

ITA - AITES WORLD TUNNEL CONGRESS 2007 PRAGUE



The 3<sup>rd</sup> Training course  
**TUNNELLING IN URBAN AREA**  
Prague, 4-5<sup>th</sup> May 2007

# Monitoring of Tunnels in Urban Areas

TRAINING MATERIAL PREPARED BY

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ASSOCIATION  
INTERNATIONALE DES TRAVAUX  
EN SOUTERRAIN  
**AITES**



**ITA**  
INTERNATIONAL  
TUNNELLING  
ASSOCIATION



**1**

**Introduction**

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**2**

**Risk Management**

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**3**

**Monitoring**

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**4**

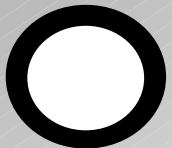
**Monitoring of Urban Tunnels, Examples**

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**5**

**Conclusions**

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# Systematic Monitoring as Part of Risk Management Can Prevent Catastrophic Failures



***Monitoring of Tunnels in Urban Areas***

# Risk Management Monitoring and Risk Management

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**Technical monitoring of tunnels provides methods and applications of measurements to control and observe entire construction projects.**

**The monitoring measurements are defined within the risk management process.**

**Therefore the following slides describe first the process of risk management and then the monitoring of tunnels in urban areas.**

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**Risk management is the systematic process of identifying, analyzing and responding to project risks.**

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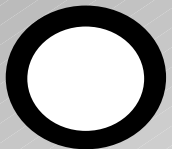
**Risk management is**

- **not only a single event**
- **a continuous process during the entire project.**

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**Therefore the risk control is part of the project life cycle from project initiation to project completion.**

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# Risk Management Steps

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Risk management consists of:

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- Risk Management Planning

- Risk Identification

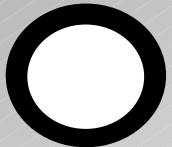
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- Risk Analysis

- Risk Responding

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- Risk Control

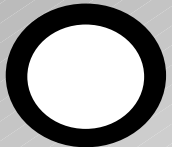


# Risk Management Flowchart

- 1
- 2
- 3
- 4
- 5



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# Risk Management Classifications According to ITA Guidelines

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## Probability of Occurance (Frequency)

- Very unlikely
- Unlikely
- Occasional
- Lokely
- Very likely

## Impact (Consequence)

- Insignificant
- Considerable
- Serious
- Severe
- Disastrous

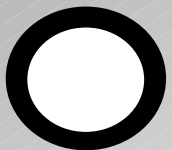
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The classifications can be defined according to the specific project.

(Quelle: Guidelines for tunnelling risk management: International Tunnelling Association, Working Group No. 2, Eskesen, S.D., Tengborg, P. et al, Tunnelling and Underground Space Technology 19 (2004)





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# Risk Management Risk Analysis Matrix According to ITA Guidelines

Conse- quency Fre- quency	insignificant	considerably	serious	severe	disastrous
very likely	unwanted	unwanted	unacceptable	unacceptable	unacceptable
likely	acceptable	unwanted	unwanted	unacceptable	unacceptable
occasional	acceptable	acceptable	unwanted	unwanted	unacceptable
unlikely	negligible	acceptable	acceptable	unwanted	unwanted
very unlikely	negligible	negligible	acceptable	acceptable	unwanted

(Quelle: Guidelines for tunnelling risk management: International Tunnelling Association, Working Group No. 2, Eskesen, S.D., Tengborg, P. et al, Tunnelling and Underground Space Technology 19 (2004)

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1

# Risk Management Risk Analysis According to ITA Guidelines

2

**Unacceptable:** The risk shall be reduced as least to **Unwanted** regardless of the cost risk mitigation.

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**Unwanted:** Risk mitigation measures shall be identified. The measures shall be implemented as long as the costs of the measures are not disproportionate with the risk reduction obtained.

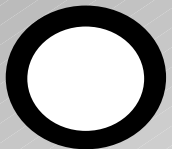
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**Acceptable:** The hazard shall be managed throughout th project. Consideration of risk mitigation is not required.

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**Negligible:** No further consideration of the hazard is needed.

(Quelle: Guidelines for tunnelling risk management: International Tunnelling Association, Working Group No. 2, Eskesen, S.D., Tengborg, P. et al, Tunnelling and Underground Space Technology 19 (2004)



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# Risk Management

## Risk Responding, Possible Strategies

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### **Avoid:**

eliminate the uncertainty or execute the project in a different way

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### **Transfer:**

transfer the risk to another party which is then responsible to handle the impact

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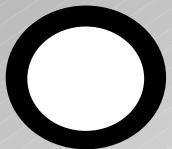
### **Mitigate:**

reduce the risk to make it more acceptable to the project by reducing the probability and/or the impact

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### **Accept:**

accept the risk (normally done for project risk which have a low priority or a low impact)



# Risk Management Risk Responding, Mitigation

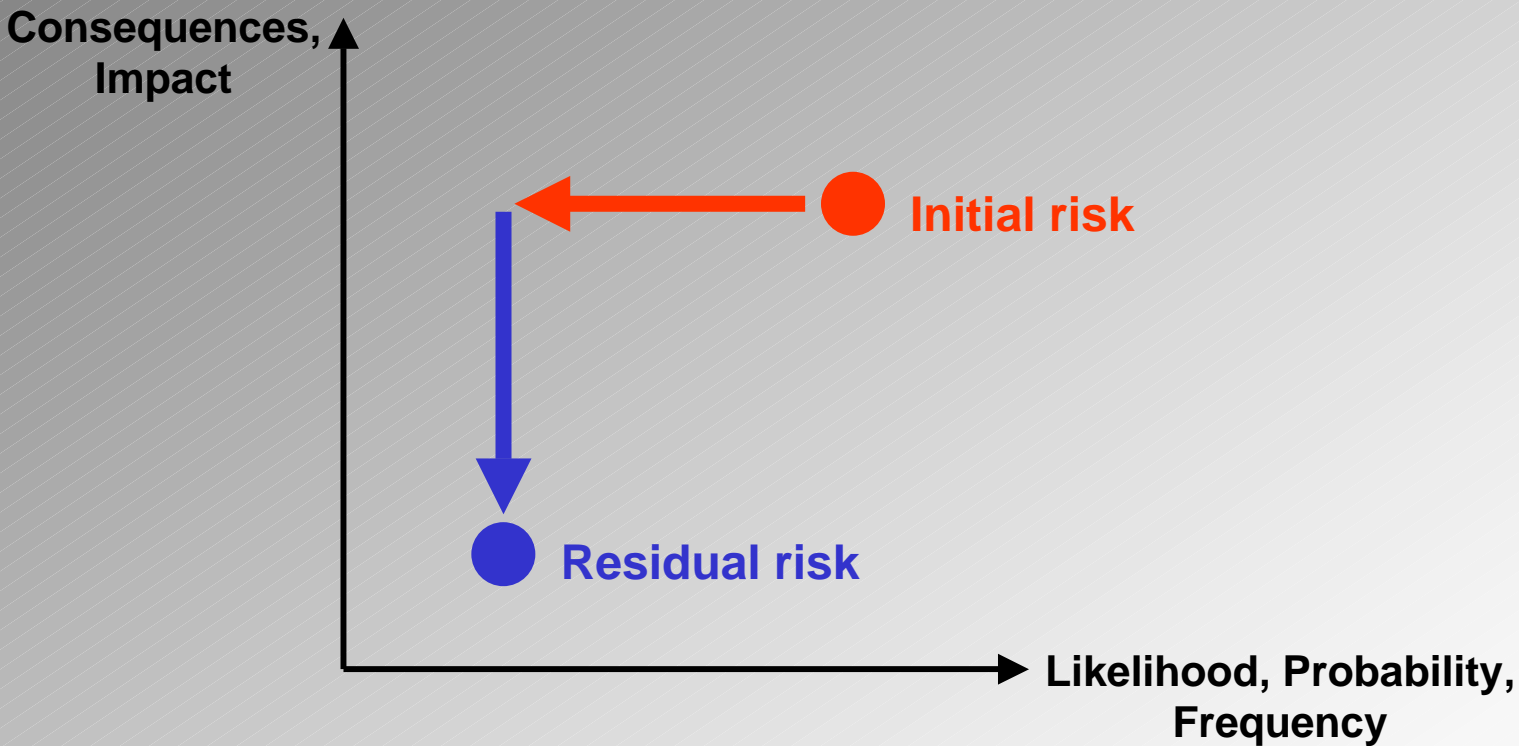
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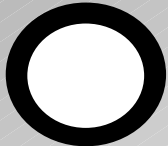
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(Quelle: Int. Tunnelling Association (ITA) and Risk; Parker, H.W.; George Fox Seminar; New York, 2005)

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**Technical monitoring consists of measurements and their continuous assessment to control a construction project .**

**-Technical monitoring is defined as part of the risk responding. The kind of measurements and the locations are defined.**

**-The measurement results are continuously recorded and assessed during the project as part of the risk control.**

**The following slides focus on the technical monitoring and describe methods and applications.**

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## Monitoring by Investigations and Measurements

### Monitoring of the surface

- Settlement control by levelling
- Vibration measurements
- Measurements by crackmeters and inclination sensors

### Monitoring of tunnel structure and ground

- Investigations (geophysical Prediction, Exploratory Drillings)
- 3D-Reflector survey
- Extensometer-, inclinometer measurements
- Control of ground water table by piezometers

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**Introduction**

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**Risk Management**

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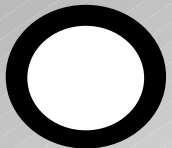
**Monitoring**

4

**Monitoring of Urban Tunnels, Examples**

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**Conclusions**



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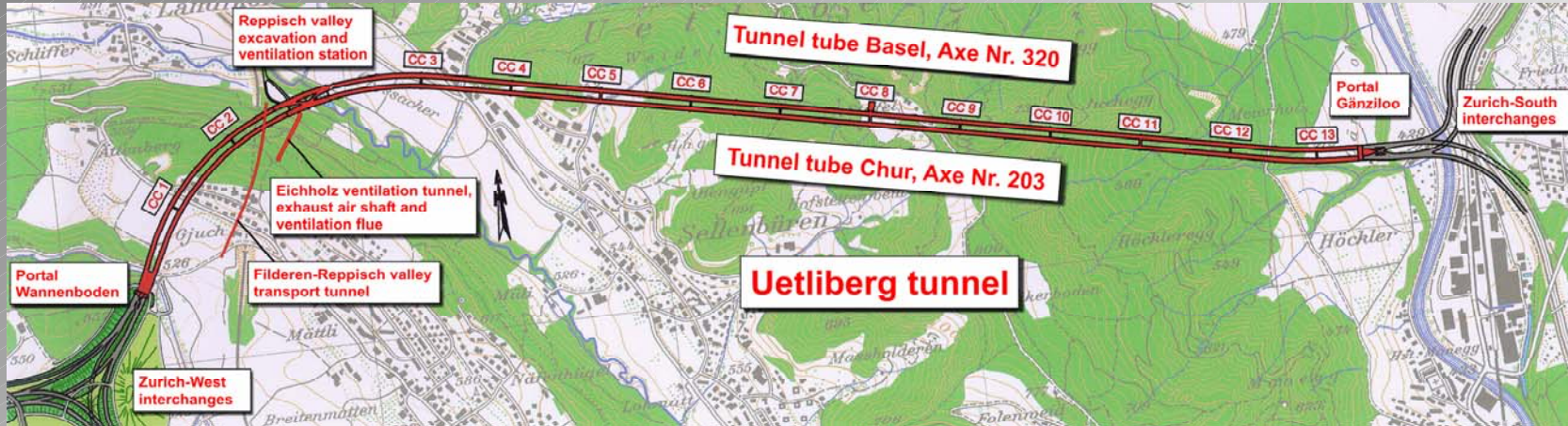
# Example Uetliberg Road Tunnel Overview

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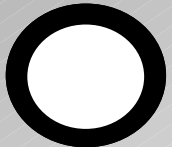
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2 tubes (each 4.4 km)  
 Cross-cut with pedestrian access every 300 m  
 Cross-cut with vehicular access every 900 m  
 SOS niches every 150 m





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# Example Uetliberg Road Tunnel

## Selected Excavation Method: Core Method

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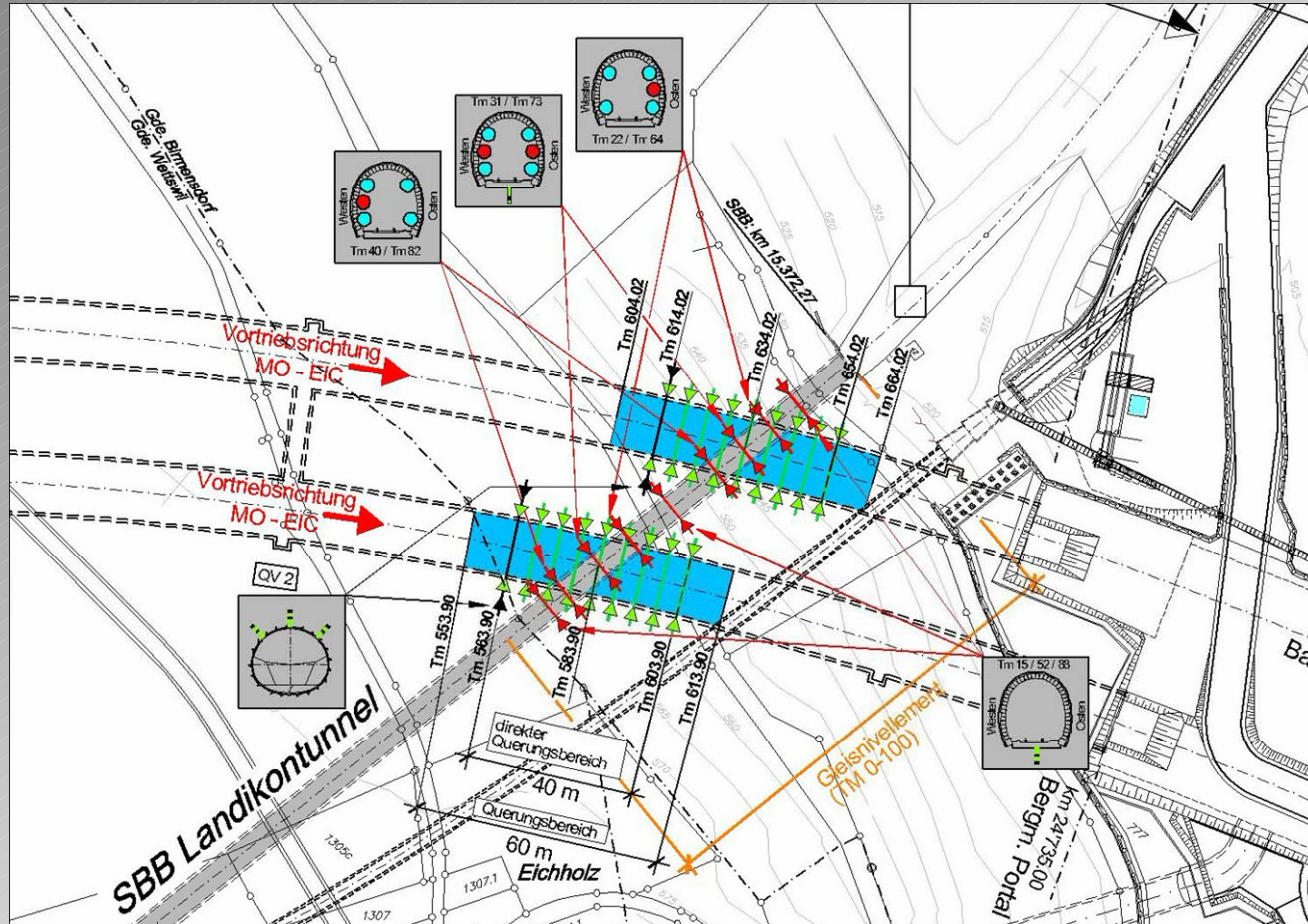
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# Example Uetliberg Road Tunnel Section under Landikontunnel



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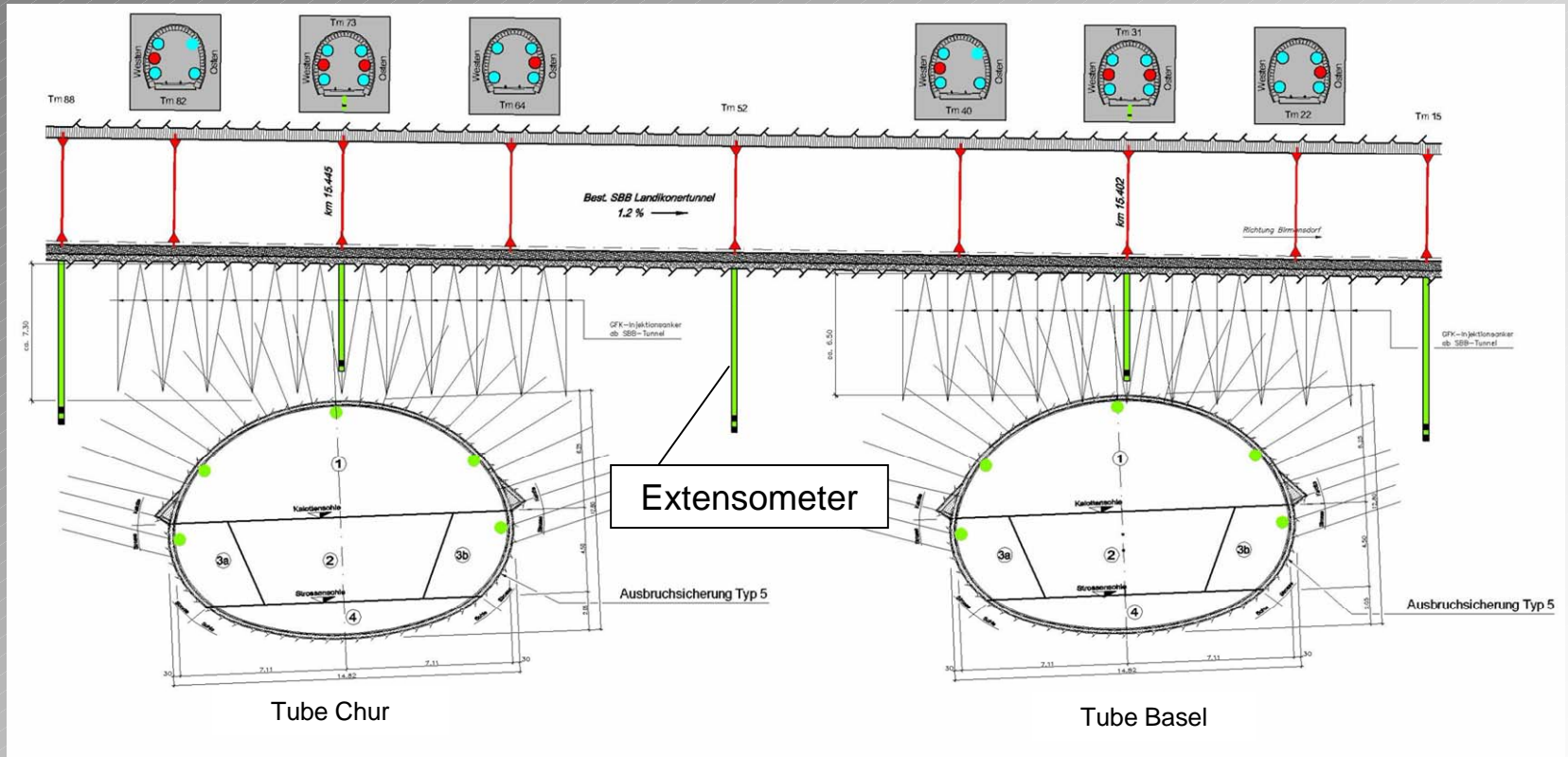
# Example Uetliberg Road Tunnel Section under Landikontunnel

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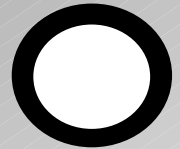
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● Vibration measurements

● Convergency measurements

● Prisms (3D Optical Survey)



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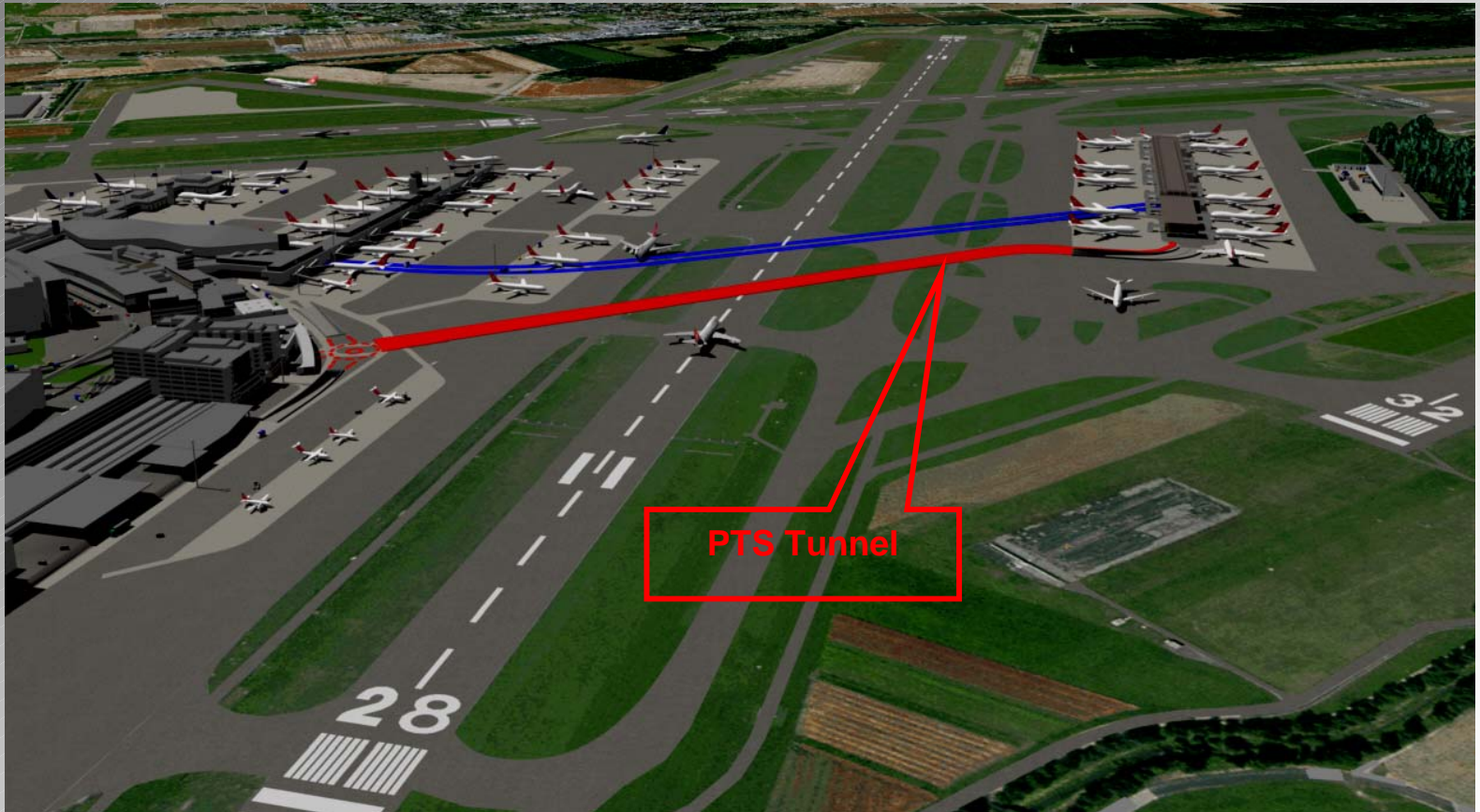
# Example PTS-Tunnel Zurich Airport Overview

2

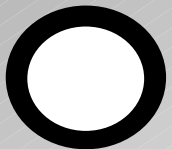
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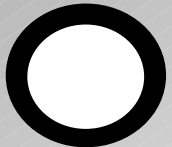
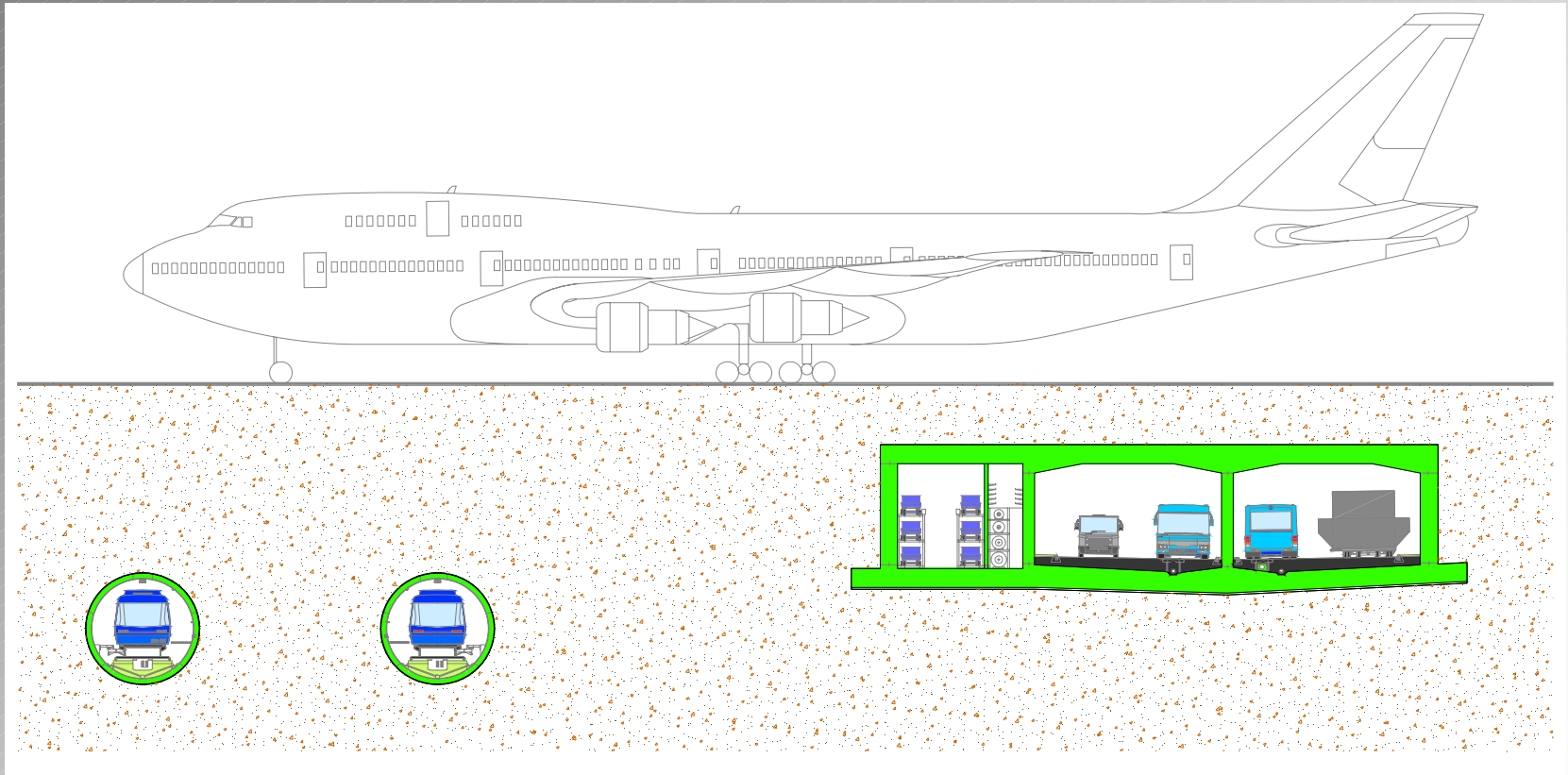
# Example PTS-Tunnel Zurich Airport PTS and Road Tunnels

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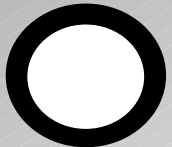
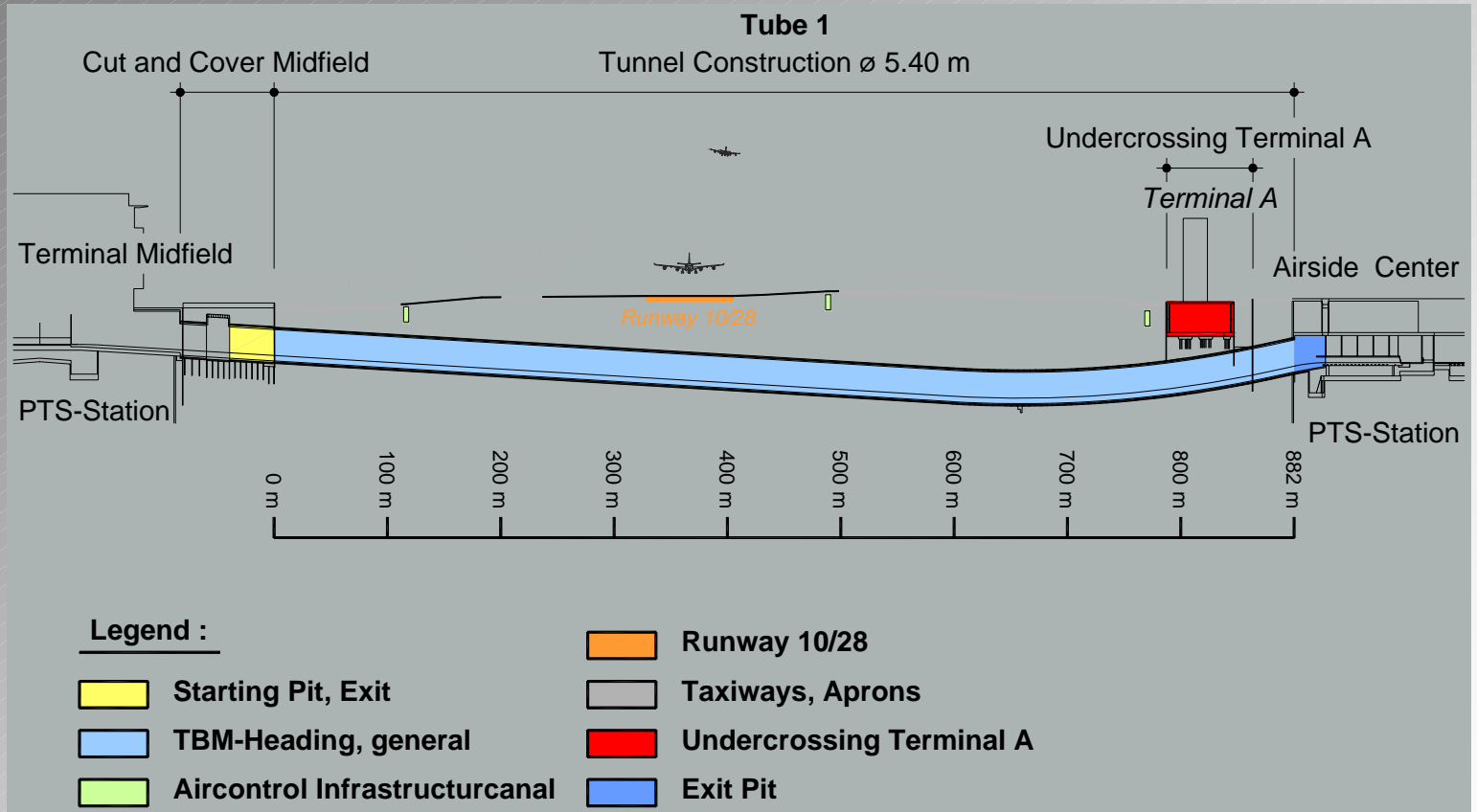
# Example PTS-Tunnel Zurich Airport Defined Risk Areas

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# Example PTS-Tunnel Zurich Airport Excavation in Soft Ground with Hydroshield

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Foto: unique zürich airport / Ralph



Foto: unique zürich airport / Ralph Bensberg / 15.11.2000

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# Example PTS-Tunnel Zurich Airport Defined Risk Areas, Undercrossing Terminal A

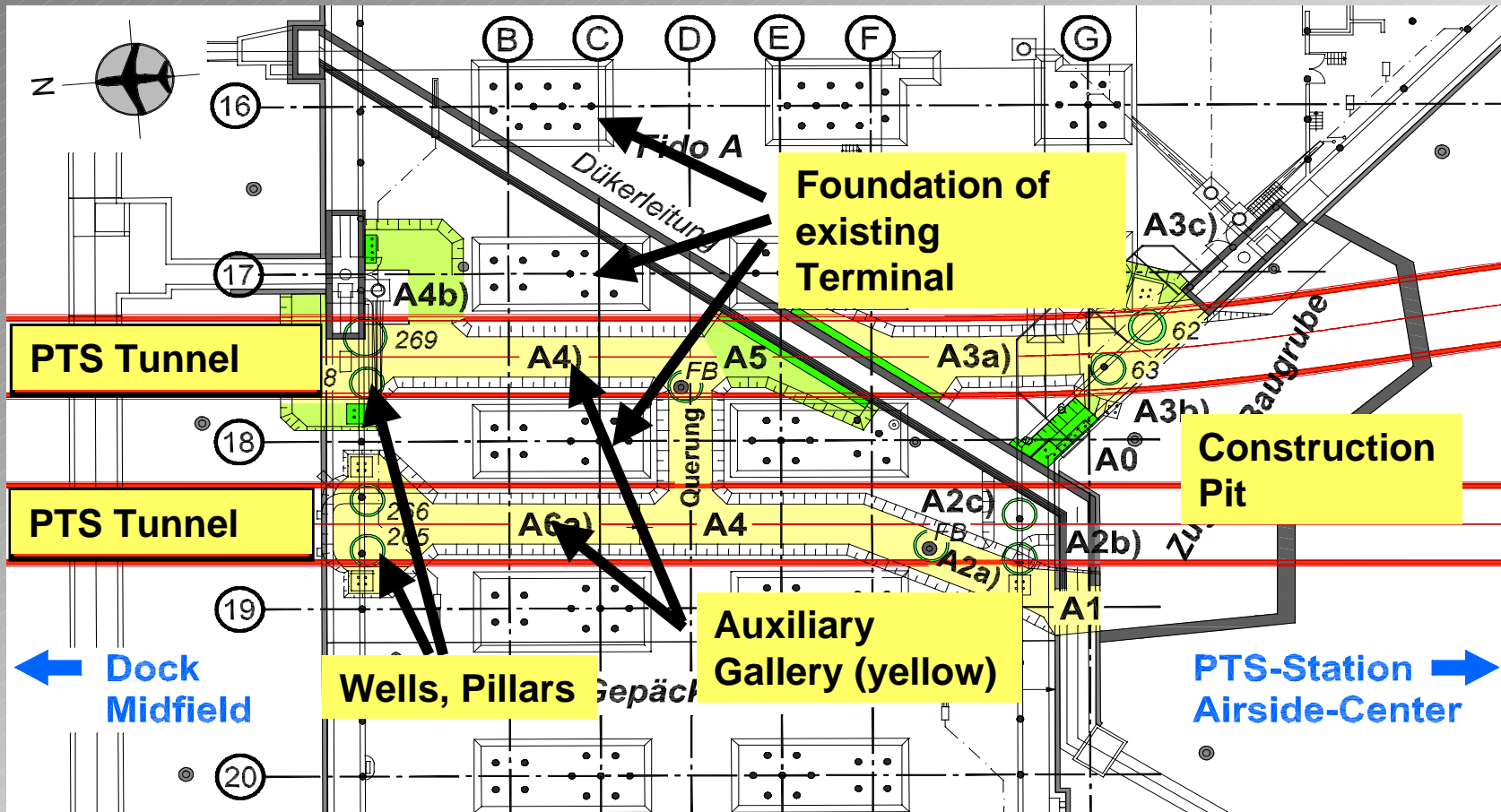
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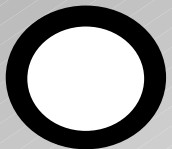
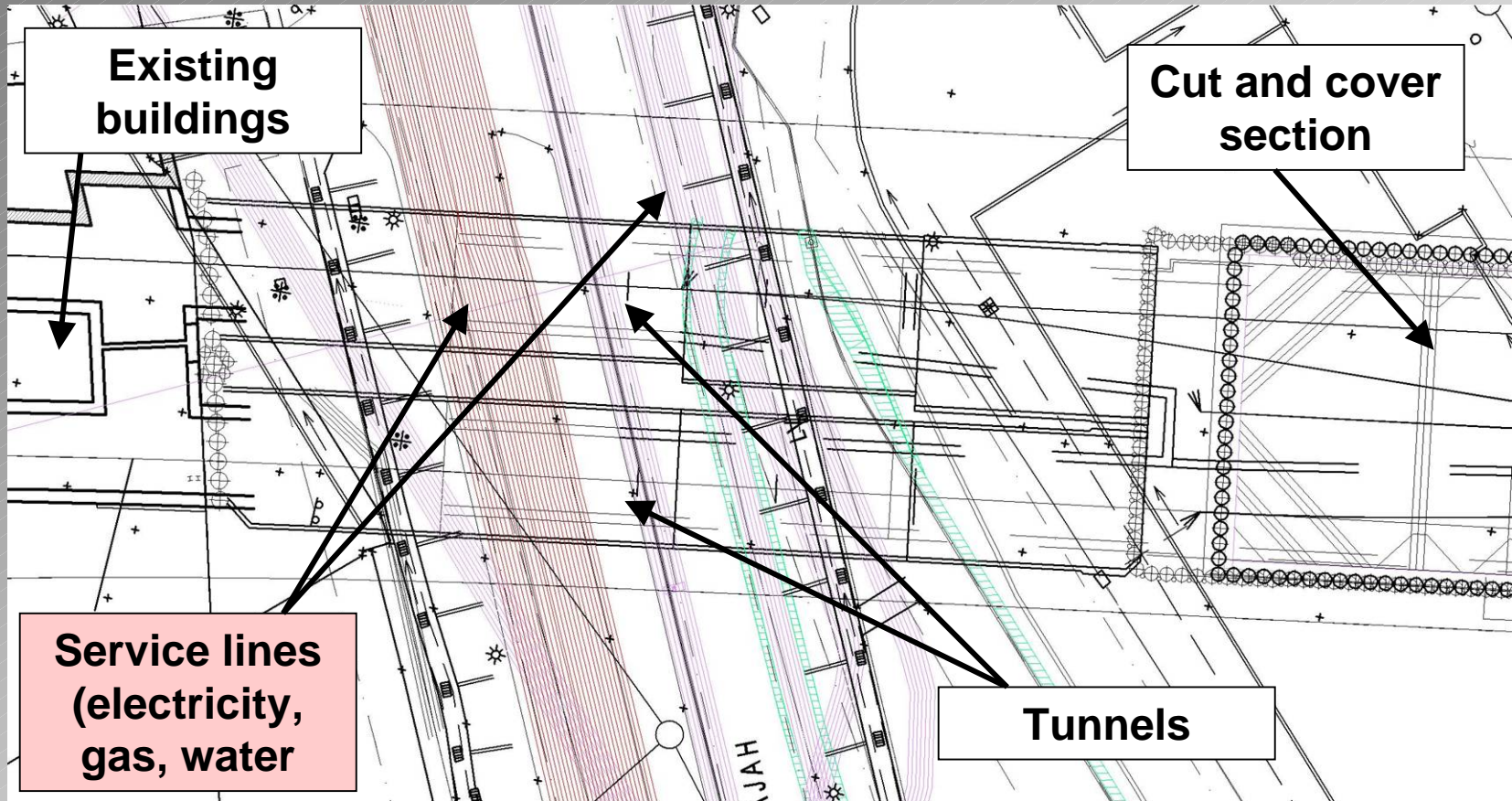
# Example Circle Line, Stage 4+5, Singapore Top View

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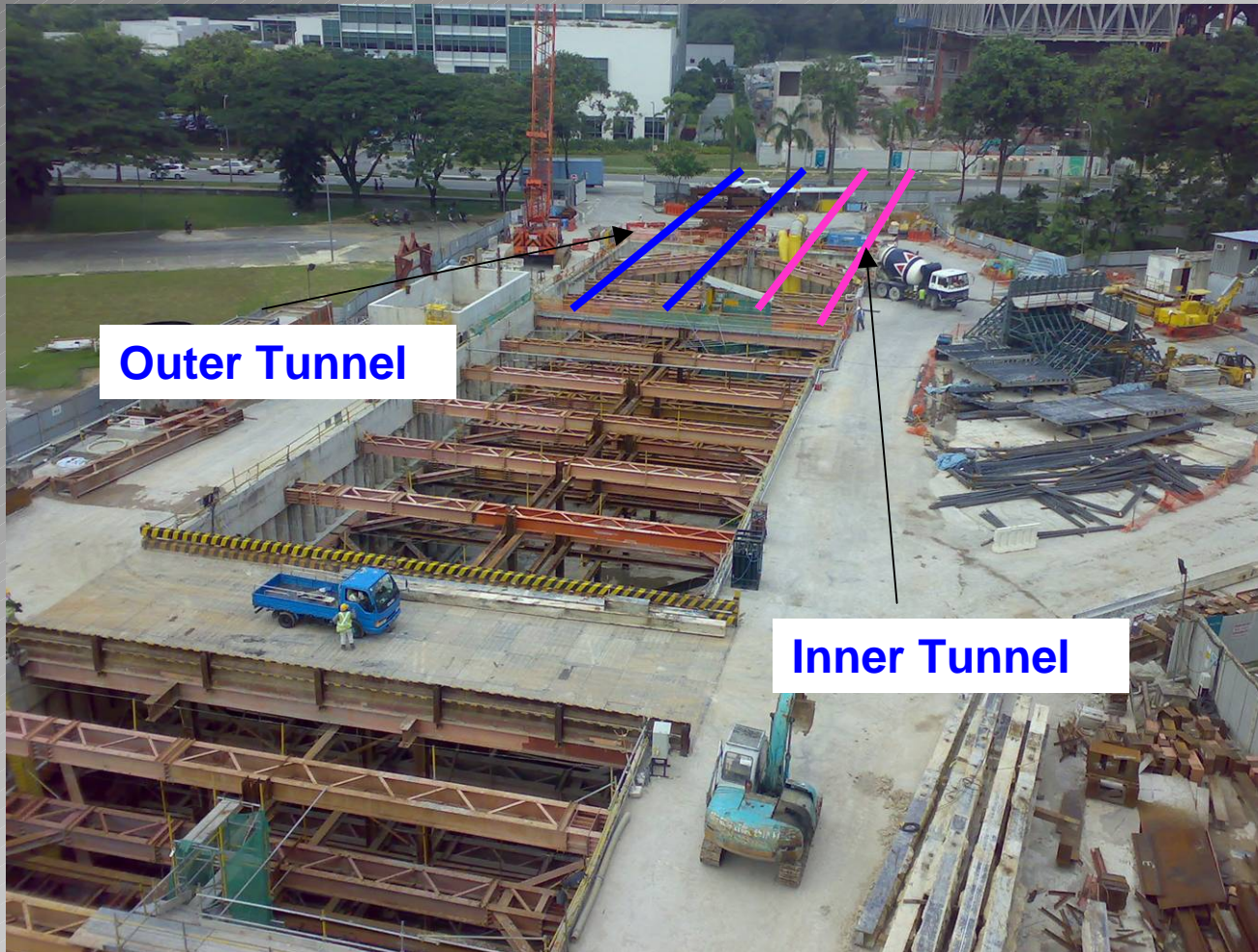
# Example Circle Line, Stage 4+5, Singapore

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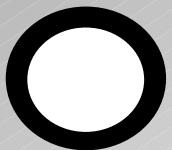
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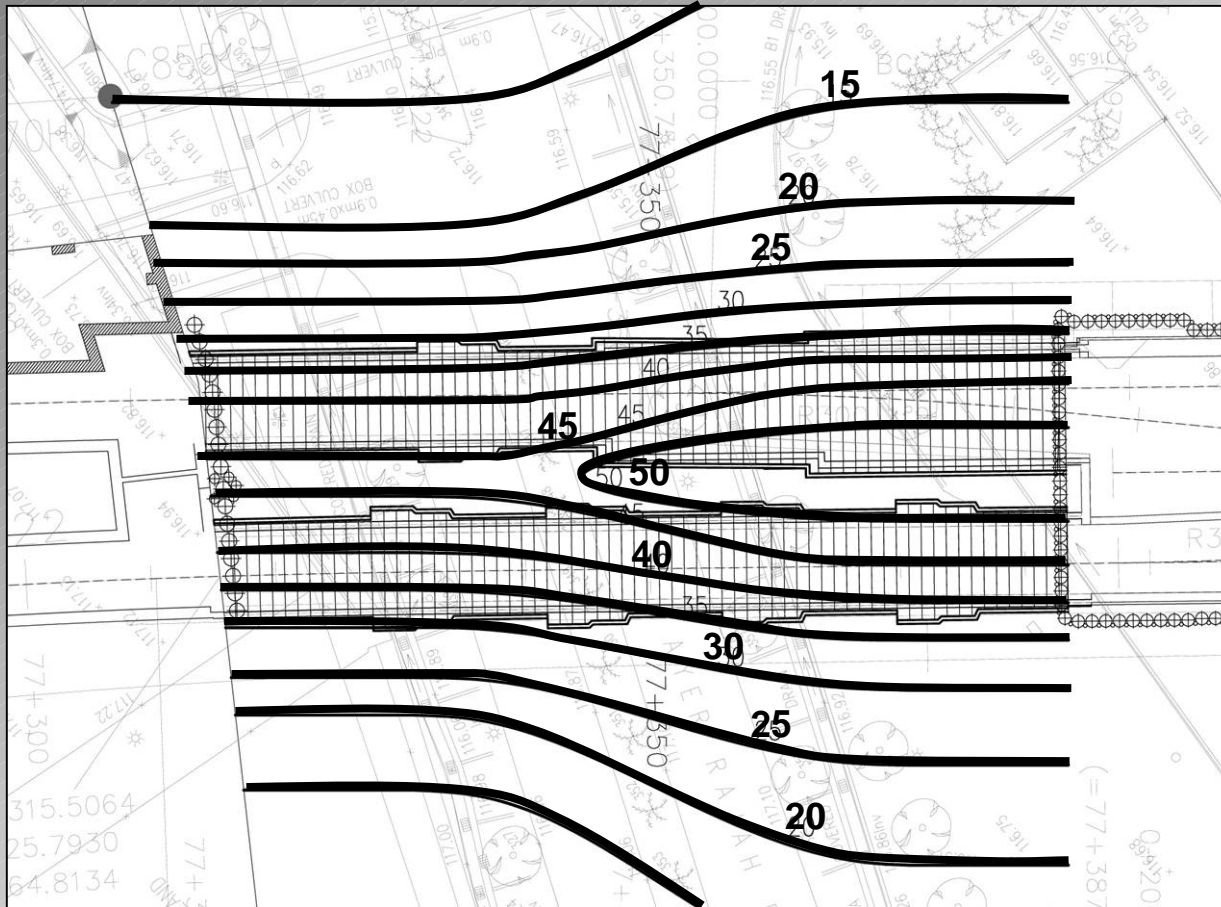
# Example Circle Line, Stage 4+5, Singapore Predicted Ground Settlements

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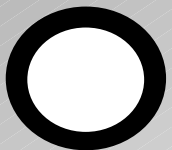
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—  
Predicted  
ground  
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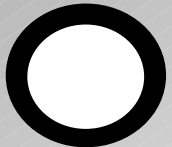
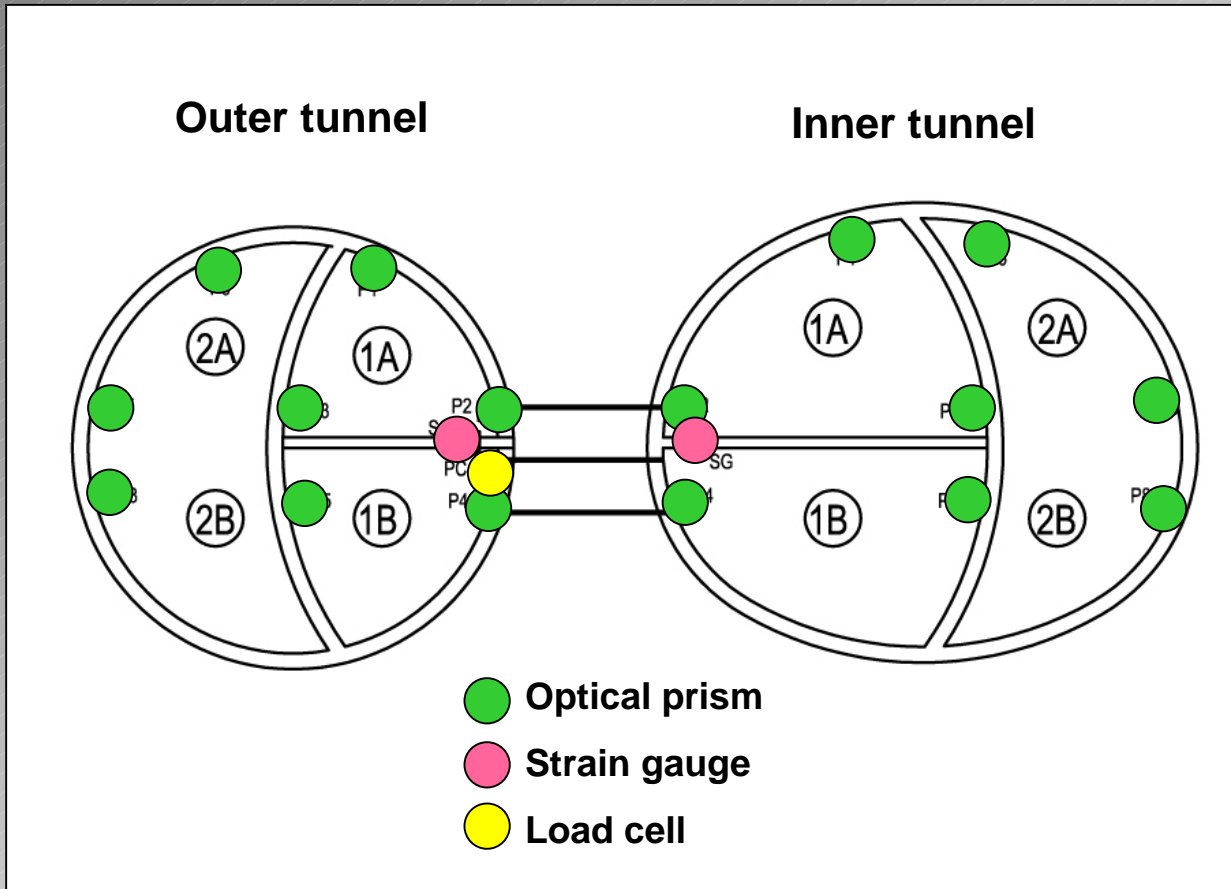
# Example Circle Line, Stage 4+5, Singapore Monitoring of the Tunnel under Construction

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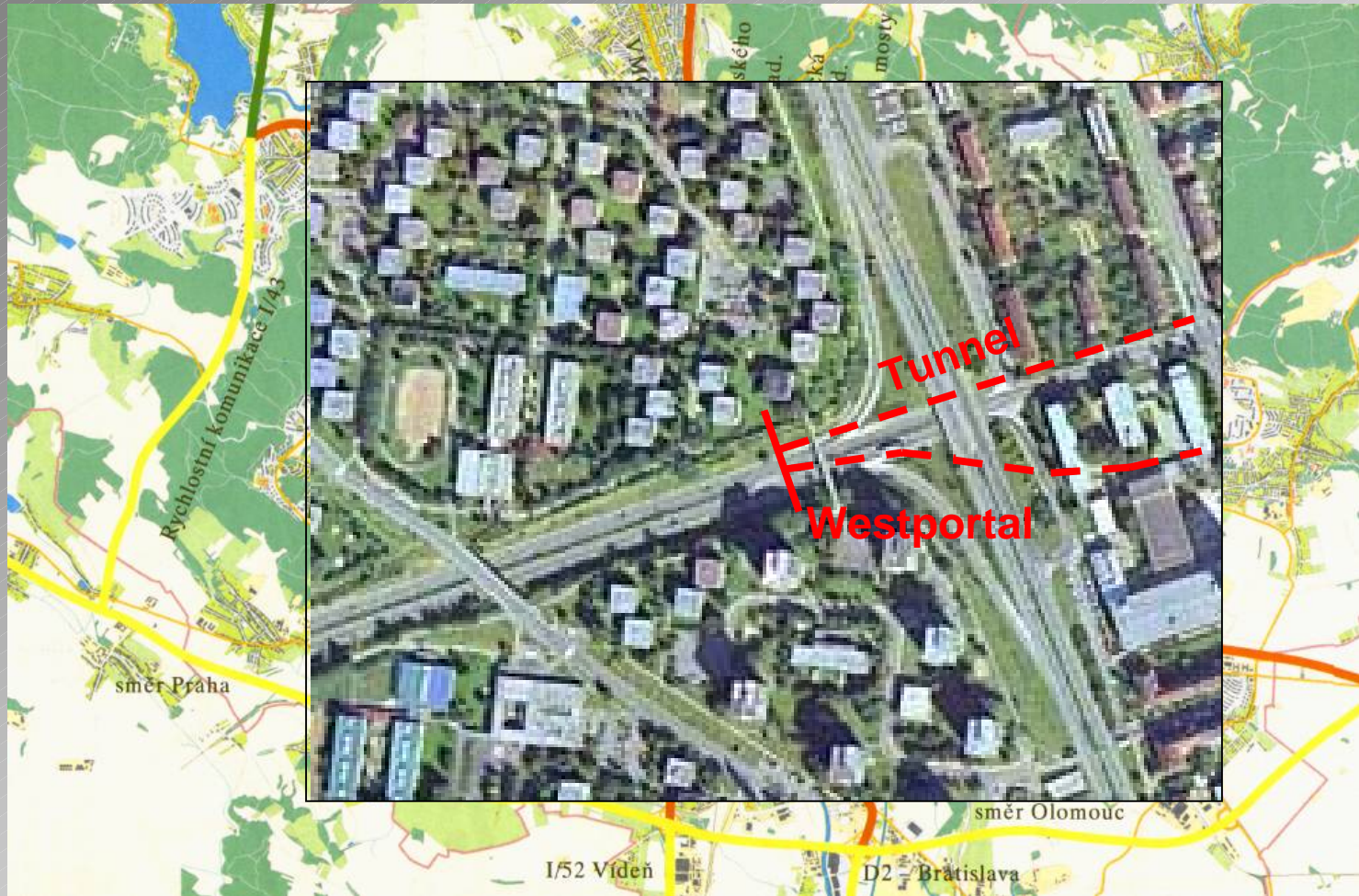
# Example Dobrovskeho Road Tunnel, Brno, CZ

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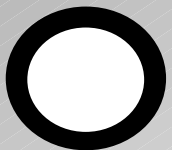
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# Example Dobrovskeho Road Tunnel, Brno, CZ West Portal

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***Monitoring of Tunnels in Urban Areas***

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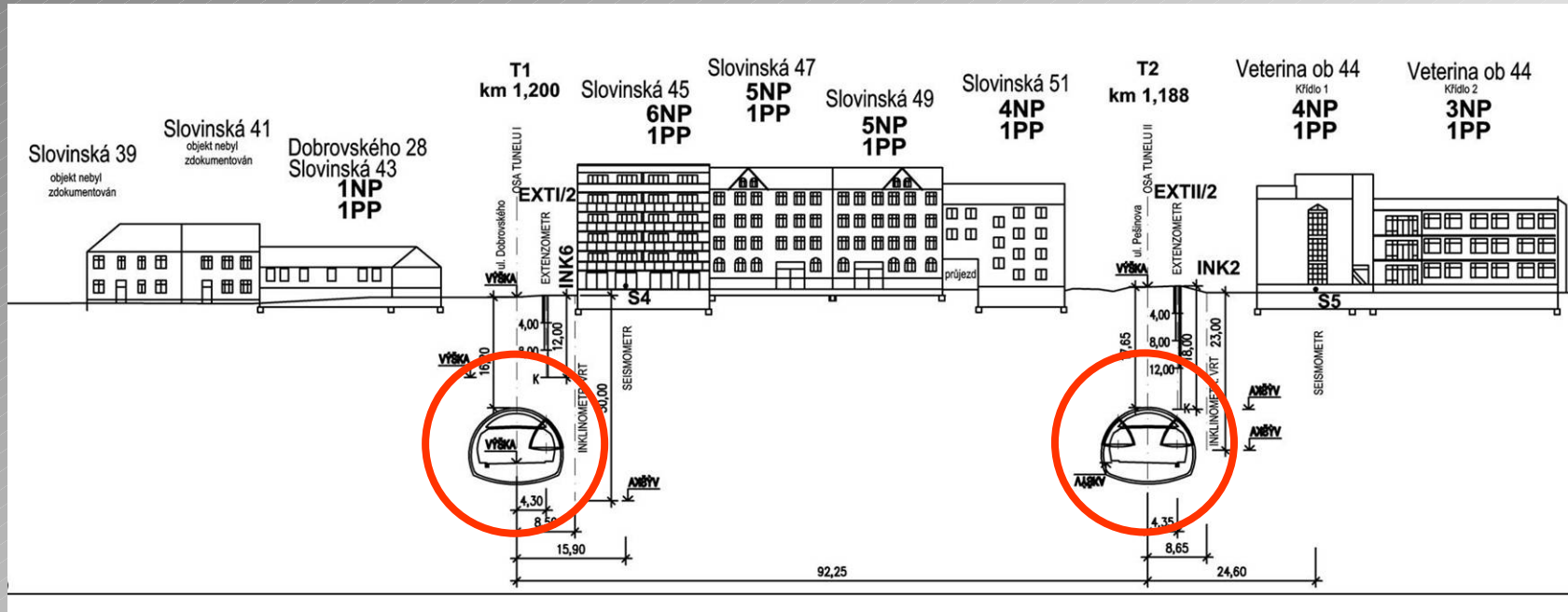
# Example Dobrovskeho Road Tunnel, Brno, CZ Cross section 10

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