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UNITED STATES PRACTICE OF SITE EVALUATION FOR NUCLEAR POWER PLANTS

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INTRODUCTION

One of the first and most critical factors in establishing viability of a nuclear power option is the availability and identification of a suitable site, considering business, site safety and health, emergency planning, and environmental factors. Although the health and safety, environmental, and emergency planning assessments are paramount in site evaluation processes worldwide, country specific processes depend on policies, regulations, and legal structures. The site evaluation process in the United States considers health, safety, security, and environmental factors. It also provides early and accessible opportunities for various stakeholders to participate in the licensing process. The U.S. Nuclear Regulatory Commission's (NRC) site evaluation process can be thought of having two distinct components:

- ***Looking inward*** - NRC considers site safety factors as part of its Atomic Energy Act responsibilities by evaluating the design of the facility to protect against natural phenomena (i.e., environmental factors that affect the design such as earthquakes, floods, tornado-generated missiles, etc.), consequences of postulated accidents and other man-made hazards, and emergency and security planning.

- ***Looking outward*** - NRC considers environmental values as part of its National Environmental Policy Act (NEPA) responsibilities by evaluating the facility impacts on the human environment (i.e., construction and operational demands and releases such as water use and quality, socioeconomics, terrestrial, and aquatic species, routine and accidental releases, etc.).

The siting of reactors has an important influence on the hazards and risks imposed by the reactor. The site-specific conditions define unique critical safety and design interfaces and mitigations for adverse environmental impacts. As a result, siting is one of the critical components in the NRC's overall defense-in-depth philosophy. The evolution of siting criteria and challenges faced during some of the earlier site reviews can be found in Okrent (1981), NRC (1984), and NRC (1978). These references include examples of site safety and environmental considerations that led to some sites being deemed unacceptable. In addition, these references describe how safety considerations affected the design basis and designs of engineered safety systems for other sites.

The selection of sites for nuclear power plants is largely made by the investor-owned power companies, based on need for power, proximity to the load center, transmission lines, railroad and other transportation facilities, availability of water for plant operations, proximity to existing power plants, and other factors. The NRC's regulatory authority regarding the acceptability of a site is limited primarily to radiological

health and safety considerations. In addition, the nuclear power plant will need permits from other State and Federal agencies, such as a Clean Water Act permit.

It should be noted that as a part of the environmental review that complements the safety review, the NRC determines whether or not there is an "obviously superior" alternative site to that proposed by the applicant. If the evaluation of the environmental impacts of construction and operation of the project determines that there would be an obviously superior site to the one proposed by the applicant, then the Environmental Impact Statement would recommend denial of the application. The NRC findings and recommendations to the Commission are included in an Environmental Impact Statement. Along with the site safety suitability, the concept of "alternative site" plays an important role in the site selection and evaluation process.

In summary, the following three factors are critical in U.S. in a site-selection process: (1) an applicant's business plans and objectives; (2) NRC site suitability and technical requirements related to radiological health and safety; and (3) NRC regulations requiring the consideration of alternative sites from an environmental perspective. The principle objective of this paper is to describe the considerations involved in the site selection and suitability assessment. The paper provides an overview of the site evaluation process along with some additional insights from recent reviews of Early Site Permit (ESP) and Combined License (COL) applications and post-Fukushima flooding and seismic hazard reevaluations (NRC, 2017a).

OVERVIEW OF REVIEW PROCESS

In the U.S., electric power companies (applicant) submit an application for a license to construct and operate a nuclear power plant. The application includes a safety analysis report (SAR) and an environmental report (ER). The Electrical Power Research Institute (EPRI), "Site Selection and Evaluation Criteria for an Early Site Permit," (EPRI, 2002), and Nuclear Energy Institute (NEI), "Industry Guideline for Preparing An Early Site Permit Application – 10 CFR Part 52, Subpart A," (NEI, 2001), represent industry guidance on site selection and evaluation criteria and for preparing an ESP application.

The NRC staff conducts the review of the application and prepares a Safety Evaluation Report (SER) and an Environmental Impact Statement (EIS). The NRC staffs makes a recommendation to the Commission regarding whether to approve or deny the permit or license application. The overarching purpose of the NRC staff review is to provide reasonable assurance that a site can safely host a future nuclear power plant or plants from the standpoint of:

- Radiological health and safety;
- Environmental protection;
- Emergency planning; and
- Safe and secure plant operation on the selected site.

The NRC evaluates siting factors and criteria that are important in assuring that: (1) radiological doses from normal operations and postulated accidents will be acceptably low; (2) natural phenomena and potential man-made hazards will be appropriately accounted for in the design of the plant; (3) site characteristics are such that adequate security measures to protect the plant can be developed; and (4) physical characteristics unique to the proposed site that could pose a significant impediments to the development of emergency plans are identified. As stated earlier, the environmental review focuses on whether or not there is an "obviously superior" alternative site to that proposed by the applicant considering impacts of plant construction and operations on environmental factors.

The safety issues to be addressed in site selection and suitability assessment include geologic/seismic, hydrologic, and meteorological characteristics of proposed sites; exclusion area and low-population zone; population considerations as they relate to protecting the general public from the potential hazards of serious accidents; potential effects on a station from accidents associated with nearby industrial, transportation, and military facilities; emergency planning; and security plans. The environmental issues to be addressed in site selection include potential impacts from the construction and operation of nuclear power stations on ecological systems, water use, land use, radiological accidents, the atmosphere, aesthetics, socioeconomics, and environmental justice.

The NRC conducts its review in an open and transparent process with significant participation of stakeholders. For example, the NRC conducts pre-application outreach activities and holds a scoping meeting in the vicinity of the proposed site once an application is filed. The objective of this scoping meeting is to understand perspectives and concerns of the population around the site to prepare the EIS. Another mandatory public meeting is held after the issuance of a draft EIS to respond to the public comments. The review period for draft EIS includes a mandated 45-day comment period and two 15-day extensions.

The NRC coordinates and collaborates its review with other agencies, such as Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), U.S. Coast Guard, Fish and Wildlife Service, National Marine Fisheries Service, State Historic Preservation Office, and State and local natural resource agencies. The agencies designated as "cooperating agencies" are considered a part of the NRC environmental review team. Among other things, the objectives of the coordination are to: (1) conduct timely consultations and initiate interaction early in the review process; (2) provide timely and direct access to the EIS for review and comment; and (3) keep agencies informed of regulatory framework and rule changes.

The NRC staff conducts its review in accordance with the applicable regulations, using applicable guidance documents such as Standard review plans (SRP) (NRC, 2007a and NRC, 2007b). NRC regulatory guides (RGs) provide guidance on acceptable methods to assure compliance with regulations.

To provide an overview of the site evaluation process, this paper condenses two principle regulatory guides: RG 4.7 (NRC, 2014) and DG-4026 (NRC, 2017). RG 4.7 discusses the major site characteristics related to public health and safety and environmental issues that the NRC staff considers in determining the suitability of sites for light-water-cooled nuclear power stations. Applicants may use the guidelines in identifying suitable candidate sites for nuclear power stations. The decision that a nuclear power plant may be built on a specific candidate site is based on a detailed evaluation of the proposed site-plant

combination and a cost-benefit analysis comparing it with alternative site-plant combinations (as discussed in DG-4026). Appendices A and B of RG 4.7 summarize the important safety-related and environmental considerations including a listing of relevant regulations and regulatory guidance. While the listings of Appendices A and B are not all inclusive, the cited regulations and regulatory guidance documents provide information on where further details can be found on NRC requirements and acceptance criteria. The draft Regulatory Guide DG-4026 is a proposed revision of RG 4.2 (NRC, 1976) and is intended to reflect current practices for preparation of ERs for nuclear power stations. DG-4026 was issued for public comments in February 2017 and is available at the NRC website using the Agencywide Documents Access and Management System (ADAMS) Accession no. ML16116A068. After addressing the public comments, the DG-4026 will be issued as Revision 3 of RG 4.2.The following subsections list principle regulations and guidance documents.

Applicable Regulations

The following list provides a summary of key regulations applicable to the siting of nuclear power plants:

- Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50), "Domestic Licensing of Production and Utilization Facilities," governs the licensing of nuclear power plants. Appendix A to Part 50 provides general design criteria (GDC). Criterion 2 (GDC 2), "Design Bases for Protection Against Natural Phenomena," requires that structures important to safety be designed to withstand the effects of expected natural phenomena when combined with the effects of normal accident conditions without loss of capability to perform their safety function.

- Title 10, Part 51, of the *Code of Federal Regulations* (10 CFR Part 51), "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," implements the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), which requires that all agencies of the Federal Government prepare detailed environmental statements on proposed major Federal actions that will significantly affect the quality of the human environment. A principal objective of NEPA is to require the Federal agency to consider, in its decision making process, the environmental impacts of each proposed major action and the available alternative actions, including alternative sites. In 10 CFR 51.45, the NRC sets forth the contents that an applicant must include in its ER. The regulation in 10 CFR 51.71 and 10 CFR 51.75, sets forth the contents of the NRC's EIS.

- 10 CFR Part 52 "Licenses, Certifications, and Approvals for Nuclear Power Plants," governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities licensed under Section 103 of the Atomic Energy Act of 1954, as amended (68 Stat. 919), and Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242). Some of the Part 52 criteria are directly related to site characteristics, as well as to events and conditions outside the nuclear power unit.

- 10 CFR Part 100, "Reactor Site Criteria," requires the NRC to consider population density; use of the site environs, including proximity to man-made hazards; and the physical characteristics of the site, including seismology, meteorology, geology, and hydrology, in determining the acceptability of a site for a nuclear power reactor. 10 CFR 100.20 provides factors to be

considered, 10 CFR 100.21 provides non-seismic criteria, and 10 CFR 100.23, provides geologic and seismic criteria.

Related Guidance

In general, RGs provide guidance to applicants for preparing SARs and ERs that are submitted as part of an application for a license to site, construct, and/or operate a new nuclear power plant. The SRPs provide guidance for NRC staff to use when reviewing an application. The following list provides a summary of key guidance document applicable to the siting of nuclear power plants:

- RG 1.206, "Combined License Applications for Nuclear Power Plants," (NRC, 2007c) identifies design-basis environmental site parameter requirements for safety-related structures, systems, and components.

- NUREG-0800, "Standard Review Plan (SRP) for the review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," (NRC, 2007a) provides the criteria used by the NRC staff for reviewing SARs submitted with nuclear power plant license applications.

- NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan," (NRC, 2007b) provides the criteria used by the NRC staff for reviewing ERs submitted with nuclear power plant license applications.

- Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," (NRC, 2014), Revision 3, (NRC, 2014).

- Draft Regulatory Guide DG-4026, "Preparation of Environmental Reports for Nuclear Power Stations," (NRC, 2017), proposed revision 3 to RG 4.2, (NRC, 1976) was discussed previously.

SITE SAFETY CONSIDERATIONS

The following description, in part, is a consolidation of Appendix A of RG 4.7 with some additional information in selected areas. Appendix A of RG 4.7 provides a checklist of site safety characteristics, relevant regulations, and regulatory guides and regulatory experience and positions for assessing site suitability for nuclear power stations.

As previously described, the structures, systems, and components (SSC) important to safety must be designed to withstand effects of natural phenomena such as earthquake, tornadoes, hurricanes, floods, tsunamis, seiches, and other applicable natural hazards as well as the effects of man-made hazards. This requires development of design bases for these hazards to establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety. The design bases for protection against all hazards are evaluated during the siting review.

Similarly, the concept of design basis accident (DBA) is used to determine whether the reactor design provide adequate mitigation of radiological consequences in the event of a major reactor accident to

protect public health and safety, as demonstrated by meeting the siting dose acceptance criteria specified in regulations. The DBAs are hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. The NRC staff reviews the selection of bounding DBAs, associated source terms, effects of mitigation measures, and evaluates the doses at the various site boundaries in accordance with the regulations considering fission product and site meteorological characteristics.

Additional details regarding the development of design bases in light of natural phenomena and accident conditions are provided in the subsections that follow.

Geologic, Seismic, and Geotechnical Considerations

Geologic and seismic characteristics of a site, such as surface faulting, ground motion, foundation conditions (including liquefaction, subsidence, and landslide potential), tectonic and nontectonic deformation, seismically-induced flood, and man-made activities may affect the safety of a nuclear power station and need to be considered.

Where the potential for permanent ground deformation such as faulting, folding, subsidence, collapse, tectonic and nontectonic deformation, and due to man-made activities exists at a site, the NRC staff considers it prudent to select an alternative site.

The applicant should provide sufficient information regarding the seismic and geologic characteristics of the site and the surrounding region to permit an adequate evaluation of the proposed site, to support evaluations performed to estimate the site ground motion response, and to permit adequate engineering solutions to potential geologic and seismic effects at the proposed site. Sites should be selected in areas for which an adequate geologic database exists or can be expeditiously developed through site-specific investigations to identify and characterize potential geological and seismic hazards. The seismic and geologic (and meteorological and hydrologic) characterization of the proposed site should consider the most severe of the natural phenomena that have been historically reported for the site and surrounding area and include sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The licensing process can be longer if there is a need for extensive additional geologic and seismic investigations.

Conservative design of safety-related structures should be presented in consideration of uncertainty in geologic, seismic, and foundation parameters. Sites with competent bedrock generally have suitable foundation conditions. If bedrock sites are not available, it is prudent to select sites in areas known to have a low subsidence and liquefaction potential. Investigations are required to determine the static and dynamic engineering properties of the material underlying the site. The geotechnical reviews are done to assure that the rocks or soils at the site are capable of supporting static and dynamic loads with adequate bearing capacity, and there are no unacceptable settlement or slope stability issues.

In determining the vibratory ground motion for which the safety-related SSCs must be designed, all currently operating plants were licensed using a deterministic framework that focused on specification of a safe shutdown earthquake (SSE) determined by considering the largest earthquake observed in the site region and accounting for appropriate uncertainties. Under this framework, the SSE serves as both a site hazard and design parameter.

Present-day NRC requirements and guidance used for characterizing seismic hazard use a probabilistic approach to develop a risk-informed, performance-based ground motion response spectrum (GMRS) for a site. This approach is described in RG 1.208, (NRC, 2007d). RG 1.208 recommends the use of the Senior Seismic Hazard Analysis Committee (SSHAC) approach for treatment of expert judgment and quantifying uncertainty to support development of the GMRS (NRC, 1995; NRC, 2012). The SSE subsequently developed for engineering purposes is expected to meet or exceed the site GMRS and, by extension, considers all sources of ground motion in the site region, as well as their uncertainties.

Exclusion Area and Low-Population Zone Considerations

In the event of a postulated accident at a nuclear power station, radiological consequences for individual members of the public outside the station must be acceptably low. The regulation requires an "exclusion area" surrounding the reactor, in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property, and a low-population zone (LPZ), which immediately surrounds the exclusion area. The size of the LPZ must be such that the distance to the nearest boundary of a densely populated center with more than 25,000 residents is at least one-and one-third times the distance from the reactor to the outer boundary of the LPZ. The regulations further require that, at any point on the exclusion area boundary and on the outer boundary of the LPZ, the exposure of an individual to a postulated release of fission products (as a consequence of an accident) be less than 25 rem total effective dose equivalent, for time periods specified in the regulations.

Based on the assumptions in the DBA radiological consequence analyses, the required distances to the exclusion area boundary and the outer boundary of the LPZ will depend on plant design aspects, such as the reactor power level, allowable containment leak rate, and those engineered safety features incorporated in the design, as well as the atmospheric dispersion characteristics of the site. Regulatory guidance specifies the fractional releases of radiological groups from the core inventory, the timing of the release, their composition, and the chemical form of the DBA source term.

Population Considerations

Locating reactors away from densely populated centers is part of the NRC's defense-in-depth philosophy and facilitates emergency planning and preparedness, as well as reduces potential doses and property damage in the event of a severe accident. Population data are to be estimated in relation to the time of initial plant approval. Population projections should be made by decade for a 40-year period beyond the start of power plant operations.

A reactor should preferably be located such that, at the time of initial site approval and within about 5 years thereafter, the population density, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the area at that distance), does not exceed 500 persons per square mile. A reactor should not be located at a site where the population density is well in excess of the above value. If the population density of the proposed site exceeds, but is not well in excess of, the preferred value, the analysis of alternative sites should pay particular attention to alternative sites with lower population density. Other factors, such as safety, environmental, or economic characteristics, will be considered, which may result in the site with higher population density being found acceptable. Transient population should be included for those sites where many people (other than

those just passing through the area) work, reside part time, or engage in recreational activities, but are not permanent residents of the area. The transient population should be considered by weighing the transient population according to the fraction of time the transients are in the area. Population data should be estimated in relation to the time of initial plant approval. Population projections should be considered over the lifetime of the facility. Further population projections should be made by decade for a 40-year period beyond the start of power plant operation. For an ESP assume plant approval is the end of the term of the permit.

Hydrology Considerations

The following three subsections describe the hydrology considerations.

External Flooding Considerations

Consequential site flooding may occur as a result of a variety of flood-causing mechanisms such as: local intense precipitation (LIP); flooding in streams and rivers; dam breaches and failures; storm surge; seiches; tsunami; ice induced flooding; channel migration or diversion; and combinations thereof. NRC's current regulatory guidance for evaluating these flood-causing mechanisms is generally deterministic (i.e., the concept of the 'worst possible' flooding elevation) and focuses on concepts of hypothetical, beyond-observed, events that are intended to reflect the most severe hazards reasonably possible at the site (e.g., the so called 'probable maximum flood' elevation). Deterministic assessments generally use the hierarchical hazard assessment concept, which is a progressively-refined, stepwise estimation of the hazard associated with a site-specific flood-causing mechanism or combination of mechanisms. It typically begins with the most-conservative-plausible assumption consistent with available data and historical insights. Refinements in the assumptions continue by introducing increasing levels of realism, while continuing to appropriately reflect the most severe of the natural phenomena reported at the site and surrounding area, with margin for the accuracy, quantity, and period of record. The resulting hazard estimate also includes margin for changes to assumptions in the future, such as the future changes in eustatic sea level at coastal sites.

NRC staff guidance for estimating site flood hazards is contained in Sections 2.4.2 through 2.4.9 (each section is dedicated to a particular flood-causing mechanism) of NUREG-0800 (NRC, 2007a). This document references several guidance documents, including RG 1.59 (NRC, 1980) and ANSI/ANS-2.8-1992 (ANS, 1992). The NRC staff is in the process of updating RG 1.59 to address advances in flood-hazard analysis in the decades since the last revision was published, such as the standard-practice use of numerical modeling software. In addition, the American Nuclear Society (ANS) is also in the process of updating ANSI/ANS-2.8. Although the updates to both ANSI/ANS-2.8 and RG 1.59 are not yet complete, there are a number of NRC contractor reports and interim staff guidance documents that discuss several updated methodologies for evaluating these flood-causing mechanisms (see NRC, 2011a, 2013a, 2013b, 2016a, and 2016b)).

Water Availability Considerations

A safety-related water supply is required for normal or emergency shutdown and cool down. A highly dependable system of water supply sources should be shown to be available under postulated occurrences of natural phenomena and site-related accidental phenomena or combinations of such phenomena as discussed in RG 1.59. To evaluate the suitability of a site, there must be a reasonable assurance finding that the applicant can obtain, from the appropriate State, local, or regional agency, permits for water use and for water consumption in the quantities needed for a nuclear power plant of the stated approximate capacity and type of cooling system. Statistical techniques (e.g., the seven-day, consecutive low flow with a ten year return frequency (7Q10) low-flow condition) should be used to extend and complement the period of record to help identify the expected minimum low flow for the region. If the 7Q10 is too low to supply adequate water for the plant, then other sources of water for non-safety-related and safety-related structures and ultimate heat sink requirements should be identified.

Radionuclide Retention and Transport

Surface and ground water conditions at a site should be characterized to appropriately model dispersion, dilution, and retardation of radioactive materials released during liquid effluent releases of fission products generated during routine operations and anticipated operational occurrences (AOOs) to show compliance with liquid effluent concentration limits of Appendix B to 10 CFR Part 20 and dose limits for members of the public under 10 CFR 20.1301 and 20.1302, and design objectives of 10 CFR Part 50, Appendix I. This information should also be used to evaluate the radiological impacts on an offsite dose receptor associated with the postulated failure of a radwaste system tank containing radioactive materials via surface and ground water pathways.

The NRC staff will use the criteria in 10 CFR Part 20 and 10 CFR Part 50 to determine permissible concentrations of radionuclides discharged to surface water and ground water during normal operations, AOOs, and postulated failure of radwaste tanks containing radioactive materials. For sites within areas that the EPA has designated as sole source aquifers, or in sites with the potential to be designated a sole source aquifer in the future, detailed justification based on potential impacts to the affected community should be provided. The regulation requires the minimization (to the extent practicable) of contamination and radioactive waste generation. RG 4.21 (NRC, 2008) explains that applicants should strive to minimize contamination and radioactive waste generation over the total life cycle of a facility, from initial layout and design through procedures for operation and final decontamination and dismantlement at the time of decommissioning.

Meteorological Siting Considerations

The meteorological siting considerations include the following review areas: regional and local climatology; onsite meteorological monitoring; and atmospheric dispersion estimates.

The regional and local climatology involves characterization of rain, snow, straight winds, tornadoes, hurricanes and other applicable meteorological events to develop design basis for severe and extreme events for the plant design. The tornado and hurricane events also need to include a spectrum of design basis missiles in accordance with the guidance. The temperature extremes are also considered in the site evaluation and plant design. Regulatory Guide 1.76 (NRC, 2007e) and Regulatory Guide 1.221 (NRC,

2011b) provide guidance on selection of design basis wind speeds for tornadoes and hurricanes and associated missiles.

The atmospheric conditions at a site should provide sufficient dispersion of radioactive materials released during a postulated accident to reduce the radiation exposures of individuals at the exclusion area and LPZ boundaries. The atmospheric conditions at a site should also be characterized to appropriately model dispersion of radioactive materials released during airborne release of fission products from routine operations and AOOs to show compliance with effluent concentration limits and dose limits for members of the public in accordance with applicable regulations.

Engineered safety features can compensate for unfavorable, safety-related design-basis atmospheric dispersion characteristics. Accordingly, a description of atmospheric dispersion of radiological effluents is also incorporated in the section "Exclusion Area and Low-Population Zone" (discussed earlier).

Industrial, Military, and Transportation Facilities Considerations

Accidents at present or projected nearby industrial, military, and transportation facilities may affect the safety of the nuclear power station. Potentially hazardous facilities and activities within 8 km (5 mi) and major airports within 16 km (10 mi) of a proposed site with associated flight-related activities should be identified. Accidents at nearby industrial facilities may produce missiles, shock waves, flammable vapor clouds, or toxic chemicals. Additionally, accidents at nearby military facilities, such as munitions storage areas and ordnance test ranges, may threaten safety of a nuclear power plant. An accident during the transport of hazardous materials by air, waterway, railroad, highway, or pipeline near a nuclear power plant might generate shock waves, missiles, and toxic gases, or pose other hazards affecting safe plant operation (e.g., a barge colliding with an intake structure or an airplane crashing at the site).

If a preliminary evaluation of potential activities accidents at these facilities indicates that the potential hazards from shock waves and missiles approach or exceed those of the design-basis tornado for the region, or potential hazards such as flammable vapor clouds, toxic chemicals, or incendiary fragments exist, the suitability of the site should be determined by detailed evaluation of the potential hazard to identify whether it is a design-basis accident or not. The acceptability of a site depends on establishing that (1) an accident at a nearby industrial, military, or transportation facility will not result in radiological consequences that exceed the dose specified in 10 CFR 50.34, or (2) the accident poses no undue risk because it is sufficiently unlikely to occur (less than about 10^{-7} per year). The design-basis event resulting from the presence of hazardous materials or activities in the vicinity of the plant or plants is identified if all postulated types of accidents are included for which the expected rate of occurrence of potential exposures resulting in radiological doses in excess of 10 CFR 50.34(a) (1) as it relates to the requirements of 10 CFR Part 100, is estimated to exceed the NRC staff objective of the order of magnitude of 10^{-7} per year. Alternatively, the proposed site may found to be acceptable if the facility design includes appropriate and adequate engineering safeguards to compensate for the observed deficiencies.

ALTERNATIVE SITES AND ENVIRONMENTAL CONSIDERATIONS.

As discussed earlier, the concept of an "obviously superior" site plays very important role in determining site suitability and is described in detail. Appendix B of RG 4.7 lists environmental protection

considerations for assessing site suitability. The details of how to evaluate the environmental impacts to the resource areas around a site are contained in other sections of RG 4.2 and in NUREG-1555, and not discussed in this paper.

Alternative Site-Selection Process

The description in this section is a summary of material from DG-4026, draft update to Regulatory Guide 4.2.

The NRC in its EIS evaluates the applicant's site-selection process and determines if the process resulted in the identification of any proposed and alternative sites that are reasonable sites. The impacts to the resource areas shown in Figure 1 are evaluated and compared for the proposed and alternative sites. The NRC then determines, based on environmental impacts, if any of the alternative sites are environmentally preferable to the proposed site. If none of the alternative sites are environmentally preferable then the proposed site prevails. If an alternative site is environmentally preferable then the NRC determines if it is "obviously superior" to the proposed site based on cost. If the alternative site is not obviously superior to the proposed site then the proposed site prevails. If the alternative site is obviously superior to the proposed site then the EIS would recommend denial of the application.

The ER should describe the process used by the applicant to identify possible sites for the new nuclear plant and to select the proposed site. The basic steps that should be described in the site-selection process are shown in Figure 2.

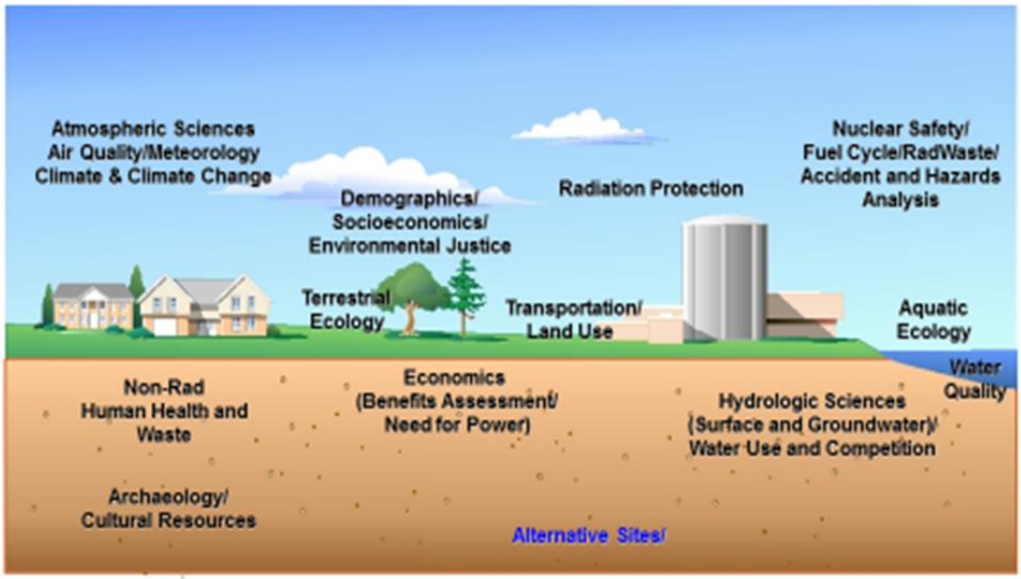

Figure 1. Resource Areas

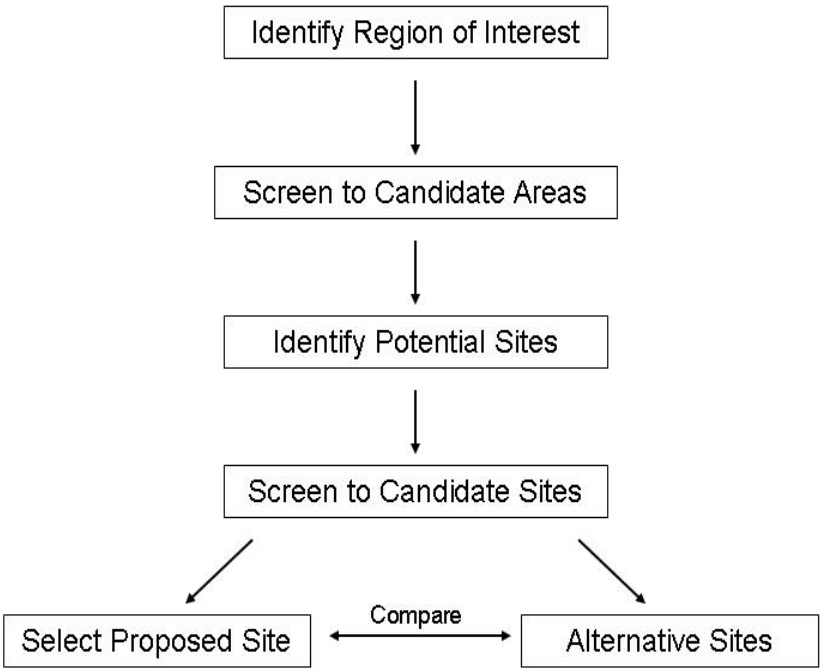

Figure 2. Site-Selection Process

The ER should include the following information:

- A description of the region of interest (ROI), candidate areas, potential sites, and candidate sites. If any potential or candidate sites have been designated by a governmental agency as an acceptable site for a new nuclear power plant, this information should be included in the ER.

- Selection procedures for the ROI, candidate areas, potential sites, candidate sites, and the proposed site.

- The basis for establishing the geographical scope of the ROI.

- Factors considered at each level of the selection process, parameters by which these factors were measured and weighted, and criteria used to define levels of acceptability (e.g., numerical limits or decision standards).

- Methodologies used in the potential and candidate site screening process, including (when used) factors such as (1) importance factors, (2) preference functions, (3) utility functions, (4) weighting factors, (5) ranking scales, (6) scoring schemes, (7) rating systems, and (8) sensitivity analyses.

- For each alternative site, reconnaissance-level information should be included in the ER for the same impact categories used for the proposed site (see Chapters 4 and 5).

While the ER summarizes the process used to select the proposed site, the NRC staff will need to know the details of the process, which is typically described in a more detailed site-selection report prepared by or for the applicant. If such a report was prepared, it should be provided to the NRC staff at the time the application is submitted to support the staff's review.

The site-selection process should follow a logical path from the definition of the ROI; to the identification of candidate areas, potential sites, and candidate sites; to the selection of the proposed site. The ROI is the geographic area considered in searching for potential and candidate sites. The geographic area of the ROI need not be contiguous, but if not, a logical basis for nonadjacent areas should be provided. "Candidate Areas" are one or more areas within the ROI that remain after unsuitable areas (e.g., unsuitable because of high population, lack of water, fault lines, or distance to transmission lines) have been removed. "Potential Sites" are those sites within the candidate areas that have been identified for preliminary assessment in establishing candidate sites. "Candidate sites" are those potential sites within the ROI and that are considered in the comparative evaluation of sites to be among the best that can reasonably be found for the siting of a nuclear power plant. The candidate sites include the proposed site and the alternative sites. The "proposed site" is the candidate site submitted to the NRC by the applicant as the proposed location for a nuclear power plant. "Alternative sites" are those candidate sites that are compared to the proposed site to determine if there is an obviously superior alternative site. In general, the identification of three to five alternative sites in addition to the proposed site could be viewed as adequate. Each of the steps in the process is discussed in more detail below.

The ROI

The ROI is typically selected based on geographic boundaries (e.g., the state in which the proposed site is located), or the relevant service area for the proposed plant. The ER should describe how the ROI was selected, the extent of and basis for restrictions to the ROI because of siting constraints, and the extent to which the ROI is constrained based on the major load centers to be supplied by the proposed plant.

Candidate Areas

The ER should describe the process used to identify the candidate areas within the ROI. Reasons that areas may be unsuitable include the following:

- 10 CFR Part 100 (e.g., seismic, proximity to major centers of population density);
- lack of existing infrastructure (e.g., roads and railroads);
- lack of a suitable cooling-water source;
- distance to transmission lines, substations, or load centers;
- unsuitable topographic features;
- potential to impact valuable agricultural, residential, or industrial areas;

- potential to impact dedicated land-use areas (e.g., parks, historic sites, and wilderness areas); and

- conflicts with land-use planning programs or other restrictions established by State, county, or local governments.

The applicant's process to identify candidate areas should consider these and other reasonable attributes to identify areas potentially suitable or unsuitable for siting a new nuclear power plant. The ER should present the determining characteristics of the identified areas and need not present other characteristics. For example, if an area did not meet the safety requirements in 10 CFR 100 or has no suitable cooling-water source, then the area would be considered unsuitable and the other factors listed above need not be considered.

Potential Sites

Once the candidate areas have been identified, the ER should describe how potential sites within those areas were identified. In selecting potential sites, applicants should use a logical process that treats all sites in the same way, and would reasonably be expected to produce sites that are among the best potential sites in the candidate areas. Applicants should not use a potential site-selection process that focuses on one group or class of sites to the exclusion of other groups of sites without a defensible technical basis. The process used to identify potential sites should typically consider attributes similar to those used in the process of identifying candidate areas. However, in general this step in the process involves a somewhat more detailed look at those criteria. In addition, in many cases, the applicant can use the inverse of the attributes listed above, looking for positive rather than negative attributes. So, for example, the applicant may identify locations in the candidate areas that have ample water, are close to transmission facilities, and load centers, have infrastructure in place, etc. However, negative attributes at a specific location (e.g., seismicity or threatened and endangered species), may also be used to de-select some sites.

An applicant is not expected to conduct detailed environmental studies for potential sites, only preliminary investigations using reconnaissance-level information.[1] A reconnaissance-level investigation should take account of information that is readily available over the Internet or from other sources (e.g., existing studies and State and Federal agencies). The applicant does not have to own the land at potential sites; however, no obvious obstruction should prevent the applicant from obtaining the land (e.g., land that is part of a National Park).

The goal of this step in the process is not to identify every potential site in the candidate areas. Depending on the size of the candidate areas, trying to identify all possible sites would yield an unworkable number

[1] "Reconnaissance-level information" is defined as information that is available from the applicant, governmental, Tribal, commercial, and/or public sources. Reconnaissance-level information does not normally require the collection of new data or new field studies. Reconnaissance should include more than just a literature search for issues that are critical to the evaluation of sites. So, for example, reconnaissance should include contact with the water-management agency about water availability in most cases, as discussed in the most recent version of RG 4.7. The amount and quality of information must be sufficient based on the expert judgment of the reviewer to make the required determination for which the information is needed.

of possible locations. However, the ER should demonstrate that the applicant used a logical process that would reasonably be expected to produce a list of the best potential sites in the candidate areas.

Candidate Sites

Candidate sites are those potential sites that are within the ROI and are considered in the comparative evaluation of sites to be among the best that can reasonably be found for the siting of a new nuclear power plant. The applicant's review of candidate sites should be directed to the identification of sites suitable for the size and type of nuclear power plant being proposed. The candidate sites include the proposed site and the alternative sites. The ER should demonstrate that the applicant's site-selection methodology resulted in the identification of candidate sites that are potentially licensable by the NRC, and among the best that can reasonably be found in the ROI.

To be a candidate site, the following minimum criteria should be satisfied:

- Consumptive use of water should not cause significant adverse effects on other users.
- The proposed action should not appreciably reduce the likelihood of survival or recovery of threatened or endangered, species or result in the destruction or adverse modification of critical habitat.
- There should not be any potential significant impacts to essential fish habitat or other federally protected aquatic habitats or to known spawning grounds or nursery areas of populations of important aquatic species.
- Discharges of effluents into waterways should be in accordance with Federal regulations and should not adversely impact efforts to meet water-quality objectives.
- There should be no preemption of, or adverse impacts on, land specially designated for environmental, recreational, or other special purposes.
- There should not be destabilizing impacts on terrestrial and aquatic ecosystems, including wetlands that are unique to the resource area.
- There should not be other significant issues (e.g., environmental justice, historic and cultural resources, traditional cultural properties, cemeteries, burials) that preclude the use of the site.

Proposed and Alternative Sites

The proposed site is the candidate site identified by the applicant as the proposed location for a new nuclear power plant. Alternative sites are those candidate sites that are compared to the proposed site to determine if there is an environmentally preferable site.

The ER should provide a sufficient description of the alternative sites to allow for an evaluation of the environmental impacts of building and operating the proposed project at each site. A figure showing the

proposed plant on each alternative site with the footprint and the environmental interfaces such as cooling-water intakes and discharges should be included.

The evaluation and comparison of the proposed and alternative sites should be performed for each resource area, including cumulative impacts, and be presented in tabular form. Figure 1 shows the resource areas that are evaluated for the proposed and alternative sites. The potential impacts of climate change should be considered under cumulative impacts.

The evaluation of the cumulative impacts at the alternative sites should be similar to that for the proposed site, except that reconnaissance-level information is used for the alternative sites. If, however, initial efforts to draw a clear differentiation between the proposed site and any alternative site prove inconclusive, then reconnaissance-level information can be expanded to include information obtained through more in-depth information gathering or visits to the affected region.

An applicant can propose to build a new nuclear power plant at a site that was not selected on the basis of a systematic site-selection process (e.g., at the site of an existing nuclear power plant or a site identified by the State). In such a case, the applicant should still follow the process shown in Figure 2 for the selection of alternative sites. The site comparison should be performed in such a case by comparing each of the alternative sites to the proposed site. The applicant's review should also take account of the reactor site criteria in 10 CFR Part 100 and RG 4.7.

The applicant should state in the ER whether any of the alternative sites would be environmentally preferable to the proposed site, and provide an explanation for the determination. An environmentally preferred site is a site for which the environmental impacts are sufficiently less than for the proposed site, so that environmental preference for the alternative site can be established. For any environmentally preferable site, the applicant should indicate whether it is obviously superior to the proposed site. Whereas the evaluation for an environmentally preferable site considers only environmental impacts, the determination whether a site is obviously superior also considers costs and institutional constraints.

Costs should include any additional costs associated with building and operating the proposed unit(s) at the environmentally preferable site. These costs could include items such as the cost of (1) modifying the plant design, (2) additional grading and fill, (3) ecological and cultural resource surveys, (4) the ongoing cost of establishing and operating a new emergency plan (if the proposed site already has such a plan in place), (5) the cost of obtaining the alternative site, and (6) the cost of any delay associated with changing sites.

If the applicant were to determine that an alternative site was obviously superior to the proposed site, then the NRC staff expects that the applicant would modify its choice of the site. If the applicant determines that an environmentally preferable site is not obviously superior to the proposed site, then the ER should explain in detail the bases for that conclusion.

The following sections describe the specific resource area information that should be provided for each alternative site. The impacts described in Chapter 6 of the ER (e.g., nuclear fuel cycle, decommissioning), would not vary significantly from one site to another. Typically, all of the alternative sites and the proposed site are in low-population areas, and the review team assumes the same reactor plant design is

applicable for each of the sites. Therefore, the same fuel cycle technology, transportation methods, and decommissioning methods would be used. Because of this, these impacts would not differentiate between the sites and would not be useful in the determination of whether an alternative site is environmentally preferable to the proposed site. For this reason, these impacts are not discussed in the evaluation of the alternative sites.

Similarly, the nonradiological waste impacts described in Chapters 4, and 5 would not vary significantly from one site to another. The types and quantities of nonradiological waste would be about the same at any of the alternative sites. For each alternative site, all wastes destined for land-based treatment or disposal would be transported offsite by licensed contractors to existing, licensed disposal facilities operating in compliance with all applicable Federal, State, and local requirements. All nonradioactive liquid discharges would be discharged in compliance with the provisions of an applicable National Pollutant Discharge Elimination System permit. In addition, the amount of nonradioactive, nonhazardous municipal solid waste to be generated annually by the plant would be a relatively small percentage of the total solid waste generated within the geographic area of influence of any of the alternative sites. The characterization and discussion of possible impacts should follow the guidance using reconnaissance-level information.

INSIGHTS FROM RECENT REVIEWS

This section summarizes some high level lessons learned and insights gained from recent ESP and combined license reviews as well as post-Fukushima hazard reevaluation reviews conducted by the NRC (Flanders, 2017). The NRC staff is revising its guidance documents related to environmental and safety reviews to incorporate these lessons learned.

With regard to environmental reviews, as discussed in this paper, NRC staff is updating Regulatory Guide 4.2: *Preparation of Environmental Reports for Nuclear Power Stations*, and NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants* (ESRP). The proposed revision to these documents will reflect changes in NRC policy, regulations, and NRC experience gained from review of prior applications. The use of these guidance documents helps to ensure the completeness and consistency of the environmental review and analyses conducted by the NRC staff.

With regard to safety reviews, NRC staff continue to evaluate the lessons learned from of new reactor licensing activities and the post-Fukushima flooding and seismic hazard reevaluations of operating plants as it proceeds with updating regulatory guidance documents. The NRC Office of Nuclear Regulatory Research has developed a seismic research plan to include issues identified as a result of these reviews. In addition, the staff is currently revising its most recent SSHAC guidance (NRC, 2012) to implement lessons learned from the recent reviews.

Similarly, as described previously, the NRC staff is in the process of updating RG 1.59 to address advances in flood-hazard analysis in the decades since the last revision was published. This revision will also consolidate guidance from other documents related to the current practice. In addition, the ANS is also in the process of updating ANSI/ANS-2.8. Recent experience has also highlighted a need for development of Probabilistic Flood Hazard Analysis to explicitly account for uncertainties and frequency

of occurrence in assessing flood hazards consistent with risk-informed, performance-based approaches. As a result, the NRC is currently executing a Probabilistic Flood Hazard Assessment Research Program.

In order to improve the quality of the applications submitted by an applicant and for timely and efficient review, NRC staff have identified the following four important considerations:

- ***Pre-application interactions***: Pre-application interactions between an applicant and NRC staff are important in identifying unique characteristics of a site that may require extensive site characterization data and analysis. Focusing on these issues and assuring sufficiency of the information will facilitate efficient and effective reviews. The early interactions will also provide opportunities to identify unique interagency coordination items so that plans for coordination can be developed by both the applicant and the NRC earlier in the review process. An applicant also benefits from insights gained by the NRC staff from other reviews.

- ***Data acquisition***: A number of siting review areas requires site-specific data for site characterization. Examples include meteorological data, geological and geotechnical data, hydrological data, and data related to local environmental conditions. In several cases, the collection of site-specific data needs to start much before the development of an application. For example, installation of meteorological tower needs to occur sufficiently in advance of application preparation to characterize the wind field around the site that is needed for dose evaluations during the siting review.

- ***Interactions with other agencies***: Obtaining the necessary permits and complying with the requirements of other agencies can be critical path items in timely completion of an EIS. The early identification of critical and timely interactions among the applicant, NRC, and the affected agencies are essential to preserve schedules. Among other things, the objectives of this coordination are to: (1) conduct timely consultations and initiate interaction early in the review and permit process; (2) provide timely and direct access to the EIS for review and comment; and (3) keep agencies informed of regulatory framework and rule changes. The agencies designated as "cooperating agencies" are considered a part of the NRC environmental review team.

- ***Alternative Sites***: As discussed in this paper, the concept of alternative site is critical in acceptability of a site from an environmental perspective. NRC determines whether or not there is an "obviously superior" alternative site to that proposed by the applicant. Therefore, the selection of candidate sites and alternative sites is fundamental to satisfy the NRC's environmental determination. A number of questions have been raised in this area during the NRC reviews of several applications.

SUMMARY

The selection of sites for nuclear power plants is largely made by the investor-owned power companies. The overarching purpose of the NRC review is to provide reasonable assurance that a site can safely host a future nuclear power plant or plants from the standpoint of: site safety; environmental protection; emergency planning; and safe and secure plant operation on the selected site. The NRC's site review process is open and provides opportunities for stakeholder participation.

DISCLAIMER

Any opinions, findings and conclusions expressed in this paper are those of the authors and do not necessarily reflect the views of the United States Nuclear Regulatory Commission.

TABLE OF ABBREVIATIONS

ADAMS	Agencywide Documents Access and Management System
ANS	American Nuclear Society
AOO	Anticipated operational occurrences
COL	Combined license
DBA	Design basis accident
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPRI	Electrical Power Research Institute
ER	Environmental report
ESP	Early Site Permit
GDC	General design criteria
GMRS	Ground motion response spectrum
LIP	Local intense precipitation
LPZ	Low-population zone
LWR	Light-water reactor
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
RG	Regulatory guides
ROI	Region of interest
SAR	Safety analysis report
SER	Safety Evaluation Report
SRP	Standard Review Plan
SSC	Structures, systems, and components
SSE	Safe shutdown earthquake
SSHAC	Senior Seismic Hazard Analysis Committee

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