safety series

No. 50-SG-S9

IAEA SAFETY GUIDES

Site Survey for Nuclear Power Plants

A Safety Guide

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1984

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SITE SURVEY FOR NUCLEAR POWER PLANTS

A Safety Guide

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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FOREWORD
by the Director General

The demand for energy is continually growing, both in the developed and the developing countries. Traditional sources of energy such as oil and gas will probably be exhausted within a few decades, and present world-wide energy demands are already overstraining present capacity. Of the new sources nuclear energy, with its proven technology, is the most significant single reliable source available for closing the energy gap that is likely, according to the experts, to be upon us by the turn of the century.

During the past 25 years, 19 countries have constructed nuclear power plants. More than 200 power reactors are now in operation, a further 150 are planned, and, in the longer term, nuclear energy is expected to play an increasingly important role in the development of energy programmes throughout the world.

Since its inception the nuclear energy industry has maintained a safety record second to none. Recognizing the importance of this aspect of nuclear power and wishing to ensure the continuation of this record, the International Atomic Energy Agency established a wide-ranging programme to provide the Member States with guidance on the many aspects of safety associated with thermal neutron nuclear power reactors. The programme, at present involving the preparation and publication of about 50 books in the form of Codes of Practice and Safety Guides, has become known as the NUSS programme (the letters being an acronym for Nuclear Safety Standards). The publications are being produced in the Agency's Safety Series and each one will be made available in separate English, French, Russian and Spanish versions. They will be revised as necessary in the light of experience to keep their contents up to date.

The task envisaged in this programme is a considerable and taxing one, entailing numerous meetings for drafting, reviewing, amending, consolidating and approving the documents. The Agency wishes to thank all those Member States that have so generously provided experts and material, and those many individuals, named in the published Lists of Participants, who have given their time and efforts to help in implementing the programme. Sincere gratitude is also expressed to the international organizations that have participated in the work.

The Codes of Practice and Safety Guides are recommendations issued by the Agency for use by Member States in the context of their own nuclear safety requirements. A Member State wishing to enter into an agreement with the Agency for the Agency's assistance in connection with the siting, construction, commissioning, operation or decommissioning of a nuclear power plant will be required to follow those parts of the Codes of Practice and Safety Guides that pertain to the activities covered by the agreement. However, it is recognized that the final decisions and legal responsibilities in any licensing procedures always rest with the Member State.

The NUSS publications presuppose a single national framework within which the various parties, such as the regulatory body, the applicant/licensee and the supplier or manufacturer, perform their tasks. Where more than one Member State is involved, however, it is understood that certain modifications to the procedures described may be necessary in accordance with national practice and with the relevant agreements concluded between the States and between the various organizations concerned.

The Codes and Guides are written in such a form as would enable a Member State, should it so decide, to make the contents of such documents directly applicable to activities under its jurisdiction. Therefore, consistent with accepted practice for codes and guides, and in accordance with a proposal of the Senior Advisory Group, "shall" and "should" are used to distinguish for the potential user between a firm requirement and a desirable option.

The task of ensuring an adequate and safe supply of energy for coming generations, and thereby contributing to their well-being and standard of life, is a matter of concern to us all. It is hoped that the publication presented here, together with the others being produced under the aegis of the NUSS programme, will be of use in this task.

STATEMENT
by the Senior Advisory Group

The Agency's plans for establishing Codes of Practice and Safety Guides for nuclear power plants have been set out in IAEA document GC(XVIII)/526/Mod.1. The programme, referred to as the NUSS programme, deals with radiological safety and is at present limited to land-based stationary plants with thermal neutron reactors designed for the production of power. The present publication is brought out within this framework.

A Senior Advisory Group (SAG), set up by the Director General in September 1974 to implement the programme, selected five topics to be covered by Codes of Practice and drew up a provisional list of subjects for Safety Guides supporting the five Codes. The SAG was entrusted with the task of supervising, reviewing and advising on the project at all stages and approving draft documents for onward transmission to the Director General. One Technical Review Committee (TRC), composed of experts from Member States, was created for each of the topics covered by the Codes of Practice.

In accordance with the procedure outlined in the above-mentioned IAEA document, the Codes of Practice and Safety Guides, which are based on documentation and experience from various national systems and practices, are first drafted by expert working groups consisting of two or three experts from Member States together with Agency staff members. They are then reviewed and revised by the appropriate TRC. In this undertaking use is made of both published and unpublished material, such as answers to questionnaires, submitted by Member States.

The draft documents, as revised by the TRCs, are placed before the SAG. After acceptance by the SAG, English, French, Russian and Spanish versions are sent to Member States for comments. When changes and additions have been made by the TRCs in the light of these comments, and after further review by the SAG, the drafts are transmitted to the Director General, who submits them, as and when appropriate, to the Board of Governors for approval before final publication.

The five Codes of Practice cover the following topics:

Governmental organization for the regulation of nuclear power plants
Safety in nuclear power plant siting
Design for safety of nuclear power plants
Safety in nuclear power plant operation
Quality assurance for safety in nuclear power plants.

These five Codes establish the objectives and minimum requirements that should be fulfilled to provide adequate safety in the operation of nuclear power plants.

The Safety Guides are issued to describe and make available to Member States acceptable methods of implementing specific parts of the relevant Codes of Practice. Methods and solutions varying from those set out in these Guides may be acceptable, if they provide at least comparable assurance that nuclear power plants can be operated without undue risk to the health and safety of the general public and site personnel. Although these Codes of Practice and Safety Guides establish an essential basis for safety, they may not be sufficient or entirely applicable. Other safety documents published by the Agency should be consulted as necessary.

In some cases, in response to particular circumstances, additional requirements may need to be met. Moreover, there will be special aspects which have to be assessed by experts on a case-by-case basis.

Physical security of fissile and radioactive materials and of a nuclear power plant as a whole is mentioned where appropriate but is not treated in detail. Non-radiological aspects of industrial safety and environmental protection are not explicitly considered.

When an *appendix* is included it is considered to be an integral part of the document and to have the same status as that assigned to the main text of the document.

On the other hand *annexes, footnotes, lists of participants* and *bibliographies* are only included to provide information or practical examples that might be helpful to the user. Lists of additional bibliographical material may in some cases be available at the Agency.

A list of relevant *definitions* appears in each book.

These publications are intended for use, as appropriate, by regulatory bodies and others concerned in Member States. To fully comprehend their contents, it is essential that the other relevant Codes of Practice and Safety Guides be taken into account.

NOTE

The following publications of the NUSS programme are referred to in the text of the present Safety Guide:

Safety Series No. 50-SG-G6
Safety Series No. 50-C-S
Safety Series No. 50-SG-S1
Safety Series No. 50-SG-S2
Safety Series No. 50-SG-S3
Safety Series No. 50-SG-S4
Safety Series No. 50-SG-S5
Safety Series No. 50-SG-S6
Safety Series No. 50-SG-S7
Safety Series No. 50-SG-S8
Safety Series No. 50-SG-S10A
Safety Series No. 50-SG-S10B
Safety Series No. 50-SG-S11A
Safety Series No. 50-SG-S11B

The titles are given in the List of NUSS Programme Titles printed at the end of this Guide, together with information about their publication date. Instructions on how to order them will be found on the last page of this Guide.

CONTENTS

1. INTRODUCTION

This Guide describes the first stage of the siting process for nuclear power plants — the site survey, which involves the study and investigation of a large region to select one or more preferred candidate sites. Its purpose is to recommend procedures and provide information for use in implementing a part of the Code of Practice on Safety in Nuclear Power Plant Siting (IAEA Safety Series No. 50-C-S), hereinafter referred to as the Code. Like the Code, the Guide forms part of the IAEA's programme, referred to as the NUSS programme, for establishing Codes of Practice and Safety Guides relating to land-based stationary thermal neutron power plants (see the List of NUSS Programme Titles printed at the end of this publication).

This Guide is concerned only with the safety aspects of site characteristics. However, it must be recognized that the review of the safety aspects of sites takes place in a larger, non-safety context in which many other issues directly affecting the selection of a site are addressed [1]. Attention is in fact given during the site survey to non-safety considerations (technical, economic, social and cultural) which may represent an important constraint in selection of a site, and may play a decisive role in rejection of a site. It will be important, therefore, especially in areas where safety and non-safety data requirements overlap, to ensure that the requirements for effective safety review are met.

It should also be taken into account that sometimes the non-safety considerations impose special design requirements that may have an effect on plant safety features. Moreover, the distinction between safety and non-safety characteristics is not always absolute. The acceptability of a site is dependent not only on site characteristics related primarily and directly to safety, but also on a large number of other aspects which are only indirectly related to safety. These include the reliability and stability of the electrical grid, and the adequacy of communications.

In many countries, the applicant is responsible for carrying out the site survey, with the role of the regulatory body being only that of providing guidelines (see Subsection 3.2). In other countries, the regulatory body is responsible for a more active role in site survey. In both cases, the regulatory body has the final responsibility, from a safety viewpoint, for deciding whether the site proposed by the applicant is acceptable.

For sites near national borders or on international waterways, collection of some of the data for the site survey would be facilitated by co-operative arrangements between the countries concerned.

1.1. Stages of the siting process

(1) *Site survey stage:* The purpose of a site survey is to identify one or more preferred candidate sites after both safety and non-safety considerations have been taken into account. This involves the study and investigation of a large region. It results in the rejection of unacceptable areas, and is followed by systematic screening, selection and comparison of those sites that are located in the remaining, acceptable areas.

(2) *Site evaluation stage:* This stage involves the study and investigation of one or more of the preferred candidate sites to demonstrate that they are acceptable from various aspects, and in particular from the safety point of view. The site-related design bases are determined at this stage.

(3) *Pre-operational stage:* This stage includes studies and investigations of the selected site after the start of construction and before the start of operation in order to complete and refine the assessment of site characteristics.

1.2. Scope

This Safety Guide deals only with the safety aspects of the site survey stage; it will be most useful to those Member States in which the number of possible sites is large. In these circumstances, the Guide will be of assistance in selecting one or more of the most suitable sites in the region.

In this Guide, the organization and procedures for a site survey are discussed in terms of three sequential phases. For the most common safety-related site characteristics which are generally used in the site survey process, the information to be collected is described and the criteria for rejection of an area or a site and for assigning suitability scaling factors are presented.[1] Guidance for documenting the site survey process are given. Methodologies for site survey are briefly discussed in Annex I. Examples of detailed procedures for some safety-related site characteristics are given in Annex II. The more important non-safety-related site considerations are identified and discussed briefly in Annex III.

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[1] The criteria used in this Guide are not absolute, and their applicability can be limited to a region or to a specific site survey. Rejection means elimination from further consideration in the subsequent survey phases.

2. SITE SURVEY PROCESS

2.1. General objective

The objective of a site survey is to identify in a region of interest one or more preferred candidate sites which have a high probability of being suitable for the installation of a nuclear power plant. The region of interest may be a country, a political subdivision, the area served by an electrical supply organization or an area defined by geographical features. It should be large enough to give adequate scope in site selection. The site survey is conducted in a systematic manner to ensure that the preferred candidate sites are among the best that could reasonably be found in the region.

2.2. Site characteristics to be considered

All site characteristics that could affect the suitability of a site from a safety viewpoint shall be considered in the site survey process [2, 3]. These include both those which could influence the potential radiological impact from the plant on the environment (e.g. population distribution, dispersion characteristics in air or water) and those which represent for the site the likelihood and severity of extreme external events which could have an impact on the plant (e.g. seismicity, exposure of the site to floods, aircraft crashes or chemical explosions).

2.3. Procedure

2.3.1. General

The site survey process generally begins with delineating the region of interest and proceeds through three phases:

- regional analysis to identify potential sites
- screening of potential sites to select candidate sites
- comparison and ranking of candidate sites to obtain the preferred candidate sites.

In each of these phases some site characteristics are considered with the aim of rejecting unacceptable areas or sites and identifying the more suitable ones. The data required and the complexity and sophistication of the selection process increase as the site survey progresses towards its goal of selecting preferred candidate sites. It must be recognized that since the quantity and quality of information obtainable during the different phases vary in relation to the site characteristic under consideration, the extent of screening possible at each phase will vary accordingly.

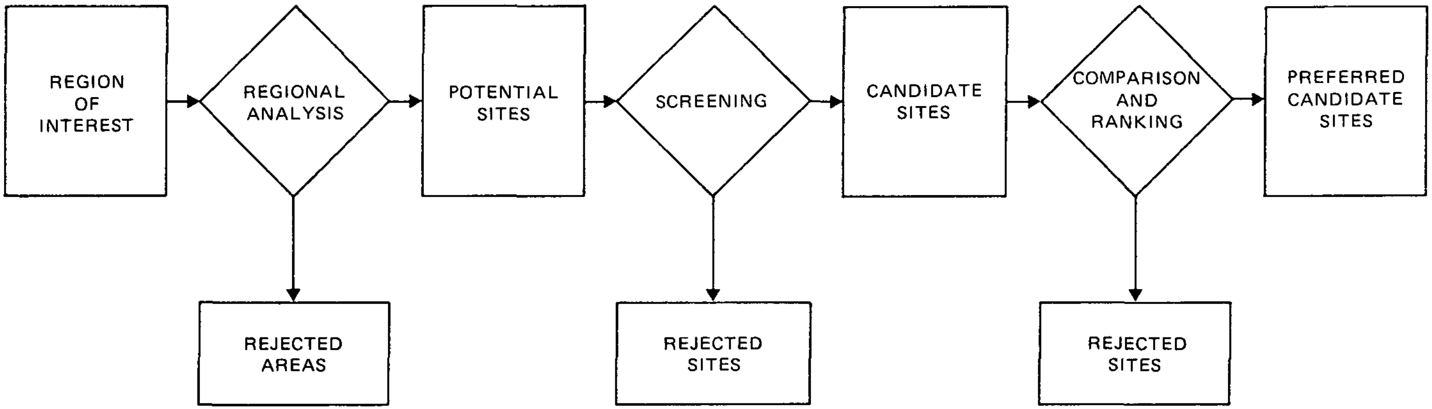

FIG.1. Schematic diagram of a site survey procedure.

Figure 1 presents a schematic of a possible procedure. It is important to note that this Guide provides only examples of:

- characteristics to be considered at each phase
- criteria for rejecting areas or sites for a given characteristic
- criteria for assigning a scaling factor, or index, for a given characteristic to each site
- comparison methodologies.

Particular situations may suggest different approaches.

The main safety requirement for a site survey is that all safety-related characteristics be considered at least once during the survey. The suitability of the site in terms of each characteristic is confirmed in the following phases. During the site survey, sites or areas are rejected on the basis of criteria which often are not absolute but represent a judgement as to what is the most appropriate acceptability threshold for the local situation. In practice an area or site is rejected if a scaling factor related to a given characteristic exceeds a predetermined rejection value. This approach can take into account both the regional conditions and the relative severity of the factor under consideration in comparison to all other factors.

Either a "parallel approach" or a "serial approach", or a combination of the two, may be followed for collecting the information. In the parallel approach all necessary information is collected for all areas or sites. The advantage of this approach is that it is not necessary to await the result of a previous rejection process before additional information or information on other site characteristics is collected. In the serial approach the information is collected only for areas and sites not rejected previously. The advantage of this approach is that the amount of work involved is less. Either of these approaches can be selected for application to a limited group of characteristics in the site survey.

2.3.2. Phase 1 — Regional analysis to identify potential sites

In the regional analysis, available information on certain site characteristics is used to eliminate major areas of the region of interest from further consideration. Usually the region of interest is very large, and it is not feasible to identify every possible site and perform a detailed survey of each one. The choice of the site characteristics used for the regional analysis is based on their relevance to the region, the ability to apply simple rejection criteria and the ready availability of the necessary data. Examples of such characteristics are population density, surface faulting, vulcanism and regional seismicity[2].

[2] Certain non-safety-related considerations (e.g. cooling water availability, electric load and transmission considerations) may cause the rejection of a number of areas during this phase.

Much of the information needed (e.g. maps, census data, existing geological data or cursory surveys of the region) relative to the characteristics selected for the regional analysis is likely to be readily available or easily obtained.

The result of the regional analysis is a delineation of the areas that have not been rejected within the region of interest. Within these areas, sites of a few square kilometres are identified as "potential sites". These should be somewhat larger than the area required for a normal nuclear power plant site so that during a later stage of the siting process, the exact plant location can be accommodated without difficulty. The identification of these potential sites is accomplished by the application of good technical judgement. The overall objective is to get a complete representation of the different areas of the region in the set of potential sites so as to permit the selection process to proceed in a comprehensive manner. The process will usually result in the selection of a considerable number of potential sites.

2.3.3. Phase 2 – Screening of potential sites to select candidate sites

The potential sites are then screened by using additional site characteristics not considered in the regional analysis, as well as more refined criteria for those characteristics that were taken into account. It will not be economically or technically feasible to make an in-depth study of all site characteristics for all the potential sites. Some potential sites may be rejected at an early stage, on the basis of those site characteristics for which sufficient information can be readily determined. Visits to potential sites and simple site examinations can provide useful information for this purpose.

Further screening of potential sites is accomplished by preliminary comparison of the sites, using elementary techniques of suitability scaling and simple comparison methodologies of the type summarized in Annex I, so that the list of potential sites is narrowed to a few candidate sites. It should be noted, however, that since there is no universally accepted methodology for conducting this comparison, care must be exercised in selecting the one to be used.

2.3.4. Phase 3 – Screening, comparison and ranking of candidate sites to obtain the preferred candidate sites

When the number of candidate sites is considered to be too large, further screening is performed, on the basis of more detailed information, to select preferred candidate sites. A comparison and ranking of this smaller group is then performed. It should be feasible, owing to the limited number of sites in this phase, to gather more detailed information on the characteristics of the candidate sites, to perform a limited amount of field work and to use sophisticated scaling and comparison techniques. Some of the available methods for scaling and comparison are summarized in Annex I.

Since this is the last phase of the site survey, a check is made to ensure that no safety-related site characteristics relevant to the region have been overlooked. It should also be confirmed, on the basis of the more detailed information gathered for these sites, that their acceptability with respect to the characteristics considered in the previous phase remains valid.

At the conclusion of this phase, the preferred candidate sites are ranked. A complete report on the entire site survey is prepared, with a careful and complete documentation of all data and analytical work. This is especially important since it will be required for the later stage of site evaluation. In addition, the final site selection invariably involves judgements based on safety, economic, environmental and other considerations.

3. ORGANIZATION OF A SITE SURVEY

Site survey studies for nuclear power plants require the involvement of a number of experts with diverse backgrounds to provide competence in many disciplines. The experts may come from different sections within the organization conducting the study or from other organizations (e.g. seismological and geological institutes) or they may be external consultants. The complexity of the process of identifying a suitable site and the variety of skills needed require that the site survey team be carefully selected and organized.

Usually the team is assigned the responsibility of examining both safety and non-safety aspects at the same time; care must be exercised to prevent inadvertent bias, such as exaggerating the importance of certain types of factors.

Although this Guide treats the site survey process as if it were continuous and done by a single team of experts, the early phases of the process may begin before a specific decision is needed. This would permit the appropriate authorities to be alerted to possible future use of the potential or candidate sites, and enable them to take this into account in such matters as land use planning or other developmental considerations. In such a case, the site survey process may well be discontinuous; and the site survey team might be disbanded and reconvened, or even reconstituted, at a later date.

3.1. Site survey personnel

In the site survey group there should be an expert familiar with each principal discipline involved. The need to collect and process local information should not be overlooked. A team of six to ten professionals is usually considered adequate, but additional specialized expert advice might be required from time to time.

During the course of a site survey, disciplines such as the following are required:

- Power engineering
- Nuclear engineering
- Radiological protection
- Ecology – Radioecology
- Demography
- Emergency planning
- Civil engineering
- Soil mechanics
- Geology
- Seismology
- Hydrology
- Meteorology.

The site survey requires experts who have general knowledge in one or more of the above disciplines. For the disciplines related to the more important site characteristics, a full-time member is usually selected (for instance, in a country of high seismicity an expert in seismotectonics). It is important that the person in charge of the team be knowledgeable and experienced in site survey problems and their safety aspects.

A well-balanced, typical site survey team might include the following experts:

- a nuclear safety engineer
- a geologist-seismologist
- a soil mechanics engineer
- a hydrologist
- a meteorologist
- an expert on site survey.

3.2. Role of the regulatory body in the site survey

An important role of the regulatory body is to review the site-related information at the site evaluation stage in order to establish that the site is acceptable. To facilitate the site survey, the regulatory body should make available beforehand the site criteria that will be used in performing the safety review at the site evaluation stage. This task is a very important one for the regulatory body of a country embarking on a nuclear power programme.

Because of the inherently judgement-oriented nature of many of the steps in site survey, the regulatory body can provide important supplemental guidance by monitoring the site survey activities.

3.3. Information collection and management

The site survey is performed and organized in such a way that all the relevant available information is collected and scrutinized to determine in particular its quality and completeness for safety purposes. Effective organization can facilitate the efficient collection of local information, which might be available only in the local language and from sources which are known only to local experts. Data should be compiled in a format which facilitates examination and comparison and the fullest possible usability. The organization of the data analysis should allow for prompt identification of information gaps. The need and the methods for filling significant gaps are also assessed.

Data are presented and classified according to existing standards. If appropriate standards and format do not exist locally for data presentation and classification, they should be established for the site survey and used throughout the study. In order to manage the data properly, standard format and maps of standard scale are used. All decisions on map scales and nomenclature, reference co-ordinates, and cartographic formats are carefully documented and decided upon after consultation with the whole survey team. The scale of the maps is chosen such that all the needed details can be shown.

3.4. Planning

A site survey plan is developed at the beginning of the site survey. It should include:

- Identification and description of the tasks to be performed during the site survey
- Sequence diagrams showing the sequential distribution of the various tasks (for example, site characteristics to be considered at each phase)
- For each site characteristic, the criteria adopted for the regional analysis and for the screening of potential and candidate sites
- An outline of procedures for applying these criteria, and a list of sources of information needed for their application
- A comprehensive schedule.

4. SPECIFIC SAFETY-RELATED SITE CHARACTERISTICS

In this section each of the main safety-related site characteristics which may be selected for use in the site survey process is discussed, and criteria for rejection or for assignment of a suitability scaling factor are presented. Annex II gives additional details on the subject, presents possible alternatives and indicates the ones which are more frequently used for considering particular site characteristics.

It should be noted that the use of rejection criteria, scaling factors, or comparison systems is only one possible approach that may be taken. Particular situations may dictate the use of other approaches.

An important initial step in the site selection procedure is to determine at what stage in the process a particular site characteristic should be taken into account and what resources should be devoted to considering it. There are no precise rules for this. The general approach is to select for consideration in the earlier phases of site survey those site characteristics which may be decisive in the acceptance-rejection process, and those for which information is most readily available.

Once an area or a site is rejected at a particular phase of the site survey process, it is automatically excluded from any further consideration unless some phases of the procedure are repeated. Therefore, it is important that careful consideration be given before areas and sites are rejected in the early phases of the site survey.

In selecting the preferred candidate sites it is essential to ensure that all site-related characteristics have been taken into account.

4.1. Surface faulting

In very seismic regions, areas that are near large known capable faults are usually rejected in the regional analysis, as are potential sites near known capable faults. The proximity of sites to suspected capable faults can also be used as a factor in later screening and selection of candidate sites. Candidate sites near known capable faults are rejected and those located sufficiently far from capable faults are usually preferred (see Annex II.1 and Fig.A.1).

Details can also be found in the Safety Guide on Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting (IAEA Safety Series No. 50-SG-S1).

4.2. Seismicity

Areas of relatively high seismicity are usually rejected in the regional analysis. In seismic regions, potential sites are screened on the basis of the severity of the vibratory ground motion which can affect each site, and candidate sites are screened and compared, with preference given to those subjected to lesser vibratory ground motion (see Annex II.2 and Fig.A.1).

Details can also be found in the Safety Guide on Seismic Analysis and Testing of Nuclear Power Plants (IAEA Safety Series No. 50-SG-S2) and in Safety Guide No. 50-SG-S1.

4.3. Suitability of subsurface material

In the early phases of a site survey, information on subsurface material may not be available. However, candidate sites can be compared on the basis of the suitability of the subsurface material for the foundation. Sites with suitable subsurface material for the foundation are preferred and ranked accordingly (see Annex II.3 and Fig.A.1).

Details can be found in the Safety Guide on Safety Aspects of the Foundations of Nuclear Power Plants (IAEA Safety Series No. 50-SG-S8), and in Safety Guides 50-SG-S1 and 50-SG-S2.

4.4. Vulcanism

In volcanic regions, areas in the immediate vicinity of potentially active volcanoes are often rejected in the regional analysis. The severity of the volcanic phenomena which could affect potential sites can be used as a screening factor. Candidate sites potentially less affected by these phenomena are preferred (see Annex II.4 and Fig.A.1). Those in the immediate vicinity of potentially active volcanoes are rejected.

4.5. Flooding

In the regional analysis, areas subject to high flood levels are usually rejected. Potential sites can be screened on the basis of the severity of effects of flooding; candidate sites that are less affected are usually preferred (see Annex II.5 and II.6 and Fig.A.1).

Details can be found in the Safety Guides on Design Basis Flood for Nuclear Power Plants on River Sites (IAEA Safety Series No. 50-SG-S10A) and Design Basis Flood for Nuclear Power Plants on Coastal Sites (IAEA Safety Series No. 50-SG-S10B).

4.6. Extreme meteorological phenomena

In regions where extreme meteorological phenomena (e.g. tropical cyclones, tornadoes) occur and are very severe, certain affected areas may be rejected. In these cases potential sites may be screened on the basis of the severity of the effects of these phenomena; candidate sites less affected by these phenomena are preferred (see Annex II.7 and Fig.A.1).

Details can be found in the Safety Guides on Extreme Meteorological Events in Nuclear Power Plant Siting, Excluding Tropical Cyclones (IAEA Safety Series No. 50-SG-S11A) and on Design Basis Tropical Cyclone for Nuclear Power Plants (IAEA Safety Series No. 50-SG-S11B).

4.7. Man-induced events

In the regional analysis, areas in the immediate vicinity of major hazardous facilities, major airports or transport routes carrying significant quantities of hazardous materials are rejected. Potential sites may be screened on the basis of distance from such facilities, and the associated impact.

In the vicinity of such facilities, those candidate sites for which the likelihood and severity of potential impact are less are preferred (see Annex II.8 and II.9 and Fig.A.1).

Details can be found in the Safety Guide on External Man-Induced Events in Relation to Nuclear Power Plant Siting (IAEA Safety Series No. 50-SG-S5).

4.8. Dispersion in air

Areas with features which may present adverse atmospheric dispersion characteristics over long periods of time, and which also have relatively high population densities, are rejected in the regional analysis. Potential and candidate sites may be screened and compared on the basis of wind direction and atmospheric dispersion factors. This subject is covered in the Safety Guide on Atmospheric Dispersion in Nuclear Power Plant Siting (IAEA Safety Series No. 50-SG-S3). They may also be screened on the basis of population distribution – for details see the Safety Guide on Site Selection and Evaluation for Nuclear Power Plants with Respect to Population Distribution (IAEA Safety Series No. 50-SG-S4).

4.9. Dispersion in water

At the regional analysis phase, an area can be considered for rejection if it contains extensive and important ground or surface drinking water sources which are used by the public, or for which there are plans for future public use. For screening potential sites, the proximity of large sources of drinking water may be adopted as a scaling factor. In the screening and comparison of candidate sites, those for which the potential for accidental contamination of sources of water for drinking is low are preferred.

Details can be found in the Safety Guides on Hydrological Dispersion of Radioactive Material in Relation to Nuclear Power Plant Siting (IAEA Safety Series No. 50-SG-S6) and Nuclear Power Plant Siting: Hydrogeological Aspects (IAEA Safety Series No. 50-SG-S7).

4.10. Population distribution

In the regional analysis, consideration is given to rejecting areas of very high population density. The screening of potential sites and the comparison and ranking of candidate sites are performed on the basis of appropriate suitability factors, with the most sophisticated being used in the final phase (see Annex II.10 and Fig.A.1).

Details can be found in Safety Guide 50-SG-S4.

4.11. Emergency planning

The feasibility of effective emergency actions (e.g. availability of communication, access, evacuation, transportation) is considered during the site survey, particularly during the later phases when individual sites have been identified. See the Safety Guide on Preparedness of Public Authorities for Emergencies at Nuclear Power Plants (IAEA Safety Series No. 50-SG-G6).

4.12. Land use

The use of land in the region may influence site selection.[3] Account should also be taken of possible future developments and regional planning (see Subsection 5.5 of the Code).

4.13. Availability of cooling water

The availability of an adequate cooling water supply is essential for safety purposes such as the ultimate heat sink. However, this need is normally taken into account in meeting the non-safety-related operational requirements for cooling water.

4.14. Other site characteristics

In some regions it is appropriate to consider other site characteristics listed in the Code (e.g. avalanche, landslide, surface collapse) at various phases of the site survey.

5. DOCUMENTATION

For each major phase of the site survey, the data collected, the criteria used and the results obtained are reviewed and recorded in interim reports so as to get thorough documentation of the entire process. Preparation of interim reports will be more easily accomplished if all the data to be collected and the

[3] From the point of view of protecting the environment, land use may play a principal role in the selection of suitable sites.

procedures to be followed are outlined in a preliminary report prepared before the site survey begins. The different sections of this report are usually written by the appropriate members of the team and suitably reviewed.

5.1. Contents of the documents on the site survey

The information to be presented in the preliminary report usually includes:

(1) A description of the site survey process, including:
   (a) objectives of the site survey
   (b) legal limitations, with the bases and rationale for their applicability
   (c) basic constraints on the site survey
   (d) procedures selected for:
      – regional analysis to identify potential sites
      – screening of potential sites to select candidate sites
      – screening, comparison and ranking of candidate sites to obtain the preferred candidate sites
   (e) aspects to be considered at each phase of the selection process:
      – scales by which suitability factors are to be measured
      – criteria to be used for rejection of areas or sites
      – methods for assigning suitability scaling values for the various site characteristics
      – methodology used to compare and rank sites, taking into account several site characteristics

(2) Specification of data to be used, and the information, study and investigation required for each characteristic at each phase of the site survey.

After each phase the following information is carefully documented in the relevant interim report:

(1) The data collected
(2) The criteria adopted
(3) The results obtained in the evaluation of each characteristic
(4) The methods adopted and the results obtained for each characteristic in the screening of the sites
(5) The methods adopted and the results obtained for comparison of sites.

At the end of the site survey, the complete results and an analysis of them, together with data, procedures, considerations and recommendations, are compiled into a final report.

Annex I

ELEMENTS OF SITE SURVEY METHODOLOGY

A.I.1. Introduction

This annex contains a summary of several formal methods frequently used in site survey studies which take different site characteristics into account in order to assess and compare the relative merits of areas or sites.

Effective use of any of these methods requires thorough appreciation of their practical limitations.

A.I.2. Suitability scaling

The use of an index[4] expressing the measure of suitability of a site characteristic is referred to in this Guide as suitability scaling [4]. The analysis of this subject given here pertains only to siting aspects and does not deal with more general applications.

The following four classes of suitability scaling can be used:

Class (1) – "Yes-No" categorization (nominal)

For the characteristic under consideration, each area or site is assigned to one of the two suitability categories: acceptable or unacceptable. For example, all areas or sites in which earthquake intensities VIII and above have been felt may be arbitrarily considered as unacceptable, and those with below VIII as acceptable.

Class (2) – Ordinal scaling

In the ordinal scaling technique, the characteristic under consideration is assigned an index that can be ranked in an order of preference, the rank being the suitability scaling factor. Since the rank represents only a position in an ordered series, the differences between these scaling factors are not quantitatively indicative of the differences of suitability for the characteristic, and the scaling factors cannot be used in any arithmetical operations.

An example of ordinal scaling for the characteristic of seismicity is as follows:

> The index used to characterize the seismicity of each site may be 0 or a number from 1 to 5 corresponding inversely to the intensity in the

[4] In the specialized literature, the term "attribute" is frequently used for what this Guide refers to as an "index".

Mercalli scale of past local earthquakes, with 5 being the most suitable. The assignment may be:

Intensity of past local earthquakes	Ordinal suitability scaling factor
less than 5	5
5 to 6	4
6 to 7	3
7 to 8	2
8 to 9	1
greater than 9	0

Class (3) – Interval scaling

For the characteristic under consideration a suitability interval scaling factor is assigned to each site in such a way that the difference between two factors has a meaning that is independent of their positions on the scale. The factors need not be integers, and they may be added, subtracted or weighted. The zero of the scale is arbitrary. An example of an interval scaling factor is the amount of soil above some norm (an arbitrary zero) that has to be removed for preparing a site.

Class (4) – Ratio scaling

For the characteristic under consideration a suitability ratio scaling factor is assigned to each site from a continuous scale that has a non-arbitrary zero in addition to the properties of the scale described under Class (3). All arithmetical operations are allowed with these ratio scaling factors; thus, a statement such as "X is so many times as much as Y" is meaningful. An example of a ratio scaling factor for the characteristic of seismicity is the additional cost of the engineering measures resulting from aseismic design necessary to protect the plant against earthquakes.

The complexity of analytical possibilities increases from Class (1) to Class (4). While the "Yes-No" categorization usually results in simple rejection criteria, ratio-scaled factors are suitable for use with more sophisticated methods such as computerized optimization models which take many site characteristics into consideration at the same time. However, data quality has to be high enough to justify this sophisticated, quantitative approach; otherwise the complexity of the analysis may hide the real uncertainties of the results and provide an unreliable screening.

A.I.3. Figure of merit

To express a suitability factor as a function of another parameter (figure of merit), a suitability curve may be used. This curve relates each value of an ordinally scaled factor to a figure of merit which, for example, may be based on cost; this figure of merit decreases with increases in cost and is ratio- or interval-scaled.

For example, earthquakes or tornadoes can be rated by means of ordinal suitability scaling factors based on the intensities of the phenomena. These factors can be transformed to figures of merit by means of suitability curves relating them to the differential cost of protection of the nuclear power plant.

A.I.4. Processing of site suitability factors

Once a suitability factor has been assigned to each characteristic of a site, it is then necessary to compare the sites with each other and to select the most suitable group of sites.

In this Guide such a process is performed twice – for comparison of potential sites, and for comparison of candidate sites. However, it must be pointed out that in certain cases these two steps may be combined. To scrutinize sites whose suitability factors are not interval- or ratio-scaled, the rejection method or the sequential ranking rejection method may be used.

Other methods are based on comparing pairs of sites (Copeland social welfare functions) or on the direct determination of indifference curves [4], but these have not had frequent use in siting. Still others make use of the concept of utility and utility curve [4, 5].

A.I.4.1. Rejection method

In this method, sites are classified as either acceptable or unacceptable with respect to a given characteristic. Various characteristics are considered sequentially, until only a sufficiently small set of sites remains.

A.I.4.2. Sequential ranking rejection method

In this type of method, all sites or areas are ranked for a given characteristic on the basis of an ordinal factor. The sites having a value for this factor lower than a given value are rejected. The same procedure is then applied sequentially for other characteristics.

A.I.4.3. Methods based on interval- or ratio-scaled suitability factors

Methods such as weight summation, decision analysis and goal programming have been proposed for processing site characteristics whose suitability factors are ratio-scaled or interval-scaled. (An extensive review of these methods can be found in Ref.[4].) In this subsection, some details are given on weighting summation techniques, which are extensively used in site surveys.

In many analytical approaches based on multi-objective decision theory, weighting techniques such as the following are used:

$$\text{Site suitability} = \sum_{i=1}^{N} F_i W_i$$

where:

F_i = figure of merit for characteristic i (interval- or ratio-scaled)
W_i = weight for characteristic i

The validity of the assumptions underlying these techniques should be carefully verified [5]. This refers in particular to:

- The independence of suitability differences. (Each suitability factor value must not depend on the level of suitability factors of other characteristics.)
- The independence of the preference. (The trade-off among suitability factors must not depend on the level of the suitability factors of other characteristics.)

There are many methods for evaluating the appropriate weights, including those known in the literature as "ratio questioning", "Churchman Achoff" [4], and "indifference". Each of these has advantages and disadvantages, and there is little empirical evidence that one is better than the others. Many of these techniques involve group questioning procedures, which help to clarify areas of value conflicts and to ensure a more comprehensive perspective. Of these, the two approaches most commonly used are the Delphi [6] and the nominal group process techniques.

Annex II

SCREENING AND RANKING OF AREAS AND SITES

This annex gives examples of information to be collected for various site characteristics and important phenomena, and explains how this information can be used to rank sites and areas. Sections A.II.1 to A.II.10 outline, for each characteristic, the information needed for a regional analysis, screening of potential sites, and screening and ranking of candidate sites. An indication is given of the frequency of use of the characteristic at each phase of the analysis, and the rejection criteria and selection methodology are described.

Figure A.1 depicts in chart form the outlined approach. This approach is only one of many possible, and the examples given in this annex are included for the purpose of clarifying the concepts of this Guide.

A.II.1. Surface faulting

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Often, in regions affected by surface faulting
Information to be collected:

- regional geological maps, including those which contain data on stratigraphy
- tectonic maps
- regional geophysical maps (indicating gravity and magnetic anomalies)
- satellite imagery

Rejection criteria: Areas which are within a given distance from a known capable fault are rejected. This distance is dependent on the type of fault and on the magnitude of the maximum potential earthquake associated with the fault.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Often, in regions affected by surface faulting
Information to be collected: In addition to the information listed for the regional analysis, information to be collected at this phase usually includes:

- aerial photographs
- local geological maps
- local geophysical data
- results of preliminary geological site reconnaissance

Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, which may be based on expert judgement of the potential capability of faulting at the site (i.e. the probability that the fault is capable and that the potential surface displacement of the fault affects the site)
Screening or rejection criteria: On the basis of more detailed information, sites within a given distance from a known capable fault are rejected (see regional analysis). Moreover, sites within this distance from faults suspected to be capable are downrated with an appropriate suitability factor

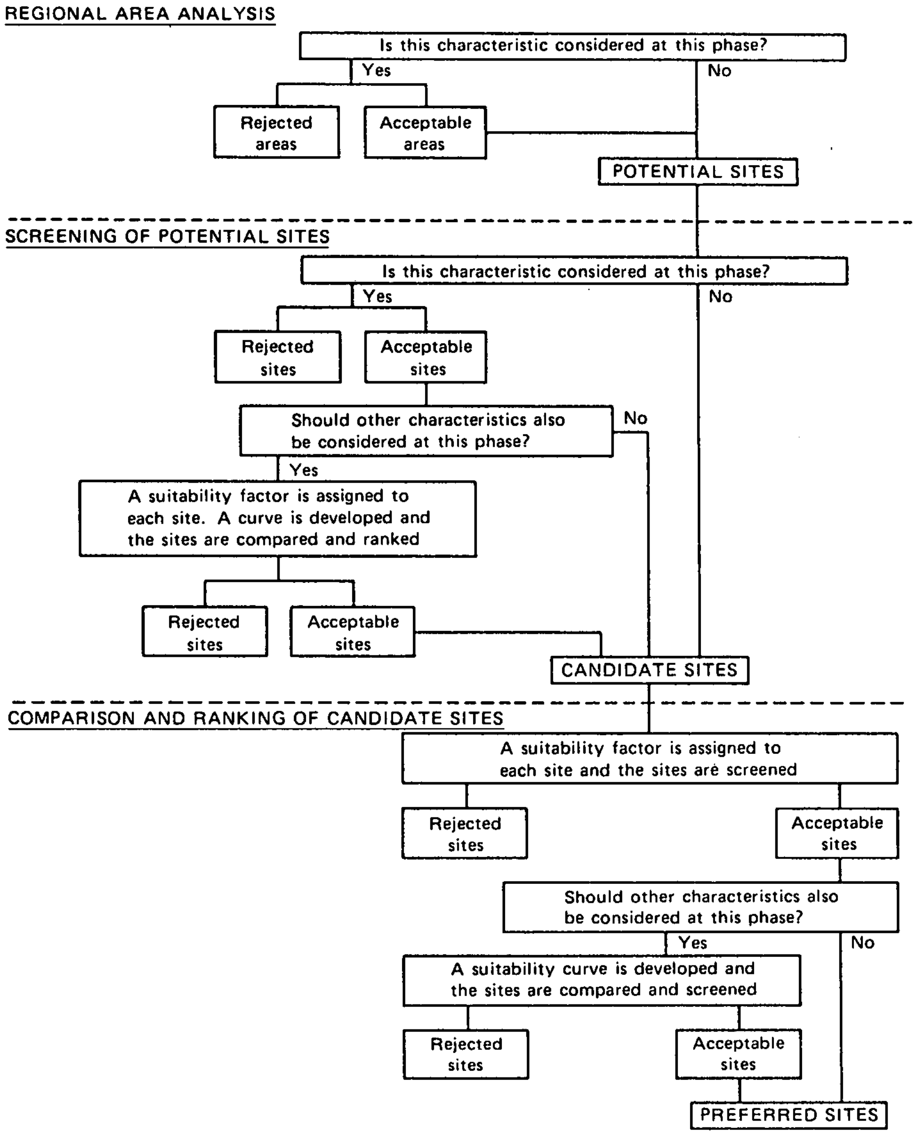

FIG. A.1. Example of an approach for considering various site characteristics.

Selection methodology: A suitability curve is constructed, correlating the ordinal factor to another parameter which is interval-scaled (e.g. a monetary cost is assigned to the risk that a site will be rejected because it is affected by a capable fault).

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: In seismic regions, capable or suspected faults are always considered in this phase
Information to be collected:

- results of geological site reconnaissance, and limited geological investigation of the site
- seismic prospecting of the site areas (in special cases)
- results of the review and analysis of aerial photographs, particularly those taken at a low level (see Safety Guide 50-SG-S1, Subsection 4.2 and Annex 1)

Type of screening: Rejection, suitability
Type of suitability factor: Same as for the previous phase
Screening and comparison criteria: On the basis of more detailed information and consideration of the actual branch faulting of the main capable fault, sites are rejected, and the remaining ones are screened as in the previous phase
Comparison methodology: Same as for the previous phase.

A.II.2. Seismicity

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Almost always, in regions of high seismicity (historical earthquakes more severe than Modified Mercalli Intensity Scale VIII (MM VIII); often, in regions of moderate seismicity (historical earthquake MM VI–VIII)

Information to be collected:

- regional geological maps, including those which contain data on stratigraphy
- tectonic maps
- regional geophysical maps (indicating gravity and magnetic anomalies, if information available)
- satellite imagery
- catalogue of past earthquakes
- isoseisms of past earthquakes
- seismic zoning maps (if available)

Rejection criteria: Areas affected in the past by earthquake intensities higher than a given value which has been chosen on the basis of technical judgement are rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Always, for areas of high seismicity; very frequently, in regions of moderate seismicity
Information to be collected: In addition to the information listed for the regional analysis, the following information is usually collected:

- results of geological reconnaissance at the sites and of limited field work on the sites
- review and analysis of aerial photographs, particularly those taken at low sun angle (see Safety Guide 50-SG-S1, Subsection 4.2 on surface faulting, and Annex 1)
- information needed for a preliminary evaluation of design basis ground motions with seismotectonic methodology (for regions of high seismicity)
- information needed for a preliminary evaluation of the expected ground motion during the lifetime of the plant (for regions of moderate seismicity) (see Safety Guide 50-SG-S1)

Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, assigned to each site on the basis of design basis ground motion or the expected ground motion
Screening or rejection criteria: Sites subjected to very severe ground motions are rejected. The remaining sites are screened:

(a) For regions of high seismicity, the main seismotectonic structures and seismotectonic provinces are identified. A preliminary assessment of the design basis ground motion for each potential site is performed and used for the screening
(b) For regions of moderate seismicity, the ground motions expected during a period of the order of the lifetime of the plant are evaluated with a simplified methodology and used for the screening

Selection methodology: A suitability curve is constructed, correlating the ordinal factor with the importance of the seismic design.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always, where there is a potential for earthquake ground motions at the site
Information to be collected: Same types of information as for the previous phase but in more detail. Detailed data on earthquakes that have affected the site in the past or on those correlated with seismotectonic structures which are critical for the ground motions at the site
Type of screening: Suitability
Type of suitability factor: Same as for the previous phase

Screening and comparison criteria: Same as for the previous phase but based on more detailed information
Comparison methodology: In cases of high seismicity a preliminary seismic design of the main parts of the plant is performed, taking into account the foundation characteristic for each candidate site. The results are then used for comparison of the sites.

A.II.3. Suitability of subsurface material

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Sometimes
Information to be collected:

- regional geology
- detailed geological maps
- stratigraphic maps
- soil map of the region (if available)

Rejection criteria: Based on an analysis of detailed geological maps and special maps showing the characteristics of the subsurface material, areas covered with deep unsuitable soil or with soil having a potential for liquefaction or subsidence are rejected; areas with consolidated soil or rock are selected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Sometimes
Information to be collected at this phase usually includes:

- detailed geological maps
- characteristics of the surface material
- existing information on subsoil (obtained, for example, during major construction in the area around the sites)
- study of local aerial photographs

Type of screening: Suitability
Type of suitability factor: Ordinal, subjectively assigned
Screening or rejection criteria: On the basis of site visits, a semi-quantitative judgement is given by the experts as to the probability that the site will have suitable foundation characteristics
Selection methodology: The comparison is made on the basis of a suitability curve that correlates the ordinal factor with the differences in importance of the foundation works.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always
Information to be collected: Same type of information as for the previous phase but in more detail; in addition, the result of limited field investigation of the sites (e.g. borings on special cases, seismic prospecting)
Type of screening: Suitability
Type of suitability factor: Ordinal, based on the characteristics of subsurface material
Screening and comparison criteria: On the basis of limited field work (a few borings) and expert engineering judgement, an ordinal factor is assigned to each site and used for the screening and comparison
Comparison methodology: An estimate of the amount of foundation work necessary for each site.

A.II.4. Vulcanism

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Often, in volcanic regions
Information to be collected:

- regional geological maps
- catalogue of past volcanic phenomena in the region
- data on magnitude of volcanic phenomena typical for the region (lava flow, mud flow or lahar, ash or block falls and burning clouds)

Rejection criteria: Since it may be difficult to find effective engineering solutions for some of the phenomena associated with volcanoes, areas within a conservative distance from each active or potentially active volcano are rejected from further consideration. Selection of the distance is based on past world-wide or regional experience concerning impacts from similar volcanoes.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Often, in volcanic regions
Information to be collected: Same as in the previous phase, but with particular reference to volcanoes which could affect the potential sites
Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, based on the severity of the impact (depth of ash fall)
Screening or rejection criteria: On the basis of more detailed information, sites which cannot be protected against the impact of volcanic phenomena

are rejected. For the remaining sites a preliminary analysis of the impact is performed, and the sites are screened on the basis of the severity of the impact

Selection methodology: A suitability curve is constructed, correlating the ordinal factor with the importance of the engineering measures.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always, in volcanic regions
Information to be collected: Detailed data on active and dormant volcanoes which can have an impact on the candidate sites
Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, based on the severity of the impact
Screening and comparison criteria: On the basis of more detailed data available at this phase, either it is confirmed that the sites are not affected, or a preliminary evaluation of the impact is performed and the sites are screened accordingly
Comparison methodology: Based on a preliminary evaluation of the engineering measures that would be required.

A.II.5. Floods on river sites

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Always, where there is a potential for river floods
Information to be collected:

- historical data on floods, precipitation and channel changes
- aerial photographs of the area
- satellite imagery (if available)
- data on water-control structures

Rejection criteria: The flood level contours are derived from the envelope curves for floods of the basins in the region. The curves are prepared using historical data and empirical formulas developed for similar basins. Failures of upstream dams are usually postulated. Areas with high flood levels are usually rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Often, where there is a potential for river floods
Information to be collected:

- historical data on floods and channel changes

– topography of the potential site area
– data on water-control structures

and, if available:

– aerial photographs of the basin
– river channel geometry
– basin meteorological data

Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, based on the reference flood level
Screening or rejection criteria: The sites affected by high flood levels are rejected on the basis of more detailed information. The remaining sites are screened through the reference flood level. The reference flood is usually evaluated on the basis of the envelope curves of the historical flood, and on the assumption of failure of upstream dams and sudden destruction of channel obstructions
Selection methodology: A suitability curve is developed, correlating the flood level with the engineering measures that would be required.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always, where there is a potential for river floods
Information to be collected: Same type of information as for the previous phase but in more detail, and

– profiles and sections of the river and flood channel in the site area
– location and description of water-control structures
– sediment transport
– detailed precipitation data for the basin
– snow cover and snow melt data for the basin
– data on ice pheomena

Type of screening: Suitability
Type of suitability factor: Ordinal, based on the flood level
Screening and comparison criteria: A preliminary evaluation of the design basis flood is performed; candidate sites having a lower design basis flood are preferred
Comparison methodology: Based on a preliminary evaluation of the engineering measures that would be required.

A.II.6. Floods on coastal sites

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Always, where there is a potential for coastal flood
Information to be collected:

- oceanographic data
- hydrological data
- historical data on coastal floods due to any cause
- historical data on tsunamis
- data on regional seismic sources for tsunamis
- aerial photographs and topographical data
- satellite imagery, if available

Rejection criteria: The flood levels caused by surges and waves are roughly estimated for the whole of the coastline from the envelope of the historical data, or by the use of empirical formulas (see Safety Guide 50-SG-S10B) which use fetch and wind speed as variables. The flood levels caused by tsunamis are estimated on the basis of comparison with similarly exposed coasts of the region. Areas subjected to very high flood levels due to the action of waves, surges, tsunamis, seiches and ice conditions may be rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Sometimes, where there is a potential for coastal flood
Information to be collected: Same as in the previous phase but more detailed. The information to be collected at this phase usually includes:

- historical data on surges and tsunamis in the area near the potential sites
- data on seismic sources for tsunamis in the area near the potential sites
- systematic data on historical tropical cyclones
- statistical data on waves

Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, based on flood level
Screening or rejection criteria: The maximum surge caused by tropical cyclones or other disturbances typical for the region is evaluated, either by extrapolating the historical record appropriately adapted to the potential sites, or by using simplified formulas based on wind speed, fetch and minimum pressure. For tsunamis the historical data are usually not adequate; therefore, it may be necessary to perform a simplified evaluation with seismotectonic methodology. The flood levels for rejection

are established on the basis of engineering judgement, taking into account local characteristics. The remaining sites are screened, using the reference flood level as a scaling factor
Selection methodology: A suitability curve is constructed, correlating the flood levels with the engineering measures that would be required.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always, where there is a potential for coastal floods
Information to be collected: Same as the previous phase but with more detail, and

- data on bathymetry offshore from the site
- more detailed study of the extreme historical surges
- more detailed study of tsunami generation and propagation

Type of screening: Suitability
Type of suitability factor: Ordinal, based on the flood level
Screening and comparison criteria: A preliminary evaluation of the design basis flood is performed; candidate sites having lower design basis floods are preferred
Comparison methodology: Performed on the basis of the importance of protecting the plant against floods.

A.II.7. Extreme meteorological phenomena (tropical cyclones and tornadoes)

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Sometimes, where there is a potential for tropical cyclones or tornadoes
Information to be collected:

- maps showing the severity of tornadoes or tropical cyclones for a given return time (if available for the region)
- data on the climatology of the region
- catalogue of past tornadoes and tropical cyclones

Rejection criteria: The region is divided into areas of homogeneous climatological characteristics. The tropical cyclone or tornado with a given return time (of the order of the plant lifetime) for each homogeneous area is evaluated, and areas subject to very severe tornadoes or tropical cyclones are rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Sometimes, where there is a potential for tropical cyclones or tornadoes
Information to be collected: Same as in the previous phase, and data on past tornadoes and tropical cyclones affecting the areas around the sites
Type of screening: Suitability
Type of suitability factor: Ordinal, e.g. the wind speed for a given return time
Screening or rejection criteria: Using a procedure similar to the regional analysis, but based on more detailed information, the wind speed having a given return time is evaluated for each site. The sites are screened, using the wind speed as a scaling factor
Selection methodology: A suitability curve is constructed, correlating the ordinal factor with the engineering measures that would be required.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Often, where there is a potential for tropical cyclones or tornadoes
Information to be collected:

- detailed data on all tornadoes and tropical cyclones which have affected the region
- climatological data sufficient for making a preliminary estimate of the design basis tornado and of the design basis tropical cyclone

Type of screening: Suitability
Type of suitability factor: Design basis wind speed
Screening and comparison criteria: A preliminary evaluation of the design basis wind speed related to tropical cyclones or tornadoes is performed; candidate sites having lower design basis wind speeds are preferred
Comparison methodology: Based on a preliminary evaluation of the engineering measures that would be required.

A.II.8. Proximity of hazardous facilities

REGIONAL ANALYSIS TO SELECT POTENTIAL SITES

Frequency of use: Very often
Information to be collected: Data on possible sources of man-induced events, such as:

(a) fixed installations, e.g. manufacturing and processing plants for chemicals and explosives, oil refineries, oil and natural gas storage facilities

(b) pipelines transporting flammable gas or other hazardous materials
(c) sea or inland waterways where hazardous cargo is carried

Rejection criteria: All hazardous facilities where the amount of hazardous material stored is significant are identified. Areas around these facilities are rejected out to a distance that corresponds to an appropriate screening distance value (SDV), depending on the type of potential impact (e.g. drifting explosive clouds, explosions).

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Often
Information to be collected:

- for the sources in (a), (b) and (c) (see regional analysis) that are relatively close to potential sites, data needed to estimate in a preliminary way the nature and the amount of hazardous material stored
- data on the nature and the amount of hazardous material that is transported by roads or railways near the potential sites, or that is stored nearby, waiting for transport
- local topography

Type of screening: Rejection, in some cases suitability
Type of suitability factor: Ordinal, based on the severity of the impact (e.g. pressure wave)
Screening or rejection criteria: On the basis of more detailed information, sites within the SDV are rejected (see regional analysis). If many of the sites are affected, a preliminary analysis of the impact is performed, and the sites are screened on the basis of the severity of the impact
Selection methodology: A suitability curve is constructed, correlating the ordinal factor with the engineering measures that would be required.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always
Information to be collected:

- data on hazardous material stored in facilities near the candidate site
- data on planned construction of such facilities near the candidate site
- more precise data on the frequency of transport of hazardous material by rail, road or sea near the candidate site and the nature and amount of material

Type of screening: Rejection, suitability
Type of suitability factor: Ordinal, based on the severity of the impact
Screening and comparison criteria: On the basis of more detailed data

available at this phase, either it is confirmed that the sites are not affected, or a preliminary evaluation of the impact is performed, and the sites are screened accordingly
Comparison methodology: Based on a preliminary evaluation of the engineering measures that would be required.

A.II.9. Aircraft crashes

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Often
Information to be collected: number and location of airports (civil, military)
Rejection criteria: Airports and military installations are identified, and areas around these facilities having a radius equal to a screening distance value are rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Often
Information to be collected: In addition to the above:

- number of movements and types of aircraft for each airport near the site, including future developments anticipated during the lifetime of the plant
- location and characteristic of future airports in the region
- orientation of runways

Type of screening: Suitability
Type of suitability factor: Ordinal, based on the potential impact
Screening or rejection criteria: Often the results of the previous phase are re-examined for confirmation. If many of the potential sites may be affected by aircraft crash, the severity of the impact is evaluated with a simplified methodology and used for the screening
Selection methodology: A suitability curve is constructed, correlating the ordinal factor with the engineering measures that would be required.

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Often
Information to be collected: Same type of information as for the previous phase but in more detail
Type of screening: Suitability

Type of suitability factor: Ordinal, based on the potential impact
Screening and comparison criteria: Based on more detailed information, including future plans for expansion of existing airports or construction of new airports in the region, a preliminary evaluation of the impacts is performed and the sites are screened accordingly
Comparison methodology: Based on a preliminary evaluation of the engineering measures that would be required.

A.II.10. Population distribution

REGIONAL ANALYSIS TO IDENTIFY POTENTIAL SITES

Frequency of use: Always
Information to be collected:

- number of inhabitants for each population centre in the region of interest
- population density maps if available
- general information on the expected growth of the population centres during the lifetime of the plant (if available)

Rejection criteria: Areas close to major population centres, and areas of relatively high population density are rejected.

SCREENING OF POTENTIAL SITES TO SELECT CANDIDATE SITES

Frequency of use: Always
Information to be collected:

- distribution of the population around each potential site
- expected growth of the population

Type of screening: Suitability
Type of suitability factor: Ordinal, based on site population factor (see Safety Guide 50-SG-S4)
Screening or rejection criteria: Sites are screened on the basis of the value of a simplified scaling factor related to population distribution. (The weight for this factor is a function of distance only, but the prevailing wind direction should be taken into account when important.) (See Safety Guide 50-SG-S4)
Selection methodology: The comparison of sites based on population is very difficult. It may be appropriate to compare all other site characteristics, and then to evaluate the sites independently from the point of view of population distribution. A suitability curve can be constructed by using

a group technique that subjectively correlates an ordinal factor which expresses the suitability of the population distribution with an interval-scaled factor (such as the potential detriment to the society of having a site with a less suitable population distribution).

COMPARISON AND RANKING OF CANDIDATE SITES

Frequency of use: Always
Information to be collected: Same type of information as for the previous phase but in more detail, including:

- expected increase of the population during the lifetime of the plant
- dispersion characteristics and prevailing wind at the site
- location of groups of inhabitants who would be difficult to evacuate in case of emergency (such as those in gaols, hospitals, schools)
- road system appropriate for emergency plan

Type of screening: Suitability
Type of suitability factor: Ordinal, based on population distribution weighted with frequency of wind direction and atmospheric dispersion factor. (See Safety Guide 50-SG-S4)
Screening and comparison criteria: Sites which have more favourable values of the factor are preferred
Comparison methodology: Same as for the previous phase.

Annex III

NON-SAFETY CONSIDERATIONS

A.III.1. Introduction

Site selection for nuclear power plants usually involves both safety and non-safety considerations. However, some non-safety considerations may also have a bearing on safety-related aspects of the plant. In some cases non-safety aspects may lead to the rejection of several areas, and hence those aspects should be investigated at the preliminary stage of site survey.

The major categories of non-safety site aspects are economic, technical, environmental and social. Some of the more important of these aspects are briefly mentioned in this annex. Further guidance on non-safety considerations in nuclear power plant siting may be obtained from Refs [1, 2].

A.III.2. Distribution network considerations

The reliability and stability of the external electricity networks are important aspects. If the reliability level of the connecting system is low, the overall probability of availability of off-site power is reduced.

Nuclear power plants should be located as close to load centres as is practicable, in order to economize on transmission costs and power losses. Load forecast data for the relevant region of a country may be necessary, together with data on any plans for development of industry and population in the region that may require a fairly large amount of power. Maps of high-electrical-voltage transmission systems are collected to study the interconnection with the proposed plant. The distance between load centres and sites is an important factor to be considered.

A nuclear power plant requires adequate and reliable startup power; therefore the availability of startup power is a factor which may need consideration. The existing and planned electrical generating stations and transmission lines in the region also need to be studied. If suitable electrical power cannot be supplied to the site, an appropriate generating plant for startup purposes may be required.

A.III.3. Cooling water

The availability of an adequate supply of water of suitable quality for power plant cooling purposes represents another important aspect to be considered in the site survey. The quantity of water required will depend mainly upon the system of cooling adopted (e.g. once-through cooling, or recirculation with cooling towers or cooling ponds), the heat output of the plant and the ambient conditions[5]. The amount of water needed by the plant should be only a small fraction of the total minimum available supply. The inlet water temperature during the warm season controls the temperature drop in the condensers, and therefore the quantity of mass flow of the water required and the thermal efficiency.

Data on the water sources (e.g. rivers, canals, reservoirs or the sea), including their supply potential, committed uses if any and reliability, are studied. Maps of cooling water supply sources close to the site are prepared. Water sources located far from the site involve economic penalties and may influence the reliability of the supply. The existence of certain natural physical

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[5] For example, when a plant of 1000 MW(e) capacity is located on a river site, the river should have a minimum flow of roughly 150 m^3/s of water if a cooling system of the once-through type having a temperature drop in the condensers of about 8 K is used. If recirculation (wet-cooling towers, ponds, etc.) is adopted, the make-up requirement will be a minimum flow of about 3–8 m^3/s.

features at the site, e.g. a steep slope in the seabed, a short intake at a coastal site, or a protruding land mass that will separate the warm water plume from the intake, is economically advantageous. Pumping costs are relevant to both the initial and the operating costs, and the seasonal differences in the water level are usually considered.

The quality of the water supply for plant cooling is an important factor. The silt content in the water, and its seasonal variation and particle size distribution, are of particular relevance.

A.III.4. Transport routes

Adequate transport links need to be available at the site. Transport routes that are suitable for conveying large and heavy equipment to the site are necessary. In this context, existing and planned roads, waterways and railroads are studied with respect to the sizes and weights of plant equipment to be transported from prospective manufacturing centres or from the port of entry.

A.III.5. Topography

The extent of preparatory work necessary for each site is a relevant factor in a site survey. It is usually evaluated through the analysis of topography maps.

At the preliminary phase, areas which present average slope higher than 15–20% are usually rejected. At the later phases, this factor may be more properly taken into account through visits to the sites.

A.III.6. Proximity to industrial centres

In order to facilitate operation and maintenance, as well as certain types of routine inspections at the nuclear power plant, the existence and availability of an industrial infrastructure not far from the site will be an advantage. Sites located far away from a general industrial base might experience problems in regard to minor repair facilities for which the plant may not be equipped. On the other hand, proximity to major industrial facilities may create secondary conventional safety problems in the event of nuclear emergencies.

A.III.7. Environmental aspects

The construction and operation of a power plant may produce an adverse impact on the aquatic life in the environment.

Aquatic organisms will, to varying degrees, be subject to entrainment, impingement and increases in temperature and salinity. Aquatic organisms in bodies of water on or near the site may also be affected by dredging and clearing of watershed vegetation. The largest impact on the terrestrial environment occurs during the clearing of terrain for construction of plant facilities. Other construction and operational considerations include effects on the terrestrial environment from noise, dust, human activity, and emissions of biocides from the cooling towers.

The effects of operation of cooling towers on the climate and microclimate of the surrounding area – e.g. changes in humidity, fogging, icing, shadowing, visibility and diffusion characteristics – and, conversely, the effects of climatic conditions on the operation of cooling towers may represent an important factor for site survey. In addition, depositional effects on agricultural land may have to be considered.

The existing and planned land use in the site areas – such as agriculture, protection of landscape, recreational facilities, tourism – are also considered in the site survey.

A.III.8. Socio-economic aspects

The construction and operation of a nuclear power plant involve several non-safety factors which influence the local population. In areas of high unemployment, a power plant may generate a significant number of jobs during the construction phase. On the other hand, the work force associated with the plant may also place demands upon local resources (housing, schools, community services). The construction and operation of a power plant also generate traffic, causing noise and visual effects which may be objectionable to local residents. It is desirable to try by appropriate siting or by other suitable means to ensure a reasonable balance of all socio-economic effects resulting from the construction and operation of a nuclear power plant.

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DEFINITIONS

The following defintions are intended for use in the NUSS programme and may not necessarily conform to definitions adopted elsewhere for international use.

Applicant

The organization that applies for formal granting of a licence to perform specified activities related to the Siting, Construction, Commissioning, Operation and Decommissioning of a Nuclear Power Plant.

Construction

The process of manufacturing and assembling the components of a Nuclear Power Plant, the erection of civil works and structures, the installation of components and equipment, and the performance of associated tests.

Nuclear Power Plant

A thermal neutron reactor or reactors together with all structures, systems and components necessary for Safety and for the production of power, i.e. heat or electricity.

Operation

All activities performed to achieve, in a safe manner, the purpose for which the plant was constructed, including maintenance, refuelling, in-service inspection and other associated activities.

Potential

A possibility worthy of further consideration for Safety.

Region

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

Regulatory Body

A national authority or a system of authorities designated by a Member State, assisted by technical and other advisory bodies, and having the legal authority for conducting the licensing process, for issuing Licences and thereby for regulating nuclear power plant Siting, Construction, Commissioning, Operation and Decommissioning or specific aspects thereof.[1]

Safety

Protection of all persons from undue radiological hazard.

Site

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

Siting

The process of selecting a suitable Site for a Nuclear Power Plant, including appropriate assessment and definition of the related design bases.

[1] This national authority could be either the government itself, or one or more departments of the government, or a body or bodies specially vested with appropriate legal authority.

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