Lecture 4.36

Site Selection Criteria for Nuclear Power Plants

Agenda

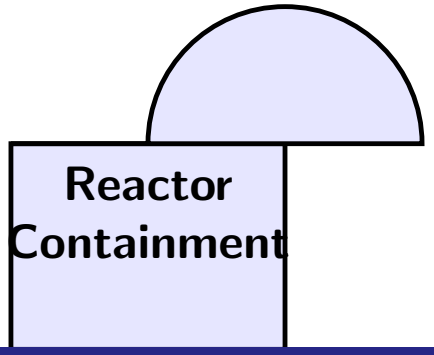
- 1. Introduction and Primary Objectives of Siting
- 2. Geological and Seismological Considerations
- 3. Hydrological Requirements and Flooding Protection
- 4. Meteorological Factors and Atmospheric Dispersion
- 5. Population Distribution and Emergency Planning Zones (EPZ)
- 6. Grid Connectivity and Transportation Infrastructure
- 7. Environmental Impacts and Regulatory Frameworks

Introduction to Nuclear Siting

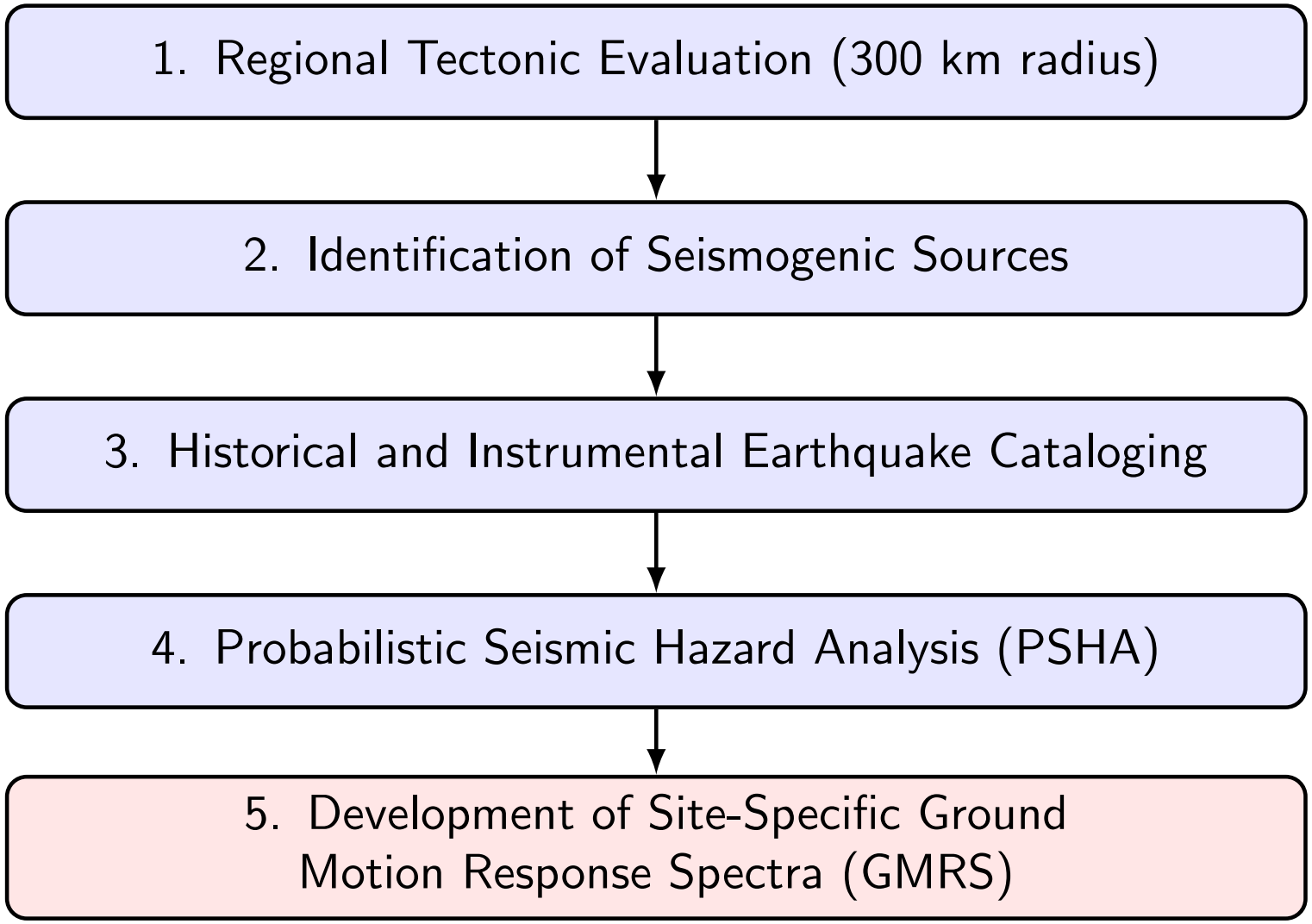
- **Primary Objective:** Ensure public safety and minimize environmental impact during normal operation and postulated accident conditions.
- Unlike thermal plants, nuclear plants cannot be sited purely on economic grounds (e.g., proximity to fuel source or load centers).
- **Defense-in-Depth** philosophy applies to siting: the site itself acts as the first barrier by providing geographic isolation and favorable natural characteristics.
- **Life-cycle approach:** The site must remain suitable for the entire plant life (60+ years) and through the decommissioning phase.

Geological and Seismological Criteria

- **Foundation Stability:** Requires competent bedrock with high bearing capacity to support massive structures like the reactor containment building.
- **Fault Avoidance:** Sites must be sufficiently distant from capable geological faults to preclude surface faulting and severe ground motion.
- **Seismic Design Basis:** Derivation of the Safe Shutdown Earthquake (SSE) and Operating Basis Earthquake (OBE) specific to the site.
- **Soil Mechanics:** Comprehensive evaluation of soil liquefaction potential, subsidence, and slope stability under dynamic seismic loading.

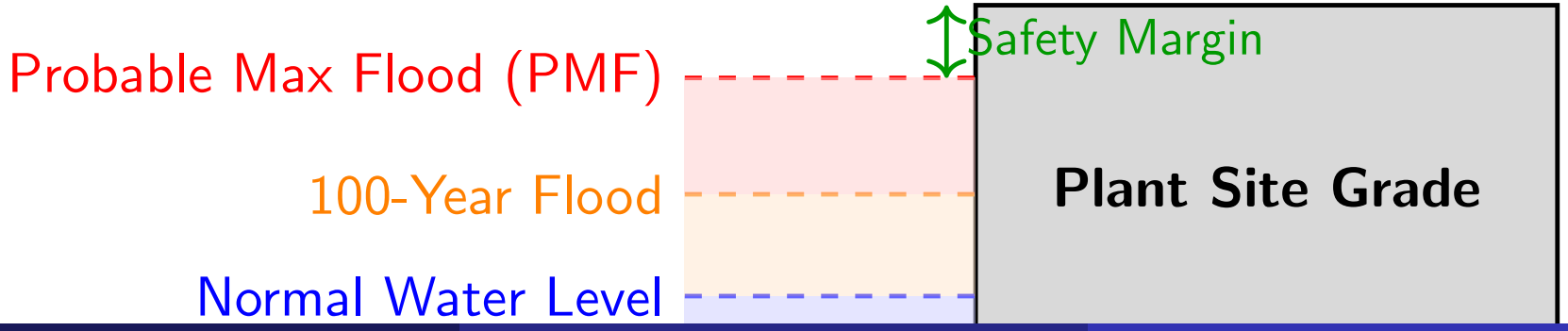


Seismic Hazard Assessment Process



Hydrological Criteria

- **Cooling Water Demand:** Requires massive and continuous water supply for condenser cooling (often > 1 million gallons per minute for a large plant).
- **Reliability of Source:** Source (ocean, large lake, major river) must be reliable even under extreme drought conditions (historical low flow).
- **Ultimate Heat Sink (UHS):** Must guarantee at least a 30-day supply of cooling water for safe shutdown during a loss of normal heat sink event.
- **Flooding Protection:** Site grade must be elevated above the Probable Maximum Flood (PMF), accounting for dam failures, seiches, tsunamis, and storm surges.



Meteorological Considerations

Atmospheric Dispersion

Evaluation of local micro-climate, wind speeds, and atmospheric stability classes (Pasquill-Gifford) to model the dispersion of routine and accidental radioactive effluents.

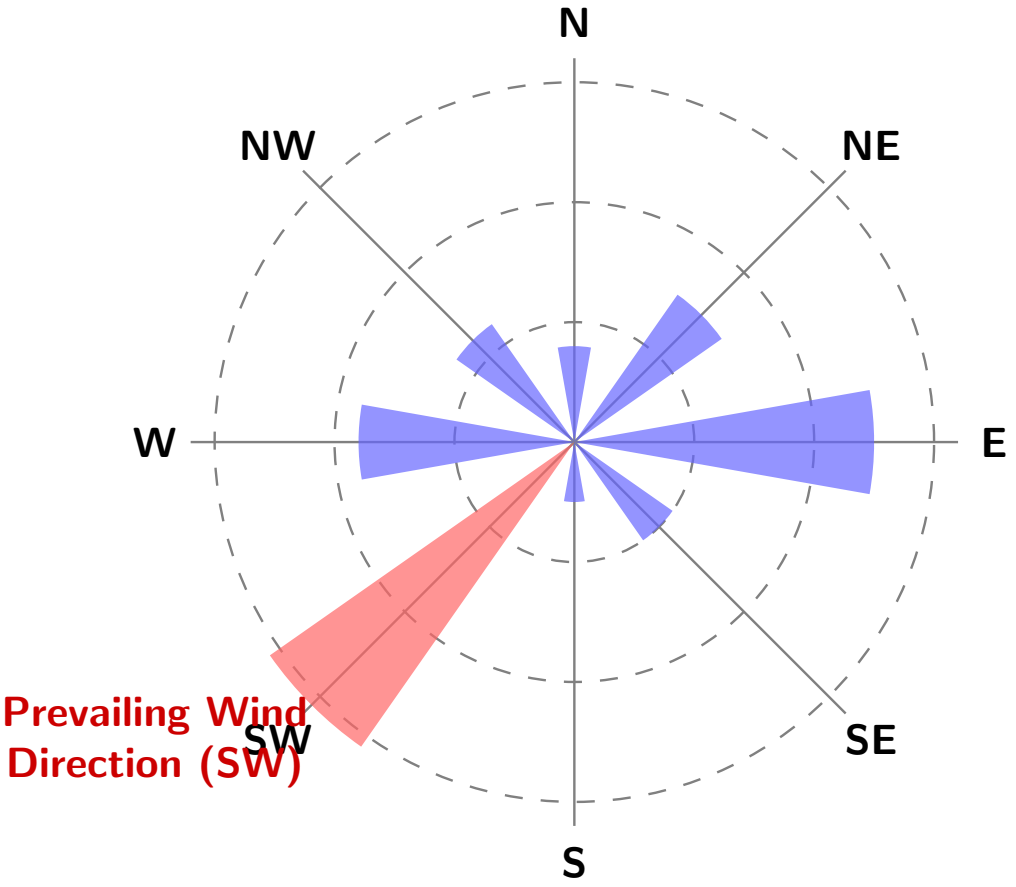
Extreme Weather

Designing against site-specific extreme events including tornadoes (evaluating wind pressure and missile impact), hurricanes, and extreme snow/ice loading.

- **Temperature Extremes:** Affects the efficiency of the cooling systems and the sizing of HVAC systems for safety-critical areas.
- **Topographical Effects:** Valleys or coastal terrains can cause localized wind channeling or stagnation, affecting plume trajectories.

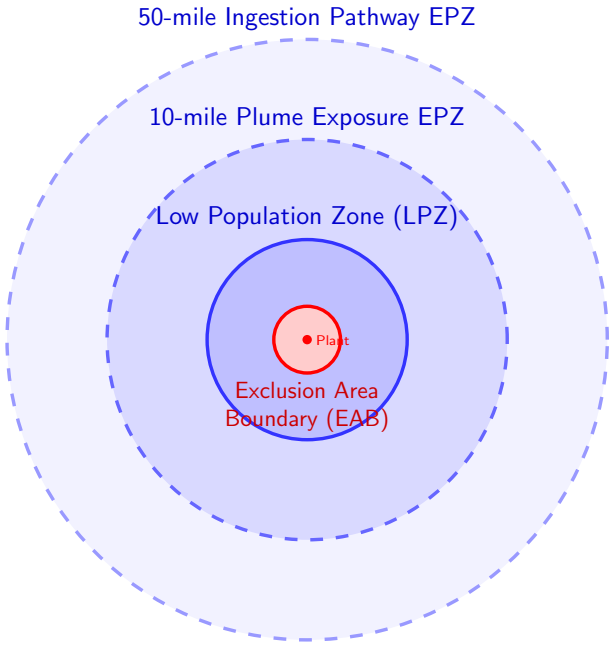
Wind Rose and Dispersion Modeling

- **Wind Rose Plot:** Shows frequency of wind direction and speed over long periods.
- Correlating wind patterns with demographic data.
- Identifying the 'sector of highest concern' for emergency planning.



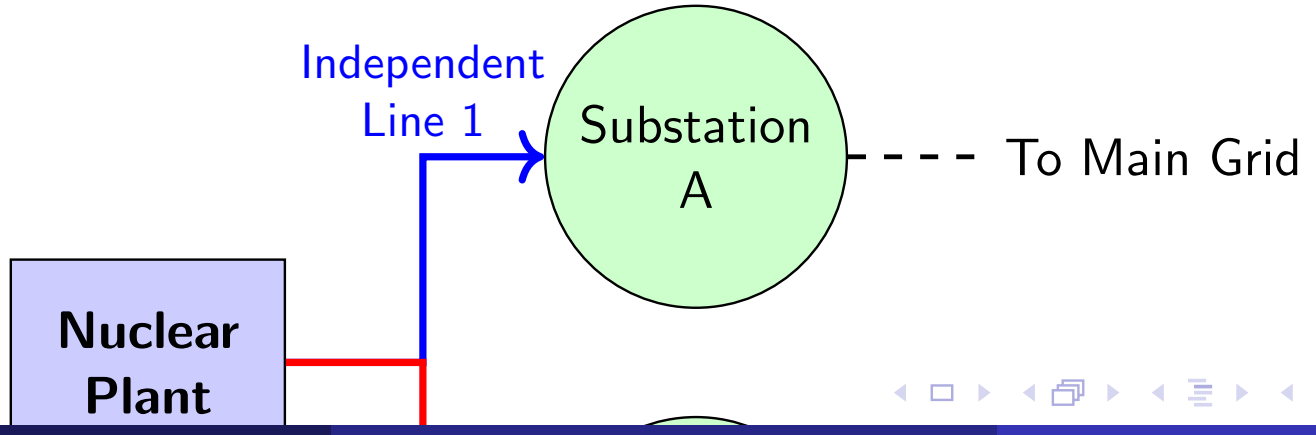
Population Distribution and EPZs

- **Exclusion Area Boundary (EAB):** Immediate area around the plant where the licensee has complete authority to determine all activities and remove personnel.
- **Low Population Zone (LPZ):** Surrounding area containing a population low enough to allow for effective evacuation or sheltering before allowable radiation dose limits are exceeded.
- **Population Center Distance:** Distance to a dense population center ($> 25,000$ residents) must be at least 1.33 times the distance to the LPZ boundary.
- **Emergency Planning Zones:** 10-mile Plume Exposure Pathway EPZ and 50-mile Ingestion Pathway EPZ (FDA/EPA guidelines).



Grid Connectivity & Off-Site Power

- **Proximity to Load Centers:** Balancing the need to be away from populations with the economic penalty of long-distance EHV transmission.
- **Grid Stability:** The local grid must be robust enough to handle a sudden trip of a large 1000+ MW nuclear unit without cascading failure.
- **Reliable Off-Site Power:** Safety systems require power. The site must have at least two physically independent grid connections to minimize the risk of a Station Blackout (SBO).
- **Right-of-Way (RoW):** Feasibility of acquiring land for wide transmission corridors.



Transport and Access Infrastructure

- **Heavy Component Transport:** Nuclear construction involves massive components (Reactor Pressure Vessel ∼500 tons, Steam Generators).
- **Waterborne Transport:** Proximity to navigable waterways or deep-water ports is highly advantageous for barge transport of heavy forgings.
- **Rail and Road:** Robust rail links and highway access required for construction materials and eventual transport of spent nuclear fuel.
- **Emergency Access:** Multiple reliable access routes required for emergency response teams to reach the site under adverse conditions.

Environmental and Ecological Impact

Thermal Pollution & Marine Life

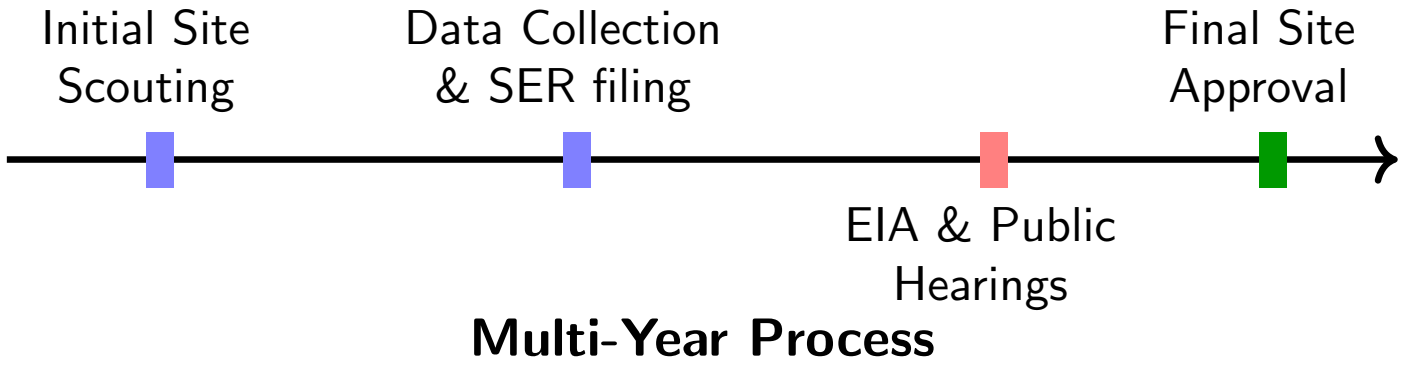
- Large volumes of heated cooling water discharged back to the source can disrupt local aquatic ecosystems. Mitigation via cooling towers or large cooling ponds.
- **Impingement and Entrainment:** Intake structures must be designed to minimize trapping fish (impingement) and drawing in small organisms (entrainment).

Ecological Baseline

- **Baseline Radiation:** Extensive pre-operational monitoring to establish background radiation levels for future comparison.
- **Flora and Fauna:** Avoidance of ecologically sensitive areas, wetlands, and habitats of endangered species.

Regulatory Framework and Licensing

- **Stringent Approval Process:** Siting is governed by national nuclear regulators (e.g., AERB in India, NRC in USA) and environmental ministries.
- **Site Evaluation Report (SER):** A massive, multi-volume document detailing every geological, meteorological, and demographic aspect of the site.
- **Environmental Impact Assessment (EIA):** Mandatory public hearings and stakeholder consultations.
- **Early Site Permit (ESP):** In some jurisdictions, a site can be approved for a nuclear plant independently of the specific reactor design chosen.



Summary

- Nuclear site selection prioritizes safety and defense-in-depth above all economic factors.
- Geology must provide a stable, fault-free foundation capable of withstanding severe earthquakes.
- Hydrology demands a massive, ultra-reliable water source while ensuring absolute protection from extreme flooding.
- Meteorology and demography dictate atmospheric dispersion characteristics and necessitate strict Emergency Planning Zones.
- The process is heavily regulated, requiring extensive environmental and social impact assessments.

Next Lecture Preview

- **Topic:** Nuclear Waste Management and Disposal
- Classification of radioactive waste (Low, Intermediate, High Level).
- Spent nuclear fuel storage (Spent Fuel Pools vs. Dry Cask Storage).
- Long-term geological repositories (e.g., Yucca Mountain, Onkalo).
- Reprocessing and closed fuel cycles.