



Site Selection

- Site Safety Considerations -

May 2015

SHIM, Taekmo

Korea Institute of Nuclear Safety

CONTENTS

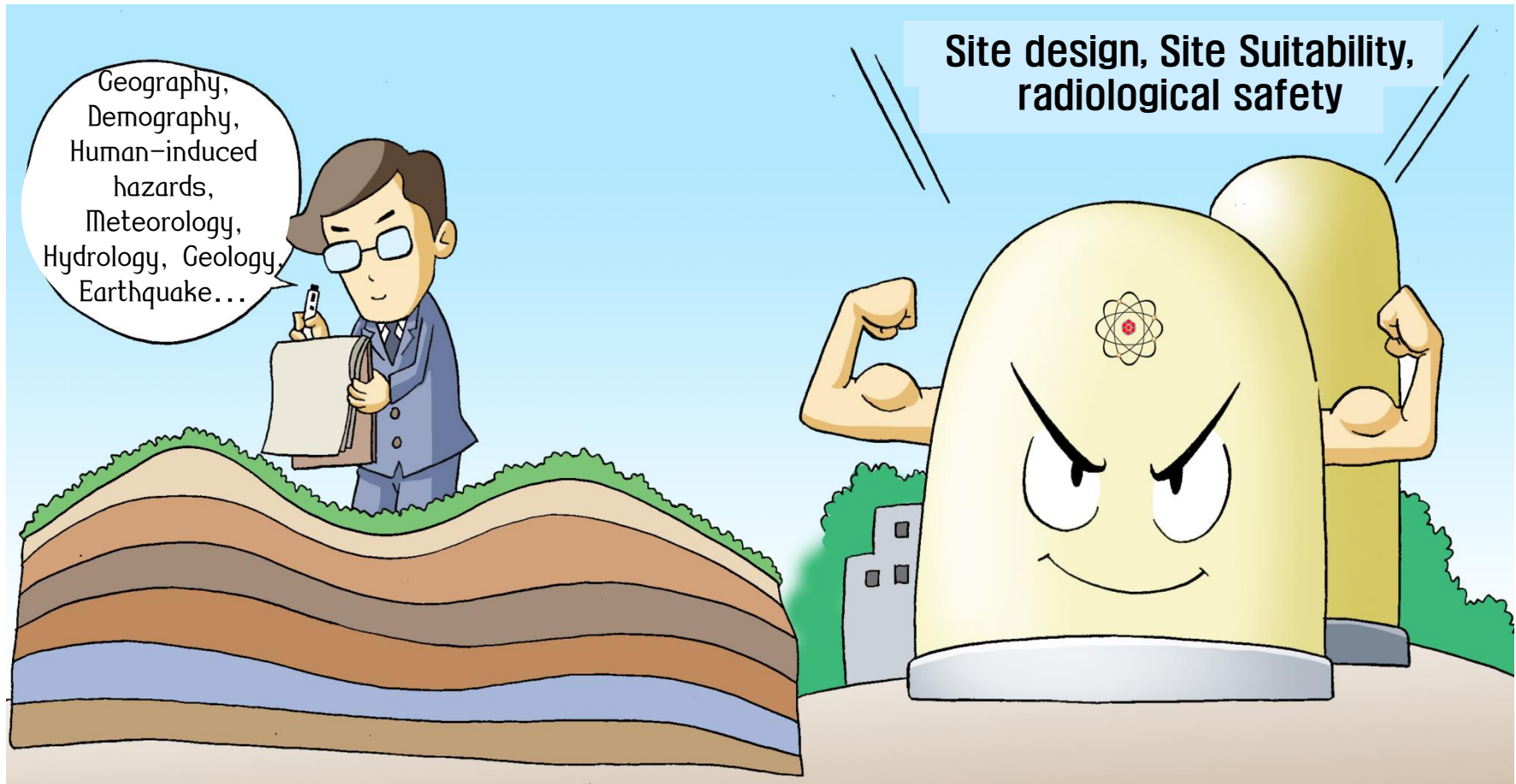
- I Introduction**
- II Geography and Demography**
- III Human-induced Hazard**
- IV Meteorology**
- V Hydrology**
- VI Geology and Seismology**
- VII Geotechnical Engineering**
- VIII Monitoring of Hazards**

I. Introduction

Why Site Safety Evaluation?

Site safety evaluation for NPPs concerns

1. Site suitability for planed NPPs
2. Input data of the NPP site for the design



□ Siting

- The process of selecting a suitable site for a facility including appropriate assessment and definition of the related design basis (IAEA, NS-R-3)
- The siting process for a nuclear installation generally consists of an investigation of a large region to select one or more candidate sites (site survey), followed by a detailed evaluation of those candidate sites (IAEA, NS-R-3)
- Siting covers the general safety requirements and criteria for site related evaluation of external natural and human induced hazards to the nuclear installations

❑ Major Subjects Related to Siting

○ Geography and Demography

- The effects of the nuclear installation on the region and matters relating to population and emergency planning

○ Human-Induced Hazard

- Nearby industrial, transportation, and military facilities

○ Meteorology

- Design consideration of the severe meteorological condition
- Strong wind, heavy rainfall or precipitation, tornadoes
- Atmospheric diffusion characteristics for the calculation of the transport and dilution of radioactive materials

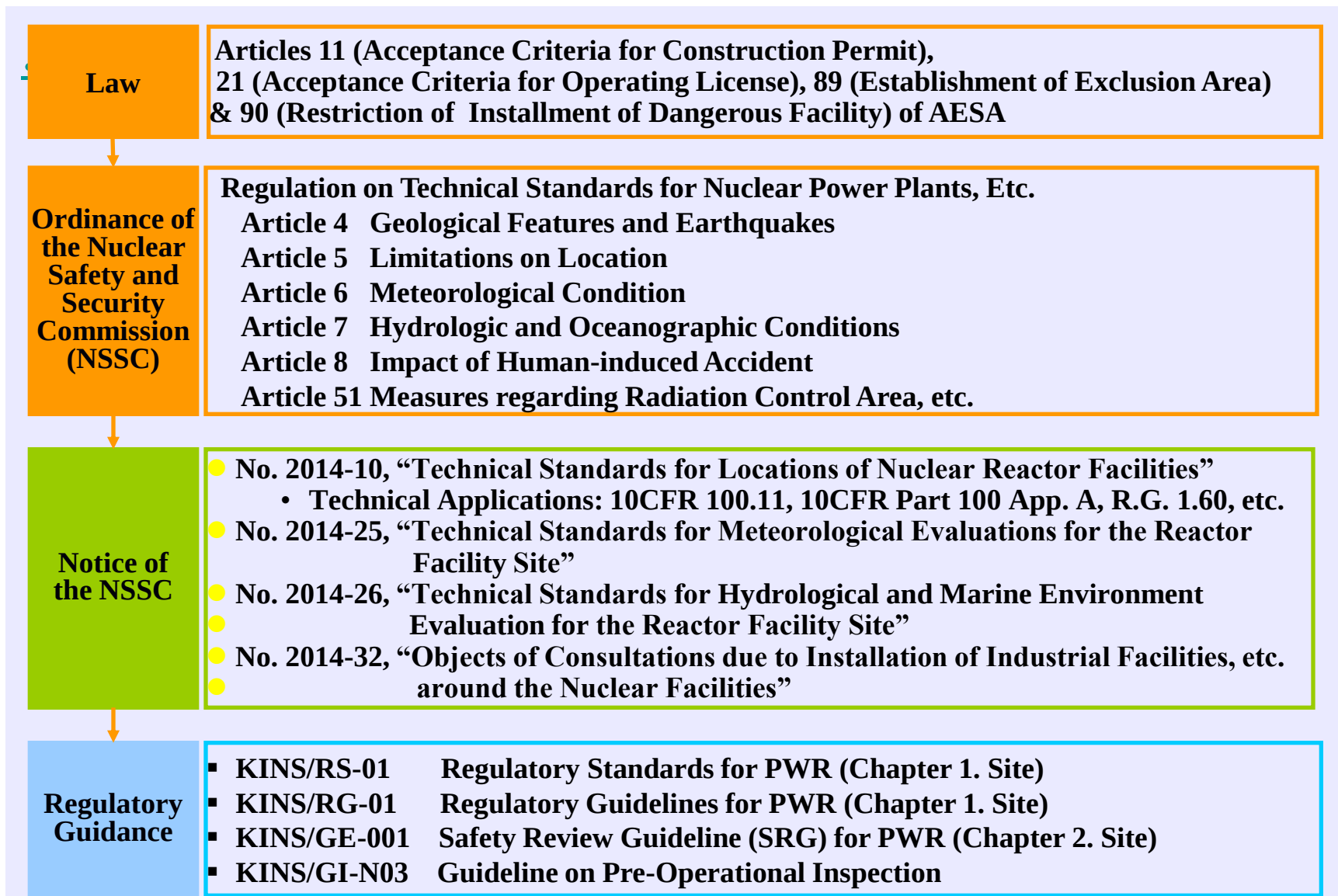
○ Hydrology

- Protection from flooding, radioactive material diffusion through ground/surface water, water use

○ Geology, Seismology, and Geotechnical Engineering

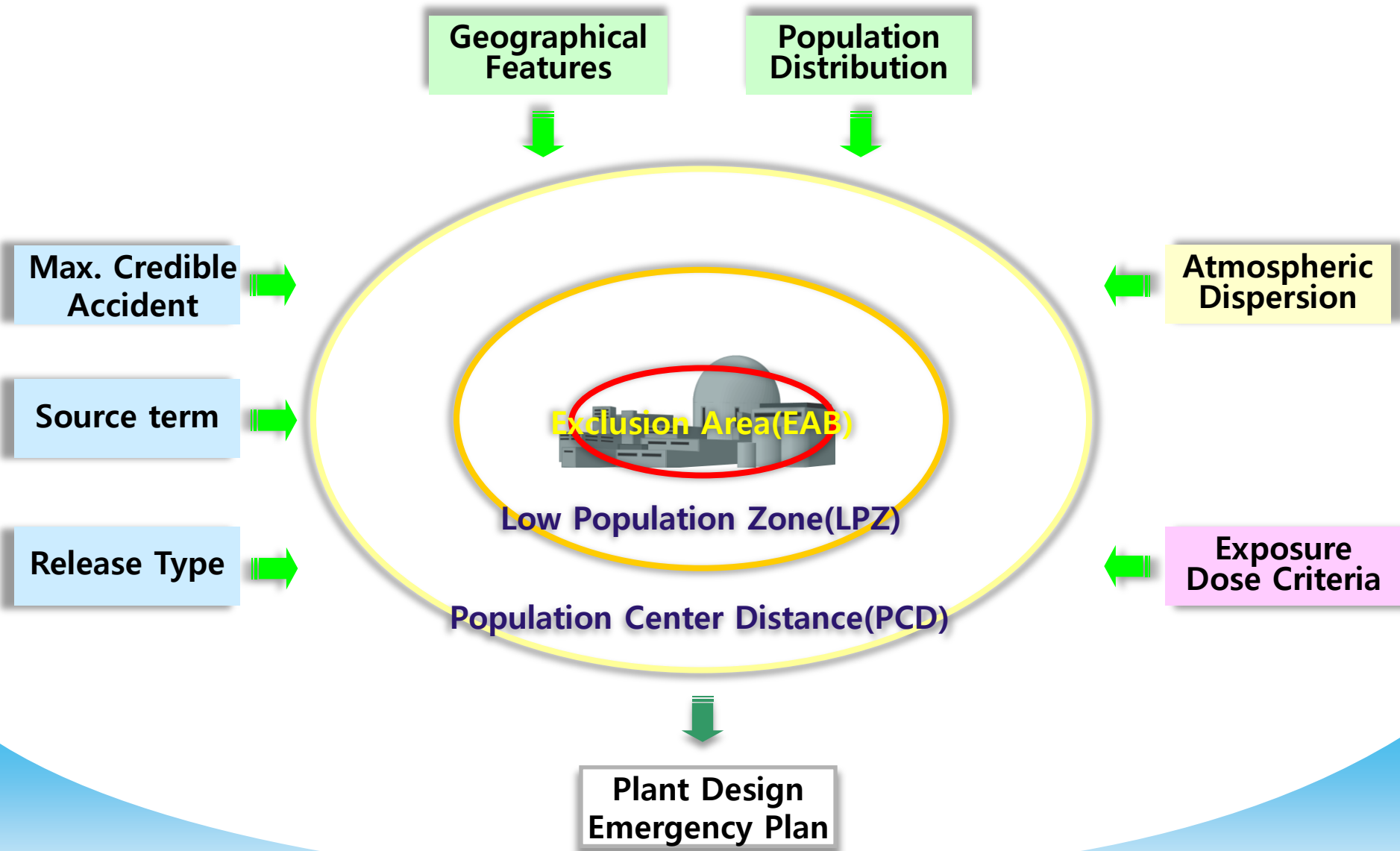
- Geological hazards, design earthquake, site layout, stability of foundation materials and slopes

Legal Requirements and Technical Standards



II. Geography and Demography

Overview



Site Location

□ Location of Reactor in

- Latitude & longitude
- Universal Transverse Mercator (UTM) coordinates

□ Site Area Map showing

- Plant property lines
 - Area of plant property
- Location and Orientation of principal plant structures
 - Functional identification: reactor bldg., aux. bldg., turbine bldg., etc.
- Exclusion Area Boundary
- True North
- Natural and man-made features
 - Mountains, rivers, lakes, sea, valleys, etc.
 - Highways, railways, and waterways that traverse or are adjacent to the site

Exclusion Area Boundary (EAB)

□ Purposes

- To protect the nearby resident from radiation exposure
- To protect the plant from activities not related to the plant operation

□ Determination of Boundary

- During 2 hours after a postulated accident
 - Whole body radiation exposure: ≤ 25 rem (0.25 Sv) (individual)
 - Thyroid radiation exposure: ≤ 300 rem (3 Sv) (individual)

□ Exclusion area authority and control

- Residence should normally be prohibited
- Authority to determine all activities should be secured

□ Procurement of exclusion area

- Ownership or superficies
- Authority to determine the access of the public
 - National roads, railways, streams, sea, parks etc.

Exclusion Area Boundary (continued)

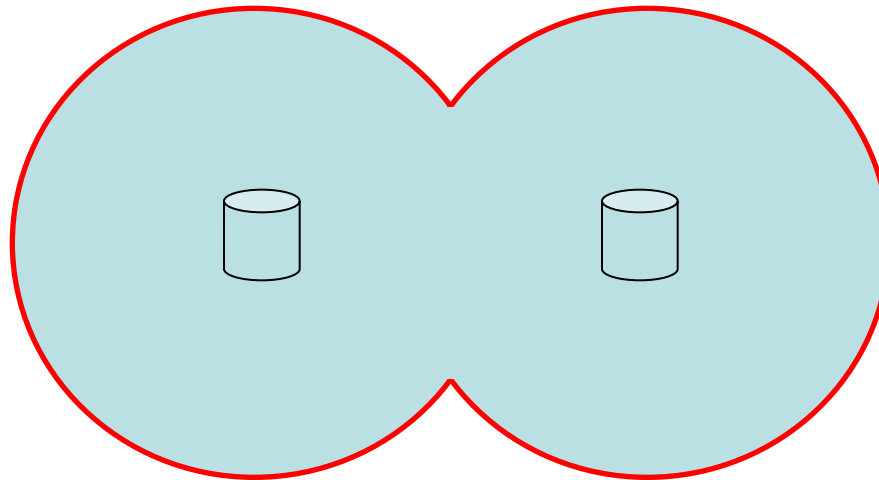
□ EAB for Multi-units

○ First Step

- Determine EABs for Individual Units

○ Second Step

- Envelop all EABs
- Assumption:
 - The probability of simultaneous occurrence of the accident at multiple units is negligible.



□ Population of Age Groups within 80 km of the Site

- in 16 azimuthal sectors
- in 10 distance intervals

□ Transient Population

- Seasonal and monthly variation of transient population within 20 km from the reactor

□ Population Projection

- For every 10 years
- From the expected first year of plant to the end of plant life

□ Population Density

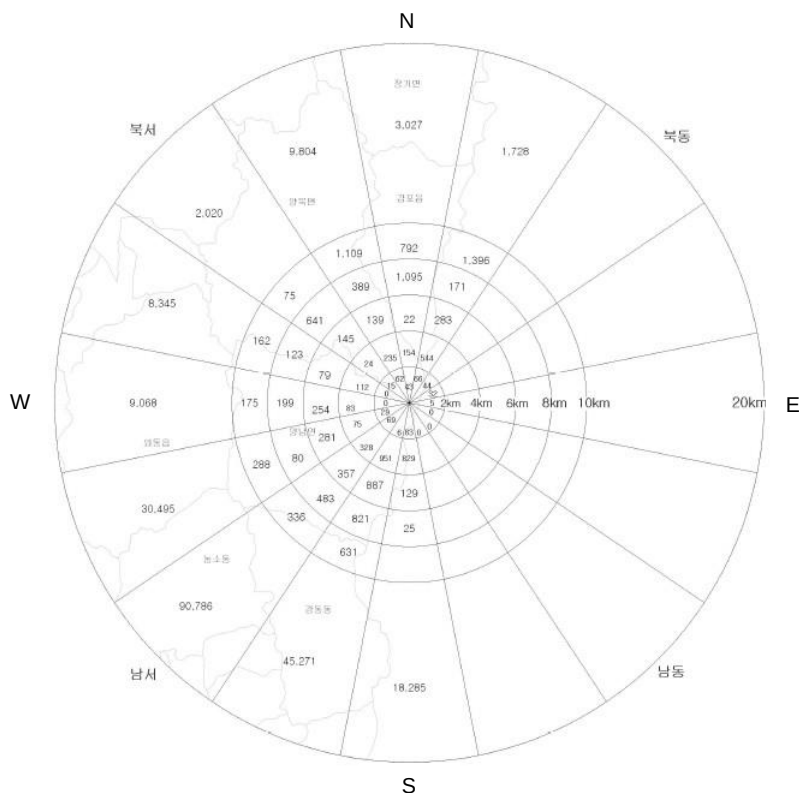
- ❖ Population density within 50 km should be lower than that of national average
 - Otherwise, it should be shown that the site has the superiority in the other aspects

Population

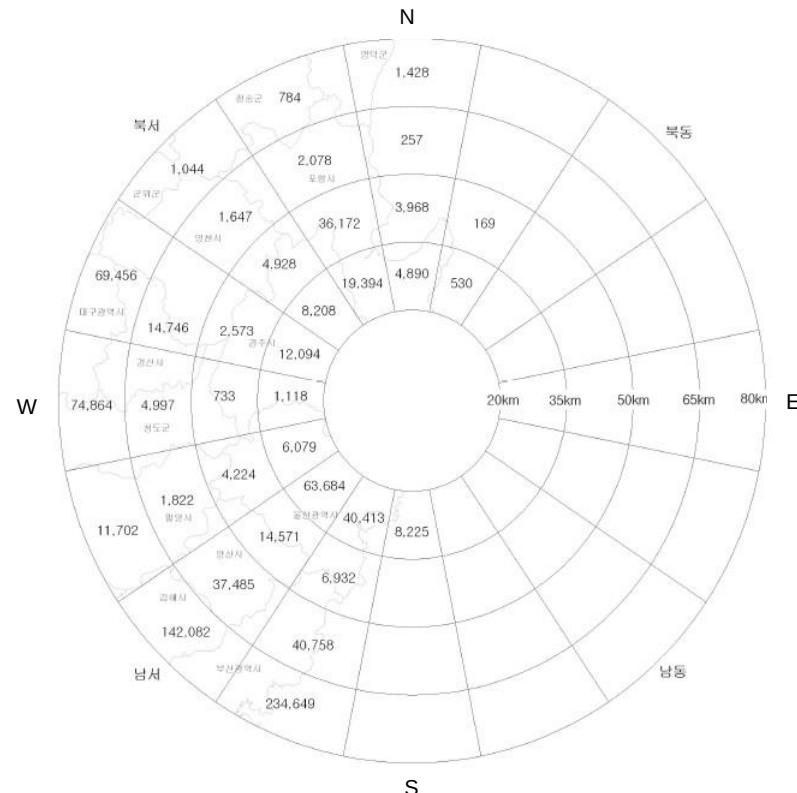
□ Example: population within 20 km

km	0~2	2~4	4~6	6~8	8~10	10~20	Sum
Pop.	454	3,335	2,576	4,027	4,964	218,829	234,185

km	20~35	35~50	50~65	65~80	Sum
Pop.	164,635	74,270	103,790	536,009	878,704



< Population - total >



< Population – teenagers >

□ Low Population Zone (LPZ)

○ Purpose

- To protect the resident in case of accidents (radiation emergency plan)

○ Determination of Boundary

- The method is the same as in EAB, but
- During the entire period after an accident
 - Whole body radiation exposure ≤ 25 rem (individual)
 - Thyroid radiation exposure ≤ 300 rem (individual)

□ Population Center Distance (PCD)

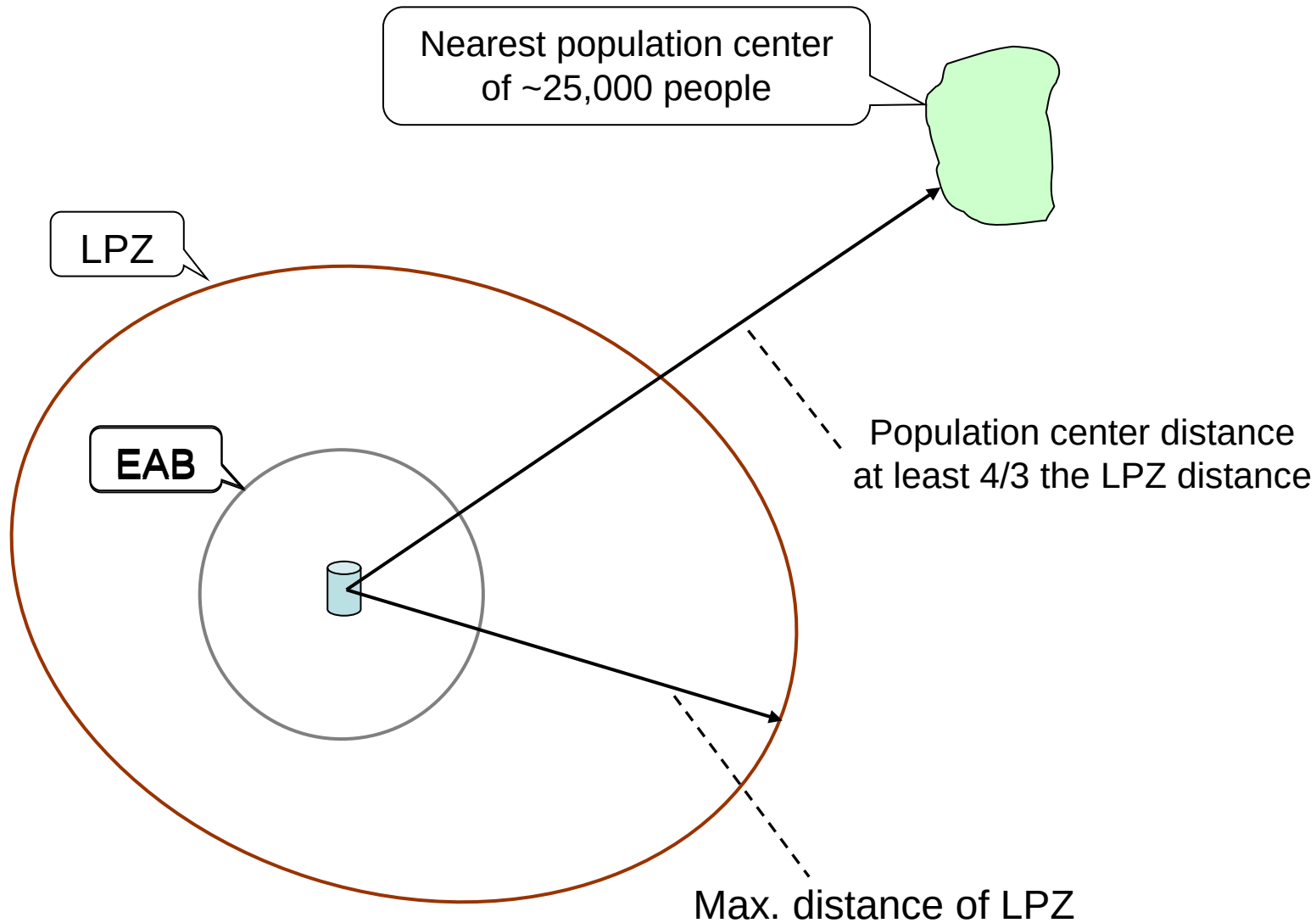
○ Distance requirement

- At least 4/3 times the distance of LPZ boundary from the reactor
- Requirement of LPZ can be relaxed if a proper emergency plan is prepared

○ Population center

- An area with the resident more than 25,000

EAB, LPZ, and PCD



EAB, LPZ, and PCD

□ Exclusion area boundary

- 560 m from reactors

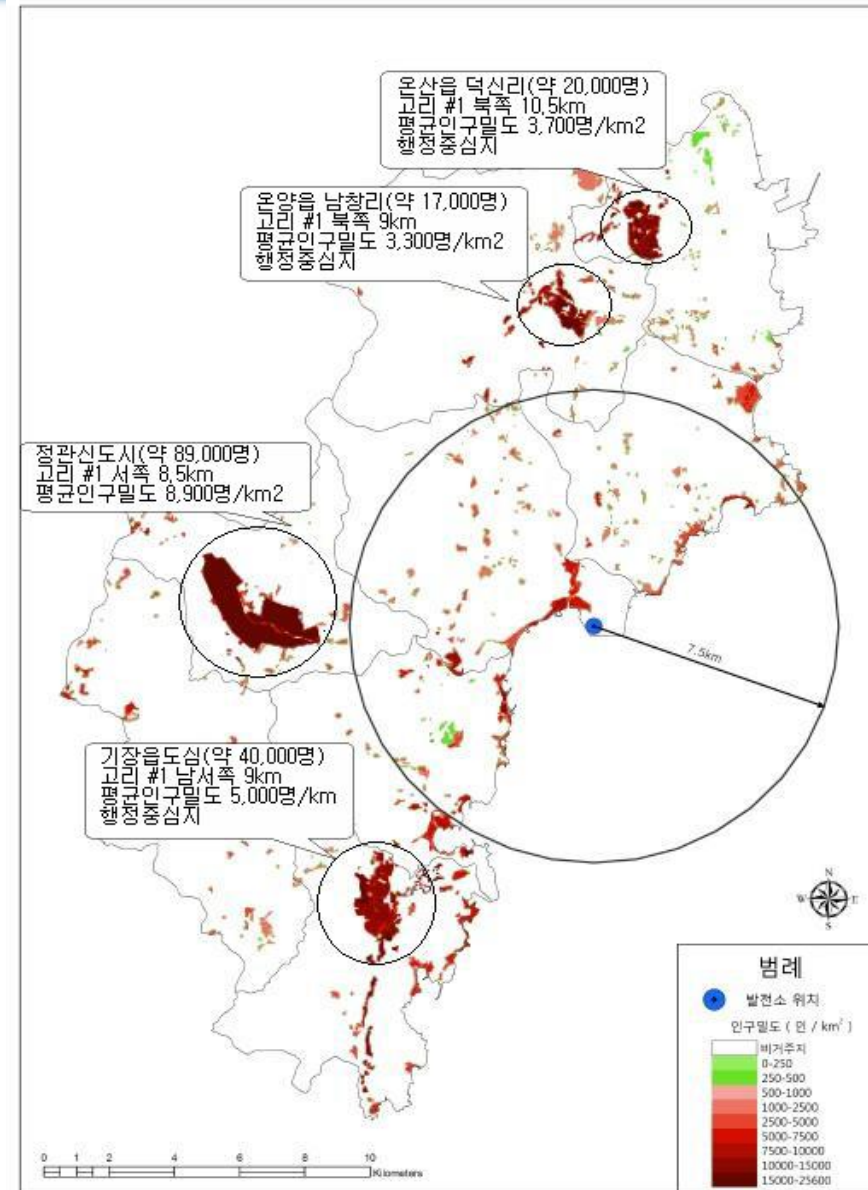
□ Low population zone

- 5.7 km from reactors

□ Population center distance

- Nearest population center
 - Population: 890,000
 - Distance: 10.4 km
 - ✓ (LPZ) $5.7 \text{ km} \times 1\frac{1}{3} = 7.6 \text{ km}$

Example of Shin-Kori Units 3&4



III. Human-Induced Hazard

□ Purposes

- Accidents at present or projected nearby industrial, military, and transportation facilities may affect the safety of nuclear stations
- Potential hazards associated with these nearby facilities must be evaluated and site parameters established such that potential hazards from such routes and facilities will pose no undue risk to nuclear stations

□ Hazards to be evaluated

- Aircraft crash
- Explosion
 - Stationary and mobile sources
- Release of hazardous materials
 - To evaluate the control room habitability
- Fire, collision of ships, etc.
 - Loss of off-site power, loss of ultimate heat sink, etc.

□ Facilities to be considered

○ Industrial facilities

- Chemical plants, refineries, mining and quarrying operations, oil or gas wells, oil or gas storages, etc.

○ Military facilities

- Munitions storage areas, ordnance test ranges, bombing training ground, etc.

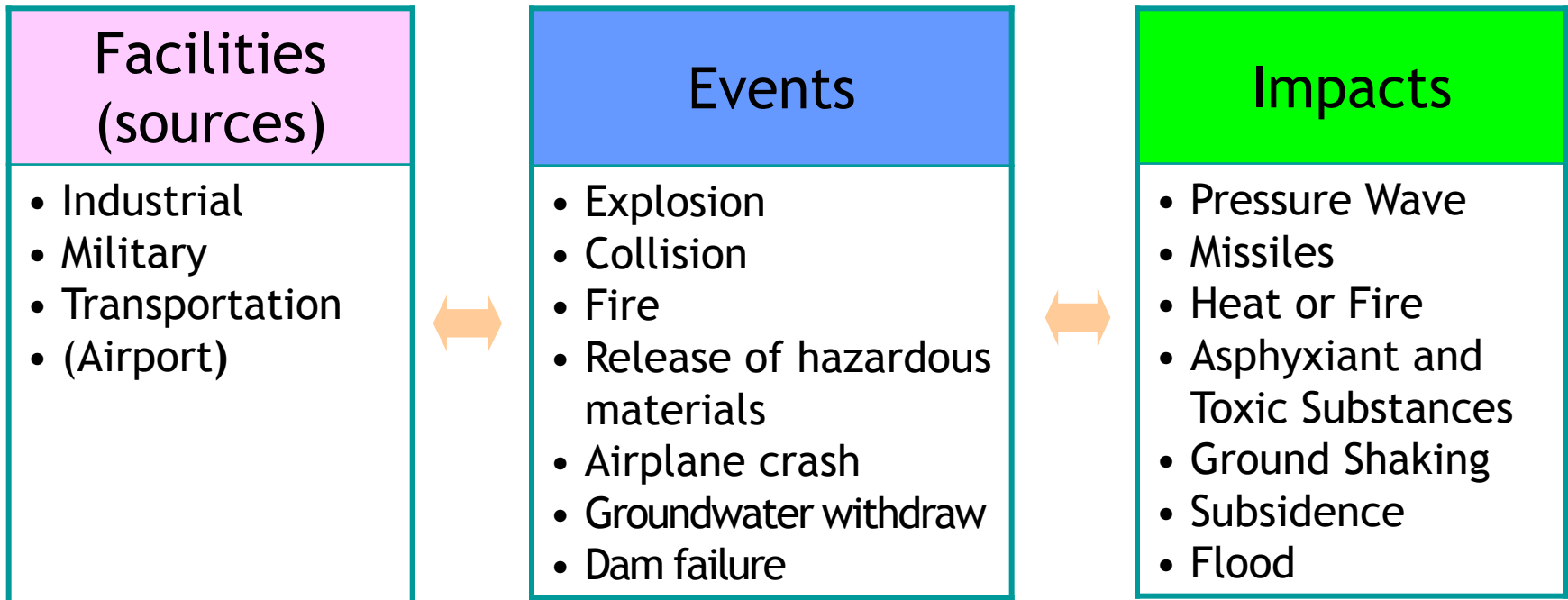
○ Transportation routes

- Air routes, waterways, railroad, highways, gas pipes

○ Airports

- Civil & military airports

□ Events and their resultant impacts from the sources



Investigation

□ Extent to be investigated

- Within 8km radius of the site
 - Industrial facilities, transportation route and facilities including the activities in them
 - Even the facility or activity are located beyond 8km radius of the site, they can be investigated according to the importance to the nuclear facility
- Within 32km of the site
 - All civil & military airports
 - Military facilities

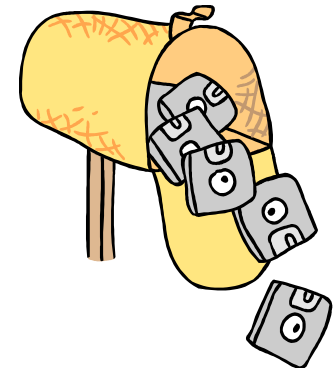


□ Screening distance value(SDV)

- The distance from a facility beyond which, for screening purpose, potential sources of a particular type of external event can be ignored (IAEA, SG No. NS-G-3.1)

□ Information to be collected

- A list of potential sources
 - The source is divided into stationary and mobile
 - The type, quantity, and condition of the hazardous material involved
- The distance between the potential source and the nuclear site
- Source display map
- Statistical (probability) data of occurrence of accidents at the source
- Information about present and planned facilities and activities in the region
- Meteorology, topography, sea current, etc.
- ※ Database



Evaluation - Preliminary

❑ Screening out

- Using the definition of the SDV and SPL

❑ Screening-out the source using the SDV

- The sources outside the Screening Distance Value (SDV) can be ignored and need not be considered as a potential hazardous source to plant
- If the site is outside the SDV for a particular source under consideration, the source need not be considered any more

❑ Screening-out the source using the SPL

- If the site is not outside the SDV for any accident source, the probability of occurrence of such an accident should be determined and compared with the specified SPL
- Screening Probability Level (SPL) means a value of the annual probability of occurrence of a particular type of event below which, for screening purpose, such an event can be ignored (IAEA SG No. NS-G-3.1)
- Generally, the SPL value is adapted as $10E-7/\text{yr}$

Evaluation - in Detail

□ Selection of candidate design basis accident

- Potential events, not eliminated at preliminary evaluation, are evaluated whether they can be considered as a design basis accident
- The probability of an accident occurrence above $10E-7/\text{yr}$ is considered as design basis accident

□ Determination of the design basis accident

- Consideration of interacting events
- If the probability of occurrence of an accident at a particular source is above $10E-6/\text{yr}$, then the results of the accident should be considered in the design of nuclear facilities.
- The value of $10E-6/\text{yr}$ is considered as design basis probability



Acceptance Criteria

□ The site is considered to be suitable for nuclear facilities, if the following criteria are met

- Even if an external events causes an accident at nuclear facility, the radiation to the public do not exceed the dose limit specified by the law
- The occurrence of an accident for a particular source is as low as SPL ($1.0\text{E-}7/\text{yr}$) and is considered to have little effect on the nuclear facilities
- Other design features (e.g., Reinforcement of facility, fire protection, etc.) can mitigate or reduce the effects on nuclear facility arose by particular accident source
- If evaluated results do not satisfy the above conditions, the events should be reflected in the plant design



Example of Evaluation – Aircraft crash (I)

□ Information to be collected

- Location of airport, length and orientation of runway
- Landing and take-off pattern, approach and holding pattern, airways
- Military air route
- Present and planned type of aircraft and number of flight

□ Preliminary evaluation

- **If the probability of aircraft accident resulting in radiological consequences greater than the national exposure guidelines is less than an order of magnitude of $10E-7$ per year, the possibility of aircraft crash onto the site is estimated to be negligible.**



Example of Evaluation – Aircraft crash (II)

- **The probability is considered to be less than $10E-7/\text{yr}$ if the following conditions are met;**
 - Within 3.2 km (2 mi)
 - No airways, no approach pattern, no holding pattern
 - Within 8 km (5 mi)
 - No nearest edge of military training route, including low-level training route
 - No airport
 - Within 16 km (10 mi)
 - No airport with projected annual number of operations exceeding $193D^2(500D^2)$
 - ✓ D: distance (km) between the airport and the plant
 - Beyond 16 km
 - No airport with projected annual number of operations exceeding $386D^2(1000D^2)$
- ※ If the evaluation results do not satisfy the above conditions, the detailed evaluation is followed

Example of Evaluation – Explosion (I)

□ Information to be collected

- The following plants are considered into the evaluation but not limited
 - Manufacturing and chemical plants, military bases, transportation routes, oil and gas pipelines, underground gas storage facilities, etc.
- The nature and maximum amount of the material that may simultaneously explode
- The distance and the orientation from the explosion center to the site
 - The explosive mass is usually expressed in term of TNT equivalent masses for generic explosive substances
- The frequency of shipments of explosive cargoes
 - This data is needed for the explosion on the transportation route near nuclear plant

Example of Evaluation – Explosion (II)

□ Preliminary evaluation

○ Explosion at storage

- Using SDV concept
- Separation distance $\geq$ Safe distance, $R = 18 \cdot W^{1/3}$
 - R: safe distance in meter
 - W: TNT equivalence weight in kg
- If the distance is within the SDV, then accident probability of that storage is to be compared with SPL..



Example of Evaluation – Explosion (III)

□ Preliminary evaluation

○ Explosion on transport route

- Using SPL concept
- Exposure probability ($n*f*s$) $\leq 1.0E-7/\text{yr}$
 - n : explosion probability per distance along a transport route
 - f : annual frequency of shipment of explosive
 - s : exposure distance (portions of a route within R)
- If the exposure probability is higher than the specified SPL level, then the effects of the explosion on the plant should be considered in plant design.

IV. Meteorology

Purposes

❑ Safe design & operation

- Plant design
 - Wind speed, precipitation (rain, snow), freezing, etc.
- Plant operation
 - Habitability of control room: humidity, temperature, wind speed & direction, etc.
 - Exposure dose limits: atmospheric diffusion

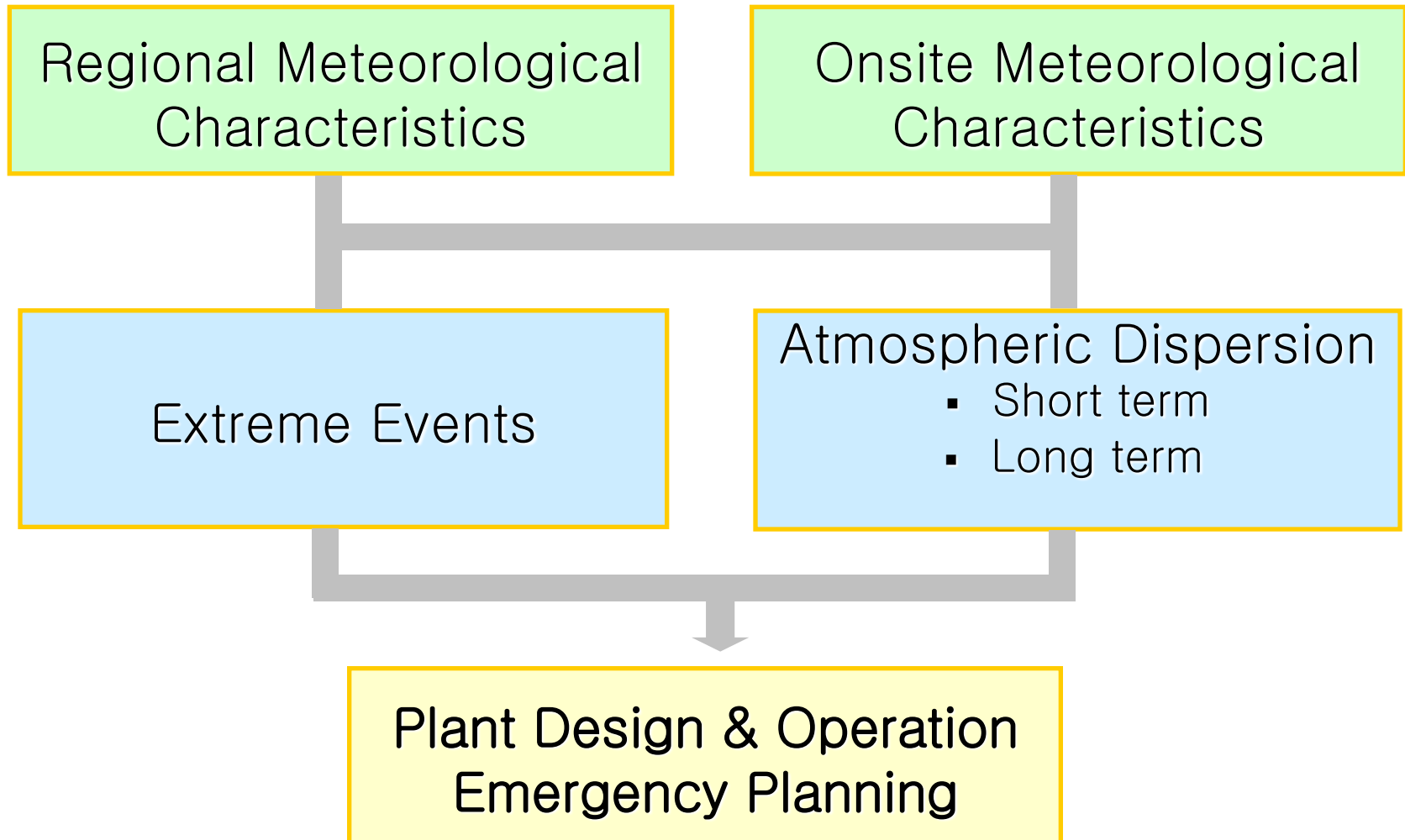
❑ Proper emergency planning

- Wind speed and direction
- Atmospheric dispersion characteristics

❑ Concentration of radioactive materials

- During normal operation and accident condition
- Meteorological parameter

Overview



Definitions (I)

○ **Calm:**

- Any wind speed below the starting threshold of the wind speed or direction sensor, whichever is greater

○ **Vertical temperature difference (ΔT):**

- Measured difference in ambient temperature between two elevations on the same tower
- It is defined as the upper level temperature measurement minus the lower level temperature measurement

○ **Wind direction:**

- *Direction from which the wind is blowing*
- Wind direction is reported in degrees azimuth, measured clockwise from true north and ranging from 0° to 360° (e.g., north is 0° or 360°, east is 90°)

○ **Wind speed:**

- Rate at which air is moving horizontally past a given point

Definitions (II)

○ Pasquill stability class:

- Classification of atmospheric stability, or the amount of turbulent mixing in the atmosphere and its effect on effluent dispersion

USNRC Reg. Guide 1.23 Rev.1

Stability Classification	Pasquill Stability Category	Ambient Temperature Change With Height ($^{\circ}\text{C}/100\text{m}$)
Extremely unstable	A	$\Delta T \leq -1.9$
Moderately unstable	B	$-1.9 < \Delta T \leq -1.7$
Slightly unstable	C	$-1.7 < \Delta T \leq -1.5$
Neutral	D	$-1.5 < \Delta T \leq -0.5$
Slightly stable	E	$-0.5 < \Delta T \leq 1.5$
Moderately stable	F	$1.5 < \Delta T \leq 4.0$
Extremely stable	G	$\Delta T > 4.0$

□ General climate

- Types of air masses
- Synoptic features: high- and low-pressure systems, frontal systems
- Temperature
- humidity
- Precipitation: rain, snow, and sleet
- Relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions

□ Seasonal and annual frequencies of severe weather phenomena

- Hurricanes, waterspouts, and tornados
- Thunderstorms and lightning
- Hail
- air pollution potential

□ Meteorological conditions for design & operating basis

- Max. snow and ice load (water equivalent) that roofs of safety-related structures must be capable of withstanding during plant operation
- Ultimate heat sink (UHS) meteorological conditions resulting in the max. evaporation and drift loss of water and min. water cooling, if applicable
- Tornado parameters, including translational speed, rotational speed, and Max. pressure differential with the associated time interval
- 100-year return period of wind, including vertical velocity distribution and gust factor
- Probable annual frequency of occurrence & time duration of freezing rain (ice storms) and dust (sand) storms where applicable
- Max. rainfall rate
- Other regional meteorological and air quality conditions used for design and operating basis considerations

□ Description of local (site) meteorology

- Airflow
- Temperature
- Atmospheric water vapor
- Precipitation
- Fog
- Atmospheric stability
- Air quality

□ Assessment of the influence of the plant on the above factors

- Effects of plant structures
- Effects of terrain modification
- Effects of heat and moisture sources due to plant operation

□ Topographical information

- Information of the site and its environs, as modified by the plant structures, including
 - Site boundary, exclusion zone, and low population zone

Onsite Meteorological Measurement Program

□ Purpose

- To provide meteorological conditions for safe design and operation, and proper emergency planning

□ Requirements

- Instrumentation
 - The tower or mast should be sited at approximately the same elevation as finished plant grade and located at a distance of at least 10 times the height of any nearby obstruction
 - Wind sensor and temperature sensor should be mounted at least two levels (at 10 m and representative height of release)
 - Wind sensors on the side of a tower should be mounted on the boom at a distance of at least twice the longest horizontal dimension of the tower
 - Booms for all sensors should be oriented normal to the prevailing wind at the site

□ Instrument accuracy

Measurement	Starting threshold	System accuracy
Wind direction	$U^{1)} \leq 0.5 \text{ m/s}$	$\pm 5^\circ$
Wind speed	$U \leq 0.5 \text{ m/s}$	0.2 m/s for $U < 2 \text{ m/s}$ 10% for $U \geq 2 \text{ m/s}$
Temperature	-	$\pm 5^\circ \text{ C}$, $\Delta T: \pm 0.1^\circ \text{ C}$
Relative humidity	-	$\pm 5\%$
Precipitation	0.5 mm	$\pm 10\%$

1) U: wind speed

□ Required onsite meteorological data

- At least one-year continuous data for PSAR
- At least two-year continuous data for FSAR

Long-term Atmospheric Dispersion

□ General

- Long-term atmospheric dispersion estimate applies to normal operation
- The transport and dilution of radioactive materials are a function of:
 - the state of the atmosphere along the plume path
 - the topography of the region
 - and the characteristics of the effluents themselves
- For a routine airborne release (long-term annual basis), the concentration of radioactive material in the surrounding region depends on
 - the amount of effluent released
 - the height of the release
 - the momentum and buoyancy of the emitted plume
 - the wind speed, atmospheric stability, and airflow patterns of the site
 - and various effluent removal mechanisms

□ Release Mode

○ Elevated release

- For effluents released from points at least twice the heights of adjacent solid structures
 - Very tall stack release
- use meteorological data measured at representative release height

○ Ground-level release

- Other than elevated release
 - Vent or building penetration release
- use meteorological data measured at 10m level

□ Removal Mechanism

- Radioactive decay
 - dependent on the half-life and the travel time of the radioactive effluent
 - 2.26 days for short-lived noble gases
 - 8 days for all radio-iodine
- Dry deposition
 - always applicable
 - deposition velocity
- Wet deposition
 - applicable only for the raining period
 - dependent on precipitation intensity

Short-term Atmospheric Dispersion

□ General

- Short-term atmospheric dispersion estimate applies to accidental conditions
- The transport and dilution of radioactive materials are a function of:
 - the state of the atmosphere along the plume path
 - the topography of the region
 - and the characteristics of the effluents themselves
- For an accidental airborne release (2 hrs basis), the concentration of radioactive material in the surrounding region depends on
 - the amount of effluent released
 - the height of the release
 - the momentum and buoyancy of the emitted plume
 - the wind speed, atmospheric stability, and airflow patterns of the site
 - and various effluent removal mechanisms

□ Calculation of χ/Q on EAB

○ Ground-level release

$$\textcircled{1} \quad \chi/Q = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + A/2)}$$

$$\textcircled{2} \quad \chi/Q = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)}$$

$$\textcircled{3} \quad \chi/Q = \frac{1}{U_{10}(\pi\Sigma_y\sigma_z)}$$

- χ/Q : atmospheric diffusion factor (s/m³)
- U_{10} : average wind speed at 10 m above the ground (m/s)
- $\sigma_{\#}$: diffusion coefficient in the #-direction (m)
- A : minimum vertical cross-section of a building (m²)
- $\Sigma_{\#}$: correction factor in the #-direction for meandering effect

○ Ground-level release (continued)

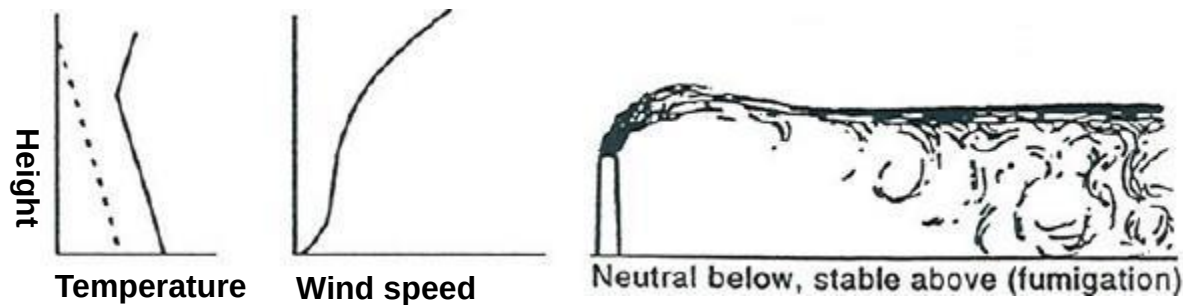
- For neutral or stable atmospheric condition, and $U < 6 \text{ m/s}$
 - Meandering effect may be considered
 - Use $\chi / Q = \min [③, \max(①, ②)]$
- Otherwise
 - Use $\chi / Q = \max(①, ②)$

○ Elevated release

- $\chi / Q = \frac{1}{\pi U_h \sigma_y \sigma_z} \exp\left[-\frac{h_e^2}{2\sigma_z^2}\right]$ for non-fumigation condition
- $\chi / Q = \frac{1}{(2\pi)^{1/2} U_{h_e} \sigma_y h_e}, \quad h_e > 0$ for fumigation condition
 - h_e : effective height (m)

❖ Fumigation

- Plume material gets rapidly fumigated down to the ground level due to downward mixing
- This situation occurs shortly after sun rise



□ Calculation of χ/Q on LPZ

- For the first 2 hrs
 - The calculation methods are the same as those for EAB
- After 2 hrs
 - Calculating χ/Q for 2~8 hrs, 8~24 hrs, 1~4 days, and 4~30 days
 - Logarithmic interpolation between short-term χ/Q and long-term χ/Q

V. Hydrology

Purposes

□ Flooding

- To protect the plant from seismically and non-seismically induced flooding
- To protect safety-related structures, systems, and component
- To evaluate the evacuation route in case of radiological emergency

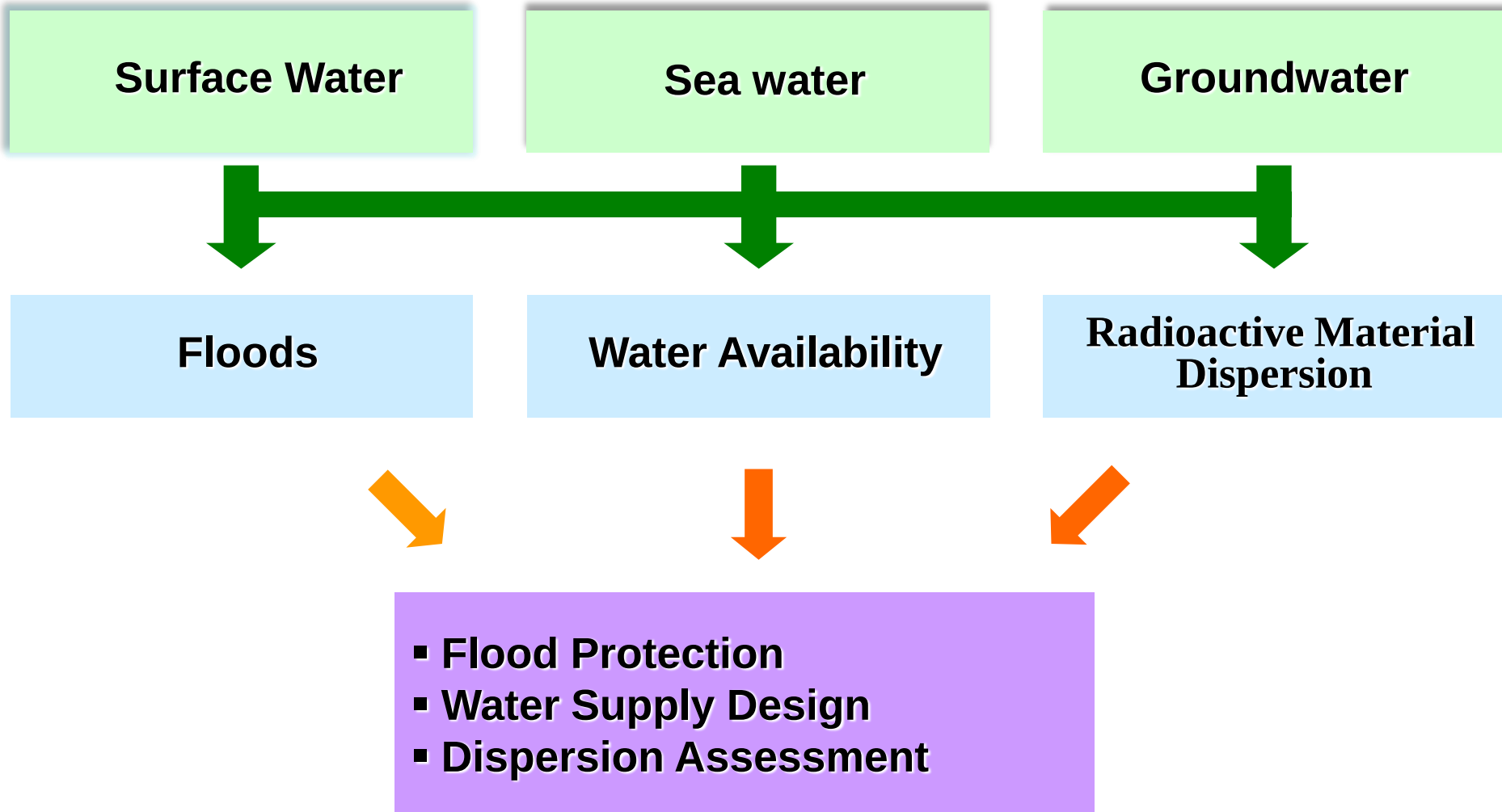
□ Water availability

- To have sufficient water supply source available and acquirable for cooling during plant operation and normal shutdown, for the ultimate heat sink, and for fire protection

□ Radionuclide retention and transport

- To assess the potential impact of the contamination of groundwater on the population
- To assess the dispersion characteristics of radioactive material through the water system

Overview



□ Inland Flooding

- Due to precipitation
 - Flood of rivers or streams
 - Inundation of site due to localized heavy rain
- Due to earthquakes or landslides
 - Failure of dams or embankments
 - Waterway blockage

□ Coastal Flooding

- Tidal waves
- High sea waves
- Storm surges
 - Uplift of sea surface
- Tsunamis
 - Due to sea floor earthquakes

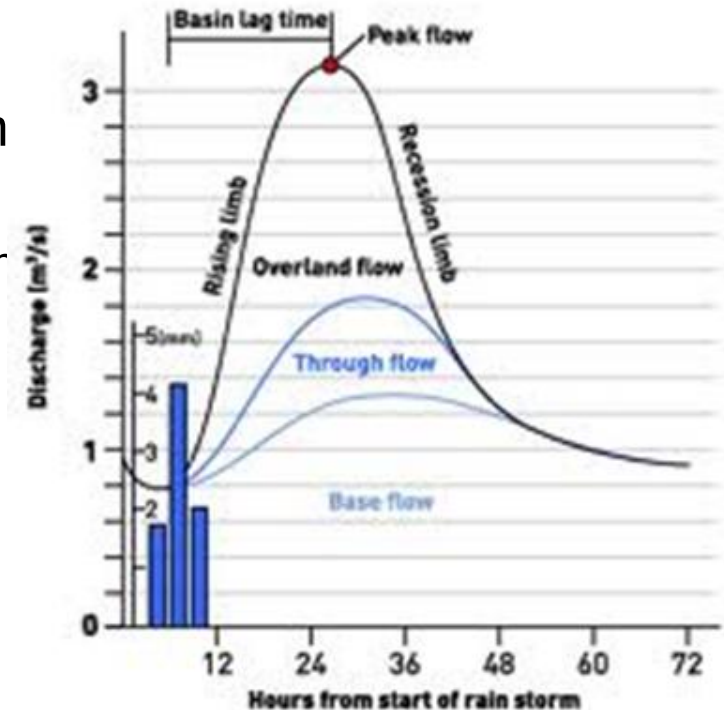
Inland Flooding

□ Local flood in the site

- Information of historical data
- Information on Probable Maximum Precipitation(PMP)
- Evaluation of flooding effect for safety-related structures

□ River flooding near the site

- Information of historical data
- Evaluation of the river flooding effect
- Flooding evaluation caused by upstream reservoir and dam failure
 - Including earthquake and other natural/human events
- ❖ Dry site?



❑ Inland Flooding(River flooding)



Global warming inundation? In fact, this photo shows the 1993 flood on the Missouri River as it recedes from Nebraska's Cooper nuclear power station.

Photo: Diane Krogh/Lighthawk

2011 Cooper Station

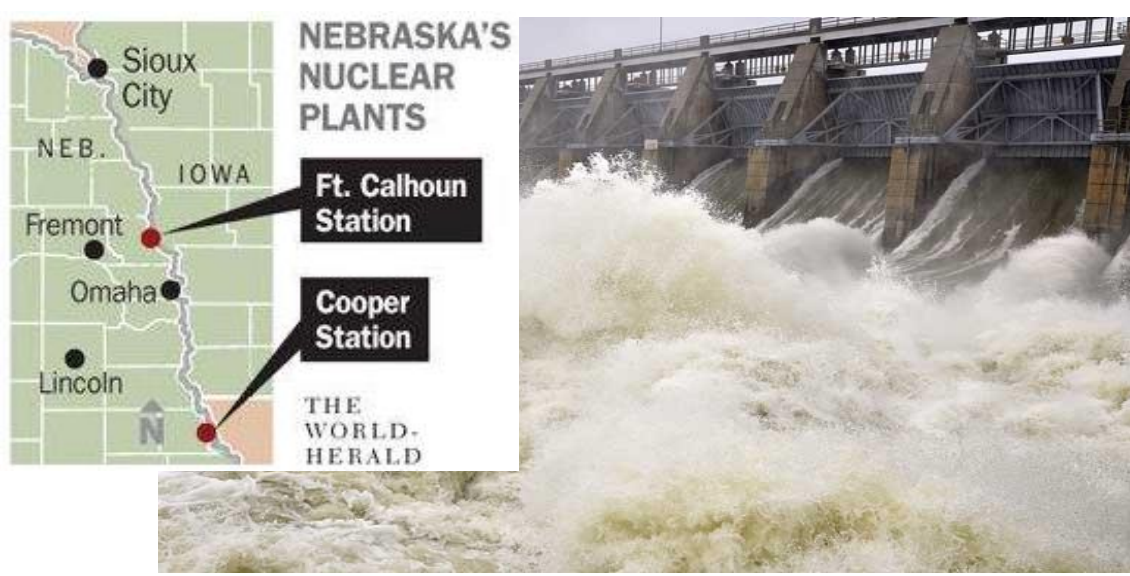
□ Inland Flooding(River flooding)

- Fort Calhoun Station

- Due to Missouri river flooding, Site also was experienced during the summer of 2011

- Cooper Station

- Exposed the potential of flooding

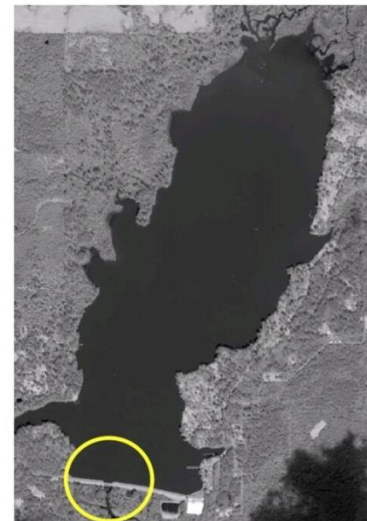


Water roils out of the spillways below the Gavins Point Dam in the Missouri River near Yankton, S.D., Tuesday, June 14, 2011. On Tuesday, the releases hit the maximum planned amount of 150,000 cubic feet of water per second. The dam releases are expected to raise the river 5 to 7 feet above flood stage in most of Nebraska and Iowa.

❑ Inland Flooding(Caused by Dam Failure)

Notable U.S. Dam Failures

Year	Name	Location	Deaths	Damage
1972	Buffalo Creek Dam	West Virginia	125	\$400 million
1972	Canyon Lake Dam	South Dakota	139	\$60 million
1976	Teton Dam	Idaho	11	\$400 million
1977	Taccoa Falls Dam	Georgia	39	\$30 million
1982	Lawn Lake Dam	Colorado	3	\$21 million
2006	Kaloko Dam	Hawaii	7	?
2008	Kingston Ash Impoundment	Tennessee	0	\$975 million



Coastal Flooding

□ Phenomena

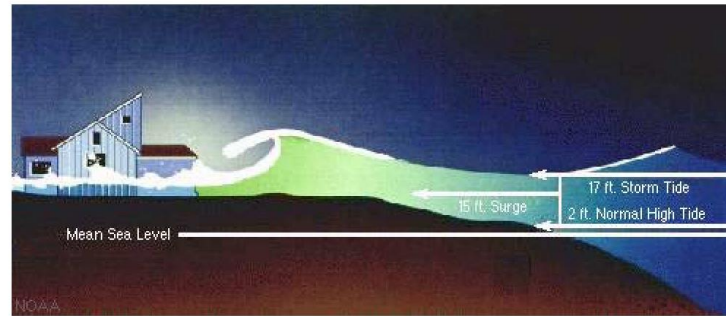
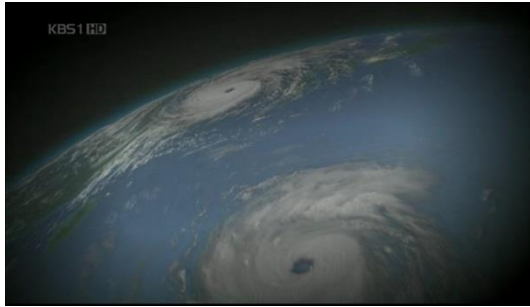


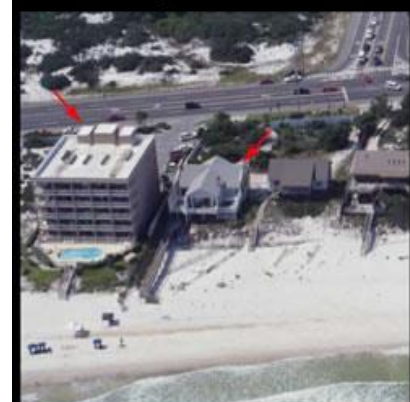
Figure 1. Schematic depicting the critical elements of a storm surge.



Figure 4. Eroded foundation and resulting collapse of a building on the coast following a hurricane-induced storm surge.



Storm Surge Before and After



Results of a storm surge - Orange Beach, Alabama. Image by USGS



Figure 2. Contrasting hypothetical coastlines with different slopes to show the potential reach of a storm surge.



Coastal Flooding

□ Information to be collected

- Historical flooding data, bathymetry and coastal configuration
- Storm surge: local surge data, Models
- Tsunamis: information about the seismic and geologic data in view of the behavior of oceanic crust, coastal and continental shelf landslide, volcanic activities, paleo-seismic tsunami data, tsunami wave transmission data and model.
- Tidal information: observatory and the data
- Wave activities
- Combination of all flood-causing factors

Listing of the main components and causes of sea-level variability at various timescales longer than 1 second, some of which overlap. Note: IFG=infragravity waves; ENSO=El Niño–Southern Oscillation; IPO= Inter-decadal Pacific Oscillation.

Phenomenon	Cause	Period
Short waves		
wind waves	winds	1 – 8 sec
swell	remote winds	8 – 25 sec
Long waves		
IFG waves (groups)	remote winds and surf beat	25 – 120 sec
far IFG, meteorological tsunami	moving weather systems	2 – 20 min
tsunami	earthquakes/landslides	5 min – 1 hr
seiche	resonance and weather	20 min – 4 hr
tides	astronomical	3 – 25 hr
storm surge	weather (winds and low pressure)	12 hr – 5 days
Climate cycles and trends		
annual (seasonal)	seasonal temperature cycle	1 yr
interannual	ENSO climate cycle	2 – 5 yr
inter-decadal	IPO climate cycle	20 – 30 yr
sea-level rise	climate change, crustal adjustments	> 50 yr

□ Design Basis Flood

- Calculate the height of flood from selected combinations of multiple events
 - Tide + wave + surge + wave run-up
- The probability of simultaneous occurrence is taken into account
 - In case of PMP, all up-stream fill dams are supposed to be failed
- Methods of event combination are prescribed

□ Design against Flood

- For all safety-related facilities and structures
- For essential safety systems only
 - Complimentary measures are required (ex: technical specification)
- Engineered measures
 - To make the site grade level higher than the flooding level
 - To protect the facilities using water-tightening doors
- Administrative measures
 - Establishment of emergency procedure in response to the flooding

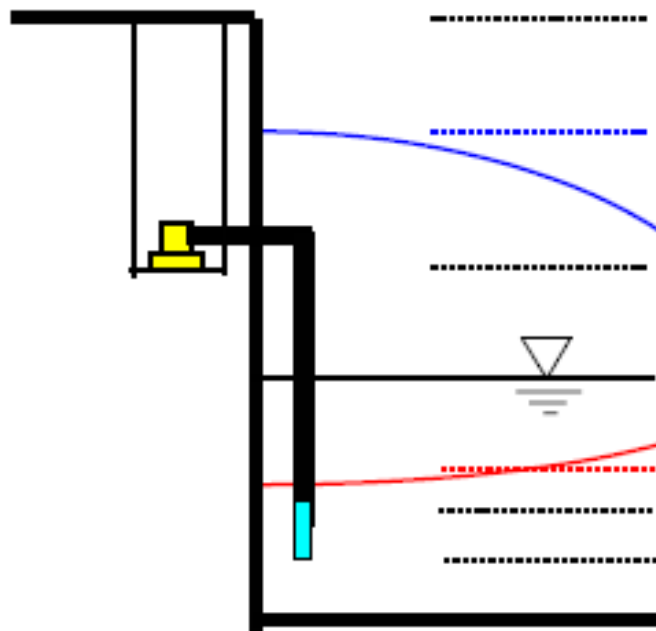
Water availability

□ Water Supply Sources

- Service water
 - Fresh water (rivers, lakes)
 - Used in the plant (ex: internal-circulating water system)
- Cooling water
 - Sea water
 - Used as the Ultimate Heat Sink (ex: essential service water)

□ Water Supply Capacity

- Service water
 - Water supply capacity during probable minimum water level
 - Capacity of water tanks
- Ultimate Heat Sink (UHS)
 - Water supply capacity at probable min. & max. sea levels
 - Below design sea-water temperature



10.0 m Ground level

5.73 m Probable max sea level

Pump level

Mean sea level

(-) 3.3 m Probable min sea level

(-) 4.66 m Design level of intake pump

(-) 6.05 m Pump mouth level

(-) 6.5 m Intake-channel floor level

Diagrammatic View of Intake Pump

Dispersion of Radioactive Materials

□ Purpose

- To assess the potential impact of the contamination of groundwater on the population
- To evaluate release patterns, expected amount, and migration and transport routes of radioactive materials hydrogeological units at or near the nuclear site

□ Acceptance Criteria

- Radionuclide transport characteristics of the groundwater environment with respect to existing and future users must be described
 - Dispersion, adsorption, transportation velocity, etc.
- Radionuclide transport characteristics of the surface water environment with respect to existing and future users must be described
 - Worst-case release and source terms
- Mathematical models are acceptable, if
 - Models are verified by field data and
 - Conservative site-specific hydrologic parameters are used

Dispersion of Radioactive Materials

□ Information to be collected

- Soil and rock characteristics (grain size, hydraulic conductivity, ..)
- Direction and flow rate of groundwater
- Site specific adsorption coefficient
- Chemistry of subsurface materials

□ Evaluation

- Potential migration and ground water transport pathways are identified using a conceptual ground water site model
 - The model should consider the ability of ground and subsurface water environment to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport

Dispersion of Radioactive Materials

□ Release Protection Measures

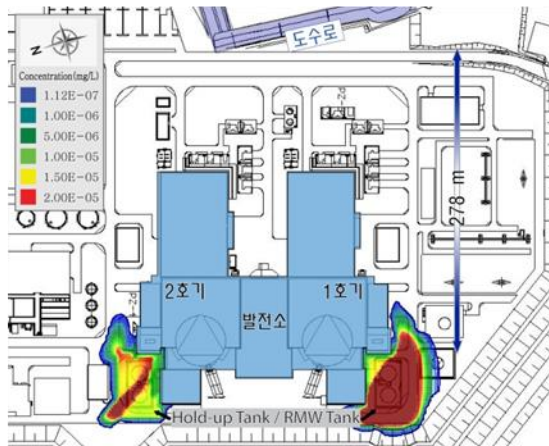
○ Engineered measures

- Comparison of concentration of released materials with release criteria
- If necessary, establish the protection measures

○ Emergency procedure

- If necessary, establish the appropriate technical specification for the normal operation and emergency operating procedure and implement it

▶ Estimated tritium concentration



10 Days



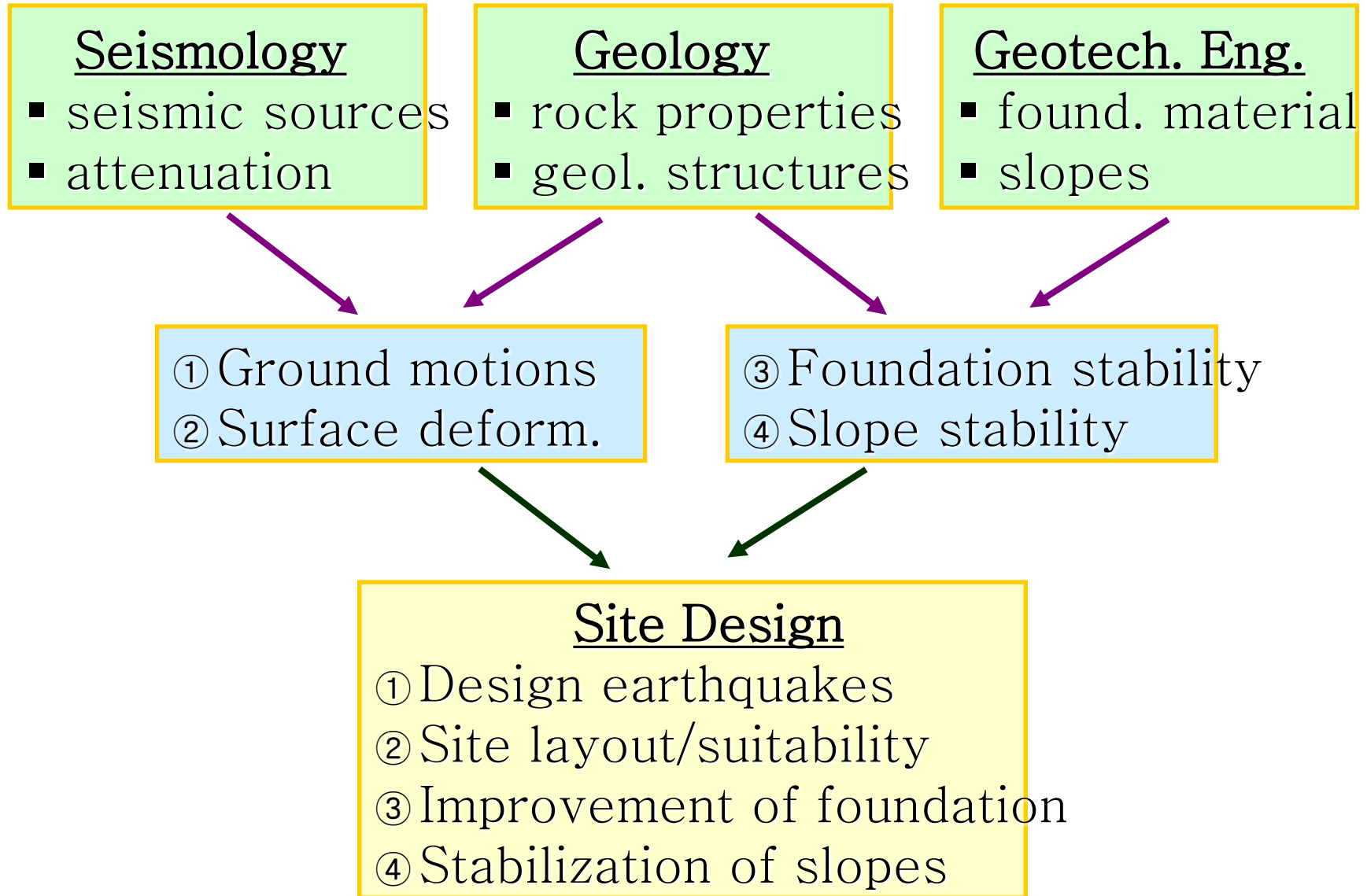
1 yr



5 yr

VI. Geology and Seismology

Overview



Fault

- A discrete surface separating two rock masses across which one mass has slid past the other

Physical evidence for past earthquakes

On-fault:

Displaced structures

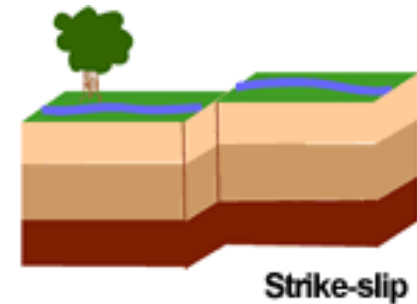


Wavefront

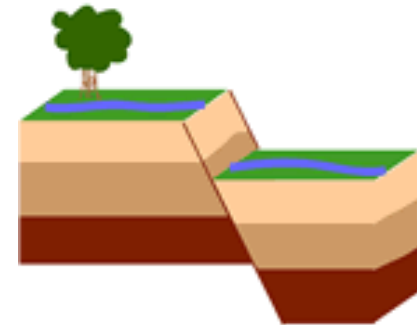
Fault plane

Off-fault:

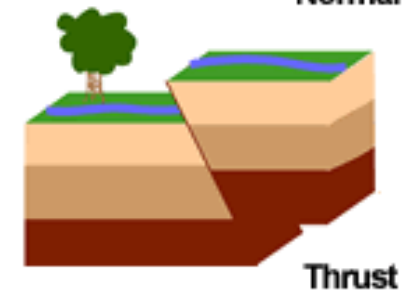
Damaged structures
Landslide



Strike-slip

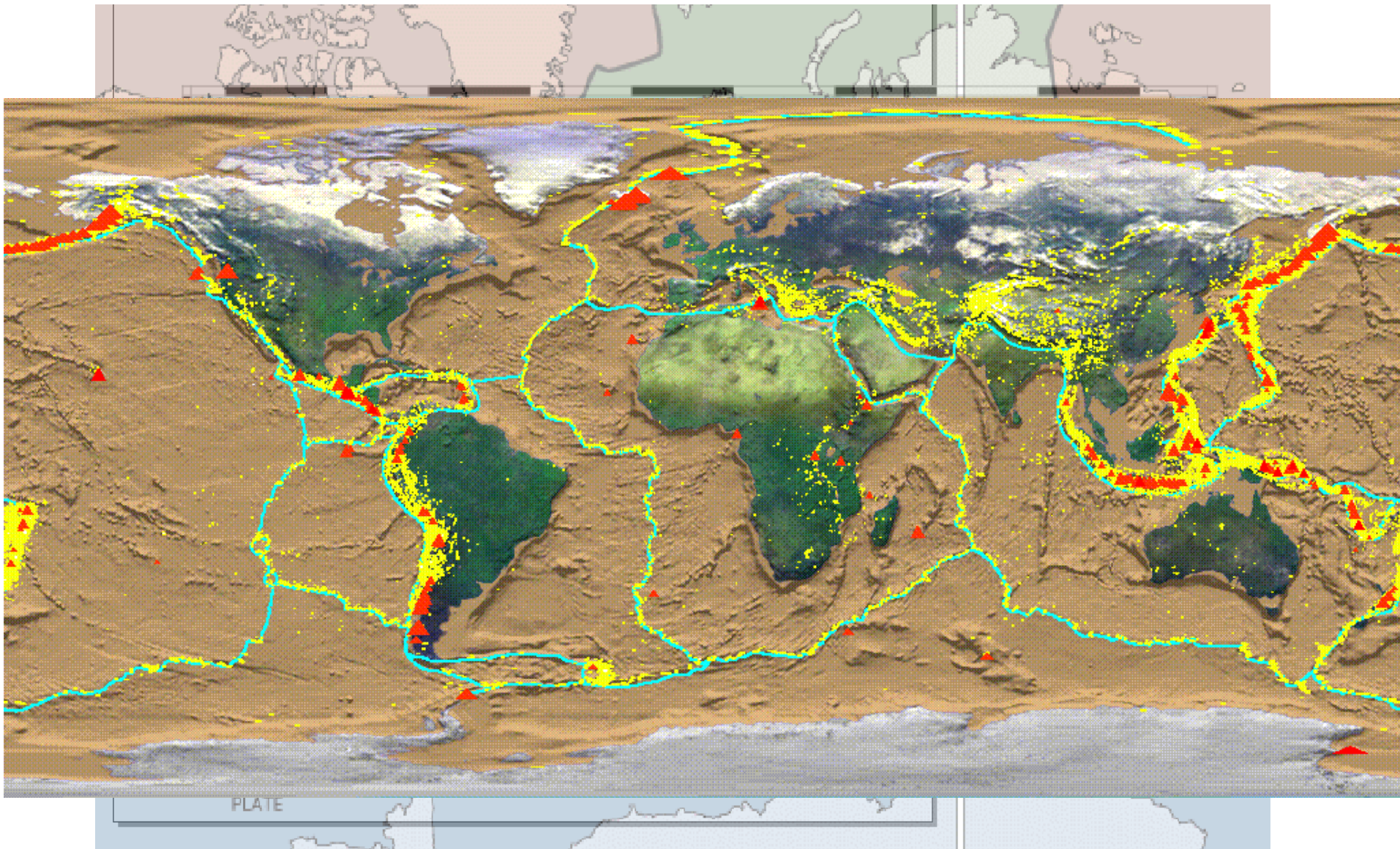


Normal

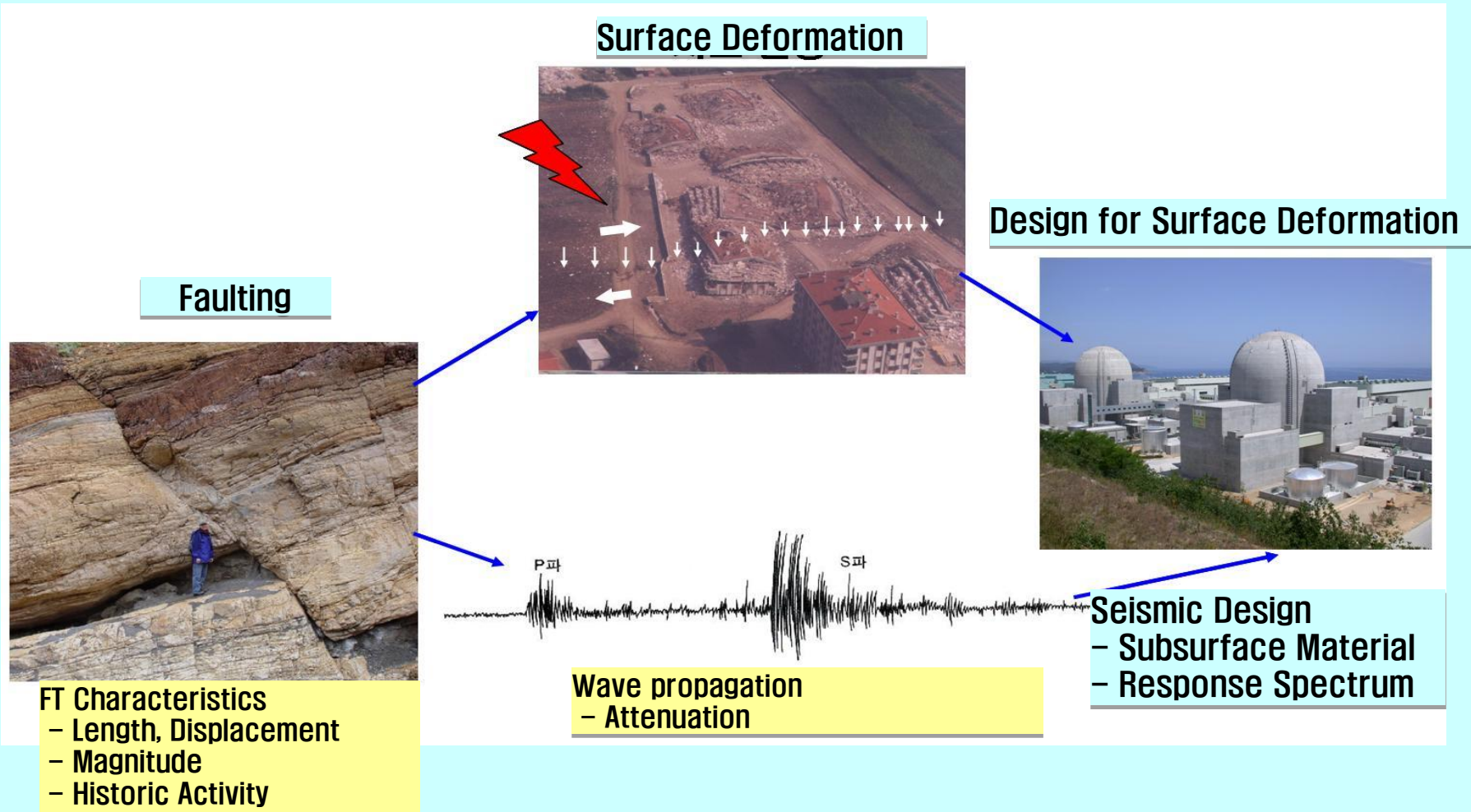


Thrust

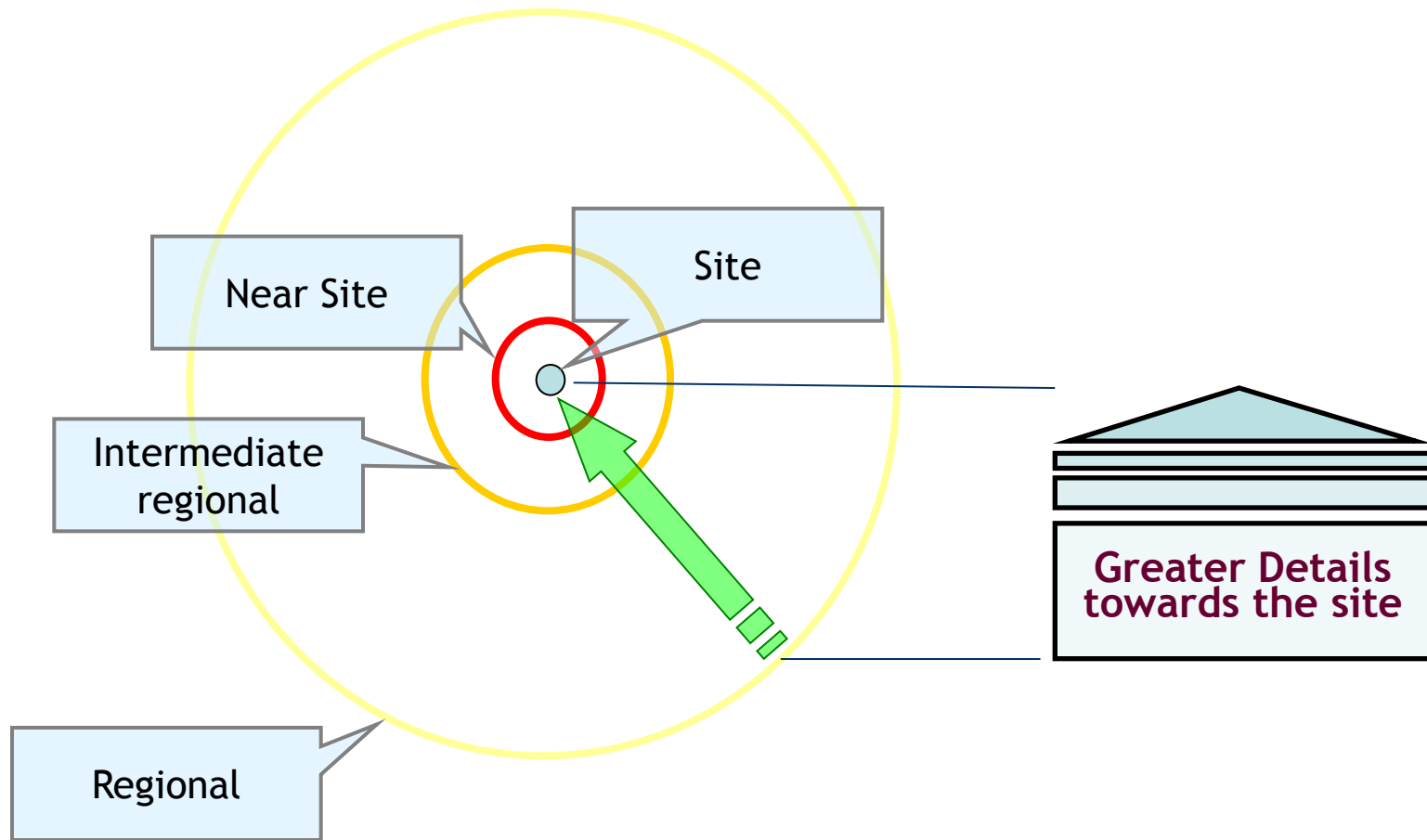
Plate Tectonics and Earthquake



Overview



Extent of Investigation



Extent of Investigation (continued)

Step	Range	Investigation Method
Regional	320 km (200 mi)	• Comprehensive literature review supplemented by geological reconnaissances • Map scale - 1:500,000 or smaller
Intermediate Regional	40 km (24 mi)	• Reconnaissance-level investigation supplemented by explorations • Map scale – 1:50,000 or smaller
Near Site	8 km (5 mi)	• Detailed investigations to delineate the geology and the potential for tectonic deformation at or near surface • Map scale – 1:5,000 or smaller
Site	about 1 km	• Most detailed investigations including geotechnical engineering investigations • Mapping of excavations and logging of trenches for plant structures • Map scale – 1:500 or smaller

Capable Fault

□ Why Capable Fault is important?

- It can cause surface deformation in near future
- It is difficult to construct NPP on a site that surface deformation is occurring or potential for it exist

□ Definition

- A fault that has a significant potential for relative displacement at or near the ground surface (earthquake & surface deformation).
- A fault shows one or more of following evidences
 - Movements at or near surface in the near past
 - At least once in the past 35,000 years, or with recurring nature within the past 500,000 years
 - Reasonable association with earthquakes
 - Structural relationship with a known capable fault

□ Primary concerns

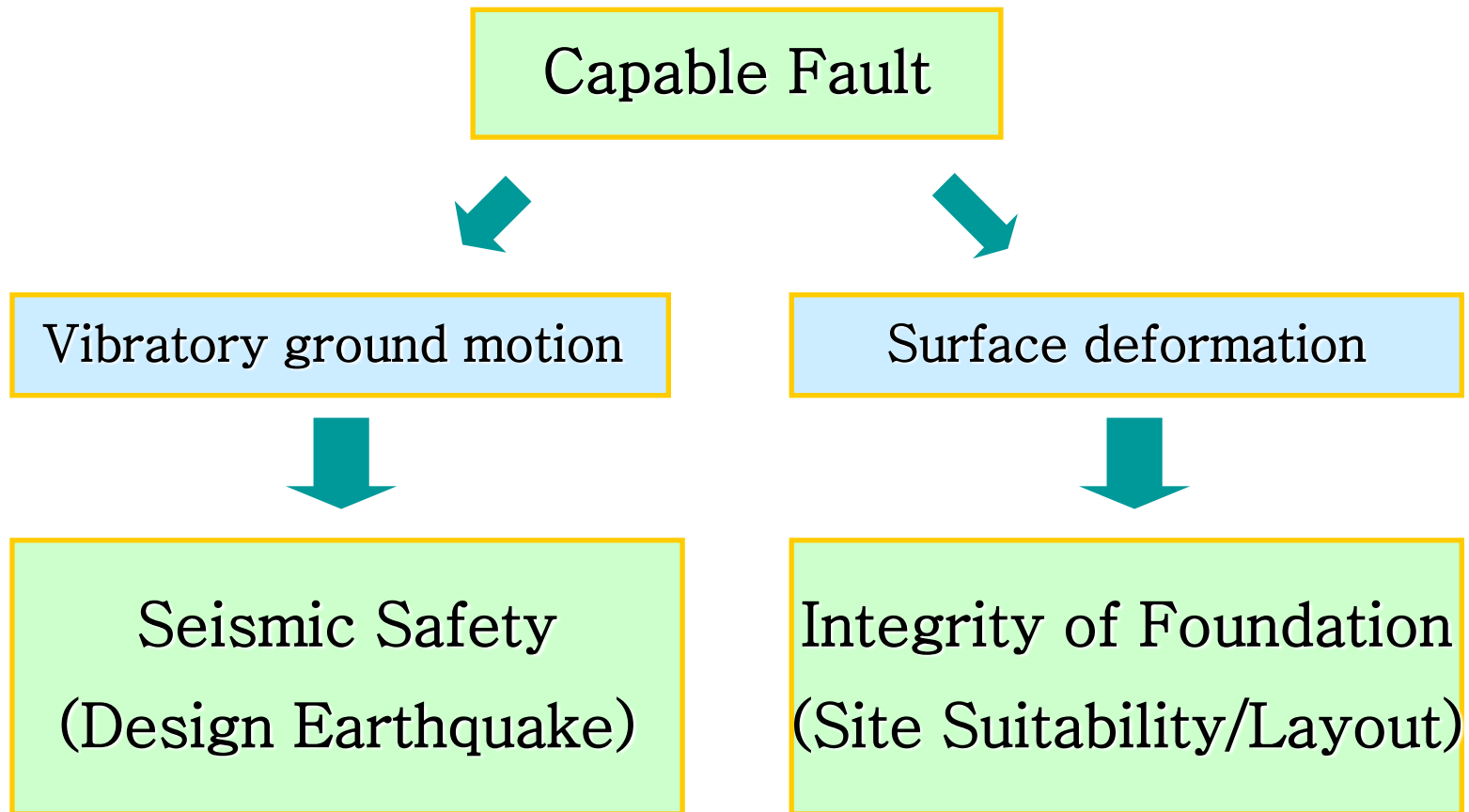
- Faults greater than 300 m long, any part of which is within 8 km

□ Comparison of Definitions of Capable Fault

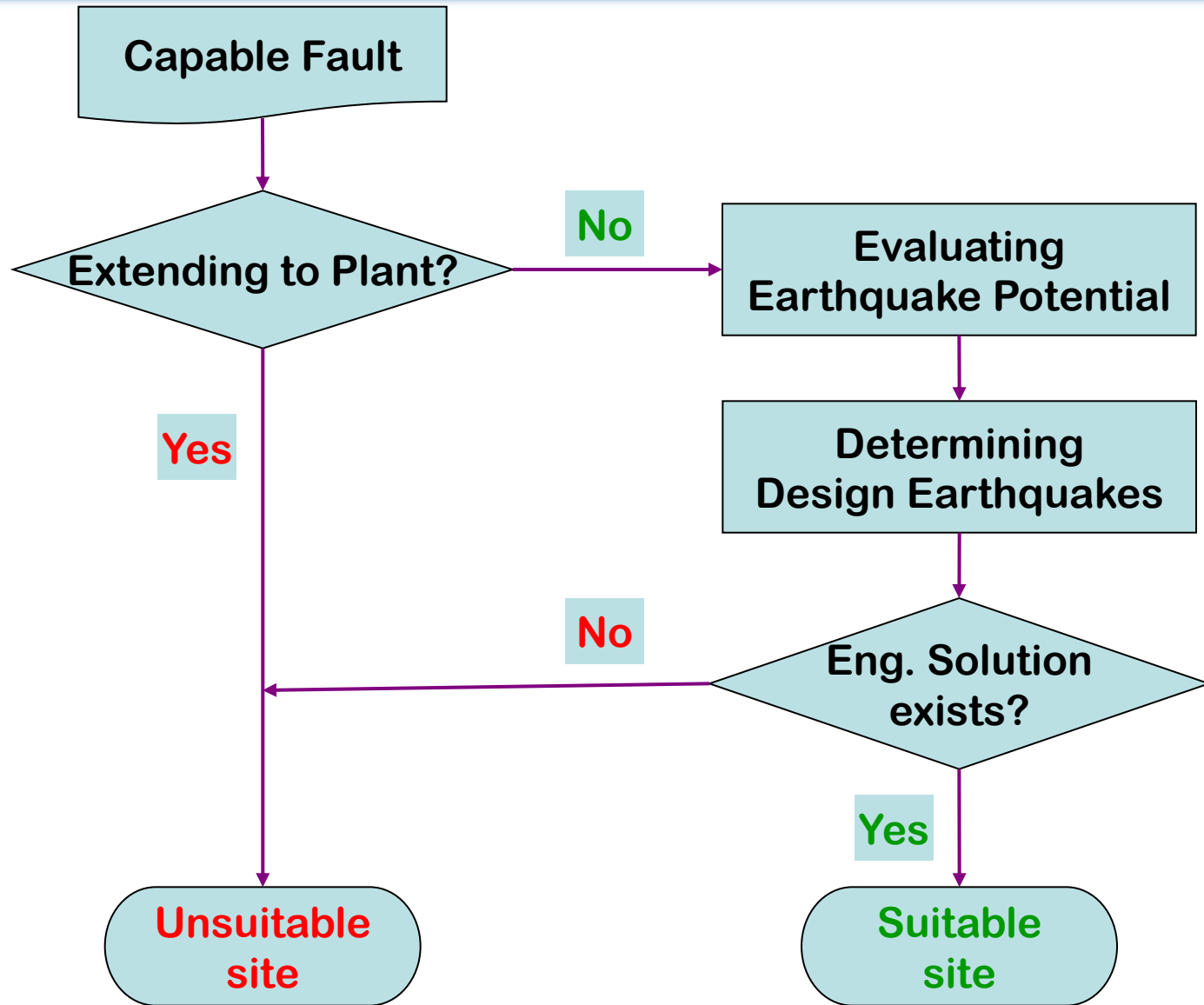
State	Definition
Japan	▪ A fault that has moved in the recent geologic time so that it has the potential to move in the future ▪ Capable faults to be considered in the seismic design: a fault shows the evidence of movements during the late Pleistocene (125~80 ka)
IAEA	▪ Similar to the definition of the US, but no specific provisions for the time of past movements
China	▪ Applying the IAEA definition with provisions for the time of past movements: the late Pleistocene Q_3 (about 10 ka)
Canada Germany France	▪ Applying the IAEA definition

Design Considerations for a Capable Fault

- ❑ Surface deformation
- ❑ Vibratory ground motions



Site Suitability vs. Capable Fault



Surface Deformation



Surface rupture cutting gas station on Adapazarı-Bilecik road

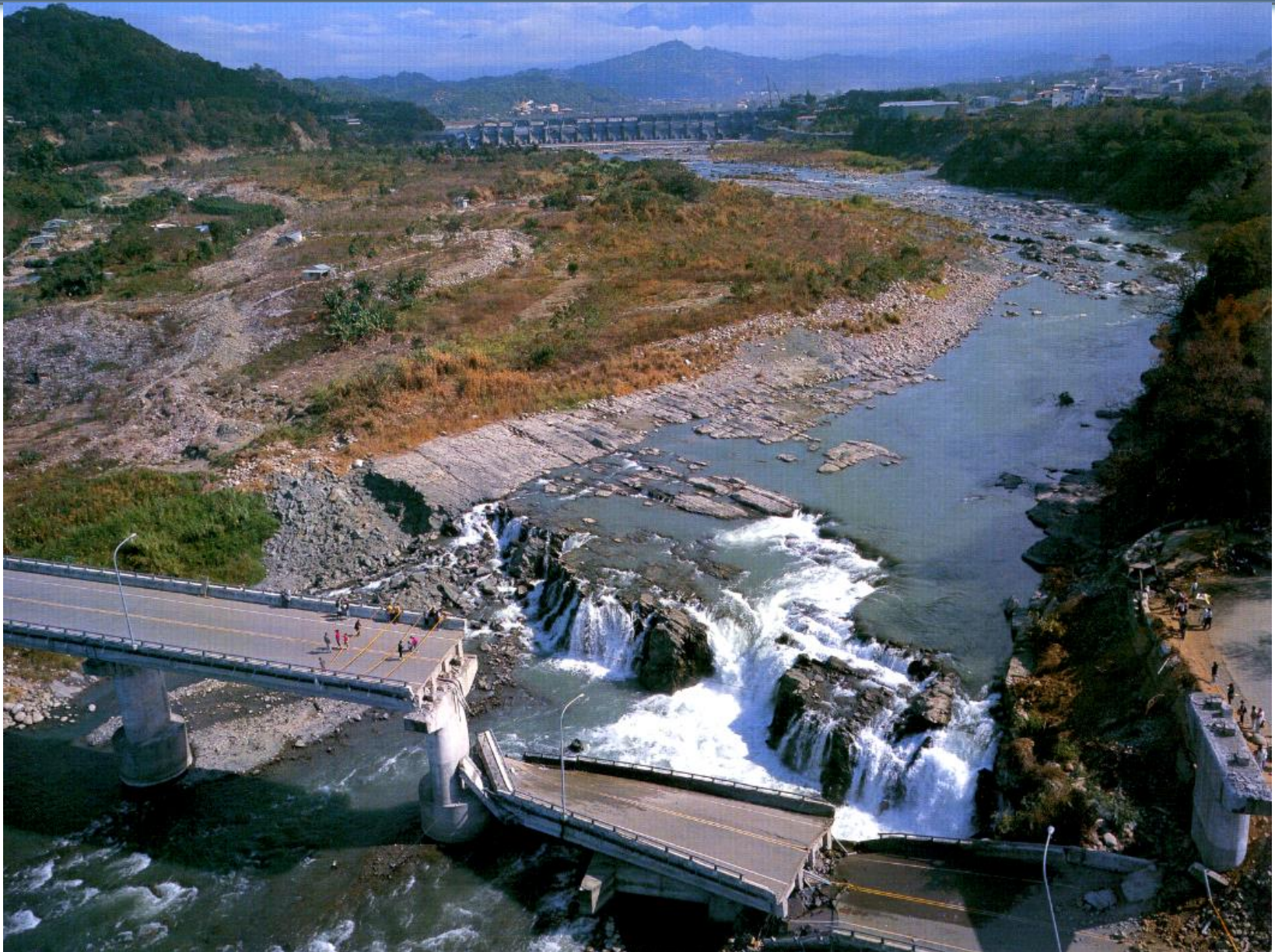
Surface Deformation



Surface rupture cutting
a village road near Arifiye



Surface Deformation



Surface Deformation



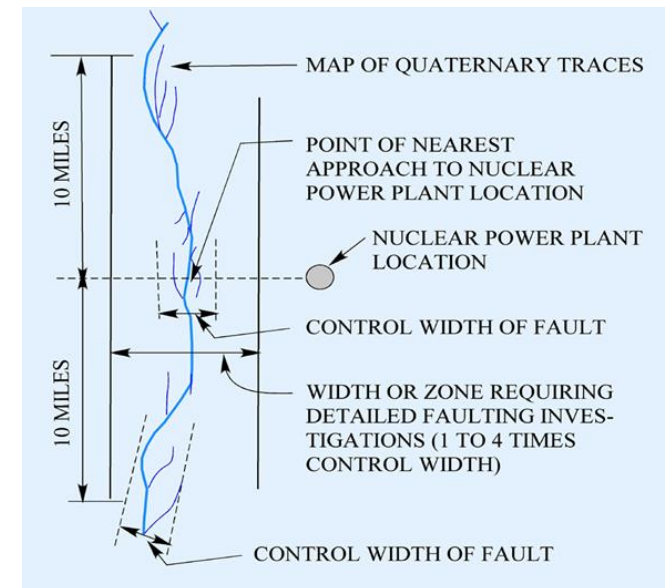
Surface Deformation

□ Control width

- Maximum width of mapped Quaternary fault traces

□ Zone of detailed investigation (ZDI)

EQ Magnitude	Width of zone requiring detailed faulting investigation
< 5.5	1 × control width
5.5 ~ 6.4	2 × control width
6.5 ~ 7.4	3 × control width
7.5 ≤	4 × control width



- ZDI is at least 0.5 mile.

□ Recommendation

- Not to locate plant structures within the ZDI

Description of Earthquake

□ Origin Parameters

○ Origin Time

- The time of earthquake occurrence: year/month/day hr:min:sec
- UTC (universal time coordinated) is preferred

○ Earthquake Location (x, y, z)

- Longitude (x) latitude (y) in degrees
- Focal depth (z) in km

○ Earthquake Size

- Intensity
- Magnitude

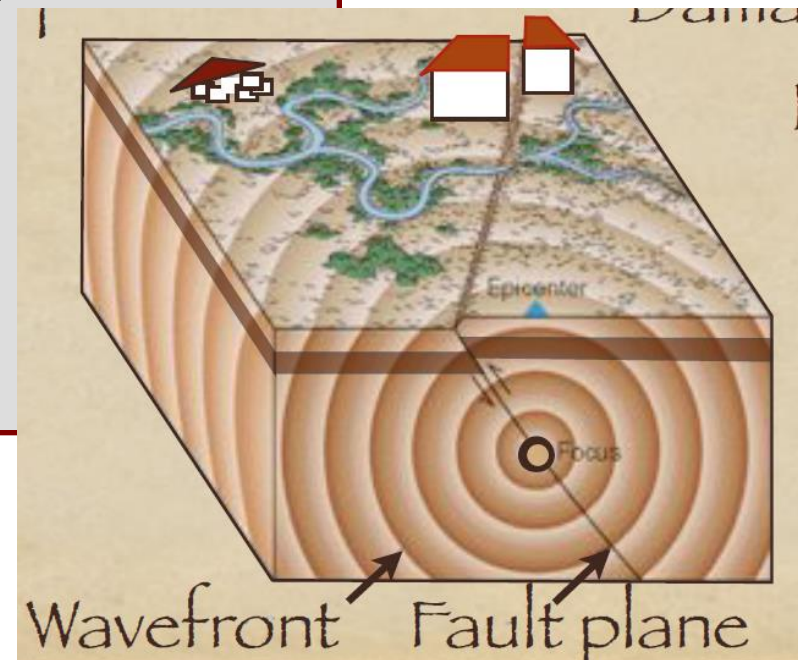
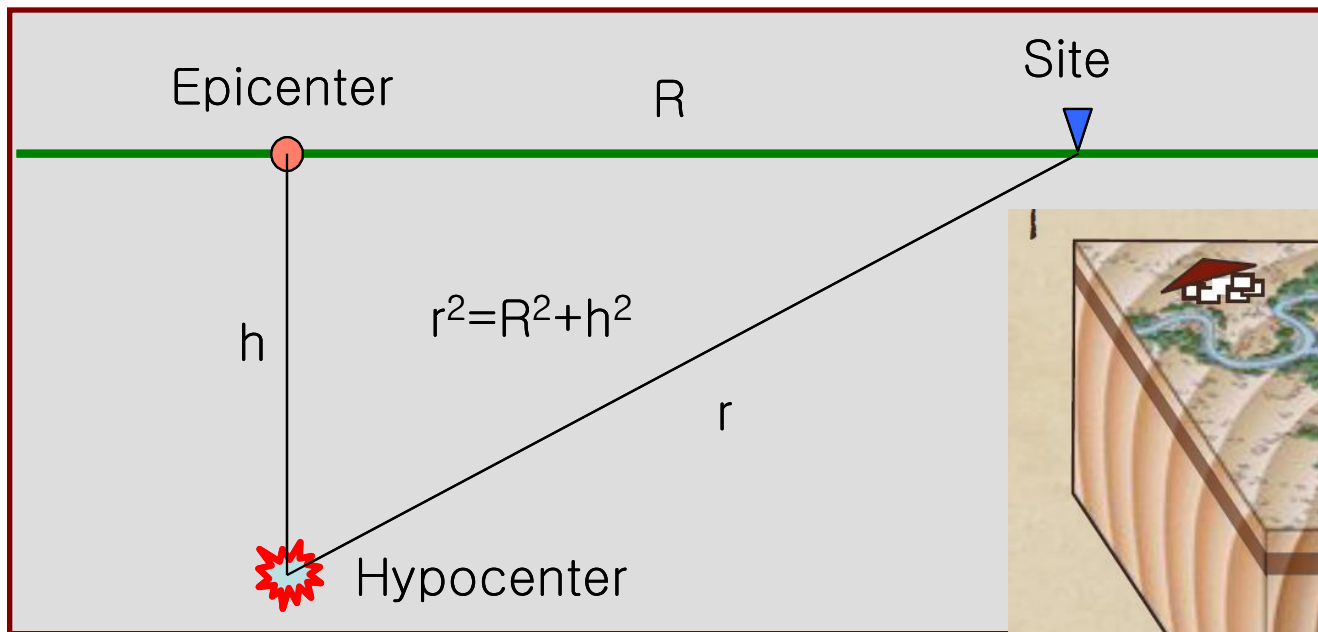
❖ Example

1999/03/02 05:33:21.13 35.712N 128.923E 14.5km 5.8(M), 5.7(Ms)

□ Earthquake Location

Epicenter: vertical projection of hypocenter to the surface

Hypocenter: a locus where the rupture was initiated



Earthquake Size

□ Intensity Scale

- Grades of the severity of earthquake impact
 - Natural phenomena, damage to man-made structures, Human's sensation
- Basically a subjective and qualitative measure
- Subject to site and structure conditions
 - Soil condition, groundwater level, slope of ground
 - Height, aging, material of structures
- Various intensity scales have been developed
 - JMAI (Japan), MMI (US), MSKI (Europe), etc.
- Increasing as decreasing distance
 - If the intensity is to be used as a measure of earthquake size, it should be evaluated at a reference point, e.g., at the epicenter

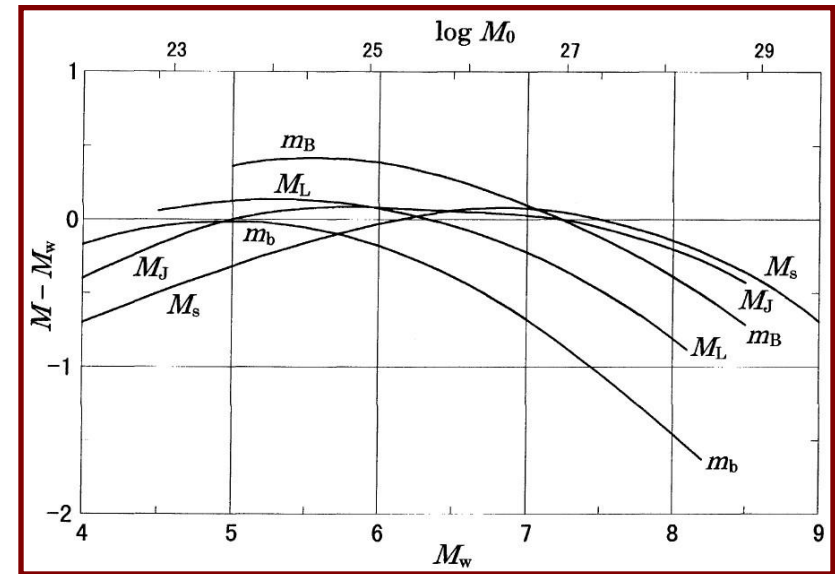
Brief Description of MMI (Modified Mercalli Intensity) Scale

MMI	Observation	MMI	Observation
I Instrumental	Not felt.	VII Very Strong	Difficult to stand. Considerable damage in poorly built structures. Some chimneys broken.
II Weak	Felt by a few people at best, especially on the upper floors.	VIII Destructive	Considerable damage in substantial buildings with partial collapse. Fall of chimneys, factory stacks, columns
III Slight	Felt quite noticeably by people indoors, especially on the upper floors.	IX Violent	General panic; well designed frame structures thrown out of plumb. Buildings shifted off foundations.
IV Moderate	Felt indoors by many people, outdoors by few people. Sensation like heavy truck striking building.	X Intense	Most masonry and frame structures destroyed with foundation. Destruction of some wooden structures. Rails bent.
V Rather Strong	Felt outside by most. Vibrations like large train passing close to house.	XI Extreme	Few, if any masonry structures remain. Bridges destroyed. Rails bent greatly.
VI Strong	Felt by all. Many walk unsteadily. Books fall off shelves. Some heavy furniture moved or overturned.	XII Cataclysmic	Total destruction. Objects thrown into the air. In some cases, even the route of rivers is changed.

□ Magnitude Scale

○ Magnitude

- Measure of the energy released by an earthquake
 - Independent of distance
- Measured by seismographs
 - objective and quantitative
- Different magnitudes for different seismic waves
 - Local magnitude, M_L is well-known (also known as the Richter magnitude)
 - m_b (body wave), M_S (surface wave), etc.
- Increasing use of the moment magnitude, M as a uniform measure



□ Comparison of Magnitude & Intensity

Magnitude scale	Intensity scale
Quantitative measure by instruments	Qualitative measure by judgment
Measure of earthquake size (energy)	Grade of earthquake impact
Independent of distance - analogous to 'watt' of an electric bulb	Dependent of distance and site conditions - analogous to 'lux' of an electric bulb
Real numbers - possible to have negative values	Non-negative integers - denoted by Roman characters

Design Earthquakes

□ Definitions

- Safe Shutdown Earthquake (SSE)
 - Seismic design for safety related SSCs
 - At least 0.1g in peak ground acceleration
 - SL-2 in IAEA terminology
- Operating Basis Earthquake (OBE)
 - Seismic design for continuous operation
 - SL-1, IAEA

□ Construction

- DEs should be given in response spectra

□ Regional Seismotectonic Models

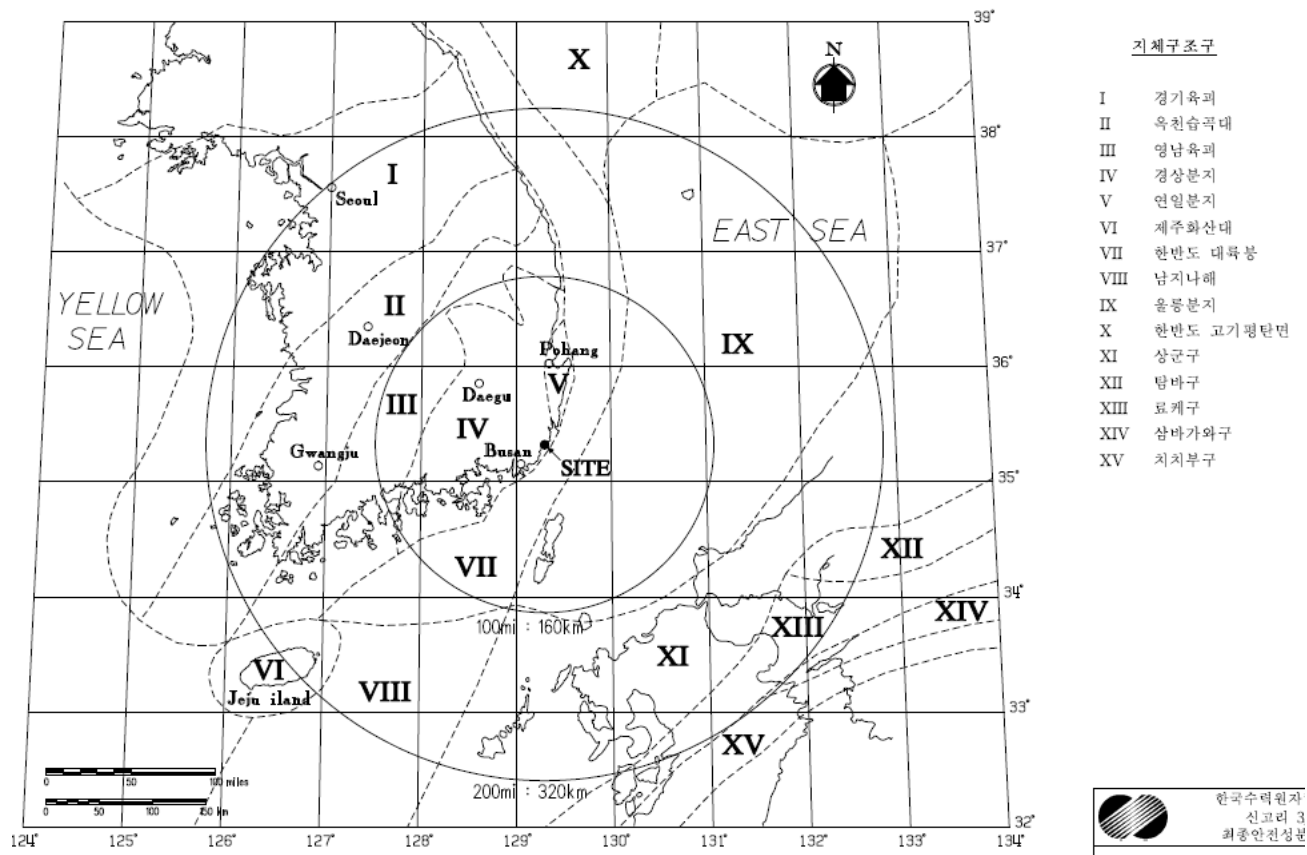
○ General considerations

- Seismic, geological, and geophysical data are combined to establish regional seismotectonic models.
- It is not desirable to establish seismotectonic models that are more sophisticated than the data support.

○ Seismic sources

- Capable tectonic structure
 - Definition: a geological structure capable of generating earthquakes
 - Characterization: location & geometry of geological structure, maximum potential earthquake, earthquake recurrence rate, etc.
- Seismotectonic province
 - Definition: a region where earthquakes diffusely occur, but no specific geological structure is identified to be responsible for those earthquakes.
 - Characterization: similar to that of capable tectonic source

Example of Seismotectonic Province



Seismotectonic province within 320km of the site

□ Seismic Hazard/Design Earthquakes

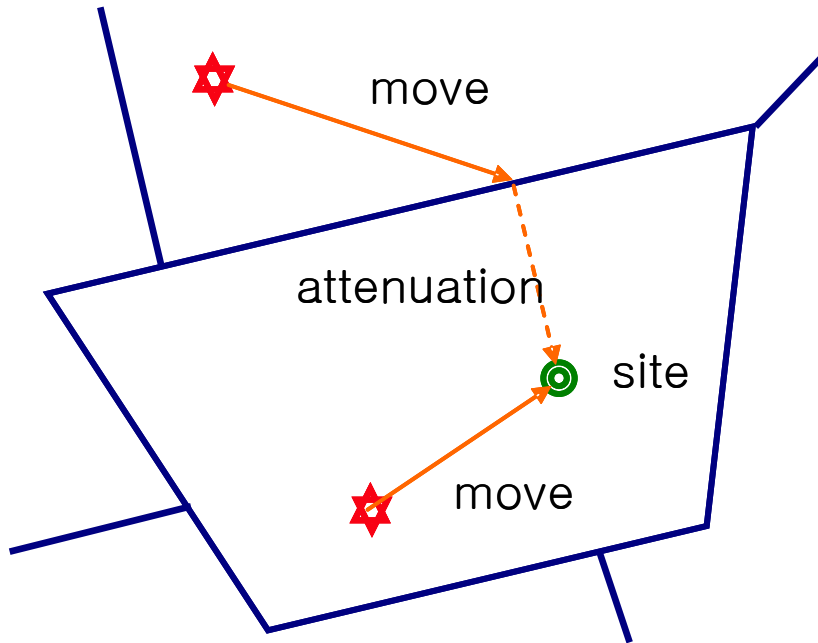
○ Methods

- Deterministic & probabilistic methods
- Korean regulation requires the deterministic method
 - Mean annual exceeding frequency of SSE should be less than $1.0E-3$

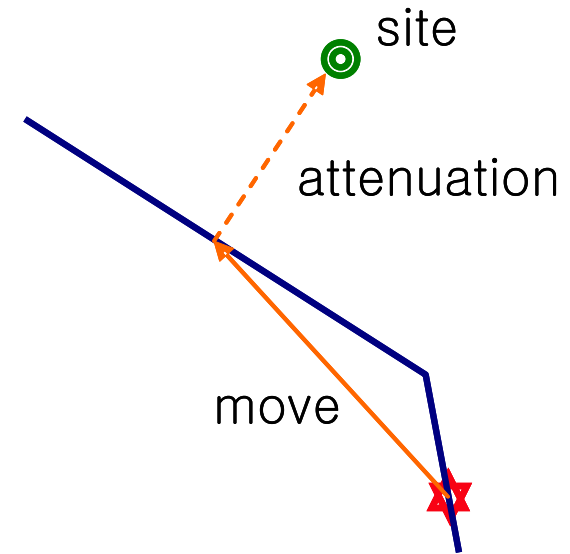
○ Deterministic method

- Establish a seismotectonic model consisting of capable tectonic structures and seismotectonic provinces (i.e., seismic sources)
- Determine the max. potential earthquake (MPE) for each seismic source
- Locate each MPE at the closest point to site
- Calculate the site ground motion by each MPE by using proper attenuation equation
- Take the largest ground motion among all MPEs (max. site ground motion)

○ Deterministic method (diagrammatic)



Seismotectonic Provinces

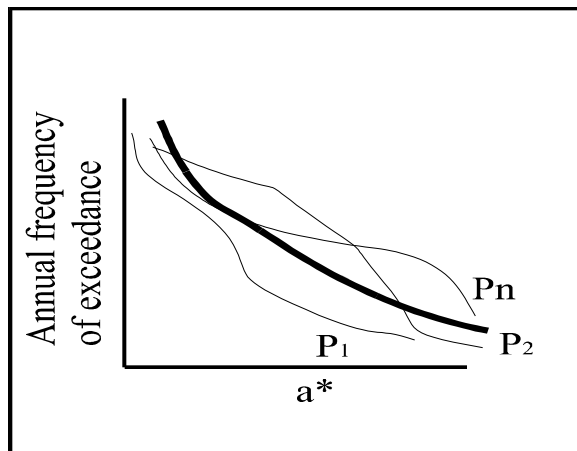
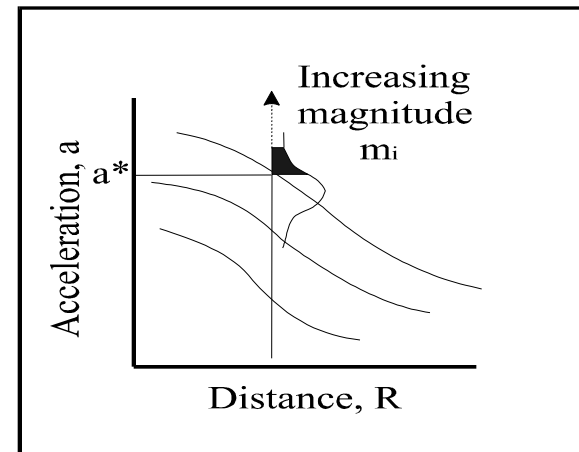
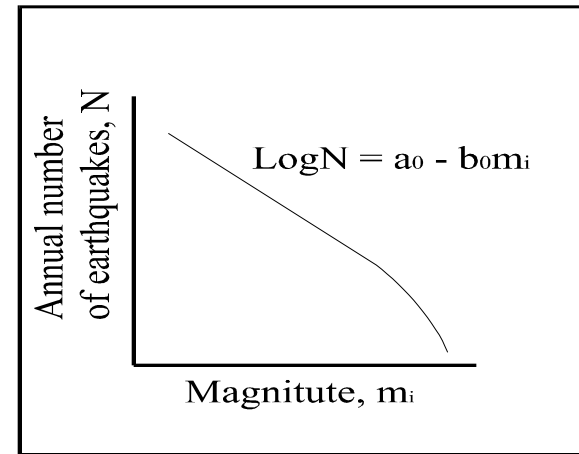
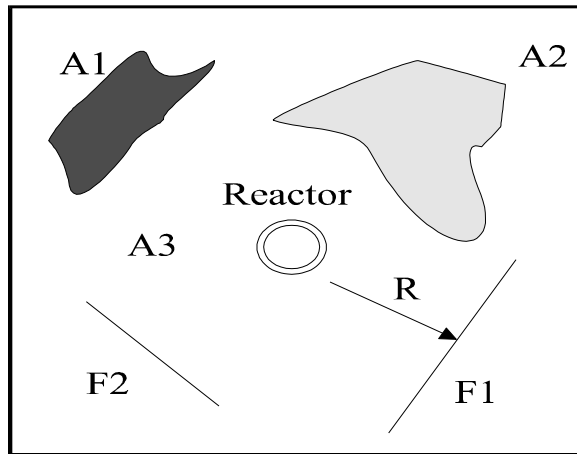


Capable Tectonic Structure

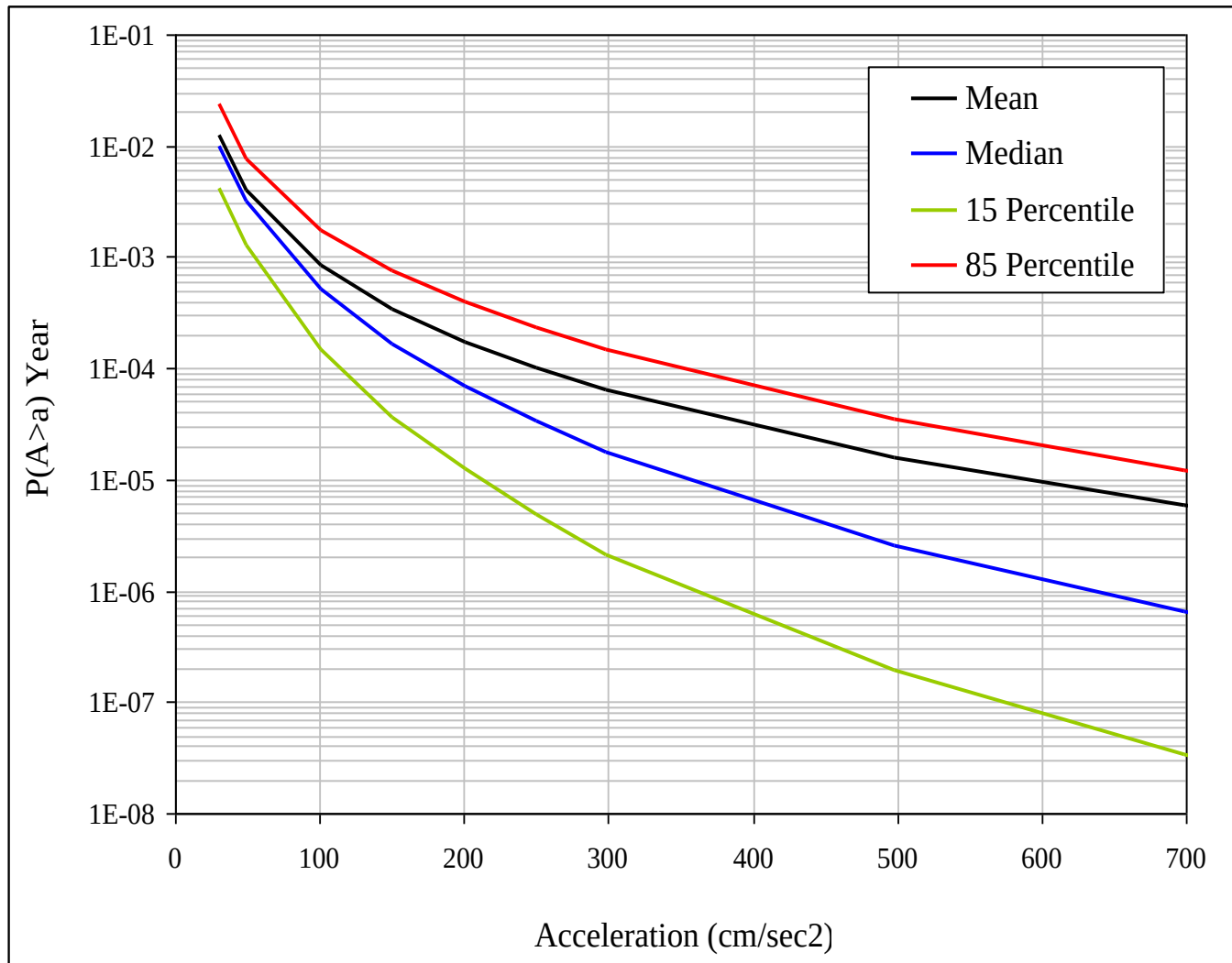
○ Probabilistic method

- Construct seismotectonic models in terms of seismic sources including uncertainty in source boundary
- For each source, determine magnitude-frequency models and MPEs including the associated uncertainties
- Select proper attenuation equations including the uncertainties
- Evaluate annual frequency of exceedance for various levels of ground motions
 - Mean, median, 15th-percentile, 85th-percentiles

○ Probabilistic method (diagrammatic)



Example of PSHA



□ Wave Transmission Characteristics

- Ground motions at the site should be corrected for those effects of
 - Seismic properties of plant site different from those of recording sites
 - Layered structures of underground materials of the plant site
 - Significant topography around the plant site
- Design earthquakes
 - Maximum site ground motions corrected for wave transmission characteristics

□ What is Response Spectrum?

- A plot of maximum responses of structures of single-degree of freedom, in terms of their natural frequencies
- Representation of a structure by a simple pendulum (single degree of freedom)
 - Pendulum mass (M) = sum of mass of structure and attached facilities
 - Spring (k) = (shear) walls
 - Damping (c) = inelastic characteristics of structure
- Response spectra are provided for various damping values of interest
- Three types of response spectra
 - (Relative) Displacement response spectra
 - (Relative) Velocity response spectra
 - (Absolute) Acceleration response spectra

Standard response spectrum

□ Tripartite chart

- Pseudo-response spectra

$$PSA = \omega_n S_V$$

$$PSD = S_V / \omega_n$$

- Method

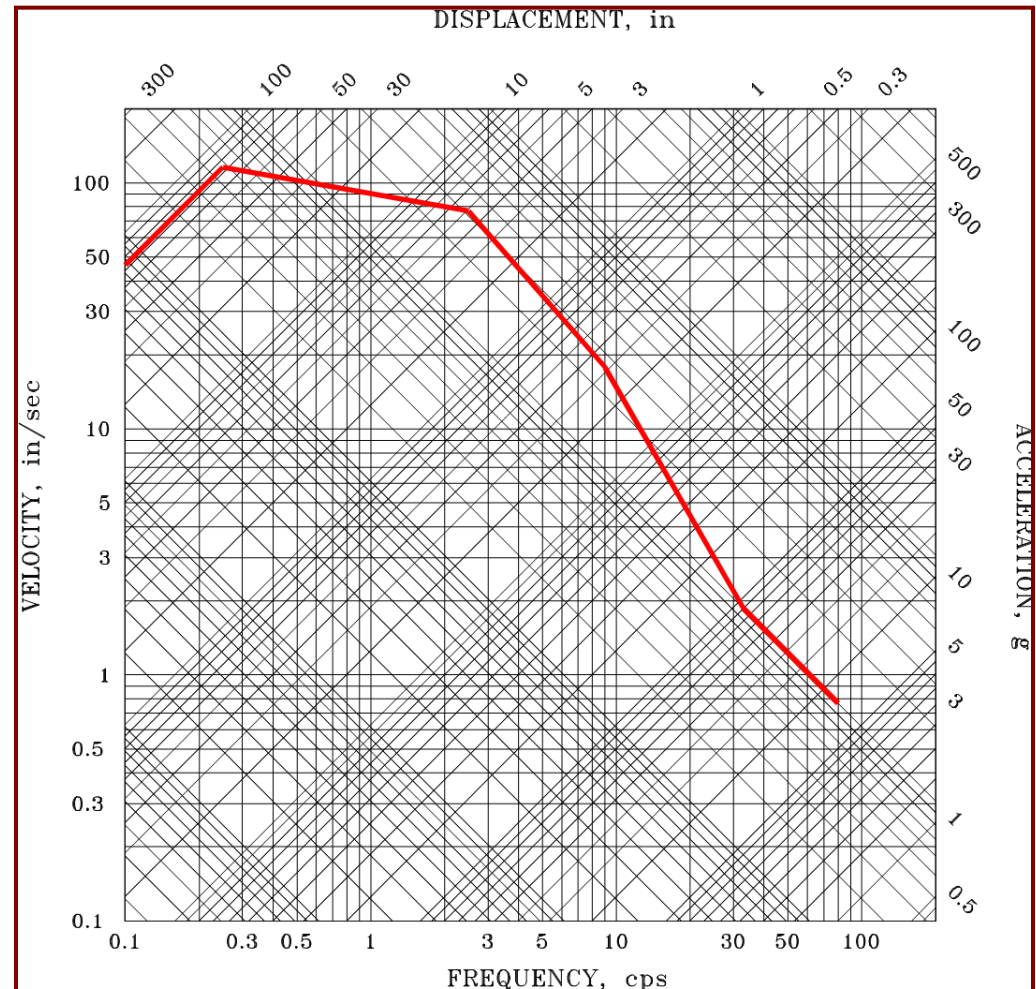
$$\log S_V = \log S_D + \log \omega_n$$

$$\log S_V = \log PSA - \log \omega_n$$

$$Y = \log S_V, \quad X = \log \omega_n$$

$$Y = \log PSD + X$$

$$Y = \log PSA - X$$



VII. Geotechnical Engineering

□ Stability of subsurface materials

- Subsurface foundation material is assumed to be homogeneous and stable in terms of geological hazards
- Sufficient bearing capacity to sustain the load of structures

□ Factors to be evaluated

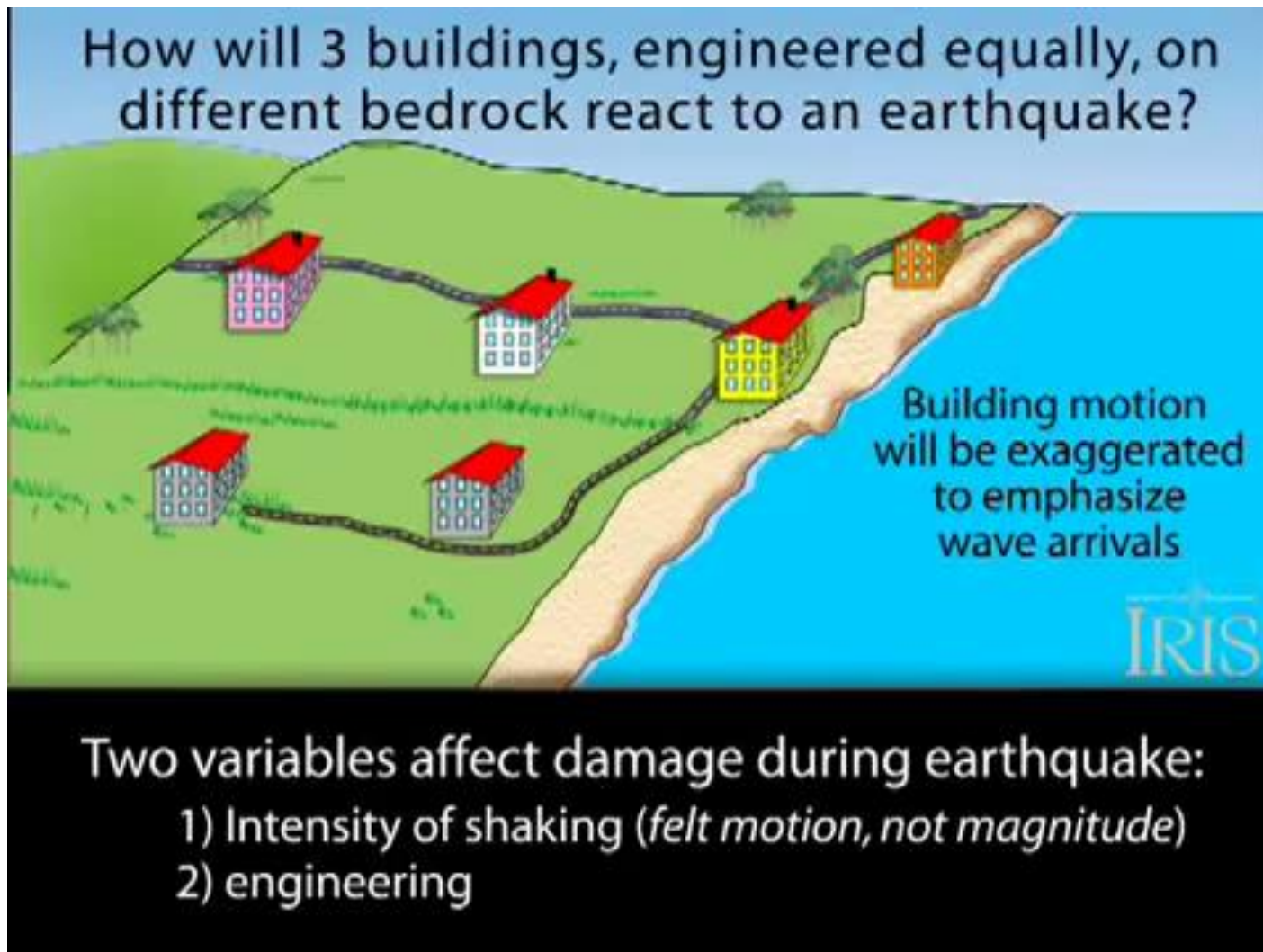
- Bearing capacity of foundation materials
- (Total) Settlement of differential settlement
- Liquefaction potential
 - The word “liquefaction” means a change in state from a solid to liquid. As applied to a soil, the term refers to a change from a solid or stable assemblage of soil particles to a complete or substantially complete suspension of the solid particles in a fluid, such that the suspension has a very low shear strength.
- Velocity model for SSI
- Slope stability
- Possibility of reinforcement of local weak zones

Example of Soil liquefaction





Earthquake vs Subsurface materials



Factors liquefaction loves

3 factors required for liquefaction to occur

- 1) Loose, granular sediment
- 2) Water saturated sediment
- 3) Strong shaking

San Francisco, 1906

IRIS



Investigation to be conducted

□ In-land investigation

- Surface geological investigation
- Borings, Trenches, Ground water condition
- Geophysical exploration
 - Reflection and refraction method
 - Cross-hole test, down-hole test, tomography
- In-situ test
 - Rock deformation test
 - Standard penetration test (SPT)
- Laboratory test (Index test, uniaxial and triaxial compressive test, sonic test, ...)

□ Off-shore or marine investigation

- Marine physical exploration

□ Determination of engineering properties of materials

- Direct measurement : In-situ test
- Indirect measurement : Correlation between parameters

Slope stability

□ Overview

- Static and dynamic slope stability analysis with realistic data
- Relevant model for rock or soil slope

□ Slope Stability

- For rock slope
 - Stereo network method
- For soil slope
 - Limit equilibrium Method (Bishop, Janbu, ..)
 - FEM method

□ Improvement of unstable slope

- Lowering the slope angle
- Increasing drainage capacity, or
- Reinforcement by rock bolts or re-bar
- Rock bolts, grouting, replacement, anchoring

VIII. Monitoring of Hazards

Monitoring of Hazards

□ Purpose

- Safety-related natural and human induced hazards are need to be monitored since the commencement of plant construction
- By monitoring the safety-related features, periodic re-evaluation, confirmation of plant safety is possible

□ Monitoring activities

- Demographic, meteorological and hydrological conditions for the updates of emergency plan
- Seismicity and fault activity monitoring using instrumentations
- Settlement and slope stability monitoring
- Sea water level and temperature monitoring

Thank you for your attention!

KINS

