ATOMIC ENERGY COUNCIL

Mandate: "To regulate peaceful applications of ionizing radiation in Uganda for the protection and safety of the public and the environment from the dangers resulting from ionizing radiation".

GUIDELINES ON CRITERIA FOR SITE SELECTION AND EVALUATION FOR NUCLEAR INSTALLATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AEC "Atomic Energy Council"

IAEA "International Atomic Energy Agency"

AEA, 2008 "Atomic Energy Act No. 24 of 2008

AER, 2012 "Atomic Energy Regulations, 2012"

DID "Defense in depth"

PSAR "Preliminary Safety Analysis report

FSAR "Final Safety Analysis Report"

PSR "Periodic safety Review"

SER "Site Evaluation report"

DEFINITIONS OF TERMS.

Combined license*:* means a combined construction permit and operating license with conditions for a nuclear power facility

Early Site Permit:means a Council's approvalfor a site or sites for one or more nuclear power facilities.

Exclusion area: means that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided these are not so close to the facility as to interfere with normal operations of the facility and provided appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety. Residence within the exclusion area shall normally be prohibited. In any event, residents shall be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety will result.

Low population zone: means the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident. This guide does not specify a permissible population density or total population within this zone because the situation may vary from case to case. Whether a specific number of people can, for example, be evacuated from a specific area, or instructed to take shelter, on a timely basis will depend on many factors such as location, number and size of highways, scope and extent of advance planning, and actual distribution of residents within the area.

Population center distance:means the distance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents.

Power reactor*:* means a nuclear reactor of a type designed to produce electrical or heat energy.

Safe Shutdown Earthquake Ground Motion: is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional.

Surface deformation: is distortion of geologic strata at or near the ground surface by the processes of folding or faulting as a result of various earth forces. Tectonic surface deformation is associated with earthquake processes.

1.0 INTRODUCTION

1.1 BACKGROUND

The effects of external events occurring in the region of a particular site and the characteristics of the site and of its environment are factors that could influence the transfer to persons and to the environment of radionuclides that might be released over the operating lifetime of the nuclear installation. As such, the section 74 of the Atomic Energy Act No. 24 of 2008 mandates the AEC to issue guidelines to better implement the law.

Principle 8 of IAEA safety fundamental SF-1 on prevention of accidents states that "All practical efforts must be made to prevent and mitigate nuclear or radiation accidents." This establishes the primary means of preventing and mitigating the consequences of accidents as 'defense in depth'. The DID is provided by an appropriate combination of specified systems and measures, one of which being "Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy". To apply the DID principle, the suitability of a site for a nuclear installation shall be evaluated with regard to the following:

a) The effects of external events occurring in the region of the particular site (these events could be of natural origin or human induced);
b) The characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material that has been released;
c) The population density and population distribution and other characteristics of the external zone in so far as they may affect the possibility of implementing emergency measures and the need to evaluate the risks to individuals and the population."

The selection and the evaluation of a site suitable for a nuclear installation can significantly affect the costs, public acceptance and safety of the installation over its operating lifetime. The outcome of the process may even affect the success of the nuclear power project. Poor planning and execution, lack of information and lack of knowledge of international safety standards and recognized good practices could lead to faulty decision making and could cause major delays, either at the construction stage or at the operational stage of a nuclear installation.

Faulty decisions made at the site selection stage might necessitate major resource commitments at a much later phase of the project. If the site related design parameters are changed during the operational stage, re-evaluation of and upgrades to the installation during operation may consequently be necessary, possibly necessitating extended shutdown periods and causing considerable costs.

The selection process for a suitable site for a nuclear installation is a multifaceted process that includes safety considerations. With regard to accident prevention, siting is intended to prevent accidents arising from external hazards associated with external events.

Siting involves a comprehensive process of screening out sites for which external hazards are significant or could become significant. Siting also involves screening out sites for which the additional safety measures in the design that would be necessary to address such hazards would be excessively demanding, or sites where knowledge is not sufficient to define these measures with a sufficient degree of confidence.

With regard to mitigating the consequences of accidents, siting is intended to reduce the possible impacts of an accident on people and on the environment. It involves the selection of a site with favorable dispersion characteristics for radionuclides in the air, in surface water and subsurface water, and also with a terrain, population distribution and infrastructure that would facilitate the implementation of an emergency plan.

The siting process, from the beginning, has to be guided by a clearly established set of criteria consistent with the requirements of the AER, 2012.

The approach in this Safety Guide ensures that issues associated with site safety are considered early in the process and that alternative sites are available in the event that the selected site does not meet the requirements on the basis of the detailed site characterization. It is important that external hazards are identified early to allow for adequate consideration of protective measures that may be necessary to provide sufficient defense in depth.

1.2 OBJECTIVES

The objective of this Safety Guide is to provide guidance in the siting process for a nuclear installation.Guidance has been provided on criteria and approaches for identifying suitable sites for nuclear installations that comply with requirements

of Council and the international safety requirements. This Safety Guide provides guidance on establishing a systematic process for site survey and site selection for a number of preferred candidate sites, from which one could be selected for the construction and operation of a nuclear installation.

This Safety Guide is intended for use by Council and other organizations with an interest in the siting process, including government bodies, future licensees (generally the operating organizations) and their contractors. This Safety Guide also has an informative role for the regulatory body. However, the siting is a non-regulated process and does not require regulatory actions.

1.3 SCOPE

This Safety Guide addresses the consideration of safety in the siting process for a nuclear installation. It is recognizes the other important factors in the siting process, possibly regarding both safety and non-safety issues, such as nuclear security considerations, technology, economics, land use planning, availability of cooling water, non-radiological environmental impacts and socioeconomic impacts, among them the opinion of interested parties, including the public.

As the siting process progresses, more and more sites are screened out. For the few potential sites that remain, safety considerations will become more pronounced.The Safety Guide covers the process that eventually terminates in the site selection for one or more nuclear installations as well as providing guidance on the siting of a nuclear installation at a new site.

The methodologies recommended for nuclear power plants can be applied to other nuclear installations through a graded approach. The recommendations can be tailored to meet requirements for different types of nuclear installation in accordance with the potential radiological consequences of accidents.

The recommended direction of grading is to start with attributes relating to nuclear power plants and, if possible, to grade down to installations with which lesser radiological consequences are associated. If no grading is performed, the recommendations relating to nuclear power plants are applicable to other types of nuclear installation.

This Safety Guide does guidance on site characterization and does not establish an assessment of site hazards for use in a design evaluation for licensing

purposes. The Safety Guide refers to but does not provide guidance on considerations relating to nuclear security.

1.4 STRUCTURE

Section 2 addresses the siting and site evaluation processes. Section 3 provides general guidance for site selection for a nuclear installation. Section 4 describes the basis for screening criteria for the siting process. Section 5 provides guidance with regard to investigations necessary for the different stages of the site survey and site selection process. Section 6 deals with criteria for ranking sites of nuclear power plants. Section 7 provides provided criteria for classifying sites. Section 8 provides the different data necessary or required at the different stages of siting processes and section 9 provides guidance for the management system for site evaluation process. The Appendix provides recommended database for the siting process. Annex I presents tables to be used in the siting process, including criteria for screening and ranking. Annex II provides example criteria for the siting process for nuclear power plants while Annex III provides examples of screening values.

1.5 AUTHORITY

Atomic Energy Act No. 24 of 2008 and Atomic Energy Regulations 2012

2. GENERAL DESCRIPTION OF THE SITING PROCESS AND THE SITE EVALUATION PROCESS.

1) There are two processes relating to the safety considerations for the site of a nuclear installation i.e.; the siting process and the site evaluation process. These two processes are further split into five stages:

a) Site survey stage;
b) Site selection stage;
c) Site characterization stage (site verification and site confirmation);
d) Pre-operational stage;
e) Operational stage.

2) The framework for the site survey stage and the site evaluation stage is elaborated in the schematic representation shown in Fig. 1.

3) Siting is the process of surveying and selecting a suitable site for a nuclear installation. The selection of a suitable site is one of the elements of the concept of defense in depth for preventing.

4) The siting process and the site evaluation process include five different stages. The siting process for a nuclear installation consists of the first two stages of these five, i.e. site survey and site selection (see Fig. 1).

5) In the site survey stage, large regions are investigated to find potential sites and to identify one or more candidate sites. The second stage of the siting process is site selection, in which unsuitable sites are rejected and the remaining candidate sites are assessed by screening and comparing them on the basis of safetyand other considerations to arrive at the preferred candidate sites.

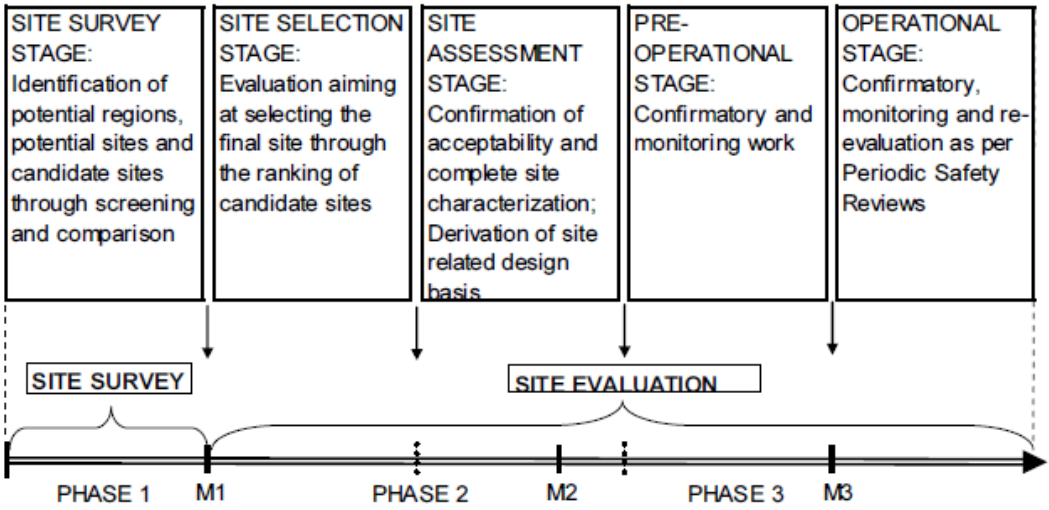

Figure 1: Stages in the siting process and site evaluation process in the operating lifetime of a nuclear installation.

6) Site evaluation is the process that extends from:

a) the last stage of the siting process (i.e. the stage of evaluation of the candidate sites in order to arrive at the preferred candidate site(s)) to;
b) the detailed site characterization stage for the selected site to confirm its suitability, its characterization and derivation of the site related design basis for the nuclear installation to;

c) the confirmation and completion of the assessment at the pre-operational stage for the installation (i.e. during the design, construction, assembly and commissioning stages) and finally to;
d) the operational stage of the installation included within the framework of periodic safety review.

7) Site evaluation continues throughout the operating lifetime of the installation, with appropriate components covered in the final safety analysis report, to take into account changes in site characteristics, the availability of data and information, operational records, regulatory approaches, evaluation methodologies and safety standards.

8) Site selection includes part of the site evaluation process and is the overlapping stage between the siting process and the site evaluation process (see Figs 1 and 2). After the site selection stage, the suitability of the site is confirmed and a complete site characterization is performed, together with finalizing the derivation of the design basis due to external events during the site characterization stage.

9) After site evaluation, an evaluation report is prepared as a basis for the 'site' section of the preliminary safety analysis report for the nuclear installation. All the site related activities involving confirmatory and monitoring work are taken up in the pre-operational stage.

10) The site evaluation at the operational stage starts after the approval of the final safety analysis report for the nuclear installation. This includes all confirmatory, monitoring and re-evaluation work conducted throughout the operational stage, and especially during periodic safety reviews of the installation. Periodic safety review reports should be submitted to Council at defined intervals.

11) Siting is a non-regulated activity and no license is required. Siting and site evaluation processes should be consistent with the licensing process as specified in the Atomic Energy Regulation, 2012 and should also be consistent with the applicable IAEA safety standards.

12) The site characterization stage is further subdivided into: site verification, in which the suitability of the site to host a nuclear installation is verified mainly according to predefined site exclusion criteria, and site confirmation, in which the

characteristics of the site necessary for the purposes of analysis and detailed design are determined.

13) In the pre-operational stage, studies and investigations should begin in the previous stages after the start of construction and before the start of operation of the nuclear installation so as to complete and refine the assessment of site characteristics. The site data obtained allow a final assessment of the simulation models used in the final design.

14) At the operational stage, appropriate safety and security related site evaluation activities are carried out over the operating lifetime of the nuclear installation, mainly by means of monitoring and periodic safety review.

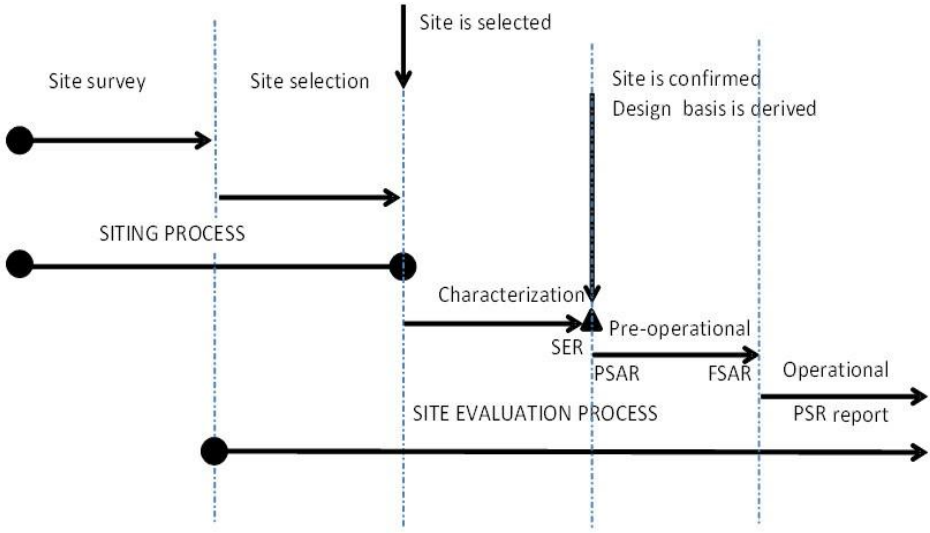

Figure 2: Outcome of the siting process and site evaluation process for a nuclear installation.

15) The three important steps that should receive input from site survey, site selection and the site evaluation process before construction starts include;

a) The decision regarding the suitability of the preferred site, i.e. confirmation that the site has no characteristics that would preclude the safe operation of a nuclear installation;
b) The definition of the site related design basis parameters on the basis of the site evaluation report;

c) The preparation of the preliminary safety analysis report or preliminary safety case which, among other things, demonstrates that the site related design basis parameters have been appropriately taken into account, in particular through the design features of the nuclear installation and the measures to be taken for site protection.

The site should be deemed unsuitable for the purposes of the licensing of the proposed installation if it is concluded during characterization of external hazards that no engineering solutions exist to design protective measures against those hazards that challenge the safety of the nuclear installation, or there are no adequate measures to protect people against unacceptable radiological risks.

The future operator of the proposed installation on the site should have an early role to play in reviewing and accepting work done during siting, even if the future operator does not have a direct role in selecting the site.

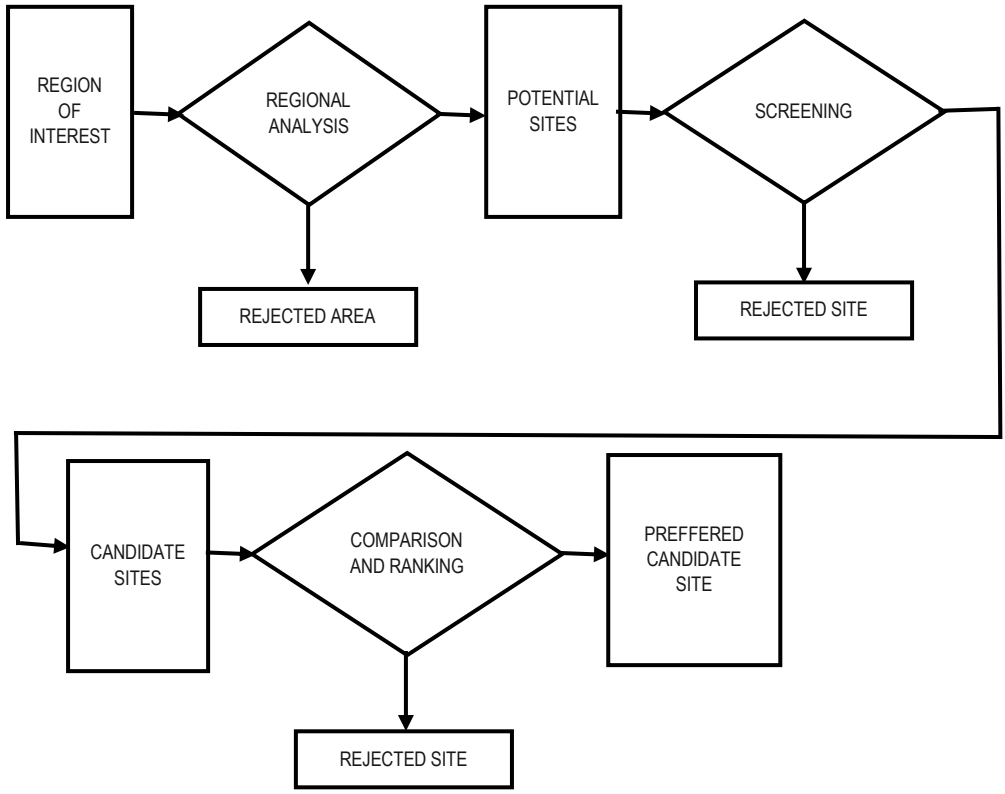

Figure 3: Site Selection process

3.0GENERAL GUIDANCE FOR THE SITING PROCESS

3.1 SITING PROCESS

1) The siting process is intended to select suitable locations for the envisaged nuclear installation. This is to ensure that its characteristics are compatible with available engineering protective measures for all natural and human induced hazards arising from external events, so that the necessary level of safety can be achieved.

2) The surrounding demographic setting and dispersion characteristics should be such as to limit the exposure of the population for any plant state to as low as reasonably achievable, and to allow the implementation of measures for mitigating the consequences of any accidental release of radionuclides over the operating lifetime of the installation.

3) The siting process consists of a series of related activities with the objective of selecting suitable sites for a new nuclear installation. A number of screening criteria must be applied to screen out those sites with attributes which contribute unfavorably to the safety of the installation. A flow chart of the siting process for a nuclear installation is given in Fig. 3.

4) The siting process has three distinct steps starting with the region(s) of interest as given.

3.1.1 Regional analysis:

This is the first step, in which region(s) of interest are analyzed to identify potential sites. All potential sites in a region should be taken to the next step (screening) unless their exclusion can be appropriately justified.

3.1.2 Screening analysis:

In the second step, the potential sites are screened to choose the candidate sites. The principal objective of this step is to exclude unfavorable sites on the basis of both safety related considerations and non-safety-related considerations.

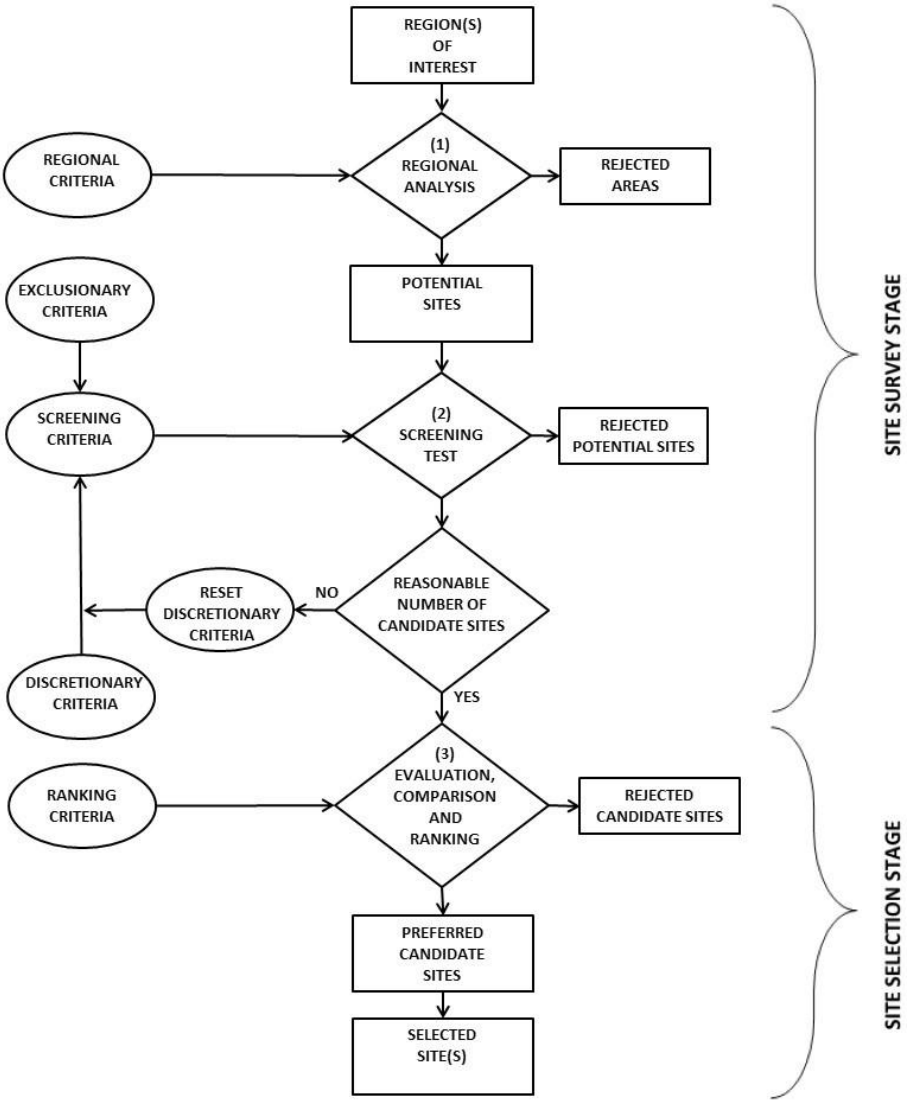

Figure 4: Flow chart for the siting process for a nuclear installation.

3.1.3 Evaluation, comparison and ranking:

1) The purpose of the third step is twofold:
   (i) to evaluate the sites in order to ensure that there are no features (at the sites or in their surrounding areas) that would preclude the construction and operation of the nuclear installation, and;

(ii) to compare the candidate sites and to rank them in order of their attractiveness as possible sites for a nuclear installation. The candidate sites should therefore be placed in an order of preference to allow the selection of a potentially suitable alternative site.

2) The siting process is completed once the site on which the nuclear installation will be located has been selected from the list of preferred candidate sites.

3) The final selection is generally made by the government or operating organization (future licensee) for the nuclear installation, with input from all the relevant stakeholders. The operating organization, the future licensee, should be involved from the outset of the siting process.

3.2 SITING CRITERIA

1) Siting criteria provides the basis on which decisions are made in consideration of the site attributes in the different steps of the siting process. Siting criteria are used to evaluate specific site related issues, events, phenomena, hazards and other considerations after the site has been investigated and analyzed.

2) As shown in Fig. 3, there are three categories of siting criteria i.e.: regional criteria, screening criteria and ranking criteria.

3) The regional criteria should becarried out to identify potential sites andshould be based on the national economic policy, national and international environmental protection or other related policies.

3) Technical constraints and the availability of resources (e.g. infrastructural constraints, availability of water) on a regional basis should also be important considerations for regional analysis. The regional criteria should identify all possible potential sites and no site should be discarded without appropriate justification.

4) The screening of potential sites should be conducted using screening criteria of two types:

i. *Exclusion criteria*: This is used to discard sites that are unacceptable on the basis of attributes relating to issues, events, phenomena or hazards for which there are no generally practicable engineering solutions.

ii. *Discretionary criteria*: The discretionary criteria are associated with those attributes relating to issues, events, phenomena, hazards, or other considerations, for which protective engineering solutions are available.[See Table 1].

5) The resulting candidate sites should be placed in an order of preference through an exercise of comparison and ranking using suitable ranking criteria.The screening criteria and ranking criteria should consist of both safety related and non-safety-related criteria. Screening criteria and ranking criteria are further elaborated in Table 1.

4. GENERAL BASIS FOR SCREENING CRITERIA

4.1 Exclusion criteria

1) Exclusion criteria should be established and used as part of the screening at the site survey stage. Screening by exclusion criteria enables sites with unfavorable characteristics to be excluded from further consideration.

2) Exclusion criteria should be selected for the negative attribute of a site characteristic, or for any site related issue, event, phenomenon or hazard for which engineering, site protection or administrative measures are not available or are excessively demanding.

3) The criteria should not only encompass inherent weaknesses in a site's characteristics, but also the feasibility of engineering solutions to compensate for such weaknesses, either through design or through site protection measures. Therefore, the existence of a certain hazard or even the high likelihood of its occurrence should not constitute the sole basis upon which an exclusion criterion is based.

4) Screening out on the basis of an arbitrary criterion may lead to the discarding of a site with otherwise favorable qualities for safety and may finally result in the choice of a site that is less safe than the site that has been discarded.

4.2 Discretionary criteria

1) Discretionary criteria should be established:

i. To decrease the number of possible candidate sites if their number is too large to conduct the exercise of comparison and ranking;
ii. To increase the number of candidate sites if their number is too small or if there are none.

2) This is generally an iterative process in which criteria may be made more or less strict depending on the desired number of potential sites for further consideration. Attributes relating to these criteria are also used for the preliminary evaluation of a site in the site selection stage of the siting process.

3) A number of candidate sites are identifiedas a result of the iterative screening of potential sites. If candidate sites are distributed in two or more regions with different attributes, this would preclude the possibility of the elimination of all the candidate sites on the basis of common regional shortcomings; e.g. for two candidate sites that are geographically widely separated, the seismic hazard may differ widely at the two sites, which reduces the risk of both sites being eliminated later in the siting process owing to concerns over the seismic safety of the proposed nuclear installation(s).

4) The siting process for a nuclear installation is expected to be completed using existing data. However, at an early stage, especially during the site survey stage, it may not always be possible to collect a sufficient amount of good quality data on which such a decision could be based with adequate certainty. In such a case, additional data should be collected to confirm the suitability of the site in the subsequent site selection stage. Some preliminary field investigation, if required, should also be conducted at this stage.

5.0 SPECIFIC SCREENING CRITERIA

In relation to the characteristics and distribution of the population, the combined effects of the site and the installation shall be such that;

1) For operational states of the installation the radiological exposure of the population remains as low as reasonably achievable and in any case is in compliance with regulatory requirements, with account taken of international recommendations;

2) The radiological risk to the population associated with accident conditions, including those that could lead to emergency measures being taken, is acceptably low.

a) If, after thorough evaluation, it is shown that no appropriate measures can be developed to meet the above mentioned requirements, the site shall be deemed unsuitable for the location of a nuclear installation of the type proposed.

b) The external zone for a proposed site shall be established with account taken of the potential for radiological consequences for people and the feasibility of implementing emergency plans, and of any external events or phenomena that may hinder their implementation. Before construction of the plant is started, it shall be confirmed that there will be no insurmountable difficulties in establishing an emergency plan for the external zone before the start of operation of the plant.
c) Where reliable evidence shows the existence of a capable fault that has the potential to affect the safety of the nuclear installation, an alternative site shall be considered.
d) Geological maps and other appropriate information for the region shall be examined for the existence of natural features such as caverns, karstic formations and human made features such as mines, water wells and oil wells. The potential for collapse, subsidence or uplift of the site surface shall be evaluated.If the evaluation shows that there is a potential for collapse, subsidence or uplift of the surface that could affect the safety of the nuclear installation, practicable engineering solutions shall be provided or otherwise the site shall be deemed unsuitable.
e) The potential for liquefaction of the subsurface materials of the proposed site shall be evaluated by using parameters and values for the site specific ground motion.If the potential for soil liquefaction is found to be unacceptable, the site shall be deemed unsuitable unless practicable engineering solutions are demonstrated to be available.
f) The potential for aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircraft.If the assessment shows that there is a potential for an aircraft crash on the site that could affect the safety of the installation, then an assessment of the hazards shall be made.
    i. The hazards associated with an aircraft crash to be considered shall include impact, fire and explosions.If the assessment indicates that the hazards are unacceptable and if no practicable solutions are available, then the site shall be deemed unsuitable.
g) Hazards associated with chemical explosions shall be expressed in terms of overpressure and toxicity (if applicable), with account taken of the effect of distance.A site shall be considered unsuitable if such activities take place in its vicinity and there are no practicable solutions available.

h) The region shall be investigated for installations (including installations within the site boundary) in which flammable, explosive, asphyxiate, toxic, corrosive or radioactive materials are stored, processed, transported and otherwise dealt with that, if released under normal or accident conditions, could jeopardize the safety of the installation. If the effects of such phenomena and occurrences would produce an unacceptable hazard and if no practicable solution is available, the site shall be deemed unsuitable.

i) Potential natural and human induced events that could cause a loss of function of systems required for the long term removal of heat from the core shall be identified, such as the blockage or diversion of a river, the depletion of a reservoir, an excessive amount of marine organisms, the blockage of a reservoir or cooling tower by freezing or the formation of ice, ship collisions, oil spills and fires. If the probabilities and consequences of such events cannot be reduced to acceptable levels, then the hazards for the nuclear installation associated with such events shall be established."

6.0 BASIS FOR RANKING CRITERIA

The ranking criteria are necessary to provide bases for comparison between the candidate sites so as to arrive at a list of preferred candidate sites. For safety related issues, comparison within topical areas is generally quite straightforward. E.g. sites with a higher seismic hazard would be penalized in comparison with those in more geologically stable areas.

1) Thoughtful considerations should be made when comparing a site with a higher seismic hazard but lower flood hazard with another site that has a higher flood hazard but lower seismic hazard.
2) Ranking criteria are generally developed by using considerations relating to discretionary criteria together with relevant non-safety-related considerations.
3) A sufficient amount of data should be collected before a comparison based on a particular criterion is made between two (or more) sites. To the extent possible, the amount and quality of the data upon which the comparison is to be based should be similar for the regions or possible sites being compared.

4) The candidate sites should be ranked in order to determine the preferred candidate site or several preferred candidate sites.
5) One criterion for ranking candidate sites may be the likelihood that the specific site parameters are within the standard plant parameter envelope of potential suppliers for nuclear installations. Suppliers of technologies for nuclear installations typically offer non-site-specific generic design information for consideration when bounding envelopes are being used in siting process.

7.0 CLASSIFICATION OF SITING CRITERIA

Criteria used in the siting process for a nuclear installation are classified as follows:

a) Safety related criteria;
b) Criteria relating to nuclear security;
c) Non-safety-related criteria.

Such criteria may be screening criteria (i.e. exclusionary or discretionary criteria) or ranking criteria.

7.1 Safety related criteria

Safety related criteria to be considered in the siting process should be consistent with the regulatory requirements and with the associated IAEA Safety Guides relating to site evaluation for nuclear installations. From a thematic perspective, these criteria are classified into four sets.

1) The first set of criteria is related to the potential impact of natural hazards on the safety of the nuclear installation. In this context, the following natural hazards should be considered:

a) Capable faults (i.e. faults that may cause surface displacement near the nuclear installation);
b) Vibratory ground motion due to earthquakes;
c) Volcanic hazards;
d) Coastal flooding or low water intake level (including inundation as well as receding water levels due to wave action, storm surges, seiches or tsunamis);
e) River flooding (overtopping of banks due to failure of water retaining structures such as dykes or dams) or low water intake level due to low river flow or drought;

f) Blockage of intake channels (e.g. due to marine organisms, ice, debris, ship collisions, oil spills or fires);
g) Combinations of coastal and river flooding (e.g. in estuaries), and flash floods due to intense precipitation or downbursts;
h) High winds — both straight winds such as hurricanes and tropical storms and rotational winds such as tornadoes;
i) Local phenomena such as sand storms and dust storms;
j) Other extreme meteorological events such as droughts, extreme precipitation, including snow pack, extreme hail, lightning and extreme temperatures, including the temperature of the source of cooling water;
k) Geotechnical hazards such as slope instability, soil liquefaction, landslides, rock fall, avalanche, permafrost, erosion processes, subsidence, uplift and collapse;
l) Forest fires;
m) Credible combinations of events (i.e. combinations of both dependent and independent events that potentially could lead to more severe consequences than for a single hazard, such as a seismic event together with flooding, or wind together with snow).

2) The second set of criteria is related to the potential impacts of human induced events and nuclear security events on the safety of the nuclear installation. In this context, the following origins of potential human induced hazards should be considered:

a) Stationary sources:
    i. Other nuclear installations, oil and gas operations, chemical plants, processing of hazardous materials such as commercial facilities for manufacturing or storing munitions, broadcasting and communication networks, mining or quarrying operations, high energy rotating equipment and hydraulic engineering structures;
    ii. Military facilities (permanent or temporary), especially shooting ranges and arsenals.
b) Mobile sources:
    i. Surface transportation (e.g. railways and roads, and oil, gas and other pipelines);

ii. Airport zones and harbor zones (military and civilian); (iii) Air traffic corridors and flight path zones (military and civilian). (c) Electromagnetic interference.

3) The third set of criteria is related to the characteristics of the site and its environment that could influence the transfer of radioactive material released from the nuclear installation to people and the environment. In this context, the following phenomena should be considered:

a) Atmospheric dispersion of radioactive material;
b) Dispersion of radioactive material in surface water;
c) Dispersion of radioactive material in groundwater;
d) Population density and population distribution and distance to centers of population, including projections for the operating lifetime of the nuclear installation.

4) The fourth set of criteria is linked to the third set but it relates mainly to the demonstration of the feasibility of implementation of the emergency plan for the nuclear installation. In this context, the following phenomena should be considered:

a) Physical characteristics of the site that could hinder implementation of the emergency plan (in particular, geographical features such as islands, mountains and rivers);
b) Infrastructural characteristics relating to the implementation of the emergency plan (especially local transport infrastructure and communications networks);
c) Considerations of populations (e.g. special population groups with regard to protective actions in the event of a nuclear or radiological emergency, such as elderly and disabled persons and hospital patients and prisoners), and land and water use considerations;
d) Specific requirements of the regulatory body for special zones, such as emergency planning zones and distances;
e) Industrial facilities that could involve potentially hazardous activities; (f) Impacts of concurrent external hazards on infrastructure.

Examples of criteria for the siting process are presented in Annex II.

7.2 Criteria relating to nuclear security

Nuclear security aspects should also be considered in siting nuclear installations, taking account of the guidance provided in the Atomic Energy regulations, 2012

and the IAEA Nuclear Security Series. Typically, this includes consideration of site characteristics that could affect the ability to implement physical protection measures and the capability to deter, detect, delay and respond to nuclear security events.

7.3 Non-safety related criteria

In the site survey and site selection process, another set of criteria are concerned with considerations that are not directly related to nuclear safety. These include; availability of cooling water, topography, access to electrical grid, non-radiological environmental impacts, and socioeconomic impacts, among others. The non-safety-related criteria should be considered together with the considerations relating to nuclear safety, especially in the ranking of the candidate sites.

8.0 DATA NECESSARY AT DIFFERENT STAGES OF THE SITING PROCESS

1) Site selection should make use of the detailed process of data collection and evaluation. In particular, the site survey stage should be based on information and data collected principally from existing sources such as available records, satellite images, topographic sheets and information available from local authorities and other institutions.

2) It may be that a potential site could not satisfy all the screening criteria on the basis of information collected at the site survey stage, but that it is likely to be able to satisfy these screening criteria with the help of additional study and investigation. Therefore, the additional study and investigation and the related screening test should be initiated as soon as possible so that the results are available in the next stage, i.e. the site selection stage. The input information and data collected during the site survey are important and should be considered for all site related activities prior to construction.

3) The siting process for a nuclear installation starts on a regional basis and each step is focused on selecting potential sites and candidate sites. The data acquisition and processing for these stages should be in line with this purpose. Accordingly, these stages should generally start with the consideration of

regional data presented on a large scale (rougher data; data of low resolution) and should proceed to the consideration of local data presented on a smaller scale (finer data; data of higher resolution).

4) The level of detail of the different sets of data should be consistent with the aims for the specific steps of the siting process.

5) In the analyses performed on the basis of the data collected, the operating lifetime of the nuclear installation should be considered. Appropriate projections should be made, especially in relation to parameters that may show significant variation with time. Data that may change gradually should be considered.

6) The potential impact of climate change on site related hazards should be considered,especially in terms of the possibility of increased incidence and intensity of extreme meteorological and hydrological phenomena. Uncertainties associated with these phenomena should be taken into account.

7) The general approach to site survey and site selection should be directed towards reducing the uncertainties at various steps of the siting process in order to obtain reliable results based on the data.

8) The acquisition and processing of data to be used in relation to siting criteria should be performed subject to the requirements for quality management.

9) All data on the site should be collected in a systematic, transparent, retrievable and traceable manner. The use of tools such as a geographical information system should be considered, especially for the data collected in relation to the preferred candidate sites.

10) A site specific database should be developed, containing all relevant site characteristics as established in the siting process. These include;

a) Geological data
b) Hydrogeological data;
c) Seismological data;
d) Data relating to fault displacement;
e) Volcano logical data;
f) Geotechnical data;
g) Data on coastal flooding including tsunamis;
h) Data on river flooding;
i) Data on meteorological events;

j) Data on human induced events;
k) Data on population, land use, water use and environmental impacts.

11) For the screening and ranking criteria, the site characteristics should be used as a basis for the decision on whether a site should be kept or screened out, and if a site is kept, how it should be ranked with respect to other candidate sites.

12) The decision for keeping or screening out a site could be based on conclusions drawn from one category of the site characteristics or more, as it is not always necessary to consider all categories for every criterion. The categories of site characteristics are described in the Appendix, and criteria associated with the data are listed in Table Iof Annex I.

13) In the initial site survey stage, readily available data should be collected from relevant national and local authorities and other organizations. The data could include contextual maps for undertaking a qualitative desktop study in order to establish relatively quickly whether the site can be screened with respect to exclusionary criteria, and the likely impacts of discretionary screening and ranking criteria on such contextual site maps.

14) In the second stage (site selection), a more detailed examination of how the site fares against the ranking criteria should be conducted. This is to obtain sufficient information and analysis to enable confident judgments to be made using the ranking criteria. A firm decision on site selection should be made by the site owner, operating organization or both with the reasoning for it recorded.

15) Comprehensive surveys of the relevant literature and, specific fieldwork will be required (e.g. to identify local sub-map-scale, topographical features of significance or to confirm geological features from local rock exposures).

16) Although the data on some external hazards are likely to be limited and of variable quality, analysis will be required and should be undertaken, such as:

a) Analysis of hazards associated with accidental aircraft crashes;
b) Analysis of effects of nearby industrial facilities on the proposed site, for example, impacts of fires and chemical explosions and effects of dispersion for hazardous airborne releases that could affect the site;
c) More detailed analysis of local fault displacement capability;
d) Estimation of the seismically induced soil liquefaction potential at the site;

e) Generation of a set of hazard curves for extreme meteorological and flooding events, e.g. in relation to wind, precipitation, temperature, and sea and river flooding, covering return periods appropriate to the nuclear installation in question.

17) The judgments made should be sufficiently robust to provide a high degree of confidence that they will not be called into question by further data collected or by further analysis in the site evaluation process.

9.0 MANAGEMENT SYSTEMFOR SITE EVALUATION PROCESS

1) The siting process should be addressed in the overall management system for the nuclear installation project. The management system for siting should be established at the earliest possible time consistent with its implementation in the conduct of activities for the site survey and site selection stages of the nuclear installation and should meet the regulatory requirements.

2) The management system established by the operating organization (future licensee)and the contractors that carry out the work for selection of the site for a nuclear installation should comprise of a comprehensive quality management program.

3) The management system, in accordance with the AER, 2012 should cover organization, planning, work control, personnel qualification and training, verification and documentation for all the activities concerned to ensure adequate performance of these tasks and adequate reporting.

4) The results of the activities for site investigation should be compiled in a report that documents the results of all in situ work, laboratory tests and geotechnical analyses and of more general safety related evaluations.The studies and investigations should be documented in sufficient detail to permit their independent review.

5) Records should be kept of the work carried out as part of the site selection activities for the nuclear installation.

The following should be considered when developing the management system for the siting process:

a) The intended end uses of the knowledge, information and data that result from the activities in the siting process, in particular in terms of their consequences for safety;

b) The capability to demonstrate, test or repeat the results;
c) The scale and technical complexity of the activities in the siting process, whether it is a new or proven concept or a model that is being applied or an extension of a new application;
d) The managerial complexity of the activity and the involvement and coordination of personnel in multiple disciplines, work units or internal or external organizations, with divided or contingent objectives and responsibilities;
e) The extent to which other site characterization work, or later work, depends on the results of the siting activities;
f) The desired use or application of the results.

9.1 SPECIFIC REQUIREMENTS

1) A project work plan should be prepared prior to, and as a basis for, the execution of the project for siting, including site survey and site selection.
   a) The work plan should convey the complete set of general requirements for the nuclear installation (such as the total power generation capacity of the nuclear power plant), including applicable regulatory requirements.
   b) The work plan should also delineate the following specific elements: personnel and their responsibilities; work breakdown and project tasks; schedule and milestones; and deliverables and reports.
2) A quality assurance program should be established, implemented and documented under the management system to cover all activities for data collection and data processing, field and laboratory investigations, analyses and evaluations that are within the scope of this Guide.
3) Results of the activities during the site survey and site selection stages should include all outputs indicated in the work plan. The reporting of the site survey and site selection should be specified in sufficient detail in the work plan.
4) The site selection process should be traceable and transparent to the users and reviewers by providing the following;
   a) A description of all elements of the process;
   b) Identification of the participants in the study and their roles;
   c) Background material that comprises the documentation of the analysis, including raw and processed data, computer software and input and

output files, reference documents, results of intermediate calculations and sensitivity studies.

5) This material should be maintained in an accessible, usable and auditable form by the responsible organization. Documentation or references that are readily available elsewhere should be cited where appropriate. All elements of the site survey and site selection should be addressed in the documentation.
6) The documentation should also identify all sources of information used in the site survey and site selection, including information on where to find important sources of information cited that may be difficult to obtain. Unpublished data that are used in the analysis should be included in the documentation in an appropriately accessible and usable form.
7) If earlier studies for site survey and site selection for the same region are available, studies should be made to demonstrate how different approaches or different data affect the earlier conclusions. These should be documented in a way that allows their review.
8) If various investigations are carried out (in field, laboratory and office), technical procedures that are specific to the activity concerned should be developed to facilitate the execution and verification of these tasks, and a peer review of the process should be conducted.
9) Requirements for the application of a management system should be established by the responsible organizations to ensure that the processes of and inputs from their contractors are appropriate. The responsible organization for siting should identify the quality assurance standards that should be met.
10) Special provisions should be specified to address document control, analysis control, software, validation and verification, procurement and audits, and non-conformance and corrective actions. Work related documents should be prepared to cover all the activities under the program mentioned in para. 7.9.

APPENDIXA:DATABASE FOR THE SITING PROCESS

The extent of the work necessary to develop an appropriate database for the siting process will depend on the nature of the site, on how easy it is to meet the siting

criteria (especially the exclusion criteria) and on the level of effort necessary for the comparison and ranking between the candidate sites.

The database for the siting process should be comprehensive and up to date, and should be compiled so as to support the evaluation and judgment of the relevant number of activities.

A.1 GEOLOGICAL AND HYDROGEOLOGICAL DATABASE

The objective for the geological and hydrogeological database is to collect all the data necessary to enable judgments of site suitability to be made confidently on the basis of the siting criteria. The extent and quality of data collection may vary depending on the stage in the site survey and site selection process for which the data are used.

The radius of the relevant region to be studied is typically 150–300 km and depends on the seismotectonic setting of the site, the type of installation and the method or approach of the hazard assessment.

The following summarizes the data necessary at different stages.

1)Site survey stage

Use should be made of existing data available from national and local archives such as the following:

a) Regional geological maps, including those containing data on stratigraphy, i.e. with appropriate cross-sections.
b) Tectonic maps;
c) Hydrogeological maps;
d) Regional geophysical maps, indicating gravity and magnetic anomalies;
e) Satellite imagery.

2)Site selection stage

At this stage, the datashould be augmented with more detailed information. This requires more detailed and site specific information such as existing borehole logs and geophysical surveys to be obtained and studies of the site to be undertaken, for example by means of geological fieldwork, to confirm its geological and hydrogeological characteristics.

A.2 SEISMOLOGICAL DATABASE

The ground motion to be considered in the siting process should be determined as appropriate for the installation under consideration by postulating a ground motion to occur with a very low probability over its operating lifetime.

Geological, seismological and geotechnical characteristics of the potential site and candidate sites should be considered. The requirements for detailed data (for the final site selection process) are the same as those for nuclear safety and are specified in the IAEA SSG-9.

1) Site survey stage

Major earthquakes that may have had significant impacts on the proposed site should be selected by using available earthquake catalogues, with account taken of the characteristics of causative faults. This preliminary information will be used for identification of the seismically active zones and for preliminary estimation of seismicity for the potential sites to be used in the screening process.

2) Site selection stage

Available information on prehistorical, historical and instrumentally recorded earthquakes in the region and paleoseismological data if available should be collected and documented. A catalogue should be compiled that includes all information on earthquakes developed for the project covering all these temporal scales.

In particular, all available ‘pre-instrumental’ historical data on earthquakes (that is, events for which no instrumental recording was possible) should be collected, extending as far back in time as possible.

A.3 DATABASE RELATING TO FAULT DISPLACEMENT

A fault displacement hazard arises when an earthquake event on a fault close to or beneath safety related structures of a nuclear installation causes displacement to occur that may directly affect the safety of the installation. This hazard is also referred to as a capable fault hazard. A clear definition of a capable fault is given in the IAEA SSG-9 together with a listing of recommended site investigations in relation to potential capable faults.

1) Site survey stage

Capable faults should be thoroughly investigated by integrating geomorphological, geological, geodetic and geophysical methods to make clear the locations, shapes, activity and characteristics of the capable faults, while also considering their distance from the proposed site. At this stage, the available site specific data may not be sufficient but a literature survey relating to the suspect features would be a reasonable source of information.

2) Site selection stage

An in-depth investigation should be made of the capable faults within the area of the site vicinity (5 km radius) that combines the survey of existing reference materials, tectonic geomorphological investigation, investigation of surface geological features, and geophysical and other investigations.

A.4 VOLCANOLOGICAL DATABASE

Volcanic products such as lava flows, pyroclastic flows, lahars and ash fall (among many others) may affect the safe operation of a nuclear installation. The effects of such products should be evaluated for potential and candidate sites if they are in volcanic regions.

1) Site survey stage

The volcanological database should include descriptions of any volcanic products at the site. For Holocene period and younger volcanoes, including those that are known to be currently active, if the volcanic products could have an impact on the safe operation of a nuclear installation under consideration, the entire geological history of the volcano should be investigated.

2) Site selection stage

An evaluation of the uncertainty in age determinations should be included in this assessment. For example, the stratigraphy of pyroclastic units is commonly complex and incomplete. Assessment of the completeness of the geological record should be attempted, even if not all volcanic deposits can be mapped. The ages of volcanic deposits should be quantified if possible to describe the history of volcanic activity. Detailed data requirements are similar to those recommended in the IAEA SSG-21.

A.5 DATABASE ON GEOTECHNICAL HAZARDS

Investigation of the subsurface conditions at the site of a nuclear installation should be carried out at all stages of the site selection and site evaluation processes. This is to provide information or basic data for decisions on the nature and suitability of the subsurface materials. At each stage of the process, the investigation program should be used to provide the necessary data for an appropriate characterization of the subsurface. The specific requirements will vary greatly from stage to stage.

1) Site survey stage

The various methods of investigation that is, the use of current and historical documents, geophysical and geotechnical exploration in situ and laboratory testing are applicable not only to the site survey stage but also, to varying extents, to all stages of the site evaluation process.

2) Site selection stage

The purpose of an investigation at the site selection stage is to determine the suitability of sites and to identify issues that may be used in comparing the site with other potential sites or candidate sites. Subsurface information for this stage is usually obtained from current and historical documents and by means of field reconnaissance, including geological and geomorphological surveys, with a limited amount of site specific field investigations in order to investigate the following:

a) Unacceptable subsurface conditions;
b) Classification of sites;
c) Groundwater regimes;
d) Foundation conditions.

A.6 DATABASE ON COASTAL FLOODING

The coastal flooding database provides information describing the flooding characteristics of the candidate site. The extent and quality of data collection can vary depending on the stage of the site survey and site selection process for which the information is used, as discussed above. This section includes all forms of flooding, including tsunami hazards.

At both the site survey stage and the site selection stage, the suitability of the site is not determined solely by whether the site is inundated during events of a particular return frequency.

The installation may be built at a sufficiently elevated platform level to support the safety related structures and equipment for protection against extreme events of a particular return frequency. The practicality of employing these defensive measures against floods should be considered together with the flood level predictions when deciding whether the coastal flooding is acceptable on the basis of the relevant criteria.

1) Site survey stage

The potential for flooding due to storm surges, seiches, tides and wind waves should be investigated. To determine the flooding potential for the site in these cases, it is necessary to know the extreme sea levels from storm surges, seiches, tidal waves and wind waves and the topography of the land around the site. At the site survey stage, a good approximation for evaluating flood levels can be made by using tidal data.

The tidal data may be obtained from national or local authorities or other national or local institutions, or more than one of these. However, these data alone are frequently not sufficient for assessing the highest astronomical tides or the combined effects of storm surge, seiche and wind wave effects. This is because data may be available for a few decades only.

Consideration should also be given to the potentially detrimental effects of extreme low water levels as well as of other related hazards (such as jellyfish and algae).

Flooding may arise because of the effects of earthquakes, volcanic activity or landslides on the floor of oceans, seas, lakes, etc. Relevant data should be collected from national authorities if they are available. There may also be historical records of large scale flooding in the region that can be associated with one of the initiators mentioned above. If the proposed site does not satisfy the conditions for applying the screening criteria in SSG-18, then there may not be enough data for a simple desktop study to be made.

2) Site selection stage

The potential for flooding from storm surges, seiches, tidal and wind waves should be investigated. More detailed work is required to provide better estimates for flood levels at the site. A preliminary analytical technique may be used at this stage to determine the extreme sea levels that are appropriate for longer return periods and for the nuclear installation under consideration.

A preliminary analytical technique may be used at this stage to determine the extreme sea levels that are appropriate for longer return periods and for the nuclear installation under consideration. Information provided in IAEA SSG-18 will be useful for further work in this area.

A.7 DATABASE ON RIVER FLOODING

The database on river flooding provides information describing the characteristics for river flooding and the characteristics for storm water flash floods of the proposed site, including changes in river courses, changes in the stability of riverbanks and changes in upstream land use. The extent and quality of data collection can vary depending on the stage in the site selection process for which the data are used.

The data on flood levels alone are not sufficient for screening a site from further consideration since it may be possible to provide flood defenses to protect the site. This should be taken into account when making judgments on site selection.

1) Site survey stage

River flooding can arise directly from rivers that have overtopped their banks or flood defenses following heavy precipitation and snowmelt upstream of the site or the failure of an upstream dam. The following information and data should be obtained at the site survey stage:

a) Regional and local maps of watercourses, rivers, lakes, streams and other waterways and local topographic maps of the site should be obtained. All watercourses that could credibly flood the site should be identified.

b) Characteristics of topographic features such as flood plains, and the locations and sizes of existing flood protection systems such as dykes and levees, should be established.

c) For major rivers, data on discharge rates versus river level should be obtained. The possibility of ice hazard, including frazil ice, should be considered. Historical data on river levels and on the extent of flooding should be obtained.

d) Information on water retaining structures, especially upstream of the site, should be collected.

e) The potentially detrimental effects of low levels of river water should also be considered and relevant information should be collected.

2)Site selection stage

For the site selection stage, preliminary flood hazard analysis should be done to estimate flood water levels at the site and the potential for flood water to interfere with safety related equipment. Simple dam break scenarios should be considered for upstream water retaining structures.

A statistical analysis of flood data to determine flood levels at longer return periods should be made if it is not already available.

A.8 DATABASE ON EXTREME AND RARE METEOROLOGICAL EVENTS

The database on meteorological events provides information describing meteorological events that could affect the potential site or candidate sites. The extent and quality of data collection can vary depending on the stage in the site selection process for which the data are used. Meteorological data alone are not sufficient to screen a site out from further consideration since it is often possible to provide defenses to protect safety related equipment at the site.

1) Site survey stage

Meteorological data should be collected on a regional basis by national authorities, although local authorities and, in some cases, particular industrial sectors, may collect specific data for special reasons. The following data should be obtained:

a) Data on the regional and local history of extreme values, both extreme highs and extreme lows, of meteorological parameters relating to temperature, humidity, atmospheric pressure, wind speed, precipitation, icing, ice storms, sand storms, dust storms, and so on. Similar regional and local data on rare meteorological events, such as storms, tornadoes, cyclones and lightning should also be collected.

b) The site drainage characteristics should be ascertained, e.g. the natural drainage routes for surface water, the height of the water table and the ability of water to flow onto the site. Consideration should be given to the fact that in-ground works of the nuclear installation can have a significant effect on the site drainage characteristics.

2) Site selection stage

The suitability of the site will also depend on the extent to which measures can be put in place to protect safety related structures, systems and components. The drainage requirements for the site should be evaluated in detail. The geotechnical features of the site should be determined, at least approximately, and their sensitivity to extremes of precipitation, temperature and drought should be established.

A.9 DATABASE ON HUMAN INDUCED EVENTS

The database on human induced events provides information describing the type, severity and frequency of past human induced events in the vicinity of the site and their relationship to the potential site and candidate sites. The extent and quality of data collection can vary depending on the stage in the site selection process for which the data are used. At both the site survey stage and site selection stages, the suitability of the site in relation to human induced events is not determined solely by the site's proximity to human induced events: the credible physical protection measures that can be taken should also be considered. For example, protective barriers can usually be erected to protect safety related equipment against vehicle impacts.

1) Site survey stage

To determine the potential of human induced events to affect the site, information about human activities around the site should be collected and analyzed. The activities may change over the operating lifetime of the installation.

The potentially hazardous human activities that could affect a site in the different categories should be considered for their hazard potential. These include:

a) Nuclear installations located on the same site;
b) Nearby industries, especially industries using quantities of toxic or explosive chemicals, or involving exothermic reactions or high pressure or high temperature processes, and industries that use ionization or strong electromagnetic fields;
c) Nearby military facilities;
d) Transport systems, including road, rail, air, shipping and pipeline transport;
e) Land use activities such as those that influence water courses or the stability of slopes affecting the site, such as upstream dams, major users of river water abstraction and industries that could deposit large amounts of debris into a river upstream of the site.

These potentially hazardous human activities can present a range of hazards and hazardous events, including:

a) Flooding hazards;
b) Forest fires and other external fires;
c) Missiles and impact hazards;
d) Toxic clouds;
e) Explosions;
f) Ground disturbance on or under the proposed site.

Information on local industrial hazards and land use hazards should be available from local government authorities or local planning authorities.

Data on the locations and movements of air traffic and other forms of transport should be available from local authorities and from relevant national authorities. Information on military facilities will be available from relevant national government authorities.

Data on human induced events and potentially hazardous human activities can be used with local and regional maps, showing transport routes and industrial locations and so on, and with local topographical maps to make an initial determination of whether the candidate site should be screened out on the basis of screening distance values for the origins of human induced events.

It is anticipated that many of the hazards listed above can be eliminated on the basis that their consequences would be very local to the source and would be unlikely to affect the site directly (such as missiles from small scale pressurized systems), or could easily be protected against (such as impacts from road traffic or rail vehicles). Other hazards might necessitate a more detailed analysis at the next stage before a judgment could be made in respect of site selection.

2) Site selection stage

A more detailed estimates of the severity and the likelihood of human induced events affecting the site or that may affect the site in the future should be provided. For several hazards listed above, a simple analysis made on the basis of site survey data alone might not be sufficient for making a judgment on site selection. For example, it is anticipated that this proviso will apply to the following:

a) Aircraft traffic (data collected for an aircraft crash of accidental origin can also be used to some extent for the evaluation of the site for an aircraft crash as part of a nuclear security event or other unauthorized act);
b) Toxic hazards or explosive hazards from nearby industries using or storing very large quantities of toxic or explosive materials, e.g. oil and gas operations, large petrochemical factories, or local quarrying or mining activities under the site.

An expert analysis maybe necessary to determine the severity of the hazard, its likely impact at the site and the frequency associated with the hazard.

A.10 DATABASE ON POPULATION, LAND USE, WATER USE AND ENVIRONMENTAL IMPACTS

The criteria for the database on population, land use, water use and environmental impacts should relate to the potential radiological and other impacts of the nuclear installation on workers, the population and the environment due to normal operation and accident conditions.

Furthermore, the feasibility of the implementation of emergency plans should also be addressed through this database over the operating lifetime of the installation.

1) Site survey stage

One of the most common parameters that should be considered at this stage is related to either population density in the site vicinity or the distance of the potential site or candidate sites from population centers (or both). This data are generally readily available.

Precautionary measures should be taken to use reasonable numbers for screening values. The population density projections for the operating lifetime of the installation should also be considered in the assessment of site suitability areas (including protected species), natural reservations, monuments and tourist spots should be identified.

2) Site selection stage

The process for evaluating population, land use, water use and environmental impacts may be more or less involved. Attention should be paid mainly to the feasibility of implementation of the emergency plan.

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ANNEX I: TABLES TO BE USED IN THE SITING PROCESS

1) Table 1 provides an indication of the type of criteria that are generally associated with various issues relating to the siting process. There may be cases that are not consistent with Table 1 owing to the specific conditions at certain sites. Table 1 is therefore to be used as an indication only.

2) Table 2 cross-references IAEA safety standards that are relevant to the siting related issues that are under consideration in this Safety Guide. The guidance provided will be useful for issues relating to the evaluation of candidate sites. In particular cases, explicit guidance may be provided by the safety standards indicated in Table 2.

Table 1: Screening and ranking criteria for purposes of site selection

Criteria		Category		
Primary	Type	Screening		Ranking
		Exclusionary	Discretionary	
Earthquake	Ground Vibration		✓	✓
	Surface rupture	✓		
Geotechnical	Slope instability (massive landslide)	✓		
	Slope instability (minor)		✓	✓
	Subsidence		✓	✓
	Massive liquefaction	✓		
	Liquefaction		✓	✓
	Karst (massive)	✓		
	Pyroclastic flow	✓		
	Ground deformation	✓		
	Tephra fall			✓
	Volcanic gases			✓
	Lahars (massive)	✓		
Flooding	River			✓
	Dam break			✓
	Coastal (storm surges, waves, etc.)			✓

	Tsunami			✓
Extreme meteorological events	High straight winds, Tornadoes			✓
	Tropical storms			✓
	Precipitation			✓
	Sand storms and dust storms			✓
Human induced events	Aircraft crashes			✓
	Explosions			✓
	Gas releases			✓
	External fires			✓
	Electromagnetic interference			✓
Nuclear security events				✓
Dispersion	In air and water			✓
Feasibility of implementation of emergency plan		✓		
Implementation of emergency plan			✓	✓
Non-safety	Topography		✓	✓
	Availability of cooling water	✓		✓
	Access to water		✓	✓
	Availability of transport		✓	✓
	Access to national or regional electricity grid		✓	✓
	Non-radiological environmental impacts	✓	✓	✓
	Socioeconomic impacts		✓	✓
	Land use planning		✓	✓

Table 2: Site selection issues cross-referenced with IAEA safety standards

Site selection issue		Safety Requirements	Safety Guides relevant to site evaluation						Safety Guides relevant to design	
Primary	Effect	NS-R-3 [I–1]	NS-G-3.1 [I–2]	NS-G-3.2 [I–3]	SSG-9 [I–4]	SSG-18 [I–5]	SSG-21 [I–6]	NS-G-3.6 [I–7]	NS-G-1.5 [I–8]	NS-G-1.6 [I–9]
Earthquake	Ground vibration	✓			✓					✓
	Surface rupture	✓			✓					
Geotechnical	Slope instability	✓						✓		
	Subsidence	✓						✓		
	Soil liquefaction	✓						✓		
	Extensive oil and gas extraction history	✓						✓		
Volcanism		✓					✓			
Flooding	River	✓				✓			✓	
	Dam break	✓				✓			✓	
	Coastal	✓				✓			✓	
	Tsunami	✓				✓			✓	

ANNEX II: EXAMPLES OF CRITERIA FOR THE SITING PROCESS FOR A NUCLEAR POWER PLANT

AII. 1. General considerations

This Annex provides certain information that could serve as examples of attributes and related criteria to be considered in the siting process for a nuclear power plant. The Annex is intended to be used by the proposed operator or any organization charged with a responsibility associated with the siting process for a nuclear power plant. It has been prepared by compiling information on practices in different States and guidance from relevant IAEA safety standards. Examples are given in relation to external natural hazards as well as external human induced events.

1) Number of attributes (issues, events, phenomena, hazards and specific considerations) are related to the siting process as well as to general information on the site. These attributes are grouped into thematic sets in Section 4 of this Safety Guideline. These sets are:

a) External natural hazards;
b) External human induced events;
c) Radiological impacts on the public and on the environment;
d) Emergency planning;
e) Considerations not directly related to nuclear safety.

The last set, considerations not directly related to nuclear safety, is considered to have a major bearing on the effectiveness of the siting process.

2) This provides examples of issues, events, phenomena, hazards and considerations that are to be taken into account in the siting process for a nuclear power plant. Screening values for some of these attributes serve as useful siting criteria. Examples of such screening values are provided.

3) General site related information:

(a) Maps of site area at a suitable scale:
    (i) Site boundary and emergency planning zones: Typically, these are zones demarcating 5 km, 16 km, 25 km (or more) and 80 km from reactors.
    (ii) Population distribution and location of existing industrial, commercial, institutional, recreational and residential buildings and

areas, including projections of relevant developments for the expected operating lifetime of the nuclear power plant.

4)External natural hazards:

(a) Geology:

i) Properties of subsurface strata, depth and type of bed rock;

ii) Characteristics of subsurface material;

iii) Groundwater.

(b) Natural events:

i. Seismic and geological considerations:Capable faults;Vibratory ground motion due to earthquakes.

ii. Volcanism;

iii. Meteorological events and variables:
High wind events, such as tropical cyclones, tornadoes and water, spouts;Precipitation;Storms; Snow, Lightning;Dust storms and sand storms;Hail;Freezing precipitation and frost related phenomena;Air temperature.

iv. Coastal flooding:
Storm surges;Seiches;Tsunamis;Tides;Wave action;Combinations of tides: variations and extremes in sea water levels;Combination of flooding with relevant meteorological events.

v. Inland (river) flooding:
Overtopping of banks;Failure of upstream or downstream water control structures such as dykes or dams;Blockage of a river or other drainage channel; Combination of flooding with relevant meteorological events.

vi. Combination of coastal and inland flooding for sites on an estuary;

vii. Geological and geotechnical hazards:
Slope instability;Soil liquefaction;Rock fall;Permafrost;Soil erosion processes;Collapse, subsidence;Expansion, uplift;Karst;Avalanches
Stability of foundation.

viii. Shoreline erosion.

c) Change of hazard with time:

i. Change due to climatic evolution: regional climatic change with global climatic change;

ii. Changes in physical geography of a drainage basin, including estuaries, offshore bathymetry, coastal profile, catchment area, etc.;

iii. Changes in land use and water use.

5) External human induced hazards:

(a) Stationary sources:

(i) Oil and gas operations (e.g. refineries);

(ii) Industrial plants and operations and other facilities processing hazardous substances;

Facilities for the storage of hazardous substances;Broadcasting and communication networks (for electromagnetic interference hazards);Mining or quarrying operations;Other nuclear installations; High energy rotating equipment; Military facilities (permanent or temporary), especially shooting ranges and arsenals.

(iii) Nuclear installations located on the same site (such as installations for the reprocessing of spent fuel, the storage of fresh fuel and the storage of spent fuel).

(b) Mobile sources:

(i) Railway trains and wagons;

(ii) Road vehicles;

(iii) Ships and barges;

(iv) Pipelines;

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

(vi) Transport of fresh fuel and spent fuel and of other nuclear material and other radioactive material.

(c) Other characteristics:

(i) Oil slick;

(ii) Transport of over dimension consignments.

6) Radiological impact:

(a) Meteorology:

(i) Wind speed and direction;

(ii) Rain and other precipitation;

(iii) Atmospheric temperature;

(iv) Humidity;

(v) Atmospheric stability;

(vi) Sand storms and dust storms.

(b) Use of land and water;

(c) Population considerations;

(d) Dispersion of radioactive material:

(i) In the atmosphere;

(ii) In subsurface water;

(iii) In surface water.

(e) Management of radioactive waste in operational states:

(i) Radioactive solid waste; Characteristics of thewaste; Quantity, Level of activity and Management strategy.

(ii) Radioactive liquid waste:

Characteristics of the waste:Quantity;Level of activity;Management strategy.

(iii) Discharges of radioactive gases:

Characteristics of the waste;Quantity;Level of activity;Management strategy.

(f) Management of radioactive releases in accident conditions; Ambient radiation;

(g) Monitoring.

7) Emergency management:

(a) Physical characteristics and site characteristics that may hinder emergency plans;

(b) Emergency procedures;

(c) Infrastructural characteristics relating to the implementation of emergency plans:

(i) Evacuation routes and access routes;

(ii) Sheltering;

(iii) Transport.

(d) Special requirements prescribed by the regulatory body for special zones, if any, such as the exclusion boundary, low population zones, etc.;

(e) Population considerations within emergency planning zones outside the site area boundary of the nuclear installation;

(f) Additional statutory requirements of:

(i) The national government;
(ii) The local government;

AII.2 Determination of exclusion area, low population zone, and population center distance.

As an aid in evaluating a proposed site, an applicant should assume a fission produce release from the core, the expected demonstrable leak rate from the containment and the meteorological conditions pertinent to his site to derive an exclusion area, a low population zone and population center distance as shown in table 2. For the purpose of this analysis, which shall set forth the basis for the numerical values used, the applicant should determine the following:

a) An exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 0.25 Sv or a total radiation dose in excess of 3 Sv to the thyroid from iodine exposure.

b) A low population zone of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 0.25 Sv or a total radiation dose in excess of 3 Sv to the thyroid from iodine exposure.

c) A population center distance of at least one and one-third times the distance from the reactor to the outer boundary of the low population zone. In applying this guide, the boundary of the population center shall be determined upon consideration of population distribution.

d) Political boundaries are not controlling in the application of this guide. Where very large cities/towns are involved, a greater distance may be necessary because of total integrated population dose consideration.

e) The whole body dose of 0.25 Sv referred to above corresponds numerically to the once in a lifetime accidental or emergency dose for radiation workers.

f) Neither the use of the dose in (5) nor that of the 3 Sv value for thyroid exposure as set forth in these site criteria guides are intended to imply that these numbers constitute acceptable limits for emergency doses to the public under accident conditions.

g) The 0.25 Sv whole body value and the 3 Sv thyroid value have been set forth in these guides as reference values, which can be used in the evaluation of reactor sites with respect to potential reactor accidents of exceedingly low probability of occurrence, and low risk of public exposure to radiation.

8) Considerations not directly related to safety:

(a) Topography:
  (i) Salient features;
  (ii) Contour maps for the region up to 30 km.

(b) Accessibility:
  (i) Nearest railway lines;
  (ii) Nearest national highways and major roads;
  (iii) Nearest sea ports.

(c) Availability of industrial infrastructure and construction facilities:
  (i) Construction materials;
  (ii) Construction power;
  (iii) Construction water;
  (iv) Infrastructural facilities.

(d) Availability of and conditions of access to cooling water:
  (i) Condenser cooling
  (ii) Fresh water for consumption.

(f) Population centers:
  (i) Locations;
  (ii) Distances from the nuclear power plant site;
  (iii) Expected populations.

(g) Proximity to load centers:

(i) Lines for the power distribution grid;
(ii) Locations of major power consuming units, facilities and populations.

9) Non-radiological environmental impacts, including ecological considerations:
   a) Heat sinks: water bodies and atmosphere;
   b) Presence of bio-sensitive areas adjacent to the site;
   c) Natural reserves, monuments or tourist spots;
   d) Restrictions by statutory bodies on:Thermal pollution:Temperature differential between the intake and outfall points of the condenser cooling water;Effects on aquatic life of discharges of condenser water; Discharge of chemical pollutants.
   e) Socioeconomic impacts, including public acceptance:
      (i) Type of area adjacent: urban or rural;
      (ii) General source of income for local population: large scale industry, small scale industry, agriculture and agro-industries;
      (iii) General economic conditions of the surrounding population with respect to national averages (e.g. per capita incomes);
      (iv) Level of acceptance of the installation by the public.

ANNEX III: EXAMPLE OF SCREENING VALUES

The screening values of different characteristics of a site could be used as exclusion criteria or discretionary criteria at the site survey stage. Examples of such screening values are given in Table II. These are examples of typical values. If a site does not satisfy any one or a combination of screening values, it could still be considered acceptable provided that engineering solutions are available, i.e. design features, measures for physical protection of the site or administrative procedures.

Table 3: Examples of screening values

No	Characteristics	Screening values	Remarks/Criterion
1	Distance from capable fault	8.0 km	Exclusion
2	Distances from flight paths approaching an airport	4.0 km	Discretionary
3	Distance from airport with attributes of type 2 event[a]	7.5 km	Discretionary
4	Distance from small airports	10.0 km	Discretionary
5	Distance from large airport: — for yearly flight operations >500 d^2 — for yearly flight operations >1000 d^2	< (d =)16.0 km > (d =)16.0 km	Discretionary
6	Distance from military installations or air space usage such as practice, bombing and firing ranges	30.0 km	Discretionary
7	Distance from military installations storing ammunition, etc.	8.0 km	Discretionary
8	Distance from facilities for storing or handling flammable, toxic, corrosive	5.0 km	Discretionary

	or explosive material		
9	Sources of hazardous clouds	8.0 km	Discretionary
10	Natural reserves, bio-sensitive regions and forests	Exclusion zone	Exclusion
11	Tsunami	10 km from sea or ocean shoreline or 1 km from lake shoreline, or 50 m above mean water level	Discretionary

Note: *d* = distance.

[a] Accidental aircraft crash at the site such as in a take-off or landing operation at a nearby airport.