CODE NO. AERB/NF/SC/S (Rev.1)

GODE NO. AERB/NF/SC/S (Rev.1)

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GOVERNMENT OF INDIA

AERB SAFETY CODE

SITE EVALUATION
OF
NUCLEAR FACILITIES

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY CODE NO. AERB/NF/SC/S (Rev.1)

SITE EVALUATION

OF

NUCLEAR FACILITIES

Approved by the Board in July 2014

Atomic Energy Regulatory Board
Mumbai-400 094
India

July 2014

Price:

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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the relevant provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of occupational workers and members of the public, as well as protection of environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety codes, safety standards and related guides and manuals for the purpose. While some of the documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific systems, structures, equipment and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by Advisory Committees of the Board before they are published. The documents are revised when necessary, in the light of experience and feedback from users as well as new developments in the field.

AERB issued a safety code titled ‘Code of Practice on Safety in Nuclear Power Plant Siting’ (AERB/SC/S) in 1990, to spell out the requirements to be met during siting of nuclear power plants in India for assuring safety. The present safety code is revised to reflect developments, which have taken place since then. Specially, provisions of this code are extended to nuclear facilities other than nuclear power plants. In drafting the Code, the relevant International Atomic Energy Agency (IAEA) documents under the Nuclear Safety Standards (NUSS) program, especially IAEA Safety Standard Series No. NS-R-3 (2003) on ‘Site Evaluation for Nuclear Facilities: Safety Requirements’ have been used extensively.

The revised code supersedes the earlier version and applies to nuclear facilities to be built after the issue of the document. However during periodic safety review, a review for applicability of current code for existing facilities would be performed.

Appendices are an integral part of the document, whereas Annexures and bibliography are included to provide further information on the subject that might be helpful to the user.

Non-radiological aspects such as industrial safety and environmental protection are not explicitly considered in this code. Industrial safety shall be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996 and the environmental safety through provisions of the Environmental Protection Act, 1986.

A working group consisting of AERB staff and other professionals experienced in this field has prepared this revised code. Experts have reviewed the code and the relevant AERB Advisory Committee and Advisory Committee on Nuclear Safety have further reviewed it before issue.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

(S. S. Bajaj)
Chairman, AERB

DEFINITIONS

Acceptable Limits

Limits acceptable to the regulatory body for accident condition or potential exposure.

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

Competent Authority

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the rules promulgated under the Atomic Energy Act, 1962.

Construction

The process of manufacturing, testing and assembling the components of a nuclear or radiation facility, the erection of civil works and structures, the installation of components and equipment and the performance of associated tests.

Design Basis External Events (DBEEs)

The parameter values associated with, and characterising, an external event (e.g. missile impact, chemical explosion in the vicinity, etc.) or combinations of external events selected for design of all or any part of a nuclear facility.

Design Basis Flood (DBF)

The flood selected for deriving a design basis for a nuclear facility.

Design Basis Natural Events

Natural events (like storm, flood, etc.) selected for deriving design basis for a nuclear facility.

Deterministic Method

A method for which most of the parameters and their values are mathematically definable and may be explained by physical relationships and are not dependent on random statistical events.

Exclusion Zone

An area extending upto a specified distance around the plant, where no public habitation is permitted. This zone is physically isolated from outside areas by plant fencing and is under the control of the plant management.

Hazard

Situation or source, which is potentially dangerous for human, society and/or the environment.

Liquefaction (of Soil)

Sudden loss of shear strength and rigidity of saturated and cohesionless soils due to vibratory ground motion.

Nuclear Power Plant (NPP)

A nuclear reactor or a group of reactors together with all the associated structures, systems, equipment and components necessary for safe generation of electricity.

Operating Basis Earthquake (OBE)

An earthquake which, considering the regional and local geology and seismology and specific characteristics of local sub-surface material, could reasonably be expected to affect the plant site during the operating life of the plant. The features of a nuclear power plant necessary for continued safe operation are designed to remain functional, during and after the vibratory ground motion caused by the earthquake.

Operation

All activities following and prior to commissioning performed to achieve, in a safe manner, the purpose for which a nuclear/radiation facility is constructed, including maintenance.

Postulated Initiating Events (PIEs)

Identified events during design that lead to anticipated operational occurrences or accident conditions, and their consequential failure effects.

Potential

A possibility worthy of further consideration for safety.

Prescribed Limits

Limits established or accepted by the regulatory body.

Probable Maximum Flood (PMF)

The postulated flood (characterised by peak flow, volume and hydrograph shape) that is considered to be most severe but reasonably possible, corresponding to the probable maximum precipitation.

Probable Maximum Precipitation (PMP)

The estimated depth of precipitation for a given duration, drainage area and time of year of which there is virtually no risk of exceeding. The probable maximum precipitation for a given duration and drainage area approaches and approximates to that maximum which is thought to be physically possible within the limits of contemporary hydro-meteorological knowledge and techniques.

Region

A geological area, surrounding and including the site, sufficiently large to contain all the features related to a phenomenon or to the effects of a particular event.

Residual Heat

The sum of the time-dependent heat loads originating from radioactive decay and shutdown fission and heat stored in reactor-related structures and heat transport media in a nuclear reactor facility.

Responsible Organisation

An organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

Run-up

The rush of water up a structure or beach on the breaking of a wave. The height of run-up is the vertical height above still water level that the rush of water reaches.

Safe Shutdown Earthquake (SSE)

The earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology, seismology and specific characteristics of the local sub-surface material. It is that earthquake which produces the maximum vibratory ground motion for which certain structures, systems and components are designed to remain functional. These structures, systems and components are those which are necessary to assure:

(i) the integrity of the reactor coolant pressure boundary; or

(ii) the capability to shutdown the reactor and maintain it in a safe shutdown condition; or

(iii) the capability to prevent the accident or to mitigate the consequences of accidents which could result in potential off-site exposures higher than the limits specified by the regulatory body; or

(iv) the capacity to remove residual heat.

Safety/Nuclear Safety

The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the public and the environment from undue radiation hazards.

Safety Limits

Limits upon process variables within which the operation of the facility has been shown to be safe.

Site

The area containing the facility defined by a boundary and under effective control of the facility management.

Siting

The process of selecting a suitable site for a facility including appropriate assessment and definition of the related design bases.

Storm

Violent disturbance of the atmosphere marked by wind and usually by rain, snow, hail, sleet or thunder and lightning.

Tsunami

A wave train produced by impulsive disturbances in a body of water caused by displacements associated with submarine earthquakes, volcanic eruptions, submarine slumps or shoreline slides.

Ultimate Heat Sink

The atmosphere or a body of water or the ground water to which a part or all of the residual heat is transferred during normal operation, anticipated operational occurrences or accident conditions.

SPECIAL DEFINITIONS
(Specific for the Present Code)

Active Fault

Fault is considered active if the following conditions apply:

(a) If it shows evidence of past movement or movements of a recurring nature within such a period that it is reasonable to conclude that further movements may 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 (e.g. Upper Pleistocene-Holocene, i.e. the present) may be appropriate for the assessment of active faults. In less active areas, it is likely that much longer periods (e.g. Pliocene-Quaternary, i.e. the present) are appropriate.

(b) If a structural relationship with a known active fault has been demonstrated such that movement of one fault may cause movement of the other.

Design Basis External Human-Induced Events

External human-induced events selected for deriving design bases.

Design Extension Conditions

Accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits. Design extension conditions could include severe accident conditions.

Epicentre

The geographical point on the surface of earth vertically above the focus of the earthquake.

External event

Events unconnected with the operation of a facility or the conduct of an activity that could have an effect on the safety of the facility or activity.
(Typical examples of external events for nuclear facilities include earthquakes, tornadoes, tsunamis and aircraft crashes.)

Fault

A fracture or fracture zone along which displacement of the two sides relative to one another has occurred parallel to the fracture.

High Flood Level

Highest possible water level in rivers, streams, etc. which is derived from the historical data on the basis of maximum precipitation, hydrological aspects and flood run off characteristics of the catchment areas.

Karstic Phenomena

Formation of sinks or caverns in soluble rocks by the action of water.

Probable Maximum Tropical Cyclone (PMTC)

The hypothetical tropical cyclone, characterised as a rapidly revolving storm having that combination of characteristics which will make it the most severe, from the point of view of flooding, that can reasonably be expected to occur in the region involved, and which approaches the point under study along the critical path and at a rate of movement that will result in the most adverse flooding.

Probable Maximum Storm Surge (PMSS)

The hypothetical storm surge generated by PMTC and associated phenomena.

Probabilistic Approach

Probabilistic approach or probabilistic hazard assessment as used in the context of external events is the method that uses probabilistic description of all involved phenomena to determine the frequency of exceedance of the parameter under consideration.

Relevant Bodies of Water

All streams, rivers, artificial or natural lakes, ravines, marshes, drainage systems and sewer systems that may produce or affect flooding on or adjacent to the nuclear facility. Bodies of water located outside the watershed in which the plant is located, but which may, by overflowing the watershed divide, produce or affect flooding of the plant are also considered relevant bodies of water.

Screening Distance Value (SDV)

The distance from a facility beyond which, for screening purposes, potential sources of a particular type of external event can be ignored.

Screening Probability Level (SPL)

A value of annual probability of occurrence of a particular type of event below which, for screening purposes, such an event can be ignored.

Seismically Active Structure

A structure or a fault which exhibits seismicity at a level which indicates significant coherent activity on the structure or fault, regardless of whether or not geologically young movement (Quarternary) on it can be demonstrated at the earth's surface.

Seismotectonic Province

A geographic area characterised by similarity of geological structure and earthquake characteristics.

Tropical Cyclone

A tropical cyclone consists of a rotating mass of warm humid air, with up to several hundreds of kilometers in diameter. The pressure is lowest near the centre and could be well below atmospheric pressure in a well developed tropical cyclone.

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1. INTRODUCTION

1.1 General

(i) Nuclear facilities, like any other industrial installations, are generally sited taking into account the economics, engineering and technical feasibility, availability of water, transport, labor and other factors. Safety is an important factor that shall be comprehensively dealt with in siting of nuclear facilities. The objective shall be to ensure protection of the plant personnel, public and the environment from the harmful effects of ionising radiation, both during normal operation of the facility as well as during and following postulated accident scenarios.

(ii) Safety of nuclear facilities is achieved through a combination of means, among which the selection of an appropriate site warrants utmost attention and careful review. Process to accomplish this involves evaluation of those site related factors that have to be taken into account to ensure that the combination of site and nuclear facilities does not constitute an unacceptable risk to the public and environment over the life time of the facilities including their decommissioning. This essentially calls for evaluation of site with respect to three basic aspects: impact of site on the facility, impact of facility on the public and the environment and feasibility of implementation of emergency management plan in public domain, if needed.

(iii) This safety code establishes requirements for evaluation of a site proposed for setting up a nuclear facility from the safety standpoint. The safety guides pertaining to siting series provide guidance for meeting the requirements of this code.

1.2 Objective

(i) The objective of this safety code is to establish the safety requirements for site evaluation of a nuclear facility. These include:

- (a) Defining extent of information on proposed site to be presented by the applicant.
- (b) Defining site related hazards.
- (c) Evaluating the proposed site to ensure that the site characteristics and related phenomena are adequately taken into account.

(d) Assessment of the impact of facility on public and environment during normal operation and postulated accident conditions.

(e) Collection of demographic data and data on biota in the region.

(f) Assessment of the capability for implementing emergency plans in public domain over the projected lifetime of the facility.

1.3 Scope

(i) The siting process for nuclear facilities generally consists of an investigation of a large region to select one or more candidate sites (site selection), followed by site evaluation (Fig. 1). This safety code pertains to the requirements of the latter stage.

(ii) Previous version of this code was related to land based stationary thermal reactor nuclear power plants (NPP). Scope of this safety code has been extended to cover a more comprehensive range of land based nuclear facilities: nuclear power plants and research reactors, as well as nuclear fuel cycle facilities, including but not limited to enrichment plants, processing plants, independent spent fuel storage facilities, independent waste management plants and vitrified waste storage facilities and reprocessing plants. The facilities for short term near surface storage of solid/solidified radioactive waste as well as near surface disposal facilities are within the scope of this code. However, facilities for ultimate disposal of high active waste are beyond the scope of this code.

(iii) This code prescribes requirements on considerations during site evaluation for limiting the radiological impact. In some instances, the requirements are set to apply to nuclear power plants, but they may also be applied suitably to other nuclear facilities using a graded approach depending upon the potential for radiological impact. For this purpose, facilities are categorised as described in Appendix-A. A list of typical nuclear facilities under each category is given in Annexure-I.

(iv) This code covers assessment of site characteristics, natural events and human-induced events specific to the site, which will have a bearing on the safety of the nuclear facility and the radiological impact on the environment and population due to the nuclear facility at the site during normal operation and accident conditions. The code lays down requirements for assessing the suitability of a site from these considerations.

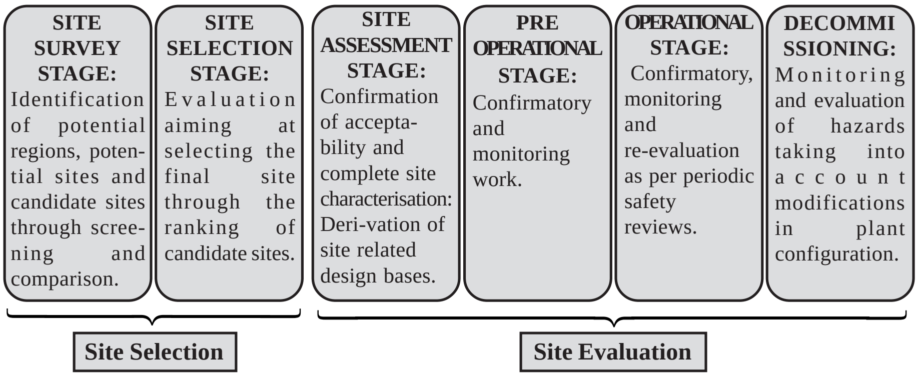

Fig. 1 : Siting Process of Nuclear Facilities

(v) Aspects of non-radiological impact are beyond the scope of this code.

(vi) The requirements related to human-induced events of malevolent nature that can affect the safety of the nuclear facility are beyond the scope of this code.

1.4 Structure

In addition to this introductory section, there are six sections, two Appendices, and two Annexures in this document. Section 2 describes the general requirements for evaluation of sites for nuclear facilities. Safety requirements to deal with external events are presented in section 3. This section also contains the criteria for evaluation of design bases for specific external events. The requirements for assessing the impact of the nuclear facility on the site are presented in section 4. Considerations for implementation of emergency management plan are delineated in section 5. Requirements with regard to monitoring and quality assurance in site evaluation are specified in section 6 and 7 respectively. Appendix-A covers the mean annual frequency of major natural events that are to be considered for establishment of design bases of various types of nuclear facilities. Salient features of site to be considered for selection and evaluation process are described in Appendix-B. A list of typical nuclear facilities, categorised with respect to their potential for radiological impact is given in Annexure-I. The screening distances for evaluation of human induced events and other site characteristics are given for ready reference, during preliminary stage of site evaluation, in Annexure-II.

2. GENERAL CRITERIA FOR SITE EVALUATION OF NUCLEAR FACILITIES

2.1 General

(i) The basic criteria for evaluation of a site for the location of a nuclear facility shall be to ensure that the site-plant interaction will not result in unacceptable radiological impact. The applicant shall ensure the following to meet the above criteria:

(a) During normal operation the possible radiological impact of a nuclear facility shall be within prescribed limits.

(b) The radiological impact from the nuclear facility due to external as well as internal events shall not exceed the acceptable criteria.

(ii) In evaluating the suitability of a site for locating nuclear facilities, major aspects that shall be considered include assessment of:

(a) Impact of natural and human-induced external events on the facility.

(b) Radiological impact of facility on public and environment.

(c) Feasibility of effective implementation of emergency management plans in the public domain.

(iii) For a multi-unit/multi-facility site, consequences of external events shall be assessed/reassessed considering their impact on all units/facilities in the site, including common cause failures. Consequential effects due to incidences in one facility/unit on other facilities/units shall also be considered.

(iv) If the evaluation considering the above aspects indicates that the deficiencies identified, cannot be compensated by means of engineering provisions, i.e. design features, measures for site protection and/or by means of administrative procedures, the site shall be deemed unsuitable for the nuclear facility of the proposed type and size.

2.2 Site and Adjoining Zones

2.2.1 Exclusion Zone

(i) An exclusion zone (EZ) of required size shall be established around the nuclear facility.

(ii) The size of the exclusion zone around a nuclear facility shall be such that :

  (a) During normal operation, prescribed dose limits shall be met at EZ boundary considering all radiation exposure pathways including inhalation and ingestion routes.

  (b) During governing design basis accident (DBA) conditions, acceptable dose limits shall be met at EZ boundary considering all radiation exposure pathways including inhalation and ingestion and without taking any credit for emergency countermeasures in public domain.

(iii) In case of NPP, the size of EZ shall not be less than 1.0 km from the center of each reactor.

(iv) The size of EZ shall also satisfy the requirements with regard to security considerations of the facility.

2.2.2 *Natural Growth Zone*

A natural growth zone up to 5 km radius from reactor centre around a nuclear power plant shall be established by administrative measures where only natural growth is permitted. This zone is synonymous to precautionary action zone (PAZ) for emergency planning.

2.2.3 *Emergency Planning Zone*

An emergency planning zone (EPZ) of 16 km radial distance (from reactor center) around an NPP shall be established. For the emergency management purpose, infrastructure including transportation network and means of communication shall be ensured within this area. This zone is synonymous to urgent protective action planning zone (UPZ) for emergency planning.

2.2.4 *Radiological Surveillance Zone*

In order to establish the baseline radiological and environmental data and for the purpose of continuous environmental surveillance, a zone of 30km radius around the NPP is designated as radiological surveillance zone (RSZ). This zone is synonymous to long-term protective action planning zone (LPZ) for emergency planning.

2.2.5 *Zones for Other Nuclear Facilities*

The requirements for zones (natural growth zone, emergency planning zone and radiological surveillance zone) for other nuclear facilities shall be established based on their hazard potential.

2.3 Dose Criteria

For a given site, the following dose criteria shall be applied for a representative person of the public, considering all routes of exposure or exposure pathways.

2.3.1 Normal Operation

The annual release limits for all the facilities within a particular site (taken together) shall ensure that the effective dose limit for any individual at off-site, due to normal operation (including anticipated operational occurrences) is less than 1.0 mSv/year.

Sufficient dose reserve shall be ensured while apportioning the doses among nuclear facilities to factor future requirements.

2.3.2 Accident Conditions : Nuclear Power Plants

(i) Design basis accident (initiating event with consequential failure and taking credit of safety systems considering single failure criterion)

Permitted calculated off site releases during accident conditions shall be linked to the radiological consequence targets as specified. For design basis accident (DBA) in a NPP there shall be no need for offsite countermeasures (i.e. no need for prophylaxis, food control, shelter or evacuation) involving public, beyond exclusion zone.

In such cases the design target for effective dose calculated using realistic methodology shall be less than 20.0 mSv/ year following the event.

(ii) Design extension condition (DEC) without core melt (multiple failure situations and rare external events)

For accidents without core melt within design extension conditions (multiple failure situations and rare external events) there shall be no necessity of protective measures in terms of sheltering or evacuation for people living beyond Exclusion Zone. Required control on agriculture or food banning should be limited to a small area and to one crop. However, the design target for effective dose, with such interventions considered, remains same as for DBA.

(iii) Design extension condition with core melt (severe accident)

In case of severe accident e.g. accidents with core melt within design extension conditions, the release of radioactive materials should cause no permanent relocation of population. The need for offsite interventions should be limited in area and time.

2.3.3 *Accident Conditions : Other Nuclear Facilities*

For nuclear facilities other than NPP, accident conditions corresponding to those specified in sec. 2.3.2 (i), (ii) and (iii) shall be established and appropriate dose criteria shall be met.

2.4 General Criteria

(i) Site characteristics that may affect the safety of the nuclear facilities as well as those having potential radiological impact on the public and the environment shall be investigated and assessed. Characteristics of the natural environment in the region that may be affected by potential radiological impacts in operational states and accident conditions shall also be investigated. All these characteristics shall be observed and monitored throughout the life cycle of the facilities [1].

(ii) Potential radiological exposure to public in the radiological surveillance zone (RSZ) during operational states and accident conditions shall be assessed during the life cycle of the facility.

(iii) In assessing the suitability of the site, consideration shall be given to safety aspects of storage and transportation of fresh and spent fuel and radioactive waste.

(iv) Salient features/characteristics that shall be considered in evaluation of a site for nuclear facility are given in Appendix-B.

(v) Sites for nuclear facility shall be examined with regard to the frequency and severity of external natural and human induced events, their combinations and in combination with internal events that could affect the safety of the facility.

(vi) Design shall meet requirements for safety against both natural and human induced external events. The foreseeable evolution of these events and their combinations related to the region, along with population growth and distribution that may have a bearing on safety and radiological impact shall be monitored, evaluated and periodically reviewed for a time period encompassing lifetime of the facility. If necessary, appropriate engineering measures shall be taken to ensure that the overall impact remains acceptable.

(vii) A site shall be evaluated for phenomena or combination of phenomena, which have annual frequency more than 10^{-7} per year.

(viii) Design bases shall be established both for natural and human induced external events. For an external event (or combination of events), the choice of values of the parameters upon which the plant design is based shall be so as to ensure that structures, systems and components (SSC) important to safety in relation to that event (or combination of events) shall remain functional during or after the design basis event.

(ix) The design parameters for external events shall be derived by means of systematic assessment of hazard associated with the events. The hazard assessment shall be performed taking into consideration site-specific conditions and the data / information collected. A thorough uncertainty analysis shall be performed as part of the evaluation of the hazard. The parameters thus derived shall be taken into account adequately in engineering of SSC.

(x) Suitability of site for implementing emergency measures effectively in case of a beyond design basis accident shall also be evaluated.

2.4.1 Screening Distance Value

(i) The screening distance values for acceptance of a candidate site during preliminary stage of site evaluation process are given in Annexure-II. If a proposed site does not satisfy screening distance values (SDVs), it can still be considered acceptable provided there exist solutions by means of engineering provisions i.e. design features, measures for site protection and /or by means of administrative procedures to satisfy basic requirement of siting.

2.5 Design Basis for External Events

2.5.1 Natural Events

(i) All natural events which have a probability of occurrence of more than10^{-7} per year shall be considered. Natural phenomena, which may exist or can occur in the region of a proposed site shall be identified and classified as per their impact on plant safety. Design bases shall be derived for each credible event and credible combination of events by adopting appropriate methodologies.

(ii) Historical records of the occurrences and severity of the natural phenomena shall be collected for the region. The data shall be carefully analysed for reliability, accuracy and completeness.

(iii) If data for a particular type of natural phenomenon are incomplete for the region, then data from other regions having sufficiently similar characteristics shall be used in evaluation of the design basis event, with proper justification.

2.5.2 Human Induced Events

(i) The site and surrounding region shall be examined for facilities and human activities that may affect the safety of the proposed nuclear facility. These facilities and activities shall be identified and the conditions under which the safety of the plant is likely to be affected shall be postulated in deriving the design basis for external human-induced events.

(ii) Information concerning the frequency and severity of important human-induced events shall be collected and analysed for reliability, accuracy and completeness.

2.5.3 Change of Hazard with Time

(i) Changes of hazard (both natural and human induced) with time over the lifetime of the facility shall be postulated in evaluating design basis parameters for external events. The assessment shall also take into account the changes due to regional climate change associated with global climate change and change in physical geography of drainage basin, offshore bathymetry, coastal profile, catchment area, etc.

2.6 Radiological Impact Assessment

(i) The population characteristics and its distribution in the region shall be evaluated including data on various aspects of population, like age group, livelihood, dietary habits, etc. and also land and water use. While carrying out radiological assessment, site specific parameters need to be used for a realistic estimation of the doses.

(ii) In evaluating a site for the radiological impact of the nuclear facility on the region for operational states and accident conditions, appropriate estimates of expected or potential releases of radioactive material shall be made taking into account the design and safety features of the plant.

(iii) The radiological consequences due to a nuclear facility on population and environment shall be as low as reasonably achievable (ALARA) taking into account social and economic factors, both for normal operation and accident conditions and within the stipulated limits/ levels for radiological safety.

(iv) The direct and indirect pathways by which the public might receive the radiation exposure due to radioactive materials released from the nuclear facility shall be identified and used in the estimation of the radiological impact.

2.7 Emergency Planning

The site and its surroundings shall be evaluated for effective implementation of emergency preparedness plans. The evaluation shall consider whether the infrastructure and facilities for implementing emergency measures would be available at all times.

2.8 Requirements During Operational Stage

(i) A review of site characteristics and site evaluation including emergency planning shall be taken up during the periodic safety review of the facility during operational stage. In addition, site characteristics shall be re-evaluated in case of the following:

   (a) Revision in safety regulation.

   (b) Occurrence of any external event/meteorological phenomena resulting in corresponding design parameters potentially higher than the ones considered originally.

   (c) Any deviation from the approved type/capacity of facility, and/or when more nuclear facilities are added.

   (d) Any expansion of activities around the site in the future that may have an impact on safety of the facilities at the site.

   (e) Additional data and/or new information on relevant climatic change, that may necessitate revision of design basis parameter.

(ii) Retrofitting of SSC shall be carried out if the review warrants it.

3. EFFECT OF SITE CHARACTERISTICS ON NUCLEAR FACILITIES

3.1 General

(i) Site shall be adequately investigated and evaluated with regard to all its characteristics and external events that could be significant to safety.

(ii) Possible natural phenomena and human induced events and activities in the region of the site shall be identified and evaluated according to their safety significance. This evaluation is used to identify the applicable natural phenomena or human induced events and activities and associated potential hazards, for deriving the corresponding design basis for the facilities.

(iii) Hazard assessment shall be conducted either by deterministic or by probabilistic approaches, or a combination of both, as brought out in the ensuing sections. The probabilistic estimates shall be derived with appropriate confidence levels. If probabilistic approach is adopted, physical upper and lower bounds of the parameters, as applicable, shall be taken into account.

3.2 External Natural Phenomena

3.2.1 Seismic and Geological Considerations

(i) The hazards associated with earthquakes shall be assessed by means of seismotectonic evaluation of the region and taking into consideration site-specific conditions. All features that can substantially affect the severity of earthquake in the region shall be studied. The geological and seismotectonic conditions in the region and geotechnical aspects of the site area shall be evaluated. Information on all earthquakes including pre-historical, historical and instrumentally recorded earthquakes in the region shall be collected, documented and considered.

(ii) NPPs and other category-I facilities shall not be sited in seismic zone V. Zones are defined in BIS 1893(2002) [2].

(iii) All seismically active structures and active faults in the region shall be identified. On the basis of geological, geophysical, geodetic or seismological data, a fault shall be considered active if the following conditions apply:

(a) If it shows evidence of past movement or movements of a recurring nature within such a period that it is reasonable to conclude that further movements may 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 (e.g. Upper Pleistocene–Holocene, i.e. the present period) may be appropriate for the assessment of active faults. In less active areas, it is likely that much longer periods (e.g. Pliocene-Quaternary, i.e. the present period) are appropriate.

(b) If a structural relationship with a known active fault has been demonstrated such that movement of one fault may cause movement of the other.

(c) If it cannot be established that a fault is not active, the same shall be considered in the seismotectonic evaluation as active.

(iv) Potential for permanent ground displacement such as surface faulting or folding, fault creep, subsidence or collapse shall be evaluated. The methods to be used and investigations to be made for assessing surface faulting shall be sufficiently detailed.

(v) Existence of an active fault within a distance of 5km of a proposed site shall render the site unacceptable for locating any nuclear power plant and other category-I facilities.

(vi) For nuclear facilities, the site shall be deemed to be unacceptable if existence of an active/capable fault can cause potential surface faulting affecting the safety.

(vii) The design basis ground motion (DBGM) is expressed by response spectra for various damping factors and time- histories of appropriate durations of shaking. Site-specific DBGM parameters shall be established for engineering design of the facility. The response spectrum derived from the hazard assessment either by deterministic approach or by probabilistic approach shall take into account the seismotectonics, geological and geotechnical characteristics of the region.

(viii) The site specific DBGM parameters shall be derived considering the maximum earthquake potential that could be attributed to the seismotectonic provinces of the region within which the site is located. Due consideration shall be given to reservoir-triggered seismicity on account of the dams existing or sanctioned to be built in the region.

(ix) The design basis vibratory ground motion for NPP shall be based on two levels of earthquakes[1], S1 and S2. The S2 level earthquake represents the maximum potential vibratory ground motion for which all safety related SSC are designed and qualified to remain functional. The S1 level motion can be derived on the basis of historical earthquakes that have affected the region around NPP site. Details of the method for fixing the S1 level motion are left to the applicant. The structures, systems and components (SSCs) required for continuous operation of NPP shall be designed and qualified for S1 level of vibratory ground motion. If the plant experiences ground motion equal to or above S1 level, the plant shall be safely shutdown and maintained in safe shutdown condition. The restart of the plant after exceedance of S1 level of earthquake shall be taken up after inspection, safety review and approval by the regulatory body.

(x) The safety related SSCs of other category-I facilities shall also be designed for a value same as S2 level earthquake. In addition, a lower level of earthquake for which the plant is capable of continued operation shall also be defined. In case of exceedance of this lower level earthquake, plant shall be shut down and inspected. The restart of the plant shall be after the approval of regulatory body.

(xi) For category-I facilities site-specific design basis ground motion parameters of S2 level shall not be less conservative than corresponding ground motion level specified in national standards for industrial facilities of highest safety or hazard category. For category-I facilities, peak ground acceleration (PGA) of design basis ground motion of S2 level shall be not less than 0.10g.

(xii) The DBGM parameters shall be derived taking into account the following when deterministic method is adopted.

(a) For NPP and other category-I facilities, the DBGM parameters are derived from design basis earthquake that could be attributed to the region surrounding the site. Design basis earthquake associated with an active/capable fault is defined by means of three parameters viz. magnitude, epicentral distance and focal depth. These parameters are selected such that the maximum potential earthquake of the active/capable fault is taken into account in seismic hazard assessment.

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[1]For NPPs S1 and S2 levels of earthquakes are also termed as operating basis earthquake (OBE) and safe shutdown earthquake (SSE) respectively.

(b) For category-II facilities, the DBGM parameters shall not be less than half of S2 level DBGM parameters applicable for category-I facilities.

(c) For category-III and other facilities DBGM parameters shall be derived following a graded approach.

(xiii) The DBGM parameters shall be derived following state of the art procedures and shall satisfy the following criteria when probabilistic methodology is adopted:

(a) Annual frequency of exceedance of S_2 level earthquake motion shall not be greater than ~$1x10^{-4}$ for category-I facilities (Return period of the order of 10^4 years).

(b) For category-II facilities, the ground motion parameter corresponding to the annual frequency of exceedance not greater than $4x10^{-4}$.

(xiv) The water control structures, such as dams located upstream or downstream, whose failure could potentially compromise the safety of category-I facilities shall be checked for structural integrity against ground motion derived similar to S2 level motion at the dam site. Method of evaluation shall be the same as that applicable to the nuclear facility. In case water control structures are not checked for their structural integrity against S2 level earthquake or integrity cannot be established, flood analysis for failure of water control structures shall be carried out. While carrying out dam break analysis for upstream dams, an incoming flood of 25 years return period along with dam failure due to earthquake with water level at full reservoir level (FRL) shall be considered for evaluating the plant safety (see cl. 3.2.3.2.vi). If potential for the loss of ultimate heat sink exists due to failure of dam located downstream, the site shall be considered unsuitable unless reliable and practical engineering solution is available (see cl. 3.2.9).

3.2.2 Meteorological Events

(i) The meteorological and climatological characteristics for the region around the site shall be investigated and evaluated to ensure the safety of nuclear facility. The following meteorological events/parameters shall be considered for evaluation of design bases:

(a) Wind

(b) Precipitation

(c) Storm surge

(d) Tropical cyclone

(e) Air temperature (dry bulb and wet bulb)

(f) Cooling water temperature

(g) Humidity

(ii) In addition to the above meteorological phenomena, the following rare meteorological events shall also be considered in the evaluation of site:

(a) Lightning

(b) Tornado

(c) Snow

(d) Waterspouts

(e) Dust and sand storms

(f) Hail storm

(g) Freezing precipitation and frost related phenomena

(h) Cloud burst

(i) Any other phenomena specific to site

(iii) Hazard associated with all relevant meteorological phenomena shall be identified and evaluated to arrive at the corresponding design basis parameter to ensure safety of the facilities to be located at the site.

(iv) Historical data of the event at and around the site shall be utilized for evaluation of potential of occurrence, frequency and severity of the meteorological event. Uncertainties involved in data, its adequacy and evaluation procedure shall be taken into account in evaluation of hazard while arriving at design basis parameter for any event. Output of the hazard evaluation shall be described in terms of suitable design parameters that could be used in ensuring safety of the facilities.

(v) Either probabilistic or deterministic or both methods can be used for evaluation of design basis parameters.

3.2.2.1 Wind

(i) Historical data on persistent high winds during cyclones, tornadoes and storms occurring at and around the region shall be used for static loading and wind induced missile generation, while data on short duration burst of winds shall be utilised for studies of dynamic loading. Historical data on circulating wind during tornadoes, if any, occurring at or around the region shall also be collected.

(ii) The collected data shall be used to generate design basis wind speeds for the event of acceptable annual frequency using probabilistic method. Deterministic method can also be used for this purpose.

(iii) For category-I facilities, the design parameters corresponding to all wind induced hazards shall be derived corresponding to an annual frequency of exceedance of 10^{-4}.

(iv) For facilities belonging to category II, III and general, the design parameters for wind load shall be estimated based on annual frequency of occurrence given in Appendix-A.

(v) Site specific design basis wind speeds shall be derived based on sufficient and reliable data. In the absence of sufficient and reliable site specific data, design basis wind speeds derived from IS 875, Part-3 (1997) [3] shall be used.

3.2.3 Flood

3.2.3.1 General

(i) The region shall be assessed for flooding hazard due to precipitation, storms, wind induced waves, seiches, failure of water storage/carrying structures, melting of snow, etc. for inland sites and high tides, cyclones/storm surge, wind induced waves, precipitation, tsunami generated waves, etc. for coastal sites. Appropriate combinations of these phenomena shall also be considered.

(ii) Highest water level reached at the site during the above events shall be used as the design basis parameter to achieve safety at site. Other associated parameters like duration of flood, flow conditions, warning time for flood, the height and period of waves (if relevant) shall also be estimated.

(iii) Historical data related to both meteorological and hydrological characteristics shall be critically examined.

(iv) Design basis flooding event shall be selected by deterministic or probabilistic method. While using probabilistic method, values corresponding to mean annual frequency of exceedance10^{-4} shall be used for category-I facilities. Criteria for other facilities are brought out in Appendix-A.

(v) Suitable meteorological, hydrological and topographical data including data on relevant bodies of water shall be collected. Uncertainty and data inadequacy, if any, shall be taken into consideration while arriving at the final design basis value of flood water level. The design basis highest water level at the site shall be arrived at by using appropriate flood routing models.

3.2.3.2 Inland flooding

(i) Inland flooding can occur due to one or more of the following causes:

(a) Heavy incessant rain at the site/region

(b) Flood in the river/water body

(c) Sudden release from upstream water storage structures like dams

(d) Failure of upstream dam

(e) Seiches

(ii) Historical data on heavy rain/cloud burst/flash flood in the region shall be collected and used for arriving at the flooding potential.

(iii) Topographical data of the channel and surrounding based on field survey/topo sheets/satellite data shall be collected.

(iv) A probable maximum storm (PMS) and resulting probable maximum flood (PMF) shall be identified. Appropriate models for routing this water along the channel/river shall be used. In case of the flood generating upstream of a reservoir, the same shall be routed downstream and water level at the site be generated using appropriate hydrological models. Starting water level in the reservoir during flood shall be taken as at full reservoir level (FRL).

(v) The outflow from the dam shall be used as the input for downstream channel and routed along the channel to arrive at the highest water level reached at the site.

(vi) Structural stability of the upstream/downstream dam against the water level rise/earthquake shall be evaluated. If the stability is not established then failure of the dam shall be assumed and consequent hazard shall be evaluated adopting appropriate methodology. For upstream dam failure initiated by overtopping, the initial water level at all downstream dams shall be assumed as at FRL.

(vii) Effect of sudden release of water from upstream dam by opening of gates shall be evaluated.

(viii) Possibility of change in river course and consequent flood hazard shall be assessed.

(ix) Potential for seiches in enclosed water bodies shall be examined for inland sites located close to such water bodies.

3.2.3.3 Coastal Flooding

(i) Coastal site shall be examined for the potential flooding caused by surge due to cyclone, wind induced waves as well as tsunami waves.

(ii) Uncertainty and data inadequacy, if any, shall be taken into consideration while arriving at the final design basis value of flood water level.

(iii) For sites located along estuaries, impact due to PMF or dam break occurring at upstream locations shall be considered.

(iv) While generating design basis value of flood, the highest tide level observed at the site and wave run-up shall also be considered taking into account any amplification due to the coastal configuration adjacent to the site.

(v) Bathymetry and topography data of the coast region shall be collected and utilised.

3.2.3.3.1 Cyclone

(i) Design basis cyclone shall be arrived at using historical data of cyclones hitting the site using appropriate hydrological and numerical models.

(ii) For sites along estuaries, evaluation shall consider the increased water levels due to storm surge and its impact on the site. An appropriate combination of both cyclone and a smaller magnitude flood in the river due to the same cyclonic depression shall also be considered.

3.2.3.3.2 Tsunami

(i) The region shall be evaluated to determine the potential for tsunamis that could affect the safety of nuclear facilities on the site. The hazards associated with tsunamis shall be derived including potential drawdown and run up as well as hydrodynamic forces, if applicable.

(ii) Design basis earthquake shall be arrived at with data of earthquakes resulting in tsunami wave landing at the site using appropriate hydrological and numerical models.

(iii) The frequency of occurrence, magnitude and height of regional tsunamis shall be estimated. On the basis of the available data, pre-historical and historical, for the region and comparison with similar regions that have been well studied, all potential tsunamigenic sources and their maximum potential shall be identified and used in determining the possible hazards associated with tsunamis. Appropriate models shall be used in the evaluation and shall take into account any amplification due to the coastal configuration adjacent to the site.

(iv) The possibility of tsunami wave propagation inside estuary/river and related hazards shall be assessed.

3.2.3.4 Site flooding

(i) Flooding from local intense precipitation shall be mitigated by the site drainage system.

(ii) Following requirements shall be satisfied in the design of site drainage:

(a) Drainage system shall be capable of discharging floodwater resulting from value of precipitation corresponding to 10^{-2} annual frequency of exceedance for overall site.

(b) The safety related systems and components, waste storage/ management areas and escape routes or entrance/exit roads to safety related areas shall not be flooded from the quantum of precipitation corresponding to annual frequency of exceedance as given in Appendix-A.

3.2.4 Geological/Geotechnical Hazard

3.2.4.1 Slope Instability

The site and its vicinity shall be evaluated for slope instability (such as land and rock slides and land erosion) which could affect the safety of the NPP. If such a potential exists, the hazard shall be evaluated using site specific parameters such as design basis ground motion of earthquakes and/or slope instability due to heavy rain etc. The site shall be rejected if suitable engineering solution is not feasible.

3.2.4.2 Surface Collapse, Subsidence or Uplift

Geological and other appropriate information of the region shall be examined for existence of natural features like caverns, karstic formations and subsidence and human induced features/activities like mines, water extraction and gas/oil wells. If potential for surface collapse, subsidence or uplift exists in the site vicinity, corresponding hazard shall be evaluated. The site shall be deemed unsuitable if no engineering solution is possible for ensuring safety of nuclear facility.

3.2.4.3 Soil Liquefaction

The potential for soil liquefaction at the site shall be evaluated using design basis ground motion parameters. If potential for soil liquefaction exists, the site shall be deemed unsuitable unless engineering solutions are demonstrated to be available.

3.2.4.4 Characteristics of Foundation Material

(i) It shall be ensured that the site has competent strata for bearing the design loads transferred through the foundation. The details of local geology, e.g. karstic phenomena, shall also be examined. Adequate geotechnical investigations shall be carried out to examine the competence of the founding media.

(ii) The geotechnical characteristics of the subsurface materials shall be investigated and a strata profile for the site in a form suitable for design purposes shall be determined.

(iii) The stability of the founding strata under static and seismic loading shall be assessed.

3.2.5 Ground Water Regime

The ground water regime and the chemical properties of the ground water shall be studied.

3.2.6 Sand Dunes

Unless engineering solutions exist, regions prone to, or having migratory sand dunes shall be avoided.

3.2.7 Volcanism

The site shall be investigated for evidence of volcanic activity in the region in last 10 million years. If such evidence exists, impact of associated phenomena shall be studied. Unless the impact of these phenomena could be mitigated by engineering measures, site shall be deemed unsuitable for category-I facilities.

Possibility of impact at site due to certain phenomena viz. pyroclastic density currents, lava flows, debris avalanches, landslides and slope failures, opening of new vents and ground deformation would deem the site as unsuitable. Other phenomena that also need to be addressed during evaluation include tephra fallout, lahars and floods, volcano generated missiles, volcanic gases, tsunamis and seiches, atmospheric phenomena (air shocks, frequent lightning, etc.), volcanic earthquakes and related hazards, hydrothermal systems and ground water anomalies.

3.2.8 Shoreline Erosion

(i) For coastal site, potential for shore instability due to erosion or sedimentation shall be investigated. Similarly, potential of riverbank erosion or change of river course in case of inland sites or sites on riverbanks shall be investigated.

(ii) If potential of such instability exists and is unacceptable from the safety consideration of nuclear facilities, the site shall be considered unsuitable unless reliable and practical engineering solution is available.

(iii) Intake structures and shore protection measures taken up as part of plant design could alter the erosion/deposition regime. The postulated effect of the same on the unprotected area within the site shall be evaluated.

3.2.9 Loss of Ultimate Heat Sink

(i) The potential for the loss of ultimate heat sink of a nuclear facility shall be analysed. Possibility of failure of downstream dam, blockage/diversion of river, excessive growth of marine organism, ship collision and consequent damage to intake structure, oil spill, draw-down due to tsunami, etc. which may result in above conditions, shall be scrutinized. If potential for the loss of ultimate heat sink exists, the site shall be considered unsuitable unless reliable and practical engineering solution is available.

(ii) Availability of adequate quantity of water storage for decay heat removal from core and spent fuel stored under water shall be ensured under all plant states for at least 7 days. In addition, provisions shall be available for ensuring continued availability of heat sink beyond 7 days by alternate means. The minimum period of 7days shall be revised to a higher value depending on site/plant characteristics.

(iii) If the minimum water supply required for the long term heat removal from the core and spent fuel stored under water cannot be ensured under all circumstances, the site shall be deemed unsuitable.

3.3 Human-Induced External Events

3.3.1 General

(i) The region shall be investigated for potential hazard due to aircraft crash, chemical explosion/toxic gas release in industrial facilities, or any other hazards that may result from industrial / radiation/ nuclear facilities located away from site as well as within the site boundary. Potential hazards resulting from various other human activities shall also be investigated. In case the hazard is unacceptable with respect to its impact on the nuclear facilities and no solution is available, the site shall be deemed unsuitable.

(ii) When probabilistic hazard assessment methodology is adopted, the design basis parameters due to external human induced events shall be derived for an annual frequency of 10^{-4} for category-I facilities, unless specified otherwise[2].

(iii) The extent of investigation and design basis shall be determined by the hazard potential of the facility and also by the impact of the hazard/event on the facility.

3.3.2 Aircraft Crash (Accidental Origin)

(i) If the screening values given in Annexure-II are not satisfied the site shall be further evaluated.

(ii) For this purpose, data such as, the distance of the nearest airport along with the present flight frequency, expected growth, air traffic corridors in the region and the type of aircraft used shall be collected. This data shall be used in conjunction with appropriate formulation to arrive at the annual frequency of aircraft crashing on the category-I facility. If this frequency is found to be greater than 10^{-7} per year [4], detailed evaluation shall be carried out to assess the impact hazard including secondary consequences such as fire and explosions due to fuel burning. If engineering solution, acceptable to regulatory body does not exist, the site shall be deemed unsuitable.

3.3.3 External Fire

Potential fire external to a category-I facility site shall be evaluated with appropriate considerations for safety of the facility (e.g. access to site, availability of power, ventilation, impairment of safety function, operator action, etc.) with special emphasis on the unavailability of power or any threat to the operator action owing to the release of smoke and toxic gases.

[2] AERB/NPP/SG/S-7, Evaluation of Design Basis for External Human-induced Events for Nuclear Power Plants (under preparation)

3.3.4 Explosions and Asphyxiant/Corrosive/Toxic Gas Releases

(i) Activities in the region around the site involving the handling, processing, transporting and storing of chemicals and explosives having potential for safety concerns such as explosions and asphyxiant/corrosive/toxic gas releases shall be identified. All activities involving storage/handling/transportation of such chemicals or explosives shall be taken into account during site evaluation of the facility.

(ii) The places where explosive chemicals are manufactured/stored/transported in the surrounding environment of the site shall be identified along with type and quantities of these chemicals stored and/or manufactured. Computations shall be carried out to arrive at the pressure wave and thermal load generated on the facility from the postulated accident scenarios.

(iii) Potential of asphyxiant and toxic gases release shall be evaluated. These events affect the nuclear facility both externally and internally, damaging or impairing safety related systems and operator action.

(iv) In case of toxic chemicals, either manufactured or handled, stored or transported in the surrounding environment of the site, the concentration levels of these chemicals at the site arising out of an accident at the manufacturing/handling plants or during transportation of these chemicals shall be evaluated. If levels are above the toxic levels stipulated for the respective chemicals, appropriate engineering measures shall be introduced to ensure safety of nuclear facility/site personnel.

(v) Design basis for chemical explosion events shall consider overpressure including variation of pressure wave with respect to time and its duration as well as impact on structural elements and humans. For chemical releases, the tolerance level of toxic material shall be considered.

(vi) The release of corrosive gases or liquids from industrial plants in the surrounding environment of the site or in transit such as in accidents and spills from ships or trains constitutes a potential hazard. Leakage of corrosive gases and liquids may also occur from storage of chemicals on the site. Impact of such event on the plant shall be evaluated.

3.3.5 Releases of Radioactive Materials

Impact of release of radioactive materials from adjacent operating nuclear facilities and from vehicles transporting radioactive material on the proposed facilities shall be evaluated considering possible scenarios.

3.3.6 *Oil Slick*

Information regarding proximity of offshore oil well, near shore oil well, movement of oil tankers in the nearby shipping channels/water ways and any other potential source of oil slick shall be obtained. Impact on nuclear facilities due to potential oil slick shall be investigated.

3.3.7 *Blasting Operation*

Information regarding blasting operations including those during site excavation in the site vicinity (up to 5 km) shall be obtained and the impact of such operations on safety of existing nuclear facilities at site shall be assessed.

3.3.8 *Mining, Drilling and Water Extraction*

All activities related to mining, drilling, subsurface extraction and injection of water and other fluids shall be carefully studied in order to assess their impact on safety of the facility.

3.4 Other Events

Natural and human induced events, other than those addressed in preceding sections, and that could cause loss of functions of structures, systems and components (SSC) important to safety shall be identified. Examples of such events are blockage/diversion of a river, depletion of a reservoir, blockage of a reservoir/cooling tower by freezing or the formation of ice, electromagnetic interferences, eddy current in ground, etc. The investigation shall also include installations that may give rise to missiles of any type that could affect safety of nuclear installation. If possibility exists, the potential hazards associated with these events shall be established. In case the hazard is unacceptable for the nuclear facilities and no practicable solution is available, the site shall be deemed unsuitable.

3.5 Other Characteristics

During evaluation of a site, following site related characteristics which do not affect safety of the nuclear facility directly but can have an indirect impact on safety of the facility are assessed.

3.5.1 *Power Evacuation/Availability*

Power evacuation scheme from the proposed nuclear power plant shall be studied in detail considering transmission scheme, generation and load centers in the electricity network. Availability of startup power and adequate transmission links even during a grid disturbance shall be ensured. Possibility of operation in an islanding mode shall also be checked and plant grid interaction studied.

3.5.2 Transportation of Over Dimensioned Consignment/Cask

(i) Availability of transport route for over dimensioned consignment (ODC) shall be ensured.

(ii) Safety aspects related to transportation of cask containing irradiated fuel/radioactive material within and outside plant site up to storage facility/reprocessing plant shall be addressed.

3.5.3 Cooling Water Requirements

Adequate quantity and assured supply of cooling water of acceptable quality shall be available for safe operation of the facility. The intake and outfall scheme and type of cooling system namely once through or closed circuits shall be considered. At sites with multiple intake and outfall structures, effect of recirculation of warm water as well as radioactivity shall be studied.

3.5.4 Thermal and Chemical Pollution

(i) The arrangement of intake and outfall structures shall be such that the temperature at the discharge point meets requirements specified by the competent authority, i.e. State/Central pollution control board or any other appropriate statutory authority. If required, appropriate model studies shall be conducted for this purpose.

(ii) Regarding the discharge of chemical effluents to a water body, appropriate limits as specified by State/Central authorities shall be adhered to.

3.6 Changes of the Hazard with Time

3.6.1 Changes due to Climatic Evolution

(i) Global climatic changes over a period of time can alter the meteorological and hydrological features of the site resulting in changes in air and water temperatures, sea level, frequency and intensity of cyclones, rainfall, etc. Due attention shall be paid to the possible implications to the consequences resulting from such changes on the safety of facility during its operating life.

(ii) Periodic re-evaluation of design parameters shall be performed as uncertainties affecting estimates of future climate extremes are reduced or observed trends show evidence of more climatic extremes.

3.6.2 Other Changes

Changes in the terrain due to natural or human induced causes like forest fires, urbanisation, construction of dams and irrigation channels, sedimentation/erosion, land subsidence, permanent uplift/subsidence of the earth's surface due to an earthquake, etc. can affect the flood potential of the region. Therefore, such changes shall be considered along with climatic changes in the periodic validation of design basis flood level parameters established at the time of construction of the facility.

3.6.3 *Considerations for Exceedance of Design Basis*

To account for the future changes, additional safety margin shall be taken into consideration in the design of nuclear facility.

Impact of cliff edge effects on the safety of nuclear facility shall also be assessed.

4. EFFECT OF NUCLEAR FACILITY ON ENVIRONMENT

4.1 General

(i) The principal safety objective of a nuclear facility is to ensure that the radiological impact of plant on the population and the environment during normal operation as well as accidental conditions are within the levels prescribed by the regulatory authority. The safety objective shall also include consideration of optimisation of exposure to the population. For this purpose, site characteristics affecting dispersion of radioactivity through air, surface water and sub-surface water shall be carefully studied in case of NPP and facilities having potential off-site impact. It shall be determined whether the site has favourable characteristics for effective dilution of radioactive discharges from the facilities. Other features considered in the radiological impact assessment (RIA) are land and water use, bioaccumulation, transfer to and from the environmental matrices, dietary habits, etc.

(ii) For radiological dose assessment, the facility shall provide details regarding management of radioactive waste generated and released during normal operation and accident conditions in the facility and details of radioactive release under such conditions.

(iii) For assessment of dose, the site specific parameters shall be used.

(iv) Information regarding use of land, water bodies, etc. shall be obtained. This data is important for radiological impact assessment and for planning off-site emergency measures.

(v) Data on other aspects such as cattle and livestock, agricultural produce, fish catches on annual basis and other relevant particulars, which may influence dose to the public during normal operation and accident conditions, shall be collected and included in the assessment. This information shall be used for development and implementation of emergency measures.

4.2 Dispersion through Air

4.2.1 General Meteorology

(i) The meteorological data shall be collected for a minimum period of one year and examined. This shall include assessment of inversion conditions, atmospheric stability, humidity, rainfall and hourly data for wind speeds, wind directions and calms.

(ii) In case of sites situated in river valleys, bowls and uneven topography, additional data if required shall be generated and appropriate model shall be used to assess the dilution factor.

(iii) If sufficient site-specific data is not available, data from a region with similar characteristics may be used for initial assessment, with appropriate justification.

4.2.2 Site-specific Data

A program of meteorological measurements shall be initiated at the site before start of construction of all nuclear facilities with a potential for activity release to atmosphere and shall continue till decommissioning. This program shall include instrumentation capable of measuring and recording meteorological parameters at appropriate locations and elevations required for the assessment.

4.2.3 Atmospheric Modeling

(i) Using the site-specific data, an appropriate atmospheric model for dispersion shall be used. This should consider the following:

(a) Release duration (for accident conditions).

(b) Source magnitude, release height and form.

(c) Atmospheric conditions (atmospheric stability, wind speed and directions).

(d) Dry and wet deposition conditions.

(e) Dilution capacity for short and long-term releases.

(f) Wake effects due to tall structures, if any.

(ii) To evaluate the influence of any unusual site conditions such as thermal interference from complex natural topography, cooling towers, etc., additional studies shall be carried out.

(iii) In coastal sites, considerations shall be given to effects of sea breeze-land breeze phenomena and formation of coastal boundary layer.

4.3 Dispersion through Aquatic Body

Dispersion characteristics of aquatic body (surface and subsurface) shall be studied for category-I and category-II facilities in order to assess impact of any radioactive release.

4.3.1 Hydrological Features

The hydrological characteristics of the region shall be studied and shall include:

(i) Location, size, shape and time variations of mass flow and velocity for rivers, current for lakes and seas and silt and other loads for all water bodies.

(ii) Major upstream and downstream water control structures and their design features.

(iii) Location of water intake points and quantum for domestic, irrigation and industrial purposes.

(iv) Thermal stratification in lakes.

(v) Tidal influence.

4.3.2 *Site Specific Data*

(i) At the point of discharge, the radioactive effluent releases shall be within acceptable limits. At coastal sites, it shall be ensured that the outlet of pipeline carrying liquid radioactive effluents is at a point where an adequate depth of water is available even during neap tide conditions. Dispersion characteristics and pick-up of radioactivity by sediment and biota shall also be appropriately accounted.

(ii) In case of inland sites, site specific data shall be generated including:

(a) Dispersion characteristics of water bodies.

(b) Pick-up of radioactivity by sediment and biota.

(c) Transfer mechanisms of radionuclides in hydrosphere and identification of exposure pathways for the significant radionuclides.

4.3.3 *Radiological Dose Assessment*

The assessment of impact of liquid effluent discharges to aquatic body on population shall be made using appropriate hydrological and radiological models.

4.3.4 *Hydrogeological Parameters*

(i) Direct discharge of radioactive effluents into the ground water shall be prohibited.

(ii) In order to assess the consequences of any inadvertent / accidental release leading to ground water contamination, a description of the hydrogeology of the region shall be developed and it shall include:

(a) Description of saturated and unsaturated zones.

(b) Water table contours and their variations.

(c) Direction of ground water movement and its velocity.

(d) The recharge and withdrawal rate of ground water and its use along with any interaction with surface water.

(e) Nature of aquifer (local/regional).

(f) Connection of aquifer with other regional water bodies.

(iii) Hydrogeological investigations of the site shall be carried out to evaluate the impact of ground water contamination on population. These investigations include:

(a) Porosity, physico-chemical properties, migration and retention characteristics of soil.

(b) Dispersion characteristics of the underground water bodies.

(c) Retention characteristics of the underground strata.

(d) Data on existing and projected use of water from ground aquifers.

(e) Pathways of radionuclides leading to population exposure through ground water.

(iv) Chemical characteristics of the soil around facilities for short term storage of waste such as near surface waste storage facilities should preferably act as natural barrier to migration of radioactive materials.

4.3.5 Hydrogeological Models

The data from hydrogeological investigations shall be used to evaluate the impact of ground water contamination using appropriate models to:

(a) Assess the extent of contamination of the ground water due to an accidental release of radioactive materials into the ground water body and leaching of radioactivity from near surface waste disposal site and from other structures of site, which contain radioactive material.

(b) Arrive at the levels of exposure to population due to ground water contamination, if any.

4.4 Population Distribution

(i) Information on population distribution (existing and projected), including permanent residents, transient and seasonal population shall be collected up to a radius of 30 km and updated during each periodic safety review during the life time of the nuclear plant. The data shall be presented in terms of direction and distance from the plant.

(ii) Data collection shall also include details of densely populated areas and population centers, industries, places of tourist interest and institutions such as educational institutions, hospitals and prisons within 30km radius.

(iii) In order to formulate emergency plan for other category-I and category-II facilities having potential off-site impact, necessary data for the possible impact zone shall be collected.

4.5 Land and Water Use

(i) The uses of land and water shall be characterised in order to assess the radiological impact of the nuclear facility on the region and also for the purposes of preparing emergency plans. The investigation shall cover land and water bodies up to a distance of 30 km that are used by the population or may serve as a habitat for organisms in the food chain.

(ii) In order to ensure that emergency measures can be effectively implemented under accident conditions, the use of the land shall be characterised. The characterisation shall include:

(a) Extent of agriculture land, principal food products, leafy vegetables and their yields and consumption pattern.

(b) Extent of dairy farming and yield.

(c) Extent of drinking water demand and its sources in the near vicinity of the plant.

(d) Water bodies up to 16km from the site and their outflow characteristics.

(e) Use of water for drinking, irrigation, fishing, agriculture and industrial use.

(f) Use of land for recreational activities.

4.6 Ambient Radioactivity

Before commissioning of the nuclear facility, the ambient radioactivity of the atmosphere, hydrosphere, lithosphere and biota in the RSZ shall be assessed. The data obtained are intended for use as a baseline in future investigations.

5. CONSIDERATIONS FOR EMERGENCY PLANNING

(i) The characteristics of site and surrounding area shall be suitable for implementation of emergency preparedness plans. Any additional features required for this purpose shall be implemented prior to commissioning of the facility.

(ii) Physical characteristics such as egress limitations from the area of the site that could pose a significant impediment to take protective actions shall be identified. Possible isolation of site due to external events shall be considered. Alternate routes for access to the site shall be identified.

(iii) Floating population in emergency planning zone and its impact on emergency planning measures shall be addressed.

(iv) During preparation of detailed emergency plans, population groups, such as those in schools, hospitals, prisons, or other institutions that could require special attention during an emergency shall be identified. Infrastructure characteristics related to implementation of emergency plans such as evacuation routes, shelters, transportation, communication facilities and medical facilities shall also be taken into account.

(v) In a multi-unit/multi-facility site, considerations shall be given to emergencies arising out of common cause failures due to external events.

6. MONITORING

(i) All the hazards and conditions that are considered and pertinent to safety of the nuclear plant shall be monitored and assessed throughout the life time of the plant.

(ii) Comprehensive periodic monitoring scheme shall be implemented for environmental surveillance program.

(iii) The characteristics of the natural and human induced hazards as well as the demographic, meteorological, geological and hydrological conditions relevant to the safety of nuclear facilities shall be monitored and assessed over their lifetime. Data collected by various national institutes and accredited agencies using state of the art technology shall be considered for the above purpose. This monitoring shall be commenced at least three years before commissioning of the first facility and continued till decommissioning.

7. QUALITY ASSURANCE IN SITE EVALUATION

(i) A comprehensive quality assurance program shall be established to control the effectiveness of the execution of the site investigations and assessments and engineering activities performed during different stages of the site evaluation for the nuclear installation.

(ii) The results of the activities for site investigation shall be compiled in a report that documents the results of all in situ work, laboratory tests and geotechnical analyses and evaluations.

(iii) A quality assurance program shall be implemented for all activities that influence safety or the derivation of parameters for the design basis for the site. The quality assurance programme shall be graded in accordance with the importance to safety from the individual activity under consideration.

(iv) The process of establishing site related parameters and evaluation involves technical and engineering analyses and judgments that require extensive experience and knowledge. In many cases the parameters and analyses may not lend themselves to direct verification by inspections, tests or other techniques that can be precisely defined and controlled. These evaluations shall be reviewed and verified by independent expert groups not directly involved in the evaluation.

(v) The results of studies and investigations shall be documented in sufficient detail to permit an independent review.

(vi) Records of the work carried out in the activities for site evaluation for the nuclear installation shall be kept in easily retrievable form.

APPENDIX-A

MEAN ANNUAL FREQUENCY OF MAJOR NATURAL EVENTS FOR DIFFERENT CATEGORIES OF NUCLEAR FACILITIES (GRADED ACCORDING TO HAZARD POTENTIAL)

Category	General Characteristics	Mean Annual Frequency of Exceedance		
		Earthquake Ground Motion	Flood/Rain	Wind
I	Potential for off-site radiological impact	SSE : ~1E-4 OBE (NPPs) : 1E-2	1E-4	1E-4
II	Potential for on-site radiological impact	4E-4	1E-3	2E-3
III	Potential for radiological impact within plant boundary	Deterministic method following graded approach, see footnote[3]	1E-2	1E-2
	Potential for radiological impact within plant boundary and off-site chemical hazard or off-site chemical hazard	Deterministic method following graded approach, see footnote[4]	1E-2	1E-2
General	Conventional or industrial buildings	Deterministic method, see footnote[5]	1E-2	2E-2

[3] DBE using BIS 1893 (Part-4) with I=1.5 and R’ = 0.67 x Response reduction factor defined in IS 1893 for structures without any special provisions for seismic resistance.

[4] MCE using BIS 1893 (Part-4) with I=1.5 and R’ = 0.67 x value of response reduction factor defined in BIS 1893 for structures without any special provisions for seismic resistance.

[5] DBE using BIS 1893 (Part-4) with I=1.0 and R’ = 0.67 x value of response reduction factor defined in BIS 1893.

APPENDIX-B

SALIENT FEATURES/CHARACTERISTICS TO BE CONSIDERED FOR EVALUATION OF SITE FOR NUCLEAR FACILITIES

A.1 Salient features of the proposed site

(1) Area map and site location

(i) Maps of site area of suitable scale indicating true North, latitude and longitude

(ii) Plant boundary with co-ordinates

(iii) Other nuclear facilities (existing and proposed) around the proposed facility

(iv) Site boundary or exclusion zone; zones demarcating 5km, 16km and 30km from facility

(v) Population distribution showing population centers

(vi) Location of existing industrial, commercial, institutional, recreational and residential facilities including projections for the lifetime of the nuclear facility

(vii) Land use pattern

(viii) Coastal regulation zone (CRZ) information, if applicable

(2) Topography

(i) General topography in the vicinity of a site (to a typical radius of 5km) with a contour line interval of 5-10m

(ii) Detailed topography of site area and area immediately surrounding the site at a contour interval of 1m

(3) Accessibility

(i) Nearest railway lines

(ii) Nearest national and/or state highways/district roads all weather approach roads

(iii) Water ways

(iv) Nearest sea port/river port

(v) Nearest airport

(vi) Transportation of over dimension consignment (ODC)

(4) Available industrial infrastructure and construction facilities

(i) Construction materials

(ii) Construction power

(iii) Construction water

(iv) Infrastructural facilities

(v) Colony for construction workers

(5) Availability of power supply and transmission lines (in case of NPP)

(i) Start-up power

(ii) Power evacuation scheme

(iii) Power distribution grid lines

(iv) Load centers

(6) Availability of water

(i) Condenser cooling

(ii) Fresh water for consumptive use

(7) Township

(i) Location

(ii) Distance from nuclear facility site

(iii) Expected population

(8) Non-radiological environmental impact including ecological considerations

(i) Heat sinks - water bodies/atmosphere

(ii) Presence of bio-sensitive areas adjacent to site and reserve forest/national park

(iii) Monuments or tourist spots that attract floating population

(iv) Restriction on thermal and chemical pollutant discharge by statutory bodies

(v) Tree cover

(vi) Coral reefs

(vii) Mangroves

A.2 External natural events/characteristics

(1) Geology

(i) Properties of sub-surface strata, depth of bed rock and type

(ii) Characteristics of sub-surface material

(iii) Characteristics of ground water

(2) Natural events

(i) Seismic and geological considerations

(a) Active faults and seismogenic structures

(b) Vibratory ground motion due to earthquakes

(c) Failure of upstream or downstream water control structure

(ii) Meteorological events

(a) High wind events, such as tropical cyclone or tornado

(b) Precipitation

(c) Cloud burst

(d) Flooding

(e) Water spouts

(f) Lightning

(g) Dust storm and sand storm

(h) Hail

(i) Freezing precipitation and frost related phenomena

(j) Air temperature

(iii) Coastal flooding

(a) Storm surges (including highest tide and wave run up)

(b) Tsunamis

(iv) Inland (river) flooding

(a) Probable maximum flood and overtopping of banks

(b) Failure of upstream or downstream water control structures such as dykes or dams

(c) Seiches

(d) Blockage of river and other drainage channel and flooding

(v) Combination of coastal and inland flooding for sites on estuary

(vi) Geological hazards

(a) Slope instability

(b) Soil liquefaction

(c) Landslides

(d) Rock fall

(e) Volcano

(f) Permafrost

(g) Soil erosion and sedimentation processes

(h) Sand dunes

(i) Collapse, subsidence or uplift

(j) Stability of foundation

(vii) Shoreline erosion

(3) Ultimate heat sink

(i) Availability of water storage

(ii) Reliability of water supply

(iii) Effect of failure of downstream water control structure

(iv) Impact of drawdown on account of tsunami/seiches

(v) Growth of marine organisms in intake channels

(vi) Blockage to intake (e.g. jelly fish, debris, ship collision or oil slick)

(vii) Water requirements for long term heat removal

A.3 External human induced events

(1) Stationary sources

(i) Other nuclear facilities

(ii) Oil refineries

(iii) Chemical plants

(iv) Explosive, toxic or radioactive material storage facilities

(v) Mining or quarrying operations

(vi) Forests/forest fire

(vii) High energy rotating equipment (e.g. turbine missile)

(viii) Military facilities (permanent or temporary), shooting ranges or arsenals

(2) Mobile sources

(i) Railway trains and wagons

(ii) Road vehicles

(iii) Ships and barges

(iv) Pipelines carrying hazardous materials

(v) Air traffic corridors and flight zones (both military and civilian)

(vi) Transportation of fresh and spent fuel and other radioactive material

(vii) Oil slick

A.4 Change of hazard with time

(1) Change due to climatic evolution: regional climatic change with global climatic change

(2) Changes in physical geography of a drainage basin including estuaries, offshore bathymetry, coastal profile, catchment area, etc.

(3) Change in land and water use

(4) Provisions for monitoring of hazards and their assessment

(5) Considerations for exceedance of design basis

A.5 Radiological impact

(1) Meteorology

- (i) Wind speed and direction
- (ii) Precipitation
- (iii) Atmospheric temperature
- (iv) Humidity
- (v) Barometric pressure
- (vi) Atmospheric stability

(2) Hydrological and hydrogeological characteristics

(3) Use of land and water

(4) Population distribution

(5) Dispersion of radioactive material through

- (i) Atmosphere
- (ii) Ground water
- (iii) Surface water

(6) Management of radioactive waste during normal operation/ source term

- (i) Solid
  - (a) Quantity
  - (b) Level of activity
  - (c) Method of disposal
- (ii) Liquid
  - (a) Quantity
  - (b) Level of activity
  - (c) Method of disposal
- (iii) Radioactive gas
  - (a) Quantity
  - (b) Level of activity

(7) Management of radioactive waste during accidents considered in design

(i) Solid waste

(a) Quantity

(b) Level of activity

(c) Method of disposal

(ii) Liquid waste

(a) Quantity

(b) Level of activity

(c) Method of disposal

(iii) Radioactive gas release

(a) Quantity

(b) Level of activity

(8) Radiological impact

(i) Normal operation

(ii) Accident conditions

(9) Co-located facilities like fuel reprocessing facility or storage of fresh and spent fuel

(10) Ambient radiation monitoring

A.6 Emergency management

(1) Physical and site characteristics that may hinder emergency plans

(2) Emergency management procedures

(3) Infrastructure characteristics related to the implementation of emergency plans

(i) Evacuation routes

(ii) Shelter

(iii) Medical facilities

(iv) Transportation

(4) Special considerations prescribed by the regulatory authority for special zones, such as exclusion zone and natural growth zone

(5) Demography within

  (i) Exclusion zone

  (ii) Natural growth zone of 5 km radius from reactor centre

  (iii) 10 km radius zone

  (iv) 16 km radius zone

  (v) 30 km radius zone

  (vi) Densely populated areas and population centers within 30 km zone

  (vii) Educational institutions, hospitals and prisons within 30 km zone

(6) Additional information on available infrastructure

  (i) Hospital/first aid center

  (ii) Fire station

(7) Consideration of emergencies arising out of common cause failures due to external events

A.7 Additional statutory requirements by the

(1) Central government

(2) State government

(3) Pollution control authority

  (i) Differential temperatures between the intake and outfall points of the condenser cooling water

  (ii) Effect of condenser water discharge on aquatic life

ANNEXURE-I

TYPICAL NUCLEAR FACILITIES AND POTENTIAL FOR IMPACT

Typical Facility [6]	General Characteristics
(i) Nuclear power plant (ii) Fuel reprocessing plant (iii) High level waste management plant (iv) Vitrified waste storage facilities (v) Waste tank farm (vi) High power research reactors (vii) Plutonium fuel fabrication plants	Potential for off-site radiological impact
(i) Fuel conversion (enrichment) plants (ii) Low power research reactors (iii) Mixed oxide fuel fabrication (iv) Spent fuel storage bay (independent) (v) Near surface disposal facilities (vi) Spent fuel dry storage facilities (vii) Intermediate and low level waste treatment facility (viii) Thorium storage facilities (ix) Tailing dams and associated check dams	Potential for on-site radiological impact
(i) Fuel fabrication plant (natural uranium fuel)	Potential for radiological impact within plant boundary
(i) Reprocessed uranium oxide plant (ii) Thorium plants (iii) Uranium mills (iv) H_2S based heavy water plant	Potential for radiological impact within plant boundary and off-site chemical hazard or off-site chemical hazard
(i) Zirconium sponge plant (ii) Other plants	Conventional or industrial buildings

[6] For nuclear facilities other than NPPs, the classification shall take into account capacity and associated inventories.

ANNEXURE-II

SCREENING DISTANCE VALUES

The screening distance values of different characteristics of a candidate site for NPP, during the stage of site evaluation process are given below for ready acceptance with respect to certain site characteristics. If a site does not satisfy any one of screening values, it can still be acceptable provided there exists a solution by means of engineering measures, i.e. design features, measures for site protection and administrative procedures.

S. No.	Characteristics	Screening Distance Value
1.	Distance from airports including military airfields	16 km
2.	Distance from military installations storing ammunitions etc.	16 km
3.	Distance from industrial facilities involving storage/handling of chemicals, explosives, etc.	16 km
4.	Distance from places of architectural/historical monuments, pilgrimage and tourists interest that could attract large floating population	5 km

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AERB SAFETY CODE NO. AERB/NF/SC/S (Rev.1)

Published by : Atomic Energy Regulatory Board
Niyamak Bhavan, Anushaktinagar
Mumbai - 400 094
INDIA.

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