



Dam Safety Practices in Turkey

Mutlu İlker Peker

The General Directorate of State Hydraulic Works of Turkey

TURKEY



PRESENTATION OUTLINE

Dams in Turkey

Seismicity in Turkey

Case studies across the world

Dam design practices

Instrumentation in dams

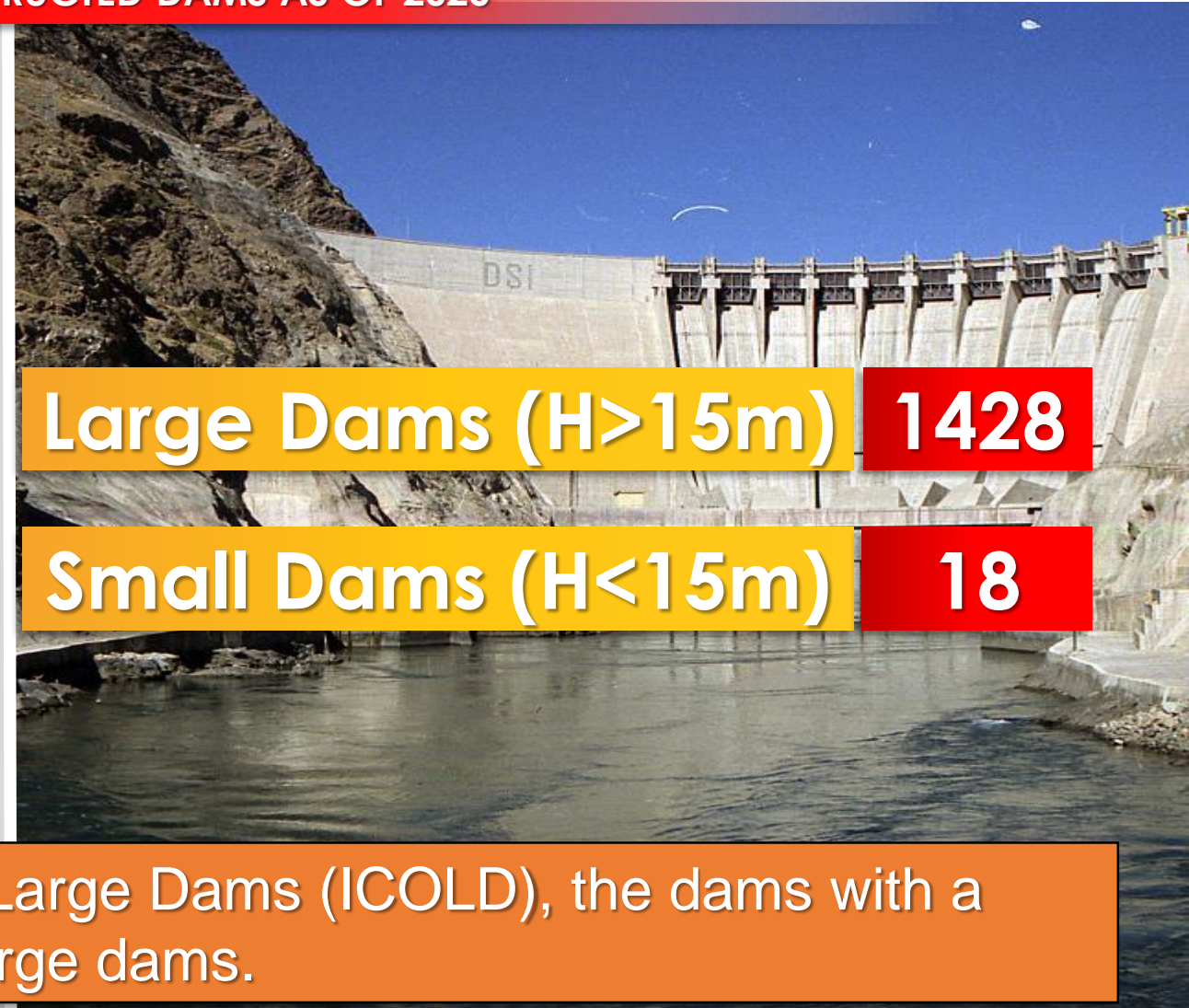
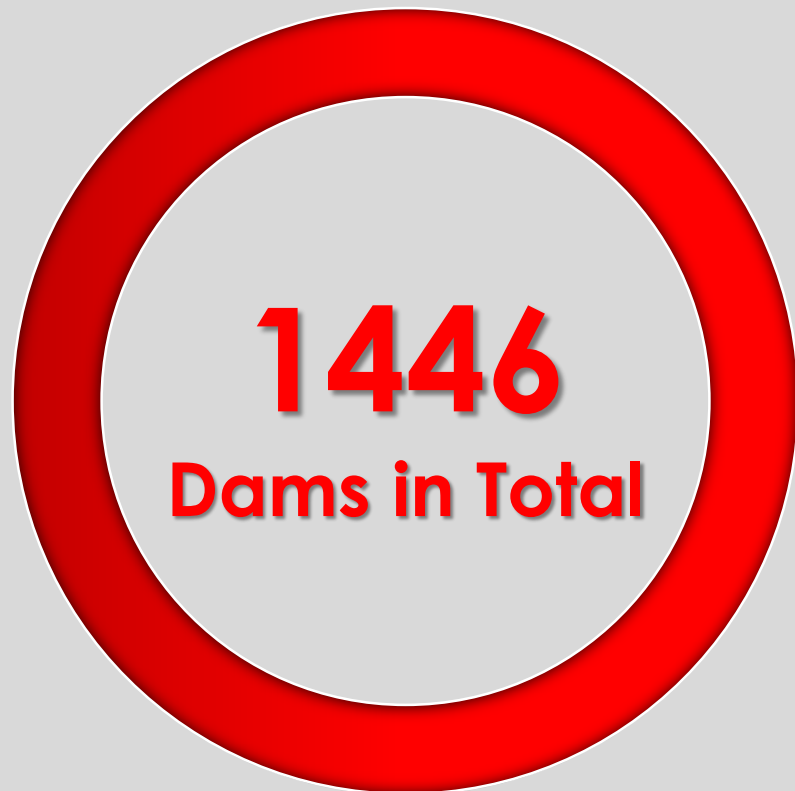
Dam safety inspections

Dam break analyses

Results and evaluations



GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS
NUMBER OF CONSTRUCTED DAMS AS OF 2020



Large Dams ($H > 15\text{m}$)

1428

Small Dams ($H < 15\text{m}$)

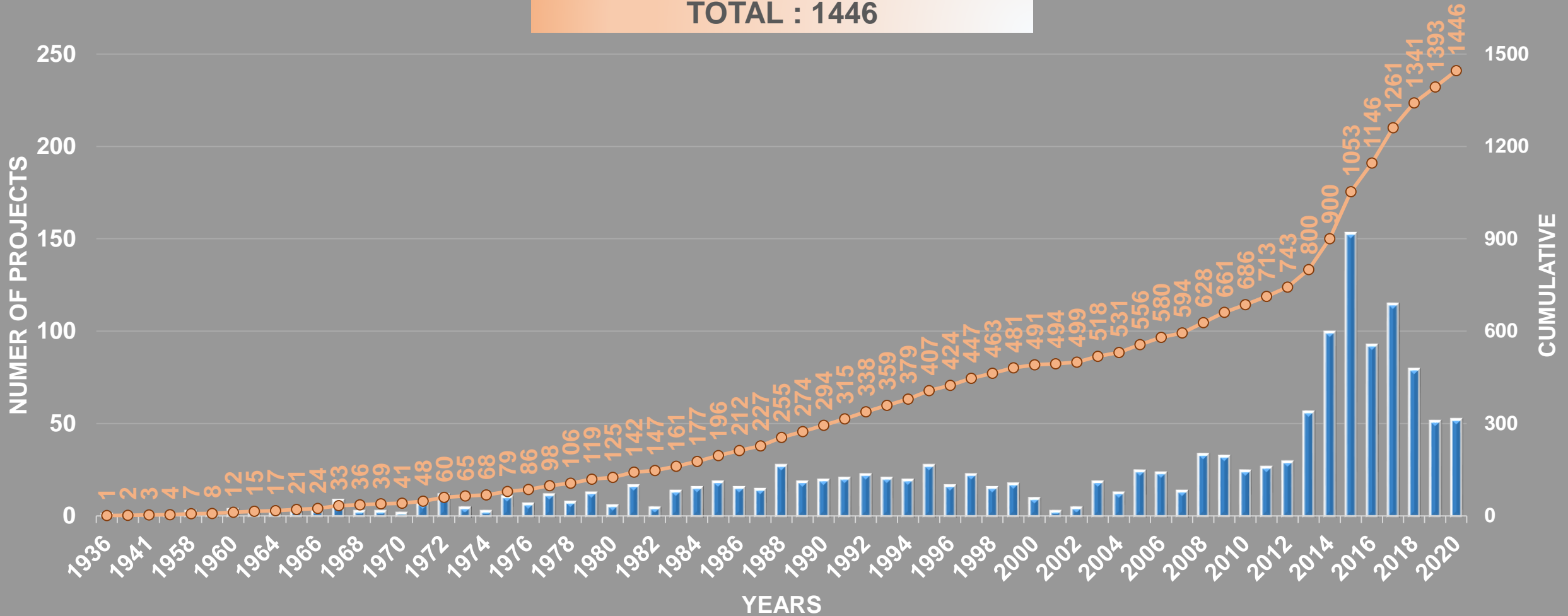
18

According to International Commission on Large Dams (ICOLD), the dams with a height of over 15 m are considered to be large dams.



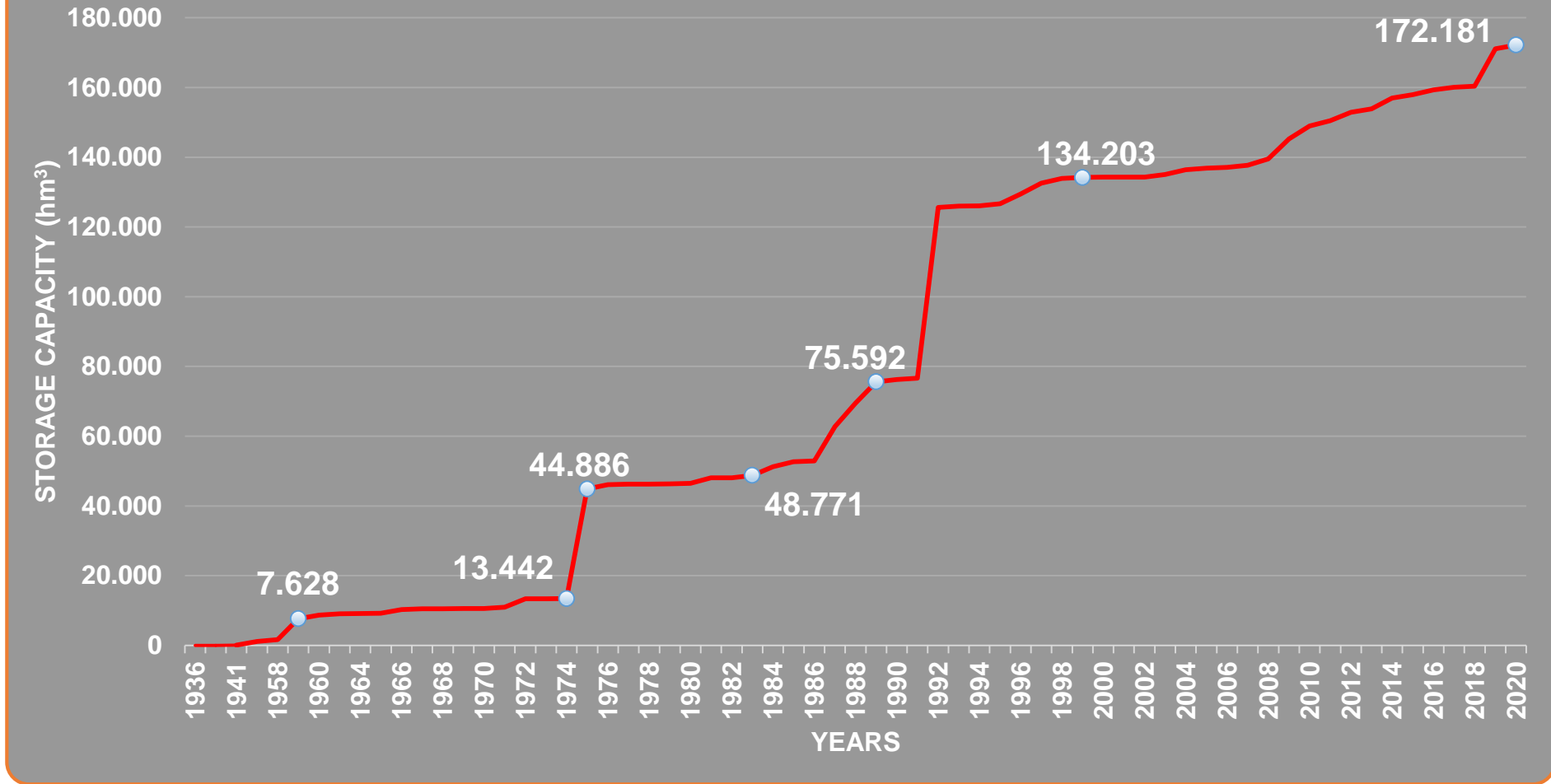
THE NUMBER OF CONSTRUCTED DAMS (1936 – 2020)

CONSTRUCTED DAMS BY YEARS
TOTAL : 1446





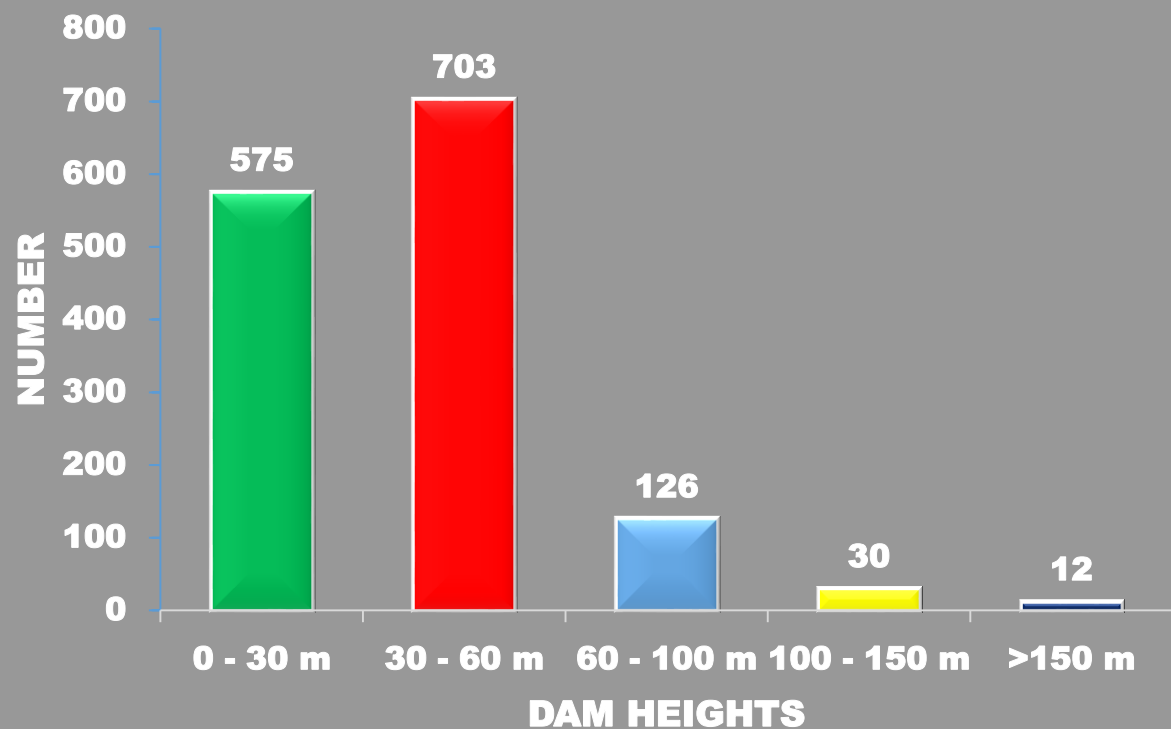
TOTAL STORAGE CAPACITY (SINCE 1936)
TOTAL : 172.181 hm³



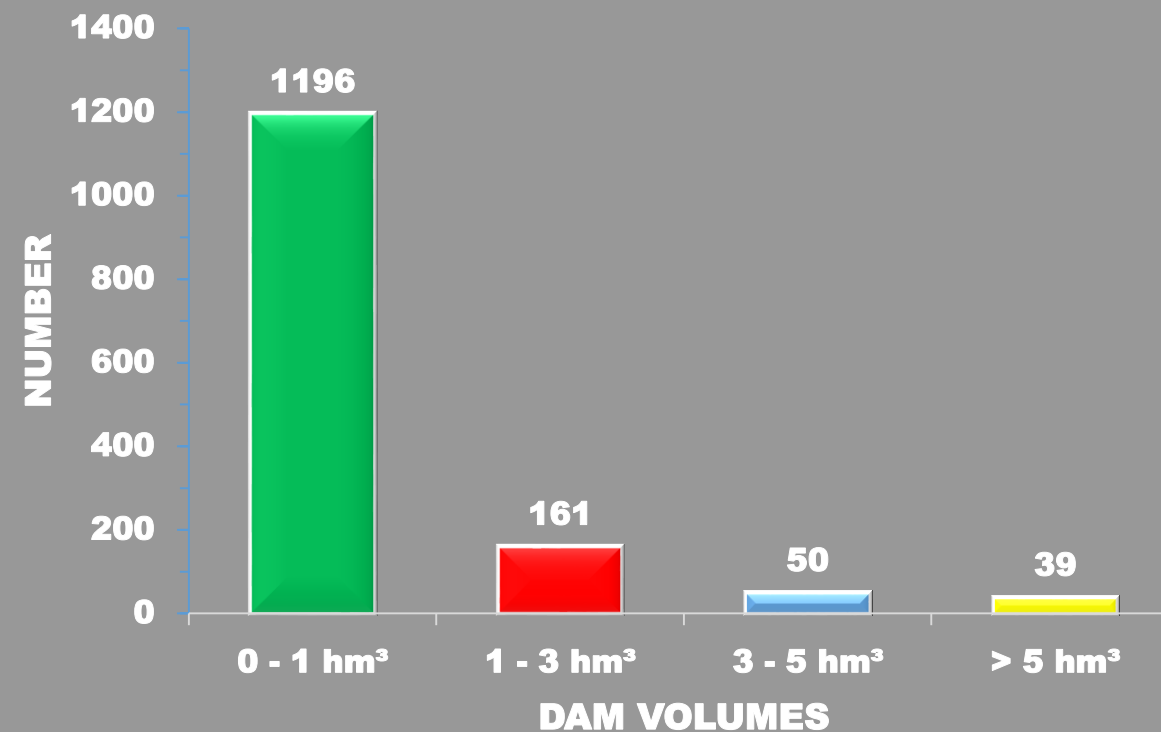


CONSTRUCTED DAMS IN TURKEY (1936 – 2020)

BY DAM HEIGHT
1 446 Dams

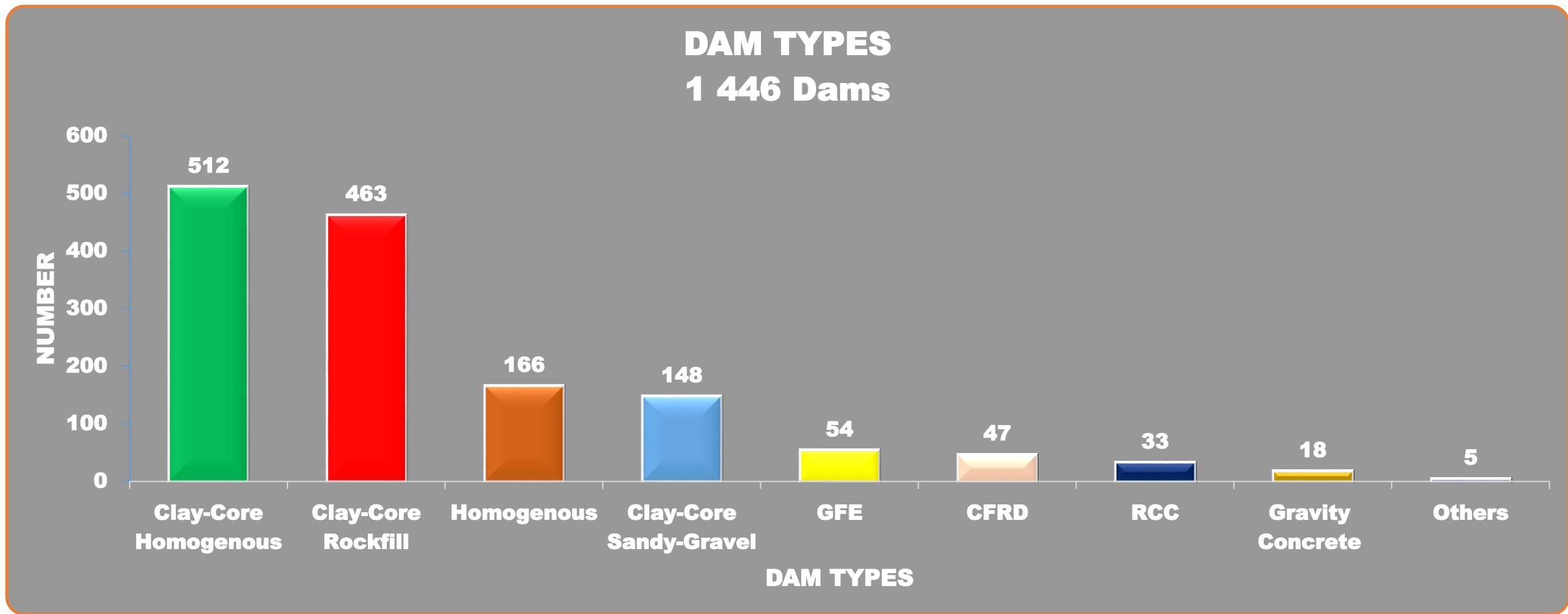


BY DAM VOLUME
1 446 Dams





CONSTRUCTED DAMS BETWEEN 1936 – 2020



*GFE: Geomembrane Covered Embankments

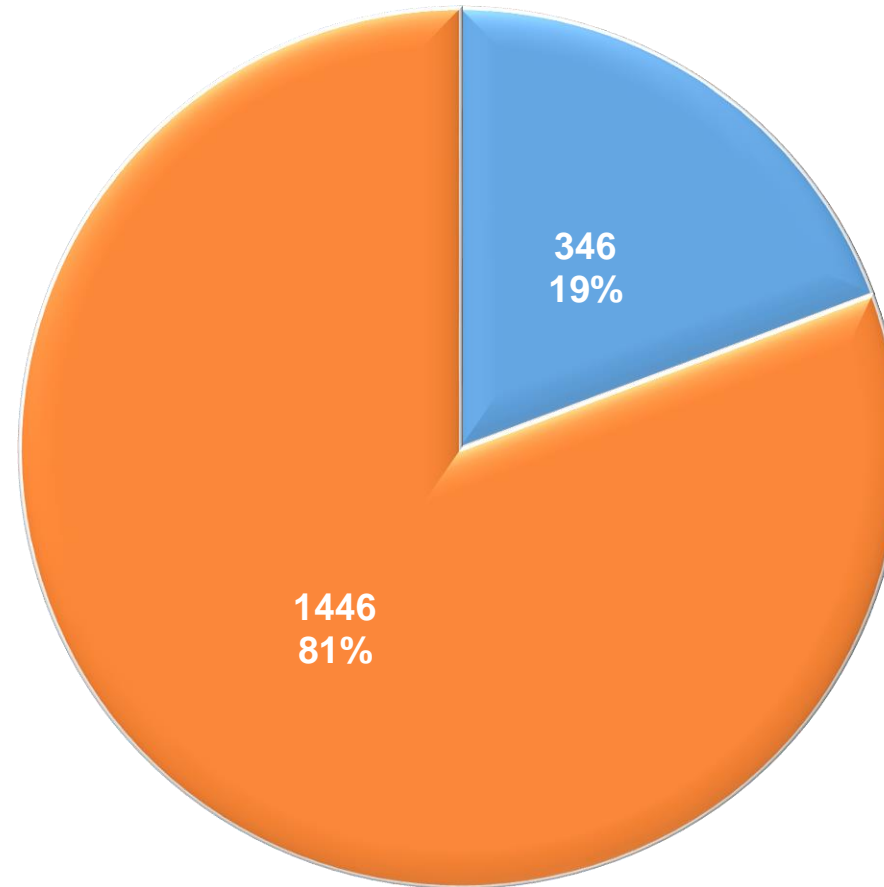
*CFRD: Concrete-Faced Rockfill Dams

*RCC: Roller - Compacted Concrete Dams



DAMS IN OPERATION AND UNDERCONSTRUCTION SINCE 1936

TOTAL : 1792



Under Construction Completed



EUROPEAN SEISMIC HAZARD MAP



European Seismic Hazard Map

edited by D. Giardini, J. Woessner, and L. Danclou, Swiss Seismological Service, ETH Zurich, August 2013

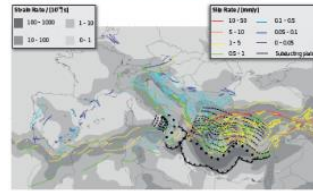


European Commission

The EU-FP7 SHARE Project

Europe has a long history of destructive earthquakes, and seismic risk can severely affect our modern society, as recently seen by the 1999 Izmit (Turkey) and the 2009 L'Aquila (Italy) events. Seismic risk defines the likelihood of ground shaking associated with the occurrence of future earthquakes and is the first step to measure seismic risk. The likelihood of damage and loss depending on vulnerability factors (e.g. the type, age and state of buildings and infrastructures, population density and land-use) and high hazard areas (e.g. high risk, frequent large earthquakes) result in high hazard but pose limited risk if they occur in vulnerable areas, while even moderate earthquakes may impose densely populated areas to high seismic risk.

Active Faults in Euro-Mediterranean Region



Active faults and subducting plates in the Euro-Mediterranean region are identified by color from equally dipping faults along dipping strand. Over 2,100 active faults have been mapped, covering more than 60,000 km of fault length. The background depicts the administrative information of the Earth's crust derived from geotectonic generalizations.

Map Content

The European Seismic Hazard Map displays the ground shaking (a Peak Horizontal Ground Acceleration) to be reached in association with a 10% probability in 50 years, corresponding to the average recurrence of a fault ground motion every 475 years, as prescribed by the national building codes in Europe for standard buildings. SHARE maps also the higher ground shaking resulting from every 1,000 to 5,000 years of recurrence for critical infrastructure such as dams or bridges.

The ground shaking values depicted in the map reach over 0.5g in the geotectonically active zones. Low hazard areas (PGA < 0.1g) are colored in blue-green, moderate hazard areas in yellow-orange and high hazard areas (PGA > 0.3g) in red.

The SHARE seismic hazard is assessed with a site-independent, probabilistic approach. Models of future ground shaking are based on the history of earthquakes of the past 1,000 years, on the knowledge of active faults (length, slip rate, on the style and rate of deformation of the Earth's crust from GPS measurements), and on the recurrence models of strong ground shaking generated by past earthquakes.

The hazard results do not replace the existing national design regulations and seismic provisions, which must be adapted for future design and construction of buildings.

Acknowledgements

Supported by the EU-7th Framework Program, the 4-year SHARE program brought together a consortium of over 50 leading scientists from 12 research institutions and 12 countries from Europe, North America, Turkey, and more than 200 additional European agencies participating in workshops, provided by their respective and host.

SHARE was funded by the EU-7th (2007-2013) under grant agreement no. 230307. SHARE hazard was computed using the SHARE OpenEarth software. Maps were created using ArcGIS Desktop and ArcGIS Online and the poster was produced with Adobe Illustrator CS5.

See the map web site: www.share-project.org

© D. Giardini, J. Woessner, L. Danclou, M. Crowley, F. Colucci, E. Enslin, S. Pimentel, S. Vassallo and the SHARE consortium. SHARE European Seismic Hazard Map for Peak Ground Acceleration, 10% Exceedance Probability in 50 years. doi:10.7757/SHARE.1308-11.079-01-01-01-1

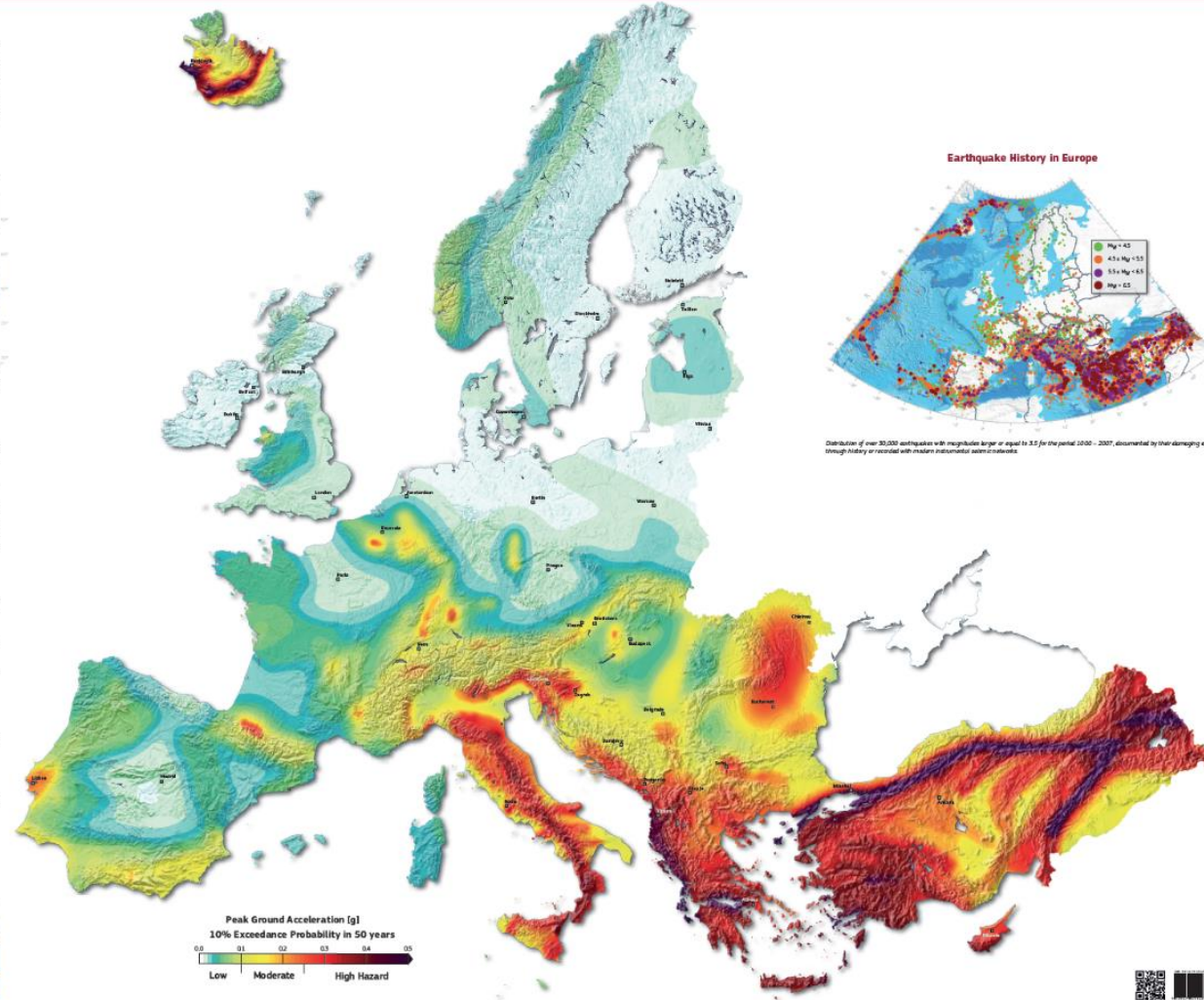
Online Access

All SHARE products, data and results are provided through the project website at www.share-project.org and the European facility for earthquake hazard and risk at www.ehrn.org

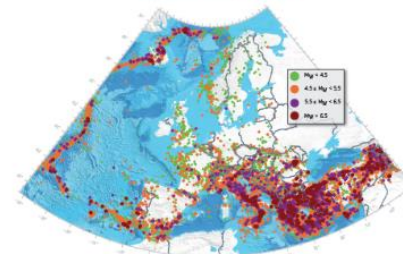
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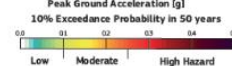
SHARE Partners



Earthquake History in Europe

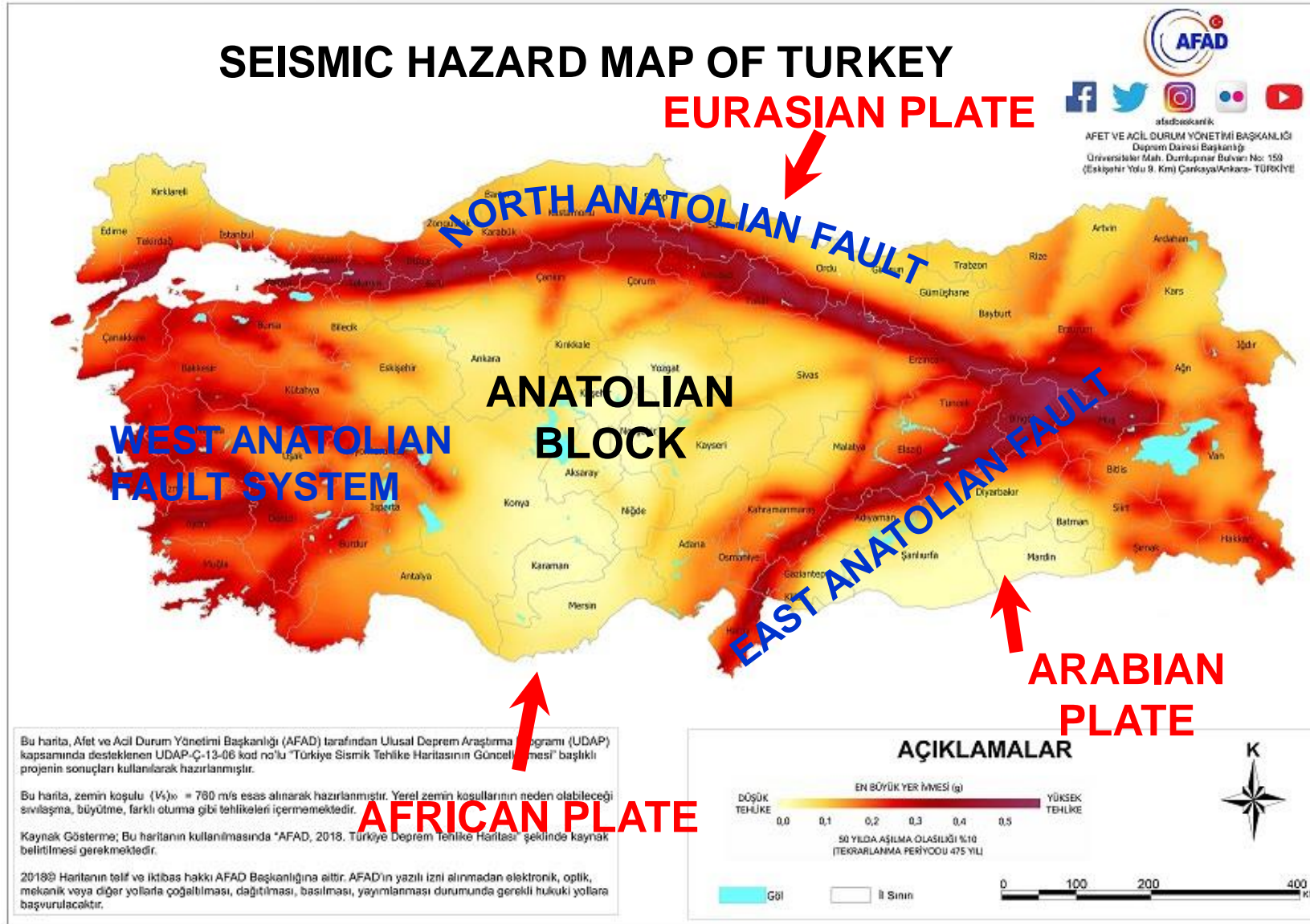


Distribution of over 30,000 earthquakes with magnitudes larger or equal to 3.0 for the period 1000 - 2007, documented by their damaging effects through history or recorded with modern instrumental instruments.



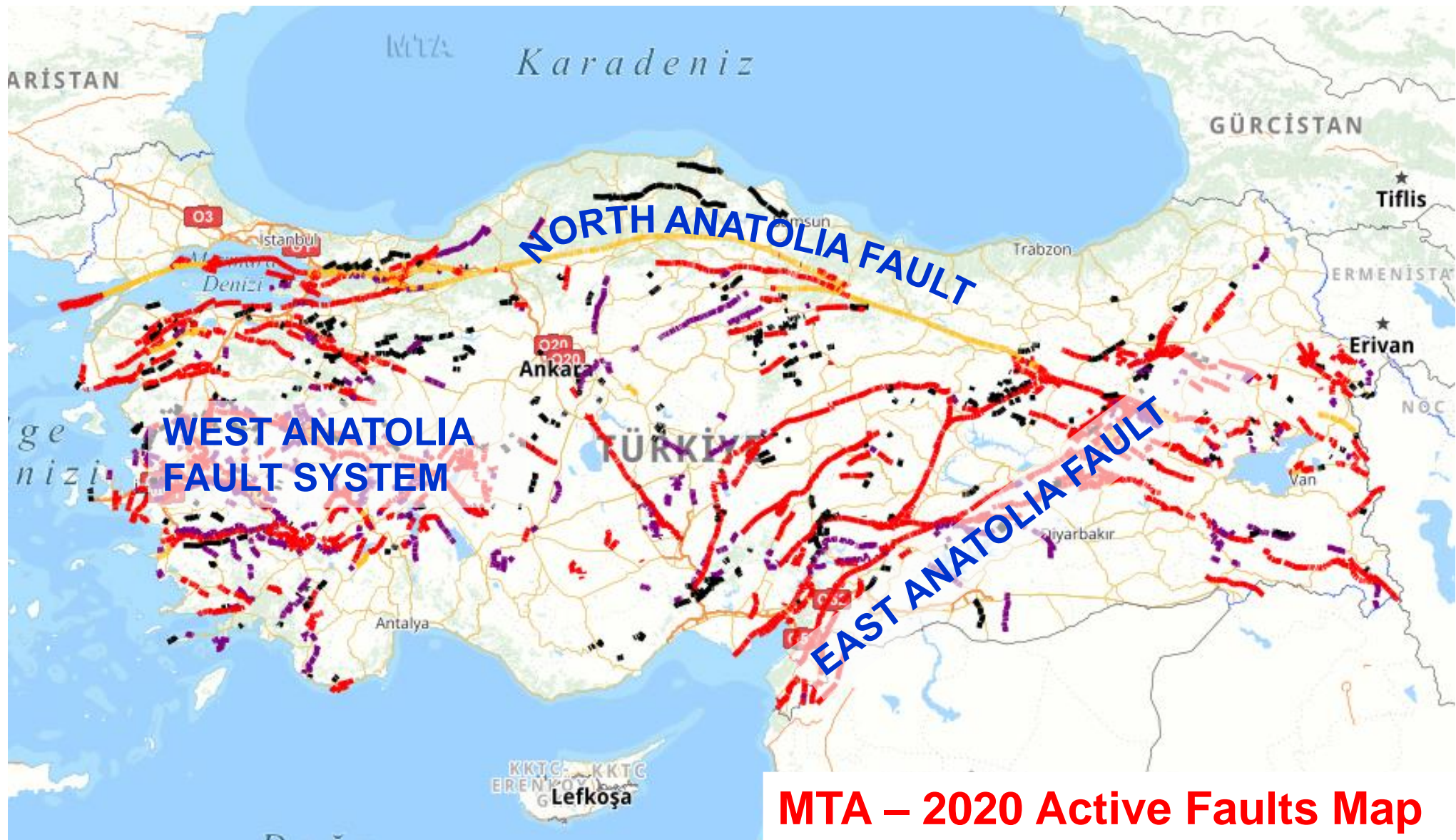


SEISMIC HAZARD MAP OF TURKEY





ACTIVE FAULTS IN TURKEY



MTA – 2020 Active Faults Map



CASE STUDIES OF DAMAGED OR COLLAPSED DAMS AROUND THE WORLD



CASE STUDIES: Oroville Dam



Oroville Dam (235 m), CA-USA

In 2017, the tallest dam in the USA has suffered from spillway failure, which was followed by rapid erosion of foundation.

To control the damage, the flow rate was decreased, which resulted in overtopping of emergency spillway.

Overtopping or sliding instabilities of ogee weir structure emerged.
180,000 evacuated.
Repair cost 1.1 Billion \$.
(damfailures.org)



CASE STUDIES: Oroville Dam



Oroville Dam
(235 m), ABD
(after repairs)

The damage was repaired, and the dam became operational again.

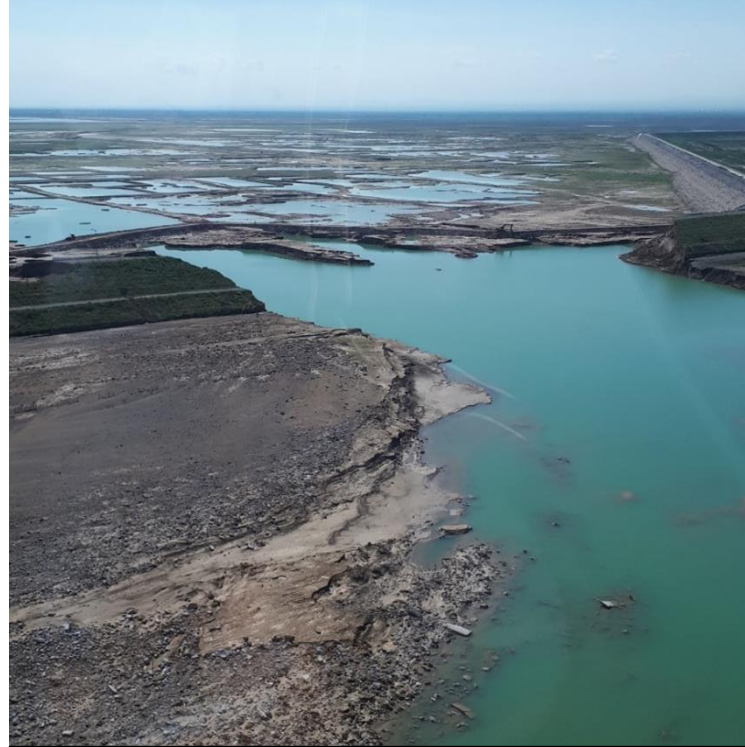


CASE STUDIES: Sardoba Dam

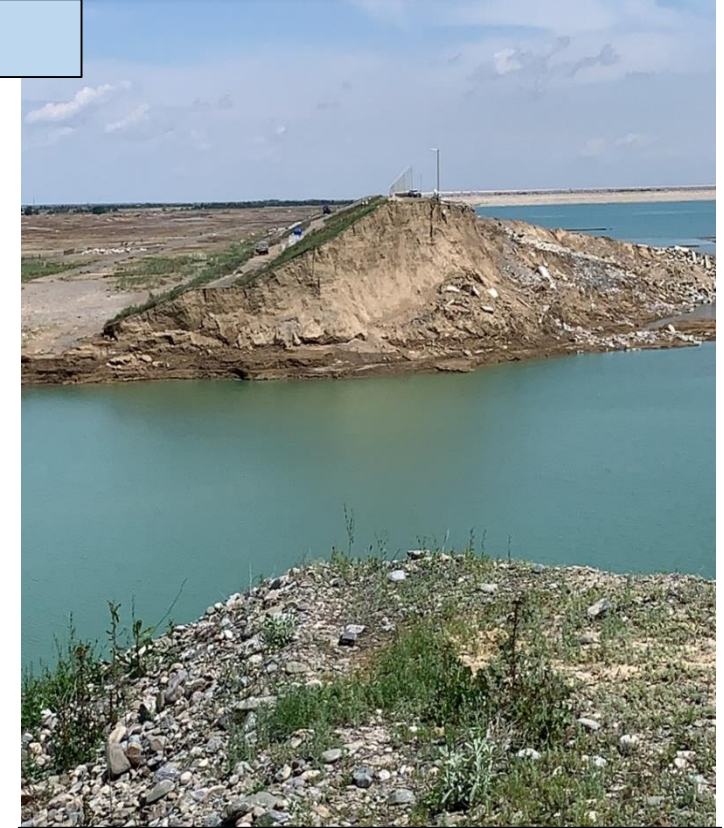
Sardoba Dam (29 m), Uzbekistan



In May 2020, the Sardoba Dam failed, causing 8 deaths and 70.000 evacuation. Estimated repair and damage cost is 500 Million \$.



An expert team by DSI visited Sardoba Dam between 18.05.2020 and 21.05.2020 to investigate the failure mechanism.



DSI team prepared a preliminary report investigating potential reasons that might trigger the collapse.



CASE STUDIES: Sardoba Dam

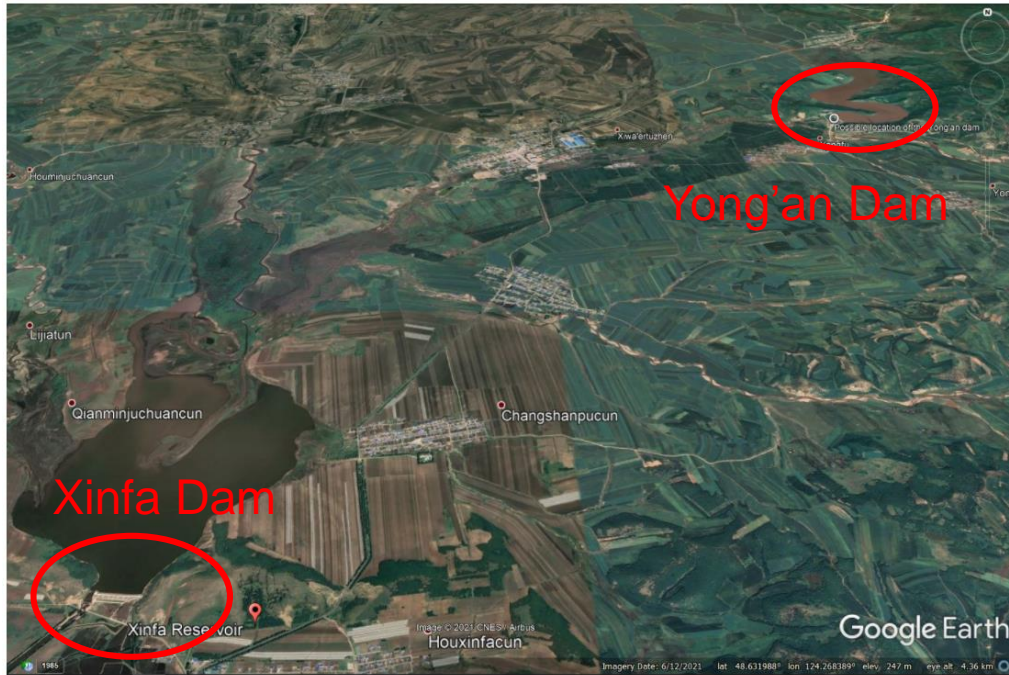


Sardoba Dam Failure (29 m), Uzbekistan
(2017 – 2020)





CASE STUDIES: Xinfa and Yong'an Dams



On 18th July 2021, two earthen dams in China were totally collapsed due to heavy rainfalls.

46 million m³ water was released, causing massive flooding in residential areas.

No casualties reported.
16 000 people were affected.
Bridges and transport infrastructure were destroyed in the downstream.



CASE STUDIES: Edenville and Sanford Dam



Edenville Dam, USA



Sanford Dam, USA



In May 2020, two dams were failed due to heavy rainfalls in Michigan State, USA.

The uncontrolled water released from Edenville Dam overtopped the Sanford Dam and eventually collapsed it.



CASE STUDIES: Edenville and Sanford Dam

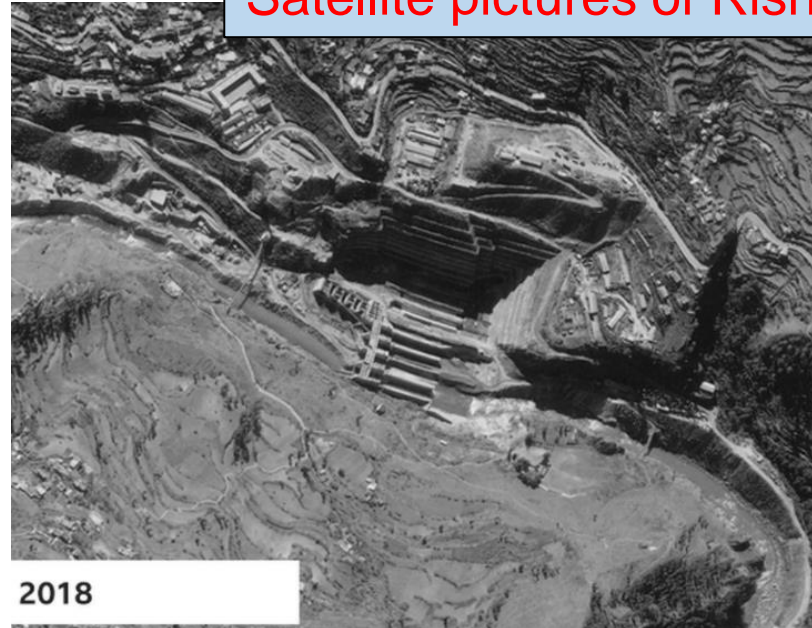


Edenville Dam, USA
(1925 – 2020)



CASE STUDIES: Rishi Ganga Hydropower Plant

Satellite pictures of Rishi Ganga Hydropower Plant



2018



February 9, 2021

Uttarakhand, India

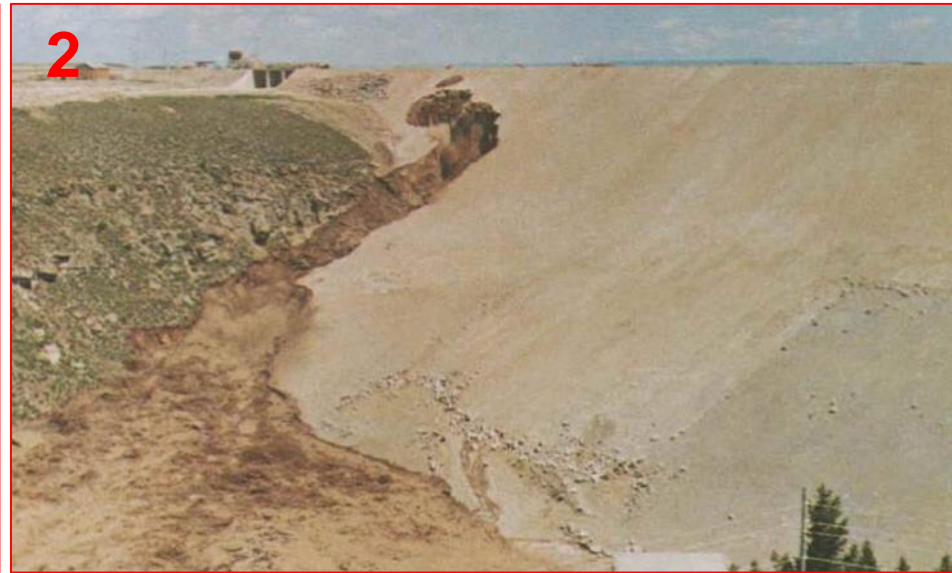
On 7th February 2021, the devastating flood washed away two (2) Hydropower Plants.

Glacier outbursts caused the flood.

At least 70 people dead, more than 150 people still missing.



CASE STUDIES: Teton Dam

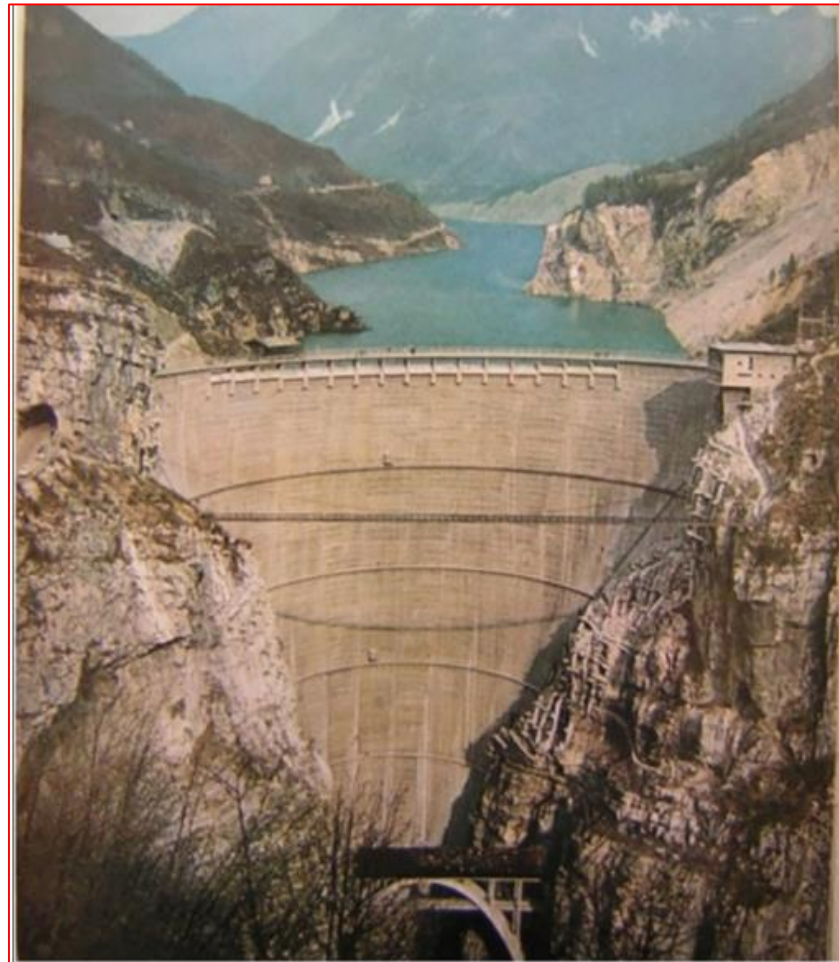


Teton Dam (93 m), USA

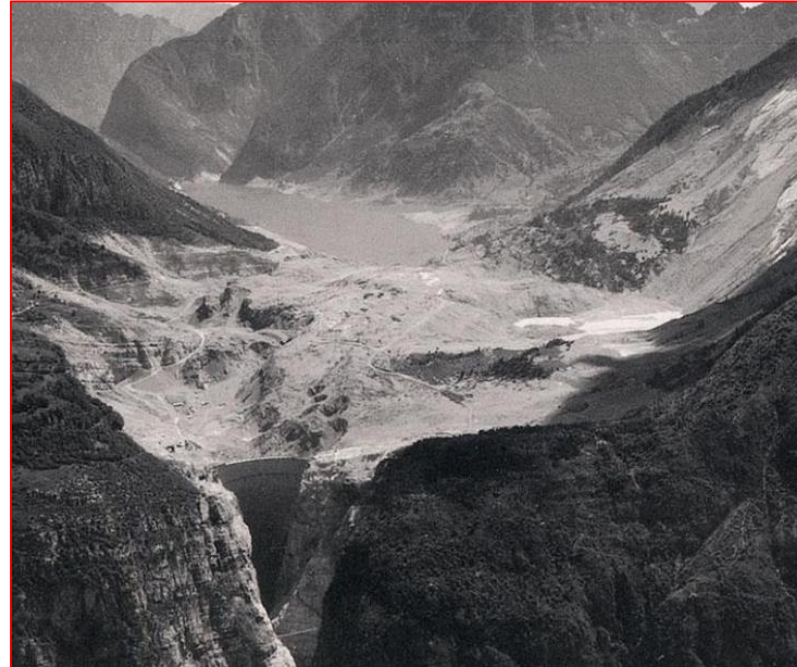
In 1976, during the first filling, the dam completely collapsed due to piping. 11 deaths, 400M \$ property damage.



CASE STUDIES: Vajont Dam



Vajont Dam, Magazine Cover. (Photo Source: Life Magazine, 1963)



Vajont Dam (262 m), Italy

In 1963, a massive rockslide occurred in the valley basin. The volume of rockslide (267 Million m³) was about twice the reservoir water.

The water overtopped the dam, causing 2056 deaths. The dam body sustained very little damage and still remains in place today with no water holding behind. (damfailures.org)



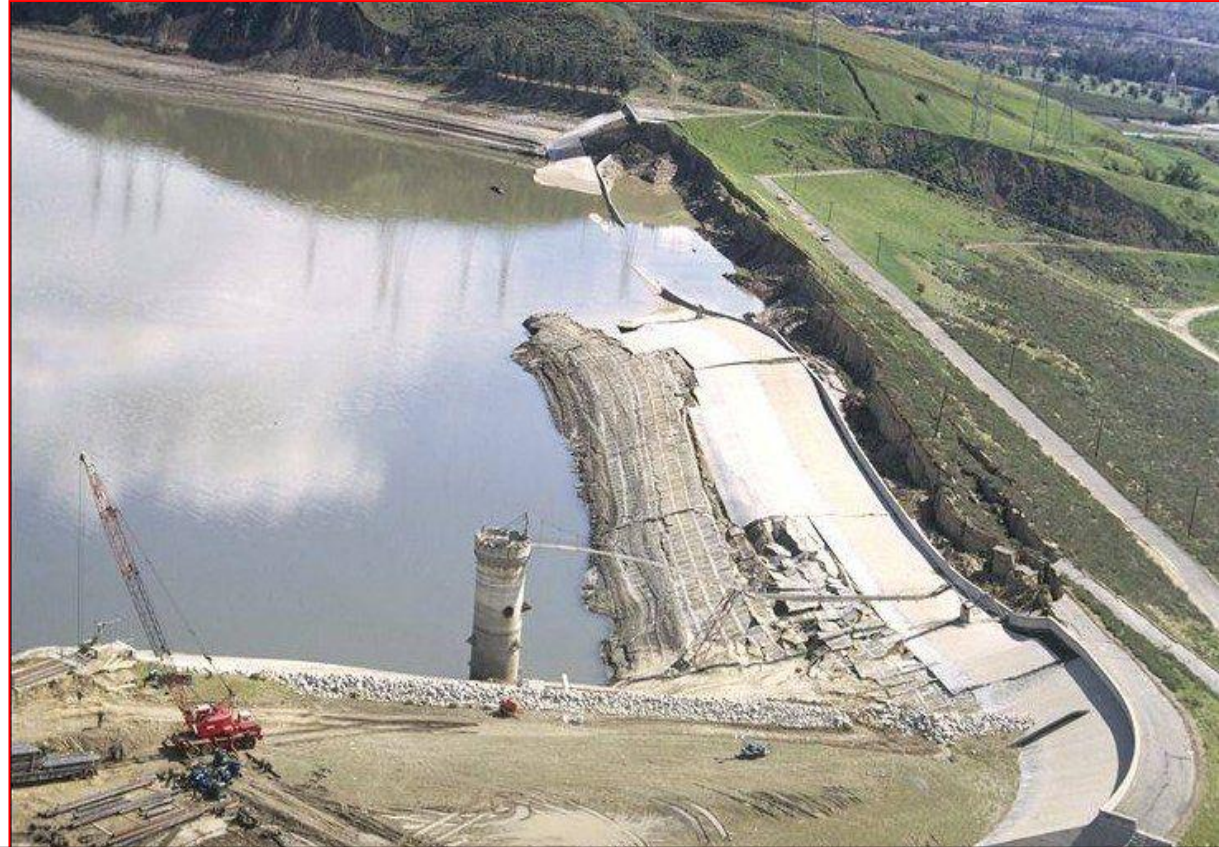
CASE STUDIES: Vajont Dam



Failure mechanism of Vajont Dam



CASE STUDIES: Lower San Fernando Dam



Lower San Fernando Dam (43 m), USA

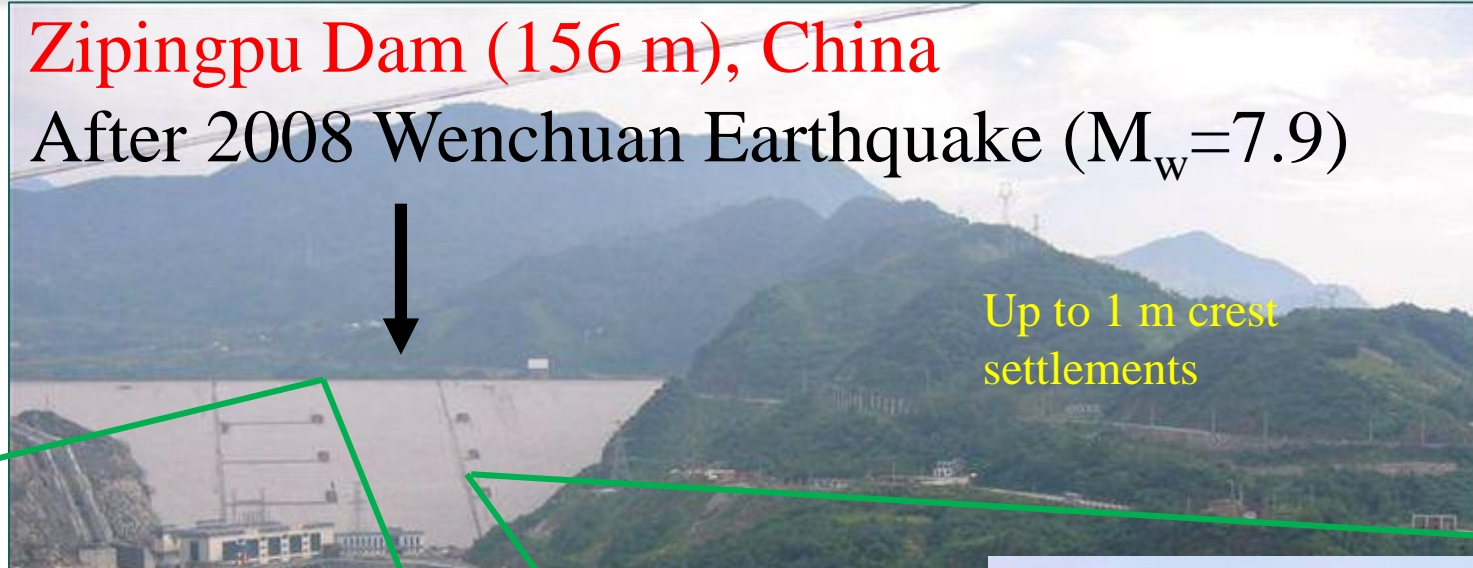
After San Fernando Earthquake in 1971 ($M_w = 6.6$)
The dam crest remained above the reservoir water level after earthquake-induced settlements, which prevented a total collapse.



CASE STUDIES: Zipingpu Dam

Zipingpu Dam (156 m), China

After 2008 Wenchuan Earthquake ($M_w=7.9$)



Up to 1 m crest settlements

Openings between concrete blocks



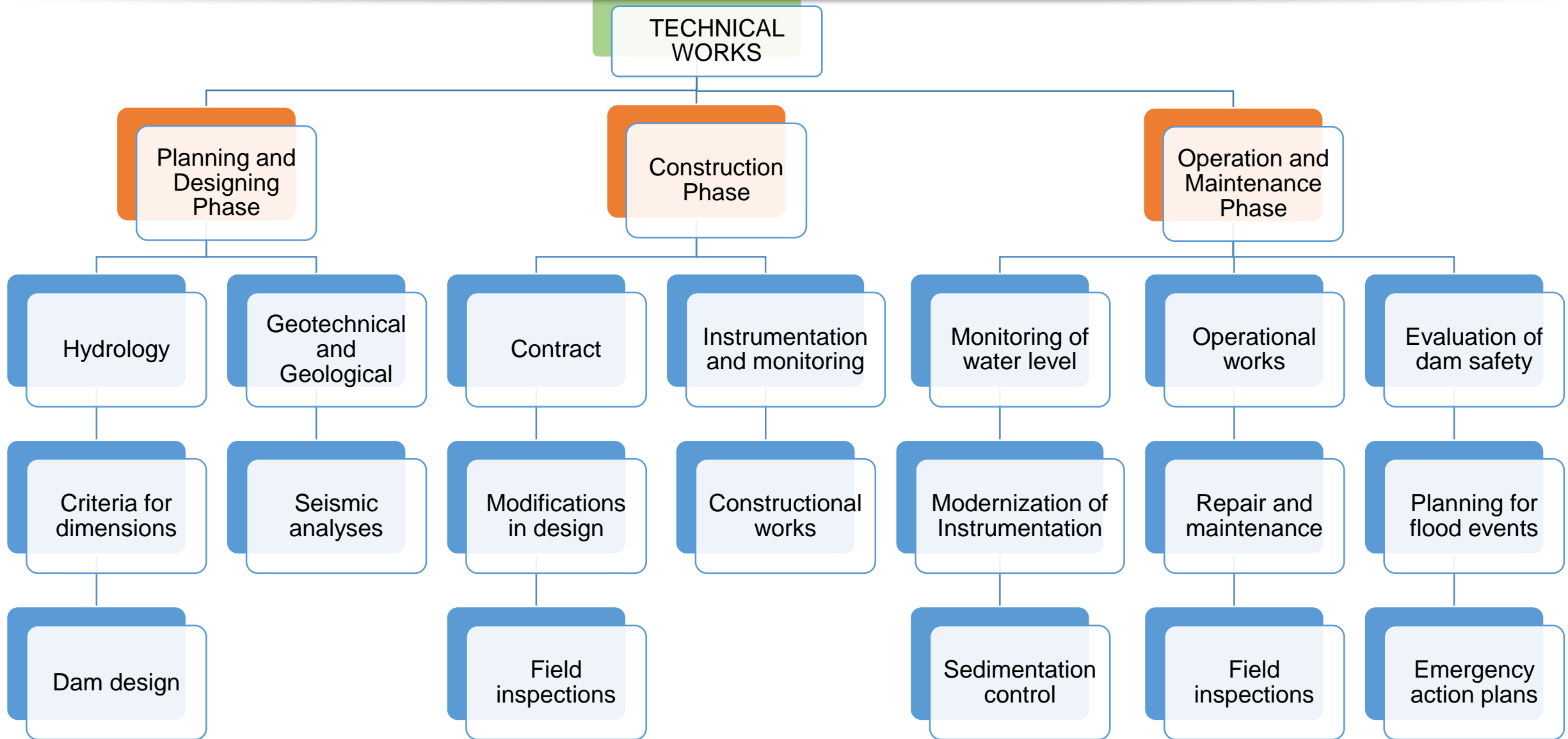
Cracks on the concrete face



DESIGN OF DAMS

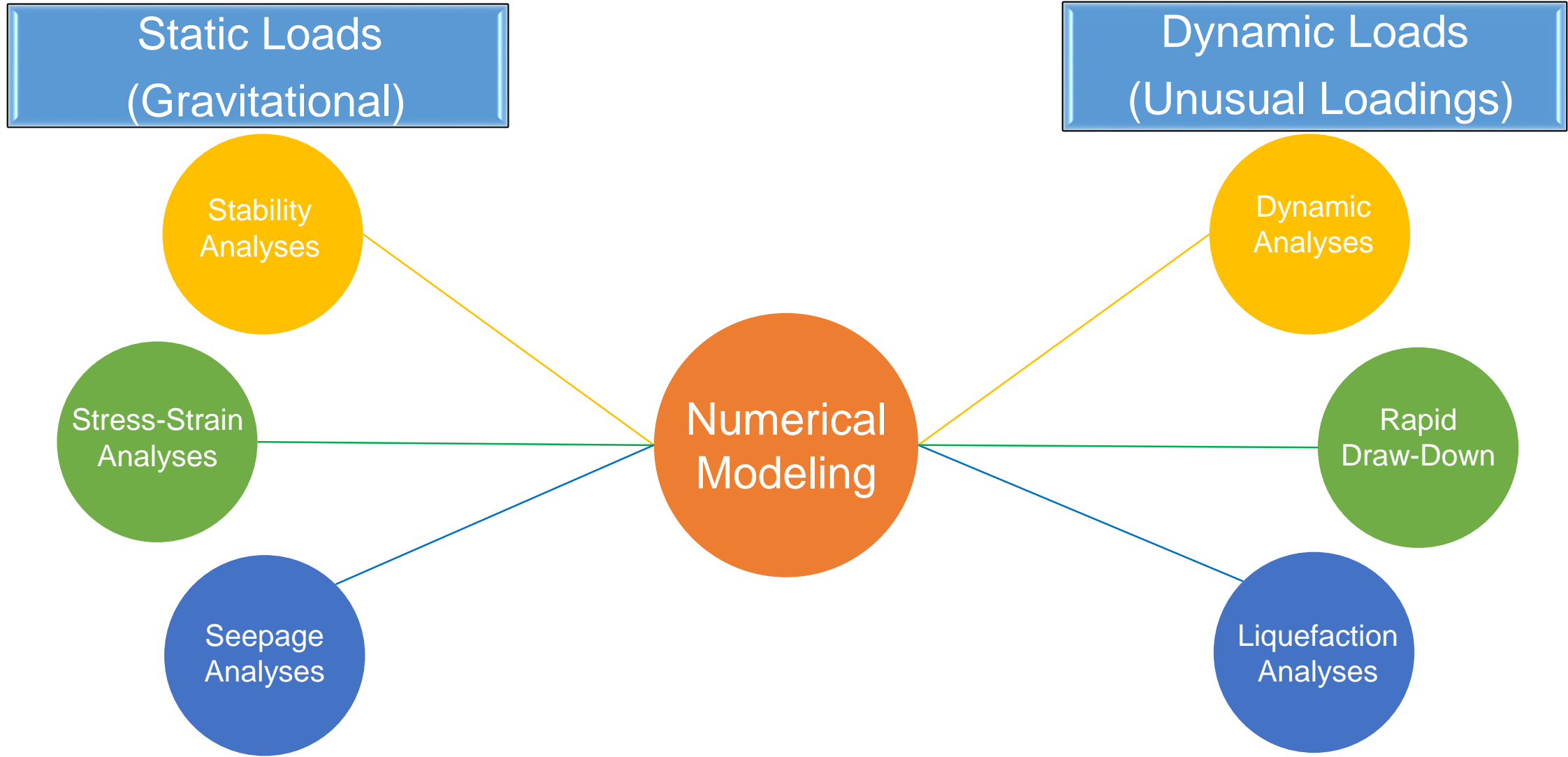


TECHNICAL WORKS FROM PLANNING TO OPERATING





MODELING PHASES IN DAM DESIGNS





RISK CLASSIFICATION OF DAMS

Risk Factor	Highest	High	Average	Low	Score
Reservoir Capacity (hm ³)	>120 (6)	120 - 1 (4)	1 - 0.1 (2)	<0.1 (0)	
Dam Height (m)	>60 (6)	60 - 30 (4)	29 - 15 (2)	<15 (0)	
Potential Evacuation Number	>1000 (12)	1000 - 100 (8)	99 - 1 (4)	0 (0)	
Potential Downstream Damage	High (12)	Average (8)	Low (4)	None (0)	
Total					

Total Risk Score	Risk Classification	
0 – 6	I	Low Risk
7 – 18	II	Moderate Risk
19 – 30	III	Substantial Risk
31 – 36	IV	High Risk

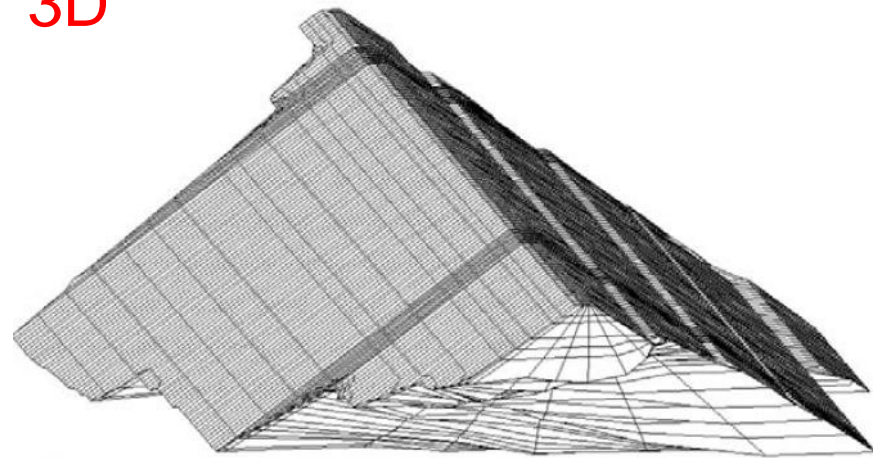
There are 4 different risk classifications. (ICOLD, Bulletin 72)



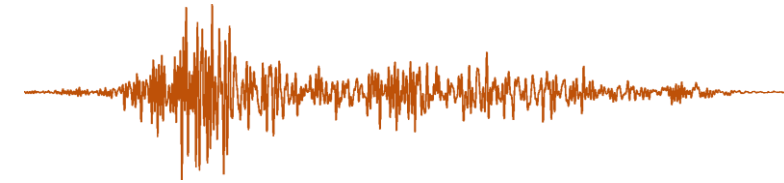
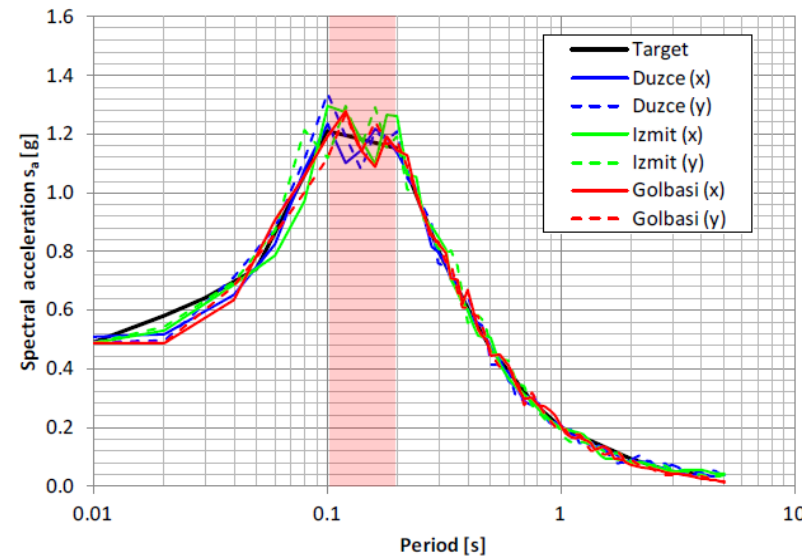
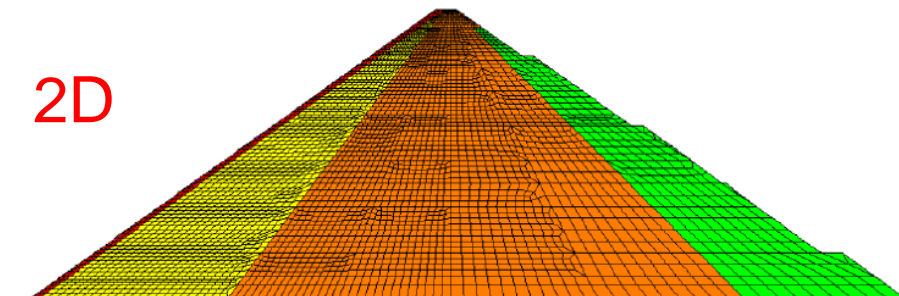
EXAMPLE FOR DYNAMIC ANALYSES

**Ilisu Prof. Dr. Veysel Eroğlu Dam
(Mardin)
CFRD, (131 m)**

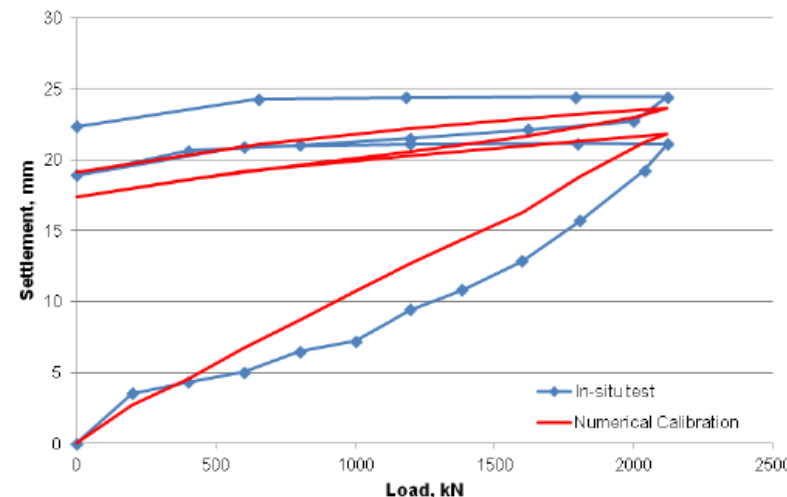
3D



2D



After design spectra is defined, the ground motions with similar characteristics are selected for dynamic analyses.



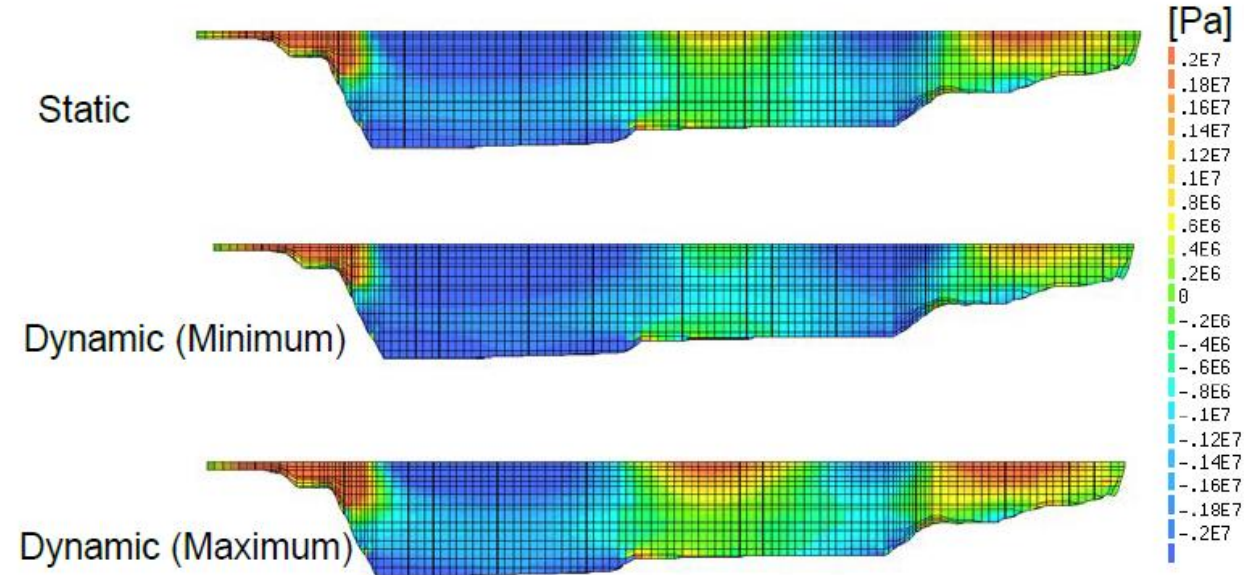
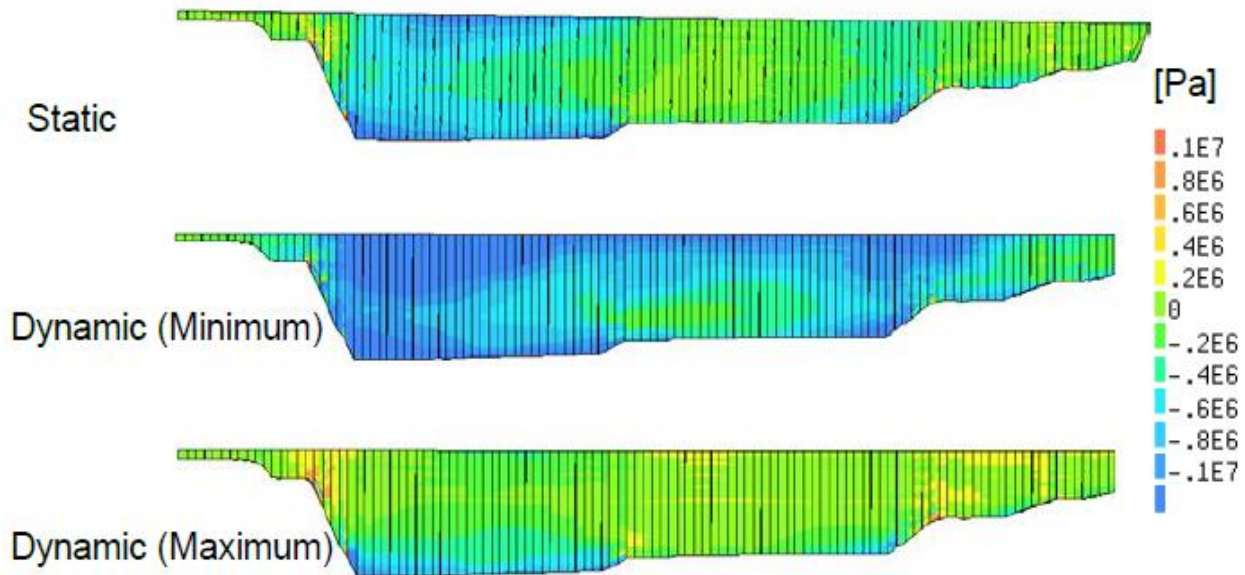
In-situ experiments conducted on rockfill material are compared with numerical results for calibration.

EXAMPLE FOR DYNAMIC ANALYSES

Ilisu Prof. Dr. Veysel Eroğlu Dam (Mardin)
CFRD, (131 m)

Estimated stresses in the concrete face when compressible joints are modelled.

Estimated stresses in the concrete face when compressible joints are not modelled.

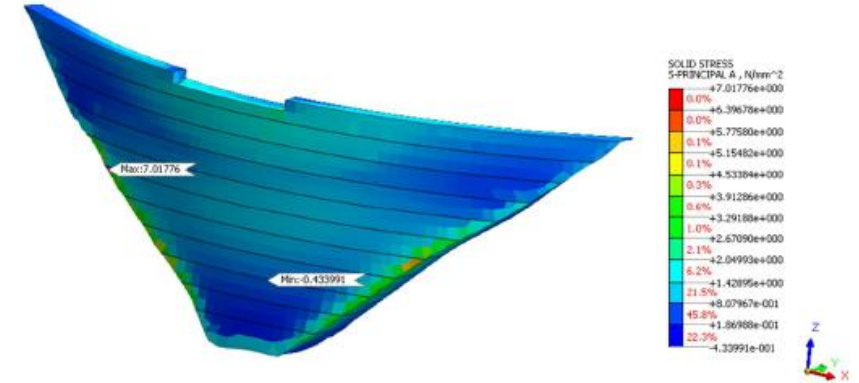
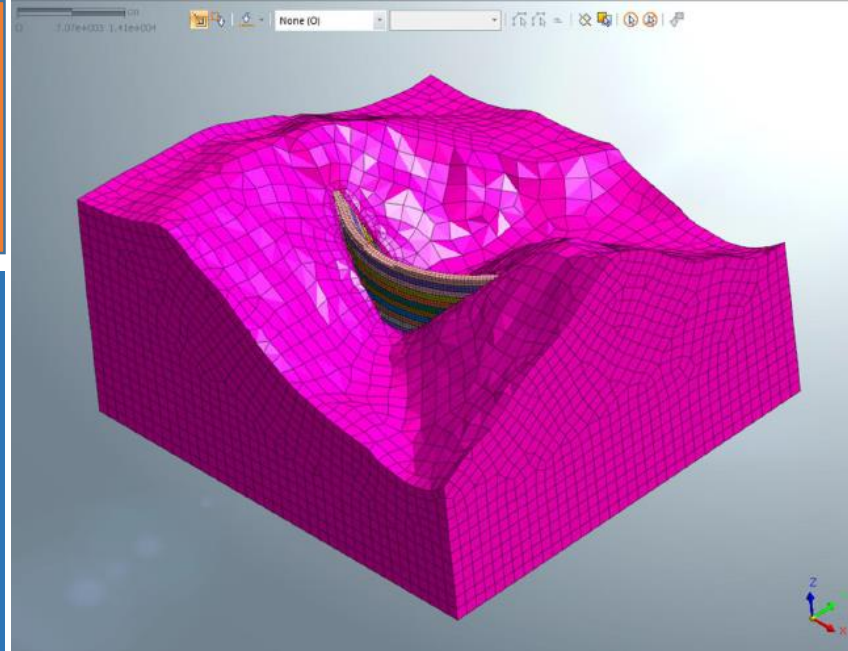




EXAMPLE FOR DYNAMIC ANALYSES

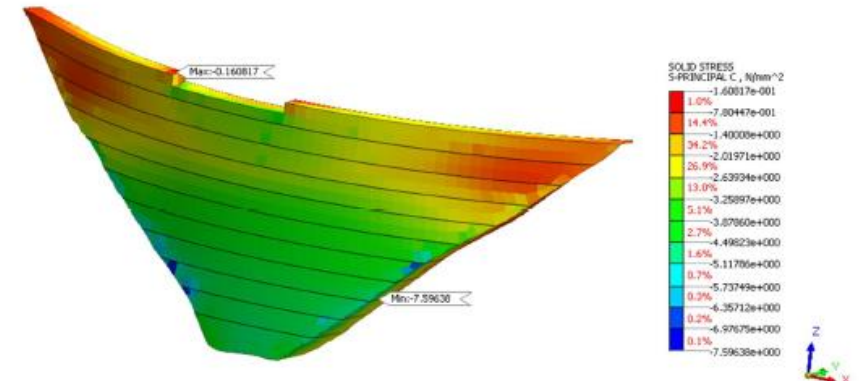
**Söylemez Dam
(Erzurum)
RCC + Arch (113 m)**

In complex geometries, the topography and 3D modelling are involved in numerical modellings.



[DATA] 2475_0302_H1, 2475_0302_H1, MAX, [UNIT] N, mm

Şekil 3.79: EED_302_H1 (Irpinia, Italy-02) – Maksimum Asal Çekme Gerilmeleri



[DATA] 2475_0302_H1, 2475_0302_H1, MIN, [UNIT] N, mm

Şekil 3.80: EED_302_H1 (Irpinia, Italy-02) – Minimum Asal Basınç Gerilmeleri

As result of seismic analyses using safety evaluation earthquakes, the seismic performance of the structure is evaluated in terms of dam safety criteria.

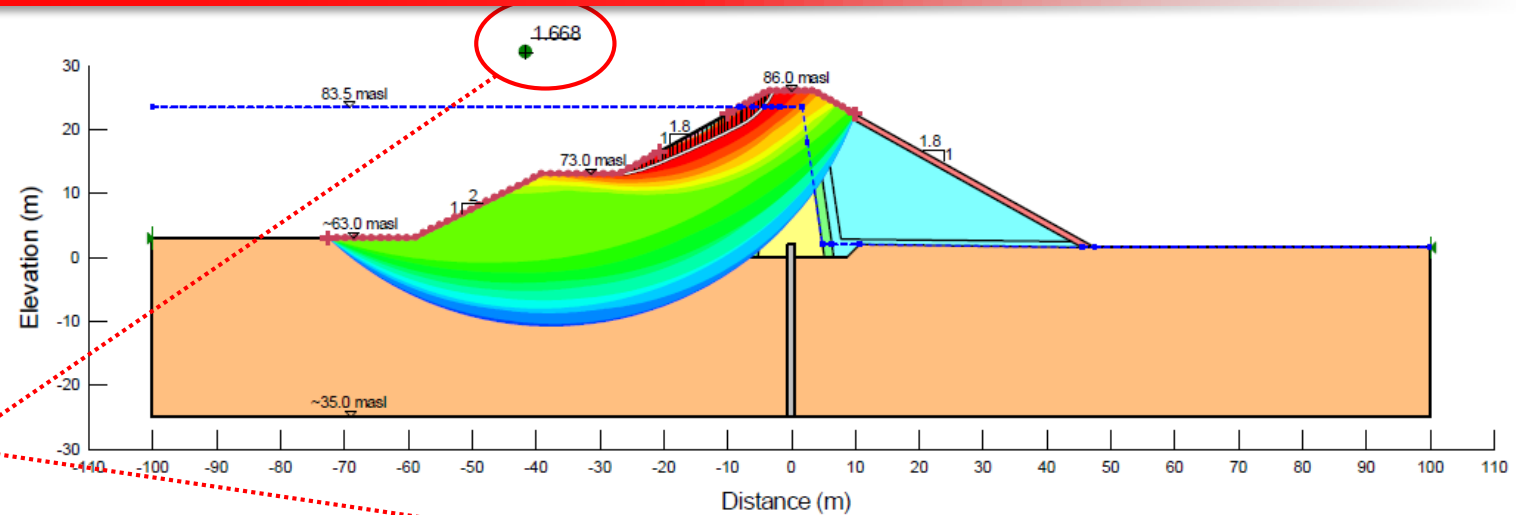


EXAMPLE FOR STATIC ANALYSES

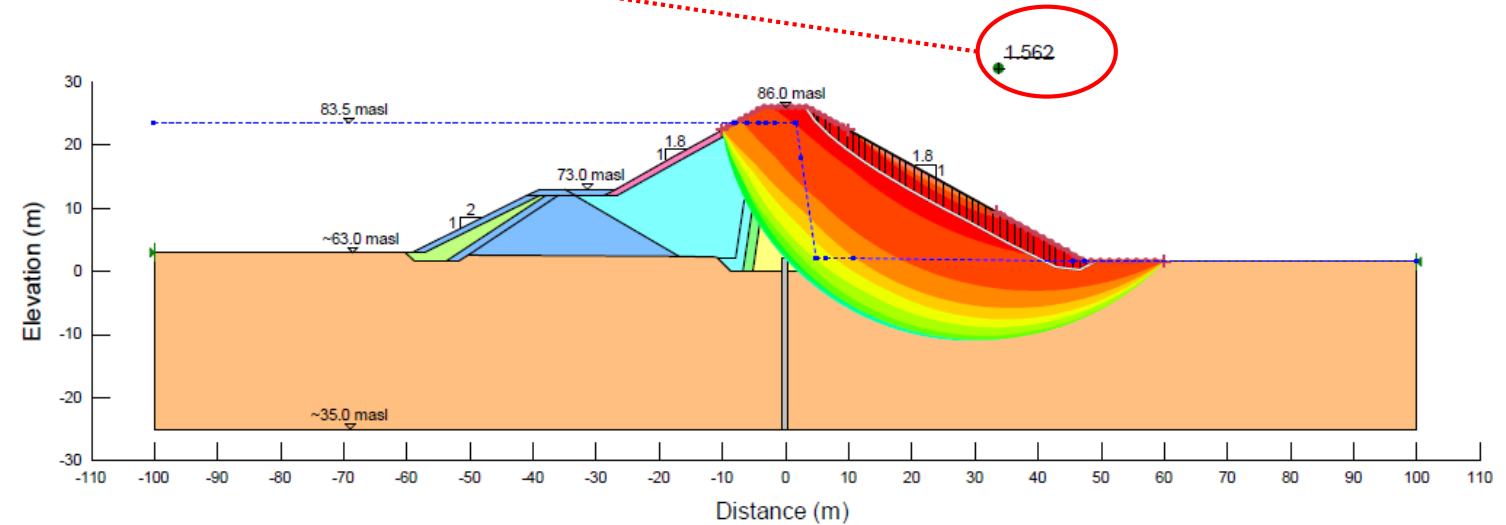
Bolaman Dam (Ordu)
Clay-Core Rockfill Dam
(28.5 m)

Factor of Safety for slopes stabilities is estimated as 1.68 and 1.56 (>1.5).

The safety factors on upstream and downstream slopes meet the required criteria.



Şekil 6-18: Memba Yamacı Stabilité Analizi. İşletim Durumu – Statik (FSL)



Şekil 6-19: Mansap Yamacı Stabilité Analizi. İşletim Durumu – Statik (FSL)



DAM CONSTRUCTION SPECIFICATIONS

The construction contracts need to be as detailed as possible. One way to achieve this is through Technical Construction Specifications which are compatible with the criteria of International Large Dam Commissions.

Some of the main DSI Technical Specifications;

- Concrete Works Technical Specification
- Earth-fill Works Technical Specification
- Roller-Compacted Concrete Works Technical Specification
- Drilling and Grouting Technical Specification
- Drainage Works Technical Specification
- Excavation Works Technical Specification
- Geotextile – Geomembrane Technical Specification
- Instrumentation Technical Specification



WORK IN THE FIELD



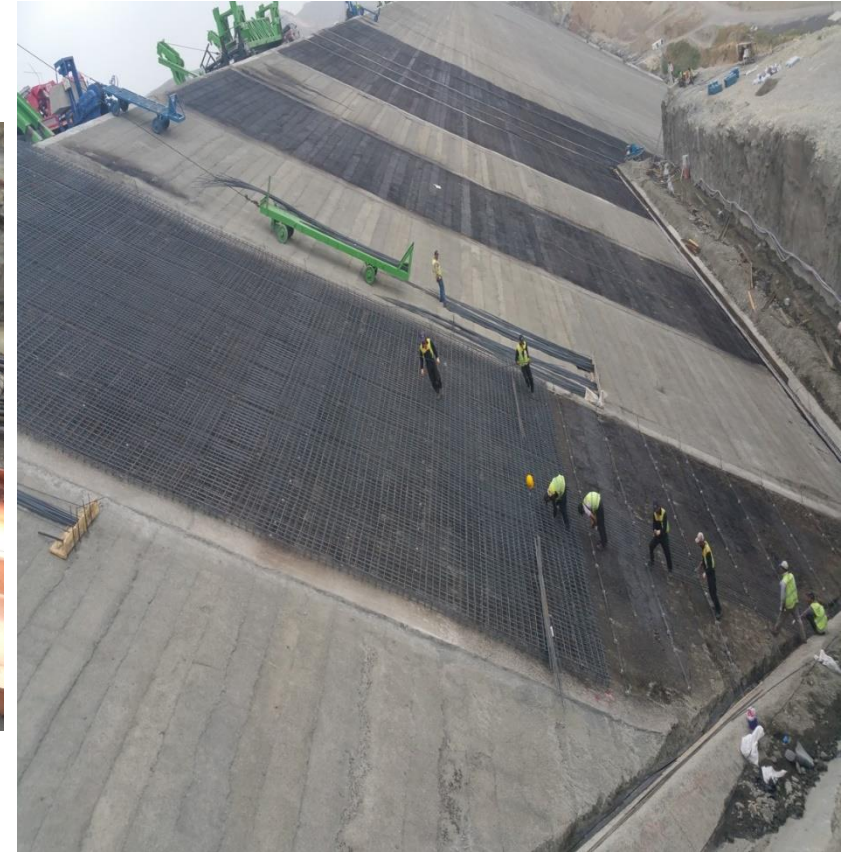


WORK IN THE FIELD





WORK IN THE FIELD





INSTRUMENTATION AND VISUAL INSPECTIONS IN DAMS



INSTRUMENTATION AND MONITORING

During construction and after construction, the dams can be monitored via instruments placed in the bodies.

Importance of Instrumentation:

- Provides vital data with regards to dam safety measures during construction and after construction.
- Provides information about the performance of the dam.
- Provides an opportunity to check the estimated performance during design works.
- Provides feedback after repairs.
- Provides data for research and development.
- Useful for detecting unexpected behavior.



YUSUFELİ DAM and HEPP

Sağ Sahil Genel Görünüm

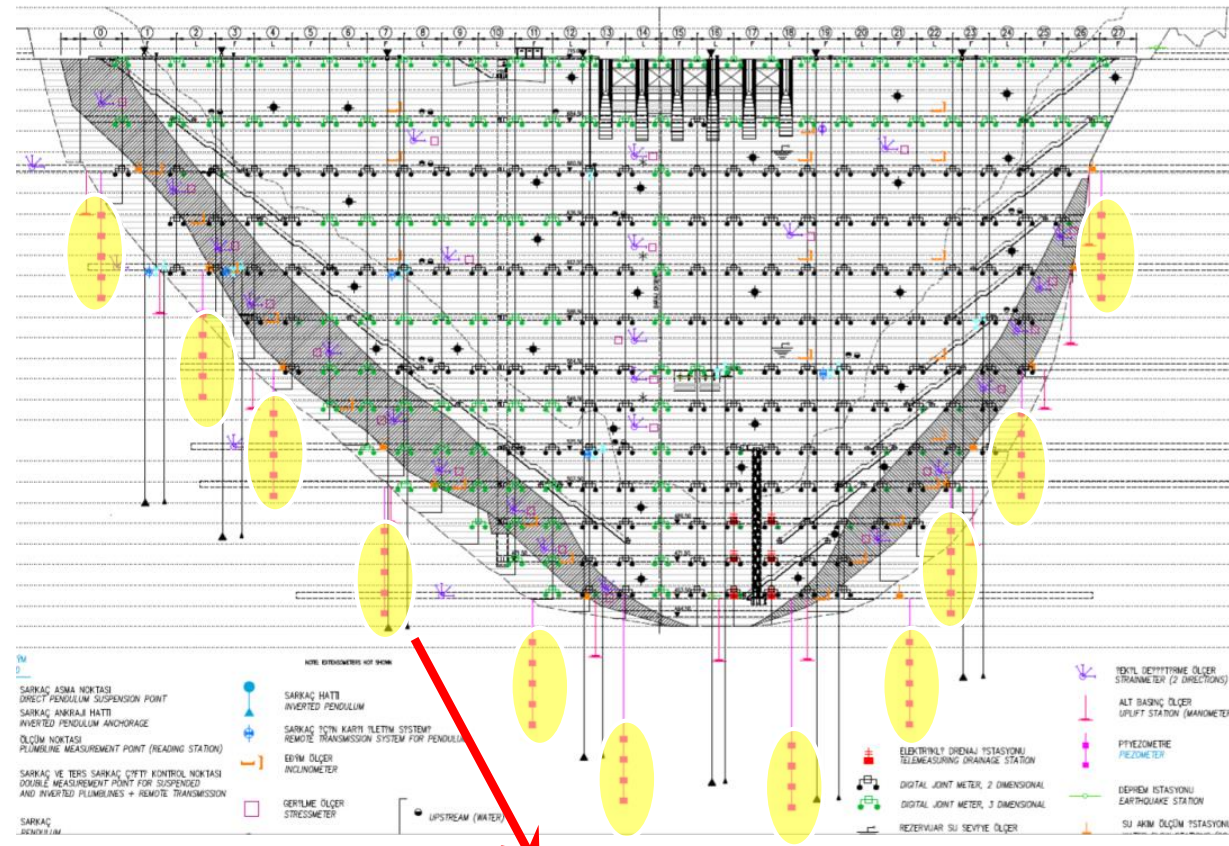
Mansaptan Genel Görünüm



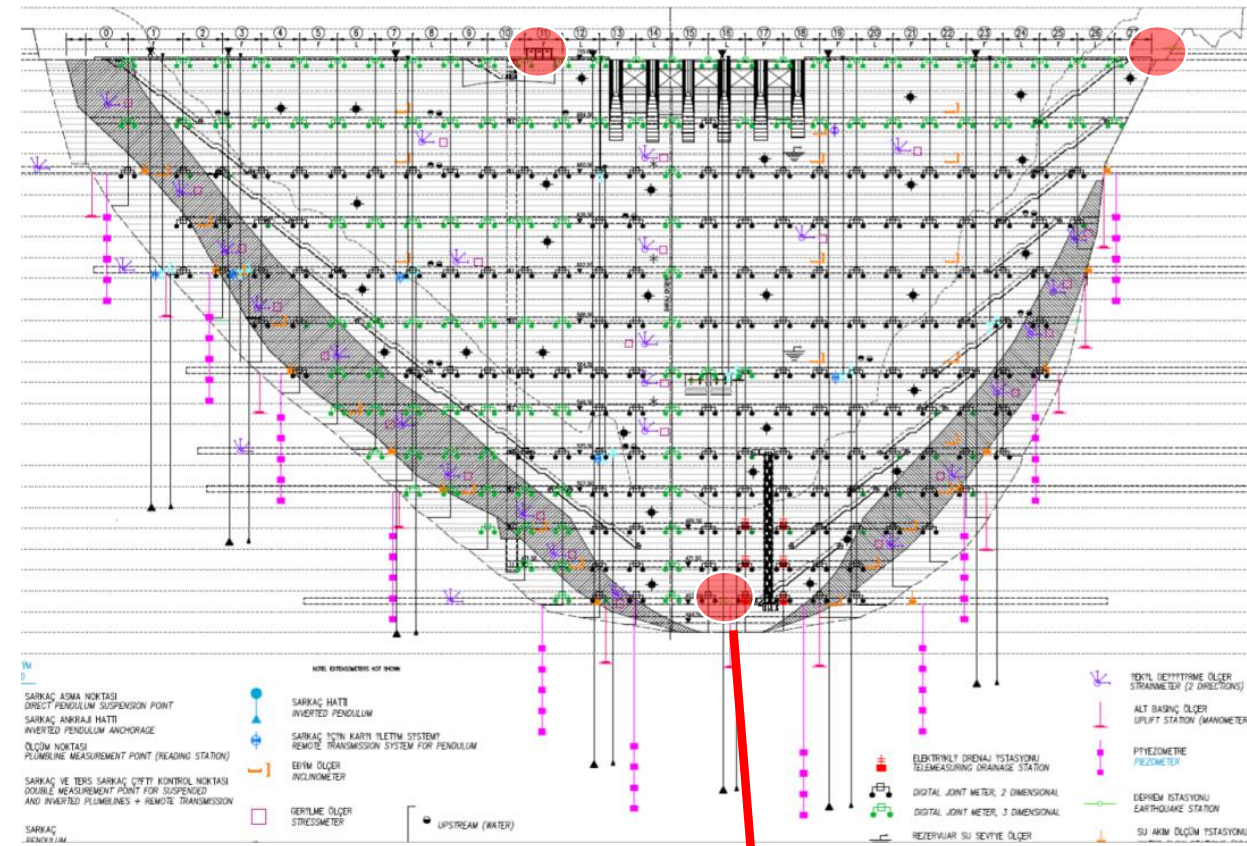
Yusufeli Dam and HPP (275 m)
Double Curvature Concrete Arch Dam
540 MW (3 Units)



YUSUFELI DAM and HEPP - INSTRUMENTATION



VW Piezometer



Accelerometer





YUSUFELİ DAM and HEPP- INSTRUMENTATION

CİHAZ ADI	ADET
Eğim Ölçer / Tilt Meters	24
Çubuk Eksansiyometre (4 Çubuklu) / Rod Extensometers	25
Çubuk Eksansiyometre (1 Çubuklu) / Rod Extensometers	12
Elektronik Akım Ölçer İstasyonu / Electronic Flow Measurements	6
Birim Şekil Değişirme Ölçer / Strain Gauges	29
Gerilme Ölçer / Stressmeters	30
Derz Ölçer (3 Boyutlu) / Joint Meters (Triaxial)	105
Derz Ölçer (1 Boyutlu) / Joint Meters (one dimensional)	152
Titreşen Telli Sıcaklık Ölçer / VW Temperature Measurement	20
Thermistör / Thermistors	3782
Termokapl / Thermocouples	150
Toplam Basınç Ölçer / Total Pressure Cells	32
Piyezometreler / Piezometers	48
Sızıntı Ölçüm İstasyonu / V Notches	12
İvmeölçer Cihazı / Accelerometers	3
Ters Sarkaç / Inverted Pendulum	7
Düz Sarkaç / Pendulum	7

Total
4441
Instruments



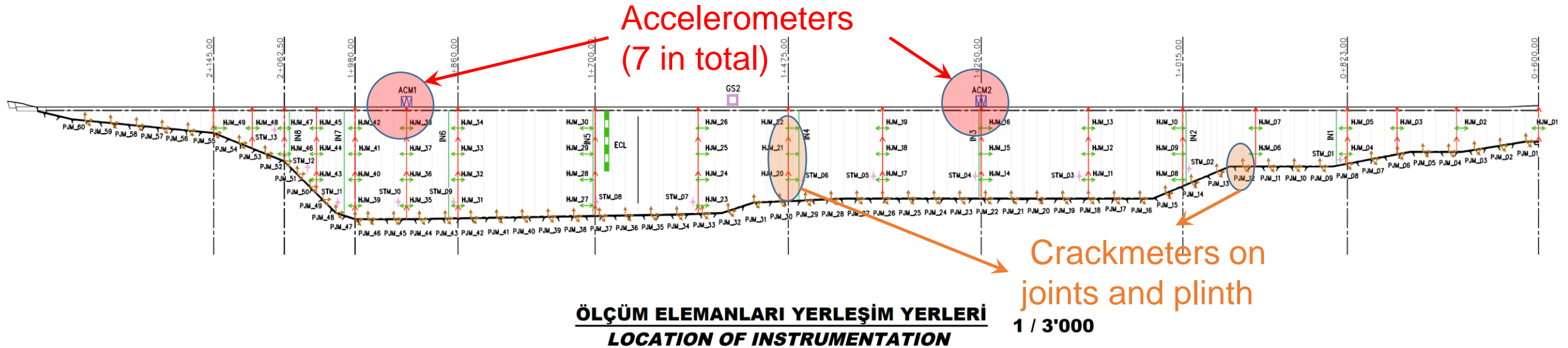
ILISU PROF. DR. VEYSEL EROĞLU DAM and HEPP

Ilisu Dam and HPP(135 m)
Concrete – Faced Rockfill Dam
1200 MW (6 Units)





ILISU PROF. DR. VEYSEL EROĞLU DAM and HEPP - INSTRUMENTATION



INSTRUMENTS	NO	INSTRUMENTS	NO	INSTRUMENTS	NO
Piezometers (foundation)	141	Accelerometers	7	Extensometers	16
Lateral Extensometer	42	Water Level Meter	1	Flow Meter	5
Pressure Cells	106	Strain Gages	45	Temperature Sensors (short term)	39
Hydraulic Settlement Cells	93	Fiber Optic Leakage Detector	1	Temperature Sensors (long term)	18
Magnetic Extensometers	4	Benchmarks	57	Strain Meters (with thermometers)	18
Inclinometers	8	Pendulum	4	Water Temperature Sensor	1
Crack Meters	163	Inverted Pendulum	4	Weather Station	1

**Total
774**



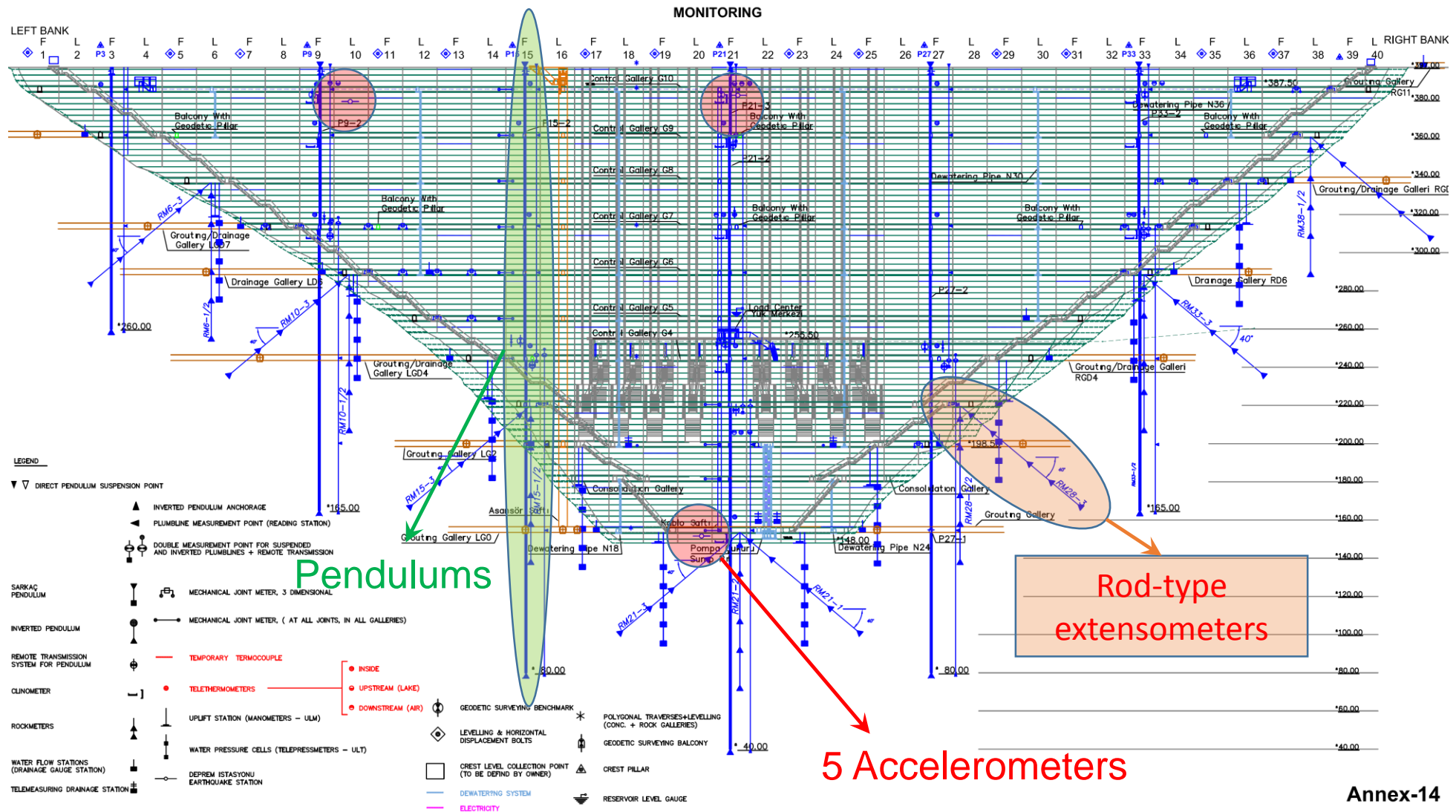
DERİNER DAM and HEPP



Deriner Dam and HPP (249 m)
Double Curvature Concrete Arch Dam
670 MW (4 Units)



DERİNER DAM and HEPP- INSTRUMENTATION





DAM BREAK ANALYSES



DAM BREAK ANALYSES

Dam Break Analyses are widely performed across the world, as the technological advances improve the capability of computers.

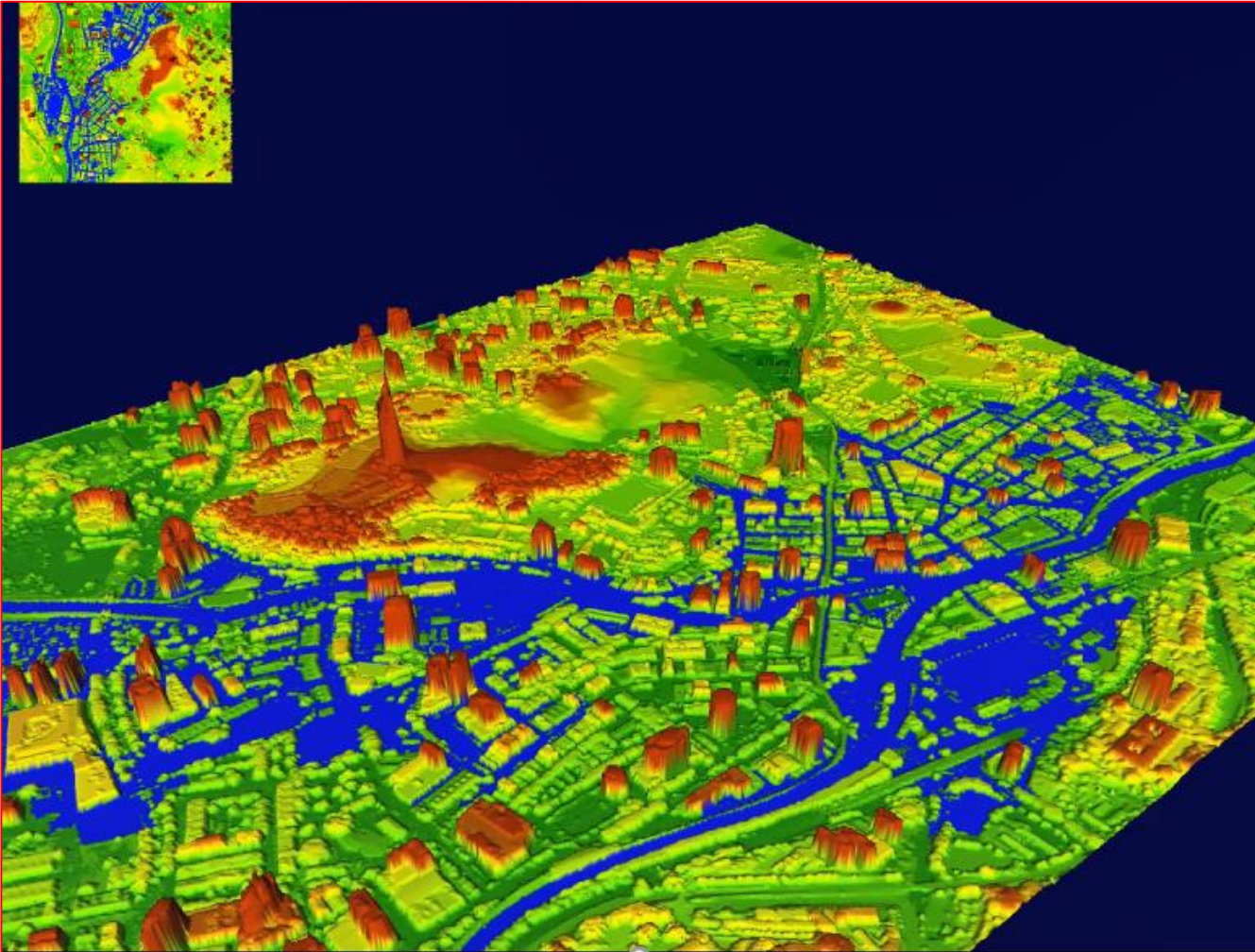
DSI performs dam break analyses within the scope of dam safety.

Primary purposes of dam break analyses:

- Estimate the amount of reservoir outflow with time
- Estimate the routing of the outflow
- Prepare emergency action plans afterwards



İZMİR ÜRKMEZ DAM - DAM BREAK ANALYSIS

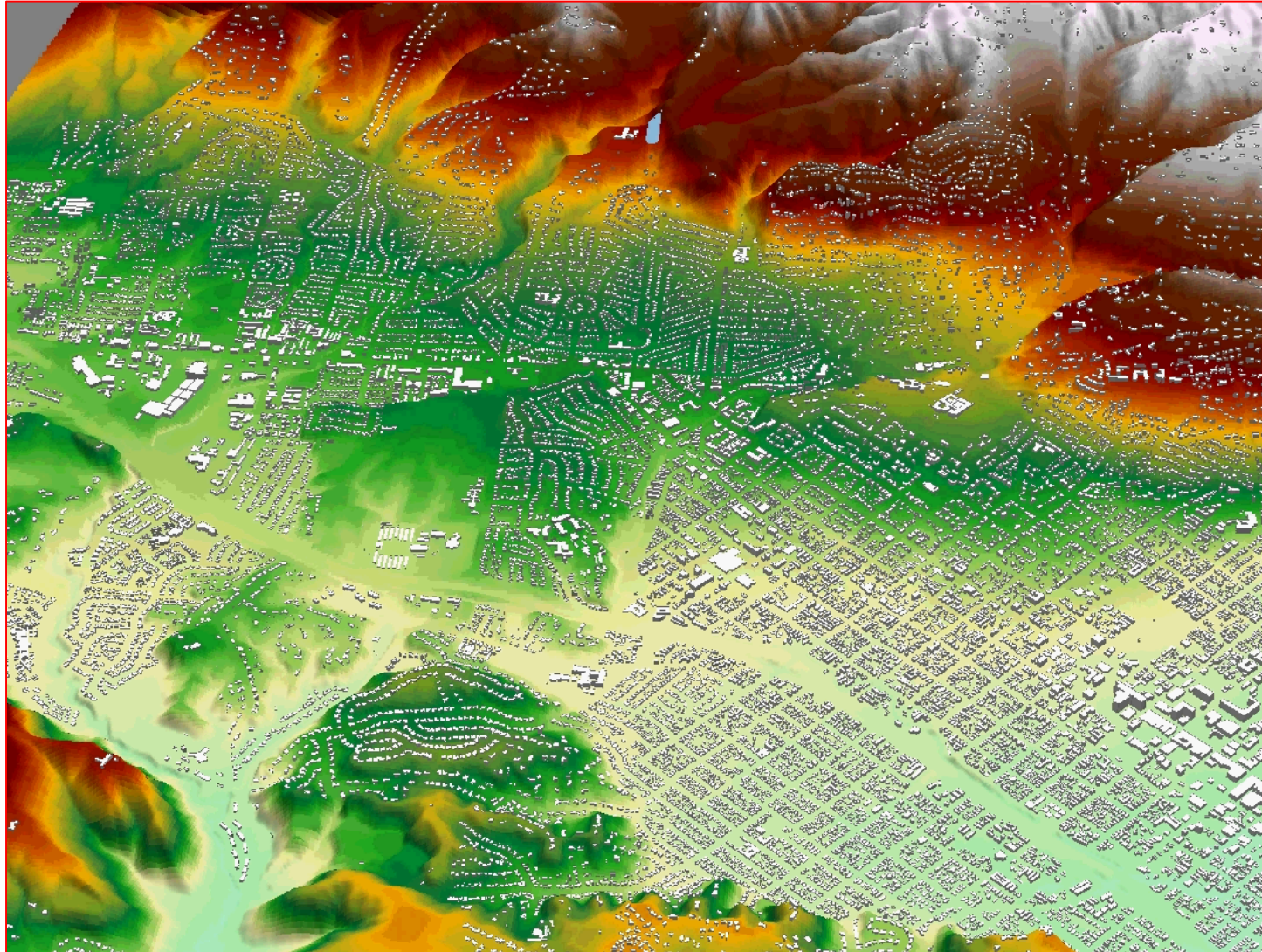


Dam break analysis of Urkmez Dam, located in city of Izmir, was performed.

The flood hazard maps are produced for emergency preparedness plan.

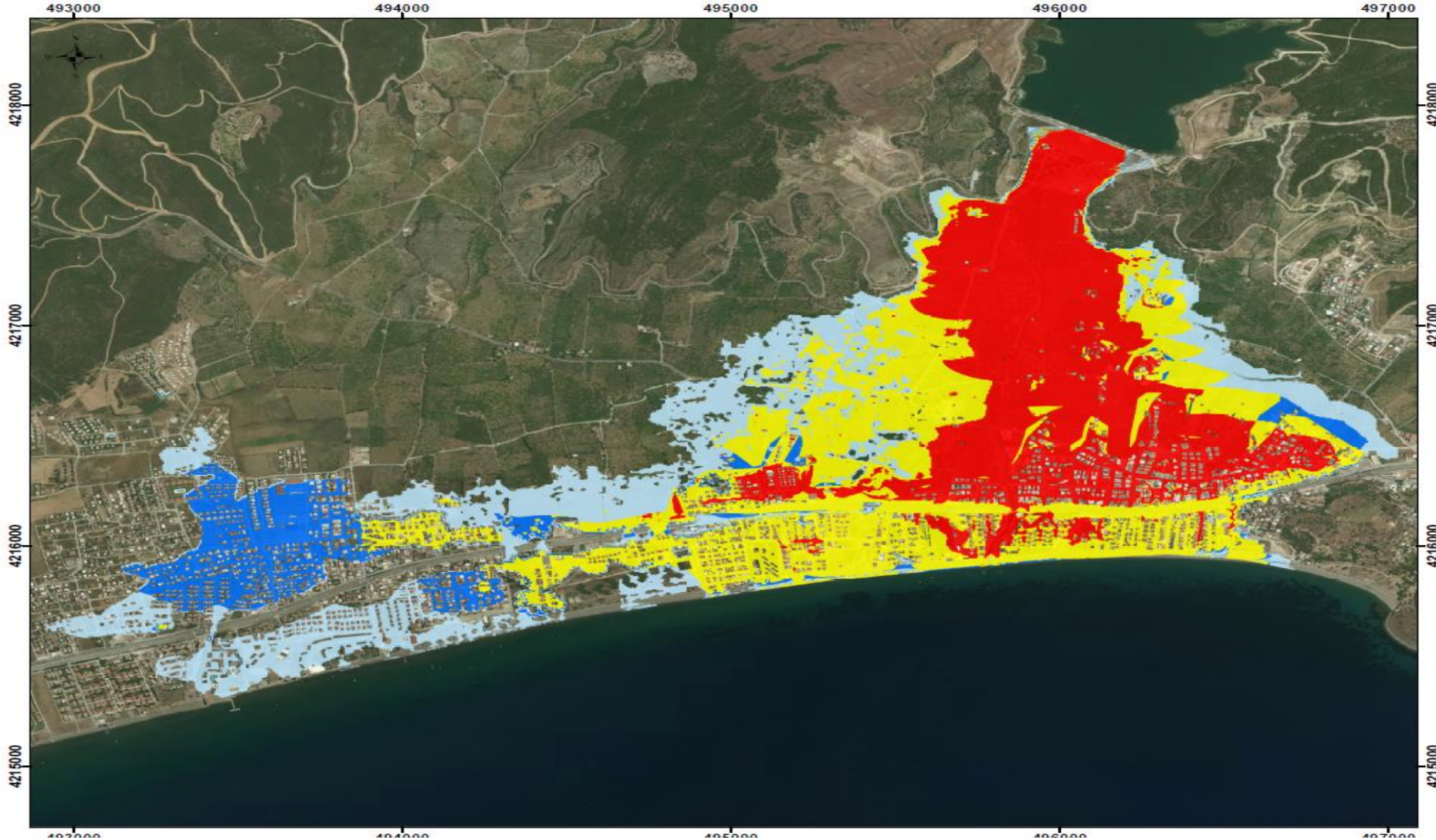


İZMİR ÜRKMEZ DAM - DAM BREAK ANALYSIS





İZMİR ÜRKMEZ DAM - DAM BREAK ANALYSIS



Tehlike Dereceleri

- Düşük (0 - 0.75)
- Orta (0.75 - 1.25)
- Yüksek (1.25 - 2.5)
- Çok Yüksek (> 2.5)

Koordinatlar: ITRF98 3 derece DGM 27'lik
0 150 300 600 Metre 1/13000

NO	TAHİR / GAZİ	REVİZYON / REVİZE	YAPAN / ONAYLAYAN

TASKIN MÜDÜRLÜĞÜ
DEVLET SU İŞLERİ GENEL MÜDÜRLÜĞÜ
BARAJLAR VE HES DAİRESİ BAŞKANLIĞI
ANKARA

PROJE MÜHÜRÜ FİRMA
BOLATIR MÜHÜR MÜHÜR VE DENEYİM LİM. Şİ.
Araç Adres: Etiler, Kat: No: 130, Çankaya, Ankara
www.bolatir.com.tr

İZMİR ÜRKMEZ DAMI YIKILMA ANALİZİ VE ACİL EYLEM PLANLARININ HAZIRLANMASI PROJE YAPIMI İÇİ

İZMİR ÜRKMEZ İLÇESİ - SENARYO 1 - TAŞKIN TEHLİKE HARİTASI

YAPAN :	ÇABRİ HASAN KARAKAN	TAHİR :	30 / 08 / 2019	
ÇİZEN :	ÇABRİ HASAN KARAKAN	TAHİR :	30 / 08 / 2019	
KONTROL :	İSMAIL KANUN TUNÇOK	TAHİR :	30 / 08 / 2019	BOYUT / BİÇİM :
KARŞI NO :		OLÇEK :	103286	A3
PROJE NO :	19081-01			MS



EARLY WARNING SYSTEMS

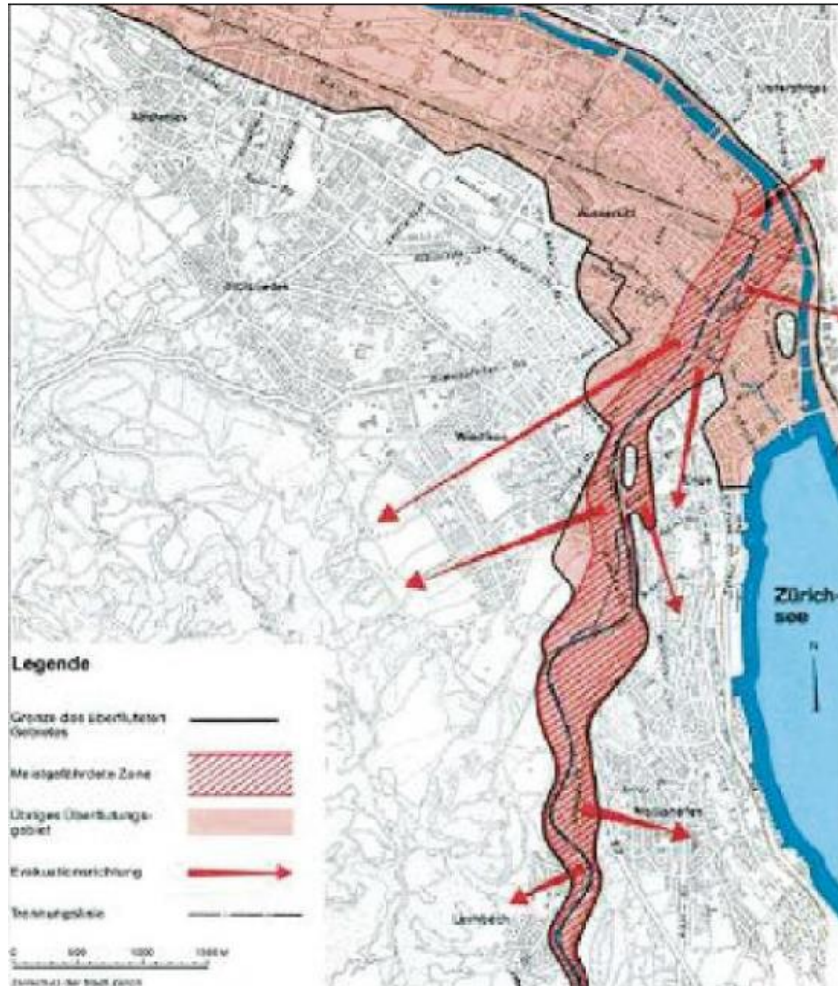


Tepekışla Dam ve HPP(Tokat)

After the flood hazard maps are produced, early warning systems are installed in downstream residential areas as part of emergency preparedness plans.



EARLY WARNING SYSTEMS



Water alarm sirens(left) and general alarm sirens (right).

**DAM SAFETY, CONSEQUENCES OF DAM FAILURE,
AND MEASURES FOR RISK REDUCTION**



RESULTS AND EVALUATIONS

- The number of constructed dams in Turkey is significantly high (currently 1446).
- Due to seismic activities in Turkey, special attention is given to design of dams accordingly.
- The experience in dam engineering gained since 1900s allowed the designs to be safely standardized. Thus, as long as the design criteria is followed accordingly, the potential risks are minimized.
- Inspections and monitoring are carried out visually and instrumentally.
- The dams are constantly being monitored during both construction and operation phases by the technical staff responsible for safety of dams .
- The flood hazard maps are produced via dam break analyses to set up emergency action plans (EAP).



Thank You.