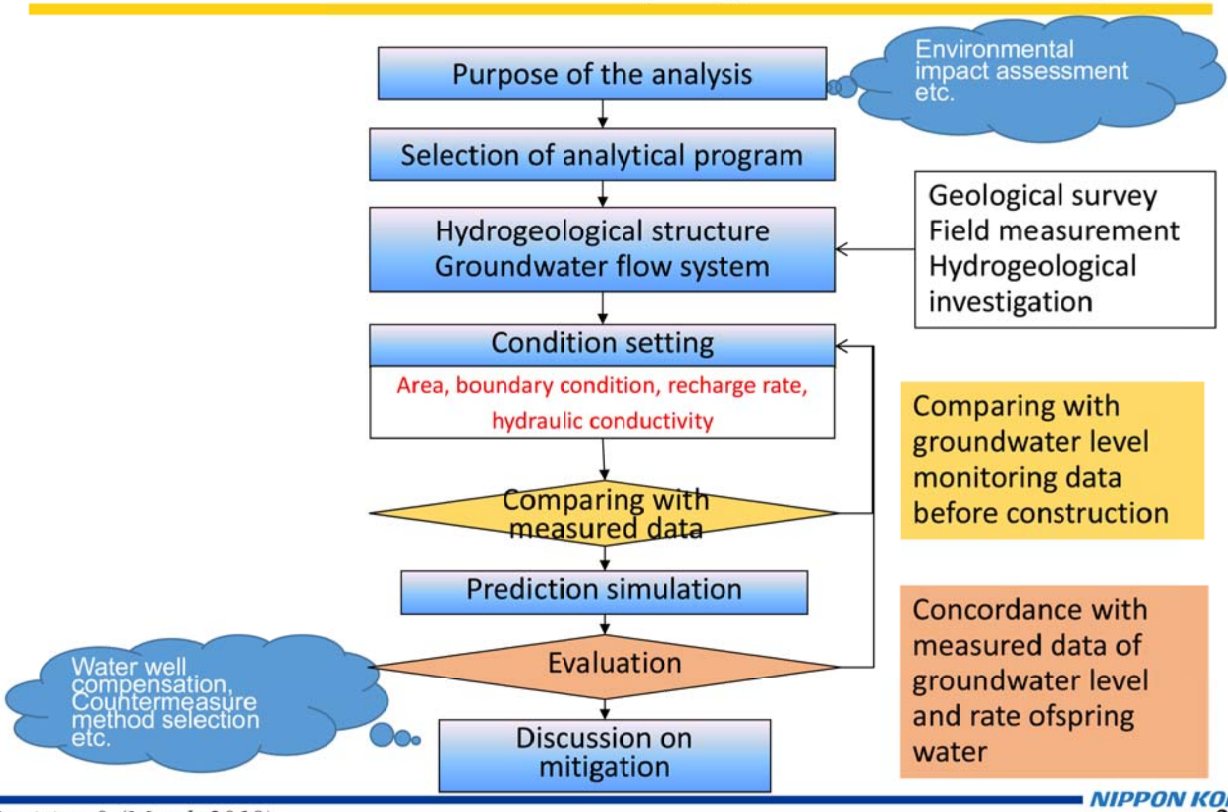
1.Law of Groundwater Flow

Groundwater flow is…

(1) Groundwater flows from high potential to low potential
(2) Described by Darcy's law
(3) Established by the law of conservation of mass

2.Procedure of Seepage flow analysis



3.Two Methods of Seepage flow analysis

・Seepage flow analysis is based on the governing equations combining the physical law of groundwater flow (Darcy's law) and law of conservation of mass. Calculated by either finite difference method (FDM) or finite element method (FEM).

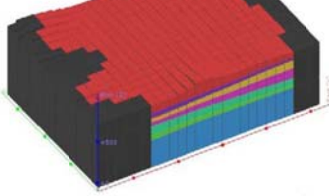
・FDM divides the analysis area into small blocks, and calculate the storage or flow between the blocks.

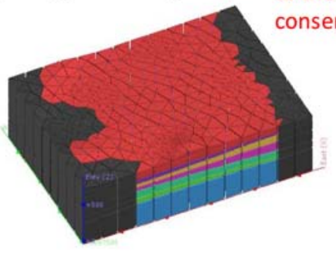
・FEM divides the analysis area into small elements or grid points, and calculate the value of water head (groundwater potential) which is the optimal solution satisfying the boundary conditions.

・The governing equations is as follow. Precipitation and pumping rate are included in [W]

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})-W=S_s\frac{\partial h}{\partial t}$$

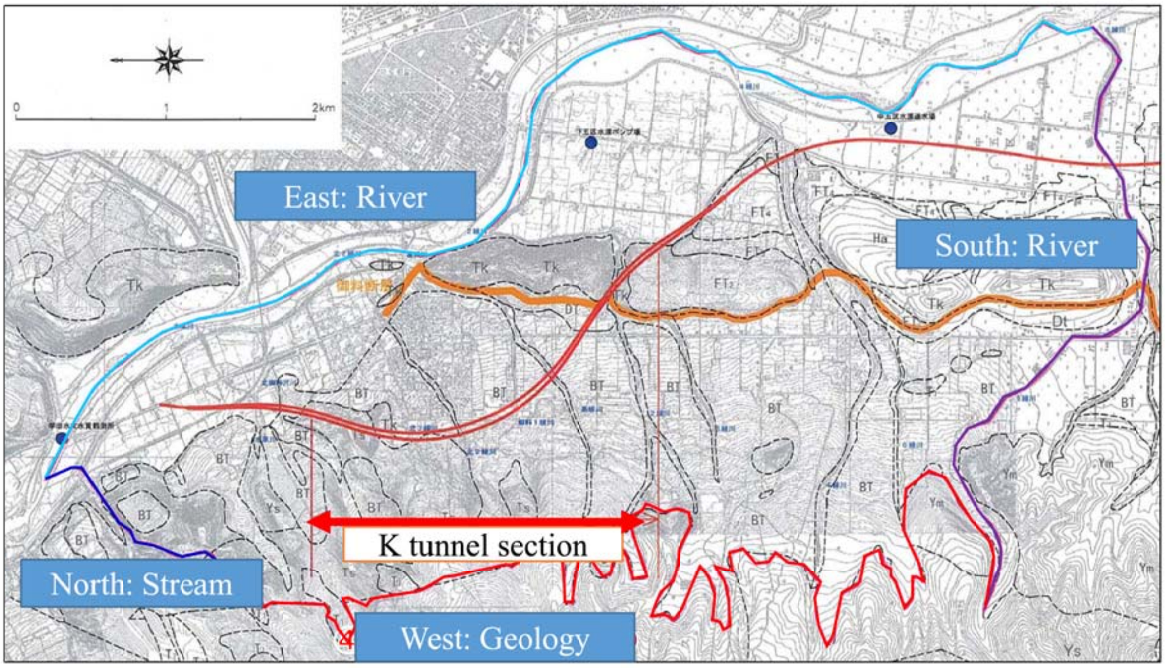
⇦ Darcy's law subjects to the law of conservation of mass


3D FDM model


3D FEM model

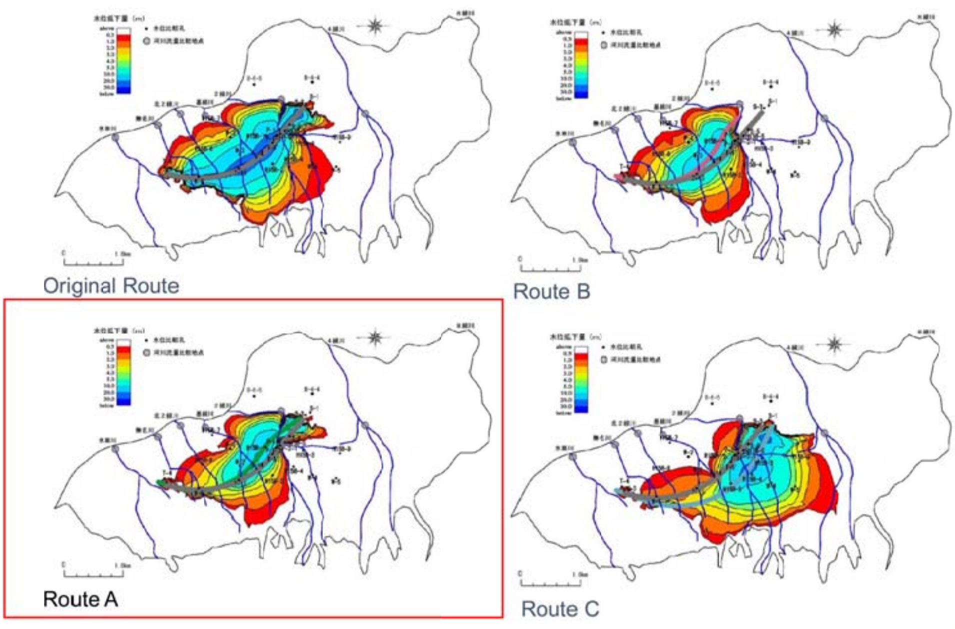
4.Boundary of Numerical Model

・River, Stream and Geological boundary are set as boundaries.



5.Simulation of groundwater drawdown

- By using Numerical Model, hydro-environmental influence is evaluated.
- Simulation result is used for selection of route and designing of mitigation measures and setting of water tight section.



6.Update numerical model and re-evaluation

Numerical model had been updated several times and simulated to re-evaluate.

- Design stage:
  - To adjust model of groundwater drawdown to observation (poor reproducibility)
- Construction stage:
  - Revise the model with additional survey data
  - Verify new construction plan (water tight section)
  - To adjust model of groundwater inflow to observation
  - To evaluate the cost down based on practice
  - etc…

5. Conclusion

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Japanese Practices Related to Tunnel Blasting Vibration

12 March 2018

Shinji & Hikaru TANAKA

NIPPON KOEI CO., LTD

Japan's No.1 International Engineering Consultants

http://www.n-koei.co.jp/english/

◇ Fundamentals of Blast Vibration

1. Vibration Subject to Item of EIA Study
2. Characteristics of Blast Vibration
3. Forecasting Model for Blast Vibration
4. Mitigation Measures of Blast Vibration

◇ Actual Practices in Japan

1. Tamagawa Tunnel
2. Kiyotani-Ikoma Road

Fundamentals of Blast Vibration

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Vibration to Be Item of EIA Study

1) Construction machinery induced vibration

- In Japan, this vibration is the main item of EIA study.

2) Rock blasting induced vibration

- In Colombia, this is the main issue. (Bogotá-Villavicencio road)

Characteristics of Blast Vibration

	Blast Vibration (B)	Earthquake (EQ)
Frequency	**10 – 200 Hz**	1 – 5 Hz
Duration	within 1 sec.	some sec. to some min.
Influential Range	hundreds of meters	hundreds of kilo meters

Vibration of high frequency is affected more by attenuation

1) Influence area of blast vibration is limited.

2) Frequency of B vibration is far higher than that of EQ.

Forecasting Model for Blast Vibration

1) Forecasting model

For estimating the influence of blast vibration on buildings, Peak Particle Velocity (PPV) below is used.

$$V = K \times W^m \times D^n$$

PPV | constant | **Amount of blast powder per explosion** | Distance

V: PPV(cm/sec)

D(m): Distance from blasting point to the observed point

W(kg): Amount of the blast powder per one delayed explosion

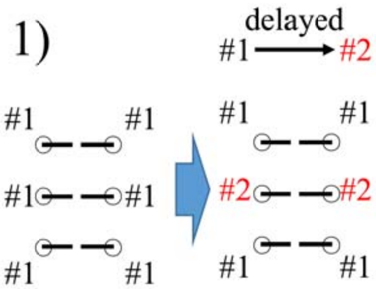
K: Site constant

The parameter "m" is generally 0.5 to 1.0 and "n" is approximately -2.

Mitigation Measures of Blast Vibration

1) Delayed detonator
2) Supplementary plough wedge V cutting
3) Tunnel excavation rate

1)

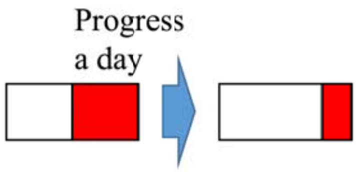


Decrease the amount of blast powder per explosion

2)

Change cutting method

3)



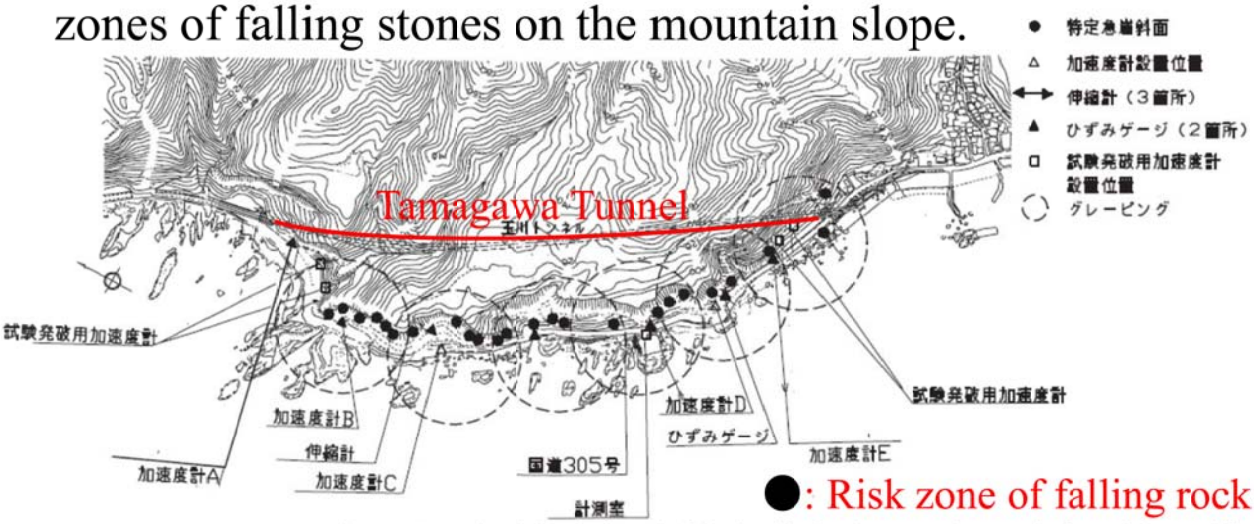
Decrease the speed of excavation

Actual Practices in Japan

Tamagawa Tunnel

1) Situation

The blast vibration caused by the construction of the tunnel has to be controlled because there are many risk zones of falling stones on the mountain slope.



Source: T.Amari, etal (2011), Control of blasting vibration due to tunnel excavation for rock slope stability

Tamagawa Tunnel

2) Mitigation measure

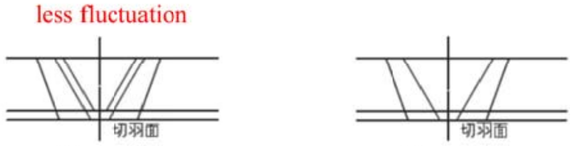
① K value (site constant) was estimated by test blasting.

(This time, m and n values are fixed as ¾ and 2.0 respectively.)

② The control limit was set as a half of the regulation limit, because PPV of blast vibration fluctuates by geological conditions.

③ W cutting was applied for decreasing the fluctuation of PPV of blast vibration.

less fluctuation



W cutting V cutting

Impact of blast vibration was controlled.
There were no falling stones.

Kiyotani-Ikoma Road

1) Situation

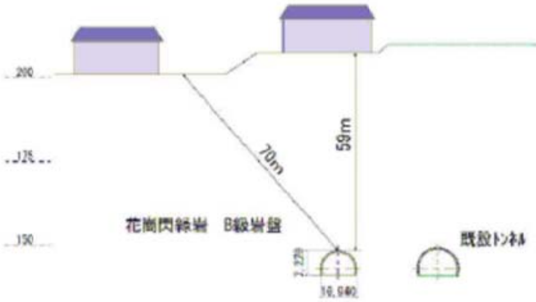
On "Kiyotaki-Ikoma Road" which is connecting between Osaka and Mie prefecture, there is mountainous section including 1,116m long mountain tunnel. On construction of this tunnel, it was required special consideration of blast vibration because of existing dwellings above the tunnel alignment.

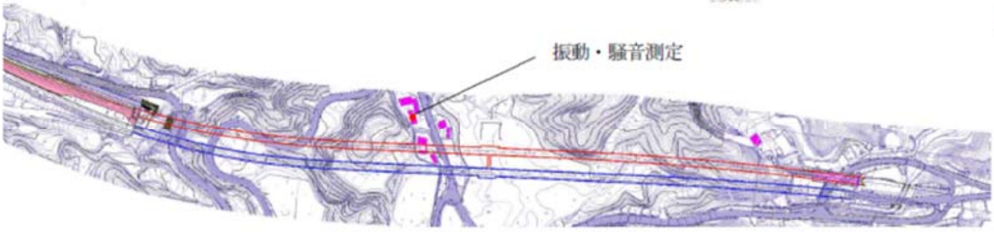
Geological conditions: Granite

Altitude : 300 – 400 m

Tunnel Length : 1,116m

Tunneling method : NATM



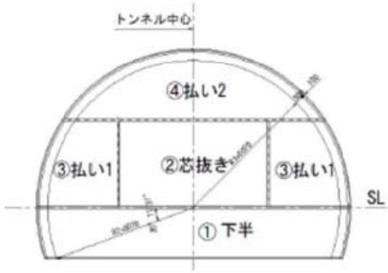


Kiyotani-Ikoma Road

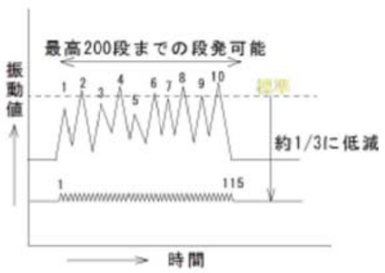
2-1) Basic mitigation measures

4 types of basic measures were considered.

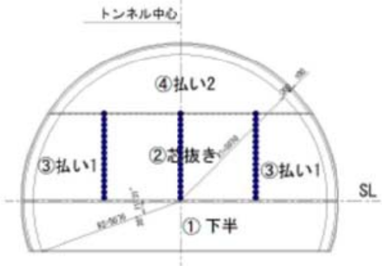
A. Dividing tunnel section into 4 areas for reducing amount of blasting powder
B. Reducing tunnel excavation rate for reducing blasting powder of 1 time blasting
C. Using Electronic Delay Detonator (EDD) for reducing blasting powder of 1 time blasting
D. Making supplemental bore hole / slit



A. Dividing tunnel section



C. Electronic Delay Detonator (EDD)



D. Supplemental blasting hole

Kiyotani-Ikoma Road

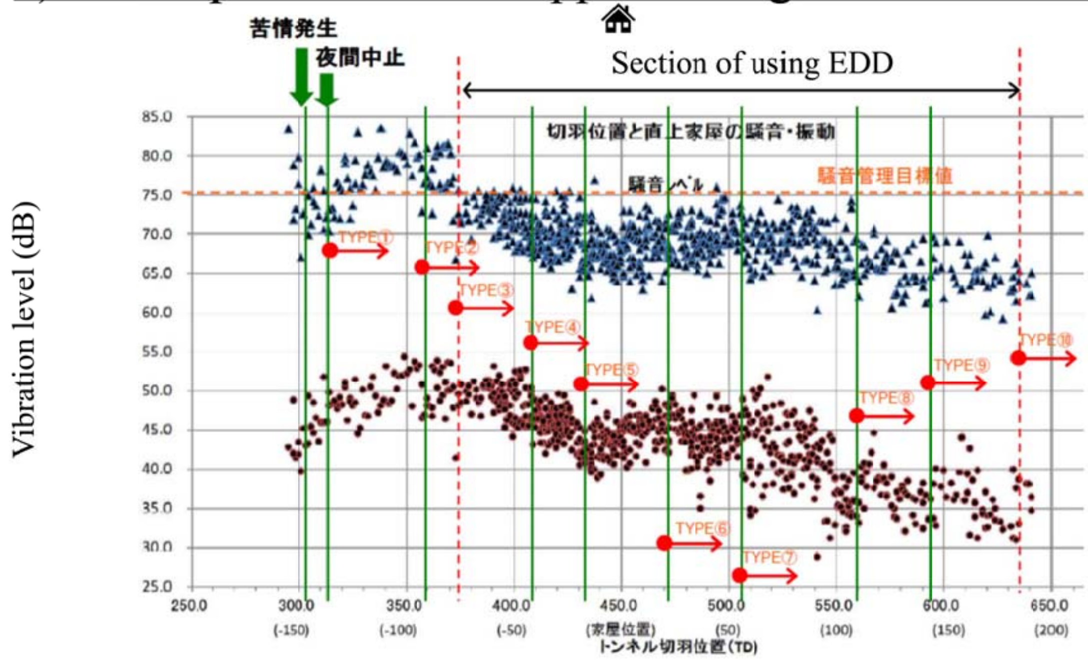
2-2) Combination of basic mitigation measures

For the actual tunnel blasting, the combination of basic mitigation measures were applied.

Type	C. Delayed Detonator	B. Reducing production rate	A. Dividing tunnel section	D. Using supplemental blasting hole
1	MS/DS detonator	1.2m	No dividing	NA
2	MS/DS detonator	1.2m	Divide into 3 sections	NA
3	EDD	0.8m	Divide into 3 sections	NA
4	EDD	0.6m	Divide into 4 sections	Bore hole
5	EDD	0.75m	Divide into 4 sections	Making slit
6	EDD	1.0m	Divide into 4 sections	Making slit
7	EDD	1.1m	Divide into 4 sections	Making slit
8	EDD	1.2m	Divide into 4 sections	Making slit
9	EDD	1.2m	Divide into 3 sections	Making slit
10	EDD	1.2m	Divide into 2 sections	Making slit

Kiyotani-Ikoma Road

3) Actual performance of applied mitigation measures



Colombia

NIPPON KOEI

Advisor for Strengthening for ANLA Institutional Capacity on the Tunnel Sector

Tunnel Auxiliary Method in Japan

12-13 March 2018

Tunnel Construction Specialist
Wako NOTO

NIPPON KOEI CO., LTD
Japan's No.1 International Engineering Consultants
http://www.n-koei.co.jp/english/

Outline

1. General
2. Example of Occurrence of Water leaking and Subsidence in Japan
3. Auxiliary Method in Japan

1. General

1.1 General

An auxiliary method is a construction method of a secondary or special nature adopted to ensure face stability and tunnel safety and to preserve the environmental in cases where either conventional support patterns or division of heading section don’t provide effective solution or where they are not advantageous.

1.2 Objectives

The major objectives of auxiliary methods;

(1) Ensuring safety of tunneling (face stabilization and measures against water inflow)

(2) Preservation of the environment (groundwater measures, countermeasures against surface settlement and measures to prevent adverse impact on neighboring structures).

2. Example of Occurrence of Water leaking and Subsidence in Japan

2.1 Conditions where the occurrence of water leaking is concerned

Water leaking occurs under the following three conditions.

a) Fault fracture zone

b) Unconsolidated ground

c) Ground where high water pressure or much ground water is anticipated

2.2 Example of water leaking in tunnel construction

Water leaking from fault fracture zone of Mizuho tunnel

2.3 Cause and mechanism of Subsidence occurrence

Cause and mechanism of Subsidence occurrence is shown the following three conditions.

a) Stress release of ground by excavation

b) Variation of groundwater

- Immediate settlement in the sandy grounds
- Consolidation settlement in the cohesive soil grounds.

c) Tunnel construction

by such as looseness of ground due to the deformation of support or excavation.

2.4 Example of Subsidence by Tunnel Construction

Road subsidence collapse accident in Hakata

3. Auxiliary Method in Japan

3.1 General of Auxiliary Method

a) History of auxiliary method

Year	Support	Groundwater measures	Subsidence measures
Before 1960	Wooden Support	・Drainage drift Human power excavation	・Only by the tunnel construction method
1960	Steel arch Support	・Drainage boring	・Only by the tunnel construction method
1975	NATM Shotcrete and Rock-bolt	・Well point, Deep well, Grouting, Cut-off wall	・Forepoling(filling, grouting), Face shotcrete, Face bolt, Long face bolt, Temporary invert, Footing reinforcement bolt, Footing reinforcement pile, Steel pipe forepiling(grouting),
after 2000	NATM New Support TBM	・Watertight tunnel	・Horizontal jet grouting (injection and mixing), Slit concrete method, Vertical pre-reinforcement, Pipe roof, Neo AGF

Auxiliary method developed with NATM

3.1 General of Auxiliary Method (continued)

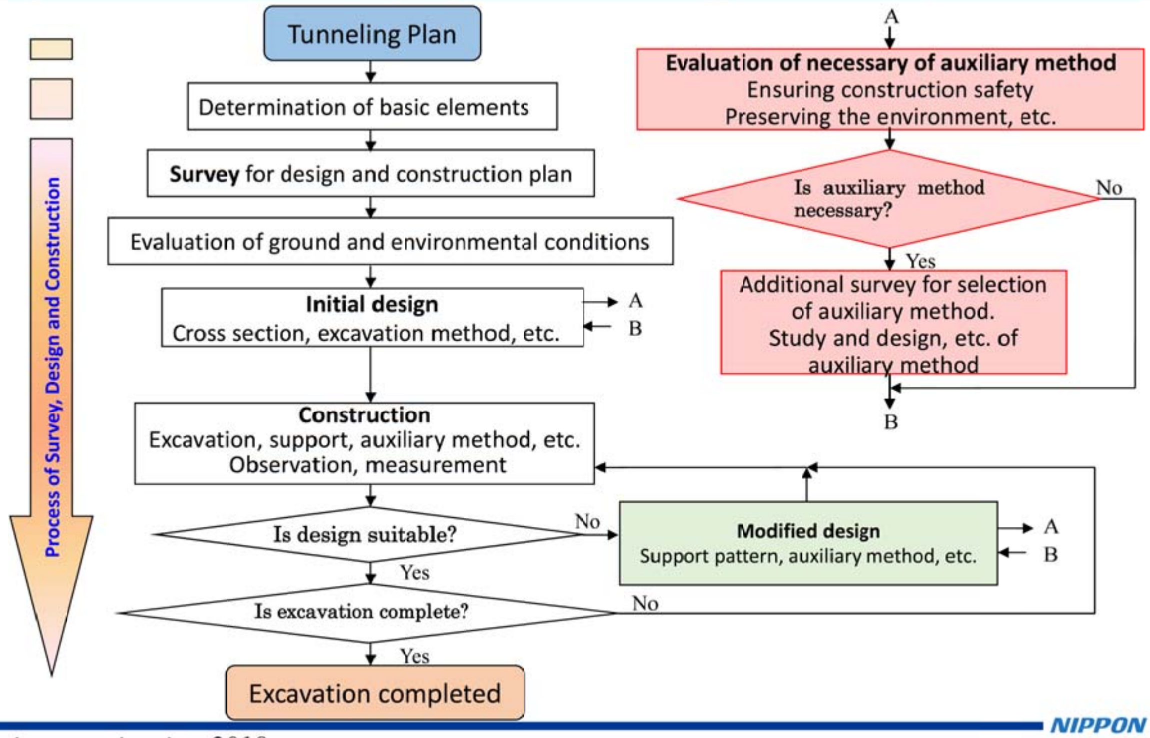
b) Process for application of auxiliary method

- In case where it is deemed realistic to apply an auxiliary method in the original design, appropriate methods shall be selected by evaluating the ground conditions, environmental conditions and construction method. ← Input survey result during design

- In case where auxiliary method is judged necessary during the tunnel excavation, an appropriate auxiliary method shall be selected after evaluating the tunnel safety, environmental impact, effectiveness, economic efficiency and compatibility with the tunneling method. ← Input survey result during excavation

3.1 General of Auxiliary Method (continued)

c) Flow of tunnel project focusing auxiliary method



3.1 General of Auxiliary Method (continued)

d) Selection of auxiliary method

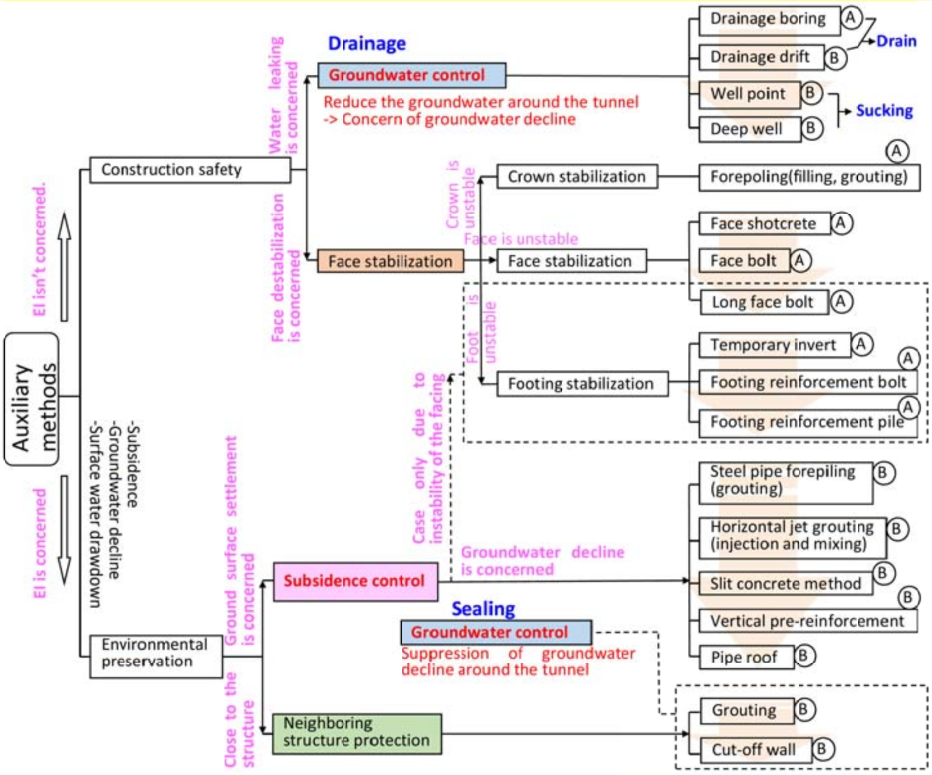
An auxiliary methods are classified into broad categories according to their objectives: face stabilization, groundwater measures, subsidence measures and measures for neighboring structures.

Auxiliary methods should be selected in terms of safety, effects and cost performance, evaluating the conditions ahead to the face, the face itself and behind the face, on the basis of comprehensive study, always involving latest available technological information.

3.1 General of Auxiliary Method (continued)

Method				Purpose: Construction safety – Face stabilization: Crown stabilization	Face stabilization	Footing stabilization	Groundwater control		Environmental preservation: Subsidence control	Neighboring structure protection	Ground which method can be applied: Hard rock	Soft rock	Soil
Face / Subsidence control	Presupport		Forepoling (filling, grouting)	X							X	X	X
Subsidence control	Presupport		Steel pipe forepiling (grouting)	X					X	X		X	X
Subsidence control	Presupport		Pipe roof	X					X	X		X	X
Subsidence control	Presupport		Horizontal jet grouting (injection and mixing)	X	X	X			X	X			X
Subsidence control	Presupport		Slit concrete method	X					X	X		X	X
Face	Face reinforcement		Face shotcrete		X						X	X	X
Face	Face reinforcement		Face bolt		X						X	X	X
Subsidence control	Face reinforcement		Long face bolt		X				X		X	X	X
Subsidence control	Footing reinforcement		Footing reinforcement bolt			X			X			X	X
Subsidence control	Footing reinforcement		Footing reinforcement pile			X			X			X	X
Subsidence control	Footing reinforcement		Temporary invert			X			X			X	X
	Groundwater control	Drainage	Drainage boring	X	X	X	X				X	X	X
	Groundwater control	Drainage	Well point	X	X	X	X						X
	Groundwater control	Drainage	Deep well	X	X	X	X						X
	Groundwater control	Drainage	Drainage drift	X	X	X	X				X	X	X
Subsidence control	Groundwater control	Water searing	Grouting	X	X	X	X	X	X	X	X	X	X
Subsidence control	Groundwater control	Water searing	Cut-off wall				X	X	X	X			X
Subsidence control	Ground reinforcement		Grouting	X	X				X	X			X
Subsidence control	Ground reinforcement		Vertical pre-reinforcement	X	X				X				X

3.1 General of Auxiliary Method (continued)



3.2 Necessity of Auxiliary Method

Face stabilization

➢Face stabilization: The mountain tunneling methods is predicated on the stability of the cutting face and the tunnel crown until the supports have been built. In case where the cutting face is unable to stand itself until the completion of the placement of the support because of the ground conditions, it is necessary to take appropriate face stabilization measures to ensure safe and efficient construction.

3.2 Necessity of Auxiliary Method (continued)

Ground water control

➢Water leaking control: When water flows is anticipated to flow into the tunnel through the face excavation, the inflow ground water need to be drained to stabilize the face and improve construction efficiency. However, caution should be exercised if water leaking is to be controlled, because it could results in surface collapse.

When the surrounding environmental might be affected including depletion of the groundwater, surface settlement caused by drainage is not permissible, the drainage measure can't be used.

The common auxiliary method applicable in such case is grouting. Grouting is the most reliable for stabilizing the face, which will reduce water leaking and discontinuous layers with sand intercalations where water drainage or weep holes are not effective.

3.2 Necessity of Auxiliary Method (continued)

Subsidence control

➢Surface settlement control: Surface settlement during the tunnel excavation could be related to several issues i.e. topographical and geological conditions, ground water condition, construction methods. Major causes of surface settlement can be loosening of ground induced by the tunnel excavation and discharge of the groundwater.

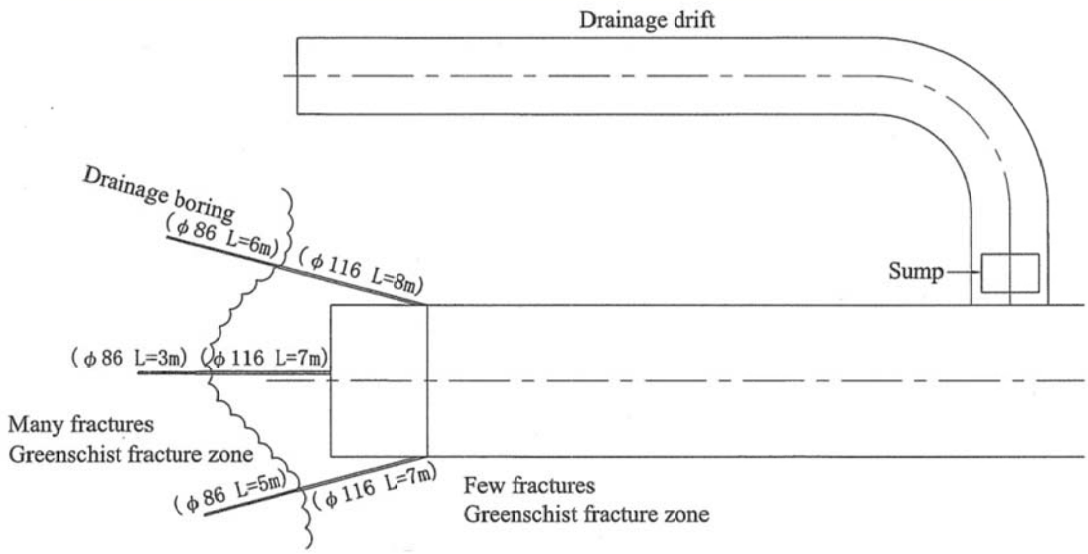
3.2 Necessity of Auxiliary Method (continued)

Protection of neighboring structures

➢Protection of neighboring structures: When tunnels are excavated in urban areas, sometimes there exists some surface structures, such as buildings and bridges, near to the excavation point. In such cases, appropriate auxiliary measures are taken to protect those structures.

3.3 Auxiliary Method for water leaking

a) Drainage boring and drift, Drainage method



Combined use of Drainage Drift and Drainage Boring

3.3 Auxiliary Method for water leaking (continued)

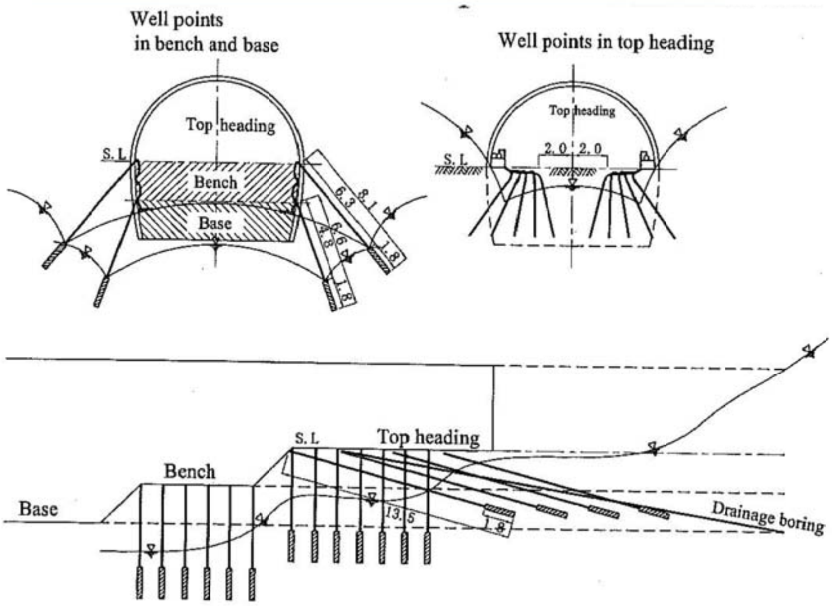
a) Drainage boring and drift, Drainage method

Drainage boring of Kanayama Gero Tunnel

Drainage Drift of Kanmuriyama Tunnel

3.3 Auxiliary Method for water leaking (continued)

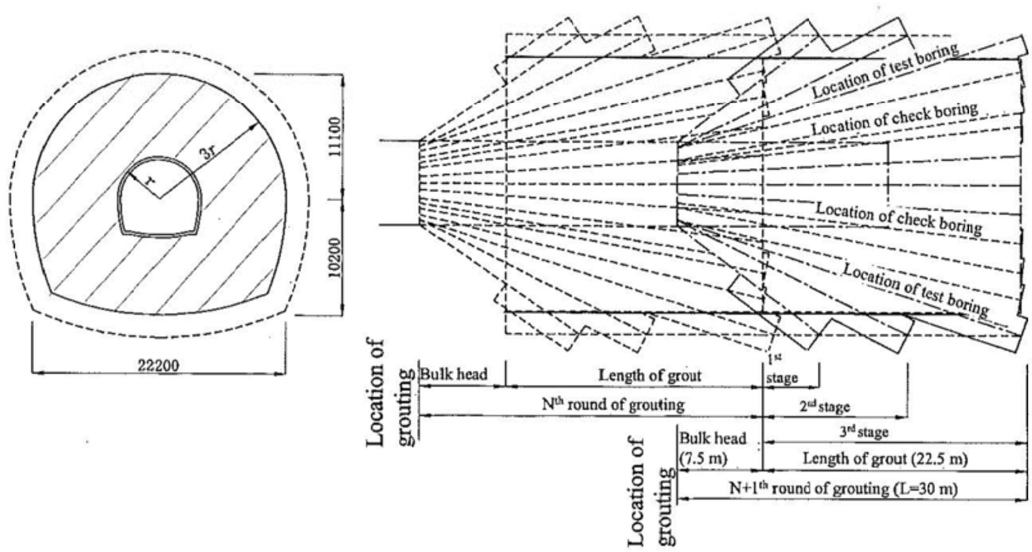
b) Well point drainage, Drainage method



Example of the well point from inside the Mugiuda tunnel

3.3 Auxiliary Method for water leaking (continued)

c) Water sealing methods, Water sealing method

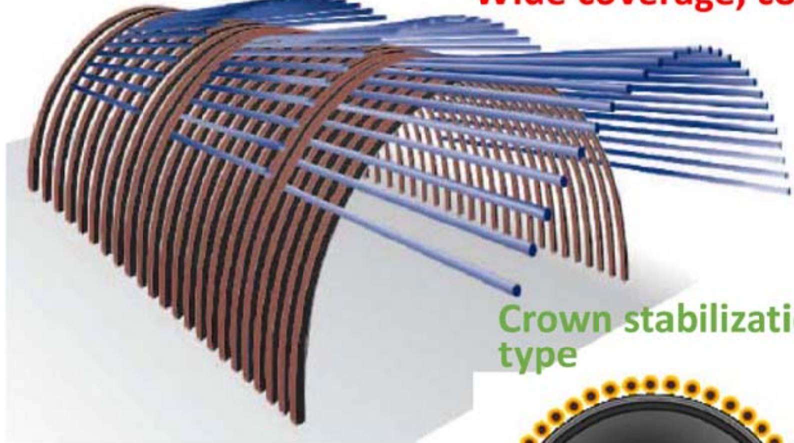


Example of the grouting from inside the Mugiuda tunnel

3.4 Auxiliary Method for subsidence

a) AGF (All Ground Fasten), Against subsidence

Wide coverage, cohesive soil - Hard rock



Long steel pipe L=12.5m

Crown stabilization type

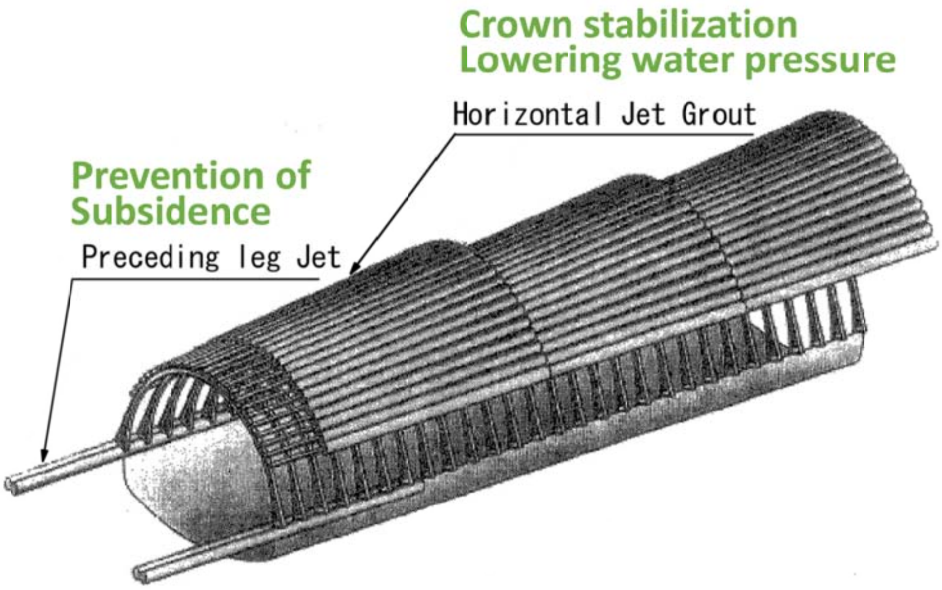
Prevention of deformation by fore-roof

Lowering water pressure type

Prevention of ground breakup with water flow

3.4 Auxiliary Method for subsidence (continued)

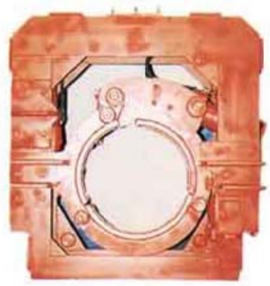
b) Horizontal jet grouting method, Against subsidence



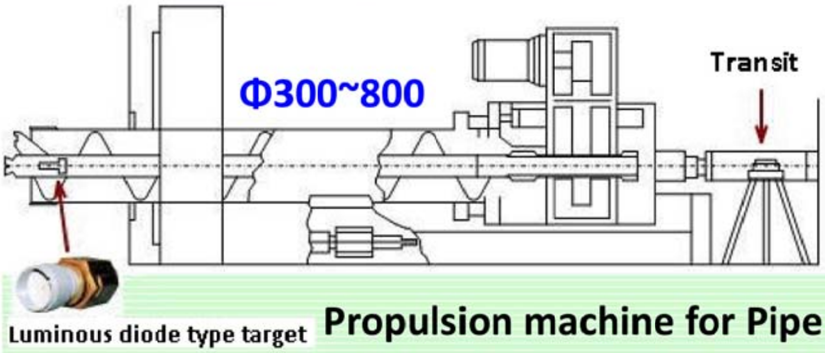
3.4 Auxiliary Method for subsidence (continued)

c) Pipe roof protection, Against subsidence

Target by LED type



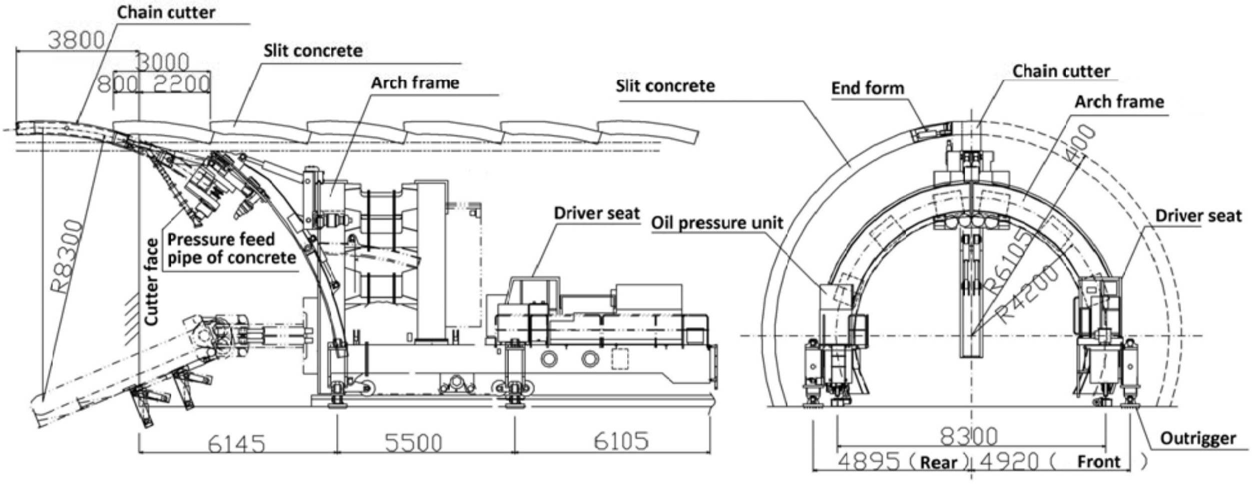
Directional correction equipment



Propulsion machine for Pipe roof

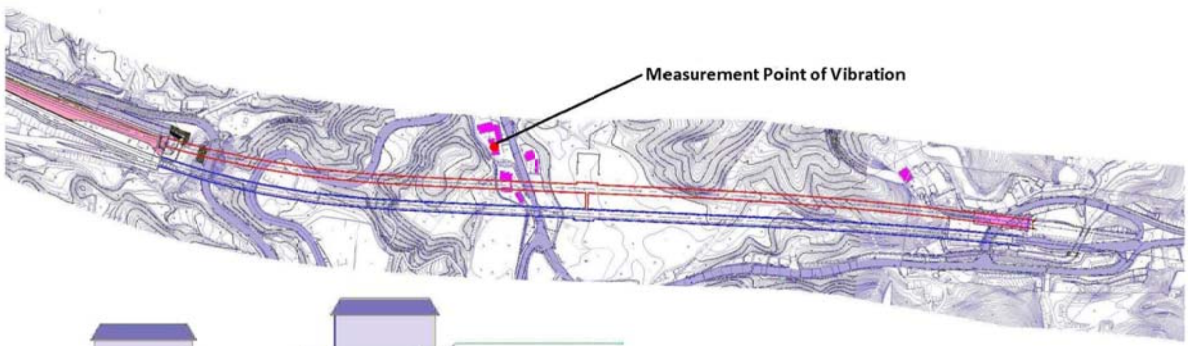
3.4 Auxiliary Method for subsidence (continued)

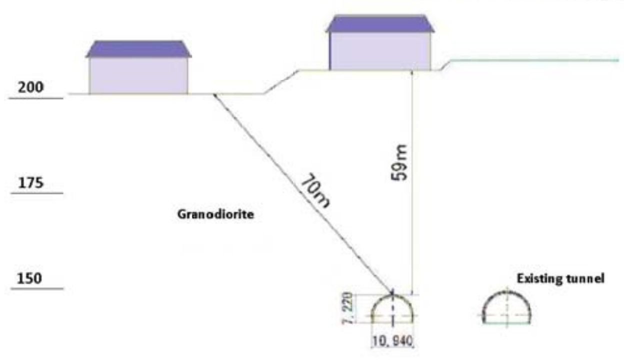
d) Slit concrete method, Against subsidence



3.5 Auxiliary Method for vibration

a) Measurement of Vibration



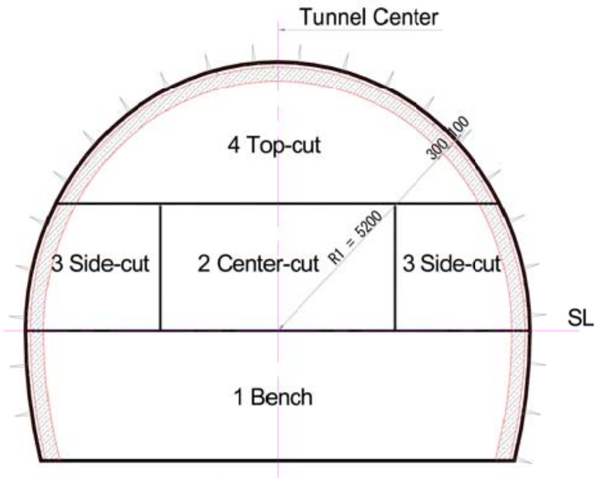


Measure the vibration at the point of houses above the tunnel.

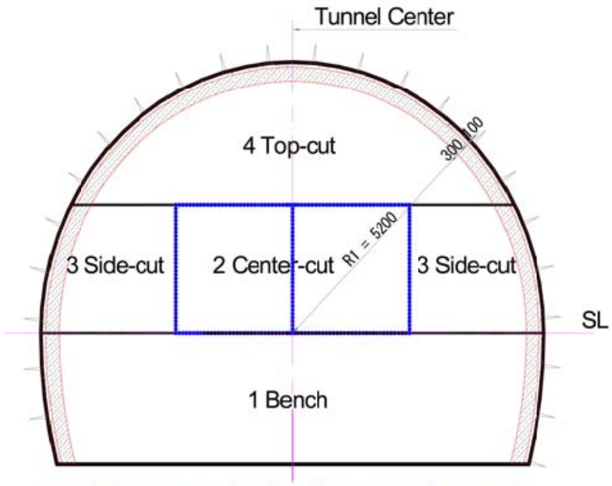
Monitor the vibration value for control value.

3.5 Auxiliary Method for vibration (continued)

b) Partial Blasting



Partial Blasting Section, 4 split



Additional Slit by Rock Drill

Sequence: 1 Bench →2 Center-cut →3 Side-cut 4 Top-cut

Muchas Gracias Por Su Atencion!