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IAEA SAFETY STANDARDS

Site Survey and Site Selection - DS433

**Regional Workshop on Volcanic, Seismic, and Tsunami Hazard
Assessment Related to NPP Siting Activities and Requirements
June 13-17, Jakarta, Indonesia**

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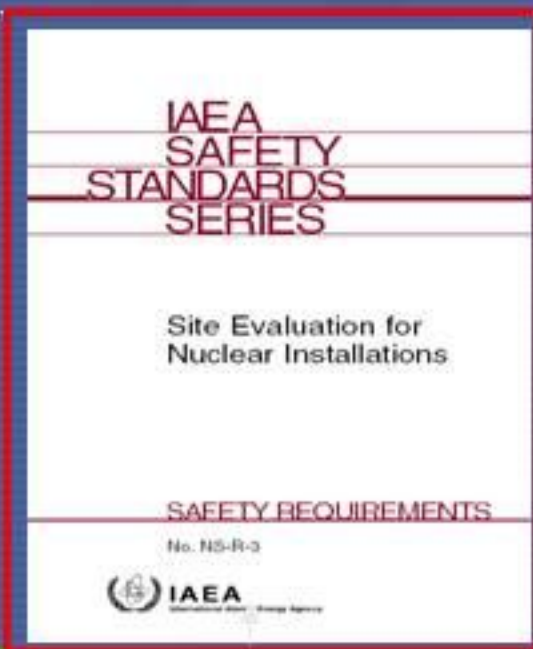
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SAFETY GUIDES



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DS 433 will supersede the Safety Guide, "Site Survey for Nuclear Power Plants", 50-SG-S9.

DS 433

Introduction

The IAEA Safety Fundamentals publication on Fundamental Safety Principles establishes that “The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation”(para 2.1).

Principle 8 of Fundamental Safety Principles (IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006)), specifies that the prevention of accidents and it's mitigation is the way to meet this objective; and establishes that “The primary means of preventing and mitigating the consequences of accidents is ‘defense in depth’” (para 3.31). Defense in depth is provided by an appropriate combination of measures, one of which is “Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy...”(para 3.32).

Introduction

To apply this principle, it is required (Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. NS-R-3, IAEA, Vienna, (2003), para. 2.1) that the suitability of a site for a nuclear installation be evaluated with regard to:

- (a) the effects of external events, which 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, and
- (c) the population density and the population distribution and other characteristics of the external zone that may affect the implementation of emergency measures.

Introduction

The selection process of a suitable site, termed as “siting”, for a nuclear installation is a multi-faceted process where safety considerations largely dominate. A properly selected site provides two distinct levels of defense in depth.

- The first level is prevention and aims at decreasing the exposure to external hazards. It involves a comprehensive process of screening out sites where hazards are dominant and complex designed safety measures would be necessary for site utilization.
- The second level is mitigation and aims at decreasing the impact of an accident on the environment. It involves the selection of a site with good dispersion characteristics of radionuclides in the air, surface as well as sub-surface water, and also terrain, population and infrastructure that are conducive for the implementation of an emergency plan.

Introduction

There is now the need to update the previous IAEA Safety Guide, “Site Survey for Nuclear Power Plants”, 50-SG-S9, 1984 in view of an increasing interest from Member States. The revision is necessary to streamline the Safety Guide with respect to NS-R-3 for covering the first stage of the siting process taking into account the safety requirements, especially in relation to the exclusion criteria to be applied and all the complete set of current safety guides providing recommendations to comply with such requirements during the stages of site evaluation.

Introduction

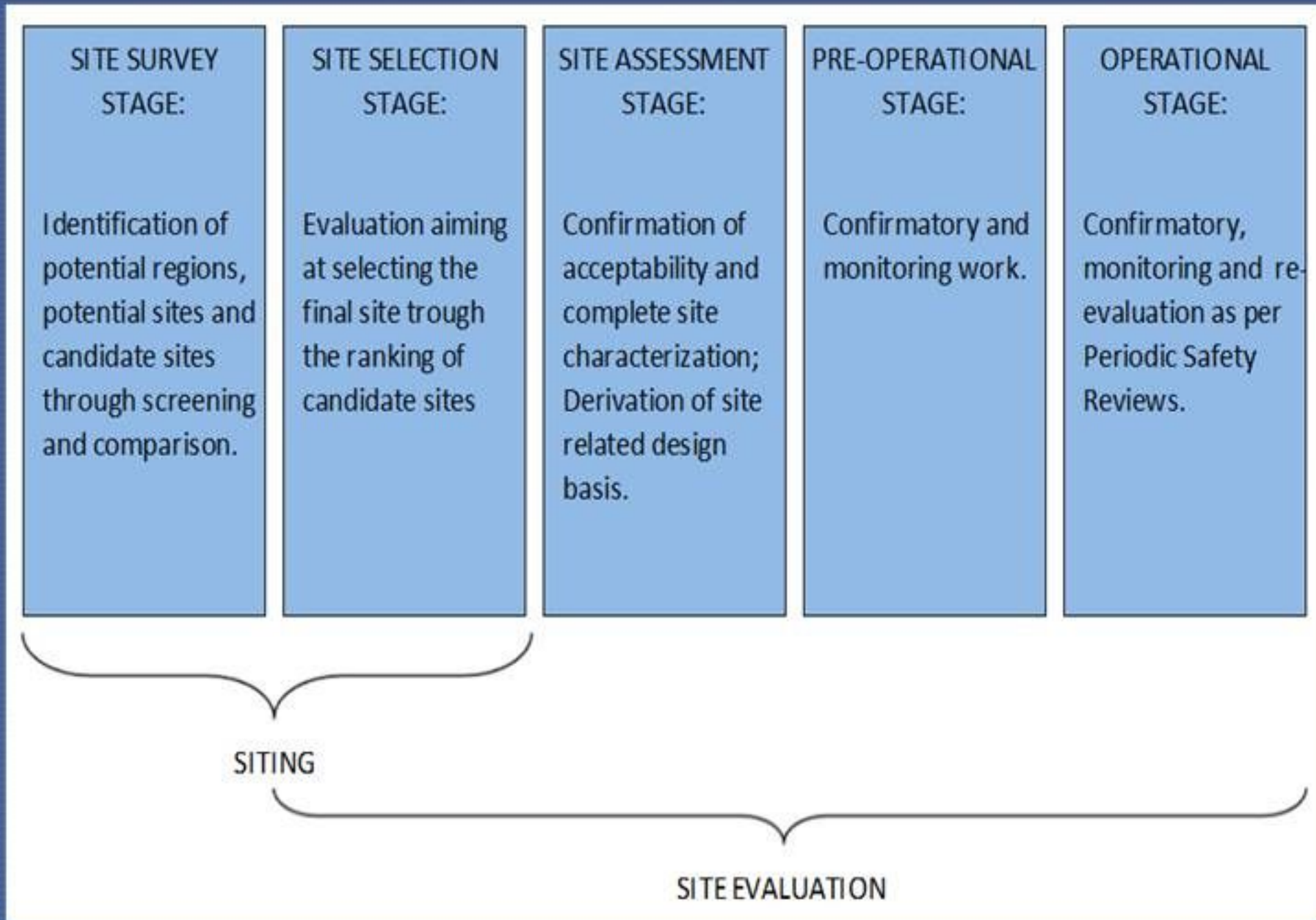
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Site survey and site selection are multidisciplinary effort:

- power engineering
- nuclear engineering
- radiological protection
- ecology-radioecology
- demography
- emergency planning
- civil engineering
- soil mechanics
- geology
- seismology
- hydrology
- meteorology

General Description of Siting and Site Evaluation process

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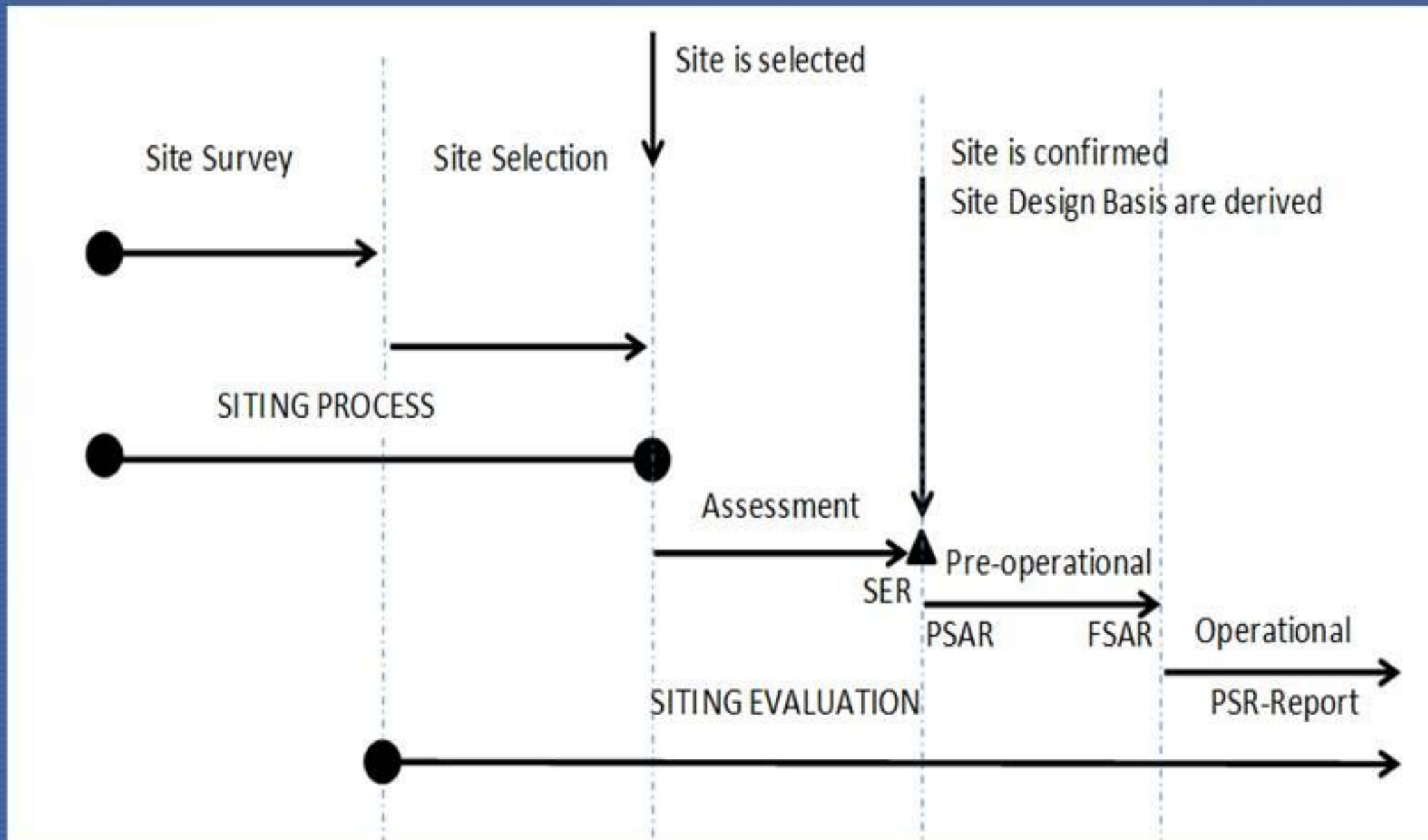
Siting and Site Evaluation Process in the Life-Cycle of Nuclear Installation



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General Description of Siting and Site Evaluation process

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Outcome of Siting and Site Evaluation Process

General Description of Siting and Site Evaluation process

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There are three important steps that will receive input from the site survey, site selection and the site evaluation process before construction starts. These are:

- a) Decision regarding the 'acceptability' 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 approval of the site related design basis parameters based on the Site Evaluation Report.
- c) The approval of the PSAR or preliminary safety case which, inter alia, demonstrates that the site related design basis parameters have been appropriately accounted for through design features, measures for site protection and administrative procedures.

General Recommendations for the Siting Process (Screening and ranking criteria)

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Siting should be a process of selecting suitable locations for a nuclear installation such that its characteristics inherently makes its exposure to natural and human induced hazards of external events as low as practicable. Further, the surrounding demographic setting and dispersion characteristics should enhance the mitigation capabilities against the radiological release.

General Recommendations for the Siting Process (Screening and ranking criteria)

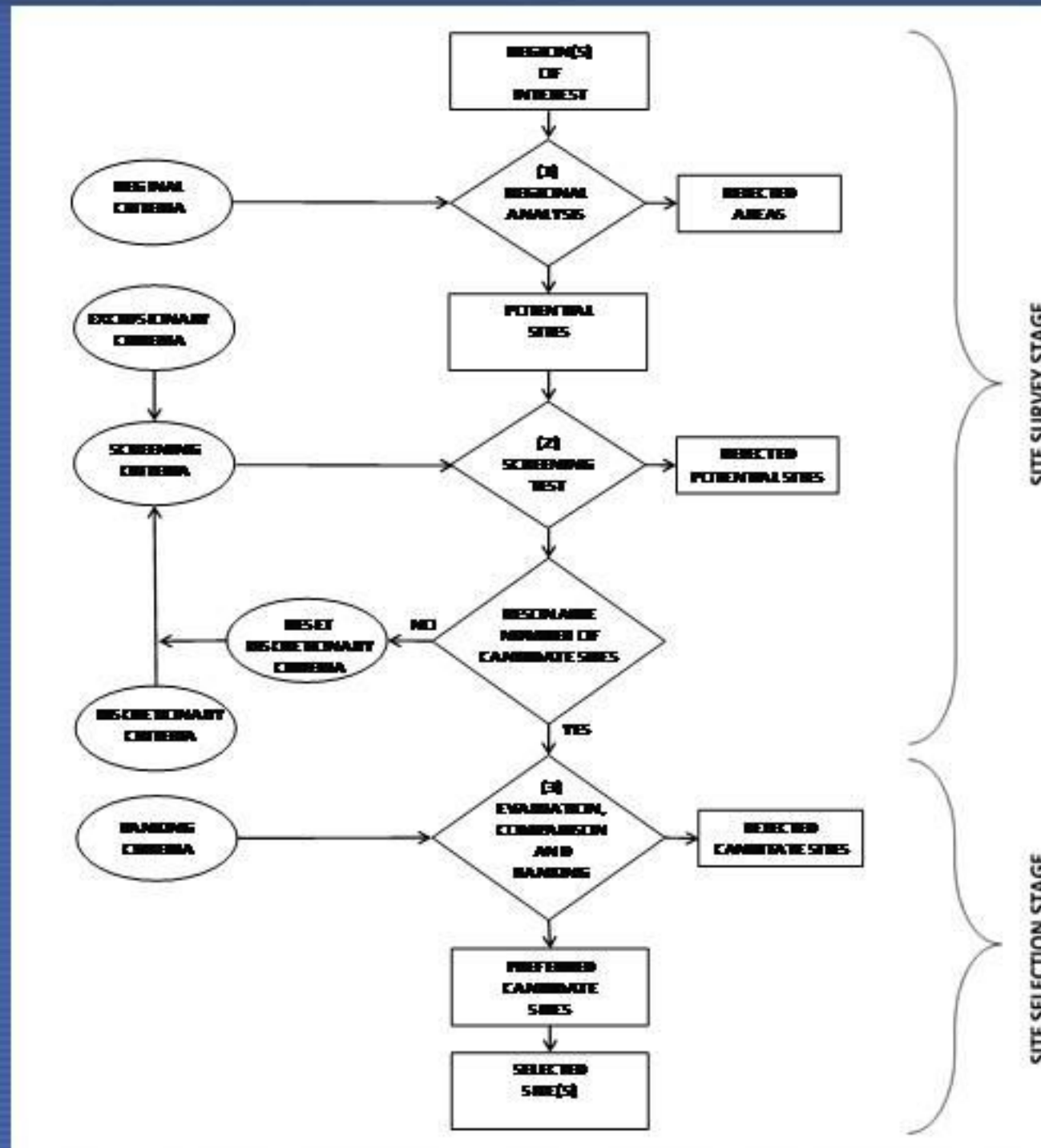
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The siting process has three distinct steps starting with given region(s) of interest.

1. Regional analysis: This is the first step, in which region(s) of interest are analyzed to identify potential sites. It is important to consider all the potential sites in this phase and not to discard any.
2. Screening test: In the second step, the potential sites are screened to choose the candidate sites. Principal objective of this step is to exclude the unfavorable site from safety as well as non-safety considerations.
3. Evaluation, comparison and ranking: Purpose of the third step twofold: (i) to evaluate the site in order to assure there are no features at the sites that would preclude the construction and operation of a NPP, and (ii) to compare the candidate sites and rank them in the order of their attractiveness as a NPP site.

General Recommendations for the Siting Process (Screening and ranking criteria)

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Classification of Siting Criteria

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Criteria used in siting process of a nuclear installation are classified as follows

- Safety related criteria,
- Criteria related to protection against sabotage, and
- Non-safety related criteria.

Criteria falling under any of the above class may be screening (exclusion, or discretionary) criteria, or ranking criteria.

Classification of Siting Criteria

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Safety Related Criteria:

From a thematic perspective, these criteria are classified in four sets that should be complied with during siting process of a nuclear installation.

1) The first set of criteria is related to the potential impact of natural hazards on the safety of the nuclear installation (capable faults, vibratory ground motion due to earthquakes, volcanic hazards, Coastal flooding (due to wave action, storm surges, seiches, tsunamis, combinations with tides – sea water level variations and extremes), River flooding Combination of coastal and river flooding (in estuaries, e.g.), flash floods due to intense precipitation or downburst, High winds, both straight winds such as hurricanes, tropical storms and rotational winds such as tornadoes, local phenomena such as sand storms, Other extreme meteorological events such as extreme precipitation, including snow pack; extreme temperatures, including the temperature of the source of the cooling water; and lightning, Geotechnical hazards such as liquefaction, landslides), rock fall, permafrost, erosion processes, subsidence, collapse)

Classification of Siting Criteria

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- 2) Criteria is related to the potential impact of human induced hazards on the safety of the nuclear installation: (Stationary (Oil refineries, chemical plants, hazardous material storage facilities, broadcasting networks, mining or quarrying operations, forests, other nuclear facilities, high energy rotating equipment, Military facilities (permanent or temporary) especially shooting ranges, arsenals) and Mobile (Railway trains and wagons, road vehicles, ships, barges, pipelines, airport zones, air traffic corridors and flight zones (both military and civilian))
- 3) The third set of criteria is related to 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 from the nuclear installation: (Atmospheric dispersion of radioactive material, Dispersion of radioactive material in surface water, Dispersion of radioactive material in ground water, Population distribution and distance to centers of population including projections for the lifetime of the nuclear installation, Common cause failure due to external hazard.)

Classification of Siting Criteria

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- 4) The fourth set of criteria is linked to the third set but it relates mainly to the demonstration of the feasibility of emergency plan implementation for the nuclear installation: (Physical site characteristics that may hinder emergency plans, Infrastructure characteristics related to the implementation of emergency plans, Population considerations, Special considerations prescribed by the Regulatory Body for special zones, such as the exclusion area boundary, low population zone, etc., Impact of concurrent external hazards on infrastructure)

Classification of Siting Criteria

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Criteria Related to Protection Against Sabotage:

Following criteria should be considered to site a nuclear installation in a location from the consideration of protection against sabotage:

- 1) A site of nuclear installation should not be located near to any area or facility with high potential threat,
- 2) It is preferable to locate a site not having clear view of sight from all directions (e.g. tip of a peninsula).
- 3) The access to the site should be restricted to a minimum number required for safety and operation considerations.
- 4) Site characteristics should be such that ultimate heat sink could not be easily accessed.
- 5) The site should be away from the population center and public transport route

Classification of Siting Criteria

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Criteria not Specifically Related to Safety:

Some examples of aspects to be considered that are not directly safety related include (but is not necessarily limited to) the following:

- 1) Topography
- 2) Availability and access conditions to condenser cooling water
- 3) Transport routes
- 4) Proximity to load centers
- 5) Considerations for the distribution network (grid)
- 6) Non-radiological environmental impact including ecological considerations
- 7) Socio-economic aspects including public acceptance

Site Survey

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Purpose: Identification of potential regions, potential sites and candidate sites through screening and comparison:

- consideration of both safety and non-safety aspects,
- regional scale,
- rejection of “unacceptable” sites,
- systematic screening, selection and comparison of the “acceptable” sites.
- use of available data

Result: the “*candidate sites*”

Site Selection

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Detailed and specific evaluation of the “*candidate sites*”.

Selection of *the site*.

For the selected site, detailed and specific investigations and studies result in the:

- demonstration of the **acceptability of the site** on the basis of established criteria,
- derivation of the **site related design bases** for the nuclear installation.

Site Survey and Site selection

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For each of the phases mentioned above, the typical project description will include the following sections:

- **Purpose** – the purpose of the particular phase is stated.
- **Methodology** – the criteria used for screening and ranking together with the methods are indicated
- **Tasks** – list of typical tasks is provided
- **Data requirements** – the type of data needed to accomplish the tasks is given
- **Deliverable(s)** – the output of each task is clearly indicated.

Regional analysis to identify potential sites

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- In this phase, it is important to consider all potential sites and not to discard any site that may eventually be selected.
- As the objective is to retain a relatively large number of sites at the end of this phase,
- Brief site visits may be made to ascertain the results of the desk studies

Regional analysis to identify potential sites

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Tasks to be considered in this phase:

- Task1. Review of previously performed studies
 - Review of the data and criteria used
 - Review of the methodology used
- Task2. Updating of the studies
 - Check the validity of previous results
 - Check whether other sites can be identified in the region
- Task3. Identification of new potential sites
 - Establish database similar to the previously studied regions including the updates
 - Select potential site(s) using the updated criteria and methodology

Regional analysis to identify potential sites

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Data Requirements:

- Data that is available either from previous studies or that can be gathered from public sources are used. No site specific investigations need to be made
- The data involve topics such as: population density, proximity to towns and cities, land use, access and transportation, proximity to hazardous activities, meteorology, topography and bathymetry, availability of cooling and industrial water, grid connection, geotechnical conditions, proximity to natural hazards, environmental impact considerations and others as required.

Regional analysis to identify potential sites

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Regional-criteria:

The regional analysis should be done to identify potential sites using well established “Regional-criteria”. These criteria are generally related to national policy for development, economy and other policy on related considerations of the Member State. Technical constraints and availability of water on regional basis are also important consideration for regional analysis. Important aspect of the regional criteria is that these criteria should identify all possible potential site and not to discard any.

Regional analysis to identify potential sites

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Deliverable:

A report describing the work performed should be prepared.

- The data, criteria and the methodology used should be described.
- The potential sites should be described with their positive and negative aspects.
- A brief description of the sites that have been considered in the process but eventually discarded should also be given substantiating reasons for rejection.

Screening of potential sites to select

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candidate sites

- The purpose of this phase is to narrow down the sites to a manageable number so that a detailed comparison and ranking can be made. The boundaries of the selected sites are better defined.
- The criteria selected should be able to discriminate between the potential sites without eliminating all the sites. It is important that the candidate sites are not all located within the same region or sub-region. This is to avoid the possibility that an unexpected factor to be discovered in a later investigation will have a negative affect on all the candidate sites and cause all of them to be rejected.

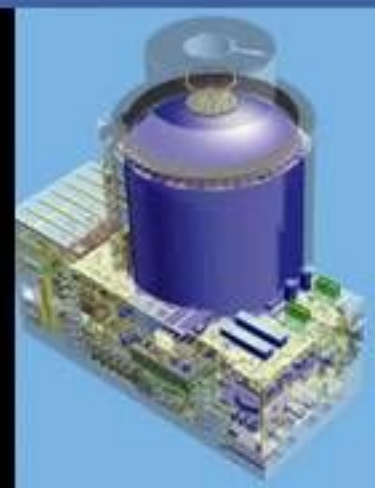
Screening of potential sites to select

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candidate sites

Tasks to be performed during Screening Phase:

- Task1. Identification of criteria for the selection of candidate sites
 - Revise the criteria used in previous phase, to eliminate less attractive sites
 - Iterate the criteria levels to check their effectiveness
 - Identify other criteria that have discriminatory qualities



Screening of potential sites to select

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candidate sites

- Task2. Data collection and verification
 - Collect additional available data on topics not considered so far
 - Verify data that have been collected in previous phase
 - Visit each site, collect a limited amount data through site investigations
 - Prepare a systematic, consistent and uniform database for each potential site and regarding each considered topic
- Task3. Identification of candidate sites
 - Using the established criteria and the collected data, identify a reasonable number of candidate sites (for example, 3 – 6)
 - Visit each candidate site once again to confirm the results

Screening of potential sites to select

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candidate sites

Data Requirements:

- Data used in previous phase need to be enhanced in two ways. Firstly, data related to topics not covered in previous phase should be collected. Secondly, the data need to be uniform for all sites if a reasonably comparative basis is to be established. For this reason further collection of data may be needed for sites where such information is lacking.

Screening of potential sites to select candidate sites

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The data to be collected can be divided into the following categories:

- Magnitude and frequency of external events of natural and/or man induced origin
- Impact of the NPP to the population and the environment, including aspects related to emergency planning
- Legal aspects
- Socioeconomic and cultural aspects
- Economical aspects (access, availability issues)
- Public acceptance aspects

Screening of potential sites to select

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candidate sites

The screening of potential sites should be conducted using two type of screening criteria,

- **Exclusion criteria:** the exclusion criteria discard sites that are unacceptable from those attributes related to issues, or events or phenomena or hazard for which engineering solution are not generally practicable. Only a few criteria (e.g. ground rupture) fall into this category.
- **Discretionary criteria:** the discretionary criteria are associated with those attributes related to issues, or events, or phenomena or hazards, or considerations for which engineering solutions are available to mitigate their impact. These criteria are used to facilitate the selection process through iterative screening to eliminate less favorable sites when a large number of possible candidate sites exist.

Screening of potential sites to select

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candidate sites

Deliverable:

A report describing the work performed should be prepared.

- The data, criteria and the methodology used should be described.
- The candidate sites should be described in detail including maps and photographs.
- Topographic maps of 1:50000 scale for a distance of 10 km from each candidate site should be prepared.
- These maps include information on transportation Infrastructure, population centers and sources of human induced hazards.

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

The purposes of this phase are:

- (i) to confirm that there are no features at the sites that would preclude the construction and operation of a NPP, and
- (ii) to compare the candidate sites and rank them in the order of their attractiveness as a NPP site. Safety and economic aspects will play the major role in this comparison process.

The confirmation of the suitability of the site may require limited site specific work such as geophysical profiles or boreholes (for example to demonstrate that there are no capable faults in the site area).

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

The exclusion criteria should be selected in a way that engineering, site protection or administrative measures would not be able to compensate for the negative attribute of the site. Otherwise, i.e. if it is possible to compensate for it, then the cost of providing these measures could be included in a comparison and ranking process.

In fact, cost differentials can be used as an objective metric for obtaining a similar level of safety for each site. Simple calculations should be performed to obtain estimates of design basis parameters.

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

Task1. Confirmation of the suitability of the sites (i.e. no exclusion factors)

- Identify the potential weakness of each site that may be the basis for excluding it from further consideration
- Conduct appropriate site specific investigations and analyses to decide whether or not the site is confirmed that it does not possess any negative features to be considered as an NPP site.

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

Task2. Establish criteria for comparison and ranking – calculate through simple methods the required parameters

- Criteria related to the design basis of the NPP with respect to external events
- Criteria related to the design of the NPP with respect to its environmental impact
- Criteria related to the operational efficiency of the NPP
- Cost differentials with respect to reference conditions

Task3. Identify the preferred candidate site(s)

- Using the established criteria quantify the selected attributes of each site
- Select the site(s) that ranks highest as the preferred candidate site(s)

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

Data Requirements

- For Task 1 of this phase, it is possible that detailed data is required for some sites through site investigations.
- For the comparison and ranking task, economic data is needed. It is not required to know the design details of any particular plant because the differentials are relative.
- Data needed for the simplified calculations of external hazard and other design parameters related to the site should be collected.

Comparison and ranking of candidate sites to

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obtain the preferred candidate site(s)

Comparison and ranking should be conducted applying ranking criteria.

Ranking criteria is of safety related as well as non-safety related. Ranking criteria is generally developed using the considerations related to discretionary criteria along with relevant non safety related issues and considerations.

Comparison and ranking of candidate sites to obtain the preferred candidate site(s)

TABLE I-1. SCREENING AND RANKING CRITERIA FOR SITE SELECTION

Criteria		Category		
Primary	Type	Screening		Ranking
		Exclusionary	Discretionary	
Earthquake	Ground Vibration		/	/
	Ground Rupture	✓		
Geotechnical	Slope Instability (Massive)	✓		
	(Minor)		✓	✓
	Subsidence	✓		
	Massive liquefaction	✓		
Volcanism	Liquefaction			/
	Lava Flow	✓		
	Pyroclastic Flow	✓		
	Ground deformation	✓		
	Lepora Fall		/	/
	Volcanic gases		/	/
	Lahars	✓		
Flooding	River		/	/
	Dam Break		/	/
	Coastal (surges, waves, etc.)		/	/
	Tsunami		/	/
Extreme Meteor. Events	High Straight Winds		/	/
	Tornadoes		/	/
	Tropical Storms		/	/
	Precipitation		/	/
Human Induced Events	Aircraft Crash		/	/
	Explosions		/	/
	Gas Releases		/	/
	External Fires		/	/
	EMI interference		/	/
Sabotage			/	/
Dispersion	In air and water		/	/
Feasibility of emergency plan implementation		/		
Implementation of emergency plan			/	/
Non-Safety	Topography			/
	Availability of Cooling Water	✓		
	Accessibility of water			/
	Transport availability			/
	Access to Grid			/
	Non-radiological environmental	✓		
	Socio-economic impact			/

Comparison and ranking of candidate sites to obtain the preferred candidate site(s)

Deliverable

A report describing the work performed should be prepared.

- The data, criteria and the methodology used should be described.
- The preferred candidate sites should be described in detail including maps and photographs.
- The documentation regarding the confirmatory studies regarding site acceptability should be included.
- The basis for the comparison and eventual ranking should be clearly explained.

Comparison and ranking of candidate sites to obtain the preferred candidate site(s)

TABLE 1. DIFFERENTIAL COST – SITE A (EXAMPLE)

Parameter	Initial cost (total)	Continued Cost (per year)
Seismic (0.4g)	X_{A1}	Y_{A1}
Aircraft impact (Cessna)	-	-
Tornado (F3)	-	-
Soil improvement	X_{A4}	-
Coast elevation	-	-
Water temperature	-	Y_{A6}
Grid Loss	-	Y_{A7}
Infrastructure development	X_{A8}	-
Required Stack Height	-	-
Need for Cooling Towers	-	-
Cooling Water Pumping	-	Y_{A11}
Groundwater pumping	-	-
Site cut and fill	X_{A13}	-
Other		
Total	$\sum X_{Ai}$	$\sum Y_{Ai}$

Site Selection – Decision Making

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- The above analysis considers the safety and economic aspects of the selection for a NPP site.
- There may be several alternatives for the eventual ranking of the candidate sites to arrive at the list of the preferred candidate sites.
- The approach outlined above is an objective approach in that the differential cost parameter is minimized, all other aspects being equal.
- Here, the assumption is made that a site with certain deficiencies, e.g. higher seismic input, will be equally safe as one with lesser seismic input as long as they are both designed to the required level (the demand coming from the site characteristics).

Site Selection – Decision Making

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- The negative aspect of the site with higher seismic input is quantified by the cost differential in the design and construction of the NPP for the higher seismic level.
- Other methods consider weighting factors for various attributes of the site. These tend to become subjective and a ranking of all aspects using this method does not necessarily convey the information related to differential cost.
- The selection and the evaluation of a site suitable for the installation are crucial. The task at this early stage of program can significantly affect the costs, public acceptance and safety of the installation during its complete lifecycle. Even, outcome of this task may affect seriously the final success of the program.

Site Selection – Decision Making

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- It is very important that the process of site selection is transparent. There may be misconceptions about the effects of a NPP on the environment both from the public and also from the decision makers in the country.
- Communicating the scientific facts relating to the interaction of the NPP with the environment is a very important part of the site selection process. When there are misconceptions about these issues the site selection process may become distorted and objective criteria may be used only to a limited extent.

Databases for Siting Process

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All site data should be collected in a systematic and retrievable manner. The use of tools such as Geographical Information System (GIS) should be considered especially for the data collected in relation to the preferred candidate sites.

The following databases should be established for the siting process:

- (a) Geological database
- (b) Seismological database
- (c) Fault displacement database
- (d) Volcanological database
- (e) Coastal flooding database
- (f) River flooding database
- (g) Meteorological extreme events database
- (h) Human induced events database
- (i) Population and environmental aspects



Siting Process for Nuclear Installations other than

Nuclear Power Plants (NPP)

For the purpose of site survey and site selection, nuclear installation other than NPP should be graded on the basis of their complexity, potential radiological hazards, and hazards due to other materials present.

Prior to categorizing an installation for the purpose of adopting a graded approach, a conservative process should be applied in which it is assumed that the entire radioactive inventory of the installation is released by the potential external hazard initiated accident.

If the results of the above conservative process show that the potential consequences of such releases would be 'significant', an appropriate site selection of the installation should be carried out using the recommendations of

Siting Process for Nuclear Installations other than

Nuclear Power Plants (NPP)

The graded approach is generally applied to the extent and detail for the data to be collected and analyzed at each step. Furthermore, depending on the consequences of the external hazards considered as screening criteria the protection feasibility and method for the installation may vary. For example, a small research reactor may not be protected against a large airplane crash unless a substantial amount of resources are not expended for this purpose which may mean that such protection cannot be considered as feasible. These aspects should be considered when setting up the screening and preference criteria for nuclear installations other than NPPs

Requirements

General Recommendations:

- As a function of the management system, quality assurance program should be established by the governmental and/or operating organizations, and their contractors directly responsible for selecting the site of a nuclear installation. This is necessary to control the effectiveness of the execution of the siting process.
- The quality assurance program should cover the organization, planning, work control, personnel qualification and training, verification and documentation for the activities to ensure that the required quality is achieved.

General Recommendations (Cont.):

- The quality assurance program for siting process is a part of the overall quality assurance program for the nuclear installation project.
- 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 evaluations.
- The results of studies and investigations should be documented in sufficient detail to permit an independent review.

Specific Recommendations for a Siting Project

Organization:

- A project work plan should be prepared prior to, and as a basis for, the execution of siting project. The work plan should convey the complete set of general requirements (such as total power generation of NPP project), including applicable regulatory requirements. In addition to general requirements, the work plan should delineate the following specific elements: personnel and their responsibilities; work breakdown and project tasks; schedule and milestones; and deliverables and reports.

Specific Recommendations for a Siting Project

Organization:

- A program should be established and implemented under the management system to cover all activities for data collection and data processing, field and laboratory investigations, analyses and evaluations.
- Results of the activities during 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.

Thank you for your attention

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