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RADIOLOGICAL EMERGENCY RESPONSE PLANNING FOR NUCLEAR POWER PLANTS IN CALIFORNIA. VOLUME 4 OF THE FINAL REPORT ON HEALTH AND SAFETY IMPACTS OF NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL ELECTRIC GENERATION IN CALIFORNIA

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NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL
ELECTRIC GENERATION IN CALIFORNIA

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Energy and Environment Division

Radiological Emergency Response Planning for Nuclear Power Plants in California

Winifred W. S. Yen

January, 1977

Lawrence Berkeley Laboratory University of California/Berkeley

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Berkeley, California 94720

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Vol. 1: "Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California: Overview Report," by the entire staff, Lawrence Berkeley Laboratory Report LBL-5924. Includes "Executive Summary" for the project.

Vol. 2: "Radiological Health and Related Standards for Nuclear Power Plants," by A.V. Nero and Y.C. Wong, Lawrence Berkeley Laboratory Report LBL-5285.

Vol. 3: "A Review of Light-Water Reactor Safety Studies," by A.V. Nero and M.R.K. Farnaam, Lawrence Berkeley Laboratory Report LBL-5286.

Vol. 4: "Radiological Emergency Response Planning for Nuclear Power Plants in California," by W.W.S. Yen, Lawrence Berkeley Laboratory Report LBL-5920.

Vol. 5: "Control of Population Densities Surrounding Nuclear Power Plants," by A.V. Nero, C.H. Schroeder, and W.W.S. Yen, Lawrence Berkeley Laboratory Report LBL-5921.

Vol. 6: "Health Effects and Related Standards for Fossil-Fuel and Geothermal Power Plants," by G.D. Case, T.A. Bertolli, J.C. Bodington, T.A. Choy, and A.V. Nero, Lawrence Berkeley Report LBL-5287.

Vol. 7: "Power Plant Reliability-Availability and State Regulation," by A.V. Nero and I.N.M.N. Bouromand, Lawrence Berkeley Laboratory Report LBL-5922.

Vol. 8: "A Review of Air Quality Modeling Techniques," by L.C. Rosen, Lawrence Berkeley Laboratory Report LBL-5998.

Vol. 9: "Methodologies for Review of the Health and Safety Aspects of Proposed Nuclear, Geothermal, and Fossil-Fuel Sites and Facilities," by A.V. Nero, M.S. Quinby-Hunt, *et al.*, Lawrence Berkeley Laboratory Report LBL-5923.

RADIOLOGICAL EMERGENCY RESPONSE PLANNING FOR NUCLEAR POWER PLANTS IN CALIFORNIA

ABSTRACT

This report reviews the state of emergency response planning for nuclear power plants in California. Attention is given to the role of Federal agencies, particularly the Nuclear Regulatory Commission, in planning for both on and off site emergency measures and to the role of State and local agencies for off site planning. The relationship between these various authorities is considered. Existing emergency plans for nuclear power plants operating or being constructed in California are summarized. The developing role of the California Energy Resources Conservation and Development Commission is examined.

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SELECTED ABBREVIATIONS

AAB	—	Accident Analysis Branch (NRC)
AFC	—	Application for Certification
CFR	—	Code of Federal Regulations
DBA	—	design basis accident
DOH	—	Department of Health (California)
ERDA	—	Energy Research and Development Administration
EPA	—	Environmental Protection Agency
FPA	—	Federal Preparedness Agency
ERCDC	—	Energy Resources Conservation and Development Commission (California)
FSAR	—	Final Safety Analysis Report
ISEPB	—	Industrial Security and Emergency Planning Branch (NRC)
LPZ	—	low population zone
NOI	—	Notice of Intention
NRC	—	Nuclear Regulatory Commission
OES	—	Office of Emergency Services (California)
PAG	—	protective action guide
PSAR	—	Preliminary Safety Analysis Report
RG	—	Regulatory Guide (NRC)
SAR	—	Safety Analysis Report
SER	—	Safety Evaluation Report
SPF	—	site population factor

1. INTRODUCTION

Nuclear power plants contain large amounts of radioactive material, and there is a potential, however small, for accidental releases to expose members of the public to large doses of radiation. The purpose of radiological emergency response planning is to minimize the effects of such releases should they occur. Such planning affects workers at the facility and members of the general public. Protection of the public has been the primary concern of various organizations, public and private, which are interested in the adequacy of emergency response planning for nuclear power plant accidents. Recently, state and local governments have become more willing to deal with energy and environmental issues. The increased interest in emergency planning may be traced to three sources. First, some state agencies have been mandated to review the adequacy of emergency response planning as part of nuclear power plant siting procedures under state laws. Second, as more nuclear power plants are licensed, the risk of radiological incidents has correspondingly increased. Third, environmental groups have widely published their concern that emergency and evacuation planning may have been slighted and that, in any event, the public has not been adequately informed about it.

Considerable controversy has also arisen from the separation of emergency planning from the licensing of nuclear production and utilization facilities. Although the NRC has jurisdiction over the licensing of nuclear facilities, it has left the development of off-site emergency preparedness to state and local agencies. This has led to confusion over which agency or party is to take responsibility for emergency planning and on what basis. At present, primary responsibility for planning and implementing emergency measures within the reactor site boundaries rests with the licensee, as regulated by NRC's licensing procedures and standards. As part of their general responsibility for emergency and disaster preparedness, state and local governments are responsible for the protection of people and property outside the reactor boundary from the effects of plant-related emergencies. While the General Accounting Office has suggested that the Nuclear Regulatory Commission consider the possibility of seeking Congressional authorization to compel state planning, neither it nor any other federal agency has the statutory authority to require radiological emergency plans at the state and local level. Many state groups, however, have been under the impression that either the NRC or the utility operating the nuclear facility has the responsibility for both onsite and offsite emergency response planning and implementation. This misunderstanding may have been supported in part by the "fail-safe" public image of nuclear power plants in the early 1960's. Also, prior to the publication of emergency planning requirements for production and utilization facilities in Appendix E to title 10, Part 50 of the Code of Federal Regulations, the regulatory emphasis of the NRC was placed primarily on reactor design and engineered safety features for the protection of the public from radioactive exposure. The requirements for licensee emergency preparedness applicable to offsite releases were very general, and the onsite-offsite division of responsibility was not given much attention.

After the publication of Appendix E, 10 CFR 50, in which explicit recognition was given to the interface between onsite licensee emergency planning and offsite agencies, the NRC initiated a program of federal guidance and assistance to upgrade the level of radiological emergency planning at the State and local level. It is assisted in this effort by various federal agencies, as well as by the previous experience that some States had with controlling radioactive hazards in the States Agreements Program (see Section 4.1) or in Civil Defense Programs in the 1960's. The Federal Assistance Program makes available to State and local emergency personnel a series of training programs for radiological emergency planning, a field cadre to assist states review local exercises and to develop State Plans, as well as guidance on protective actions, emergency instrumentation, and the opportunity for review and concurrence with State Plans. Some States, however, have experienced difficulty with their new responsibility for the radiological emergency planning because the number of parties involved in the process is large (federal, state, local, utilities), and the responsibility for planning and implementation has at times exceeded the capabilities of the agencies concerned.

In California, the involvement of the State Office of Emergency Services (OES) with the radiological emergency planning for nuclear power plants began shortly after the publication of Appendix E, 10 CFR Part 50. In the midst of the Energy Crisis in 1974, OES and the State Department of Health Radiological Section, were asked by the State Assembly Sub-Committee on State Energy Policy to prepare a radiological emergency response plan for California and to assist local and county governments in the development of their emergency response and evacuation plans. OES was formally made the "Designated State Authority" for coordinating State responses to radiological emergencies in the "Nuclear Power Plant Emergency Response Plan," which was completed in July 1975. OES was also assigned responsibility for review of State and local emergency plans relating to nuclear power plants. At present, all four existing nuclear power plants in California — San Onofre, Humboldt, Rancho Seco, and Diablo Canyon — have local emergency response and evacuation plans in various stages of completion.

Another State agency, the Energy Resources Conservation and Development Commission (ERCDC), is presently drafting requirements for emergency planning for proposed nuclear power plants. ERCDC was created by the Warren-Alquist Act (1974) to rationalize the production and use of energy in California. Along with four other functions, it is charged with responsibility for the siting of thermal power plants in California and must condition certification upon a showing of adequacy of emergency planning and of possible population density controls, a related subject.

This report will present a review of emergency and evacuation planning, from the NRC licensing process (Section 2) to the development of State and local radiological emergency response plans (Section 4), for nuclear power plants in California. A description of the Federal Interagency Assistance program is included in Section 3. The emerging role of the California Energy Resources Conservation and Development Commission in State emergency planning relative to certification of nuclear power planning facilities and sites is explored in Section 5.

The emphasis of this report is necessarily descriptive. In the regulation of nuclear power, compliance with regulatory procedures is a mechanism for assuring an adequate level of radiological protection. Although emergency response planning is more directly related to protective actions on an emergency basis than are other aspects of nuclear regulation, a procedural review is useful as background for a discussion of the regulatory complementarity that is possible among the Federal, State, and local agencies involved in the development of emergency plans for nuclear power plant incidents. This review is intended to facilitate the use by State emergency planners of the information made available to the Nuclear Regulatory Commission by the applicant in the licensing process, and to identify areas where State and local agencies may have to develop their own sources of information for emergency and evacuation planning.

Several developments concerning emergency planning have occurred since this report was completed in January, 1977. First, the NRC Office of Nuclear Reactor Regulation has issued a revision of Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants" (March, 1977). The revised guide provides that "development of an effective interface" with State and local governments, particularly for the low population zone, is a necessary part of emergency planning by the licensee.

(continuation of footnote on page 3)

Second, the issue of whether the NRC can legally require licensees to extend emergency planning beyond the low population zone has been brought before an appeals board of the Atomic Safety and Licensing Panel in connection with applications for construction permits by the Public Service Company of New Hampshire (Seabrook Plant, New Hampshire, Docket No. 443,444) and New England Power Company (New England No. 1 and 2, Rhode Island, Docket No. 568,569). An opinion by the appeals board is expected in April, 1977.

Third, on March 10, 1977, the NRC Office of Nuclear Reactor Regulation (NRR) concluded a Memorandum of Understanding with the Office of State Programs (OSP) to provide for consultation and coordination of their activities related to state and local emergency preparedness. The Agreement requires that NRR shall request OSP to verify an applicant's representations at the construction permit stage concerning the manner and extent to which state/local agencies are involved in emergency planning, and to provide a written assessment of the emergency response capabilities of offsite agencies when an operating license is sought. OSP will also encourage the early participation of state and local agencies in emergency planning and submit periodic evaluations of their emergency response capabilities in connection with particular licensed facilities.

The Office of Nuclear Reactor Regulation will prepare an Accident Potential Statement for each nuclear power reactor site which addresses the accident potential at the site in both generic and site-specific terms relevant to emergency planning. NRR expects to utilize the report of the current joint NRC/EPA Task Force effort as part of the basis for the generic portion of such statements.

The Agreement also provides that NRR and OSP will examine the nature and scope of licensees' responsibility for training of state and local emergency response personnel and the practical effect and adequacy of such training that is presently available.

The attempt has been made to incorporate certain of these alterations in the body of the report largely in the form of footnotes. While the procedural implications of these developments for cooperation between state, local, federal agencies and the licensee is not clear at the present, joint planning should allow for a better exchange of information and sharing of costs among the parties concerned with emergency preparedness.

2. EMERGENCY PLANNING FOR NUCLEAR POWER PLANTS: THE LICENSING PROCESS.

The Nuclear Regulatory Commission's (NRC) approach to radiological protection is organized around the concept of "defense-in-depth." In this concept are three mutually reinforcing levels of protection, including (1) the reliable design and construction of power plants to minimize system malfunctions, (2) provision of safety systems to cope with failures if they do occur, and (3) the evaluation of a series of highly unlikely, postulated accidents to establish the adequacy of safety systems.[1] Emergency planning for nuclear incidents is regarded by the NRC as the "capstone" of the defense-in-depth concept.[2] It is an expanding program which affects the development of regulations, guides, and standards, the licensing process, and the program of continuing inspection and enforcement by the NRC Regulatory Staff. The present focus of the regulatory effort on emergency planning is to insure that individual licensees develop a response capability (in cooperation with Federal, State, and local authorities) sufficient to qualify as a "reasonable state of preparedness" to deal with emergencies which may arise during the operation of a nuclear facility.

Historically, the earliest reactors (Yankee, Dresden, and Indian Point) relied mainly on basic design features, such as high pressure containment vessels and reactor shut down systems, to minimize the probability and consequences of power plant accidents.[3] These early systems, along with more sophisticated devices developed later, became known as "engineered safety features," and performance standards were prescribed for them in the computation of dosage resulting from postulated accident conditions as a part of reactor site criteria. Population density as a factor in site selection and establishment of an emergency response capability on behalf of the public in the low population zone (LPZ) were first expressed as a part of the Reactor Site Criteria, 10 CFR Part 100, published in 1962. As the number of nuclear power plants increased, the responsibility of the licensee for emergency preparedness became more explicit in the regulatory process. In 1970, the Atomic Energy Commission codified its emergency planning requirements for licensed nuclear facilities as Appendix E to 10 CFR Part 50, "Licensing of Production and Utilization Facilities". These two regulations, 10 CFR Part 100, Appendix E to 10 CFR Part 50, and supporting guidance documents issued since then, represent the current requirements for radiological emergency planning in the licensing of nuclear facilities.

Accident analysis is instrumental to both reactor site selection and emergency planning in the licensing process. In site selection, it provides a quantitative framework for validating compliance with the individual dose reference criteria prescribed by 10 CFR Part 100, and allows a broader look at possible trade-offs between additional engineered safety features and site population distance factors. In emergency planning, accident probabilities and consequences are translated into organizational responses and instrumental requirements necessary to mitigate the impact of population exposure and property contamination. Due to the complexity and limited experience with nuclear power technology, accident analysis is often the center of controversy in the assessment of nuclear risk. The conservative analysis used by the NRC may be regarded as a regulatory response to analytical uncertainty which seeks to minimize risk associated with nuclear facilities by "overestimating" the consequences of postulated accidents. The fission product release hypothesized for purposes of site analysis is based on a major core meltdown, and is greater than the maximum release from "credible" design-basis accidents.* This postulated overreacting of design parameters used for evaluation of reactor safety systems (which, contrary to the postulated meltdown just mentioned, are required to preserve the physical integrity of the reactor core) is intended as an additional level of protection for station personnel and the public rather than as a mechanistic accident analysis.

Construction and operation of nuclear power plants are accompanied by radiological safety and environmental reviews at both the construction permit and operating license stages.+ (see figure 2-1) These reviews are very extensive and contain information which might be utilized by state agencies during their review of proposed sites.

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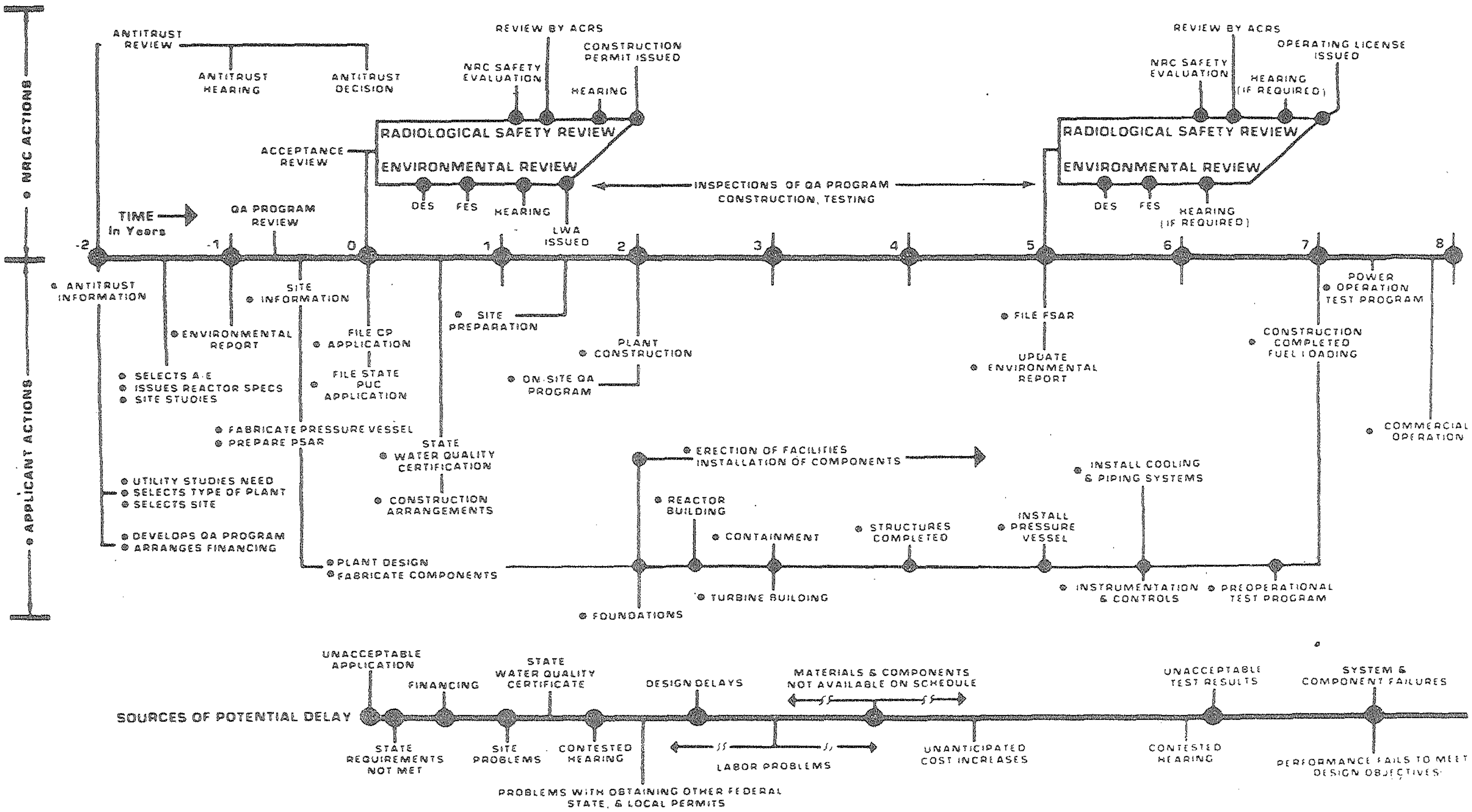
*Footnote 1 to 10 CFR Part 10, Section 100.11 states: "The fission product release assumed for these calculations should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events, that would result in potential hazards not exceeded by those from any accident considered credible. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products."[4]

+For detailed description of the regulatory process for the licensing of nuclear facilities, see ref. 5.



Abbreviations: A-E = architect engineer, QA = quality assurance, CP = construction permit, PUC = Public Utility Commission, DES = draft environmental statement, FES = final environmental statement, LWA = limited work authorization

Figure 2-1 NUCLEAR POWER PLANT LICENSING AND CONSTRUCTION PROCESS

Source: U.S. Nuclear Regulatory Commission. Annual Report 1975.

The applicant's safety report supporting the application for permit or license is prepared in accordance with Revision 2 of Regulatory Guide‡ 1.70, "Standard Format and Content of Safety Analysis Report". Included in a Safety Analysis Report (SAR) are: site characteristics; design, fabrication, construction of plant structures, systems, and components; plant operation; system response to postulated accidents; and quality assurance. Light water reactor applications are reviewed in accordance with the recently published Standard Review Plan,* which describes areas of review and review procedures. Highly conservative assumptions are used in both the SARs and the safety evaluation by the NRC Regulatory Staff to ensure that public health and safety will be protected if the proposed nuclear power plant is built and operated. Also, the Safety Evaluation Reports (SERs) issued by the NRC Regulatory Staff sometimes include comparatively more conservative calculations than those provided in the applicants' SARs. The criteria in the review process include NRC regulations and regulatory guides, supported by consensus standards developed by technical societies, often in conjunction with the NRC.

The applicant's environmental report is organized according to Revision 2 of Regulatory Guide 4.2, "Preparation of Environmental Reports for Nuclear Power Plants". The focus of review is on the potential impact of the proposed plant on surrounding populations, ecosystems, land use patterns, and socio-economic balance. Applicants are required to justify the reasons for their choice of site and to consider nuclear power at alternative sites and alternative energy sources in a cost-benefit analysis. Among the criteria used in the selection of site-plant alternatives are engineering and environmental factors, land use factors, and institutional considerations.[7] The determination of accident potential at each nuclear facility contained in the applicant's environmental reports is based on realistic, rather than conservative assumptions.

‡NRC Regulatory Guides specify acceptable methods for complying with the regulations in 10 CFR.

*"Regulatory Standard Review Plans are prepared for the guidance of the Directorate of Licensing staff responsible for the review of applications to construct and operate nuclear power plants ... Standard Review Plans are not substitutes for Regulatory Guides or the Commission's regulations and compliance with them is not required. The Standard Review Plan sections are keyed to Revision 2 of the Standard Format .... Not all sections of the Standard Format have a corresponding review plan."[6]

2.1 Reactor Site Criteria and Radiological Protection

Section 50.34 of 10 CFR Part 50 requires that each application for construction permit or operating license provide a description and safety assessment of the site on which the facility is to be located, with special attention to the site evaluation factors identified in 10 CFR Part 100, "Reactor Site Criteria." Paragraph 100.10(b) of 10 CFR Part 100 requires that "Population density and use characteristics of the site environs, including the exclusion area, low population zone, and population center distance" be taken into account in determining the acceptability of a site for a nuclear reactor.

In considering population density in the area surrounding a proposed site, a basic regulatory purpose is to insure that the choice of the reactor site will minimize radiological exposure of individuals outside the site under both routine and emergency conditions. The current NRC position is that siting close to metropolitan areas should be avoided unless it is shown to be extremely advantageous from the standpoint of economic, environmental, or other factors. Two approaches to the evaluation of reactor sites are presented in 10 CFR Part 100. In the exclusion area and the low population zone, analysis of radiological impact from a postulated accident is made primarily by the comparison of calculated accident dose consequences with levels of individual exposure prescribed by 10 CFR Part 100. This approach is based on the conservative analysis used in NRC safety evaluations and reflects the possibility of effecting compliance with specified exposure levels through inclusion of engineered safety features and the provision of adequate emergency protective measures. Dose computations employed to determine the exclusion area and low population zone are based on reference values stated in 10 CFR Part (100.11 (a), which limit individual exposure to 25 rem whole body and 300 rem to the thyroid at specified time intervals following a postulated release of fission products under adverse meteorological conditions.* The second approach involves the prescription of a minimum population center distance, which gives consideration to population risk where effective emergency measures may not be feasible. A Site Population Factor (SPF) Index has been developed by the NRC staff to compare the population distribution of alternative sites under representative meteorological conditions, weighted by a function which is inversely

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*At the construction permit stage, the computations should be based on 20 rem whole body and 150 rem thyroid dose.[8]

related to the distance from the reactor.

10 CFR Part 100 refers the applicant to TID 14844, "Calculation of Distance Factors for Power and Test Reactors Sites,"[9] as a guide to the evaluation factors relevant to the determination of the exclusion area, low population zone, and the population center distance. Recent regulatory practice suggests that the population criteria for siting nuclear power plants are based on a case-by-case comparison with existing high density sites such as Indian Point and Zion.[10] However, other considerations in TID 14844, particularly the meteorological conditions associated with a specific site and the level of operating capacity, will continue to affect the acceptability of a proposed site. In addition, the distance factors prescribed by 10 CFR Part 100 and TID 14844 are dictated primarily by the release of radioactive iodine. Thus the existence of engineered safety features directed at reducing iodine releases (and/or the release of particulate and noble-gas activity) may be an important variable in the calculation of the exclusion area and the low population zone at an individual site.[12]

Because the interplay of variables relevant to the determination of the exclusion area, low population zone, and population center distance is a useful introduction to the manner in which reactor site selection may be utilized as an effective preventive measure to reduce radiological risk, information requirements applicable to the definition of these areas are set forth in detail in Section 2.1.1, 2.1.2, and 2.1.3 *infra*. Although the problem of land use and population density is considered in a separate report,[11] Section 2.1.4 will discuss the process of site population evaluation at the construction permit stage. A brief description of the Site Population Factor Index developed by the NRC regulatory staff is included in Appendix A.

It should be noted that Footnote 1 to 10 CFR Part 100.11(a) explicitly states that the dose reference values of 25 rem* whole body and 300 rem to the thyroid are intended to be used for evaluation of the reactor sites in conjunction with site characteristics that influence plant design and operating criteria; they are not intended as acceptable dose levels for the public under accident conditions. In this context, while the discussion in Section 2.1.2 *infra* suggests that the determination of the low population zone for siting purposes interacts with the review of emergency planning at the construction

*The basic measure of the energy deposited by ionizing radiation in a gram of material is known as the rad (radiation absorbed dose). However, since some types of radiation are more damaging than others, the rem (roentgen equivalent man) is used as the biological unit of dose. The dose in rem is equal to the absorbed dose in rad multiplied by the relative biological effectiveness (RBE) of the radiation. (Here, 'relative' means compared to x rays, for which the RBE is equal to one.)

permit stage, it should be kept in mind that they are essentially independent analyses based upon different reference dose criteria. Emergency planning is a type of protective action which is directed at minimizing the impact of a specific release. The current criteria used by the NRC Regulatory Staff to review the sufficiency of an applicant's emergency planning for the low population zone includes the Protective Action Guides in Chapter 2 of the Manual of Protective Action issued by the Environmental Protection Agency in September 1975. The emergency exposure level at which protective action for the general public is recommended is 1 - 5 rem whole body and 5 - 25 rem thyroid (see discussion *infra* in Section 2.3.4.3, "Anatomy of Emergency Planning Evaluation," and Section 3.2.2, "EPA: The Manual of Protective Action Guides and Protective Actions for Nuclear Accidents").

2.1.1 Exclusion Area

Section 2.1.2 of the Standard Format sets out the information requirements for "Exclusion Area Authority and Control" in the applicant's safety analysis report. The general purpose of Chapter 2 is for the applicant to indicate how site characteristics (including present and projected population distribution, land use, site activities and controls) have influenced plant design and operating criteria, and to show that the choice of reactor site is adequate from a safety viewpoint. Primary responsibility for reviewing Section 2.1.2 is placed in the Accident Analysis Branch (AAB), with secondary responsibility shared by the Office of the Executive Legal Director, Industrial Security and Emergency Planning Branch, Division of Operation Safety, Emergency Preparedness Branch, and the Site Analysis Branch.*

Regulatory Requirements. 10 CFR Part 100.3(a) defines "exclusion area" as that area surrounding the reactor in which a reactor licensee has authority to determine all activities including exclusion or removal of people and property. 10 CFR Part 100.11(a)(1) requires an applicant for a construction permit or operating license to make a determination of:

> "An exlusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose in excess of 25 rems to the whole body and 300 rem to the thyroid from iodine exposure."

Unless otherwise noted, the following summary of review procedures for the exclusion area is based on Section 2.1.2 of the Standard Review Plan.

*Since the recent re-organization at NRC, the Accident Analysis Branch is now under the Division of Site Safety and Environmental Analysis, and the Industrial Security and Emergency Planning Branch is under the Division of Project Management. The names of NRC offices with responsibilities discussed in this report may have changed.

Review Procedure. The application should establish that the applicant has the authority to determine all activities within the exclusion area. Absolute ownership of all lands within the exclusion area is considered sufficient evidence of the required authority. However, if authority is contingent upon future procurement of ownership, a determination must be made whether the applicant's claimed authority will meet the requirements of Part 100.3(a) by the time of issuance of the staff safety evaluation report. In addition, where the designated exclusion area adjoins bodies of water routinely accessible to the public, the applicant must make arrangements with local, state, federal, or other public agencies having authority over the particular body of water to provide for emergency evacuation.

Activities within the exclusion area unrelated to plant operation are acceptable provided that no individual engaged in such activities is likely to receive, as a consequence of the postulated design basis accidents, radiation doses in excess of 10 CFR Part 100 guidelines. The application should provide an estimate of the time required to evacuate all persons from the area in order that calculations of radiation doses can be made.[13] If the designated exclusion area is traversed by a transportation route accessible to the public, the applicant's emergency plan must include adequate provisions for control of traffic on these routes in the event of an emergency.

Determination of the exclusion area will establish the minimum distance to the exclusion area boundary that is used in dose computations. An important environmental consideration here is that the meteorological conditions of the proposed site should provide sufficient dispersion of radioactive materials released during a postulated accident to reduce the radiation exposures of individuals at the exclusion area boundary to the prescribed 2-hour dose values.[7] Based on past experience, the NRC AAB has found that an exclusion boundary distance of 0.4 mile, even with the most unfavorable atmospheric dispersion characteristics, would assure that the calculated dose can be brought within the guidelines of 10 CFR Part 100.

2.1.2 Low Population Zone

Regulatory Requirements. 10 CFR Part 100.3(b) defines the "Low Population Zone" (LPZ) as the area immediately surrounding the exclusion area in which the population number and distribution are such that, "there is a reasonable probability that appropriate measures could be taken in their behalf in the event of a serious accident." 10 CFR Part 100.11(a)(2) requires the applicant to determine:

> "A low population zone of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure."

Section 2.1.3.4 of the Standard Format requires the applicant to specify the LPZ and to discuss the basis for its selection. In addition, the safety analysis report should include the following information on emergency planning:

1) A scale map of the LPZ which illustrates topographic features; transportation routes that may be used for evacuation purposes; and the location of all facilities and institutions such as schools, hospitals, prisons, beaches, and parks.

2) Identification of facilities and institutions beyond the LPZ, to a distance of 5 miles which may require special consideration when evaluating emergency plans.

3) A table of population distribution within the LPZ which will provide estimates of peak daily, as well as seasonal, transient population.

Review responsibilities for Section 2.1.3 on "Population Distribution" are shared by the Accident Analysis Branch, which has primary responsibility for dose calculations, and the Industrial Security and Emergency Planning Branch (ISEPB). Review of the LPZ is based on Section 2.1.3 of the Standard Review Plan.

Review Procedure. At the construction permit stage, on the basis of the LPZ specified by the applicant, the NRC performs an independent calculation of the radiological consequences at the outer boundary of the low population zone based upon a postulated design basis accident. The specified low population zone is acceptable if the following requirements can be met:

"a) ISEPB has determined that there is reasonable assurance that appropriate protective measures could be taken on behalf of the population in the event of a serious accident;

b) dose computations for the outer boundary of the LPZ are within 10 CFR Part 100 guidelines, and

c) the nearest boundary of the closest population center is at least one and one-third times the distance from the reactor to the outer boundary of the low population zone."[14]

At the operating license stage, the acceptability of the exclusion area and the LPZ with respect to Part 100 dose criteria will be reaffirmed using the latest available engineered safety features design data and X/Q values (ratio of concentrations to emissions).[15] The final determination of acceptability is made in conjunction with analysis of design basis accidents reviewed in Section 15 of the Standard Review Plan.

2.1.3 Population Center Distance

Regulatory Requirements. 10 CFR Part 100.3(c) defines "Population center distance" as the "eistance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents." 10 CFR Part 100.11(a)(3) requires the applicant to specify.

> "A population center distance of at least one and one-third times the distance from the reactor to the outer boundary of the low population zone.... Where very large cities are involved, a greater distance may be necessary because of total integrated population dose calculation."

Section 2.1.3.5 the Standard Format provides that the applicant's Safety Analysis Report should identify the nearest population center and specify its distance and direction from the reactor. In addition, the SAR should indicate the basis for the selection of the population center boundary and the extent to which transient population has been considered in establishing the population center; and should discuss the present and projected population distribution and population density within and adjacent to local population centers.

The Accident Analysis Branch is responsible for reviewing the applicant's description of the population center distance. Review criteria are described in Section 2.1.3 of the Standard Review Plan.

Review Procedure. When the Atomic Energy Commission published "population center distance" as a site criterion in 1962, it was intended to reflect the Commission's past practice and current policy of keeping stationary power and test reactors away from densely populated areas.[16] The minimum population center distance criterion was prescribed when it was found, for several projects evaluated, to be consistent with existing siting practices and with two desired regulatory objectives:

> "One basic objective of the criteria is to assure that the cumulative exposure dose to large numbers of people as a consequence of any nuclear accident should be low in comparison with what might be considered reasonable for total population dose. Further, since accidents of greater potential hazard than those commonly postulated as representing an upper limit are conceivable, although highly improbable, it was considered desirable to provide for protection against excessive exposure doses to people in large centers, where effective protective measures might not be feasible. Neither of these objectives were readily achievable by a single criterion."[16]

Section 2.1.3 of the Standard Review Plan states that population distribution, rather than political boundaries, shall be the main consideration in the determination of the relationship of the nearest population center to the LPZ outer boundary distance. The population center distance is acceptable if it is determined by the AAB that over the lifetime of the power plant there will be no probable concentrations of greater than 25,000 people closer to the reactor than the population center distance designated by the applicant.

Multiple Facilities. For sites intended for multiple reactor facilities, 10 CFR Part 100.11(b) provides that consideration should be given to the following:

"1) If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone, and population center distance shall be fulfilled with respect to each reactor individually. The envelopes of the plan overlay of the areas so calculated shall then be taken as their respective boundaries.

2) If the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area, low population zone, and population center distance shall be based upon the assumption that all interconnected reactors emit their postulated fission releases simultaneously. This requirement may be reduced in relation to the degree of coupling between reactors and the probability that an individual would not be exposed to the radiation effects from simultaneous releases."

3) The applicant is expected to show that the simultaneous operation of multiple reactors at a site will not result in total radioactive effluent releases beyond the allowable limits of applicable regulations."

2.1.4 Site Population Evaluation

Information Requirements. Section 2.1.3 of the Standard Format states that the following information on population distribution should be presented as part of the applicant's safety analysis report.

1) Significant population within a 10 mile radius and between 10 and 50 miles radius from the reactor should be identified on maps of suitable scale. The maps should indicate distances from the reactor at prescribed time intervals in concentric circles divided into 16 equal sectors of 22.5° each. Tables appropriately keyed to each map should provide data on current residential population within each area of the map formed by the rings and radial lines.

2) Projected population within each area for the expected first year of plant operation and by census decade through the projected plant life should be tabulated.

3) If the plant is located in an area where significant population variations due to transient land use are expected, additional tables on population distribution should be provided to indicate peak seasonal and daily figures for current as well as projected populations.

Environmental Report. The population data requested by Chapter 2 of Regulatory Guide 4.2., Preparation of Environmental Reports[17] are similar to that in the safety analysis, except that the applicant is requested to include the age distribution of the projected population for the year corresponding to the midpoint of the station operating life. In addition, the applicant is requested to examine proposed and existing uses of adjacent lands and water as a part of its site-plant selection process and to summarize the views, if any, of local planning groups and interested citizens concerning use of the candidate area.[7]

Review Procedure. Demographic information is reviewed by both the Accident Analysis Branch and the Industrial Security and Emergency Planning Branch. Analyses of data submitted is primarily by comparison with independent projections made by other governmental agencies such as the Census Bureau, Bureau of Economic Analyses, Environmental Protection Agency, local and State agencies, and regional Councils of Government. Data on present population in the region of the site is acceptable if it is based on the 1970 Census and updated to the year of the application. A programmed census tape is available to the Regulatory Staff to give population distributions in 22½° sectors at the prescribed radii from a proposed site at any given latitude and longitude. Population projections for the relevant counties by local or regional planning councils is consulted over other national projections because they tend to be more sensitive to local factors than national forecasts.[19] Section 2.1.3, "Population Distribution" of the Standard Review Plan also describes a method of comparing the growth rate derived from the data submitted by the applicant and applicable OBERS information.*

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*OBERS is the descriptive title of a projection program conducted by the U.S. Department of Commerce former Office of Business Economics (OBE), now renamed the Bureau of Economic Analysis, and the Economic Research Services (ERS) of the U.S. Department of Agriculture.[14]

Review Procedure. At the construction permit stage, if the population density projected at the time of initial plant operation exceeds 500 persons per square mile average over any radial distance out to 30 miles, or the projected population over the lifetime of the facility exceeds 1,000 persons per square mile averaged over any radial distance out to 30 miles, special attention will be given by the regulatory staff to the consideration of alternative sites in the environmental review.[14]

At the time of the operating license review, any new population data and projections developed since the construction permit review are evaluated for significant discrepancies to determine the effect on the acceptability of the low population zone and emergency evacuation capabilities. The nearest boundary to the closed population center is compared with the low population zone at the outer boundary to ensure that Part 100 guidelines are satisfied. An enclosure on population density is prepared for the Environmental Report acceptance review memorandum, noting whether or not the density averaged over any distance out to 30 miles exceeds 500 people per square mile, or 1000 people per square mile over the projected lifetime of the plant.[14] An examination of the particular population distribution as reflected by the computed Site Population Factor (see Appendix A) may be required in borderline cases. The applicant's information on population distribution surrounding the site is acceptable upon verification by the NRC Regulatory Staff that:

> "The present and projected populations surrounding the site, including transients, have been reviewed and comparison with independently obtained population data confirms the applicant's estimates.
>
> "On the basis of the specified low population zone and population center distance, and the calculated radiological consequences of design basis accidents at the outer boundary of the low population zone, ... it is concluded that the low population zone and population center distance meet the guidelines of 10 CFR Part 100..."14

In reviewing the process of site population evaluation by the NRC, it should be noted that while NRC has a policy of siting power plants away from population centers — and indeed U.S. siting policy in this respect has been more conservative than that of European countries[3] — there is no routine monitoring of site population growth after the issuance of the operating license.* The rationale for this is that the local services and facilities necessary for public protection in the event of a ratiological emergency are assumed to grow with population.[18] Where there are significant changes within the LPZ in terms of population distribution grossly inconsistent with projected growth in the final SAR,+ it may be the responsibility of the licensee to bring this situation to the attention of NRC inspectors as an "unreviewed safety question" pursuant to 10 CFR 50.59, and to propose a means to deal with it.++ This, however, has never occurred. Alternatively, interested State or local parties may bring the matter to the attention of the Commission by petition under 10 CFR Part 2, Section 2.206: "Procedure for Imposing Requirements by Order, or for Modification, Suspension, or Revocation of a License, or for Imposing Civil Penalties." For states concerned with this problem, the NRC index for comparing the populations of alternative sites, the Site Population Factor (SPF) index (Appendix A) may be useful in evaluating the impact of changing population distributions on emergency radiological response capabilities.

2.2 Emergency Planning for Nuclear Power Plants

2.2.1 Determination of Accident Potential

Accident analysis is a focal point of regulatory review in the licensing of nuclear power plants. It involves multiple analysis of a plant's responses to postulated disturbances and component failures in order to determine the consequences of such failures and occurrences and the plant's capability to control or to accommodate them. These analyses make a significant contribution to the selection of design specifications for components and systems from the standpoint of public health and safety. Accident analysis may also be seen as the culmination of the site evaluation process relative to the calculation of exposure dose limits for the exclusion boundary and the low population zone as provided by 10 CFR Part 100, and as the quantitative basis for emergency planning for radiological incidents.

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*Procedure No. 30702B of the NRC Inspection and Enforcement Manual provides that during the meeting with licensee management at three year intervals senior NRC regional personnel should ascertain whether significant changes have occurred in the general environs of the facility including population increase in excess of predicted.

+The SAR submitted for construction permit review is the Preliminary SAR (PSAR); that submitted for operating license review is the final SAR (FSAR).

++Greater specificity with respect to the characterization of the LPZ in the technical specifications issued with the operating license to the licensee may provide a procedural basis for future reviews of population changes by the Office of Inspection and Enforcement. See NRC Standardize Technical Specifications for Pressurized Water Reactors.

Section 15 of the Standard Format states that applicants should examine operational occurrences, off-design transients, postulated component failures, and should categorize each by type and expected frequency. It is suggested that individual events should be analyzed step-by-step from event initiation to the final stabilized condition, and that the effect of single failures and operator errors should be discussed and evaluated. Initiating events are classified by the NRC according to the probability of occurrence:

a) Incidents of moderate frequency — incidents which may occur once during a calendar year for a particular plant.

b) Infrequent incidents — incidents which may occur once during the lifetime of a particular plant.

c) Limiting faults — occurrences that are not expected to happen but are postulated because their consequences would include the potential for the release of significant amounts of radioactive material.

Limiting faults, which assume a process fault with several of the safety features operative to the minimum degree necessary, are used as the Design Basis Accidents (DBAs) for purposes of accident analysis. DBAs may be environmentally caused (earthquakes, tornadoes, tsunamis, floods) or arise as a consequence of component and system failures. Nuclear power plants are designed to withstand the impact of most environmental DBAs,* in that they should safely shut down and maintain integrity with no effect on public health and safety. The accident initiation events considered in the design basis evaluation include the following Class 8† events:

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*The effects of potential accidents within 5 miles of the nuclear power plant from nearby industrial transportation and military installations are also included as design basis events for plant design.[20]

†The classification system for accident assumptions (Class 1 through 8) was developed for environmental assessment purposes by the Atomic Energy Commission, after the enactment of the National Environmental Protection Act (1970) and the *Calvert Cliffs Decision* (1972). Prior to that time, the design basis assumptions for accident analysis were dispersed throughout the Safety and Regulatory Guides issued by the AEC. While Class 8 events refer to those design basis accidents considered in safety analysis reports and safety evaluations, the applicable assumptions are set forth in AEC Regulatory Guide 1.3 and Regulatory Guide 1.4.[21]

8.1 Loss of coolant accidents

8.1(a) Break in instrument line from primary system that penetrates the containment

8.2(a) Rod ejection accident (PWR)

8.2(b) Rod drop accident (BWR)

8.3(a) Streamline breaks (PWRs outside containment)

8.3(b) Streamline breaks (BWR)

In the evaluation of radiological consequences, applicants are requested to summarize the assumptions, parameters and calculations used to determine the doses resulting from various DBAs. The descriptions must be in sufficient detail to permit independent calculations by the NRC. Two separate analyses for each DBA are included in the information submitted by the applicant. First, a "conservative design basis analysis," which should be based on design basis assumptions acceptable to the NRC for purposes of determining plant design adequacy. Prior to 1970, the calculated doses based on a conservative analysis in safety analysis reports approached the 10 CFR 100 limits of 25 rem whole body and 300 rem thyroid. Since 1970, the dose assessment as a result of changes in engineer safety features at the construction permit stage tends to approach 150 rem thyroid dose.[22,21] Secondly, a "realistic analysis" is included in the applicant's environmental reports. This analysis is based on what the applicant believes to be realistic assumptions (usually related to the mechanical causes of accidents), and is used for environmental impact analyses as well as for quantifying the margins of safety that are inherent in the design basis approach. The NRC, as a part of its statutory responsibilities, also makes a realistic determination of the accident potential at each licensed nuclear power plant in its Final Environmental Impact Statement. The realistic accident analyses in both the environmental reports (applicant) and Statement (NRC) assume that engineered safeguards will be operable in a degraded state in the event of a DBA, and offsite consequences of such accidents are estimated to be factors of 10^3 to 10^5 less than that contained in the safety analysis report.

A major reservation in risk assessment for nuclear power plants is whether all significant events which may result in radiological consequences affecting the public have been identified and evaluated in the individual safety analysis reports. In particular, concern has been expressed over the lack of proper assessment of events which involve failures to cope with design basis accidents. These occurrences, known also as Class 9 accidents, have been excluded from analysis because their probability of occurrence is so small that their environmental risk is considered extremely low. Recently, the NRC has treated such occurrences in its "Reactor Safety Study." The conclusion of the study report,[23] as summarized by Dr. Saul Levine of the NRC's Division of Regulatory Safety, is that:

1) For an accident to be significant risk, the reactor core must melt. This requires a fuel heat imbalance which can only occur as a result of LOCAs (loss of core coolant accidents) or transient events. The best estimate of the probability of core melt is about 6×10^{-5} per reactor year in a system of 100 operating reactors.

2) Core melt is not a catastrophe. It results in a wide spectrum of possible consequences, relatively few requiring evacuation or necessarily having any offsite effects at all. The largest consequences of core melt are much smaller than many people believed; and the probability of nuclear accidents is much smaller than non-nuclear accidents.[24]

WASH-1400 has been criticized on several grounds. A criticism relevant to emergency planning is that the study assumed, in its calculation of radiological consequences, the evacuation of a 5 mile radius of the plant and as far as 25 miles in a 45° sector. The effect of evacuating a lesser area on resulting injuries is not explicitly calculated.* Another observation is that the presentation of the results in WASH-1400 tends to obscure the comparison between small consequence and large consequence accidents by emphasizing the accidents which are most probable, rather than those which present the greatest risks.

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*WASH-1400 states that "an effective evacuation speed of 1.2 mph (modal value) reduces the individual early mortality probability by a factor of 10. For effective speeds of 4.7 mph (mean value) and 7.0 mph, the probability of early death is reduced to essentially zero within 25 miles.... In the event of a very ineffective evacuation in which the evacuees were exposed to ground contamination for longer than 4 hours the number of early fatalities and illnesses might be increased by a factor of 3 or 4."[25]

> "The discussion in WASH-1400 leaves one with the impression that the accidents with small consequences are the important ones, although all that it states directly is that they are the more probable ones. The distinction is important because risk does not depend alone on the probability of accidents. It depends on a product of probability and consequences, as is made clear in the study's discussion of the meaning of risk." 26†

This comment mirrors the frustration experienced by state and local emergency planners when they are confronted with the low priority placed upon offsite radiological emergency planning because of the low probability of large accidents. Their frustration is sometimes difficult to articulate in factual terms because Class 9 accidents — or events involving failures to cope with design basis accidents — are not dealt with in the emergency planning review process of the NRC conservative safety analyses; and the state and local agencies lack the resources and expertise to fully evaluate the potential consequences of such an event. The NRC position is that emergency planning based upon a broad spectrum of credible accident probabilities extending up to and including the most serious design basis accident is "an adequate but not excessively conservative position which balances the costs of allocating resources to creating and maintaining the state of preparedness for these types of emergencies with the uncertainties that they will ever be needed."[2] This issue is currently being debated by an NRC and EPA task force which shall evaluate all available data and experience in order to ascertain whether a revision of the regulatory position is warranted.[2]

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†Despite the attitude in Environmental Statements that the environmental risk posed by "Class 9" accidents is "extremely low," the discussion in ref. 26 of WASH-1400 results indicates that this class dominates the risk to the public.

2.2.2 Definition of Nuclear Emergencies

Accident analysis for purposes of Safety Analysis Reports is primarily concerned with the design responses of a plant to postulated malfunctions or equipment failure. Before these analyses can serve as useful guidance for emergency planning, the radiological consequences from discrete design basis accidents must be related to individual and organization responses. The current practice is to establish a system of emergency classifications with pre-planned action levels. Annex A to Regulatory Guide 1.101 recommends that such a system of classification should consist of mutually exclusive protective action levels covering the entire spectrum of possible situations. Each class should incorporate (1) a specific emergency organization alerting and mobilization procedure, and (2) a set of pre-defined preliminary actions to be taken by designated emergency personnel.* For planning purposes, the NRC Regulatory Staff has suggested the division of emergencies into five classes, involving activation of progressively larger segments of the emergency organization.[27]

1. Personnel Emergency. Accidents or occurrences onsite in which emergency treatment of one or more individuals is required. The importance of this class as a part of the classification scheme rests to some extent on its "negative" information content, viz, that the incident giving rise to the emergency is restricted in its scope.

2. Emergency Alert. This class involves specific situations that can be recognized as creating a hazard potential such as bomb threats, floods, earthquakes, fires at adjacent facilities. Emergency alert conditions imply a rapid transition to a state of readiness by the plant personnel, and possible precautionary actions which the specific situation may require.[28]

3. Plant (Unit) Emergency. Physical occurrences within the plant requiring full plant staff emergency organization response. Evacuation of the plant is not anticipated, although protective evacuation or isolation of certain plant areas may be necessary. Notification of corporate headquarters as well as appropriate offsite agencies is considered prudent and advisable.

4. Site (Station) Emergency. Moderate uncontrolled release of

*Revision 1 to Regulatory Guide 1.101 indicates that the system of classification should also be compatible with the system used by State and local governments. US NRC, Office of Standards Development, Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants," Revision 1, March 1977. (Hereafter cited as "Revised Guide.")

radioactive materials into the air, water, or ground to an extent that initial assessment indicates protective actions offsite may be desirable. Emergency action levels declaring a site emergency should be defined in terms of instrument readings or alarms in the station control room; or upon evidence of apparent breeches in fuel cladding, primary system boundaries, or containment of the reactor.*

5. General Emergency. This is an occurrence which requires that protective actions be taken in both onsite and offsite areas. The protective actions in this class must address both short term (direct radiation, inhalation) and long term (contamination from radioactive fallout) hazards.†

Table 2-1 summarizes the degree of involvement that would be required by participating groups in responding to each of these events.

TABLE 2-1 EMERGENCY CLASSIFICATIONS AND DEGREE OF INVOLVEMENT BY PARTICIPATING GROUPS

Emergency classification	Necessity for protective action		Necessity for corrective action	Degree of participation by various organizations		
				Licensee		
	On site	Off site		Plant staff	Headquarters staff	Off-site agencies
Personnel emergency	Possible	Not required	Possible*	Action required	No action required	No action required
Emergency alert	Not required	Not required	Not expected	On alert status	On alert status	No action required
Plant emergency	Possible	Not required	Possible*	Action required	On alert status	No action required
Site emergency	Probable	Possible	Probable*	Action required	Action required	On alert status
General emergency	Probable	Probable	Probable*	Action required	Action required	Action required

*Action could involve local firemen, police, ambulance services, and/or medical facilities.

Source: D.W. Moeller and J.M. Selby, "Planning for Nuclear Emergencies." Nuclear Safety, Vol. 17, No. 1, January-February 1976.

*The Revised Guide 1.101 states that emergency situations more severe than plant emergencies are not expected to occur during the life of a plant because of design features and other measures taken to guard against their occurrence. It also provides that in addition to instrument readings, emergency levels for declaring a site emergency should be defined "alternatively in terms of specific contamination levels in environmental media, e.g., water, soil, and milk."

†Under the Revised Guide 1.101, emergency plans for a general emergency class should provide for early warning of the public and prompt initiation of protective actions within the LPZ. Coordination with local authorities is an essential element of planning for this class which is designed to prevent and/or minimize public exposure from an airborne radioactive plume resulting from a substantial meltdown of the reactor core.

2.2.3 Developing an Emergency Plan

Emergency planning commences with the designation of emergency classes and associated emergency organization, and then proceeds with the establishment of action levels and criteria which specify when different emergency measures should be implemented. The essence of the planning process consists of pre-planned commitment of resources and manpower which is designed to guide decision-making in a stressful situation. Its objective is to minimize the number of possible responses so that resources are expended only on viable alternatives in emergency situations. The success of an emergency plan will depend on how carefully the plan is fitted to the capabilities and the resources of the intended users, and whether procedures have been established for critical events.[28]

While onsite emergency planning for radiological incidents will differ with each nuclear power plant, an emergency plan will encompass the following basic steps or responses:

1. Detection of the emergency
2. Activation of the responding organization
3. Assessment of the situation
4. Initiation of protective actions
5. Initiation of corrective actions
6. Assistance to affected persons
7. Recovery actions[28]

Each emergency measure should be related to specified action levels or criteria in the emergency classification system, with consideration given to release timing, response times, and instrumentation and manpower requirements.[27] The nature of individual emergency response actions are described below.

> "Assessment Actions — those actions taken during or after an accident which are collectively necessary to make decisions to implement specific emergency measures.*
>
> Corrective Actions — those emergency measures taken to ameliorate or terminate an emergency situation at or near the source of the problem.
>
> Protective Actions — those emergency measures taken after an

*The Revised Guide 1.101 states that assessment actions should provide for a reasonable determination, in a timely manner, of the magnitude of radioactive releases, the magnitude of resulting contamination, and the projected exposure of persons onsite or offsite.

uncontrolled release of radioactive material has occurred for the purpose of preventing or minimizing radiological exposures to persons that would be likely to occur if the actions were not taken.

Recovery Actions — those actions taken after the emergency to restore the plant as nearly as possible to its preemergency condition."[27]

2.2.4 Regulatory Review of Utility Emergency Plans

There are five NRC documents which are important guides to the development of radiological emergency plans for nuclear power plants. They are: (1) Appendix E to 10 CFR Part 50, "Emergency Plans for Production and Utilization Facilities;" (2) the "Guide to the Preparation of Emergency Plans for Production and Utilization Facilities," December 1970; (3) Section 13.3 of Revision 2 to the "Standard Format and Content of Safety Analysis Reports" on "Emergency Planning;" (4) the accompanying Section 13.3 of the Standard Review Plan; and (5) Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants."

2.2.4.1 Regulatory requirements

As a part of the licensing process, applicants are required by 10 CFR Part 50, Section 50.34 to submit a discussion of emergency plans in their applications for construction and operation of a nuclear power plant. Information submitted in each application must comply with the requirements of Appendix E, 10 CFR Part 50, "Content of Emergency Plans."

At the construction permit stage, the application must contain sufficient information to establish the compatibility of proposed emergency plans with facility design features, site layout, and site location.[29] Section II of Appendix E provides that a description of the following items must be included in the Preliminary Safety Analysis Report:

"A. The organization for coping with emergencies, and the means for notification, in the event of an emergency, of persons assigned to the emergency organization;

B. Contacts and arrangements made or to be made with local, State and Federal governmental agencies with responsibility for coping with emergencies, including identification of the principal agencies;

C. Measures to be taken in the event of an accident within and outside the site boundary to protect health and safety and prevent damage to property and the expected response in the event of an emergency, to offsite agencies;

D. Features of the facility to be provided for onsite emergency first aid and decontamination, and for emergency transportation of individuals to offsite treatment facilities;

E. Provisions to be made for emergency treatment of individuals at offsite facilities.

F. The training program for employees and for other persons, not employees of the licensee, whose services may be required in coping with an emergency;

G. Features of the facility to be provided to assure the capability for plant evacuation and the capability of facility reentry in order to mitigate the consequences of an accident or, if appropriate, to continue operation."[29]

For the Final Safety Analysis Report, applicants must provide a detailed description of their Final emergency plans, sufficient to demonstrate that appropriate measures can and will be taken in the event of an emergency. The requirements of the final emergency plan (Section II, Appendix E, 10 CFR Part 50) are similar to that contained in the PSAR. It includes such elements as the applicant's emergency organization, agreements with, and procedures for, notifying Federal, State and local officials and agencies to implement evacuation or other protective measures, emergency first aid and decontamination, arrangements made for treatment of individuals at offsite facilities, provisions for training of employees and other persons responding to radiological incidents, and reentry criteria. An additional procedure described in the FSAR concerns the following:

> "I. Provisions for testing, by periodic drills, of radiation emergency plans to assure that employees of the licensee are familiar with their specific duties, and provisions for participation in the drills by other persons whose assistance may be needed in the event of a radiation emergency."[29]

Appendix E was published as a regulation by the Atomic Energy Commission in December 1970. At the same time, the Commission also published a "Guide to the Preparation of Emergency Plans for Production and Utilization Facilities." The Guide was developed to help applicants develop adequate plans pursuant to Section 50.34 and Appendix E. Explanations of the general elements of an emergency plan are provided in the Guide, with examples of the kinds of matters which the AEC expected to be covered in an emergency plan. Included were: normal and emergency operating organization, coordination with offsite groups, spectrums of accidents, protective measures, and periodic review and update, medical support, drills, training, recovery and reentry, and implementation procedures. The specific requirements covered by the Guide have been enlarged upon in subsequent Regulatory Guides, but the Guide remains a useful reference as an introduction to the overall radiological planning process. Since the publication of Appendix E, the NRC Regulatory Staff has undertaken to make all emergency plans for power plants licensed prior to 1970 comply with Appendix E; and as of 1974, all licensees have submitted emergency plans to the NRC in compliance with 10 CFR Part 50, Appendix E.

It is evident that much of the thrust of Appendix E and supporting guidance is directed toward dealing with emergencies whose effects are largely or wholly confined to the plant itself and persons located at the plant.[2] This focus shifted somewhat when Regulatory Guide 1.70.14 was issued in December 1974 to update provisions of Revision 1 of the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. It is now perceived by one utility that R.G. 1.70.14 was developed to create a more precise information base for offsite emergency planning for radiological incidents.[30] Subsequently, the changes provided by R.G. 1.70.14 have been substantially incorporated in Revision 2 of the Standard Format, and the Guide has been withdrawn.[31]

The following discussion of Section 13.3, "Emergency Planning", of Revision 2 to the Standard Format, the accompanying Standard Review Plan (Section 13.3), and Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants" is applicable only to the licensing of future nuclear power plants. Licensees are not required to comply with Regulatory Guides promulgated after the issuance of their operating license unless the guidance is specifically "backfitted." The Nuclear Regulatory Commission has indicated that although Section 13.3 and R.G. 1.101 represents its latest position on acceptable methods of emergency planning pursuant to 10 CFR Part 50, Appendix E, it has no immediate intention to make the guidance retroactively applicable to existing power plants.[22] Thus the extent of compliance, if any, is essentially voluntary on the part of existing licensed nuclear facilities.

2.2.4.2 <u>Guidance documents for proposed nuclear power plants</u>

The second revision of Regulatory Guide 1.70, Section 13.3, describes supplemental information which should be included in the utility's Preliminary Safety Analysis Report pursuant to Section II of Appendix E to 10 CFR Part 50. Applicants are requested to submit the following information as part of their application for a construction permit:

1) An identification of the agency with primary responsibility for emergency preparedness planning for radiological hazards in the state where the facility is to be located, and the arrangements that the applicant has made with this agency and local authorities. Similar arrangements with neighboring states should be described if any part of the neighboring state is within the low population zone.

2) The PSAR should confirm that coordinated emergency plans provide for evacuation from the site and any potentially affected sector of the environs. Supporting information on the implementation of evacuation as a protective measure should be provided:

   - Plots showing projected ground-level doses for stationary individuals, for both whole body (1, 5, 25 rems) and thyroid (5, 25, 150, 300 rems), resulting from the most serious design basis accident analyzed in the SAR. Each curve should represent the elapsed time (ordinate) to reach the specified dose level as a function of distance (abscissa) from the release point. Each curve should be extended to an ordinate of not less than 8.0 hours either from an ordinate of 2.0 hours or from an abscissa equal to the exclusion radius, whichever results in the greater range of coverage. If any such curve does not intersect the outer LPZ boundary it should be extended to such intersection or to an elapsed time of 24 hours, whichever occurs first.

- Estimates of critical times required to identify and characterize the accident; to predict the projected radiation doses resulting from the accident; to notify offsite authorities before warning can be given to the population at risk by the utility (exclusion area) and offsite (authorities); to evacuate persons from site and affected surroundings. Sections of the environs chosen for the evacuation analysis should generally cover an arc of not less than 45° centered on the plant, and extending outward at least to the outer boundary of the proposed low population zone, or five miles, whichever is greater.

- A map showing all roads available for vehicular evacuation of the exclusion area and environs out to a distance of ten miles from the plant.

- Demographic data (both resident and transient) for each sector around the plant in one mile annular increments based on the population levels projected as peak values during the expected life of the plant.

- The identity and locations of agencies responsible for providing warning and direction to offsite persons.

- Identification of at least two offsite hospital facilities which have agreed to receive and treat persons affected by radiological emergencies.

Section 13.3 suggests that a comprehensive emergency plan should be submitted as a physically separate document in the Final Safety Analysis Report. Licensees are advised to consult Regulatory Guide 1.101, "Emergency Plans for Nuclear Power Plants," for the suggested content of this comprehensive plan. In addition, geographical and demographic information should be updated and included in an appendix to the emergency plan.

The intent of the NRC in publishing Regulatory Guide 1.101 is to provide more complete guidance to applicants for the preparation of emergency plans in the FSAR stage than the previously issued "Guide to the Preparation of Emergency Plans for Production and Utilization Facilities." The criteria specified for an Emergency Plan include the following:

a. The plan should be an expression of the overall 'concept of operation' that describes the essential elements of advance planning that have been considered and the provisions that have been made to cope with emergency situations. The plan should incorporate information about the emergency response roles of supporting organizations and agencies. The information should be sufficient to enable a determination of the interface and coordination required among the supporting groups and between them and the licensee.

The regulatory position is that the scope and content of the emergency plan for a nuclear power plant should be substantially equivalent to that recommended in Appendix A to R.G. 1.101.† Provision should be made for an annual review of the emergency plan and for updating and improving procedures based on training, drills, and changes onsite and in the surrounding area.* The preparation of specific procedures for implementing the emergency plan are described in Appendix B. "Implementing Procedures for Emergency Plans."[36] Such procedures should not be incorporated into the emergency plan and are not required to be submitted as part of the FSAR to the NRC. They should, however, be available for review

† Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants," provides that "except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described in Annex A1 is being and will continue to be used in the evaluation of FSAR until this guide is revised as a result of suggestions from the public or additional staff review."[32]

* The Revised Guide 1.101 directs that the applicant's emergency plan should provide for an initial exercise prior to full loading of the first unit at any site and annual exercises thereafter using "site emergency" or "general emergency" class scenarios. Each exercise should test minimally the communications links and notification procedures with offsite agencies to demonstrate that capability for early warning of the public is maintained. Training should include delineation of methods to evaluate its effectiveness and to correct deficiencies through feedback, from experiences with periodic drills

by the Office of Inspection and Enforcement during its prelicensing and routine inspections.

2.2.4.3 Anatomy of emergency planning evaluations by the Industrial Security and Emergency Planning Branch

Evaluation of emergency planning information submitted by applicants in their safety analysis reports is performed by the staff of the Industrial Security and Emergency Planning Branch (ISEPB) in accordance with Standard Review Plan, Section 13.3, "Emergency Planning." The reviewer develops familiarity with the proposed site at the commencement of the evaluation process by examining the relevant sections of the PSAR, particularly Chapter 1, "Introduction and General Description of Plant," Chapter 2, "Site Characteristics," and Chapter 15, "Accident Analysis" for information on the exclusion area, low population zone, demography, and land use factors as they relate to proposed plant design and on the calculated dose consequences of design basis accidents postulated by the applicant. This information is sometimes supplemented by the use of U.S. Geological Survey grid maps and personal visits to the site by the reviewer.

At the PSAR stage, the applicant's information on emergency planning is considered satisfactory if it complies with the following acceptance criteria:

"1) If it conforms to the requirements of 10 CFR Part 50, Appendix E, Part II;

2) If the emergency planning information, submitted in accordance with Section 13.3 of Revision 2 of the "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," is consistent with facility design features, analyses of postulated accidents, and characteristics of the proposed site location; and

3) If it provides reasonable assurance that appropriate protective measures can be taken in the event of a serious accident within and beyond the site boundary."[33]

ISEPB considers that there is "reasonable assurance" of emergency preparedness if preliminary planning and analysis indicate that emergency plans can be designed to meet, at minimum, the following objectives based upon calculated radiological dose consequences of an airborne release following the most serious design basis accident:

"1) Completion of evacuation of persons within the exclusion area within two hours from the onset of release. In this connection, ISEPB considers that the required assurance cannot be given if non-plant related activities (e.g., recreational activities) are permitted anywhere within the exclusion area where siting dose guidelines of 10 CFR Part 100 might be reached in less than two hours, as shown by calculation.

2) Completion of evacuation of persons within 45° sectors of the environs beyond the exclusion radius boundary, within two hours from the onset of release, or within the times calculated as a function of distance for a potential dose to reach the upper limit of the range of protective action guide levels to be adopted as warranting evacuation as a protective measure for the general public, whichever is larger at each distance considered. ISEPB considers that the minimum range of acceptable distances within which this determination is to be made is the distance at which the referenced protective action guide level is reached in 8 hours from the onset of release.

3) Completion of initial accident assessment measures, including dose projection, and notification to offsite authorities within fifteen minutes or within the calculated times at which the dose at the exclusion radius would reach the lower limit of the range of protective action guide levels to be adopted (for evacuation), whichever is larger."[33]

Paragraph 2) above focuses on the quality of the utilities' emergency preparedness for the low population zone. The language with respect to the "reference protective action guide level" is somewhat ambiguous because the Standard Review Plan was published prior to the promulgation of the Environmental Protection Agency's Protective Action Guides, and an attempt was made to allow for a certain flexibility in analysis of evacuation planning. After the publication of the EPA's Protective Action Guides in December 1975, the PAG criteria of 1 to 5 rems whole body and 5 to 25 rems thyroid were adopted by the Regulatory Staff at ISEPB for purposes of site evaluation and evacuation analysis.[22,34] In the determination of emergency preparedness relative to site characteristics, the applicant's specified low population zone is compared with the 8 hour terminus of projected dose consequences of the most serious design basis accident referenced by the time-distance plots submitted by the applicant. The larger resulting distance will be used to evaluate the utilities emergency preparedness in the low population zone based on EPA's Protective Action Guides.[35] Based on this analysis, the acceptability of the applicant's definition of the low population zone is transmitted to the Accident Analysis Branch at the conclusion of the PSAR review. While the NRC has no jurisdiction over the conduct of offsite emergency protective actions, it is concerned with the capability of the licensee to assist in the implementation of protective measures in the LPZ beyond the site boundaries. In this context, paragraph 2) attempts to ensure the quality of the utilities' emergency preparedness by specifying evacuation of the LPZ to at least the 8 hour terminus of the EPA's protective action guide levels within 2 hours, or the times required to reach the upper limit of the PAGs, e.g. 5 rem whole body, 25 rem thyroid.[34] Other findings made during the PSAR review concern the credibility and adequacy of time factors for emergency responses presented by the applicant and the calculation methods and assumptions employed in dose projections.

At the FSAR stage, the review consists of a careful examination of the applicant's emergency plan. The requirements of 10 CFR Part 50, Appendix E, Parts III and IV, and the elements of emergency planning set forth in Appendix A to Standard Review Plan Section 13.3 is used as a checklist for detailed comparisons with the applicant's comprehensive emergency plan. The findings on emergency preparedness at the FSAR stage should be substantially equivalent to the following:

> "The applicant has formulated and submitted an Emergency Plan which describes the program for coping with emergencies within and beyond the site boundary. The plan includes a description of the organizational control extending from the on-site emergency organization to off-site agencies, specific emergency measures to be taken as indicated by defined accident assessment techniques including protective measures, for persons subject to potentially excessive radiological exposures, and facilities and supplies needed for coping with emergencies, including redundant communications equipment. The plan also describes arrangements made for providing necessary medical attention for persons with contaminated injuries, and provisions for maintaining an adequate

emergency preparedness posture throughout the expected lifetime of the plant through training, exercises, and drills.

The plan has been determined to be acceptably coordinated with the radiological response planning of the (State name and agency identification)."[33]

2.3 Onsite Assessment and Response

The first indication of a radiological emergency is expected to be provided by in-plant monitors. Following the alert of the onsite emergency organization, action proceeds according to explicit emergency-plan implementing procedures. Preliminary assessment of the radiological incident is carried out by the staff at the onsite emergency operations center which is usually the control room. Assessment may include the following:

1. Surveillance of control room instruments and emergency control center, radiological and meteorological monitors.
2. Surveillance of containment integrity.
3. In-plant radiological surveys.
4. Site and site boundary surveys.
5. Calculation of projected doses.

At this point, offsite support organizations such as the licensee's headquarters emergency team and local emergency response agencies, are notified. Contact with offsite authorities is often established as a matter of procedure in advance of any immediate necessity for offsite protective measures. Initial communication will contain specific data in a pre-planned format to indicate whether immediate response is required.

Onsite emergency responses include corrective actions directed at mitigating the source of the problem, and protective measures instituted to minimize exposure to radioactivity. Corrective actions include fire control, repair, and damage control. Protective actions, which are keyed to radiation levels (based on instrument readings) in the emergency plan implementation procedures, may involve sheltering and evacuation of the population-at-risk, personnel accountability, and contamination control measures. The effectiveness of protective measures will be a function of prior onsite emergency planning, provision of adequate protective facilities, proper designation of evacuation routes and assembly areas, existence of a system for warning individuals within the site boundary of imminent threats and hazards, and arrangements made for first aid and medical care of injured and contaminated persons.

Throughout an emergency, protective activities will be modified by the continuous assessment of the plant system status as well as by offsite monitoring of the radioactive plume and effluent releases. Since radiation hazards are not really observable, it is important to have reliable instrumentation with adequate range and with durability to withstand the mechanical stresses, pressures, temperatures, humidities, and radiation fields likely to be encountered under emergency conditions.[28] Reactor emergency instrumentation should be able to accomplish the following tasks:[37]

1) liquid and gaseous radiological effluent monitoring
2) determination of magnitude and direction of the plume based on radiological and meteorological data, and
3) ambient dose rate measurement in the containment vessel and building

Recently, the Advisory Committee on Reactor Safety expressed concern that, although all nuclear power plants have useful emergency instruments of one or more types, few plants are equipped with instruments of a sufficient variety and range of applicability for dealing with the spectrum of possible accidents.[38] It cannot be assumed that instrumentation and laboratory facilities used for routine environmental monitoring and bioassay will be capable of measuring large releases or handling heavily contaminated supplies.[28] The necessary range for emergency radiological instrumentation should be as great as seven orders of magnitude above the top range of routine instrumentation.[39] Possible detection range requirements are shown in Table 2-2.

According to a recent series of studies on emergency instrumentation, current instrumentation capabilities at all reactor sites seem to be deficient to some degree in design, response range, installation, or calibration.[37] Problems which require attention are: development of emergency instrumentation evaluation criteria, the design of instrumentation that meets criteria (especially plume detection systems), and development of calibration and test criteria.[37]

Table 2-2 DETECTION RANGE REQUIREMENTS - REACTOR FACILITIES

AIR MONITORS	DETECTION LEVELS (CURIES PER cm^3)					
	NOBLE GASES		HALOGENS		PARTICULATES	
	MIN	MAX	MIN	MAX	MIN	MAX
CONTAINMENT CELL MONITOR	10^{9}	10^{-2}	10^{-10}	10^{-3}	10^{-10}	10^{-3}
STACK MONITOR	10^{9}	10^{-2}	10^{-10}	10^{-3}	10^{-10}	10^{-3}
ENVIRONS MONITOR			10^{-13}	10^{-8}	10^{-12}	10^{-7}

	DETECTION LEVELS
PLUME DETECTOR	10^{-2} TO 10^{3} Ci/meter
LIQUID MONITOR	10^{-9} TO 10^{-4} Ci/cm^3

AMBIENT RADIATION MONITOR	DETECTION LEVELS	
	GAMMA (R/HR)	BETA (RAD/HR)
CONTAINMENT VESSEL	1 TO 10^{6}	10 TO 10^{6}
REACTOR BUILDING	10^{-2} TO 10^{4}	10^{-2} TO 10^{4}
ENVIRONS	10^{-2} TO 10^{4}	10^{-2} TO 10^{4}

Source: Selby, J. "Emergency Surveillance - Immediate Evaluation". Presented at a Seminar on Planning for Nuclear Emergencies Harvard School of Public Health May 17-21 1976.

3. CURRENT FEDERAL ACTIVITIES TO ASSIST STATES AND LOCAL GOVERNMENTS IN RADIOLOGICAL EMERGENCY RESPONSE PLANNING

3.1 Federal Register Notice on "Radiological Incident Emergency Response Planning: Fixed Facilities and Transportation"

In December 1975, the Federal Preparedness Agency issued a Federal Register Notice on "Radiological Incident Emergency Response Planning: Fixed Facilities and Transportation," which set forth the responsibilities of federal agencies in radiological emergency preparedness. The Notice assigned to the Nuclear Regulatory Commission the role of the lead agency with the following functions:

"1. Issuance of guidance to other Federal agencies concerning their responsibilities and authorities in radiological incident emergency response planning and in providing planning assistance to State and local governments.

2. Development and promulgation of guidance to State and local governments in coordination with other Federal agencies for the preparation of radiological emergency response plans.

3. Review and concurrence in such plans. (Proper correlation among State, local government, licensee, and national plans is an element of this review.)

4. Determination of the accident potential at each licensed fixed nuclear facility.

5. Issuance of guidance for establishment of effective systems of emergency radiation detection and measurement."[40]

The roles of other federal agencies in radiological incident emergency response planning, training, and other assistance activities under the provisions of the Notice is presented in Table 3-1.

TABLE 3-1 RESPONSIBILITIES OF FEDERAL AGENCIES IN RADIOLOGICAL INCIDENT EMERGENCY RESPONSE PLANNING, TRAINING AND OTHER ASSISTANCE ACTIVITIES

Lead Agency	Functions	Supporting Agencies	Functions
NRC	* Issues guidance to other federal agencies related to national level planning and their responsibilities and authorities in providing planning assistance to state and local governments.	FPA (OP, GSA)	-Exercises general oversight of federal agency activities -Reviews and endorses NRC guidance to other federal agencies and to state and local governments -Assists in resolving federal interagency or federal-state problems -Encourages states to develop emergency response plans -Assists NRC and DOT to develop priorities for providing planning assistance to state and local governments
	* Develops and promulgates guidance to State and local governments in coordination with other Federal agencies for preparation of radiological emergency response plans.	EPA	-Establishes Protective Actions Guides for use by states -Recommends appropriate protective actions which can be taken by governmental authorities in the event of a radiological incident at fixed nuclear facilities or in the transportation of radioactive materials -Provides assistance to state agencies according to NRC guidance
	* Review and concurrence in State Plans.	ERDA	-Cooperates with other federal agencies in the development and implementation of assistance to state and local governments -Provides guidance to state and local governments on the development of those portions of their radiological response plans which are related to ERDA-managed and operated facilities and ERDA-controlled radioactive materials in transit.
		DHEW	-Assists states in developing plans for prevention of adverse effects from radiation exposure -Develops recommendations for evaluating and preventing radioactive contamination of food, drugs, and animal feed -Provides guidance on emergency dose limits for ambulance, hospital, and health care personnel
		DOT	-Cooperates with NRC and other federal agencies in providing guidelines and assisting state and local agencies in development of emergency plans for transportation incidents involving radioactive materials
		DPCA	-Assists state and local authorities in planning emergency preparedness actions required to provide the mechanism for coordinating emergency operations -Issues guidance on use of civil defense resources
		FDAA	-Provides guidance to state and local authorities on disaster preparedness -Assisted by DCPA, oversees mechanism for coordinating emergency operations
	* Determines accident potential for each licensed nuclear facility.	ERDA	-Determines accident potential at each non-license ERDA fixed nuclear facility
	* Issues guidance for establishment of effective systems of emergency radiation detection and measurement.	EPA	-Cooperates with NRC in the establishment of guidelines on emergency radiation-detection and measurement systems
		ERDA	-Assists other agencies in the development and establishment of guidelines on effective systems of emergency radiation detection and measurement, including instrumentation, for State and local governments, in cooperation with NRC
		DHEW	-Establishes and issues guidelines for radiation detection and measurement systems for use by ambulance services and hospital emergency departments, in cooperation with NRC

Source: Radiological Incident Emergency Response Planning: Fixed Facilities and Transportation. Interagency Responsibilities. Federal Preparedness Agency, General Services Administration Notice, Federal Register, Vol. 40, No. 248, December 24, 1975.

Abbreviations: FPA - Federal Preparedness Agency; EPA - Environmental Protection Agency; ERDA - Energy Research and Development Administration; DHEW - Department of Health, Education and Welfare; DOT - Department of Transportation; DPCA - Defense Civil Preparedness Agency; FDAA - Federal Disaster Assistance Administration of the Department of Housing and Urban Development.

3.2 A Brief Report on Current Activities

3.2.1 Role of the NRC as the Lead Agency

Federal interagency cooperation for radiological emergency planning assistance to states and local government predates the Federal Register Notice of December 1975. The interagency effort originated with an earlier "Notice of Interagency Responsibilities" published by the Federal Office of Emergency Preparedness, predecessor to the present Federal Preparedness Agency, on January 24, 1973.[41] That notice was reissued in 1975 primarily to expand it to include emergency planning for transportation accidents in addition to fixed facility emergency planning. In December 1974, the Atomic Energy Commission, Office of Government Liaison Regulation (now NRC, Office of State Programs), in cooperation with other Federal agencies, published the "Guide and Checklist for Development and Evaluation of State and Local Government Radiological Emergency Response Plans in Support of Fixed Nuclear Facilities (WASH-1293)."[42] The "Guide and Checklist," (which has been reissued as NUREG-75/111) contains about 150 elements that the Federal agencies considered essential to a radiological emergency plan. It is used as a set of standards by the NRC Office of State Programs in its review of State emergency plans, and is also designed to facilitate evaluation of emergency plans by State and local governments.[43]

Some confusion has arisen over the review and concurrence function assigned to the NRC by the Federal Register Notice. The concurrence envisioned by the Federal Register Notice (40 FR 59494) is not part of the licensing process — the NRC does not have any statutory authority to require the development of, or to determine the adequacy of, State and local government emergency plans.* Rather, the review is usually accomplished at the request of the States concerned, and concurrence represents the NRC's belief that the State plan has met all of the elements set forth in NUREG 75/111. At present, the NRC has not yet concurred in any State plan because no State has met all of the criteria set forth in the Guide and Checklist. Some States have protested that although total commitment to the elements in the Guide and Checklist may be an ideal to aim for, some of the elements, e.g. recovery and reentry, are not

*In a recent speech before the Atomic Industrial Forum, Robert DeFayette of the Nuclear Regulatory Commission's Office of State Programs indicated that the absence of concurrence with a specific plan should not be equated with a finding of inadequacy.[45]

really necessary to mitigate the immediate consequences of an accident and should be excluded. The NRC is now in the process of re-examining the guidelines listed in the Guide and Checklist with a view toward selecting only the essential elements as requirements for its concurrence. It has also requested National Conference of Radiation Control Program Directors to assist in this effort by providing a list of what the States believe to be the essential elements. The NRC hopes to reissue this guidance document in early 1977.*[44]

To coordinate the activities of the various Federal agencies, a "Federal Interagency Central Coordinating Committee on Radiological Emergency Planning" has been established. This Committee is chaired by the Director of the Office of State Programs, NRC. It is composed of a representative from each of the seven supporting agencies. Two Task Forces have been established by the Committee. The "Federal Interagency Task Force on Training and Exercises," chaired by a representative of the Defense Civil Preparedness Agency, has developed a training program in Radiological Emergency Response Planning at the Defense Civil Preparedness Agency Staff College at Battle Creek, Michigan.[43] The course is based on the Guide and Checklist published by the NRC and is designed to acquaint State and local emergency planning personnel with the elements of radiological emergency response planning. The NRC has also contracted with Reynolds Electrical & Engineering Company to develop and initiate a course oriented to State response teams, e.g. rad-health personnel.[46] The second task force is the "Federal Interagency Task Force on Offsite Emergency Instrumentation for Nuclear Incidents — Fixed Facilities." It is chaired by a representative of the Environmental Protection Agency and is scheduled to issue guidance for offsite emergency instrumentation in the near future.[43]

The Interagency Task Force on Training and Exercise works with the Federal Interagency Field Training Cadre; it provides field assistance to State and local governments in developing and improving their radiological emergency response plans[47] (see figure 3-1). The "Cadre" is composed of a group of Headquarters and regional personnel from various Federal agencies involved. At the request of a State, Cadre teams observe field emergency response exercises conducted by State and local governments. Their evaluations are used as a basis for improving the emergency plans. Recently, a recommendation was made by the General Accounting Office in a report entitled "Stronger Federal Assistance to States Needed for Radiation Emergency Response Planning"[48] that

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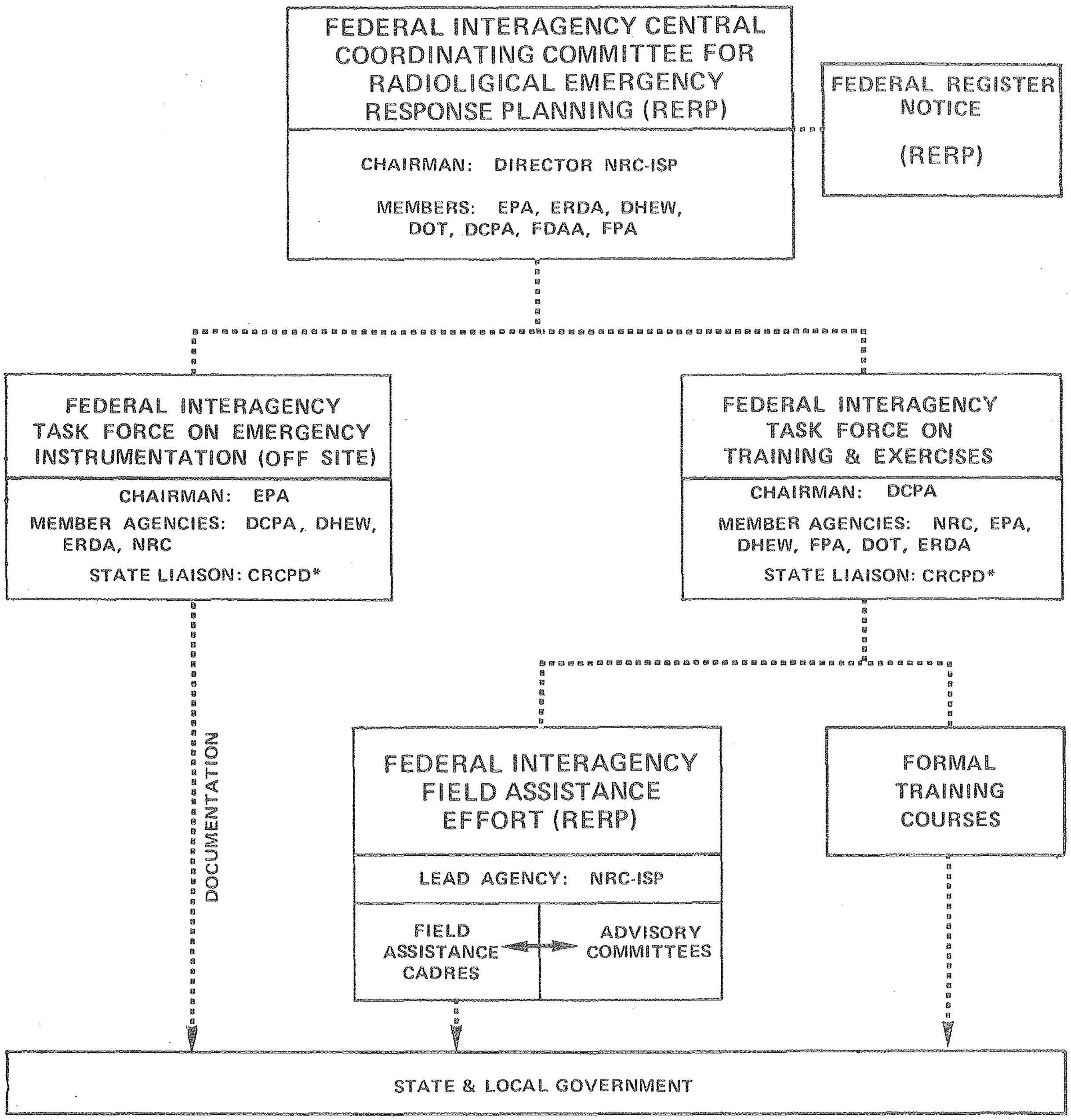
*A supplement to the Guide and Checklist has been issued which limits the number of essential elements in an emergency plan. See Supplement No. 1 to NUREG 75/111, March 15, 1977.



*CONFERENCE OF RADIATION CONTROL PROGRAM DIRECTORS

Figure 3-1 RELATIONSHIP OF FIELD ASSISTANCE CADRES TO THE OVERALL FEDERAL INTERAGENCY EFFORT IN SUPPORT OF RADIOLOGICAL EMERGENCY RESPONSE ASSISTANCE TO STATE & LOCAL GOVERNMENTS

Source: U.S. Nuclear Regulatory Commission. Office of International and State Programs. Radiological Emergency Response Planning - Handbook for Federal Assistance to State and Local Governments, June, 1976.

these Cadre teams should specifically include participation by full-time regional representatives of the NRC's Office of State Programs who are familiar with the licensee's emergency plans under review, and should involve representatives from ERDA's regional Operations Offices who are familiar with the radiologial assistance program. This recommendation is presently under consideration by the NRC.

A question often encountered by federal interagency Assistance Teams at the State and local level is,"What type of accident should be planned for?" The Advisory Committee on Reactor Safeguards has also indicated to the NRC the advisability of developing a series of hypothetical accident scenarios for drills and for testing emergency plans.[38] In an attempt to arrive at some standardization of accident scenarios, the NRC has joined the Environmental Protection Agency in a task force to study this problem; the Task Force plans to offer recommendations early in 1977.[2] The NRC has also initiated a program to

accident scenarios. The object is to provide guidance to State and local governments in their selection of accident scenarios upon which to test emergency plans. This program is scheduled to be completed in late 1977 for fixed nuclear facilities.[45]

3.2.2 EPA: The Manual of Protective Action Guides and Protective Actions for Nuclear Accidents

Protective Action Guides for exposure to airborne radioactive noble gases and iodines were issued to the public in September 1975 in a Manual of Protective Action Guides and Protective Actions for Nuclear Accidents. Since then, the Industrial Security and Emergency Planning Branch of the NRC has utilized the guides informally as reference criteria in the evaluation of utilities' emergency plans with respect to the determination of the low population zone and for compliance with Appendix E, 10 CFR Part 50 evacuation criteria (see discussion *supra* in Section 2.2.4.3). In issuing the "Guide for Exposure to Airborne Radioactive Materials," the EPA took into consideration the fact that exposure to cloud or plume passage is the exposure mode which allows the least time for adopting viable protective measures, and therefore deserves the highest priority and poses the greatest need for operational preplanning.[34] Further guidance, when developed, will include protective action guides for particulates in air, contaminated foodstuffs and water, and radioactive material deposited on property or equipment.[49] It should be noted that the present Guide is not yet "official", and before it is published as a regulation, the Guide must be subjected to a review and comment process. However, both the EPA and the NRC support adoption of the Guides by State and local emergency planning agencies as the uniform reference criteria for protective actions[22] (but see Section 4.2 for current California criteria).

Protective Action Guides specify the projected doses which would be received by individuals in the population at risk from a contaminating event if no protective actions were taken. The Protective Action Guide for Airborne Release from Fixed Nuclear Facilities provides for the following protective action levels:[34,50]

Population at Risk	Projected Dose (rem) Whole Body	Thyroid
Nonessential personnel (a)	1 - 5	5 - 25
Emergency workers	25	125
Lifesaving activities	75	(b)

(a) When ranges are shown, the lowest should be used if there are no major local constraints in providing protection at that level, especially to sensitive populations. Local constraints may make lower values impractical to use, but in no case should the higher value be exceeded in determining the need for protective action.

(b) No specific upper limit is given for thyroid exposure, since in the extreme case complete surgical or radiological thyroid loss might be an acceptable penalty for a life saved. However, loss should not be necessary if respirators and/or thyroid protection for rescue personnel are available as the result of adequate planning.

Although the PAGs for cloud or plume passage are intended to set criteria for protection against acute effects of radiation exposure, delayed effects are assumed to occur at every exposure level above zero.[51] It should be noted that PAGs under no circumstances imply an acceptable dose. PAGs balance risks and costs against the benefits obtained from protective action, assuming that the projected threat will transpire. The responses made in a given situation should be based on PAGs and the spectrum of possible protective actions available at the time.[34,50]

For whole body exposure to the public, the 5 rem projected dose was selected to avoid acute effects in the population and the exposure of fetuses to levels of radiation at which abortion is generally deemed advisable.[51]

The 5 rem criterion also allows for the probability that exposure dose estimation in an emergency situation is likely to be in error by a factor of two; it represents one half of the projected dose (10 rems) that would theoretically begin to produce acute effects. The PAG for projected thyroid exposure at a range of 5 to 25 rem was selected on the basis that this is the dose which would produce approximately the same number of malignancies as 1 to 5 rem of whole body exposure. Using the BEIR Report data, the risk of thyroid cancer per rem is estimated to be about one fifth of the total cancer risk following whole body exposure; consequently, the levels recommended for whole body exposure were multiplied by 5 to obtain an equivalent thyroid exposure.[51]

The protective measures considered by the EPA to be appropriate responses to avoid whole body and thyroid dose from exposure to a gaseous plume include the following:[50]

1. Evacuation — effective for protection against any radiation exposure.
2. Sheltering — probably ineffective against continuous gaseous releases after about two hours in the absence of shelters with ventilation control.
3. Prophylaxis — effective blocking of thyroid possible, but some contraindication because of potential side effects.
4. Respiratory protection — effective to the extent that appropriate apparatus can be provided.
5. Control access — effective in preventing additional members of the public from being significantly exposed.

Table 3-2 shows the recommended protective actions based on the EPA Protective Action Guides for Exposure from Airborne Releases. As a result of studies conducted by EPA in cooperation with other Federal Agencies on the risks and costs of various protective actions, the EPA has concluded that evacuation is the most effective means of minimizing health risks for the general population.[52] Recently, the EPA has received the results of a contract study on the effects of sheltering as a protective measure. The study consists of two reports: one evaluates sheltering as a protective measure, the other then compares sheltering with evacuation.[53,54] The thrust of the study is that sheltering is a good alternative to evacuation for exposure periods of less than 3 or 4

Table 3-2 RECOMMENDED PROTECTIVE ACTIONS TO AVOID WHOLE BODY AND THYROID DOSE FROM EXPOSURE TO A GASEOUS PLUME

Projected Dose (Rem) to the Population	Recommended Actions[a]	Comments
Whole body <1 Thyroid <5	·No protective action required. ·State may issue an advisory to seek shelter and await further instructions or to voluntarily evacuate. ·Monitor environmental radiation levels.	Previously recommended protective actions may be reconsidered or terminated.
Whole body 1 to <5 Thyroid 5 to <25	·Seek shelter and wait further instructions. ·Consider evacuation particularly for children and pregnant women. ·Monitor environmental radiation levels. ·Control access.	
Whole body 5 and above Thyroid 25 and above	·Conduct mandatory evacuation of populations in the predetermined area. ·Monitor environmental radiation levels and adjust area for mandatory evacuation based on these levels. ·Control access.	Seeking shelter would be an alternative if evacuation were not immediately possible.
Projected Dose (Rem) to Emergency Team Workers		
Whole body 25 Thyroid 125	·Control exposure of emergency team members to these levels except for lifesaving missions. (Appropriate controls for emergency workers, include time limitations, respirators, and stable iodine.)	Although respirators and stable iodine should be used where effective to control dose to emergency team workers, thyroid dose may not be a limiting factor for lifesaving missions.
Whole body 75	·Control exposure of emergency team members performing lifesaving missions to this level. (Control of time of exposure will be most effective.)	

[a] These actions are recommended for planning purposes. Protective action decisions at the time of the incident must take into consideration the impact of existing constraints.

Source: Environmental Protection Agency, Office of Radiation Programs. Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, September 1975.

hours, depending upon the type of structure. Both reports have been distributed for comment and EPA hopes to issue them as formal EPA documents at the beginning of 1977.[45]

Chapter 5 of the Manual also suggests a method for estimating projected whole body and thyroid radiation exposures on the basis of gamma-radiation exposure rates in downwind areas. It has been pointed out that such estimated exposure rates are based on certain assumptions regarding the composition of the airborne release which may not be obtained under accident conditions.[28] The EPA has not yet developed procedures to assure that the actual and expected extent and path of the radioactive plume are determined on a real time basis. However, work is in progress to develop an appendix to the Manual which discusses recommended offsite emergency radiation monitoring systems; it will include a procedure for making field measurements to determine the exact location of the centerline of the plume at various distances from the point of release.[55]

EPA is a member of the Federal Interagency Task Force on Training and Exercises and is the lead agency in developing a course for State radiological emergency response coordinators and their staffs. The Agency has also been involved in the review of state and site plans by its representatives on the Interagency Field Assistance Cadre.

3.2.3 Other Agencies

Federal Preparedness Agency (FPA). The Director of the FPA is charged by Executive Order to give policy and planning guidance to the Federal government for emergency preparedness, and to advise and assist the President by stimulating interest in emergency preparedness in the States. In this context, FPA also exercises an overview of federal agency activities under the provisions of the Federal Register Notice on Interagency Responsibilities. Recently the FPA issued a draft of a Federal Response Plan for Peacetime Nuclear Emergencies. The plan is national in scope and sets forth planning doctrine for Federal departments and agencies in response to a spectrum of non-war-related nuclear accidents/incidents.[56]

Energy Research and Development Administration (ERDA). For more than 15 years, ERDA and its predecessor, the AEC, have maintained an Aerial Radiological Measuring System (ARMS) that has successfully provided both routine and emergency surveys of environmental dose levels.[28] This system includes various types of aircraft carrying specialized monitoring equipment which can be used to detect radioactive material on the ground or in a cloud, and to determine plume size, radioactivity level, and direction of the dispersion. Data collected can be transmitted to an ERDA emergency response center.[57] A proposal to utilize KC-135 jet aircraft as rapid ARMS aircraft is currently under consideration by NRC for assessment of airborne releases in cases of emergency.[46]

At the Lawrence Livermore Laboratory, ERDA is developing a sophisticated computer model to provide nuclear facilities with real-time predictions of the health hazards that might result from a release of radionuclides. The system is called the Atmospheric Release Advisory Capability (ARAC). Information on a particular release is coupled with real-time meteorological data and suitable transport and dispersion codes to provide estimates of the dose at any time at points downwind of the movement of a radioactive plume.[58] This capability will assist the facility operator to provide better advice to offsite authorities on ameliorative actions such as evacuation. During the next three years, ERDA intends to implement ARAC service for six of its nuclear facilities. Implementation involves installing a central facility at LLL for acquiring, processing, and communicating data, linking this facility with national and global weather services, and installing local data-acquisition, assessment, and communication facilities at the six sites.[59] At some future time the system will be available to commercial power plants. However, questions of equipment and operating costs to be paid by a non-ERDA user will need to be resolved before the system can be extended to other organizations.[57]

Department of Health, Education, and Welfare (DHEW). A planning guide for emergency health and medical services issued in 1973 has been revised to incorporate specific provisions for planning for nuclear facility incidents. Requirements of the AEC as expressed in the Regulatory Guides are incorporated in the references to the Guide. In cooperation with EPA, DHEW is developing guidance on contaminated foodstuffs and water. DHEW is scheduled to issue a statement of policy on the administration of potassium iodine in emergency response situations as well as detailed guidelines on how the drug should be administered.[61]

Department of Transportation (DOT). NRC contracted with the Western Interstate Nuclear Board to develop preliminary transportation accident guidance and an "Example Plan" for States. The initial study was completed in 1975. Recently, NRC has signed a contract with the Sandia Corporation to draft a guidance document for transportation accidents involving radioactive materials similar to the Guide and Checklist for fixed facilities. The document will be available in one to two years.[45]

Defense Civil Preparedness Agency (DCPA). In fulfillment of their responsibilities under the provisions of the Federal Register Notice, DCPA drafted a new chapter entitled "Nuclear Facility Accidents" for inclusion in the DCPA Disaster Operations Handbook. The new chapter is a companion to NRC's Guide and Checklist for Development and Evaluation of State and Local Radiological Emergency Response Plans. DCPA has also awarded a contract to Brookhaven National Laboratory to assist in application of standard DCPA instruments to the special radiological problems associated with fixed facility accidents. Future work by Brookhaven will include the incorporation of detection and alarm systems into training courses proposed for local policy and fire personnel as well as field testing these courses. Another project is the application of DCPA warning systems, such as the DCPA National Warning System (NAWAS), which is a hard-wired, private, dedicated telephone system for nuclear facilities. A proposal has also been made to test a low-frequency radio warning system (DIDS) in conjunction with a nuclear power plant accident. DCPA also intends to apply its Onsite Assistance (OSA) program to improving local preparedness around nuclear facilities. Cooperation with ANSI, AEC, NBS, and private industry will continue in the development of standards for nuclear instrumentation.[62]

Federal Disaster Assistance Administration (FDAA). Under the authority of the Disaster Relief Act of 1974 (42 U.S.C. 5121), FDAA can grant States up to $250,000 to develop disaster preparedness plans, programs, and capabilities. However, in mid-1974, FDAA reversed its position of encouraging States to develop radiation emergency plans because it did not consider such plans to be a top priority under the grant program. The current position of the FDAA is that States must concentrate first on basic disaster planning needs and those specific disasters to which they are most vulnerable. Assuming that a State's basic disaster preparedness needs have been adequately addressed and there are grant funds remaining, FDAA regulations permit the State to amend its grant work plant to provide for radiation emergency response planning and other specific disaster contingencies.[48]

3.3 ERDA: The Radiological Assistance Program and the Interagency Radiological Assistance Plan

In 1957, the Atomic Energy Commission established the Radiological Assistance Program to provide technical assistance to regularly constituted authorities at the scene of an emergency involving radioactive materials. This program was expanded to include the Interagency Radiological Assistance Plan (IRAP) in 1961. IRAP was developed to provide a means to coordinate Federal radiological emergency response activities with those of State and local agencies. In this regard, it provides operational support in the event of an emergency and complements the Federal interagency effort to provide radiological planning assistance to the States. The AEC, as a signatory agency to IRAP, was assigned the responsibility for overall implementation of the Plan. ERDA has assumed this function as successor to AEC. Present signatory agencies to IRAP include: Defense Civil Preparedness Agency; Department of Agriculture; Department of Commerce; Department of Defense; Department of Health, Education and Welfare; Department of Labor; Department of Transportation; the Energy Research and Development Administration; Environmental Protection Agency; Interstate Commerce Commission; National Aeronautics and Space Administration; and the Nuclear Regulatory Commission.

In the event of an emergency, signatory agencies are responsible for making their resources available on request by ERDA, unless such resources are involved in essential operations related to the agency's primary responsibilities and for carrying out support functions within the scope of their jurisdictions.[63]

<u>The Radiological Assistance Program (RAP)</u> is implemented through eight ERDA Regional Coordinating Offices. Each Office is responsible for maintaining a radiological assistance plan for the region in which it is located. By contacting any one of the Offices, a caller (any person or organization) can request assistance and obtain access to the combined resources and capabilities of ERDA and its contractors, as well as those of the other signator agencies to IRAP.[64] Assistance may be provided in various ways. For minor accidents, information may be given by telephone, or the caller may be referred to nearby

persons or agencies. If the incident warrants it, radiological emergency assistance teams may be dispatched to the scene of an accident. Teams may include a team leader, radiation monitors, a medical officer, a public information officer, and other specialists as required.[64] In those incidents where an organization other than ERDA has primary jurisdiction or responsibility, ERDA radiological assistance is limited to advice and emergency action essential for the control of immediate hazards to public health and safety and is terminated as soon as the emergency situation is under control.[57]. Most incidents that Offices have responded to are transportation related; none of the incidents, however, have resulted in a known radiation injury to a member of the public.[64]

State or local organizations can also obtain assistance in developing their radiological emergency plans through the coordinating Office in their region. Assistance may involve establishing lines of communication, orientation on ERDA radiological assistance plans and procedures, advice and guidance on how to obtain ERDA radiological assistance, organization and training of radiological assistance teams, consultation and guidance on the development of plans and procedures, and arrangements for the integration of other radiological emergency capabilities with the Federal System.[57] ERDA has also issued a bulletin entitled "Emergency Action Guidelines for Incidents Involving Radioactive Material" (revised, January 1975).

California is within the jurisdiction of Region 7 Regional Coordinating Office, which also directs the emergency radiological assistance program for the States of Nevada and Hawaii. There are four Radiological Assistance Teams in California and one in Nevada, comprised of specialists from ERDA and ERDA contractor organizations.[57] The ERDA Region 7 contractors participating in the Radiological Assistance Program are:

Lawrence Berkeley Laboratory — Team No. 1
Atomics International — Team No. 2
General Atomics — Team No. 3
Reynolds Electric & Engineering (ERDA-Nevada) — Team No. 4
Edgerton, Germeshausen, & Grier (ERDA-Nevada) — Team No. 4
Lawrence Livermore Laboratory — Team No. 5

Members of the teams have engaged in exercises conducted at the Rancho Seco Nuclear Generating Station of the Sacramento Municipal Utilities District and at the commercial nuclear facilities at Humboldt Bay and San Onofre. In addition, ERDA emergency coordinators have participated in:

- The State Office of Emergency Services' "Peacetime Radiation Incident Training" courses; speaking on the RAP program annually since the course inception in 1972.

- The State Radiological Health's "Radiological Assistance Workshop," developing and moderating the accident scenario session held in 1975, and

- The Oakland Police Department Emergency Services' "Radiological Accident Response" course.[57]

4. RADIOLOGICAL EMERGENCY RESPONSE PLANNING IN CALIFORNIA

4.1 The California Nuclear Power Plant Emergency Response Plan

California's involvement with radiation control began in September of 1962, when the State entered into an agreement with the Atomic Energy Commission to assume regulation of "byproduct materials, source materials, and special nuclear materials" under the States Agreement Program.[65] As a part of the agreement, California consented to the maintenance of a program for the control of radiation hazards adequate to protect the public health and safety of the citizens of the State.[66] The State Department of Public Health, Bureau of Radiological Health, was appointed as the agency to assume regulatory responsibility.

Following the AEC agreement, a Memorandum of Understanding was executed between the State Department of Health and the Office of Emergency Services. The agreement in essence designated OES and local Civil Defense/Emergency Service offices as agents of the Department of Health to contain and control the scene of an incident until their personnel arrived on the scene.[67] Independent activities by the Office of Emergency Services involving radiological emergency planning for nuclear power plants began shortly after the Atomic Energy Commission promulgated 10 CFR Part 50, Appendix E, requiring reactor owners to coordinate their emergency plans with those of local governments.[68] Subsequently, on January 25, 1974, OES and DOH were jointly asked by the State Assembly Subcommittee on State Energy Policy to develop a "Nuclear Power Plant Emergency Response Paln," and to work with appropriate counties to update their plans for nuclear reactor emergencies.[65]

The Nuclear Power Plan Emergency Response Plan was completed in July 1975[69] and adopted as a part of the California State Emergency Plan. The new Plan identified the Office of Emergency Services as the Designated State Authority (DSA), which has executive authority and responsibility for general planning and coordination of state response to radiological incidents. The Office of Emergency Services is also responsible for the coordination, review and approval of emergency response plans prepared by other State agencies and local jurisdictions. OES is assisted by the Department of Health, Radiological Health Section, which provides technical support for its field activities. The support functions assigned to other State agencies by the Response Plan are described in Table 4-1. Standard operating procedures have been developed

Table 4-1 STATE GOVERNMENT ASSIGNMENTS

ORGANIZATION	FUNCTIONS										
	Planning	Training, Exercises	Alerting	Monitoring	Evacuation	Medical	Health	Welfare	Public Information	Recovery	Other
OFFICE OF EMERGENCY SERVICES	✓	✓	✓	✓					✓		✓
HEALTH	✓	✓		✓		✓	✓			✓	✓
MILITARY	✓	✓			✓	✓		✓			
CALIFORNIA HIGHWAY PATROL	✓	✓		✓	✓						
CALTRANS	✓	✓		✓	✓					✓	
FISH & GAME	✓	✓		✓						✓	
PARKS & RECREATION	✓	✓		✓	✓			✓			✓
CONSERVATION	✓	✓		✓				✓			✓

Source: California Office of Emergency Services, Radiological Section, Department of Health, Radiologic Health Section. Nuclear Power Plant Emergency Response Plan, July, 1976.

by OES, Radiologic Health Section, and other responsible State agencies.

The concept of operations adopted by the Nuclear Power Plant Emergency Response Plan emphasizes that preparation for coping with a nuclear power plant accident is a cooperative effort of the plant operator, local, state, and federal governments. Accidents are assessed according to the type of releases involved (airborne, liquid), the magnitude of the release, and whether it involves onsite effects only or offsite effects. A flow chart (figure 4-1) illustrates the chain of events from a hypothetical accident. In the event of an accident involving offsite effects, the local government warns the people in the zone which may become affected and instructs them to take appropriate countermeasures, including preparations to evacuate if necessary. An on-scene Emergency Operations Center (EOC) is established, with representation from the plant operator, local, state, and federal governments. Communications are established between the on-scene EOC and each government EOC that is activated. The station operator provides the on-scene EOC with monitoring reports and meteorological information. Public information notices are jointly prepared by local and state authorities; information relating to on-site conditions and operations are released by the utility's public information personnel.[69]

Local governments are directed to develop a radiological response plan, and to designate a local agency (Sheriff's Office, Health Department, etc.) as the primary local response agency responsible for planning, initiating, and coordinating protective measures in the event of an incident. The local plan should specify the functions and responsibilities of supporting agencies. Each local agency so designated should prepare an operating procedure which describes in detail how its emergency assignment will be accomplished. It is the responsibility of the local primary response agency to coordinate the procedures and keep them updated.

The State Response Plan also encourages local primary response agencies to prepare evacuation plans, and very detailed guidance is provided.[69] Local evacuation plans must:

1) Be developed in coordination with OES, local California Highway Patrol commanders, and other jurisdictions that may be involved in the evacuation and/or reception and in the decisions as to which evacuation routes will be used.

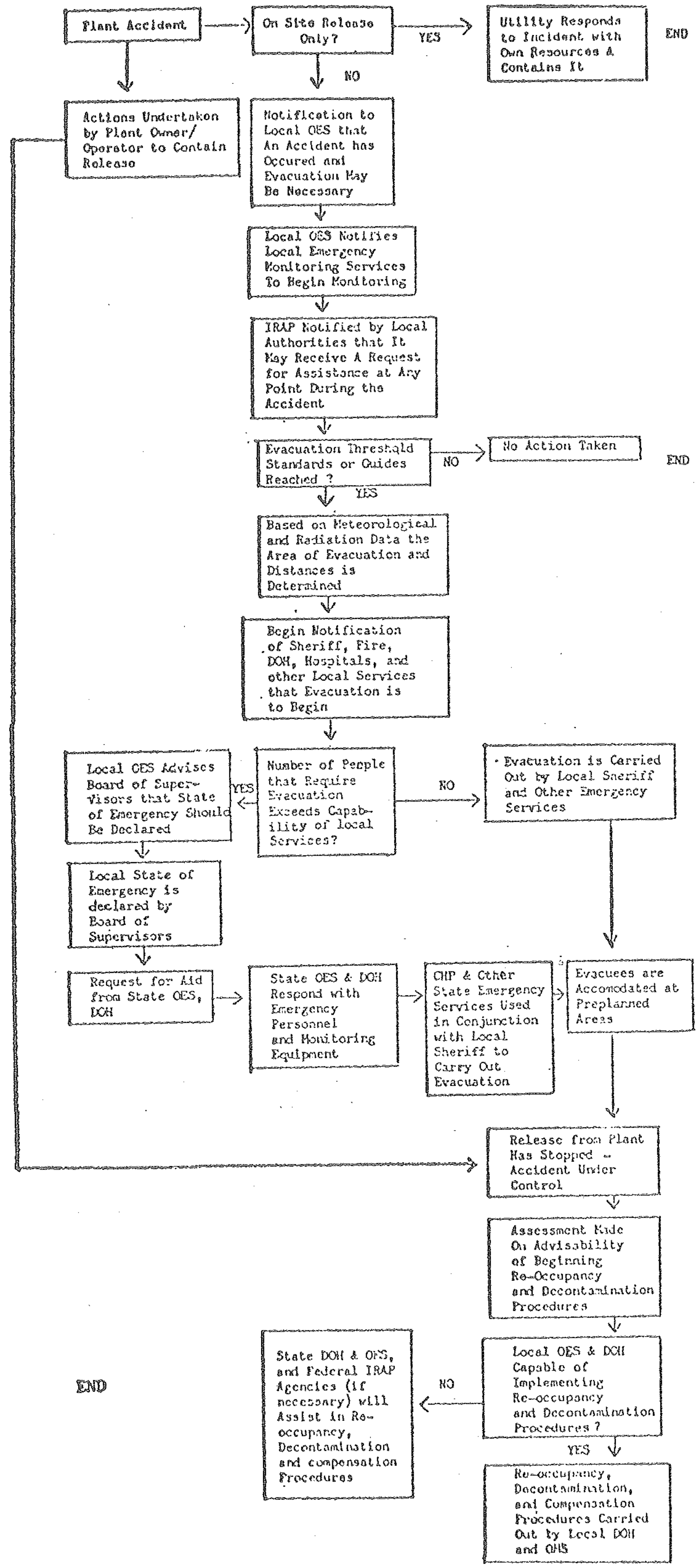


Figure 4-1 FLOW CHART ILLUSTRATING CHAIN OF EVENTS FROM A HYPOTHETICAL ACCIDENT.

Source: California Energy Resources Conservation and Development Commission, Facilities Siting Division. Emergency Response Planning for Nuclear Power Plant Incidents in California. August 1976.

2) Designate areas which are likely to require evacuation from radioactive contamination and identify points of safety nearby.

3) Establish primary and alternate evacuation routes.

4) Identify and make arrangements with sources of transportation for mass evacuation of both people and livestock.

5) Provide emergency crews (monitoring teams, etc.) with access to the area(s) being evacuated.

6) Provide for barricading access roads to the contaminated or exclusion area.

7) Designate evacuee assembly and departure points to expedite mass evacuation.

8) Set up procedures for orderly access to, progress along, and exit from evacuation routes.

9) Designate relocation sites for people and livestock, coordinate reception arrangements with the Red Cross, Salvation Army, and other appropriate relief and agricultural agencies.

10) Consider special needs for evacuation of school children, hospital patients, and other groups which may require specialized transportation and other attention.

11) Provide for alerting and warning to persons located in a potential evacuation area.

12) Provide for preparation and dissemination of appropriate instructions to the general public.

The decision whether or not to evacuate portions of an affected area is expected to be an early major decision for offsite authorities.* Making this decision will require radiation data supplied by the plant operator or measured by field monitors. Therefore surface monitoring teams, aerial monitoring teams, and evacuation support teams are to be dispatched to the on-scene EOC as early

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*Evacuation is not the only protective measure considered in the Nuclear Power Emergency Response Plan; Appendix B of the Plan also includes a reprint from "The Clinch Valley Study"[70] on Prophylactic Measures to Limit the Uptake of Inhaled Radioactive Materials.

as possible.[69] Later decisions to be made by emergency coordinators include the selection and scheduling of appropriate combinations of countermeasures to protect emergency workers, the population at risk, and vital resources. If local resources are insufficient to carry out these decisions, local authorities may declare a local emergency, and State mutual aid support and federal (IRAP) assistance will be available.

4.2 Role of the OES as the Designated State Authority

At present, the Office of Emergency Services does not mandate the preparation of radiological emergency response plans at the local level because the passage of Senate Bill 90 (1973) requires that any State mandated program must be supported with State funds to the local government. However, if the local authorities have established a "Local Disaster Council" under the State Emergency Services Act (1970), they are required to prepare plans to meet any contingency affecting the health and safety of their citizens.* Under the California Nuclear Power Plant Emergency Response Plan, OES is responsible for review of all State radiological emergency plans and will assist local governments with radiological planning once it is commenced. The OES task is to assure that a smooth flow of information exists and that the response capabilities of the appropriate county agencies are consistent with the utilities' emergency plans. Local emergency plans are sometimes developed in a joint effort with OES — comments and ideas are exchanged between the local and State planners involved long before the final plan is submitted for a formal review.[72]

Section 30263 of the California Administrative Code, Title 17, limits the permissible levels of radiation in uncontrolled areas to 500 millirem in any one year. OES has adopted this criterion in the State Nuclear Power Plant Emergency Response Plan as the basis for initiating protective measures for the general population. Since Section 30268 is based on the reference criteria

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*Article 10 of the California Emergency Services Act provides that "Counties, cities and counties, and cities may create disaster councils by ordinance. A disaster council shall develop plans for meeting any condition constituting a local emergency, state of emergency, or state of war emergency; such plans shall provide for the effective mobilizationof all of the resources within the political subdivision, both public and private."[71]

stated in 10 CFR Part 20 for routine emissions, it has been observed that the application of 500 millirem as the mandatory protective action level for radiological emergencies may be overly conservative.* OES's attitude[74] is that, until the Environmental Protection Agency's Protective Action Guides (see discussion *supra* at Section 3.2.2) are completed and published as official emergency population exposure criteria, Section 30268 is the legal reference criteria to which agency action must conform.

In addition to providing technical guidance and assistance in the development and conduct of emergency exercises at the county and State level (see discussion *infra* at Section 4.3), OES has provided training to local jurisdictions through the Radiological Defense Officer and the Peacetime Civil Preparedness Agency and conducted by that Office. These courses provide basic radiological concepts, instrument use and accident response procedures that are useful for local jurisdictions in developing emergency response capabilities.[75]

From earlier involvement with Civil Defense activities in the 1960's, OES has distributed throughout California some 15,000 radiation detection kits in the hands of trained monitors — people who can read the instruments and have had training of 16 hours or more.[76] These kits are available to ground surveillance teams in the event of a radiological incident and include a Geiger counter that can measure low level gamma radiation and high energy beta, as well as a dosimeter which would measure higher levels of radiation. There are no alpha detection instruments. The kits are exchanged every two years by the OES and are periodically checked by local personnel.[76] In an emergency OES also has available aerial monitoring equipment to determine the extent of a radioactive cloud, supplemented by a direct line tied in with the Weather Bureau for information on the speed and direction of a moving plume.[76]

The State OES is connected with local emergency response agencies by dedicated communications systems and redundant communications systems such as the California Law Enforcement Teletype System and the National Warning System (NAWAS). OES's general response capability in radiological incidents is complemented by its emergency preparedness for and experience with other types of disasters, e.g. floods, earthquakes, and hurricanes.

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*It has been suggested that since, according to generally applicable standards,[73] a facility may be permitted to routinely release up to 500 millirem per year into the atmosphere, it is somewhat incongruous to require evacuation at 500 or even 501 millirem.

4.3 Local Radiological Emergency Response Plans

4.3.1 San Onofre

Unit 1 of San Onofre Generating Station went into operation in 1967. The original San Onofre Emergency Plan was prepared by Southern California Edison in 1966. Since then, it has been revised six times to reflect changes in NRC regulations, guidance, and experience gained from exercises. The present station plan is entitled "San Onofre Nuclear Generating Station Unit 1 Emergency Plan;" it was issued in February 1976. Offsite emergencies are defined as those predicted to result in an offsite dose of > 500 mrem to the whole body and/or > 5000 mrem to the thyroid.[77] Protective actions will be taken at the Station and recommendations made to offsite response agencies to begin protective actions offsite if two out of three channels of the ERMS (Emergency Radiation Monitoring System) reach the "alarm" level. There is a lower point on the ERMS (the "alert" level) at which precautionary measures are taken. Estimates of potential offsite consequences are accomplished by evaluation of ERMS instrument readings in conjunction with meteorological information and site sector maps and overlays.[77]

Coordinated plans have been developed by San Diego County,[78] Orange County, and the U.S. Marine Corps at Camp Pendleton[79] as the primary response agencies. Offsite plans include provisions for:

- Monitoring the environment to determine potential doses to the population at risk
- Evacuation of the population at risk
- Monitoring of evacuees
- Aid to affected persons
- Reentry of evacuated areas.

Standard operating procedures detailing the necessary tasks and responsibilities in the three jurisdictions have been completed.[65]

In addition to the response plans, a separate evacuation plan for the area surrounding San Onofre Nuclear Generating Station was completed in July 1975.[80] The evacuation plan takes into consideration the actions required to evacuate the State Beach adjacent to the nuclear power plant, the Marine Corps base, the highway and the nearby residential areas of the two counties. Testimony at recent hearings on emergency and evacuation planning at

San Onofre conducted by the California Energy Resources Conservation and Development Commission suggested that the response times for evacuation of the beach and park areas need to be clarified further.[81]

Station personnel receive training in radiation protection and emergency response. Annual exercises and periodic drills are conducted to test various aspects of emergency preparedness, including communication links with offsite response agencies. These exercises are reviewed by both the facility operator and the NRC Office of Inspection and Enforcement in Region V. Though an exercise for Orange County, San Diego County, and San Onofre has been scheduled for 1976, as yet there have been no tests conducted for offsite response plans.

4.3.2 Humboldt Bay

The Humboldt Bay Station, which went into operation in 1963, is the first commercial nuclear power plant in California. At present the power plant is temporarily shut down. The station emergency plan is contained in the Humboldt Bay Final Hazards Summary Report submitted to the AEC; it was subsequently updated to conform with Appendix E, 10 CFR Part 50, after the publication of the regulation in 1970. Emergency procedures of the Pacific Gas and Electric Company for Humboldt Bay identify recommended action levels as those contamination levels which would result in a whole body dose of 500 mrem or a thyroid dose of 5 rem via the appropriate food chain.[82] In the event of an incident involving offsite consequences, the onsite Emergency Coordinator is charged with the responsibility for alerting the local primary response agency and keeping it informed of current data on release rate, expected offsite doses, and wind speed and direction of the radioactive plume.[82]

The first offsite response plan for incidents at Humboldt dates back to 1962 and was prepared under the jurisdiction of the California Highway Patrol. The first county plan was written in 1974 and revised in March 1976. It is entitled "County of Humboldt Contingency Plan, Nuclear Reactor, Humboldt Bay."[83] The Office of Emergency Services, Humboldt County, is designated as the primary response agency for radiological incidents. The contingency plan addresses meteorological considerations, emergency operations, radiation countermeasures, and evacuation of the population in a $67\frac{1}{2}^{\circ}$ sector for a distance of three miles from the power plant. The plan also provides for annual review of operating procedures and the conduct of biennial exercises involving agencies with responsibilities in support of the contingency plan.

On June 30, 1976 an exercise was held in Humboldt County to test the County Contingency Plan. The exercise was divided into three parts. Part 1 consisted of simulated in-plant personnel injuries involving radioactive contamination. Plant personnel responded to the emergency and ambulance and hospital services were implemented. Part 2 consisted of simulated airborne radiation release. Plant personnel responded to the emergency according to the emergency procedures, and the county agencies assembled at the Civil Defense Headquarters in Eureka. Part 3 consisted of county OES activities and personnel deployment for an evacuation scenario in which the County Sheriff and the Coast Guard participated in the mock evacuation of the area around the power plant.[82] In these exercises, the evacuation routes were actually traversed by representatives of those agencies in charge of evacuation.[65]

Among the problems which were identified through local exercises at Humboldt and elsewhere are:

"1. In providing the public with information, it is important that only an official source provide information to the press. This assures that factual, accurate information and instructions are given to the public and rumors are negated.

2. It is important to know when evacuation actually took place and where people were sent so that follow-up countermeasures such as decontamination and health treatment for exposed individuals can be taken."[76]

4.3.3 Rancho Seco

Rancho Seco Nuclear Power Plant Station began operation in 1974 under the management of the Sacramento Municipal Utility District. Plant emergency procedures provide that if two or more area monitors (which are equipped with both alert and high level alarm points with annunciators) exceed their high alarm points, or two or more ventilation air monitors exceed their alarm points, or if other plant conditions pose a threat to the safety of a significant number of personnel, a plant evacuation will be declared. The Plant Emergency Coordinator will also notify support services, including the Sacramento County Sheriff's Office (for establishment of traffic control), the Sacramento County Health Department and Office of Emergency Services (for manpower call-up), and the AEC's Region V Regulatory Operations Office (now NRC).

In the event of an incident involving offsite releases, the Emergency Coordinator will determine whether or not an evacuation of the offsite population is required, based on projected downwind radiation concentration and exposure levels. The criteria for evacuation are as follows:

"A. 2 to 10 mrem/hr or 20 to 100 × mpc,* evacuate within 48 hours.
B. 10 to 100 mrem/hr or 100 to 1000 × mpc, evacuate within 5 hours.
C. 100 to 500 mrem/hr or 1000 to 5000 × mpc, evacuate within one hour.
D. Greater than 500 mrem/hr or 500 × mpc, evacuate immediately."[85]

At levels less than 500 millirem, the onsite emergency coordinator may notify the offsite primary response agencies, which in turn may alert the population-at-risk. If an evacuation of the general population in the affected areas is required, the coordinator will notify both the Sacramento County Sheriff's Office and the Sacramento County Health Department. He will also inform the Office of Emergency Services and the NRC Region V Regulatory Operations Office of the recommendation for evacuation. If onsite or offsite conditions warrant, the Emergency Coordinator may also request support from the ERDA's Region VII Radiological Assistance Team.

Sacramento County has prepared a recent re-draft of their offsite response plan and it should be finalized shortly. Prior to the development of the plan, the State Office of Emergency Services assumed the lead role for responding to an emergency at Rancho Seco. However, their responsibility ended when the County established an emergency services section.[65] In addition, the Sacramento County Sheriff's Office has developed a plan for evacuation of nearby residents in the event of an accident at Rancho Seco.

An exercise/seminar was held in Sacramento June 19, 1974, in which an offsite release of radioactive materials from the Rancho Seco nuclear plant was simulated. A total of 110 persons representing 48 different agencies participated in the drill.[65] A second test was conducted at Rancho Seco on September 24, 1975. This exercise was designed to check communications and alerting procedures, and to train offsite monitors from the Sacramento County Health Department.[65]

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*"Maximum permissible concentration" (MPC) is the concentration of radioactive material in air (or water) which, if sustained over a specified period will cause a specified dose. For protection of the general public, the dose is usually 500 mrem, and the period is one year.

4.3.4 Diablo Canyon

Diablo 1 is tentatively scheduled to begin operation in approximately one year. The county of San Luis Obispo has completed a preliminary draft of its emergency plan and standard operating procedures, and a final draft is expected to be approved shortly. The Sheriff of San Luis Obispo County has completed an evacuation plan for the area surrounding the Diablo reactor. The objective of the evacuation plan is stated as follows:

> "It is the purpose of the plan to evacuate all people affected by the class of release within a six (6) mile radius of the Diablo Canyon Plant site within a two (2) hour period. This area is called the low population zone (LPZ) and is based on a region of population base below 5,000. In this case, there would in fact be far fewer than 5,000 people involved."[87]

Both the County and the Evacuation Plan have adopted the reference dose criteria provided in Section 30268 of the California Administrative Code, Title 17, Public Health, which limits permissible doses to an individual in an uncontrolled area to 500 mrem per year from routine releases.

The following evacuation criteria is stated in Amendment 6 (1974) to the Final Safety Analysis Report submitted by Pacific Gas & Electric Company to NRC.

> "1. On-site personnel not actively engaged in recovery operations will be evacuated as required to prevent them, insofar as is possible, from exceeding a whole body dose of 2.0 rem, or a thyroid dose of 10 rem. These values are consistent with the interim recommendations of the Environmental Protection Agency contained in the paper, 'Interim Protective Action Levels,' by David S. Smith, September 1972.
>
> "2. The decision to institute evacuation of members of the general public rests with the State Department of Public Health, Bureau of Radiological Health. However, in a case where the recommendations of the Company are requested, the Emergency Coordinator will recommend that persons be evacuated in accordance with the guidelines given in 1. above."[88]

The discrepancy between the evacuation reference criteria specified in Amendment 6 of the PG&E Final Safety Analysis Report for Diablo Canyon and that required by Section 30268 is problematic. A potential for delay in the implementation of offsite protective measures exists unless actual notification to primary response agencies occur at a time when the projected offsite dose level is approaching 500 millirem. However, this problem has been remedied by the recent draft of the onsite Emergency Implementation Procedures for Diablo Canyon, which changed the evacuation reference criteria for offsite populations to 500 millirem. The Implementation Procedures, which have not yet been finalized, also amended the evacuation reference criteria for onsite personnel to reflect the recommendation of the latest EPA PAGs of 1 to 5 rem whole body dose.[89]

4.4 ERCDC: The Site Certification Process and Population Exposure Controls

The Warren-Alquist Act conferred exclusive jurisdiction on the California Energy Resources Conservation and Development Commission (ERCDC) to certify all power plant sites and related facilities in California to the extent permitted by federal law.[90] To obtain certification for a site, a utility must file an application for certification (AFC) with the Commission no later than 18 months before the commencement of construction. The site designated in the application must have been approved by the Commission in a previous notice of intention.

The Notice of Intention (NOI) process is intended by the Warren-Alquist Act as a means of allowing for government and public input into the utility's site selection process before it focuses on a particular site at the construction permit stage.[91] Each notice of intention must contain at least three alternative sites, each accompanied by a cost-benefit analysis of the choice of sites and facilities.

Several requirements in the ERCDC review process are relevant to the control of population exposure from accidental release of radioactivity. First, for the NOI review, Section 25511 provides that in determining the appropriateness of a site, the Commission shall "require detailed information on proposed emergency systems and safety precautions, ... proposed methods to control density of population in areas surrounding nuclear power plants, ..." Secondly, the Commission is also required by Section 25528 to condition the certification of any site and facility upon:

> "[the applicant's acquisition] by grant or contract, the right to prohibit development of privately owned lands in the area of the proposed site which will result in population densities in excess of the maximum population densities which the Commission determines, ... are necessary to protect public health and safety."[92]

The power of condemnation is granted to the applicant to acquire such development rights.[91] Section 25528 provides that the standards for the area and population density in the case of an application involving a nuclear facility "shall be that as determined from time to time by the United States Atomic Energy Commission (now NRC), if the Commission (ERCDC) finds that such determination is sufficiently definitive for valid land use planning requirements."[93] The Commission may waive the requirement of development rights to the extent that it finds existing governmental land use restrictions are of a type "necessary and sufficient to guarantee the maintenance of population levels and land use development over the lifetime of the facility which will insure the public health and safety requirements..."[94] However, if certification of a site involves a waiver based upon existing land use restrictions, any future changes in governmental land use restrictions in such areas must be approved by the Commission.[95]

Third, in addition, Section 25532 requires the Commission to establish a monitoring system to assure that certified facilities are constructed and operated in compliance with air and water quality, public health and safety, and other applicable regulations, guidelines, and conditions. The costs which the applicant incurs to comply with the decisions of the Commission are allowed for ratemaking purposes.[96]

4.4.1 ERCDC Activities

To implement the mandate of the Warren-Alquist Act with respect to the control of population exposure from radiation hazards, the Energy Resources Conservation and Development Commission must develop criteria for evaluating information submitted with notices of intention and applications for site certification. At the NOI stage, the detailed statements of "proposed emergency systems and safety precautions" should allow the ERCDC staff to make a determination of the status of existing and proposed levels of radiological emergency preparedness. The statements may include descriptions of the proposed planning process, important site-community interfaces, and the types of engineered safety features and emergency instrumentation which will be available. In essence, the NOI statements may be used to formalize the existing exchange between the Office of Emergency Services and station operators, emphasizing special NRC regulatory requirements (e.g. time-distance-dose plots, critical response times) to establish a useful information base for local agencies. Since notices of intention must be filed at least 28 months prior to the commencement of construction, it will complement the development of site-related information useful to the utilities in the preparation of their preliminary safety analysis report, although the information submitted to ERCDC may be of a more general nature than that to be submitted with the construction permit application to the NRC or with the application for State certification.[91,97]

Current hearings are being conducted by ERCDC on "Emergency Evacuation Plans Associated with Nuclear Powered Electric Generating Facilities" at San Onofre, Diablo Canyon, Humboldt Bay, and Rancho Seco. The purpose of the hearings is to receive comments and information on jurisdictional matters among federal, state and local agencies and on general topics involving federal and California emergency response evacuation plans.[98] Specific emergency evacuation plan issues addressed at the hearings include

"1. The critical time in a nuclear reactor accident progression when there is sufficient evidence of a core meltdown to warrant notification of offsite authorities of the impending need for evacuation.

2. Possible actions to alert automatically (without human intervention) offsite authorities of an impending need for evacuation.

3. The geographic area of evacuation for different nuclear power plants and accident progressions.

4. The ability of current California emergency evacuation plans to react to correlated disasters, such as a loss of coolant-induced meltdown caused by an earthquake.

5. Necessary interim and ultimate mechanisms for continuous ground and air monitoring of areas around an affected nuclear power plant.

6. Present plans for extended accommodations for large numbers of evacuees."[99]

In addition, a questionnaire on "Emergency Evacuation Planning" was distributed to federal, state and local agencies involved in radiological response planning and the utilities operating existing nuclear power plants in California. Among the questions that were raised concerning the determination of the potential evacuation area is the applicability of the assumptions relating to evacuation distances used in the NRC Reactor Safety Report (WASH-1400) to actual evacuation planning.[100]

4.4.2 Population Density Criteria

Under the terms of the Warren-Alquist Act, population density control is presented as a method of reducing radiological risks to populations surrounding a nuclear power plant. Table 4-2 describes the site characteristics of existing nuclear power plants in California. The population density around these plants is summarized in Table 4-3 and figure 4-2. Site certification for nuclear facilities are conditioned upon the applicant's compliance with one of the following requirements:

1) Acquisition of development rights.
2) Siting in low density areas which have existing land use restrictions sufficient to guarantee the maintenance of low population levels over the lifetime of the facility.
3) Siting in low density areas which will adopt land use restrictions necessary to guarantee the maintenance of low population density levels.

Two NRC guidelines may be considered as the appropriate reference criteria for determination of population density levels necessary to minimize radiological risk. The first criterion involves the use of an unweighted cumulative population vs. distance and is the current criterion used in the evaluation of population distribution in the NRC siting review (see discussion *supra* at Section 2.1.4, "Site Population Evaluation"). It recommends the consideration of alternative sites if the population density, projected at the time of initial plant operation, exceeds 500 persons per square mile averaged over any radial distance out to 30 miles at the time of construction, or will exceed 1000 persons per square mile averaged over any radial distance out to 30 miles over the lifetime of the facility.

The second is a proposed interim regulatory guide, "Population Distribution Around Nuclear Power Plants" which was released in April 1974 and

Table 4-2 SITE CHARACTERISTICS OF EXISTING NUCLEAR POWER PLANTS IN CALIFORNIA

Station	Capacity Net MWe	Exclusion Distance (Miles)	Low Population Zone (Miles)	Land Use in 5 Mile Radius	Topography Site	Topography Surrounding Area
Diablo Canyon 1 & 2	2,120	0.50	6.0	Undeveloped Wooded	Hilly	Hilly to Mountainous
Humbolt Bay 3	68.5	0.13 Rad	2.0(*)	Residential Agricultural Lumber	Flat to Rolling	Rolling Hills
Rancho Seco	900	0.4 Rad	4.7	Agricultural Grazing Land	Flat to Rolling	Rolling
San Onofre 1, 2 & 3	2,710	0.1	2.0	Military Base	Sea Cliffs	Hilly

Source: U.S. Atomic Energy Commission. Directorate of Regulatory Standards. Land Use and Nuclear Power Plants - Case Studies of Siting Problems, WASH - 1319.

* California Energy Resources Conservation and Development Commission. Hearings on Emergency Response and Evacuation Planning. (Humboldt Bay Reactor) September 28, 1976.

Table 4-3 POPULATION DISTRIBUTIONS AROUND CALIFORNIA NUCLEAR POWER PLANTS

Miles	San Onofre	Humboldt	Diablo Canyon	Rancho Seco
0 - 1	0	1,700[a]	0	8
0 - 2	0		4	93
0 - 3	500	5,000[*]	6	175
0 - 4	5,040		10	244
0 - 5	12,600	37,900	14	352
0 - 10	36,200	48,700	4,440	6,061
0 - 20	228,000	81,400	75,990	121,932
0 - 30	644,000	87,900[b]	134,690	907,789
0 - 40	2,285,000		188,290	1,060,792
0 - 50	5,680,000	104,892	226,540	1,381,581
Census	1980[c]	1970	1970	1970

Source: California Resources Agency. Energy Dilemma - California's 20-Year Power Plant Siting Plan, June 1973, citing as source of data: California Department of Public Health.

(a) 1.5 miles

(b) 25 miles

(c) 1980 census is an estimated growth prediction

(*) California Energy Resources Conservation and Development Commission. Hearings on Emergency Response and Evacuation Planning. (Humboldt Bay Reactor) September 28, 1976.

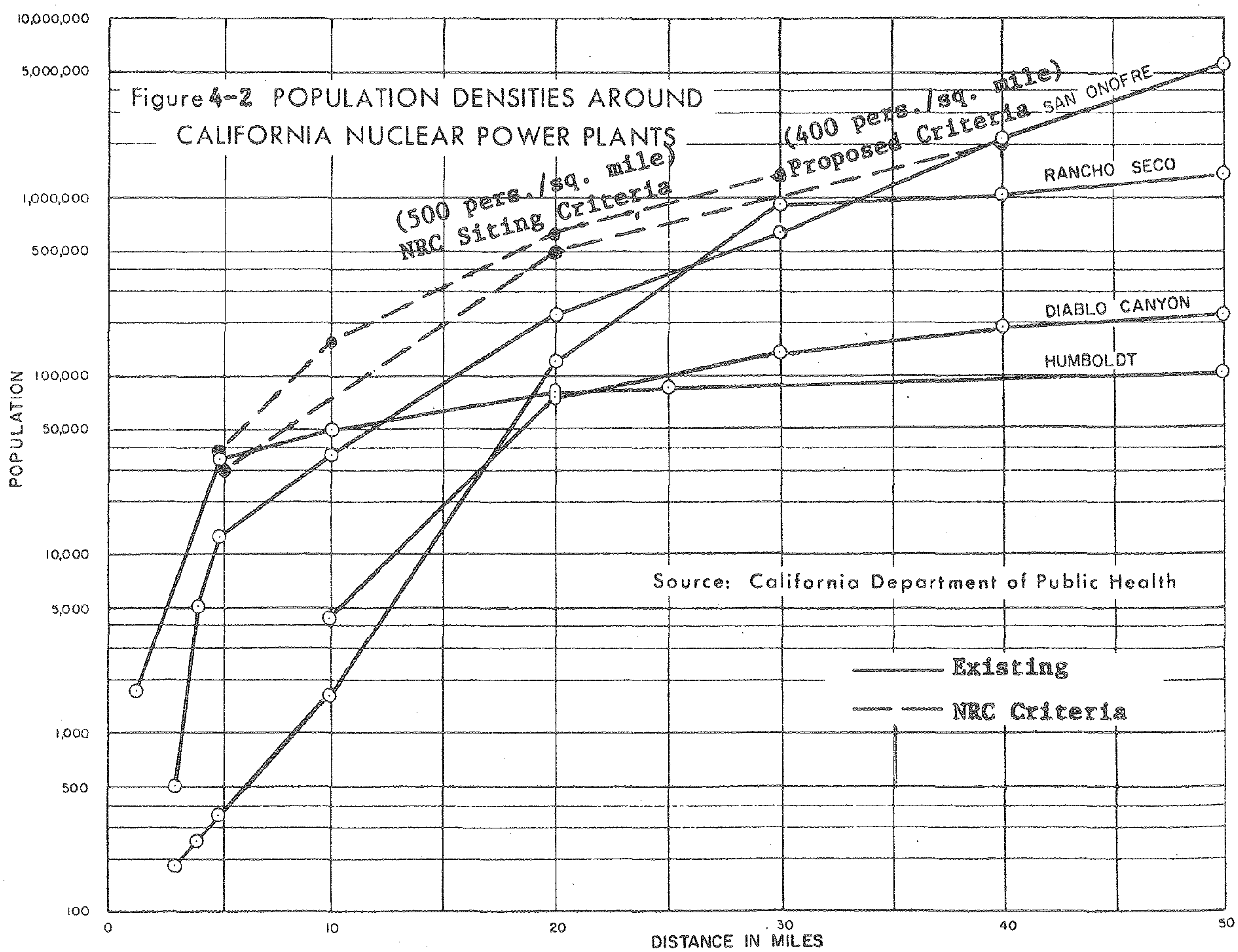

Figure 4-2 POPULATION DISTRIBUTIONS AROUND CALIFORNIA NUCLEAR POWER PLANTS

Source: California Resources Agency. Energy Dilemma - California's 20-Year Power Plant Siting Plan, June, 1973.

circulated for discussion.[101] The main thrust of the proposed guide is to provide further guidance, from the standpoint of compliance with 10 CFR Part 100, as to low-population-density characteristics and to require a sufficient justification for sites where the population densities are higher. It contains the following five requirements that expressed the AEC Regulatory Staff's position on acceptable population distributions around the nuclear plant sites based on the Site Population Factor Index (see discussion in Appendix A).

"1. Applications for sites having a cumulative population projected from the date of application for a construction permit, as indicated in Item 2, greater than 30,000 within 5 miles, 500,000 within 20 miles, or 2,000,000 within 40 miles should:

a) Present an analysis of alternative sites, including a showing that the proposed site offers significant advantages from the standpoint of environmental, economic or other factors.

b) Provide state-of-the-art engineered safety features to assure that the conservatively calculated consequences of postulated design basis accidents are significantly below the dose guidelines of 10 CFR Part 100.

c) Have a minimum exclusion distance of at least 0.4 mile and a low population zone of at least 2 miles.

2. If population projections indicate that any of the values in Item 1 would be exceeded during the plant lifetime, a detailed study of economic and population growth patterns for at least 10 years after the date of application for the construction permit should be performed. The guideline values in Item 1 will be deemed to have been exceeded if

a) the detailed 10-year projection indicates that any of the guideline values are exceeded, or

b) at the time of the construction permit application, any of the guideline's values can be reasonably expected to be exceeded by more than a factor of two over the projected lifetime of the plant.

3. Plant sites which fall below the population criteria of

Item 1 above, and which can reasonably be expected to remain at a population level less than these guidelines over the projected plant lifetime will be individually evaluated against the dose guidelines of 10 CFR Part 100 and a detailed 10-year projection need not be performed.

4. Significant unusual population distributions within the distances specified in Item 1 above will also be taken into account in determining site acceptability.

5. Should the population at any approved site rise to unexpectedly large values during the plant lifetime, the AEC may review the population growth to determine whether additional engineered safety features should be provided or plant operations modified."[101]

It is important to note that this guide has not been formally issued and remains an example of NRC's continuing work in the area. The requirements for siting are still those set out in 10 CFR Part 100, and there is no requirement for routine monitoring of population growth surrounding nuclear plants after the issuance of the operating license. The use of development rights to limit population density compared to other protective measures will be explored further in the next Section.

5.0 RADIOLOGICAL EMERGENCY RESPONSE PLANNING IN CALIFORNIA: A SECOND LOOK

5.1 A Reasonable State of Preparedness

Under existing Federal and State rules and regulations, the responsibility for emergency response planning for nuclear power plants is shared by the Federal, State and local governments and the private utilities that operate the plants. After the permit or licensing stage, the emphasis is placed on both onsite and offsite implementing procedures. A brief review of the respective roles of the organizations involved is useful here.

- Utilities have the primary responsibility for onsite emergency planning. Under existing NRC review procedures, they must also establish that there is reasonable assurance that appropriate protective measures could be taken in behalf of the population within the LPZ in the event of a radiological incident.

- At the Federal level, the NRC has a dual function with respect to emergency planning. First, it exercises a statutory responsibility for licensing nuclear facilities, which involves promulgation of regulations on emergency planning and the review of utility emergency planning in conformance with them, particularly for onsite emergencies. Secondly, the NRC has the lead agency role in the Federal interagency effort to assist States in developing a program of radiological preparedness. In this role, the NRC participates in the review and concurrence of State radiological emergency response plans as well as in the development of guidance materials and training programs for State and local agencies involved.

- The primary responsibility of the EPA in the interagency effort to assist State emergency planning is to develop protective action guides for use by Federal, State, and local planners.

- The Energy Research and Development Administration (ERDA) is on call under the Radiological Assistance Program to respond with technical assistance and equipment to meet any incident that exceeds the capabilities of the primary response agency.

ERDA is the lead agency under the Interagency Radiological Assistance Plan and has the responsibility for coordinating Federal assistance in the event of a radiological incident.

- In California, the Office of Emergency Services (OES) is the designated state authority responsible for radiological emergency response planning at the State level. It is also responsible for the review of local radiological plans to ensure that they coordinate plans with both the State Nuclear Power Plant Emergency Response Plan and emergency planning by individual utilities with the Department of Health, Radiological Section, OES oversees training of emergency response teams, adequacy of emergency instrumentation, and the conduct of exercises and drills to test local response plans.

- Local emergency service agencies in the vicinity of a nuclear power plant are responsible for formulating and implementing an emergency plan to deal with the offsite consequences of a radiological incident. Such a plan should include standard operating procedures for all responsible local entities and be coordinated with both plant and State emergency response measures.

Radiological response preparedness is a function of coordinated planning and implementation by the plant operator, local government, State and Federal agencies, and is tailored to each site and facility. In California, State emergency response planning has benefitted from experience derived from the States Agreement Program and civil defense efforts in the 1960s. The preparation of the State Nuclear Power Plant Emergency Response Plan was timely in 1974-75 and coincided with the stepped-up Federal interagency program to assist States with radiological emergency planning. At present, offsite radiological emergency response and evacuation plans for each of the four power plants in California are at various stages of completion (see discussion *supra* at Section 4.3). The variation in local preparedness may be accounted for in part by differences in the availability of local emergency services support in the absence of a specific State mandate to prepare local emergency plans, and in part by the degree of utility participation.[72] For example, while the County Office of Emergency Services at Humboldt and San Diego Gas and Electric Company has been very active in the development of emergency and evacuation plans for the Humboldt Bay Reactor and San Onofre, both Rancho Seco and Diablo Canyon Offices of Emergency Services have experienced a shortage of staff due to reductions in the local budget.

Site characteristics at each nuclear facility may also affect the types of emergency countermeasures necessary to protect public health and safety. In California, there are significant differences among the existing power plants with respect to size, geographic location, and demographic distribution. Meteorological conditions associated with the individual sites will also affect the impact of a radioactive release involving offsite consequences. These differences suggest that the same level of release may call for different protective actions at each reactor site considered. A reasonable state of emergency preparedness will require that the available spectrum of countermeasures be evaluated according to local constraints (both radiological and social). Thus far, the protective actions which have been recommended for radiological incidents involving offsite releases include: evacuation, shelter and prophylaxis (thyroid protection). The constraints associated with the implementation of each of these measures are discussed in Section 5.2.2 below.

5.2 Alternative Approaches to Population Exposure Control

5.2.2 Population Density Controls: A Preventive Measure*

The Nuclear Regulatory Commission has had a long-standing policy that encourages the siting of nuclear power plants away from densely populated areas. This policy is expressed primarily by reactor site criteria contained in 10 CFR Part 100 (see discussion *supra* at Sections 2.1 and 2.2). Over the years, nuclear power plant sites have been evaluated from a radiological-risk standpoint by comparing the results of design-basis dose calculations with the numerical guidelines provided by 10 CFR Part 100 for individual exposure. As to population risk, a minimum population center distance was defined with the proviso that "where very large cities are involved, a greater distance may be necessary because of total integrated population dose considerations." The considerations of 10 CFR Part 100 have been implemented through the adoption of the principle of compensating safety features which allowed for some trade-offs between undesirable site characteristics and the addition of compensating engineered safety features.[103] The issue raised in the Warren-

*For discussion of the control of population densities surrounding nuclear power plants, see Ref. 11.

Alquist Bill concerns the fact that NRC does not monitor population growth surrounding a nuclear power plant once the operating license has been issued, and that the assumptions used in evaluation of compensating engineered safety features for location of reactors close to large population centers may be undermined by population growth in excess of projections.

The Warren-Alquist Act has tried to minimize the potential increases in radiological risk in the course of future population growth by requiring that certification of nuclear power plant sites in California be conditioned upon some assurance that future population densities can be maintained within guidelines prescribed by the NRC. Such assurance may be given by the applicant through the acquisition of development rights for privately owned land in the environs of the proposed site, or by a showing that existing or proposed land use restrictions at the site will be sufficient to guarantee the maintenance of the desired population density throughout the lifetime of the power plant. While the legal machinery exists for facilitating the acquisition of development rights (condemnation proceedings) and imposition of land use restrictions (zoning), the State Energy Resources Conservation and Development Commission must still confront the following cost-benefit implications of population density controls to reduce radiological risks:

1) What criteria should be established for area and population density? Are existing NRC population distribution criteria sufficiently definite for land use purposes? How shall local population growth be projected?

2) What kinds of development rights or land use restrictions should be required? Since contamination of animal feed or milk production contributes significantly to radiological risk, should development rights or restrictions be limited to residential users or extended to include uses for agricultural or dairy purposes? Should other types of uses be encouraged in its place?

3) Who should hold the title to the development rights acquired by condemnation proceedings? The utility? The State? What provisions are made to return these development rights to the public after the power plant is no longer in operation? How should the cost of acquisition be apportioned with respect

to present and future consumers of electricity?

4) If the construction of a nuclear power plant will inhibit the development of surrounding property for some purpose, how should this cost to private land owners be recognized? When should the disability be recognized? What conditions are proper for the acquisition of development rights by condemnation versus the imposition of land use restrictions through the exercise of the State's police powers?

5) Population density controls provided by the Warren-Alquist Act will involve a substantial interference with the traditional land use powers of local governments. What kind of state assistance is available to ameliorate adverse effects? What should be the role of the local governments in reducing radiological risk associated with the operation of nuclear power plants?

5.1.2 Protective Actions for Acute Exposure to Radiation from an Airborne Release: Evacuation, Sheltering, and Prophylaxis

Evacuation, sheltering, and prophylaxis are among the protective countermeasures which have been considered as appropriate to limiting population exposure from an airborne release. However, before a decision is made to implement a given protective action, there are local constraints associated with each of these protective actions which must be considered. Such constraints may be the result of a balancing of radiological risks and fiscal and societal costs; or they may arise from physical constraints existing at the local level. It should be kept in mind that the balancing of risks and costs implies that in emergency planning for nuclear incidents, as in other activities, certain cut-off points can be identified where the marginal increase in protection may not justify the required expenditures or extensive disruption of daily activities.[34] Physical constraints at the local level may be environmental (meteorologic and/or geographic considerations), demographic (population density, distribution; age and health status of the population), temporal; or involve a problem of resource availability or exposure duration (e.g. puff or continuous release).[34] The task of the local planner is to evaluate all these factors in some analytical fashion, even though not all of the constraints can be quantified, and delineate appropriate protective actions in the emergency plan.

The constraints on evacuation are described in the Manual of Protective Action Guides and Protective Actions issued by the Environmental Protection Agency. The considerations for determining whether evacuation is a viable protective action for a given situation include:

1) effectiveness of evacuation
2) risk of death or injury
3) cost of implementation

The effectiveness of evacuation in limiting radiation dose is a function of the time required to evacuate. Since dose will increase with the time of exposure, anything which delays evacuation may be characterized as a constraint. The evacuation time T(EV) — defined as the time lapsed between the start of the incident to the time that the evacuees have cleared the affected area — may be expressed[34] as

$$T(EV) = T_D + T_N + T_M + T_T \quad ,$$

where

T_D = time delay after occurrence of the incident associated with notification of responsible officials, interpretation of data, and the decision to evacuate as a protective action.

T_N = time required by officials to notify people to evacuate

T_M = time required for people to mobilize and get underway

T_T = travel time required to leave the affected areas

Table 5-1 summarizes the approximate range of time segments that act as constraints in evacuation.

Risk of Death or Injury. It is important in considering the advisability of evacuation to consider whether the health risks of radiation exposure are greater or less than the health risks associated with evacuation for a nuclear incident. The present data history of U.S. evacuations which are comparable to radiation incidents is not sufficient to derive any statistically reliable forecasting estimate of death risks in evacuation. Based only on a comparison of radiation death risk with evacuation auto accident death risk, the Environmental Protection Agency presented hypothetical protective action guides as low as 0.013 rem. Inclusion of permanent impairments raised the PAG value from 0.013 rem to 0.021 rem. Persons with particularly severe health conditions which may be aggravated

Table 5-1 APPROXIMATE RANGE OF TIME SEGMENTS MAKING UP THE EVACUATION TIME

Time Segment	Approximate Range Hours
T_D	0.5 - 1.5[b]
T_N	0.2 - 1.0[c]
T_M	0.2 - 2.0[d]
T_T	0.2 - 1.5[e]
	1.1 - 6.0

[a] High population, high density areas such as those around Indian Point, present a different situation, and evacuation times are more complex, probably longer, and must be analyzed on a case by case basis.

[b] Maximum time may occur when offsite radiation measurements and dose projections are required before protective action is taken.

[c] Maximum time may occur when population density is low and evacuation area is large.

[d] Maximum time may occur when families are separated, a large number of farms or industries must be shut down, and special evacuations are required.

[e] Maximum time may occur when road system is inadequate for the large population to be evacuated and there are bottlenecks.

Source: U.S. Environmental Protection Agency. Office of Radiation Programs. Manual of Protective Action Guides and Protective Actions for Nuclear Incidents. September 1975.

by emotional anxiety will probably incur risks of death or permanent impairment higher than those suffered by healthy persons, thereby raising these hypothetical values slightly . In any case, these hypothetical PAGs are so low that other constraints cause much higher values to be set.[104]

Costs of Implementation. Practical considerations such as direct cost of evacuation and indirect costs of disruption of community or personal activities become more important than the relatively small direct evacuation risks just indicated. The economic cost of evacuation will mediate against the inclination to evacuate in radiological incidents where the radiation dose would be small. Parameters that would affect the costs of the evacuation of an area around a specific site are numerous, including physical and demographic characteristics, business activities, mode of evacuation (see Ref. 34). Consideration of such parameters and their effect on cost should allow the planner to calculate the approximate monetary costs of an evacuation.

Sheltering. Evacuation is regarded as the protective action of choice following an incident involving a radioactive airborne release. Depending on the exposure duration (e.g. puff or continuous release), seeking shelter in a dwelling with windows and doors closed and ventilation turned off may be an effective protective measure from inhalation of radioactive gases and vapors for a short period, but would be generally ineffective after about two hours due to natural ventilation of the shelter.[34] However, since the local constraints on sheltering as a protective action in terms of time to take action, costs, and disruption of normal activities is relatively small, sheltering is being given a closer look from a cost-benefit perspective in comparison with evacuation.

In California, the Office of Emergency Services maintains an index of radiation shelters by localities for civil defense purposes.[75] It is possible this information should be incorporated into local radiological emergency response planning. Also, since the protection offered by dwellings against radiation varies with the type of structure (e.g. wood frame versus concrete), local radiological planning may evaluate the shelter effectiveness of buildings surrounding a power plant and encourage the use of specific materials in construction.

Prophylaxis. The oral administration of about 100 milligrams of potassium iodide will result in sufficient accumulation of stable iodine in the thyroid of the average person to prevent significant uptake of radioiodine from an airborne release occurring shortly thereafter.[34] In the United Kingdom, prophylaxis used in conjunction with sheltering is considered the primary protective action in a radiological accident.[105,106] However, in the U.S., the use of potassium iodine is normally administered by prescription. Its use as a prophylaxis is recommended by both the EPA and the California Office of Emergency Services as a protective action for emergency workers only. The efficacy of administering stable iodine as a protective action for the general population is still under consideration by the Food and Drug Administration.

5.3 ERCDC: A Supportive Interface

The constraints discussed in the previous Sections in connection with both preventive (population density controls) and protective (evacuation, sheltering, prophylaxis) actions suggest that control of population exposure from radiological emergencies is a complex problem, where the reduction of health risks cannot be separated from other socio-economic considerations. Because not all of the important considerations are quantifiable, the emergency planner must make a value judgment as to what preventive and protective measures are appropriate. In the assessment of radiological risk from nuclear power plants, he may rely on a number of more or less formalized models of analysis to provide him with the necessary perspective. One such model is the portfolio approach, where mortality risk is defined in terms of the probability of death to each person affected, and this risk is compared with the portfolio of risks from the same or other sources to which the population in general is already exposed.[107] This approach is adopted in WASH-1400, the "Reactor Safety Study" sponsored by the Nuclear Regulatory Commission. The probability of death per person per year of 100 nuclear power plants in the U.S. is estimated at 10^{-9} compared with, for example, 10^{-7} for death from lightning and 10^{-4} for death from a motor vehicle accident. The implicit assumption behind these comparisons is that the acceptability of a hazard is related to how much it increases the average probability of death.[107]

A limitation of the portfolio approach is that while the numerical comparisons of different types of risks are interesting as comments on the range of activities considered, there may be no common basis for the risk comparison which would allow it to be useful as a policy tool — because of the degree of uncertainty of the estimates, the distribution and timing of consequences, the public perception of the risk, and the associated anxiety in the public response.[107] Risk from radioactive exposure from a nuclear incident is more or less randomly distributed across a population composed of men, women and children, whereas other types of populations-at-risk have different compositions.[51] It has been suggested by some social scientists that until some hierarchical system of risk analyses is established to allow classification of the risk by the major factors involved, decision-makers should recognize the significance of having an equitable and widely accepted process to evaluate the positive and negative consequences of their policy choice.[51,107] For in the case of risk from large scale application of technology, the individual's feelings about an increased chance of death cannot easily be separated from the feelings he might have about other social values implied by the hazard.[107]

It is in this context that the California Energy Resources Conservation and Development Commission's role in the area of emergency planning for nuclear power plants in California must be viewed. Its immediate task is to accommodate the execution of the duties imposed upon it by law with the programs of other agencies presently dealing with radiological emergency response planning and evacuation, in order to maximize the flow of information and ensure the serious participation of all Federal, State, and local agencies as well as the individual utilities concerned.

It is apparent from the regulations and programs reviewed in this report that since the promulgation of Appendix E (10 CFR Part 50) in 1970, a comprehensive Federal program to insure radiological emergency response preparedness has emerged. Within the limits of Federal jurisdiction, this program affects the licensing of nuclear power plants, the quality of State radiological emergency planning, and the coordination of response capabilities in the event of an accident. As a consequence of the Federal assistance program, as well as public concern over the health and safety impact of nuclear power and the environmental impact of nuclear power plants on local communities, a number of States are preparing for a more direct involvement with radiological emergency planning. However, the appropriate level of State action has yet to be clarified with respect to the jurisdiction of the Nuclear Regulatory Commission. For example, Oregon has enacted legislation which in effect requires the licensee to submit its emergency plan to the State for approval before the facility can operate; Michigan is in the process of promulgating similar procedures. Both of these states have been notified by NRC that such action is preempted by Appendix E as the expression of Federal intention to regulate the subject area, and it remains to be seen whether there will be a judicial test of the legislation.[44]

Putting aside the question of Federal preemption for the moment, the issue before the California Energy Conservation and Development Commission in carrying out the mandate of the Warren-Alquist Act is how to minimize radiological risk to surrounding populations within the context of site certification proceedings. In confronting this issue, ERCDC must create a regulatory and administrative framework that responds to present problems in emergency preparedness, and at the same time complements the existing Federal and State efforts for radiological emergency response planning. Specifically, the problem areas involve 1) the variability of local emergency planning caused by the lack of State funding and local perception of priorities in disaster preparedness, and 2) the cost versus benefit of population density controls surrounding nuclear power plant sites.

Consistent with the function of the Office of Emergency Services as the Designated State Authority for radiological emergency planning, and the role of ERCDC as the State Siting Authority, ERCDC may give impetus to local emergency response planning by instituting local emergency preparedness reviews as an "appropriate aspect of design, construction, or operation of the proposed site and facility" under Section 25506 and 25519 of the Warren-Alquist Act. While there is no specific mandate in the Warren-Alquist Act to require preparation of radiological response plans, Section 25506 and 25519 reviews are supported by State funds under Section 25538, and a review of the status of local radiological planning at the NOI and AFC stage would serve as timely initiation of the planning process. For example, the product of a local review may include a statement describing the necessary local activities to cope with a radiological incident. Such a statement may be used to clarify local disaster preparedness priorities in light of proposed construction of a nuclear power plant, and to define the need for further assistance from OES.

With respect to population density controls, local reviews of population projections and relevant land use restrictions under Sections 35506 and 25519 would enable the Commission to make a determination of whether the maintenance of appropriate population density levels under existing land use restrictions is probable, or whether the utilities should proceed with acquisition of development rights. An independent monitoring capability for population density could be created within the monitoring system established pursuant to Section 25532. Such a capability could include a reporting system in the communities where a site has been approved to allow for update of population distribution patterns and an evaluation of its impact as a function of distance from the plant site.* In addition, a representative from the monitoring system could maintain periodic contact with the licensee and the inspection staff of the NRC Region V Office in order to keep informed of the operating status of power plants, modifications in engineering safety features, regulations, agreements with offsite emergency response agencies, and other matters relevant to public health and safety. Such information should be forwarded to the appropriate local planning agencies and to ERCDC staff responsible for the review of land use restrictions under Section 25528. However, as discussed in ref. 11, a decision on the extent and form of population density controls must precede ERCDC regulatory activity in this area.

At the state level, ERCDC could conclude an agreement with the Office of Emergency Services which would preserve the role of the OES as the Designated State Authority for radiological emergency response planning, and set forth a procedure whereby the pre-planning information collected as a part of the local reviews instituted by ERCDC is transmitted to OES. ERCDC might also make a commitment to provide an annual contribution of funds to be administered by OES for specific purposes, e.g. training of local personnel, conduct of drills, emergency instrumentation, or for general research and development which will upgrade the status of the State's radiological emergency preparedness, e.g. atmospheric monitoring capability, the effect of alternative protective actions such as sheltering, prophylaxis, or guides for the use of construction materials. At the same time, ERCDC should establish an internal capability for reviewing land use restrictions relevant to the maintenance of appropriate population density levels and the acquisition of development rights. This capability would address the problem of population density criteria, permissible uses within such a "buffer zone," alternative ways to minimize

*The Site Population Factor (SPF) Index described in Appendix A may be modified to show the impact of population growth on emergency preparedness as a function of distance from the reactor at a specific site. Other indices (geological, meterological, evacuation capability) may be included as weighing factors in the SPF Index to provide an aggregate indicator of where additional uses in the buffer zone will be in conformance with radiological protection of the public.

radiological risks to surrounding populations, and the State-local relationship in land use planning.

A State Interagency Liaison Committee could usefully be established with representatives from ERCDC, OES, and the Department of Health, Radiologic Section, to provide a forum where the various State agencies may discuss problems and priorities with each other and with the NRC. The logical NRC correspondent with such a Liaison Committee would be the NRC Office of State Programs, which could keep the Committee informed of developments in the Federal Assistance Program and new directions in the licensing and regulation of nuclear facilities relevant to population exposure control. ERCDC may also be interested in other forms of NRC-State cooperation such as the development of protocols for joint hearings in the siting of nuclear power plants. Areas of continuing interest to California with respect to radiological emergency preparedness include:

- Guidance for States in the area of transportation incidents involving nuclear materials. Specifically, the level of emergencies that State agencies should be prepared to deal with, and specific procedures which should be followed in the event of an incident.

- Emergency planning for fuel processing and fuel fabrication facilities.

- Accident scenarios for emergency preparedness at the State and local level relating to incidents at fixed nuclear facilities, including evacuation scenarios which state and local agencies should follow in evaluating the adequacy of their emergency plans.

- Types of radiological emergency instrumentation which will to useful for State and local governments to improve their offsite radiological assessment capabilities, including performance criteria for such emergency instrumentation.

- Requirements for offsite medical facilities, including equipment, supplies, training necessary for the provision of emergency medical care of contaminated persons.

- Additional Protective Action Guides for radiological exposure from contaminated food stuffs, animal feeds, water, and property.

- Guidance on the use of sheltering and radioprotective drugs as alternatives to evacuation.

To summarize, ERCDC may be able to minimize emergency radiological risks to populations surrounding a nuclear power plant by participation in local planning, contributing financial support to State radiological emergency preparedness, and providing an arena where both problems and information can be reviewed. At best, these are first order responses to problems of institutional complementarity identified in this review of emergency and evacuation planning in California; future tasks will emerge from the actual discharge of the Commission's site certification and monitoring responsibilities.

REFERENCES

1. U. S. Nuclear Regulatory Commission. Annual Report 1975.

2. U. S. NRC. Office of Nuclear Regulatory Commission. Statement of Ben C. Rusche, Director of the Office of Nuclear Reactor Regulation before the State of California Energy Resources Conservation and Development Commission, San Diego, California. August 23, 1976.

3. H. B. Piper and F. A. Heddleson, "Siting Practice and Its Relation to Population." Nuclear Safety, Vol. 14, No. 6, November-December 1973, pp. 576-584.

4. U. S. Nuclear Regulatory Commission. Title 10, Chapter 1, Code of Federal Regulations - Energy. Part 100. "Reactor Site Criteria."

5. H. P. Green and C. Fridkis, "Radiation and the Environment" in Dolgin & Guilbert (eds.), Federal Environmental Law, pp. 1023-1056.

6. U. S. Atomic Energy Commission. Directorate of Licensing. Regulatory Standard Review Plans. October 1974.

7. U. S. Nuclear Regulatory Commission. Office of Standards Development. Regulatory Guide 4.7. "General Site Suitability Criteria for Nuclear Power Stations." September 1974.

8. Regulatory Guide 1.3. "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," and 1.4. Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant for Boiling Water Reactors."

9. U. S. Atomic Energy Commission. Division of Licensing and Regulation. "Calculation of Distance Factors for Power and Test Reactor Sites." Technical Information Document by J. J. DiNunno, F. D. Anderson, R. E. Baker, R. L. Waterfield, TID-14844. March 23, 1962.

10. J. R. Buchanan, "AEC Working Paper on Population Density Around Nuclear Power-Plant Sites." Nuclear Safety, Vol. 16, No. 1, January-February 1975, pp. 1-7.

11. A. V. Nero, C. H. Schroeder, and W. W. S. Yen, Control of Population Densities Surrounding Nuclear Power Plants. LBL-5921, Lawrence Berkeley Laboratory, January 1977.

12. H. N. Culver, "Effect of Engineered Safeguards on Reactor Siting." Nuclear Safety, Volume 7, Number 3, pp. 342-346; Spring (1966).

13. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation. Regulatory Guide 1.70. Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. (Revision 2), Section 2.1.2. "Exclusion Area Authority and Control."

14. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Licensing. Standard Review Plan. Section 2.1.3. "Population Distribution." November 24, 1975.

15. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation. Standard Review Plan. Section 2.1.1. "Site Location and Description." November 24, 1975.

16. U. S. Nuclear Regulatory Commission. Title 10, Chapter 1, Code of Federal Regulations - Energy. Part 100. "Reactor Site Criteria." Statement of Considerations.

17. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation. Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Plants. Revision 2. July 1976. This guide will be used by the NRC staff in the evaluation of environmental reports submitted in connection with applications docketed after December 31, 1976.

18. Personal Communication with B. Weiss, Safety and Environmental Inspection Program, US NRC.

19. Personal Communication with W. F. Nischan, Accident Analysis Branch, US NRC.

20. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation. Regulatory Guide 1.70. Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. (Revision 2). Section 2.2.3.1. "Determination of Design Basis Events."

21. NRC Regulatory Guide 1.3, "Assumptions used for evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," and Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressuraized Water Reactors."

22. Personal Communication with R. W. Houston, Chief, Industrial Security and Emergency Planning Branch, U. S. Nuclear Regulatory Commission.

23. U. S. Nuclear Regulatory Commission. Reactor Safety Study: An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants. WASH-1400 (NUREG 75/014), October 1975.

24. S. Levine, "Overview of Reactor Safety Study, WASH-1400," U. S. Nuclear Regulatory Commission, Washington, D.C. 20555.

25. U. S. NRC. Reactor Safety Study: An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants. WASH-1400. October 1975.

26. A. V. Nero and M. R. K. Farnaam, "A Review of Light-Water Reactor Safety Studies," Lawrence Berkeley Laboratory Report LBL-5286, January 1977.

27. U. S. Nuclear Regulatory Commission. Office of Standards Development. Annex A. Organization and Content of Emergency Plans for Nuclear Power Plants. Regulatory Guide 1.101. "Emergency Planning for Nuclear Power Plants." November 1975.

28. D. W. Moeller and J. M. Selby, "Planning for Nuclear Emergencies" Nuclear Safety, Vol. 17 No. 1 , January-February 1976.

29. U. S. Nuclear Regulatory Commission. Title 10, Chapter 1, Code of Federal Regulations - Energy. Part 50. Licensing of Production and Utilization Facilities. Appendix E - Emergency Plans for Production and Utilization Facilities.

30. Southern California Edison Company. Statement on Emergency Planning for Nuclear Generating Facilities. August 13, 1976. Submitted to the California Energy Resources Conservation and Development Commission Hearings on "Emergency Evacuation Plans Associated with Nuclear Power Electric Generating Facilities."

31. U. S. Nuclear Regulatory Commission. Office of Standards Development. Introduction to Regulatory Guide 1.70, Revision 2, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants - LWR Edison." NUREG-75/094, October 1975.

32. NRC Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants."

33. U. S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation. Standard Review Plant. Section 13.3. "Emergency Planning." November 24, 1975.

34. U. S. Environmental Protection Agency. Office of Radiation Programs. "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents." September 1975.

35. Personal Communication, R. Priebe, Industrial Security and Emergency Planning Branch, U. S. Nuclear Regulatory Commission.

36. U. S. Nuclear Regulatory Commission. Office of Standards Development. Annex B. "Implementing Procedures for Emergency Plans." Regulatory Guide 1.101. "Emergency Planning for Nuclear Power Plants." November 1975.

37. J. M. Selby, "Emergency Surveillance — Immediate Evaluation." Presented at a Seminar on Planning for Nuclear Emergencies, Harvard School of Public Health, May 17-2], 1976. See also: J. M. Selby et al. Technological Considerations in Emergency Instrumentation Preparedness, Phase 1 - Current Capabilities Survey, BNWL-1552, Battelle-Northwest, Richland, WA, January 1971; Phase II-A - Emergency Radiological and Meteorological Instrumentation Criteria for Reactors, BNWL-1635, Battelle-North, Richland, WA. May 1972; Phase II-D - Evaluation Testing and Calibration Methodology for Emergency Radiological Instrumentation. BNWL - 1991, Battelle-Northwest, Richland, WA Septermber 1976.

38. Letter from W. Kerr, Chairman, Advisory Committee on Reactor Safeguards, to W. A. Anders, Chairman U. S. Nuclear Regulatory Commission on "Emergency Planning." April 8, 1975.

39. American National Standards Institutue (ANSI). Proposed ANSI Standard - Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation. Working paper: ANSI N13/42 WC6, April 1976.

40. Radiological Incident Emergency Response Planning: Fixed Facilities and Transportation, Interagency Responsibilities. Notice issued by the Federal Preparedness Agency, General Services Administration. Federal Register, Vol. 40, No. 248. December 24, 1975.

41. Nuclear Incident Planning - Fixed Facilities. Notice of Interagency Responsibilities. Issued by the Office of Emergency Preparedness. Federal Register, Vol. 38, No. 16. January 24, 1973.

42. U. S. Nuclear Regulatory Commission. Office of International and State Programs. Guide and Checklist for Development and Evaluation of State and Local Government Radiological Emergency Response Plans in Support of Fixed Nuclear Facilities. NUREG-75/111 (Reprint of WASH-1293, Revision No. 1, 12-01-74).

43. H. E. Collins. The Federal Interagency Radiological Emergency Response Planning Program in Support of Fixed Nuclear Facilities. IEEE Transactions on Nuclear Science, Vol. NS-23, No. 1, February 1976.

44. Personal communication with R. W. DeFayette, Office of State Programs, US NRC.

45. R. W. DeFayette, "Trends in Emergency and Evacuation Planning." Presented at the Atomic Industrial Forum Conference on Nuclear Dialogue for State Regulators, Detroit, Michigan, October 19, 1976.

46. H. E. Collins, "Latest Developments in Emergency Preparedness Planning." 7th Annual National Conference on Radiation Control. "Assuring Radiation Protection" April 27-May 2, 1975 , Hyannis, Mass. U. S. Department of Health Education and Welfare, Publich Health Service, Federal Drug Administration.

47. U. S. Nuclear Regulatory Commission. Office of International and State Programs. Radiological Emergency Response Planning, Handbook for Federal Assistance to State and Local Governments. NUREG-0093/1. June 1976.

48. U. S. General Accounting Office. "Stronger Federal Assistance to States Needed for Radiation Emergency Response Planning." Report to the Congress by the Comptroller General of the United States. March 18, 1976.

49. "Environmental Protection Agency Roles and Responsibilities in Radiological Emergency Response Planning." Statement by J. K. Channell, Chief, Hazardous Materials Branch, EPA, Region IX, San Francisco. Before the California Energy Resources Conservation and Development Commission. San Diego, California, August 23, 1976.

50. U. S. Environmental Protection Agency. Office of Radiation Programs. "Emergency Response Protective Action Guides: Airborne Releases from Fixed Nuclear Facilities." January 1975.

51. U. S. Environmental Protection Agency. Office of Radiation Programs. "Approaches to Population Protection in the Case of Nuclear Accidents." Draft, November 1974.

52. U. S. Environmental Protection Agency. Office of Radiation Programs. Evacuation Risks - An Evaluation. EPA-520/6-74-002. June 1974.

53. Pacific Sierra Club. "The Effectiveness of Sheltering as a Protective Measure Against Nuclear Accidents Involving Gaseous Releases." Draft Final Report. PSR Report 515. This report is currently being reviewed by the Environmental Protection Agency.

54. Pacific Sierra Club. "Evacuation and Sheltering: Protective Measures Against Nuclear Accidents Involving Gaseous Releases." Draft Final Report. PSR Report 517.

55. Personal Communication with J. K. Channell, Chief, Hazardous Materials Branch, Environmental Protection Agency, Region IX, San Francisco.

56. U. S. Department of Defense: Energy Research and Development Administration. Federal Response Plan for Peacetime Nuclear Emergencies. May 3, 1976.

57. Statement by C. D. Jackson, Director, Environment and Safety Division, San Francisco Operations Office U. S. Energy Research and Development Administration. Before the California State Energy Resources Conservation and Development Commission, August 23, 1976.

58. M. H. Dickerson and R. C. Orphan. Atmospheric Release Advisory Capability (ARAC): Development and Plans for Implementation, USAEC Report UCRL-51839, Lawrence Livermore Laboratory, June 5, 1975.

59. Lawrence Livermore Laboratory. Energy and Technology Review. August 1975. UCRL-52000-75-8.

60. U. S. Nuclear Regulatory Commission. Annual Report on Emergency Preparedness, Fiscal Year 1975. Submitted to W. Bray, Jr., Director Federal Preparedness Agency, General Services Administration, by L. V. Gossick, Executive Director for Operations; US NRC. November 13, 1975.

61. Personal Communication. H. E. Collins. Office of State Programs. U. S. Nuclear Regulatory Communication.

62. Status Report on Federal Emergency Response Planning Effort. C. K. Beck, Moderator, US AEC, C. L. Weaver, Office of Radiation Programs, EPA, Sanders, Federal Disaster Assistance Administration, C. Siebentritt, Defence Civil Preparedness Agency, E. C. Anderson, Bureau of Radiological Health, FDA. From: "6th Annual NATIONAL CONFERENCE ON RADIATION CONTROL - NEW CHALLENGES." April 28-May 2, 1974, San Antonio, Texas. USDHEW, PHS, FDA (October 1974) Publication (FDA) 85-8010.

63. U. S. Energy Research and Development Administration. Division of Operational Safety - Headquarters. Radiological Assistance Plan. July 1975. ERDA-60.

64. W. L. Smalley, "The ERDA Radiological Assistance Program." Nuclear Safety, Vol. 16, No. 3, May-June, 1975. ppm 345-353.

65. California Office of Emergency Services. "Responsibilities in the Event of a Nuclear Power Plant Accident Involving an Off-site Release of Radioactive Material." Statement submitted to L. Forrest, Executive Director, Energy Resources Conservation and Development Commission (California). August 20, 1976.

66. Agreement between the United States Atomic Energy Commission and the State of California for Discontinuance of Certain Commission Regulatory Authority and Responsibility within the State Pursuant to Section 274 of the Atomic Energy Act of 1954, as Amended. April 11, 1962.

67. Memorandum of Understanding. Executed between the State Department of Health and the Office of Emergency Services. (California).

68. Letter from C. Manfred, Director, California Office of Emergency Services to L. Forrest, Executive Director, California Energy Resources Conservation and Develop,ent Commission. August 20, 1976.

69. California Office of Emergency Services, Radiological Section. Department of Health, Radiologic Health Section. Nuclear Power Plant Emergency Response Plan. July 1976.

70. J. A. Auxier and R. O. Chester edited. Report of the Clinch Valley Study, May 15-June 2, 1972. ORNL-4835, Oak Ridge National Laboratory, January ;973.

71. California Government Code, Title 2, Division 1, Chapter 7 (as amended). Effective January 1, 1975.

72. Personal Communication with D. Maestretti, California. Office of Emergency Services.

73. U. S. Nuclear Regulatory Commission. Title 10, Chapter 1, Code of Federal Regulations - Energy. Part 20. "Standards for Protection Against Radiation."

74. Personal Communication with J. Kearns, California Office of Emergency Services.

75. Testimony of E. Blizzard, Office of Emergency Services, in the matter of "Emergency Response and Evacuation Plan," before the California Energy Resources Conservation and Development Commission. Eureka, California. September 28, 1976.

76. California. Office of Emergency Services. "OES Questioned and Answers on Nuclear Reactor Emergency Planning." Submitted to the Energy Resources Conservation and Development Commission. August 1976.

77. Southern California Edison Company. Statement of Emergency Planning for Nuclear Generating Facilities. Submitted to the California Energy Resources Consevation and Development Commission. August 13, 1976.

78. California Unified San Diego County. Emergency Services Organization. Nuclear Power Plant Emergency Response Plan, July 1975.

79. United States Marine Corps. Annex K. Appendix 3. "Radiological Emergency Response Plan." Emergency Response Plan, Marine Corps Base, Camp Pendleton, California. 1-74.

80. Evacuation Plan, San Onofre Nuclear Generating Station. Developed jointly by representatives of State of California, Office of Emergency Services; Orange County, Office of Emergency Services and Appropriate County Agencies; Unified San Diego County, Office of Emergency Services and Appropriate County Agencies; United States Marine Corps, Camp Pendleton; State of California, Dept. of Parks and Recreation; Southern California Edison Company. June 1975.

81. See Testimony of L. H. Hicks. In the Matter of: Emergency Evacuation Plans Associated with Nuclear Powered-Electric Generating Facilities. Hearings before a Committee of the State Energy Resources Conservation and Development Commission. San Diego, California. August 23, 1976; and testimony of J. Kearns, October 7, 1976.

82. Pacific Gas and Electric Company. Responses to Questions and Answers on Emergency Evacuation Planning. Submitted to the California Energy Resources Conservation and Development Commission in the matter of "Emergency Evacuation Plans Associated with Nuclear Powered Electric Generating Facilities." September 29, 1976.

83. California County of Humboldt. Office of Emergency Services. Contingency Plan - Nuclear Reactor, Humboldt Bay. March 1976.

84. Testimony of E. Chambers, Coordinator of the Office of Emergency Services, County of Humboldt. In the matter of: Emergency Responses and Evacuation Plan. Hearing, State Energy Resources Conservation and Development Commission. Eureka, California. September 28, 1976.

85. Sacramento Municipal Utility District. Final Safety Analysis Report for Rancho Seco Nuclear Generating Station.

86. California. County of San Luis Obispo. Emergency Evacuation Plan. October 19, 1976.

87. California. County of San Luis Obispo. Emergency Evacuation Plan. October 19, 1976.

88. Pacific Gas and Electric Company. Amendment 5. Section 13.3. "Emergency Planning." Final Safety Analysis Report, Units 1 and 2, Diablo Canyon Site. March 1974.

89. Personal Communication with H. North, Office of Inspection and Enforcement, Region V, USNRC.

90. California Public Resources Code, Section 25500, as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act.)

91. Personal Communication with Facilities Siting Staff, California Energy Resources Conservation and Development Commission.

92. California Public Resources Code, Section 25528 (a), as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act.)

93. California Public Resources Code, Section 25528 (b), as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act).

94. California Public Resources Code, Section 25528 (c), as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act.)

95. California Public Resources Code, Section 25528 (d), as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act).

96. California Public Resources Code, Section 25532, as amended May 21, 1974. (Warren-Alquist State Energy Resources Conservation and Development Act).

97. California. Energy Resources Conservation and Development Commission. Facility Siting Division. "Staff Report on Criteria for Data Adequacy Determination of Notice of Intent" 4/26/76.

98. California Energy Resources Conservation and Development Commission. Notice of Hearings on Emergency Response and Evacuation Plans. Order No. 76-628-7, as amended. June 28, 1976.

99. California Energy Resources Conservation and Development Commission. Notice of Hearings on Emergency Response and Evacuation Plans. Order No. 76-SIT-1. May 12, 1976.

100. California Energy Resources Conservation and Development Commission. Questions on Emergency Evacuation Planning. July 26, 1976.

101. U. S. Atomic Energy Commission. Appendix A. Proposed Policy Statement and Regulatory Guide. Press Release T-160. "AEC Makes Public Staff Working Paper on Population Density Around Nuclear Power Plant Sites." April 9, 1974.

102. J. R. Buchanan, "AEC Working Paper on Population Density Around Nuclear Power-Plant Sites." Nuclear Safety, Vol. 16, No. 1, January-February 1975, pp. 1-7.

103. Introduction, U. S. Nuclear Reactor Siting, J. R. Buchanan edited, Oak RidgeNational Laboratory, June 1976. See also H. N. Culver, "Effect of Engineered Safeguards on Reactor Siting." Nuclear Safety, Vol. 7,No. 3, Spring 1966, pp. 342-346; H. B. Piper and F. A. Heddleson, "Siting Practice and Its Relation to Population," Nuclear Safety, Vol. 14, No. 6, November-December 1973, pp. 576-584.

104. U. S. Environmental Protection Agency. Office of Radiation Programs, The Comparative Risk Perspective for Setting Protective Action Guides. January 1975.

105. Oak Ridge National Laboratory, Health Physics Division. Appendix II. "European and United States Power Reactor Emergency Programs." Report of the Clinch Valley Study, May 15-June 2, 1972. Edited by J. A. Auxier and R. O. Chester. ORNL-4835, UC-41-Health and Safety. January 1973.

106. Personal Communication with J. Bresee, Energy Research and Development Administration.

107. J. Linnerooth, "Methods for Evaluating Mortaility Risk." Futures, August 1976.

APPENDIX A: SITE POPULATION FACTOR

Several techniques may be used for detailed analysis of population distribution. The purpose of this Appendix is to indicate briefly the utility of the "site population factor" as compared with more elementary approaches. One such approach is to draw a curve of the cumulative population for the individual site under consideration and compare that curve with those for previously-licensed high-density sites on a case by case basis. Another — the population point density technique — is to divide the area into a grid and average the population distribution within each grid, then locate the reactor site in the relatively low density areas. A third technique is to average the cumulative population over radial distances for a reactor site.[1]

However, these elementary techniques do not offer sufficient information to provide a precise basis for the comparison of alternative sites. Specifically, they do not respond to the question of whether a high-density population segment 30 to 40 miles from a proposed site should be considered as significant as a high-density population segment close to the site. To address this, the NRC Regulatory Staff has developed a population index, designated as the Site Population Factor (SPF), which weights cumulative population with a function that is inversely related to the distance from the proposed reactor site. According to the weighting, a population close to the site would be considered to present a higher risk than the same population farther away. The following explanation of the SPF is excerpted from Kohler *et al*, "Population Distribution Considerations in Nuclear Power Plant Siting."[1,2]

In computing the SPF, discrete annular ring elements of population are weighted by a decreasing function of distance. The total weighted population within a boundary radius is then normalized for numerical convenience to an area having a uniform population of 1000 people per square mile. Thus, a site having an SPF equal to 0.3 within a boundary radius of 30 miles, SPF(30) = 0.3, is numerically equivalent to having 300 perople per square mile uniformly distributed out to a distance of 30 miles from the site. The SPF concept thereby allows a population distribution skewed in the radial direction to be compared with a uniform population distribution.

The weighting factor selected for study was distance r from the reactor site, raised to the -1.5 power ($r^{-1.5}$). It was derived from an analysis of meteorological dispersion data representative of several sample sites. An examination of the meteorological dispersion graphs in Regulatory Guide 1.4 for short-term diffusion, as well as typical annual dilution factors, indicated that the choice of $r^{-1.5}$ was a good representation of the approximate distance dependence of the diffusion of released radioactivity from the emission point.

The site population factor (SPF) for a reactor site is defined as

$$SPF(r_n) = \frac{\sum_{J=1}^{n} W(J) * P(J)}{\sum_{J=1}^{n} W(j) * P_o(J)} , \qquad (1)$$

where

r_n = "boundary radius," i.e. the outer radius of the largest annular circle

$W(J)$ = weighting factor for the Jth annular ring

$P(J)$ = population in the Jth annular ring

$P_o(J)$ = population in the Jth annular ring of a hypothetical (normalizing) population distribution

In Equation (1) the Jth annular ring has inner radius r_{J-1} and outer radius r_J. The annular ring for J=1 is a circle of radius r_1 with the center at the geographical coordinates of the nuclear power reactor site.

The weighting factors, as indicated above, are defined as:

$$W(J) = r_J^{-1.5} . \qquad (2)$$

The SPF is normalized to a uniform population distribution of 1000 people per square mile. Thus,

$$P_o(J) = 1000 \pi (r_J^2 - r_{J-1}^2) , \qquad (3)$$

where r_J, r_{J-1} are in miles.

Substituting the weighting and normalizing factors into Equation (1), the SPF may be expressed as

$$SPF = \frac{\sum_{J=1}^{n} r_J^{-1.5} P_J}{1000 \pi \sum_{J=1}^{n} r_J^{-1.5} (r_J^2 - r_{J-1}^2)} . \qquad (4)^*$$

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*A modified equation based on the SPF using local meteorological data in the calculation of population risk is presented in ref. 3.

Figure A-1 shows graphically the dependence of the SPF on the radial distance from reactor location of a fixed number of people.

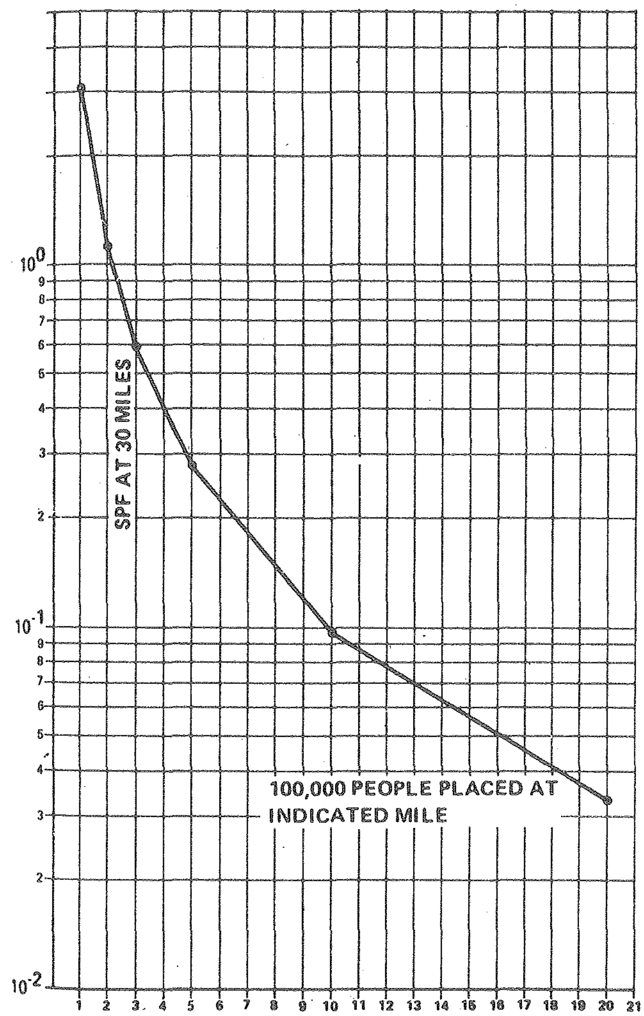

Figure A-1 SPF DISTANCE DEPENDENCE

The SPF for a 30 mile boundary radius, SPF(3), has been calculated for a hypothetical site which has a total population of 100,000 people placed at various radial distances from the site. It can be seen that the presence of 100,000 people close to the site yields a larger calculated SPF(30) than the same population place farther away. Figure A-1 also demonstrates the difference between cumulative density and SPF. While the cumulative population density for 100,000 people within a circle of radius 30 miles is always the same regardless of the location of the people within thirty miles, the SPF(30) is higher when the 100,000 people are close to the site.

Using the SPF, Kohler *et al*[2] characterized existing reactor sites into five representative groups, on the basis of existing plants, as shown in figure A-2.

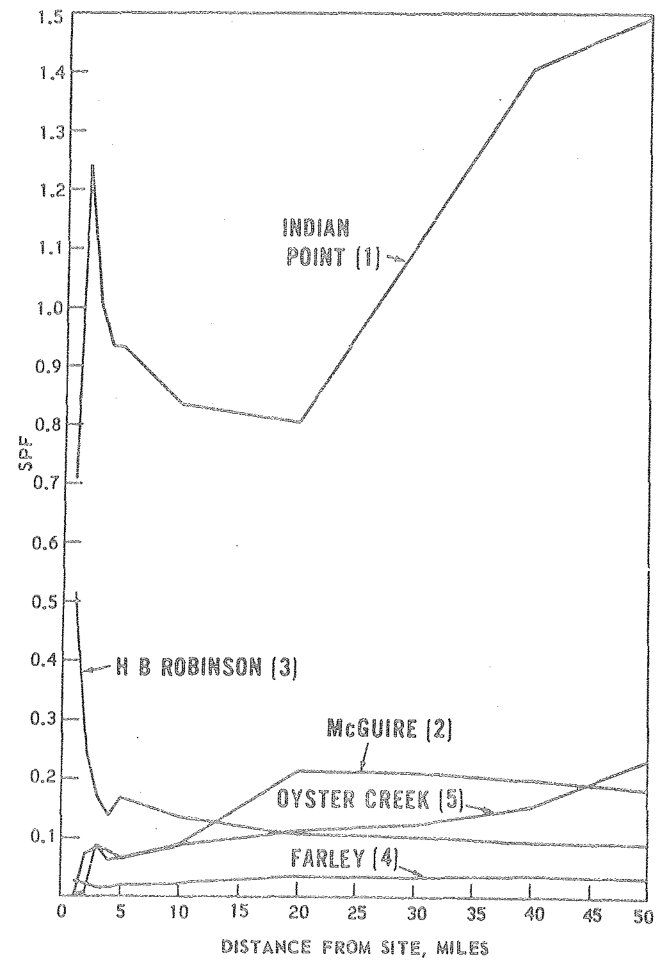

Figure A-2 REPRESENTATIVE SPF GROUPS

Group 1 contains the sites in close proximity to metropolitan areas with SPF values of 1.00 or more. Group 2 contains sites that encounter a large city 10 to 30 miles away and have maximum SPF values of 0.3. Group 3 includes sites that are in relatively unpopulated areas but that have a small town 1 to 5 miles from the reactor site. For Group 3, the SPF generally peaks in the 1 to 4 mile region and then drops to a constant level of 0.3. Group 4 contains sites in unpopulated areas, the SPFs of which remain constant at 0.3 or less. Finally, Group 5 contains those sites that encounter large metropolitan areas in the 40 to 50 mile region. The SPF curve of this category is an increasing function to that distance.

In addition, through the Oak Ridge National Laboratory (ORNL) computer capabilities, two-dimensional representations of the SPF index were generated for the continental United States. SPFs were calculated at the intersection of each 0.1 degree latitude and longitude line for densely populated areas, and at the intersection of each 0.25 degree latitude and longitude line for low density areas, corresponding to subareas of 2.65 miles by 3.45 miles at latitude 40 deg. N. The entire country was subdivided into seven regions and SPF maps were generated for the population distribution within distances of 20, 30, and 40 miles from the intersection of each fractional latitude and longitude line. From the SPF maps, Table A-1 was constructed describing the total area within each region and the percent of land area of a region enclosed within an SPF contour line of a given value. Upon examination of Table A-1, Kohler *et al* observed that there is significant land area, even within the densely populated northeast, with population distributions attractive to nuclear power plant siting.

Figure A-3 shows Region 7 (Utah, Arizona, Nevada, California) Population Density with contour lines equal to 200, 400, 600, 1000 people per square mile. It should be noted that the result of weighting the cumulative population as a decreasing function of distance allows the inclusion of adjacent low population density or high population density areas within the same SPF contours. Figure A-4 shows Region 7 SPF at 30 miles. It seems to indicate that there are large regions in California with low SPF(30), a fact that is undoubtedly true considering the large rural, mountain, and forested areas of the state.

Table A-1 REGIONAL POPULATION DISTRIBUTION

Region	Total Area (square miles)	SPF (r_n)	$r_n = 20$ Area Within SPF Contour (square miles)	Percent of Total Area	$r_n = 30$ Area Within SPF Contour (square miles)	Percent of Total Area	$r_n = 40$ Area Within SPF Contour (square miles)	Percent of Total Area	Population Density (per square mile)	Area with Population Density Greater than (square miles)	Percent of Total Area
1	155 748	0.2	47 800	31	53 200	34	55 700	36	200	32 500	21
		4.4	25 900	17	27 300	18	28 700	18	400	19 000	12
		0.5	20 600	13	22 000	14	22 000	14	600	14 000	9.0
		0.7	14 300	9	15 500	10	15 900	10	1000	9 500	6.1
		1.0	8 800	6	9 000	6	9 200	6			
2	300 680	0.2	82 500	27.4	89 500	29.8	93 700	31.2	200	57 700	19.2
		0.4	42 700	14.2	42 600	14.2	44 400	14.8	400	32 100	10.7
		0.5	34 100	11.3	33 600	11.2	32 900	10.9	600	23 700	7.9
		0.7	21 900	7.3	23 000	7.6	22 600	7.5	1000	15 900	5.3
		1.0	15 600	5.2	15 300	5.1	15 300	5.1			
3	330 518	0.2	31 500	9.5	29 800	9.0	24 300	7.35	200	30 300	9.17
		0.4	12 800	3.9	9 090	2.75	6 330	1.92	400	14 900	4.5
		0.5	8 810	2.7	4 800	1.45	3 310	1.00	600	10 100	3.06
		0.7	3 280	0.99	2 540	0.77	1 290	0.39	1000	6 170	1.87
		1.0	1 537	0.47	1 290	0.39	516	0.16			
4	468 222	0.2	37 200	7.9	38 200	8.16	41 600	8.88	200	28 400	6.07
		0.4	15 500	3.3	15 400	3.29	16 100	3.44	400	15 200	3.25
		0.5	11 900	2.5	12 400	2.65	12 600	2.69	600	11 100	2.37
		0.7	8 170	1.74	8 390	1.79	7 500	1.60	1000	7 490	1.60
		1.0	5 300	1.13	5 070	1.08	5 300	1.13			
5	803 751	0.2	28 400	3.53	28 600	3.56	26 500	3.30	200	27 100	3.37
		0.4	13 100	1.63	11 000	1.37	7 810	0.97	400	15 000	1.87
		0.5	9 740	1.21	7 550	0.94	5 580	0.69	600	11 000	1.37
		0.7	5 820	0.72	4 840	0.60	3 640	0.45	1000	7 190	0.89
		1.0	3 870	0.48	2 450	0.30	1 690	0.21			
6	489 722	0.2	7 060	1.44	7 670	1.16	7 040	1.44	200	7 309	1.49
		0.4	2 470	0.5	2 470	0.50	2 050	0.42	400	3 930	0.80
		0.5	2 470	0.5	2 050	0.42	1 420	0.29	600	2 900	0.59
		0.7	1 420	0.29	1 220	0.25	818	0.17	1000	1 890	0.39
		1.0	818	0.17	609	0.12	201	0.04			
7*	461 763	0.2	21 400	4.63	21 500	4.66	23 100	5.00	200	13 000	2.82
		0.4	10 900	2.36	11 300	2.45	12 300	2.66	400	8 520	1.85
		0.5	9 170	1.99	9 700	2.10	9 710	2.10	600	6 780	1.47
		0.7	7 270	1.57	7 030	1.52	7 290	1.58	1000	5 170	1.12
		1.0	5 100	1.10	4.860	1.05	4 130	0.89			
Total	2 863 316	0.2	255 860	8.94	268 000	9.36	272 000	9.50	200	196 000	6.85
		0.4	123 400	4.31	119 000	4.16	118 000	4.12	400	109 000	3.81
		0.5	96 800	3.38	92 100	3.22	87 500	3.06	600	79 600	2.78
		0.7	62 200	2.17	62 500	2.18	59 000	2.06	1000	53 300	1.86
		1.0	41 000	1.43	38 600	1.35	36 300	1.27			

Source: J.E. Kohler, A.P. Kenneke, and B.K. Grimes. "Population Distribution Considerations in Nuclear Power Plant Siting." Nuclear Technology, Vol. 25, April 1975.

* Region 7: Utah, Arizona, Nevada, California.

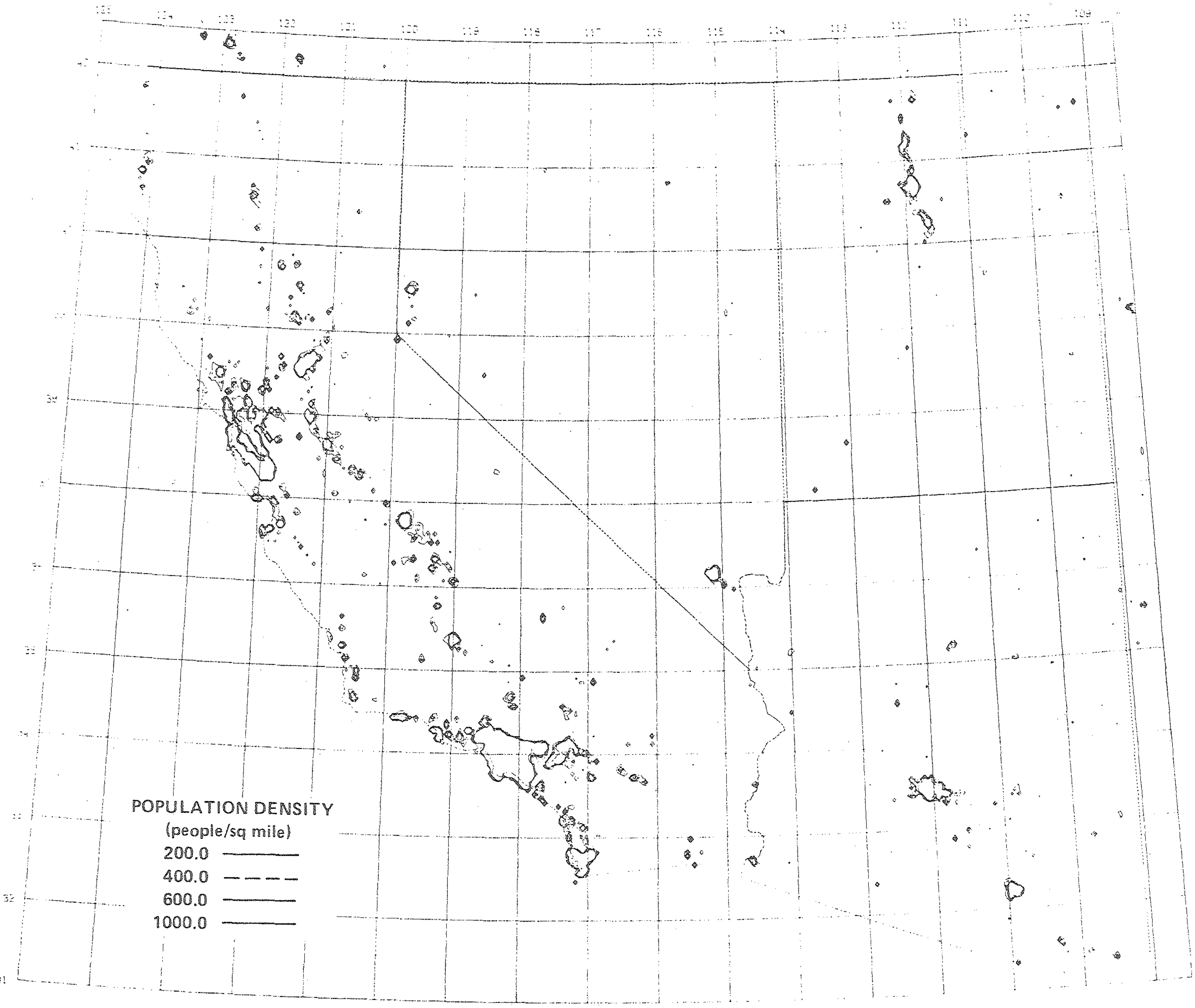

Figure A-3 REGION 7 POPULATION DENSITY

Source: J.E. Kohler, A.P. Kenneke, B. Grimes. Technical Report on a Technique for Consideration of Population in Site Comparison. WASH-1235, October 1974.

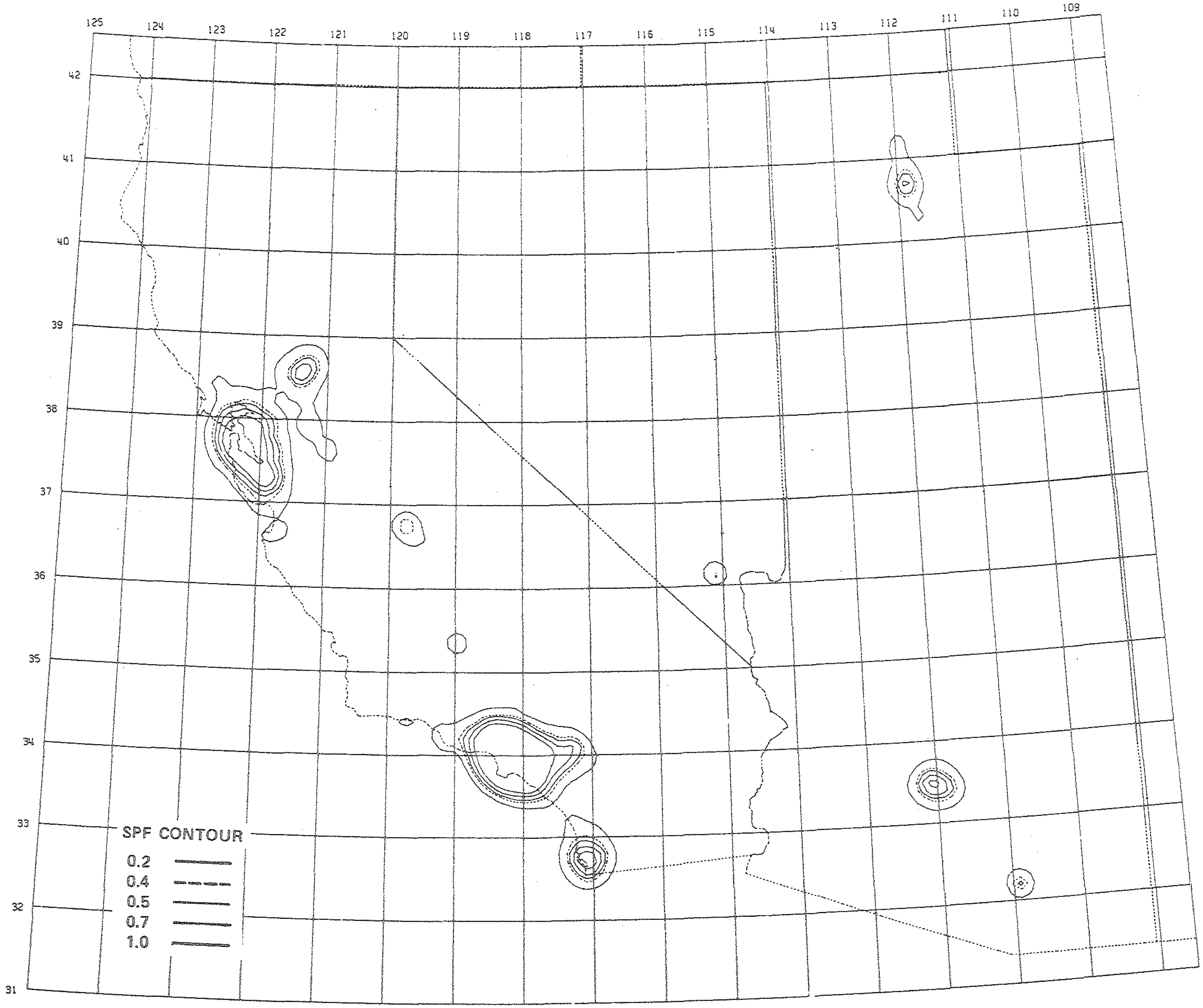

Figure A-4 REGION 7 SPF AT 30 MILES

Source: J.E. Kohler, A.P. Kenneke, B. Grimes. Technical Report on a Technique for Consideration of Population in Site Comparison. WASH-1235, October 1974.

References for Appendix A.

1. J. E. Kohler, A. P. Kenneke, and B. K. Grimes, "Population Distribution Considerations in Nuclear Power Plant Siting." Nuclear Technology, Vol. 25, April 1975 pp. 617-625. (U. S. Atomic Energy Commission, Directorate of Licensing, Washington, C.C. 20545).

2. See also: U. S. Atomic Energy Commission. Press Release T-160. "AEC Makes Public Staff Working Paper on Population Density Around Nuclear Power Plant Sites." April 9, 1974. Staff Paper: Population Distribution around Nuclear Power Plant Sites. April 17, 1973.

   Appendix B.I. Previous Metropolitan Site Reviews. II. Distance Versus Engineered Safety Features. III. Population Data for Existing Sites. IV. Site Population Factor (SPF). V. SPF Categories for Presently Docketed Plants.

   U. S. Atomic Energy Commission. Directorate of Licensing. Technical Report on A Technique for Consideration of Population in Site Comparison. WASH-1235. October 1974.

3. C. S. Kang, and R. P. Siu. "Site Population Evaluation." Transactions of the American Nuclear Society, 22 November 1975, pp. 511-512.

4. H. N. Culver. "Effect of Engineered Safeguards on Reactor Siting." Nuclear Safety, Volume 7,Number 3, pp. 342-346; Spring (1966).

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