Western European
WENRA RHWG
Nuclear Regulators Association

Guidance Document

Issue TU: External Hazards

Guidance on External Flooding

Annex to the Guidance Head Document

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Introduction
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The purpose of this Guidance Document on External Flooding Events is to provide additional explanations specific to external flooding hazards. Flooding hazards that are addressed in this guide are mainly caused by natural events, but man-made structures or activities may contribute to the risk posed. The document forms an Annexe to the Guidance Head Document on External Hazards for the RLs of Issue TU and should be read in conjunction with this Guidance Head Document. It is further recommended that the chapters on design extension conditions are read in combination with the Reference Levels of issue F and the Guidance Document of Issue F. Precipitation is also addressed in the Guidance Document on extreme weather conditions.

This Guidance Document does not define any requirements in addition to those defined in the RLs of Issue TU, External Hazards.

01
Objective

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TU1.1 External hazards, comprising natural and external human induced hazards[1] shall be considered an integral part of the safety demonstration of the plant (including spent fuel storage). Threats from external hazards shall be removed or minimised as far as reasonably practicable for all operational plant states. The safety demonstration in relation to external hazards shall include assessments of the design basis and design extension conditions with the aim to identify needs and opportunities for improvement.

[1] Within these reference levels malicious acts are not considered.

No guidance needed in addition to the guidance provided for Reference Level TU1.1 in the Guidance Head Document on External Hazards.

02
Identification of External Hazards
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TU2.1 All external hazards that might affect the site shall be identified, including any related hazards (e.g. earthquake and tsunami, accidental aircraft crash with consequential aircraft fuel fire)[2]. Justification shall be provided that the compiled list of external hazards is complete and relevant to the site.

[2] Human induced external hazards originate from any kind of human activity outside the site area. In accordance with IAEA Safety Glossary the "site area" is defined as the geographical area that contains an authorized NPP. It is enclosed by a physical barrier to prevent unauthorized access, by means of which the management of the authorized facility can exercise direct authority.

See guidance to Reference Level TU2.2.

TU2.2 The list of external hazards from which identification as stated in TU2.1 is conducted shall at least include:

- **Geological hazards;**
- **Seismotectonic hazards;**
- **Meteorological hazards;**
- **Hydrological hazards;**
- **Biological phenomena;**
- **External fire;**
- **Accidental aircraft crash;**
- **Accidents at facilities outside the site area;**
- **Transportation accidents;**
- **Electrical disturbances and electromagnetic interferences.**

The identification of external flooding hazards, which includes but is not limited to hydrological and meteorological hazards, can be done by carrying out the following steps:

- Identify water sources that could cause or contribute to flooding at the site of an NPP. Contrary to some other external natural hazards, the nature of external flooding often allows for the identification of specific sources, such as reservoirs of water, which could contribute to the hazard depending on the phenomena acting on them. Such identification contributes to the understanding of the hazard and may increase the effectiveness of the protection concept;

- Determine potential phenomena and credible combinations of phenomena acting on each of the identified water sources;
- Identify causal dependencies of external events (not necessarily limited to flooding hazards) whose conjunction may extend the design basis parameters and/or impact on the installation.

Guidance on each of the steps is provided below.

As a starting point for the identification, the following list of potential sources of water should be considered:

- Sea or ocean
- Water courses (streams, rivers and canals including their hydrological catchment areas)
- Natural reservoirs such as lakes, snow and glaciers
- Human-made reservoirs such as artificial lakes, tanks, water towers and pipes (both off-site and on-site, but outside of the buildings)
- Clouds (as source of precipitation)
- Groundwater

The next step is to determine the phenomena that can act on the identified sources and thus contribute to the external flooding hazard for the site and its installations. The following non-exhaustive list based on Appendix 1 of Guidance Head Document on External Hazards may be considered:

- Tsunami (N7)
- Flooding due to local extreme rainfall - flash flood (N8 and N25 from meteorological phenomena)
- Water level rising caused by, for example, increased discharge from snow melt, glacier melt, or precipitation (grouping N9 and N10, as causes could act in combination)
- High groundwater levels (N11)
- Flood due to obstruction of a river channel (downstream or upstream) by landslides, ice, jams caused by logs or debris, or volcanic activity (N12)
- River diversion resulting from changes in a river channel due to erosion or sedimentation (N 13)
- Landslides, glacier failures or avalanches into water bodies (N14)
- Flood and waves caused by failure of water control structures and watercourse containment failure (dam failure, dyke failure) due to hydrological or seismic effects (N15). Failures also include deterioration, overloading or blockage, and water control structures also include structures such as tanks, water towers, water intakes, pipes and drainage systems[1]
- Seiche (N16)
- Bore (N17) corresponding to swelling of water in a channel due to a sudden change in the flow rate; the origin may be natural, for example a tidal bore, or artificial, as in the case of closure of a hydroelectric plant
- Seawater level, high tide, spring tide (N18)
- Seawater level, lake level or river: wind generated waves (N19)
- Seawater level, storm surge (N20)

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[1] These structures maybe located on-site and under control of the licensee. Nevertheless they are usually categorized under external flooding, rather than internal flooding. The reason is that the associated protection measures are often the same as those for other sources/phenomena that could lead to external flooding.

- Waterspouts (N42 - from meteorological phenomena)

It should be noted that for seawater level and wind generated waves, the impact of human made structures such as tide breaks and jetties (N21) may be significant.

Some phenomena identified as part of this hazard identification could lead to other adverse effects although they do not necessarily give rise to a hazardous external flood. This could for instance include:

- Corrosion from salt water (N22)
- Sedimentation and erosion that can cause instability of the coastal area, both for sea and river (N23)
- Loss of soil stability
- Fouling and blockage of intakes by debris (floating or underwater - N24) potentially leading to a loss of ultimate heat sink
- Loss of off-site external electrical supplies due to flooding (e.g. direct flooding of connecting equipment on the grid, in the vicinity of the plant, or collapse of electrical towers or lines due to storm conditions)
- Limited accessibility or inaccessibility of the site due to flooding

03
Site Specific External Hazard Screening and Assessment

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TU3.1 External hazards identified as potentially affecting the site can be screened out on the basis of being incapable of posing a physical threat or being extremely unlikely with a high degree of confidence. Care shall be taken not to exclude hazards which in combination with other hazards[3] have the potential to pose a threat to the facility. The screening process shall be based on conservative assumptions. The arguments in support of the screening process shall be justified.

[3] This could include other natural hazards, internal hazards or human induced hazards. Consequential hazards and causally linked hazards shall be considered, as well as random combinations of relatively frequent hazards.

Some phenomena cannot physically occur at a specific site and credit should be taken of this. Screening of external flooding hazards often starts from the location of the site, typically near a river, in a coastal area or both. Typical examples of screened out phenomena could be:

- Flooding caused by failure of a dam for a site not located downstream of such structures (however, the possibility of an upstream blockage and subsequent failure of the blockage should not be screened out)
- Flooding caused by a tsunami for a site located at a sufficiently large distance from oceans, seas and large water bodies
- Springtides for non-coastal sites located at a sufficiently large inland distance

Note, “sufficiently” should be demonstrated through the use of a justified argument.

For external flooding, the screening should generally focus on determining the physical possibility that a phenomenon can occur at or near the site rather than the physical threat that it poses. More frequently occurring phenomena such as springtide, seasonal river flooding, etc. should not pose threats to a plant by themselves, but, given their more frequent occurrence, they may well contribute to the overall level of a hazard by being coincident with extremes of other phenomena. Such phenomena should be identified, kept during the screening process and included in the site specific hazard assessment, if such a combination is credible.

TU3.2 For all external hazards that have not been screened out, hazard assessments shall be performed using deterministic and, as far as practicable, probabilistic methods taking into account the current state of science and technology. This shall take into account all relevant available data, and produce a relationship between the hazards severity (e.g. magnitude and duration) and exceedance frequency, where practicable. The maximum credible hazard severity shall be determined where this is practicable.

No guidance is needed in addition to the guidance provided for RL TU3.2 in the Guidance Head Document on External Hazards. Also [1] and [2] may be consulted for additional guidance.

TU3.3 The following shall apply to hazard assessments:

- **The hazard assessment shall be based on all relevant site and regional data. Particular attention shall be given to extending the data available to include events beyond recorded and historical data.**
- **Special consideration shall be given to hazards whose severity changes during the expected lifetime of the plant.**
- **The methods and assumptions used shall be justified. Uncertainties affecting the results of the hazard assessments shall be evaluated.**

The severity of a flood - or the underlying phenomena, can typically be expressed in terms of water height, rainfall intensity, duration, wave height, water pressure, flow rate etc.

Relevant site and regional data

The site specific hazard assessment requires several forms of data and [1] provides an extensive overview of data that should be considered as input data. Two kinds of data should be gathered:

- The characterisation of a specific phenomenon in terms of the annual frequency of exceedance and its severity (e.g. rainfall frequency and intensities, storm frequency and severity, etc.)
- The effect of the phenomena on the site and its contribution to the flooding hazard (e.g. the local topography, human activities influencing the local flooding hazard)

The effect of the phenomena on the site and its contribution to the flooding hazard usually requires bathymetric, geological and geographical data including the topography of the relevant area with sufficient detail and aims at characterising the movement of water to and from the site. Note that this part of the assessment may be complicated when combining different phenomena and when non-linear effects are relevant. For instance, a relationship between the discharge flow rate and the water level in the river will usually not be linear and depend on details such as the shape of the riverbed, its inclination, topography, etc.

The data required for the characterisation of a specific phenomenon may include:

- Measurements for most phenomena (e.g. rainfall, river/sea levels)
- Technical data; for instance the (assumed) failure rates of dams, dykes or levees
- Historical records
- Geological data for instance to assess faults and volcanoes as sources for the formation of dams, dam failure, tsunamis, stability of slopes for landslides into water bodies, likely course alteration of rivers and channels
- Geological (stratigraphy) data which may indicate the occurrence of past flooding episodes (e.g., tsunami deposits)

The area over which data is obtained should be sufficiently large to include all relevant sources of hazards to the site. This could for instance range from a nearby localised area for historical records and data of a river level to seismic characterisation of faults at large distances from the site.

Relevant measured data for flooding events is typically only available for approximately 100 years. Nevertheless, to achieve a relationship between severity and frequency, appropriate statistical models should be used as far as possible for the extrapolation up to 10^{-4}/y (exceedance frequency for the design basis flood (DBF)) and beyond (for DEC analysis). Relevant other sources of information to the extent available such as historical data (including anecdotal 'evidence') and geological data should be used to support such extrapolations.

The large variety of data necessitates the use of different sources of expertise. For example:

- Meteorologists or meteorological institutes could provide measurement records and interpretation for rainfall, wind and storm
- Hydrologists or hydrological institutes could provide measurement records and interpretation for river flow rates, storm surge, seiches and tides
- Geologist or geological institutes could provide data on earthquakes with oceanographers providing information on subsequent tsunamis
- Engineers could provide data on the failure rates of dams, dykes or levees

Hazards whose severity changes

For the external flooding hazard assessment several potential causes (see [1]) of non-stationary behaviour should be considered. This should include:

- Climate change which
  - generally increases the mean sea level
  - may affect the frequency and intensity of meteorological phenomena
  - may affect river water flow rates
- Physical geography changes such as:
  - Deforestation or other changes of land use which may change the retention potential
  - Changes in the management of waterways or coastal defences against storm surge
  - Natural changes in waterways (e.g. river course alteration due to erosion)
  - Land subsidence due to gas or oil extraction or other sub-surface activities
  - Other human-induced changes in waterways and/or reservoirs of water

Uncertainties affecting the results

For the external flooding hazards assessment, as part of the treatment of uncertainties, consideration should be given to performing a sensitivity analysis aimed at identifying parameters that have a large influence on the outcome. Such parameters may subsequently be subjected to further validation of their representativeness or be set to a conservative value. To allow for limitations in the quantity and reliability of available data, uncertainties inherent to the current state of knowledge (modelling etc.) and future climate and environmental changes, the hazard assessment should be based on conservative hypothesis.

04
Definition of Design Basis Events for External Hazards

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TU4.1 Design basis events[4] shall be defined based on the site specific hazard assessment.

[4] These design basis events are individual external hazards or credible combinations of hazards (causally or non-causally linked). The design basis may either be the original design basis of the plant (when it was commissioned) or a reviewed design basis for example following a PSR.

A DBF should be defined after considering individual events, causally linked events and credible combinations of several events depending on their occurrence frequency and/or duration, taking into consideration:

- Severe and infrequent event (e.g. severe rainfall, tsunami, dam failure, severe storm);
- Causally connected events (e.g. wind generated waves with severe storm surge, run-off and/or high river level with severe rainfall)
- Non-causally connected but frequent events (e.g. springtide, annual high river levels, annual rainfall, wind waves[2]), only if such a combination is credible
- Non-causally connected, less-frequent but long-lasting events

Multiple DBF events or combinations of events may need to be defined depending on how the different design basis parameters are related to the different phenomena. For instance, a DBF event or combination of events in which high ground water levels cause the ingress of water in a basement may need to be treated separately from a DBF event or combinations of events in which the effects of dynamic pressures and debris loading on exterior walls are caused by the overflowing of a river.

TU4.2 The exceedance frequencies of design basis events shall be low enough to ensure a high degree of protection with respect to external hazards. An exceedance frequency, not higher than 10^{-4} per annum[5], shall be used for the design basis events. Where it is not possible to calculate these frequencies with an acceptable degree of certainty, an event shall be chosen and justified to reach an equivalent level of safety.

For the specific case of seismic loading, as a minimum, a horizontal peak ground acceleration value of 0.1 g (where 'g' is the acceleration due to gravity) shall be applied, even if its exceedance frequency would be below 10^{-4} per annum.

[2] Wind waves are present twice in this list as an example of a phenomenon that can be either causally or non-causally connected to the severe and infrequent event.

For accidental airplane crashes and explosion blast waves a design basis event shall be defined to ensure a minimum protection of the plant.

[5] According to the current practices, several WENRA countries require a value lower than 10^{-4} per annum for human induced and some also for natural hazards.

Relevant guidance on RL TU4.2 is also provided in the Guidance Head Document on External Hazards.

When it is not possible to reach an exceedance frequency of 10^{-4} per year with an acceptable degree of certainty, an event should be chosen to reach an equivalent level of safety. This event could be, for example, a combination of events, causally or non-causally linked or an increase of the design basis parameters (see RL T4.4).

TU4.3 The design basis events for natural hazards shall be compared to relevant historical data to verify that historical extreme events are enveloped by the design basis with a sufficient margin.

No guidance is needed.

TU4.4 Design basis parameters shall be defined for each design basis event taking due consideration of the results of the hazard assessments. The design basis parameter values shall be developed on a conservative basis.

The characterisation of the phenomena, i.e. their physical severity (e.g. volume, height, rate of flow, duration) and, where appropriate, the accompanying frequency of exceedance, should be used to derive the appropriate design basis parameters of the DBF which should primarily be expressed in terms of:

- Water level (or flow rate)
- Wave height if relevant (tsunami, wind-waves…)
- Static and dynamic pressures (including hydrostatic uplifting forces)
- Duration of the event
- Additional loads due to debris and wave run-up

To allow the development of the protection concept, the DBF scenario should be accompanied by information on:

- Flood extent (i.e. including the surroundings of the site)
- Available warning time (for the surrounding area and the nuclear installation in particular)
- Site accessibility
- Associated conditions (lightning, high wind, earthquake…)

05
Protection Against Design Basis Events

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TU5.1 Protection shall be provided for design basis events.[6] A protection concept[7] shall be established to provide a basis for the design of suitable protection measures.

[6] If the hazard levels of RL TU4.2 for seismic hazards were not used for the initial design basis of the plant and if it is not reasonably practicable to ensure a level of protection equivalent to a reviewed design basis, methods such as those mentioned in IAEA NS-G-2.13 may be used. This shall quantify the seismic capacity of the plant, according to its actual condition, and demonstrate the plant is protected against the seismic hazard established in RL TU4.2. A comparable approach may be used for demonstrating the minimum protection against aircraft crashes and explosion blast waves.

[7] A protection concept, as meant here, describes the overall strategy followed to cope with external hazards. It shall encompass the protection against design basis events, events exceeding the design basis and the links to EOPs and SAMGs.

In order to establish a protection concept, the SSCs that have to be protected should be defined for design basis events (TU5) and events more severe than the design basis events (TU6). These SSCs are called 'SSCs required by the protection concept' in this guidance.[3]

Potential effects of an external flood that should be prevented or controlled by the protection concept include:

- Instability of structures due to erosion or buoyancy effects due to elevated groundwater levels;
- Water ingress resulting from external flooding in buildings/rooms/shafts/openings housing or giving access to SSCs required by the protection concept and resulting in (partial) submersion of equipment and their subsequent failure

[3] Some but not all SSCs important to safety may be necessary to fulfil the fundamental safety functions depending on the hazards postulated. For a specific hazard:
- Some SSCs important to safety are needed to perform their safety function,
- Some SSCs important to safety may be needed to protect the aforementioned, and
- Some SSCs important to safety do not play a role in coping with the hazard.

For example, it is likely that emergency power generators will be needed to cope with some hazards affecting the plant. These generators will have to be protected against flooding hazards. In addition, they will need to be located in a building resistant to flooding hazards. Therefore both the emergency power generators and the building will be required by the protection concept.

Another example is the containment (reactor building) which is both necessary for the confinement function and protecting equipment located in the containment. Both of these functions are required by the protection concept.

- Dynamic effects affecting the availability of equipment and structural integrity of buildings, for example, the erosion of embankments, banks and dykes, changes in the turbidity of the water and loading due to debris
- Impact of the flood on support functions, such as external electrical supplies, water intake, telecommunications, etc.
- Impact of the flood on site access and on-site transport of personnel and equipment;
- Effects on the availability of protective measures by the flood itself or due to correlated phenomena (such as lightning, high wind, earthquake).

[1] and [3] provide further guidance on the development of the protection concept such as:

- Sufficiently high elevation of site, individual SSCs required by the protection concept and/or of entrances and other openings through which water may enter. It should be noted that heavy rainfall could lead to a layer of standing water on the site
- Dedicated structures for protection such as dams, dykes and levees
- Water drainage systems
- Appropriate material selection to counter the erosive effects of water
- Appropriate layout of the facility and the SSCs required by the protection concept and placing SSCs required by the protection concept at sufficient elevation when possible
- Waterproof buildings housing SSCs required by the protection concept
- Waterproof rooms housing SSCs required by the protection concept
- Waterproof or leak tight SSCs required by the protection concept
- Specific building structures as parapets

TU5.2 The protection concept shall be of sufficient reliability that the fundamental safety functions are conservatively ensured for any direct and credible indirect effects of the design basis event.

As part of the demonstration of the reliability of the protection concept, it is beneficial to identify the critical SSCs required by the protection concept and their protection measures, the failure of which would cause a rapid decrease in the level of safety (e.g. a dam board preventing water damaging multiple SSCs). Provisions to strengthen the protection concept for such cases should be evaluated.

TU5.3 The protection concept for external hazards shall:

a) apply conservatism to provide safety margins in the design;

b) rely primarily on passive measures as far as reasonably practicable;

c) ensure that sufficient measures to cope with a design basis accident remain effective during and following a design basis event as defined in TU4.2;

d) take into account the predictability and development of the event over time;

e) ensure that procedures and means are available to verify the plant condition during and following design basis events;

f) consider that events could simultaneously challenge several redundant or diverse trains of a safety system, multiple SSCs or several units at multi-unit sites, site and regional infrastructure, external supplies and other countermeasures;

g) ensure that sufficient resources remain available at multi-unit sites considering the use of common equipment or services;

h) not inadmissiby affect the protection against other design basis events (not originating from external hazards).

The use of several (as far as practicable) independent lines of defence with priority given to permanent measures according to the following hierarchy is seen as good practice:

- If the installation is located on a level below the DBF level a permanent external barrier, preferably passive, should be provided for site protection. Attention should be given to the possibility of bypassing (passages built into dykes, exhaust lines, potential failures of barriers etc.).
- The installation should be designed such that any ingress of water into the buildings, notably the rooms housing SSCs required by the protection concept, is prevented. Attention should be paid to all openings allowing water to enter a building (galleries, shafts, pipes, spaces between buildings, etc.). Preference should be given to passive measures to seal these by-passes to the buildings or rooms.
- If the ingress of water into rooms housing SSCs required by the protection concept cannot be excluded, then these SSCs should be protected from flooding (raised in order to be kept dry, or protected with a wall, etc.).
- In general, preference should be given to using (passive) measures that do not require any human intervention or energy supply (the external electricity supply to the site could be lost). The choice for, and design of measures requiring human intervention or an energy supply should take into account the possibility of anticipating the flooding events and their kinetics. Temporary measures should only be used to augment permanent protection and should only be claimed as part of the protection concept when there is sufficient warning time to install them.

It should be noted that this hierarchy may depend on the phenomena involved, for instance: protecting the plant by external barriers may not be an effective measure against extreme local precipitation and could give rise to adverse effects.

If certain protective measures or other relevant structures are not under the full control of the licensee, for instance a dyke or a dam, then the responsible organisation should be identified as well as their exact responsibilities. The means and scope of potential interaction between this organisation and licensee should be defined and proper arrangements between the different parties should be made.

The protection concept should also include administrative and other measures besides permanent measures most notably when the protection of the plant benefits from pre-planned human interventions. Such measures should include:

- Early warning systems, e.g. upstream monitoring stations, weather forecasting or for tsunamis; (including formalized arrangements with external parties like national or regional meteorological institutes)
- The specification of pre-planned plant control actions linked to flood conditions
- Detection systems, e.g. in order to detect any abnormal presence of water in (specific spaces in) the facility
- Monitoring systems and procedures in order to monitor the evolution of the situation on site, e.g. the level of the sea/river, including procedures to anticipate the impact of the flood on site access and on-site transport of personnel and equipment

Where the protection concept relies on temporary flood protection equipment, the availability and maintenance should be ensured and operating instructions for executing the measures should be developed. Any monitoring system should be capable of measuring events which are larger than the DBF scenario. When other parties are involved (e.g. meteorological institutes or water authorities) the arrangements and procedures should be clear and ensured.

The site layout should allow performance of the actions necessary to maintain the safety of the facilities and manage the situation in the case of flooding. Consideration should be given to **access** to the installations, movement on the site, etc.

Depending on the extent of the actual flooding, dedicated inspections should be carried out during and after the event to determine the state of SSCs important to safety in contact with the water, taking into account secondary effects such as salt corrosion.

It should be recognized especially for plants with a dry site that heavy rainfall could lead to a standing layer of water on the site. The credible blockage of the drainage system due to floating debris should be considered. In these cases, buildings - in particular their basements - where SSCs required by the protection concept are located should be sufficiently water tight.

The protection concept should also take account of the adverse effects of flooding in the region surrounding the site. Countermeasures for such effects could for example be:

- Multiple access roads, helipads and/or transport by boats
- On-site storage of sufficiently large stocks of critical resources and equipment for all facilities on a suitable on-site location with respect to the anticipated flooding
- Dedicated facilities, resources and procedures allowing personnel to remain at their post for longer than usual time spans (notwithstanding the need for arrangements to replace personnel in a timely manner)
- For predictable hazards, preventive actions and procedures in order to supply the site with sufficient resources and equipment

TU5.4 For design basis events, SSCs identified as part of the protection concept with respect to external hazards shall be considered as important to safety.

No guidance is needed in addition to the guidance provided for RL TU5.4 in the Guidance Head Document on External Hazards.

TU5.5 Where appropriate, monitoring and alert processes shall be part of the protection concept to cope with external hazards and thresholds (intervention values) shall be defined to facilitate the timely initiation of protection measures. In addition, thresholds shall be identified to initiate the execution of pre-planned post-event actions (e.g. inspections).

No guidance is needed in addition to the guidance provided for RL TU5.5 in the Guidance Head Document on External Hazards, and in TU5.3 of this document.

06
Considerations for Events more severe than the Design Basis Events

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TU6.1 Events that are more severe than the design basis events shall be identified as part of DEC analysis. Their selection shall be justified.[8] Further detailed analysis of an event will not be necessary, if it is shown that its occurrence can be considered with a high degree of confidence to be extremely unlikely.

[8] See issue F section 2.

The identification of design extension conditions (DEC) related to external flooding should rely both on simulations and walk downs and aims to determine the site-specific potential for an increased flood severity and the consequences of an increased flood severity:

- Effects of elevated flood heights can be determined by review of the detailed "as-is" design of the installation, updated and detailed topographical maps of the site and local surroundings, and a plant walk down. The results should provide insight firstly in the areas and then in the systems or components that may be affected depending on the postulated increased water level, identifying which fundamental safety functions are lost. In this analysis, simplified and conservative approaches should be preferred as it is generally not possible to precisely define the flood height at a specific location, or the precise failure conditions of equipment.
- The effects of an increased duration of events should be considered. This assessment should include technical aspects such as the effects on SSCs required by the protection concept (e.g. increased erosion) as well as the impact on administrative measures.
- Effects of elevated static and dynamic pressures in combination with loads by debris should be estimated using relevant good practice, including codes where available s and information on construction and material. A walk down could be carried out to identify critical areas/structures and to confirm the state of the construction. The results should provide insight into the effect of increased loading on the structures.
- The effect of extreme groundwater levels, notably elevated levels that could lead to additional buoyancy effects, should be considered.

One approach could be to define a set of flooding scenarios -not unrealistic - that significantly exceed DBF parameters (in terms of severity/probability) and to verify that fundamental safety functions are still maintained.

The assessment should also be used to gain insight in the extent of the flooding in the region of the site and the resulting availability of licensee's resources and, where appropriate, other relevant off-site resources.

TU6.2 To support identification of events and assessment of their effects, the hazards severity as a function of exceedance frequency or other parameters related to the event shall be developed, when practicable.

No guidance is needed.

TU6.3 When assessing the effects of external hazards included in the DEC analysis, and identifying reasonably practicable improvements related to such events, analysis shall, as far as practicable, include:

a) demonstration of sufficient margins to avoid "cliff-edge effects" that would result in unacceptable consequences;

b) identification and assessment of the most resilient means for ensuring the fundamental safety functions;

c) consideration that events could simultaneously challenge several redundant or diverse trains of a safety system, multiple SSCs or several units at multi-unit sites, site and regional infrastructure, external supplies and other countermeasures;

d) demonstration that sufficient resources remain available at multi-unit sites considering the use of common equipment or services;

e) on-site verification (typically by walk-down methods).

The definition of critical water levels necessary for identification and assessment of the most resilient means should be supported by identification of flooding paths (near the site, on-site and in the buildings).

07
Review of the Site Specific Hazards

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The principle of continuous improvement of nuclear safety applies to the issue of external hazards [see RL A2.3]. The site specific hazards and the protection concepts against external hazards should be reviewed at least as part of the PSR [see RL P2.1 and P2.2] according to the advances of science and technology, and new information. This guidance provides further, specific guidance for the treatment of flooding hazards in such reviews.

Attention should be given to changes to the site and its surroundings such as physical geography changes as well as to climatic change and other human-made changes. The consequences of such changes on the characteristics of the potential flood situations throughout the life of the plant should be assessed. The review of the site specific flooding hazard should include:

- The evaluation of new knowledge on the flooding hazard, due to new data or new assessment methods and models
- The evaluation of recent experience from flooding events, particularly those with impact to nuclear power plants worldwide and those close to the site
- The assessment of the condition of SSCs required by the protection concept with particular focus on their compatibility with the design requirements

References

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[2] IAEA, 2019. Site Evaluation for Nuclear Installations, Specific Safety Requirements No. SSR-1, Vienna

[3] IAEA, 2004. Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants, Safety Standards Series No. NS-G-3-6, Vienna.