



**International Atomic Energy Agency**

## ***Site Characteristics***

**Presented by:** **Tibor Szikszai**  
**Ri-man Consulting, Hungary**  
*t.szikszai@riman.hu*

**Joint ICTP-IAEA Essential Knowledge Workshop on Deterministic Safety  
Analysis and Engineering Aspects Important to Safety, Trieste, Italy 12 – 23  
October 2015 (week 1)**

# Contents

- **Introduction**
- **Site evaluation general requirements**
- **Requirements for evaluation external events**
- **Requirements for evaluation of the potential impacts of the nuclear installation**
- **Monitoring of the hazards and the potential impacts**

IAEA  
SAFETY  
STANDARDS  
SERIES

Site Evaluation for  
Nuclear Installations

SAFETY REQUIREMENTS

No. NS-R-3



IAEA Safety Standards  
for protecting people and the environment

Meteorological and  
Hydrological Hazards  
in Site Evaluation for  
Nuclear Installations

Jointly sponsored by the  
IAEA and WMO



Specific Safety Guide  
No. SSG-18



IAEA Safety Standards  
for protecting people and the environment

Geotechnical Aspects  
of Site Evaluation  
and Foundations for  
Nuclear Power Plants

Safety Guide  
No. NS-G-3.6



IAEA  
SAFETY  
STANDARDS  
SERIES

External Human Induced  
Events in Site Evaluation  
for Nuclear Power Plants

SAFETY GUIDE

No. NS-G-3.1



# Introduction

- **The important questions of determining the design basis for a nuclear facility are:**
    - **what site properties are needed for the installation**
    - **what should the facility withstand**
    - **what are the potential impacts of the facility on the environment and human life**
  
  - **Site selection plays an important role in answering these questions**
    - **the environmental impacts on the facility are highly dependent on the site selection,**
    - **the potential impacts of the facility on the environment and the human life is also highly dependent on the site selection,**
- ⇒ the design basis should be site specific**

# Introduction

- **The site specific design should be based on the site characteristics**
  - **considering only technical aspects, a nuclear facility can be designed to any location, given the site characteristics are taken into account in the design**
  - **however, there are other aspects also to be considered that are limiting the possibilities for a suitable site, like political and financial aspects**
- **Site characteristics shall be specified for the design in the design specification**
- **This requires a complete and comprehensive characterisation of the site**

# Site evaluation general requirements

- **There must be national regulatory requirements defining the extent of information on a proposed site to be presented by the licensee**
- **The proposed site should be evaluated to ensure that the site related phenomena and characteristics are adequately taken into account;**
- **The characteristics of the population of the region and the capability of implementing emergency plans over the projected lifetime of the plant should be analyzed**
- **The site related hazards should be identified and characterized**
  - **human induced hazards**
  - **natural induced hazards**

# Site evaluation general requirements

- **The main objective in site evaluation for nuclear installations in terms of nuclear safety is to protect the public and the environment from the radiological consequences of radioactive releases due to normal operation of the facility and due to accidents.**

## Site evaluation general requirements

- **Characteristics of the natural environment in the region that may be affected by potential radiological impacts in operational states and accident conditions shall be investigated. These characteristics should be monitored throughout the lifetime of the installation**
- **The site for the nuclear installation shall be examined with regard to the frequency and severity of external natural and human induced events and phenomena that could affect the safety of the installation**
- **The foreseeable evolution of natural and human made factors in the region shall be evaluated for the duration of the projected lifetime of the nuclear installation.**



# Site evaluation general requirements

- **These factors, particularly population growth and population distribution, shall be monitored over the lifetime of the nuclear installation.**
- **If necessary, appropriate measures shall be taken to ensure that the overall risk remains acceptably low.**
  - **design features,**
  - **measures for site protection (e.g. dykes for flood control) and**
  - **administrative procedures.**
  - **Design features and protective measures are the preferred means.**

# Site evaluation general requirements

- **For an external event (or a combination of events) the parameters and the parameter values used to characterize the hazards should be chosen so that they can be used easily in the design of the installation.**
- **In the derivation of the hazards associated with external events, consideration should be given to the effects of the combination of these hazards with the ambient conditions (e.g. hydrological, hydrogeological and meteorological conditions).**
- **Consideration shall be given to the storage and transport of fresh and spent fuel and radioactive wastes.**

# Site evaluation general requirements

- **The possible non-radiological impact of the installation, due to chemical or thermal releases, and the potential for explosion and the dispersion of chemical products shall be taken into account in the site evaluation process.**
- **The potential for interactions between nuclear and non-nuclear effluents, like combination of heat or chemicals with radioactive material in liquid effluents, should be considered.**

# Site evaluation general requirements

- **The potential radiological impacts in operational states and in accident conditions on people in the region, including impacts that could lead to emergency measures, shall be evaluated**
- **The total nuclear capacity to be installed on the site should be determined as far as possible at the first stages of the siting process. If it is proposed that the installed nuclear capacity be significantly increased to a level greater than that previously determined to be acceptable, the suitability of the site shall be re-evaluated.**

## Requirements for evaluation external events

- **Possible natural phenomena and human induced situations and activities in the region of a proposed site shall be identified and evaluated according to their significance for the safe operation of the nuclear installation.**
  - **This evaluation should be used to identify the important natural phenomena or human induced situations and activities in association with which potential hazards are to be investigated.**
- **Foreseeable significant changes in land use shall be considered, like expansion of existing installations and human activities or the construction of high risk installations.**

# Requirements for evaluation external events

- **Prehistorical, historical and instrumentally recorded information and records, as applicable, of the occurrences and severity of important natural phenomena or human induced situations and activities shall be collected for the region.**
  - **These shall be carefully analyzed for reliability, accuracy and completeness.**
- **Appropriate methods shall be adopted for establishing the hazards that are associated with major external phenomena.**
  - **The methods shall be justified in terms of being up to date and compatible with the characteristics of the region.**

# Requirements for evaluation external events

- **The size of the region to which a method for establishing the hazards associated with major external phenomena is to be applied shall be large enough to include**
  - **all the features and**
  - **areas that could be significant in the determination of the natural and human induced phenomena.**
- **Major natural and human induced phenomena shall be expressed in terms that can be used as input for deriving the hazards associated with the nuclear installation**
  - **appropriate parameters for describing the hazard should be selected or developed**

# Specific requirements for evaluation external events

## ■ Earthquake

- Hazards due to earthquake induced ground motion shall be assessed for the site with account taken of the seismotectonic characteristics of the region and specific site conditions. A thorough uncertainty analysis shall be performed as part of the evaluation of seismic hazards.



# Specific requirements for evaluation external events

## ■ Earthquake

- **determination of the seismic characteristics**

- ✓ to determine Operation Basis Earthquake (OBE) and Design Basis Earthquake (DBE)

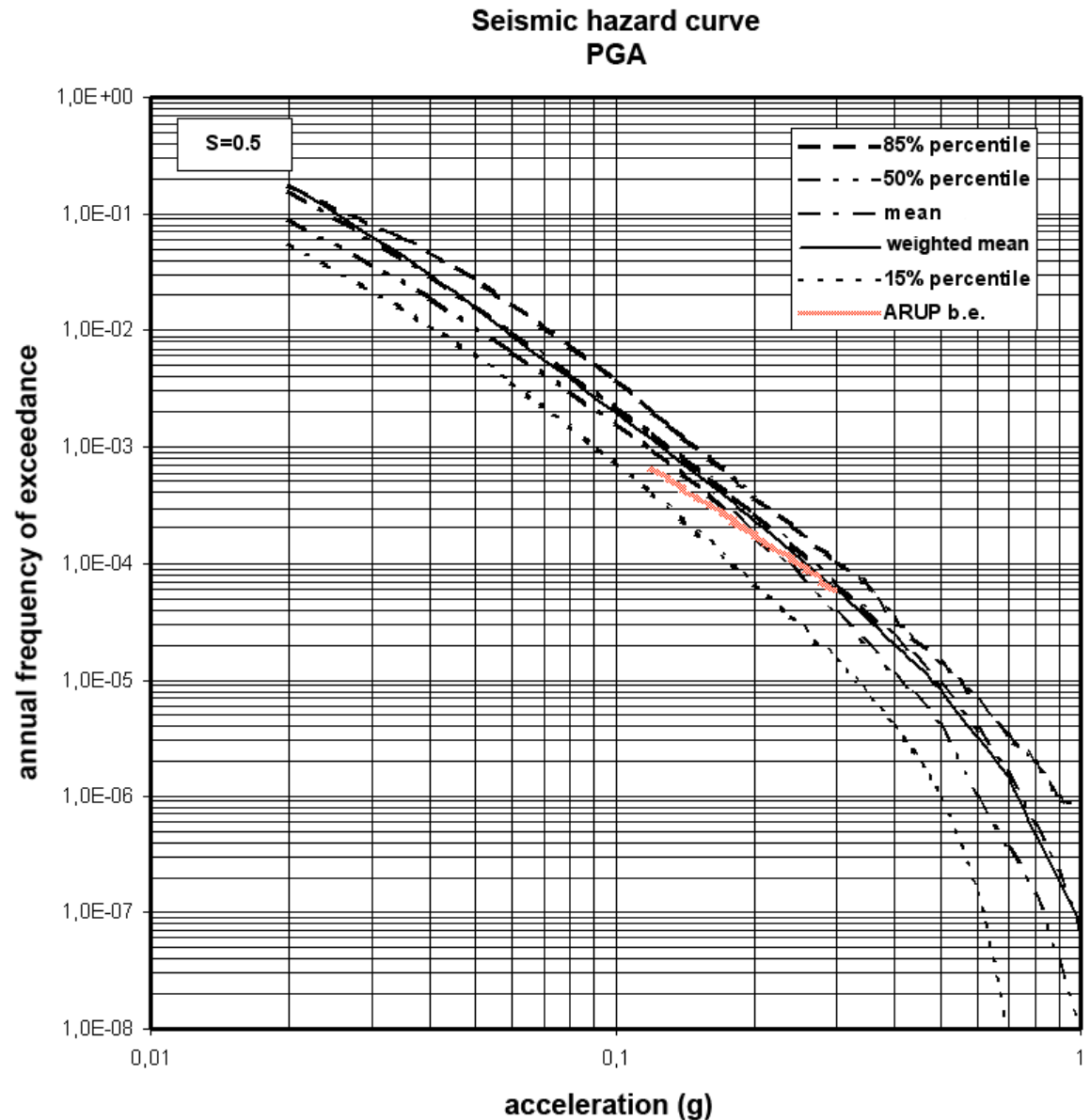
***OBE: An earthquake that could be expected to affect the site of the unit, but for which the power production equipment of the unit is designed to remain functional***

***DBE: A suite of vibratory ground motions which have been chosen on the basis of the likely seismicity and geology at and around probable nuclear power plant sites. (e.g. DBE is defined as an event with 0.005 non-exceedance probability for the total lifetime of the plant. The total lifetime has to be taken as 100 years)***

# Specific requirements for evaluation external events

## ■ Earthquake

- Example hazard curve



# Specific requirements for evaluation external events

## ■ Surface faulting

- The potential for surface faulting (i.e. the fault capability) shall be assessed for the site.
- The methods to be used and the investigations to be made shall be sufficiently detailed that a reasonable decision can be reached using the definition of fault capability.

# Specific requirements for evaluation external events

## ■ Surface faulting

**A fault shall be considered capable if, on the basis of geological, geophysical, geodetic or seismological data, one or more of the following conditions applies:**

- **It shows evidence of past movement or movements (significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to infer that further movements at or near the surface could occur.**
  - ✓ In highly active areas, where both earthquake data and geological data consistently reveal short earthquake recurrence intervals, periods of the order of tens of thousands of years may be appropriate for the assessment of capable faults.
  - ✓ In less active areas, it is likely that much longer periods may be required.

## Specific requirements for evaluation external events

- **A structural relationship with a known capable fault has been demonstrated such that movement of the one may cause movement of the other at or near the surface.**
- **The maximum potential earthquake associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to infer that, in the geodynamic setting of the site, movement at or near the surface could occur.**
- **Where reliable evidence shows the existence of a capable fault that has the potential to affect the safety of the nuclear installation, an alternative site shall be considered.**

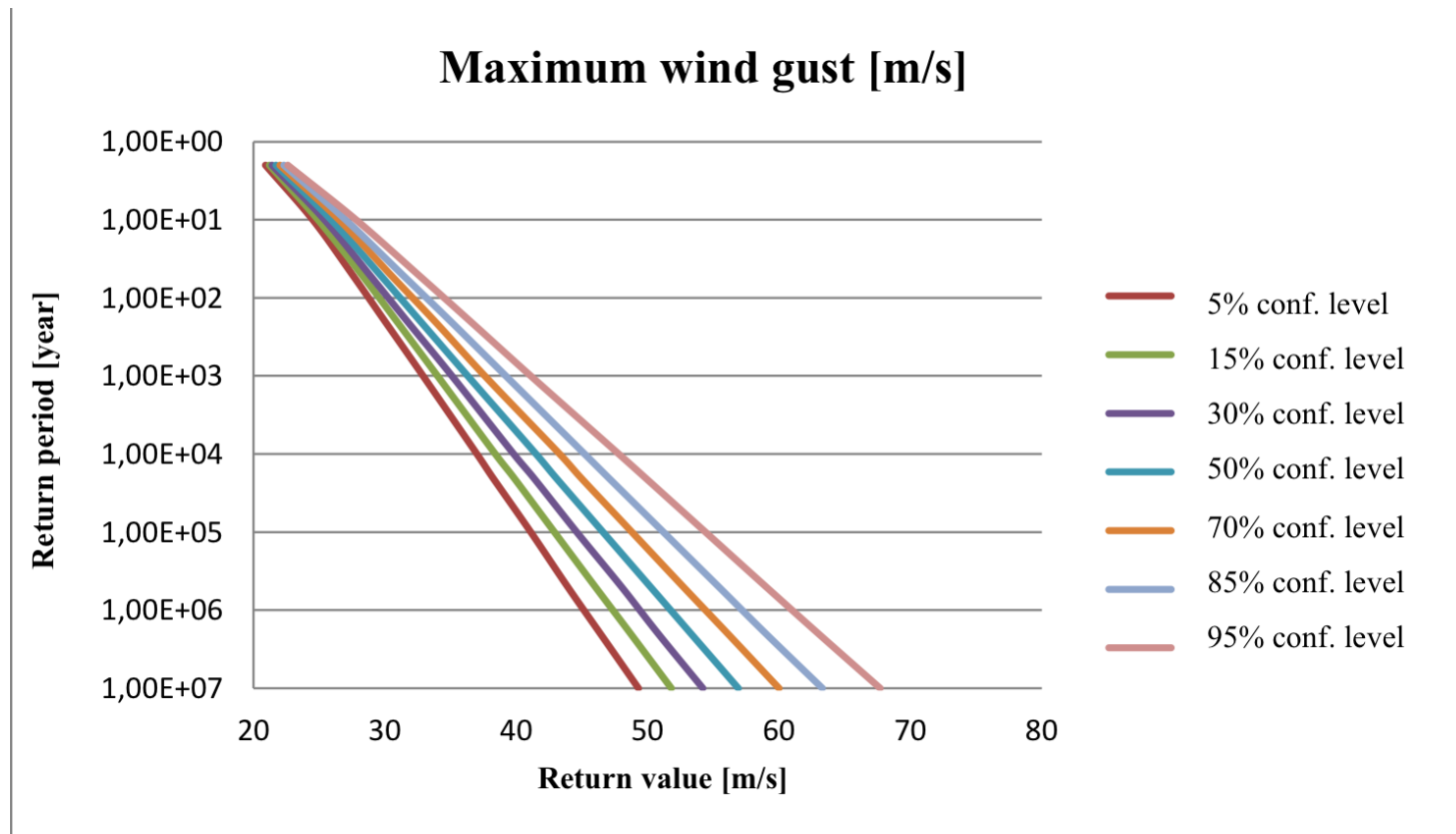
# Specific requirements for evaluation external events

## ■ Meteorological events

- **The extreme values of meteorological variables and rare meteorological shall be investigated for the site of any installation.**
  - ✓ wind,
  - ✓ precipitation,
  - ✓ snow,
  - ✓ temperature
  - ✓ storm surges
- **Rare meteorological events:**
  - ✓ Lightning
  - ✓ Tornadoes
  - ✓ Tropical cyclones

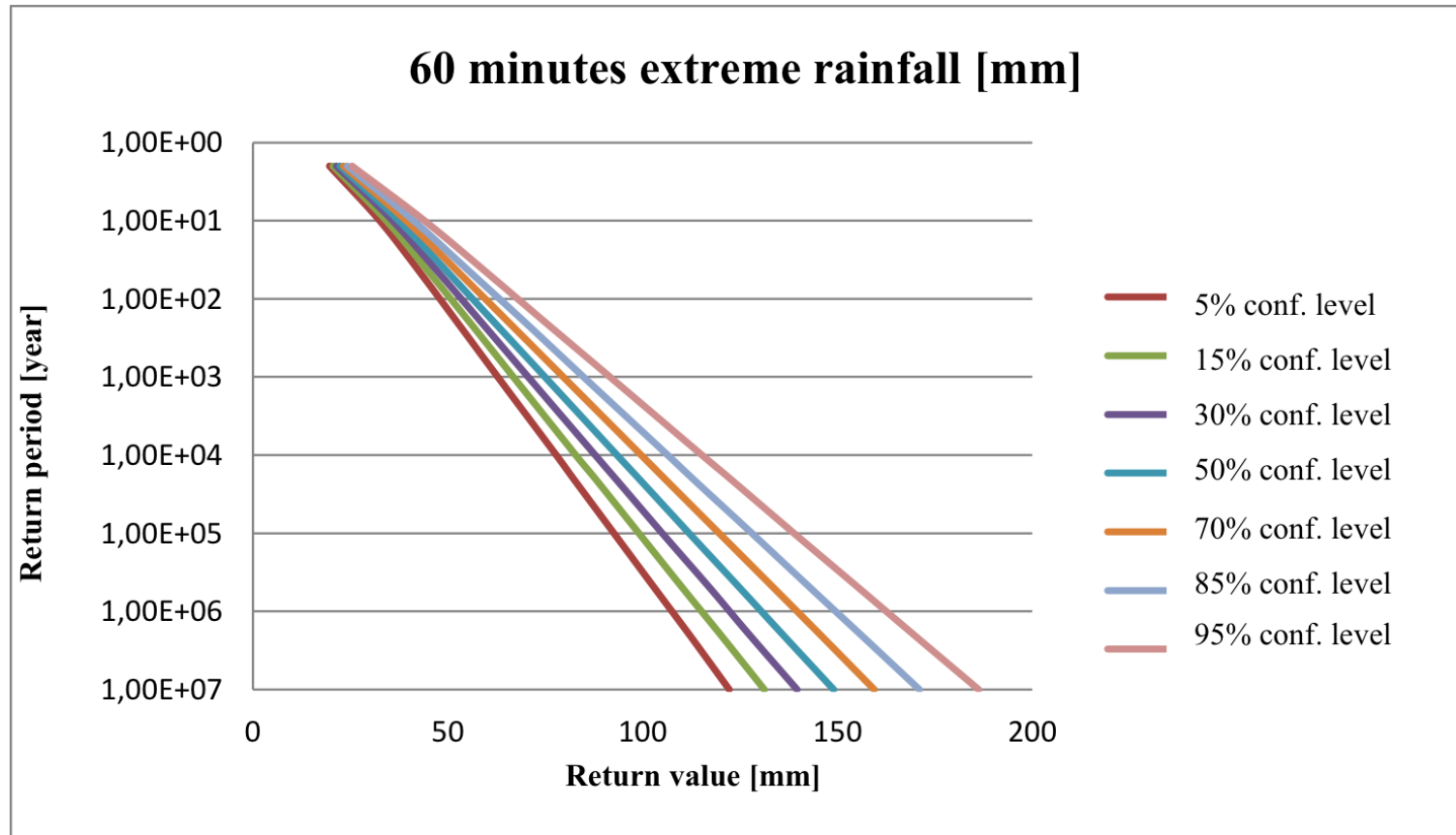
# Specific requirements for evaluation external events

- Meteorological events
  - Example hazard curves



# Specific requirements for evaluation external events

- Meteorological events
  - Example hazard curves





# Specific requirements for evaluation external events

## ■ Flooding

### Floods due to precipitation and other causes

- **The region shall be assessed to determine the potential for flooding due to one or more natural causes waves that may affect the safety of the nuclear installation, such as runoff resulting from**
  - ✓ precipitation
  - ✓ snow melt,
  - ✓ high tide,
  - ✓ storm surge,
  - ✓ seiche and wind.
- **The possible combinations of the effects of several causes shall be examined.**

# Specific requirements for evaluation external events

## ■ Flooding

**Water waves induced by earthquakes or other geological phenomena**

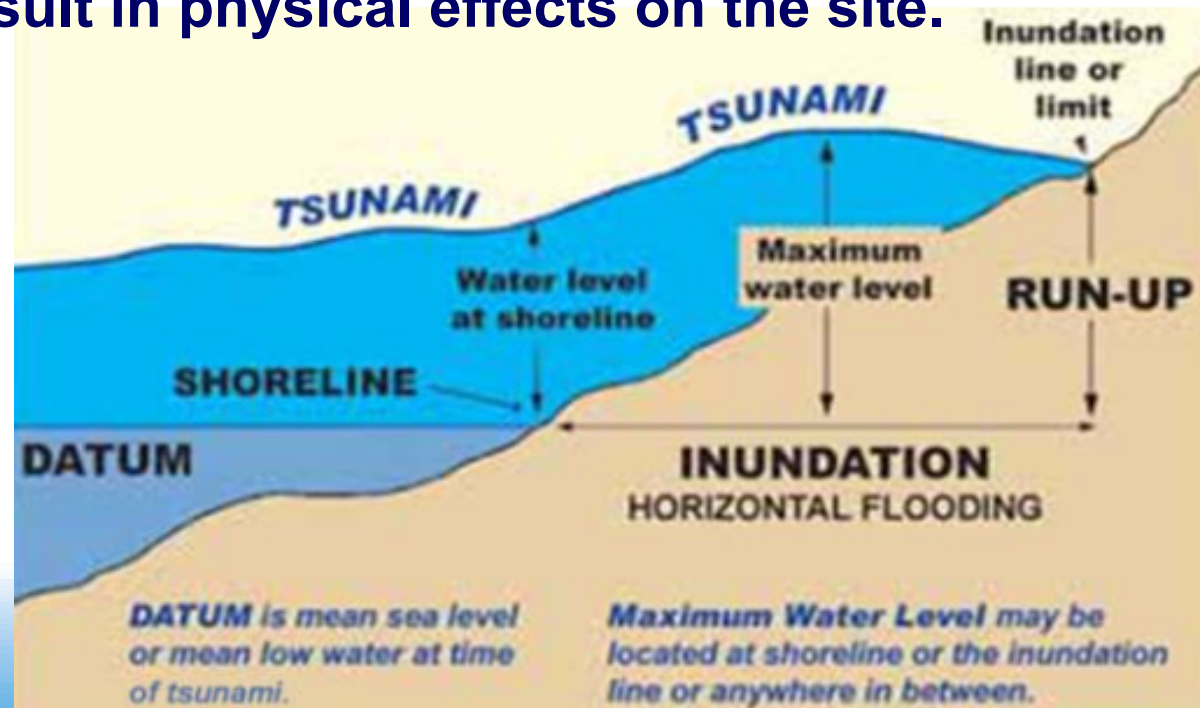
- **The potential for tsunamis or seiches that could affect the safety of a nuclear installation on the site shall be determined.**
- **The frequency of occurrence, magnitude and height of regional tsunamis or seiches shall be estimated and shall be used in determining the hazards associated with tsunamis or seiches.**
- **The potential for tsunamis or seiches to be generated by regional offshore seismic events shall be evaluated on the basis of known seismic records and seismotectonic characteristics.**

# Specific requirements for evaluation external events

## ■ Flooding

Water waves induced by earthquakes or other geological phenomena

- The hazards associated with tsunamis or seiches shall be derived from known seismic records and seismotectonic characteristics as well as from physical and/or analytical modelling. These include potential draw-down and runup that may result in physical effects on the site.



# Specific requirements for evaluation external events

## ■ Flooding

### Floods and waves caused by failure of water control structures

- Information relating to upstream water control structures shall be analysed to determine whether the nuclear installation would be able to withstand the effects resulting from the failure of one or more of the upstream structures.
- If a preliminary examination of the nuclear installation indicates that it might not be able to withstand safely all the effects of the massive failure of one or more of the upstream structures, then the hazards associated with the nuclear installation shall be assessed with the inclusion of all such effects.

# Specific requirements for evaluation external events

## ■ Flooding

### Floods and waves caused by failure of water control structures

- The possibility of storage of water as a result of the temporary blockage of rivers upstream or downstream (e.g. caused by landslides or ice) that can cause flooding and associated phenomena at the proposed site shall be examined.

# Specific requirements for evaluation external events

## ■ Geotechnical hazards

### Slope instability

- The potential for slope instability that could affect the safety of the nuclear installation shall be determined such as land and rock slides and snow avalanches.
- If there is found to be a potential for slope instability that could affect the safety of the nuclear installation, the hazard shall be evaluated by using parameters and values for the site specific ground motion.

# Specific requirements for evaluation external events

## ■ Geotechnical hazards

### **Collapse, subsidence or uplift of the site surface**

- **The potential for collapse, subsidence or uplift of the site surface shall be evaluated.**
- **Geological maps and other appropriate information for the region shall be examined for the existence of natural features such as caverns, karstic formations and human made features such as mines, water wells and oil wells.**
- **If there is found to be a potential that could affect the safety of the nuclear installation, practicable engineering solutions shall be provided or otherwise the site shall be deemed unsuitable.**
- **A detailed description of subsurface conditions obtained by reliable methods of investigation shall be developed for the purposes of determination of the hazards.**

# Specific requirements for evaluation external events

## ■ Geotechnical hazards

### Soil liquefaction

- The potential for liquefaction of the subsurface materials of the proposed site shall be evaluated by using parameters and values for the site specific ground motion using accepted methods of soil investigation and analytical methods to determine the hazards.
- If the potential for soil liquefaction is found to be unacceptable, the site shall be deemed unsuitable unless practicable engineering solutions are demonstrated to be available.



# Specific requirements for evaluation external events

## ■ Geotechnical hazards

### Behavior of foundation materials

- The geotechnical characteristics of the subsurface materials, including the uncertainties in them, shall be investigated and a soil profile for the site in a form suitable for design purposes shall be determined.
- The stability of the foundation material under static and seismic loading shall be assessed.
- The groundwater regime and the chemical properties of the groundwater shall be studied.

# Specific requirements for evaluation external events

## ■ Human induced events

### Aircraft crashes

- The potential for aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircraft.
- The hazards associated with an aircraft crash to be considered shall include impact, fire and explosions.
- If the assessment indicates that the hazards are unacceptable and if no practicable solutions are available, then the site shall be deemed unsuitable.

# Specific requirements for evaluation external events

## ■ Human induced events

### Chemical explosions

- **Activities in the region that involve the handling, processing, transport and storage of chemicals having a potential for explosions or for the production of gas clouds capable of deflagration or detonation shall be identified.**
- **Hazards associated with chemical explosions shall be expressed in terms of overpressure and toxicity, with account taken of the effect of distance.**
- **A site shall be considered unsuitable if such activities take place in its vicinity and there are no practicable solutions available.**

# Specific requirements for evaluation external events

## ■ Human induced events

### Other important human induced events

- The region shall be investigated for installations (including installations within the site boundary) in which flammable, explosive, toxic, corrosive or radioactive materials are stored, processed, transported and otherwise dealt with that could jeopardize the safety of the installation, if released under normal or accident conditions.
- This investigation shall also include installations that may give rise to missiles of any type that could affect the safety of the nuclear installation.

# Specific requirements for evaluation external events

## ■ Human induced events

### Other important human induced events

- The potential effects of electromagnetic interference, eddy currents in the ground and the clogging of air or water inlets by debris shall also be evaluated.
- If the effects of such phenomena and occurrences would produce an unacceptable hazard and if no practicable solution is available, the site shall be deemed unsuitable.

# Specific requirements for evaluation external events

## ■ Other important considerations

- **In the design of systems for long term heat removal from the core, site related parameters, such as the following, should be considered:**
  - ✓ (a) Air temperature and humidity;
  - ✓ (b) Water temperatures;
  - ✓ (c) Available flow of water, minimum water level and the period of time for which safety related sources of cooling water are at a minimum level, with account taken of the potential for failure of water control structures.

# Specific requirements for evaluation external events

## ■ Other important considerations

- **Potential natural and human induced events that could cause a loss of function of systems required for the long term removal of heat from the core shall be identified, such as the blockage or diversion of a river, the depletion of a reservoir, an excessive amount of marine organisms, the blockage of a reservoir or cooling tower by freezing or the formation of ice, ship collisions, oil spills and fires.**
- **If the probabilities and consequences of such events cannot be reduced to acceptable levels, then the hazards associated with such events shall be considered.**
- **If the hazards for the nuclear installation are unacceptable and no practicable solution is available, the site shall be deemed unsuitable.**

# Requirements for evaluation of the potential impacts of the nuclear installation

- **Atmospheric dispersion of the radioactive material**
  - **A meteorological description of the region shall be developed, including descriptions of the basic meteorological parameters, regional orography and phenomena such as wind speed and direction, air temperature, precipitation, humidity, atmospheric stability parameters, and prolonged inversions.**
  - **A programme for meteorological measurements shall be prepared and carried out at or near the site with the use of instrumentation capable of measuring and recording the main meteorological parameters at appropriate elevations and locations. Data from at least one full year shall be collected, together with any other relevant data that may be available from other sources.**



# Requirements for evaluation of the potential impacts of the nuclear installation

- **Atmospheric dispersion of the radioactive material**
  - On the basis of the data obtained from the investigation of the region, the atmospheric dispersion of radioactive material released shall be assessed with the use of appropriate models.
  - These models shall include all significant site specific and regional topographic features and characteristics of the installation that may affect atmospheric dispersion.

# Requirements for evaluation of the potential impacts of the nuclear installation

- **Dispersion of the radioactive material through surface water**
  - **Investigation and measurements of the surface hydrology shall be carried out to determine to the extent necessary the dilution and dispersion characteristics for water bodies, the re-concentration ability of sediments and biota, and the determination of transfer mechanisms of radionuclides in the hydrosphere and of exposure pathways.**
  - **The potential impact of the contamination of surface water on the population shall be analyzed by using the collected data and information in a suitable model.**

# Requirements for evaluation of the potential impacts of the nuclear installation

- **Dispersion of the radioactive material through groundwater**
  - **A description of the groundwater hydrology of the region shall be developed, with descriptions of the main characteristics of the water bearing formations, interaction with surface waters and data on the uses of groundwater in the region.**
  - **A program of hydrogeological investigations shall be carried out.**
    - ✓ This program should include investigations of the migration and retention characteristics of the soils, the dilution and dispersion characteristics of the aquifers, and the physical and physicochemical properties of underground materials, mainly related to transfer mechanisms of radionuclides in groundwater and their exposure pathways.

# Requirements for evaluation of the potential impacts of the nuclear installation

- **Dispersion of the radioactive material through groundwater**
  - **The potential impact of the contamination of groundwater on the population shall be analyzed by using the collected data and information in a suitable model.**

# Requirements for evaluation of the potential impacts of the nuclear installation

## ■ Population distribution

- The distribution of the population within the region shall be determined.
- In particular, information on existing and projected population distributions in the region, including resident populations and to the extent possible transient populations, shall be collected and kept up to date over the lifetime of the installation.
- The radius within which data are to be collected should be chosen on the basis of national practices, with account taken of special situations.

# Requirements for evaluation of the potential impacts of the nuclear installation

## ■ Population distribution

- Special attention shall be paid to the population living in the immediate vicinity of the installation, to densely populated areas and population centers in the region, and to residential institutions such as schools, hospitals and prisons.
- The data shall be analyzed to give the population distribution in terms of the direction and distance from the plant.
- An evaluation shall be performed of the potential radiological impacts of normal discharges and accidental releases of radioactive material, including reasonable consideration of releases due to severe accidents, with the use of site specific parameters as appropriate.

# Requirements for evaluation of the potential impacts of the nuclear installation

## ■ Uses of land and water in the region

- The uses of land and water shall be characterized in order to assess the potential effects of the nuclear installation in the region and particularly for the purposes of preparing emergency plans.
- The investigation should cover land and water bodies that may be used by the population or may serve as a habitat for organisms in the food chain.

# Requirements for evaluation of the potential impacts of the nuclear installation

## ■ Ambient radioactivity

- Before commissioning of the nuclear installation the ambient radioactivity of the atmosphere, hydrosphere, lithosphere and biota in the region shall be assessed so as to be able to determine the effects of the installation.
- The data obtained are intended for use as a baseline in future investigations.



## Monitoring of the hazards and the potential impacts

- **The characteristics of the natural and human induced hazards as well as the demographic, meteorological and hydrological conditions shall be monitored over the lifetime of the nuclear installation.**
- **This monitoring shall be commenced no later than the start of construction and shall be continued up until decommissioning.**
- **All the hazards, potential impacts and conditions that are pertinent to the licensing and safe operation of the installation shall be monitored.**