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Vogtle ESP Mandatory Hearing

March 23-25, 2009

NRC Staff Presentation Topic #2

Radiological Impacts

(Safety Review)

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Presenters:

Charles Kincaid, Ph.D., PNNL

Hosung Ahn, Ph.D., NRC

Division of Site and Environmental Reviews

Hydrologic Engineering Branch

Office of New Reactors

Purpose of Presentation

- Review the Staff's analysis of release and transport of radioactive liquid effluent under postulated accident conditions
- Focus: How the staff assured results were conservative
- Included are remarks on
  - Sequence of the review
  - Relevant site hydrology
  - Site characteristics that impact transport
    - Model parameters versus on-site measurements
  - Transport paths – post-construction
    - Effluent release points
    - Plausible pathways
    - Compliance points
  - Analysis & Assurance of Conservative Results

Staff – Sequence of Review

- Site Audit and RAIs
  - Challenged the applicant's concept of a single pathway to Mallard Pond draining to the Savannah River.
  - Sought information on use and presence of chelating agents.
- Plausible Alternative Conceptual Models
  - Performed review of the groundwater model for the water table aquifer – submitted by SNC in response to Open Items 2.4-2, 2.4-3 & RAIs.
    - January 2008 version – Public meeting at NRC HQ in April
    - June 2008 version – RAIs sent July 22
    - August 2008 version – Used as basis for final review
  - From the model files submitted, Staff selected a base case model that most closely represented the measured water table – then modified it slightly (drain elevations & conductivity) – for independent confirmation.
- Performed sensitivity analyses – based on post-construction recharge distributions.

Staff Reviews to Assure a Plausible Pre-Construction Conceptual Model

- Relevant Site Hydrology Reviewed
  - Land Surface: reviewed use of LiDAR and DEM data sets
    - LiDAR – Light Detection and Ranging
    - DEM – Digital Elevation Model
  - Aquifer base: reviewed use of top of Blue Bluff Marl (BBM)
  - Boundary Conditions (BC)
    - Drain BC – outcrop of BBM and streambeds - elevation, conductance
    - Constant Head BC – ponds, perennial wetlands
  - Hydraulic conductivity distributions and magnitude
    - Influence of the Utley limestone and engineered backfill
  - Recharge distributions and magnitude
    - Influence of the surface, slope, structures, vegetation
  - Reviewed SNC's combinations of hydraulic conductivity and recharge (space & magnitude), & the selection of representative values

Staff Review: Site Characteristics Important to Transport (1)

- Topography: LiDAR and DEM data sets examined and utilized
- Top of Blue Bluff Marl: Site investigation data from Units 1&2, Units 3&4
- Hydraulic Conductivity: On-site Measured Values
  - Barnwell Group sands, silts & clays 0.03 to 0.8 ft/day – Units 1&2 site investigation
  - Barnwell Group sands, silts & clays 0.12 to 2.65 ft/day – Units 3&4 site investigation
  - Utley limestone 0.3 to 343 ft/day – Units 1&2 site investigation
  - Engineered backfill 1.3 to 3.3 ft/day – post Units 1&2 construction
- Hydraulic Conductivity: Applied numerous zonations & magnitudes in models
  - Barnwell zone northwest/southeast of ridge on which plants are constructed; lower values, tested range from 12 to 34 ft/day
  - Barnwell zone south of proposed Units 3&4; lowest values; tested values as low as 5 ft/day
  - Ridge top where the Utley limestone causes higher values; tested values up to 65 ft/day
  - South of (above) Mallard Pond where the Utley limestone results in a cave; tested up to 400 ft/day
  - Engineered backfill at Units 1&2 and post-construction at Units 3&4; tested measured range of values from 1.3 to 3.3 ft/day

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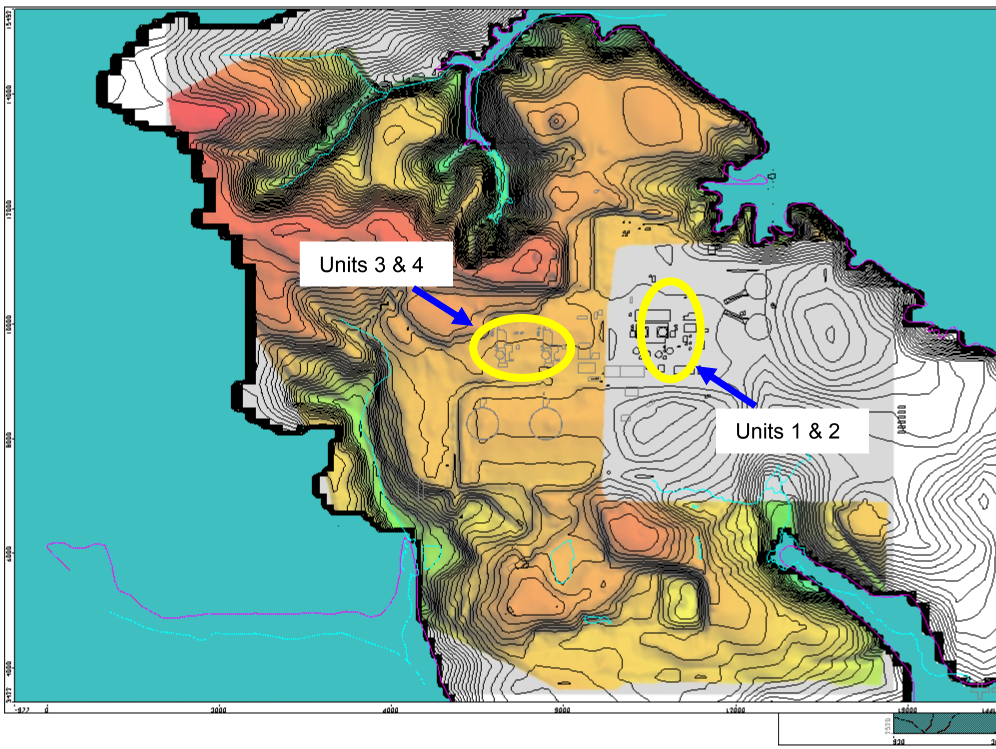
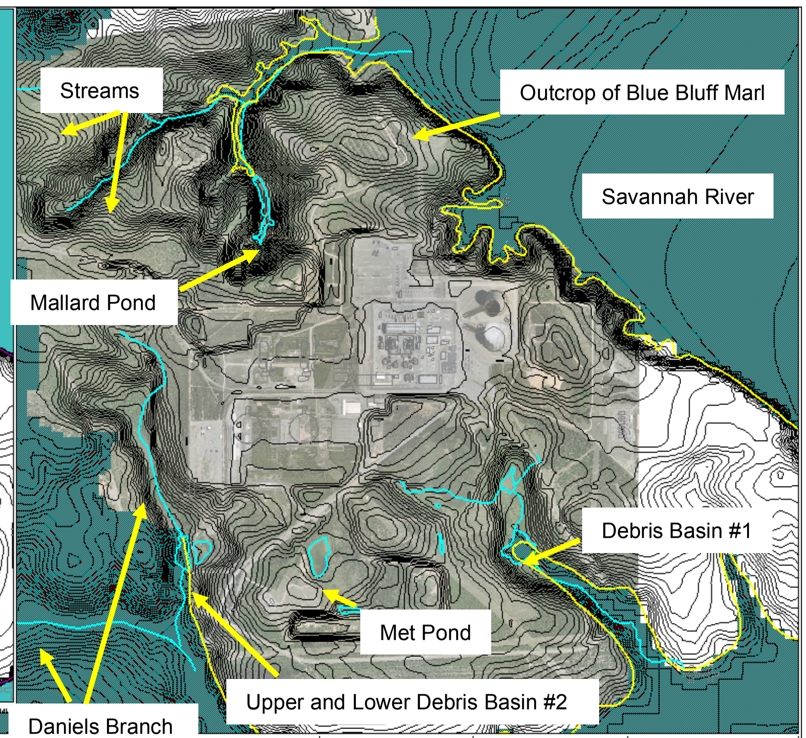
Site Topography & Boundaries

LiDAR (color)

Model: Top Elevation Contours





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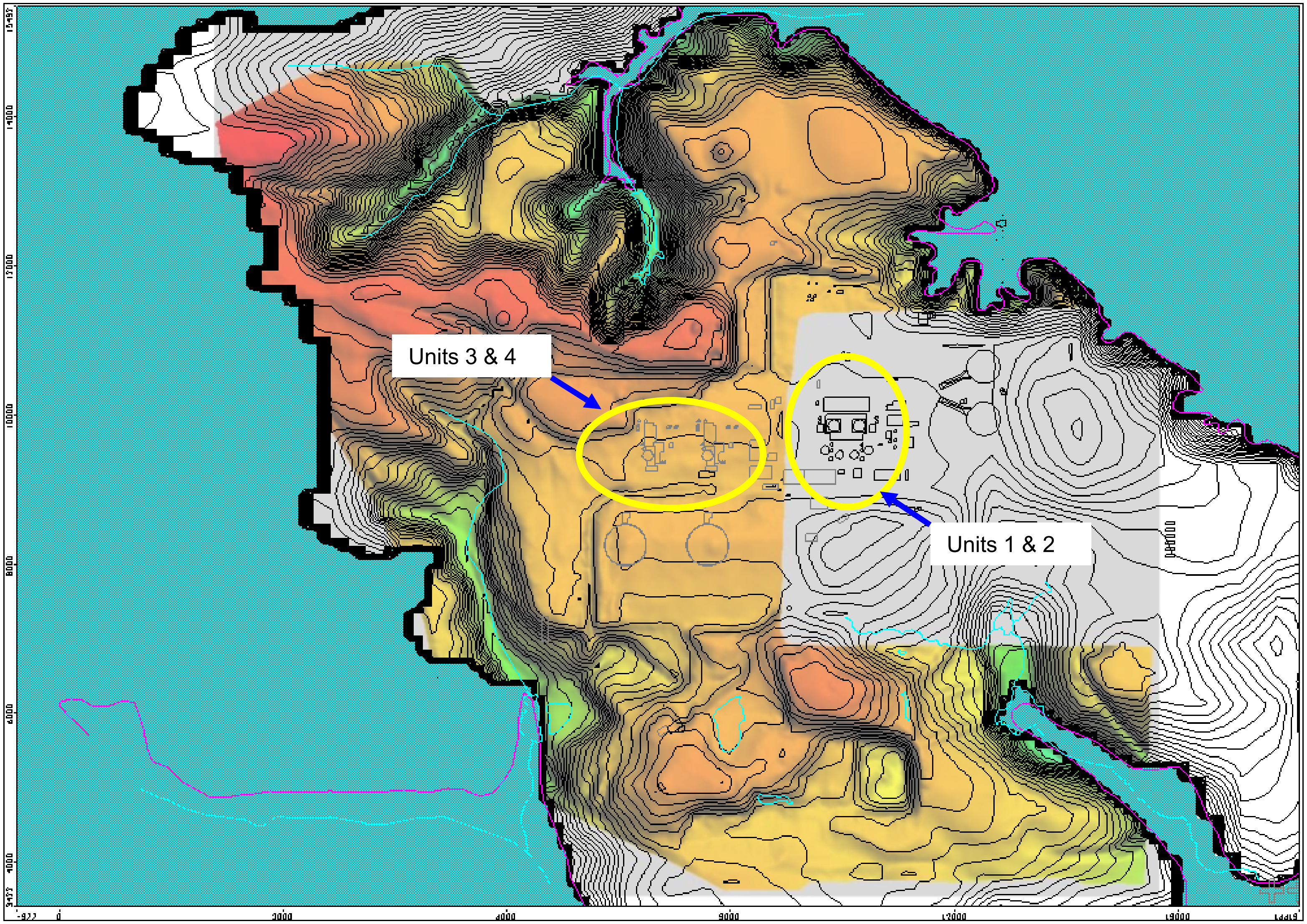
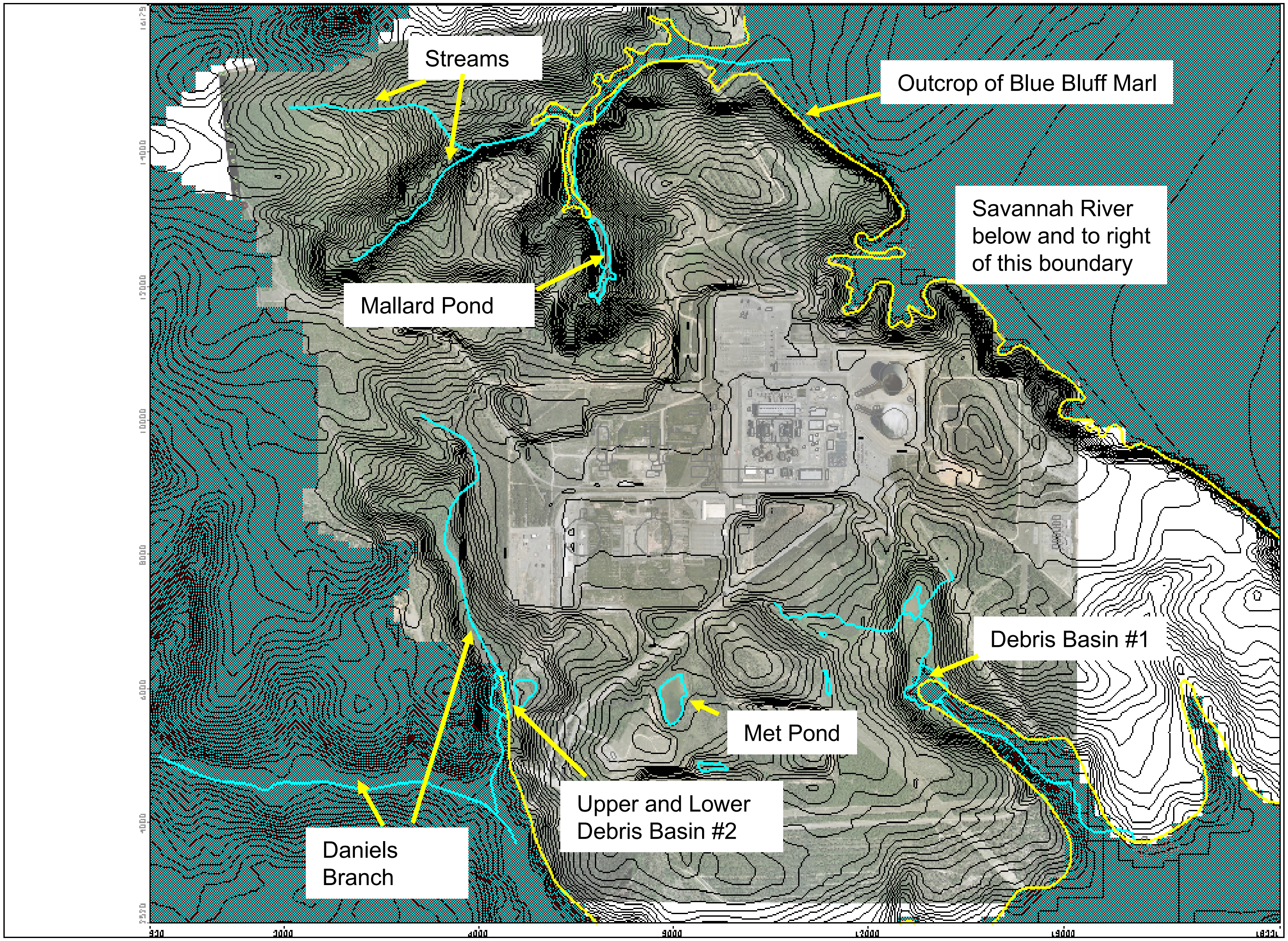
Site Topography: LiDAR (in color)



Site Topography & Boundaries

Model: Top Elevation Contours



Hydraulic Conductivity

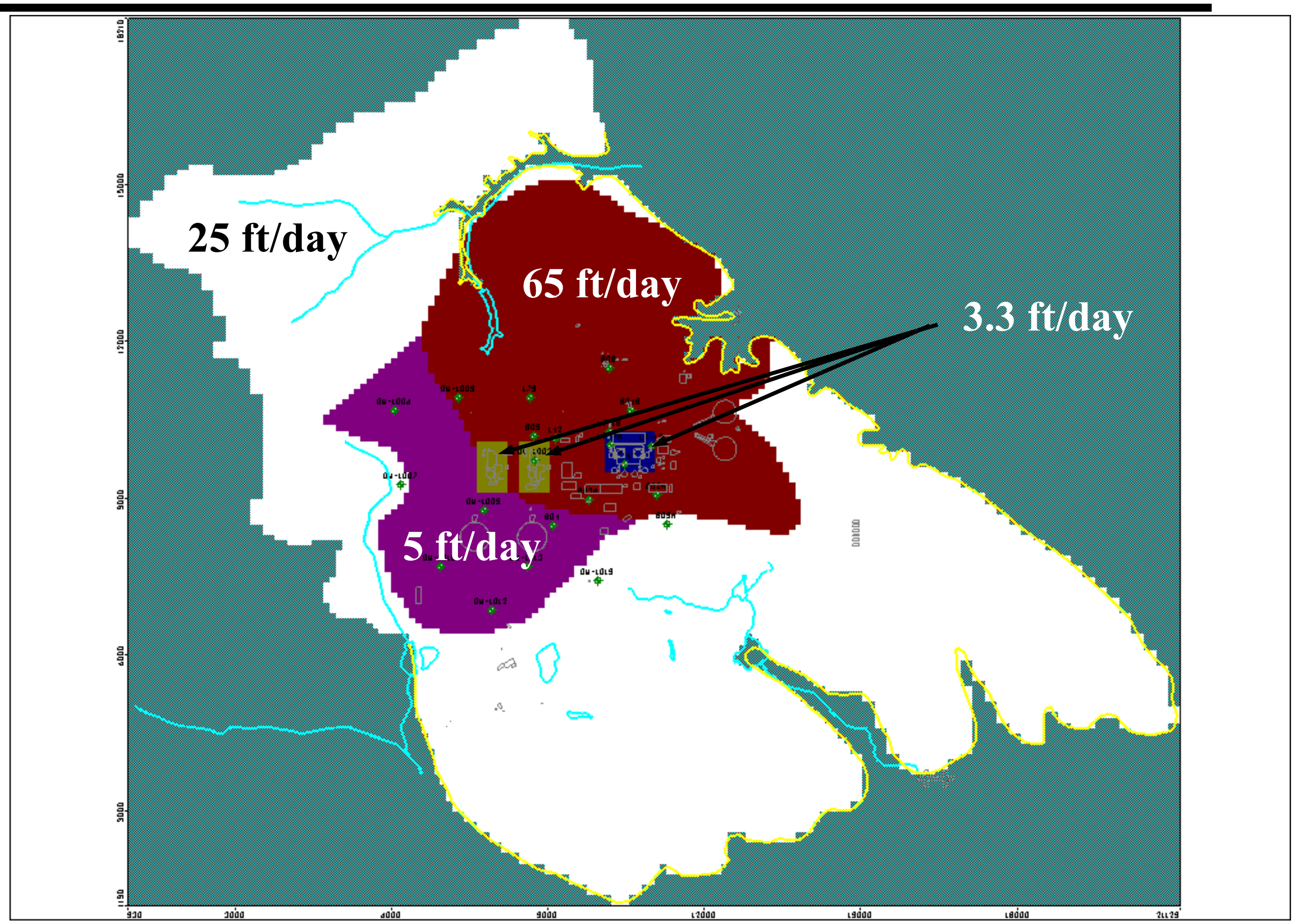
(Figure source: simulation run 721-PC; PC = post-construction)

Measured Values:

Barnwell Group sands, silts, and clays
0.03 to 2.65 ft/day

Utley limestone
0.3 to 343 ft/day

Engineered backfill
1.3 to 3.3 ft/day



Staff Review: Site Characteristics Important to Transport (2)

- Recharge Rates: Regional Model – inferred from average groundwater discharge to the Savannah River – based on measured streamflow above and below the VEGP site
  - USGS regional model (WRIR 97-4197)
    - Long-term average recharge 14.5 in/year over region; 6.8 in/yr to local aquifer
- Recharge Rates: Applied numerous zonations & magnitudes
  - Open areas w/ minimal vegetation, mild slopes; range 6 to 12 in/yr
  - Forested areas, mild slopes; range 6 to 8 in/yr
  - Open area w/ minimal vegetation, steep slopes; range 5 to 8 in/yr
  - Forested areas, steep slopes; range 2 to 5 in/yr
  - Buildings, paved surfaces; 0 in/yr
  - Open area, minimal slope, no vegetation; up to 14 in/yr
  - Ponds or infiltration areas, 40 in/yr, when modeled as infiltration and not “constant head”

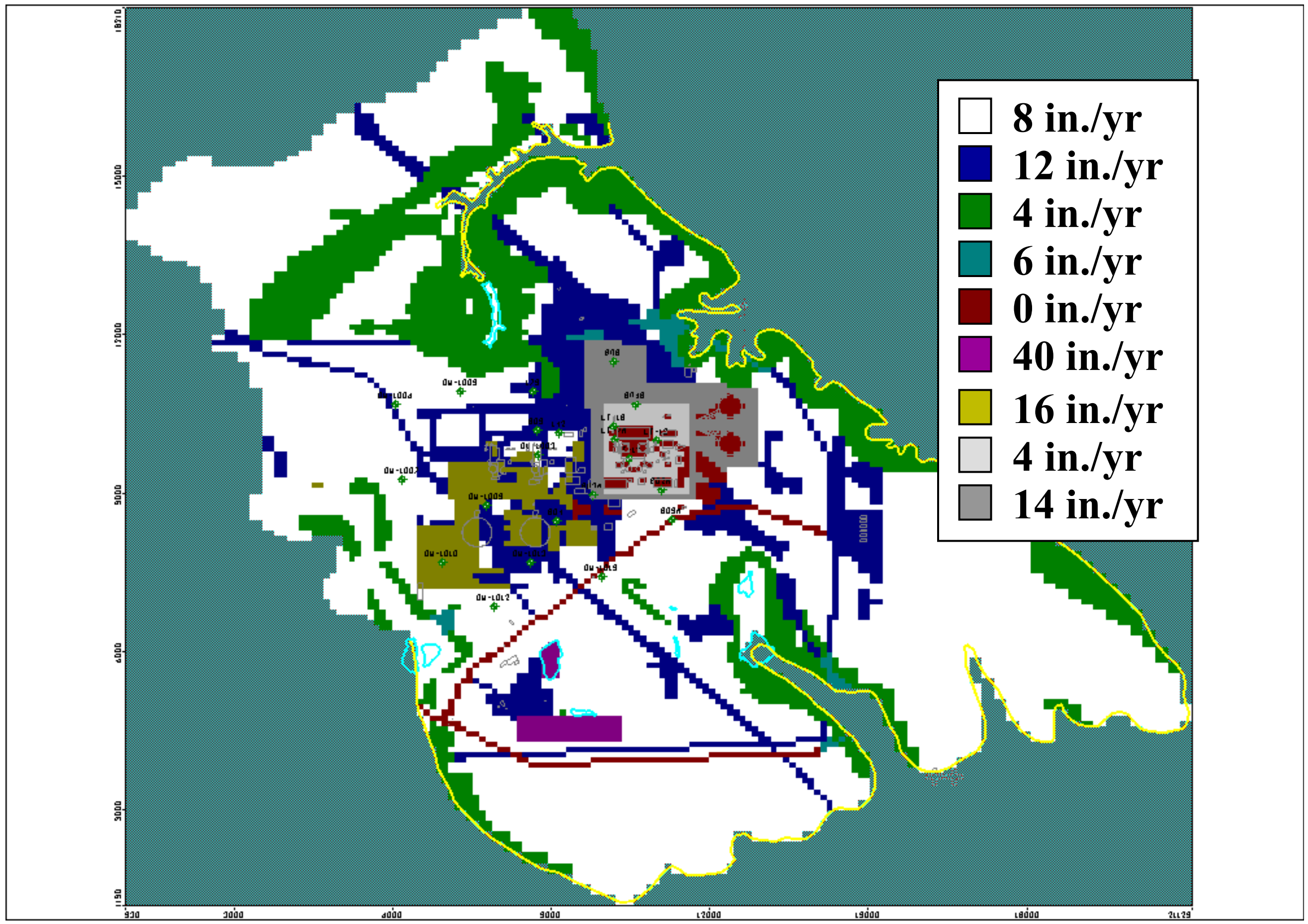
Site Recharge

(Figure source: simulation run 721)

USGS regional model: Long-term average recharge 14.5 in/yr in region; 6.8 in/yr to local aquifer (WRIR 97-4197)

Local conditions vary

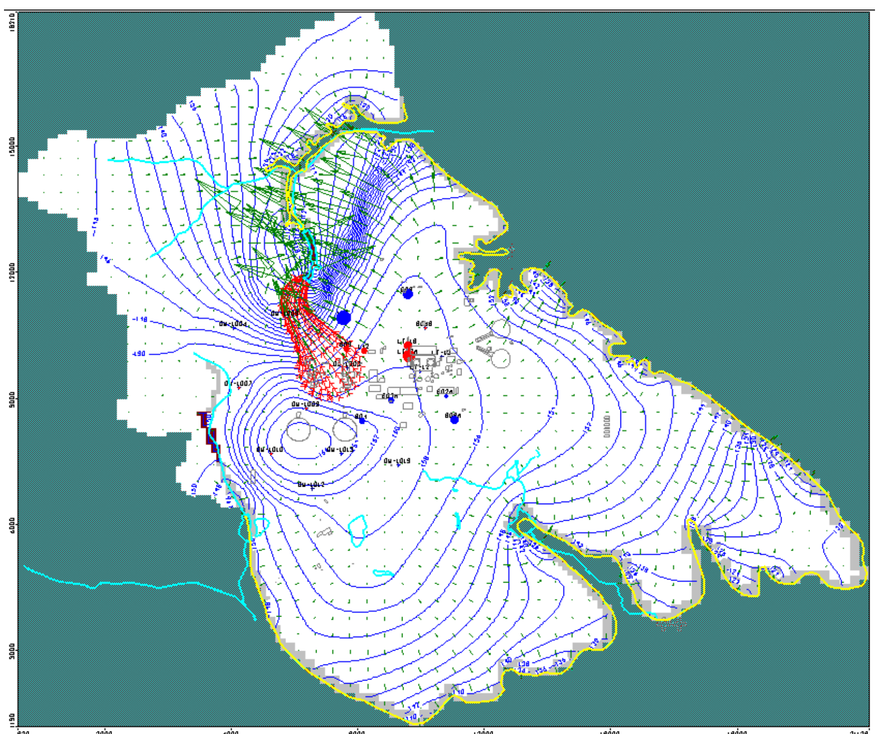
- ponds - > precipitation possible
- forest, grassland, soils, slopes - < precipitation
- structures, asphalt – zero if water routed away and not allowed to infiltrate

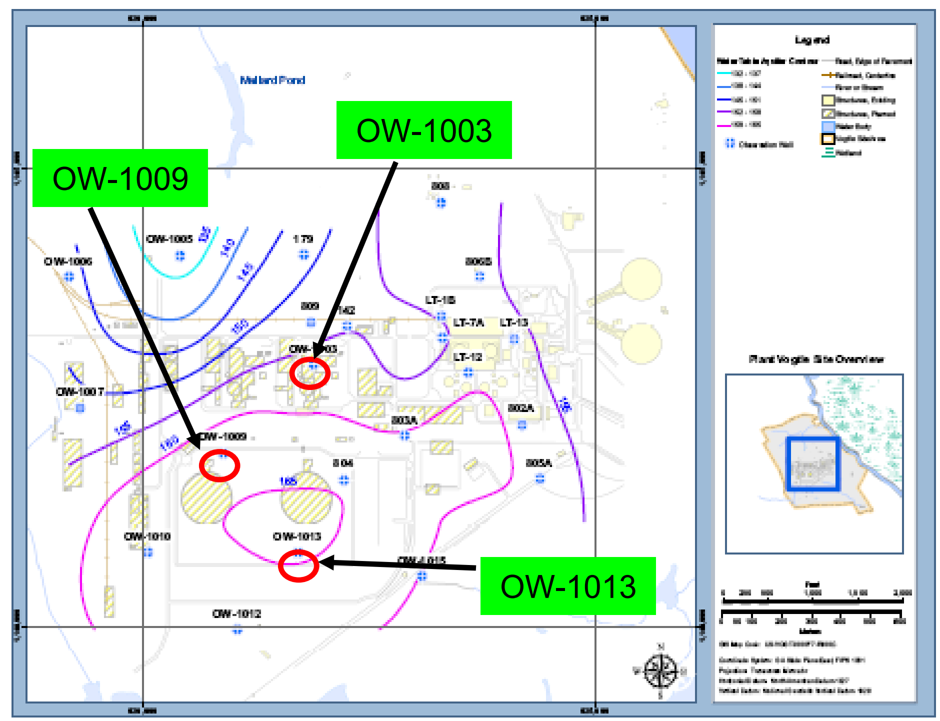


Pre-Construction Hydraulic Head: Comparison of Modeled vs Measured

Pre-Construction Model Results
Max Value, Cooling Towers = 166.8 ft MSL
Max Value, Powerblock = 162.8 ft MSL
Applicant values 166.9 and 162.9 ft MSL
(Source: Run 721 with corrected drains)

Observed March 2006 Hydraulic Head
Max Value = 165.31 ft MSL at OW-1013
Value = 163.01 ft MSL at OW-1009
Value = 156.43 ft MSL at OW-1003





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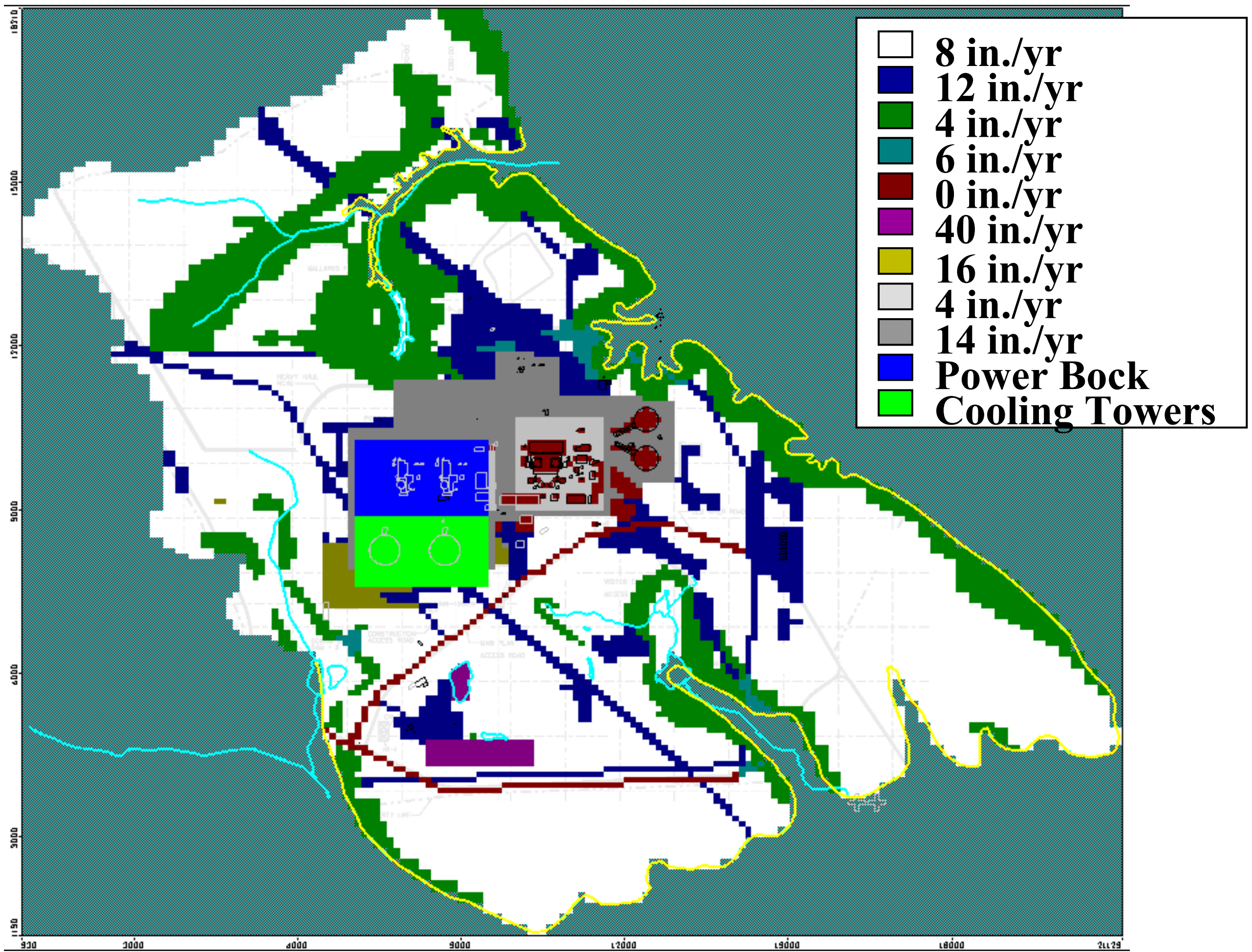
Post Construction: A Matrix of Recharge Rates; Evaluation of Transport towards Daniels Branch

√ = simulation completed; recharge to cooling area ≥ that to powerblock area
(mean annual precipitation 44 to 48 in/year)

Powerblock / Cooling Tower	**High** (½ × Avg. Annual Precipitation)	**Plausible** (⅛ × Avg. Annual Precipitation)	**Low** (Zero)
High (½ × Avg. Annual Precipitation)	√	√	√
Plausible (¼ × Avg. Annual Precipitation)		√	√
Low (Zero)			√

Post Construction: Powerblock & Cooling Tower Recharge Zones

Source: Simulation run 721pc (post-construction)



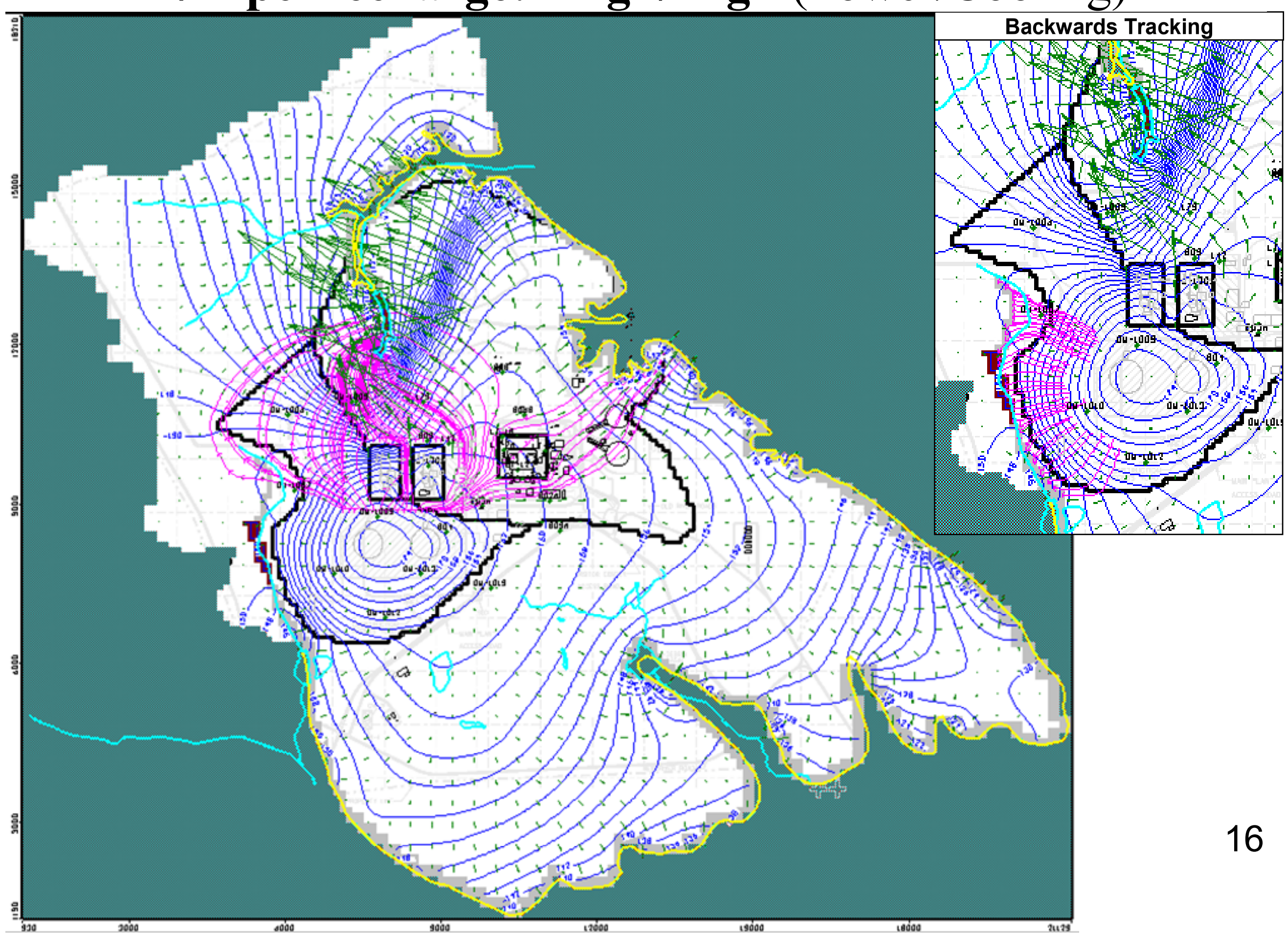
Post Construction: Pathlines for High/High Recharge Rates

Effluent Release Points from Power-block: Perimeter of the Powerblock Area

Release occurs:
- Tank rupture
- Floor drains
- Sump pumps
- 3-ft exterior wall
- 6-ft basemat
- 20-ft vadose

Plausible paths
-Mallard Pond – more likely
-Daniels Branch – less likely

721pc Recharge: High/High (Power/Cooling)



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Staff Review: Site Characteristics Important to Transport (3)

- Distribution Coefficients, K_d
  - Measured K_d in both backfill and aquifer sediments for cobalt (Co), strontium (Sr), and cesium (Cs). Tritium, Co, Sr, and Cs were identified as most significant to dose. Co, Sr, and Cs are known to be subject to adsorption.
  - Applied minimum K_d for Co, Sr, and Cs in both backfill and aquifer sediments.
  - While K_d measurements did use sediments and groundwater from the VEGP site, they did not consider the influence of chelating agents in the radioactive liquid released
  - Necessary to use adsorption process (K_d) to demonstrate the standard (10 CFR Part 20, Appendix B, Table 2, Column 2) can be met
  - COL Action Item 2.4-1. SNC to confirm no chelating agents comingled with radioactive waste liquids, or that distribution coefficients including chelating agents yield acceptable analyses of radionuclide migration
  - Relevance of chelating agents
    - Not aware of data suggesting their presence
    - Past use and potential future use acknowledged
    - Chelating agents known to influence sorption and result in faster migration

	Backfill – range (mL/g)	Aquifer – range (mL/g)
Cobalt (Co)	1.4 – 15.3	3.9 – 21.3
Strontium (Sr)	6 – 51.7	14.4 – 17.4
Cesium (Cs)	3.5 – 56.2	22.7 – 33.2

Staff Review: Site Characteristics Important to Transport (4)

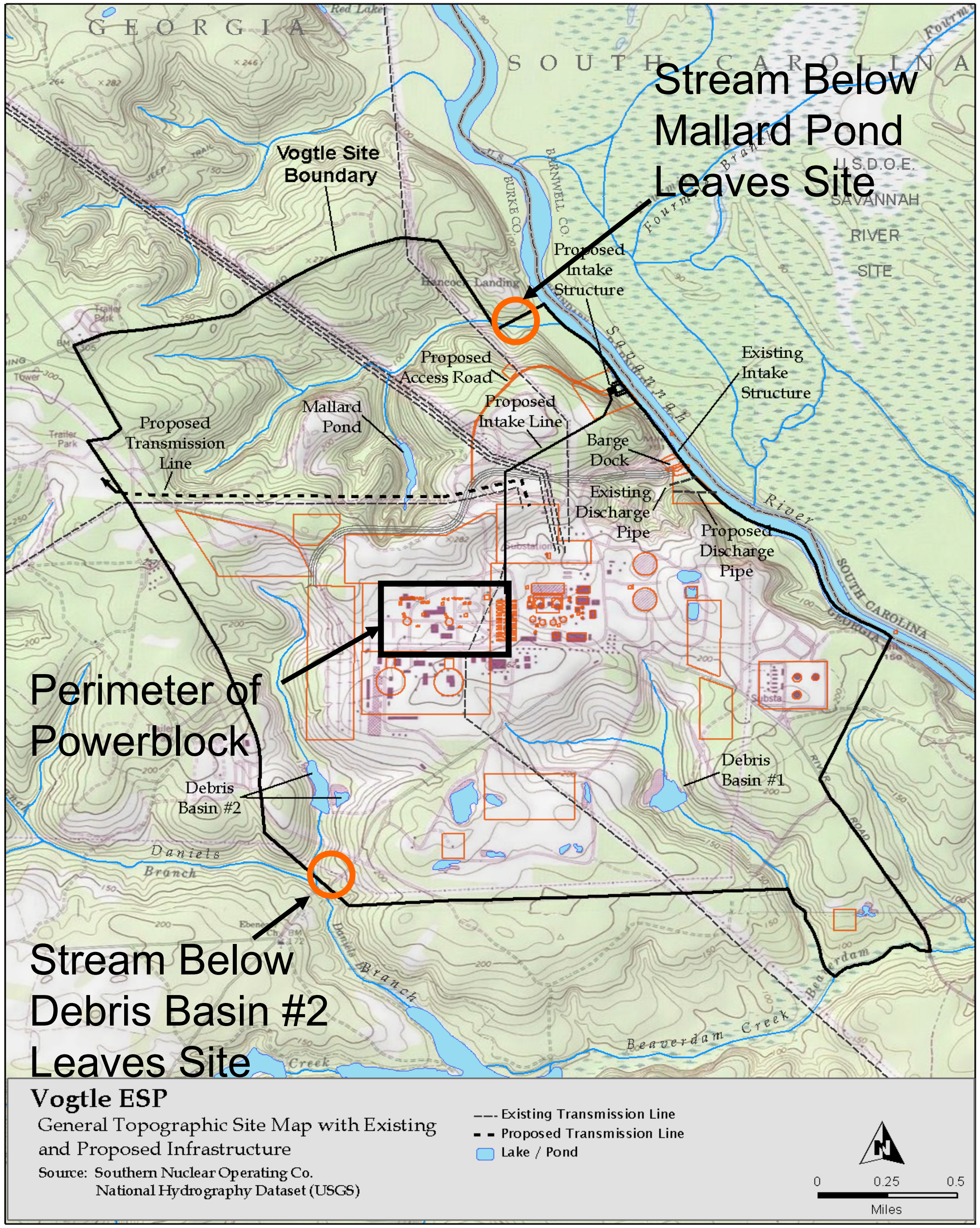
- Catchment Area
  - Estimated catchment area
    - Standard 10-m resolution USGS Digital Elevation Model (DEM)
      - DEM data provided a single, consistent data set for each catchment.
    - Evaluated flow direction from DEM, and accumulated surface area as indicated by runoff direction.
    - Catchment area is the land surface area contributing to surface water runoff, and, therefore, contributing to the stream discharge at the discharge point of interest, i.e., the compliance point.
      - Assumes the surface water catchment divide and groundwater divide are roughly the same.
- Catchment Discharge – low-discharge year
  - USGS data from 5 unregulated but monitored streams
  - Average of 5 drainage catchments applied by scaling to catchment area to obtain flow rate of the low-discharge year

Mallard Pond and Daniels Branch Catchment Areas Analyzed

- A streamtube, plug-flow model, neglecting dispersion in groundwater
- Mallard Pond catchment
  - Applied travel times from the groundwater model.
  - Compliance point – stream leaving Mallard Pond crosses site boundary.
  - Applied combinations of decay, retardation, and dilution in low-annual flow of the Mallard Pond catchment (279 cfs).
  - For all radionuclides in the inventory the sum of fractions is less than one (0.235); tritium fraction greater than 1% of its standard. Standard (10 CFR Part 20, Appendix B, Table 2, Column 2) can be met for the Mallard Pond catchment.
- Daniels Branch catchment
  - Applied travel times assuming linear movement to nearest point.
  - Compliance point – stream leaving Debris Basin #2 crosses site boundary.
  - Applied combinations of decay, retardation, and dilution in low-annual flow of the upper Daniels Branch catchment (267 cfs);
  - For all radionuclides in the inventory the sum of fractions is less than one (0.336); tritium and cesium-137 greater than 1% of their standard. Standard (10 CFR Part 20, Appendix B, Table 2, Column 2) can be met for the Daniels Branch catchment.

Compliance Points

Mallard Pond & Daniels Branch Catchments



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Assurance of Conservative Results

- Relevant pre-construction model of unconfined aquifer
  - Model (1) incorporated topography and aquifer base; (2) incorporated boundary conditions (especially drains); (3) incorporated distributions of hydraulic conductivity and recharge; (4) exhibits correspondence between measured and modeled parameters; and (5) achieves correspondence to measured hydraulic head
- Evaluated post-construction recharge rates / pathways
  - Established Mallard Pond drainage as the most plausible path
  - Staff also identified Daniels Branch as plausible but unlikely path
  - Included a plausible but unlikely pathway through Tertiary aquifer
- The Staff's analysis is conservative because
  - Evaluated alternative conceptual models and multiple pathways
  - Neglected dispersion in the groundwater environment
  - Applied lowest measured distribution coefficients
  - Applied low-discharge-year catchment flows
- The Staff confirmed the applicant's conclusion that the standard of 10 CFR Part 20, Appendix B, Table 2, can be met.

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Radiological Impacts

(Environmental Review)

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Presenter:

J. V. Ramsdell, Jr

Pacific Northwest National Laboratory

Richland, Washington

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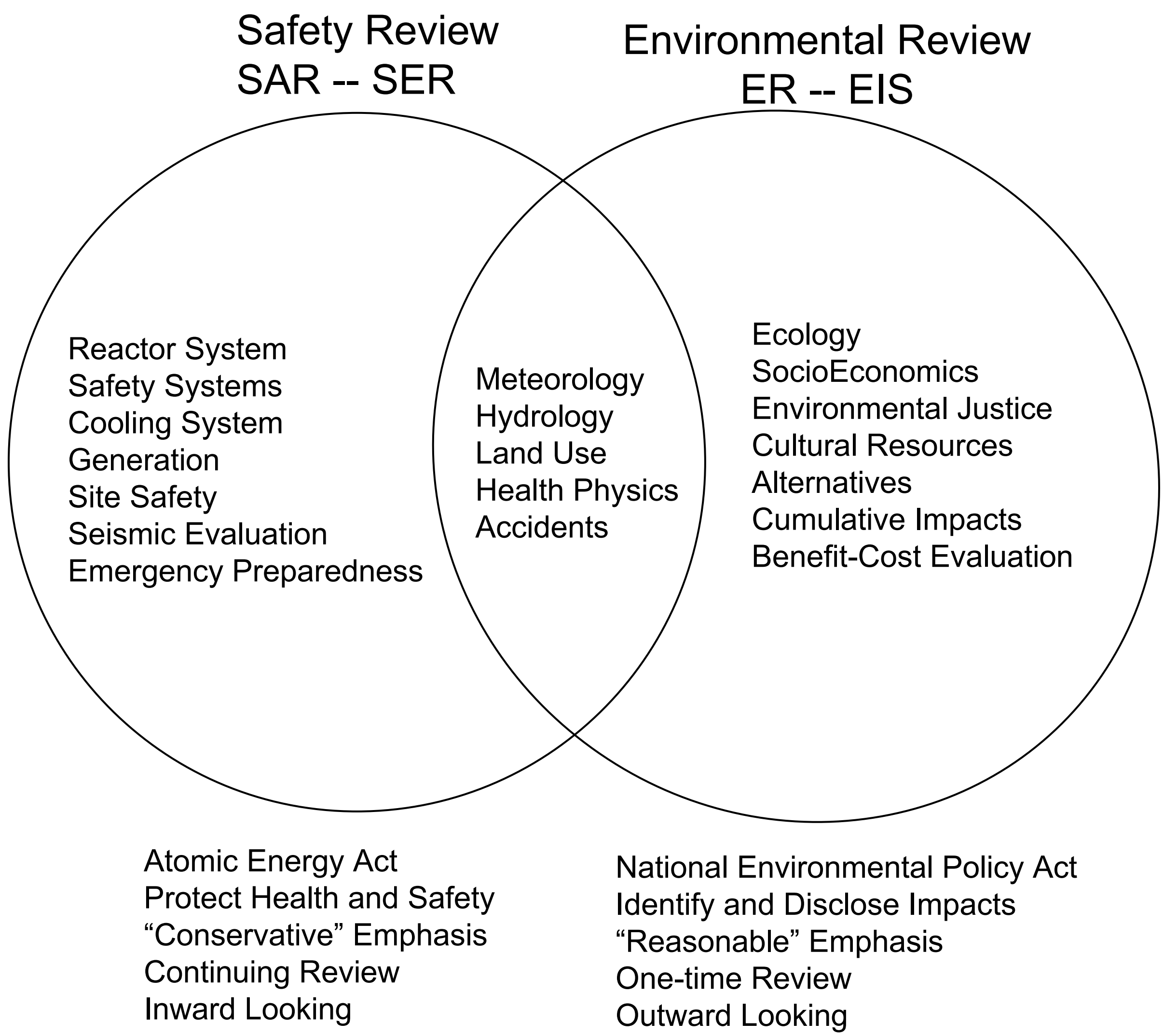
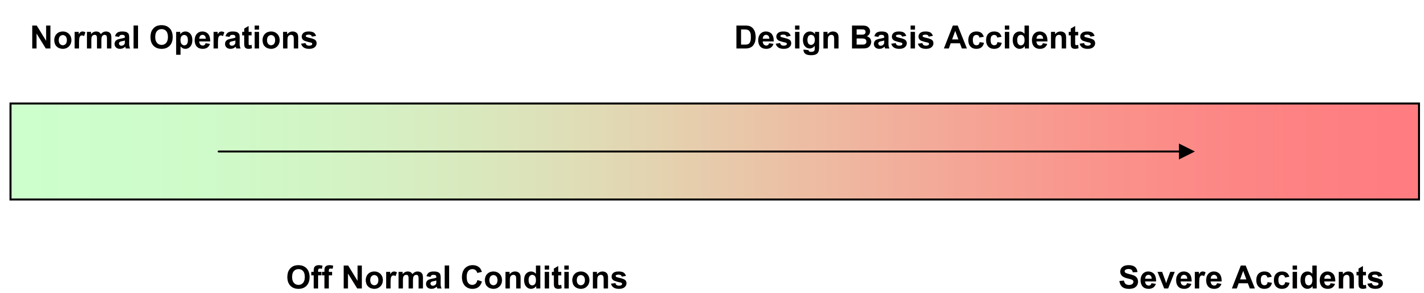
New Reactor Licensing Reviews



Radiological Review Components



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Radiological Impacts
(Normal Operations)

Michael A. Smith
Pacific Northwest National Laboratory
Richland, Washington

Reviewer Background

- MS Nuclear Engineering, Ohio State University
- MS Environmental Science, Ohio State University
- Certified by American Board of Health Physics
- 10 years health physics experience related to performance assessment, safety analysis, dose assessment, computer modeling, environmental assessment, and environmental impact for:
  – new nuclear power
  – high-level waste geologic repositories
  – spent fuel storage facilities
  – uranium reprocessing facilities
  – uranium in-situ leaching facilities
  – various decommissioning projects

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Environmental Review of Radiological Impacts

- Description of Radiological Environment
- Radiological Impacts During Construction
- Radiological Impacts of Normal Operations
- Uranium Fuel Cycle Impacts
- Cumulative Impacts

Regulatory Standards and Guidance

- Regulations
  - 10 CFR Part 51 and implementing NEPA
- Review Guidance
  - NUREG-1555 (Environmental Standard Review Plan)
    - Sections 4.5, 5.4, and 5.7
  - Regulatory Guides 1.109, 1.111, 1.112, and 1.113

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Description of Radiological Environment

- Radiological environmental monitoring program established in 1987 for Unit 1 and expanded in 1989 to include Unit 2
- Pre-operational program (1981-1987)
- Results of annual environmental operating reports
- Annual radioactive effluent release reports
- Doses to maximally exposed individual meet regulatory standards

Radiological Impacts During Construction

- Reviewed Southern estimate of dose from Units 1 and 2 (and Unit 3) operation to site preparation workers for construction of Unit 3 (and Unit 4)
- Considered dose from direct radiation and liquid and gaseous effluents
- Estimated annual dose of 26.3 mrem is less than 100 mrem annual public dose limit in 10 CFR 20.1301
- Staff conclusion – impacts would be SMALL

Radiological Impacts of Normal Operations

- To assess impacts, Staff
  - Evaluated applicant's estimated dose from gaseous and liquid effluents for members of the public and biota.
  - Performed independent evaluations.

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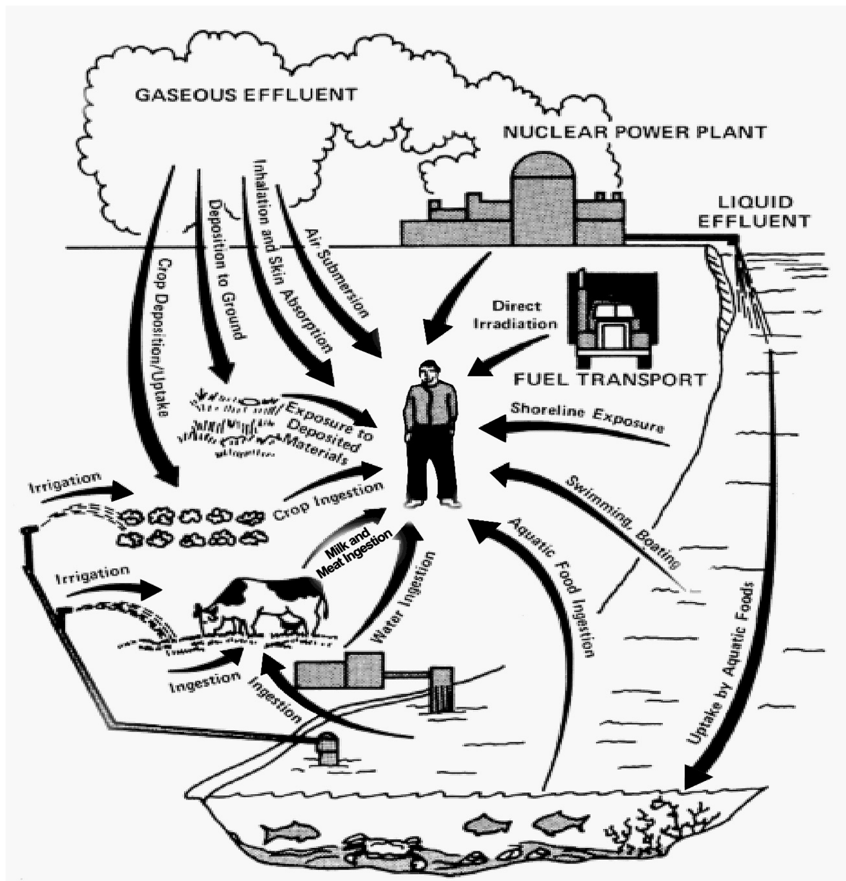
Exposure Pathways to Humans



Doses from Liquid Effluents

- LADTAP II (NRCDOSE version 2.3.8)
- Source term (AP1000 DCD, Rev. 15)
- Reviewed parameter values
  - Inputs found to be appropriate
- Estimated total body dose and organ dose
- Staff and Southern results were similar and met regulatory standards

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Doses from Liquid Effluents

Comparison of Doses to the Public from Liquid Effluent Releases for a New Unit

Type of Dose	Southern ER	Staff Calculation	Percent Difference
Total Body (mSv/yr)	0.00017 (adult)	0.00017 (adult)	0
Organ Dose (mSv/yr)	0.00021 (child liver)	0.00021 (child liver)	0
Thyroid (mSv/yr)	0.00015 (infant)	0.00015 (infant)	0
Population (person-mSv/yr)	0.185	0.222	+20

LADTAP II

- LADTAP estimates radiation exposure from: potable water, aquatic foods, shoreline deposits, swimming, boating, and irrigated foods.
- LADTAP was developed specifically for calculating doses from routine releases of liquid reactor effluents.
- LADTAP has been benchmarked against similar computer codes (e.g., GENII, RESRAD) and found to give reasonable results.
- ESRP Sections 4.5 and 5.4 suggest use of:
  - LADTAP to implement NRC Regulatory Guide 1.109.
  - LADTAP default parameter values when site-specific information is not available.
- LADTAP implements radiological exposure models described in NRC Regulatory Guide 1.109, Revision 1, Appendix A.
- LADTAP implements surface water transport models described in NRC Regulatory Guide 1.113, Appendix B.
- Site-specific data includes: discharge flow rate, consumption and usage factors, population data, site type, and reconcentration model.

Doses from Gaseous Effluents

- GASPAR II (NRCDOSE version 2.3.8)
- Source term (AP1000 DCD, Rev. 15)
- Reviewed parameter values
  - Inputs found to be appropriate
- Estimated total body dose and organ dose
- Staff and Southern results were similar and met regulatory standards

Doses from Gaseous Effluents

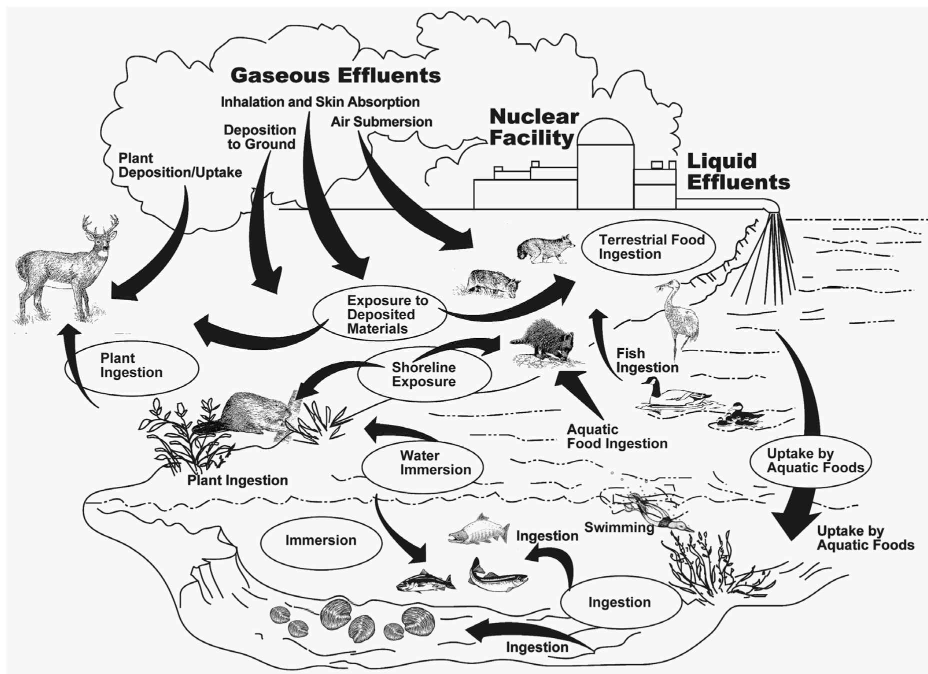
Comparison of Doses to the Public from Gaseous Effluent Releases for a New Unit

Type of Dose	Southern ER	Staff Calculation	Percent Difference
Gamma air (noble gases) (mGy/yr)	0.0068	0.0068	0
Beta air (noble gases) (mGy/yr)	0.0284	0.0284	0
Total body (noble gases) (mSv/yr)	0.0056	0.00564	+0.7
Skin dose (noble gases) (mSv/yr)	0.023	0.0225	-2.2
MEI plume (μSv/yr)	2.56 (adult)	2.57 (adult)	+0.4
MEI inhalation (μSv/yr)	2.83 (teen)	2.83 (teen)	0
MEI vegetable (μSv/yr)	6.65 (child)	6.65 (child)	0
MEI meat (μSv/yr)	0.905 (child)	0.905 (child)	0
Total body population (person-Sv/yr)	0.0180	0.0271	+20

GASPAR II

- GASPAR estimates radiation exposure from release of: noble gases and radioiodine and particulate emissions.
- GASPAR was developed specifically for calculating doses from routine releases of gaseous reactor effluents.
- GASPAR has been benchmarked against similar computer codes (e.g., GENII, RESRAD) and found to give reasonable results.
- ESRP Sections 4.5 and 5.4 suggest:
  - Use of GASPAR to implement NRC Regulatory Guide 1.109.
  - Use of GASPAR default parameter values when site-specific information is not available.
- GASPAR implements the air release dose models described in NRC Regulatory Guide 1.109, Revision 1, Appendix A.
- Site-specific data includes: population data and milk, meat, and vegetable production; along with meteorological data and dispersion/deposition estimates.

Exposure Pathways to Biota Other than Humans



Exposure to Biota Other than Humans

- Liquid pathway for terrestrial and aquatic biota
- Gaseous pathway for terrestrial biota
- LADTAP II and GASPAR II
- Reviewed parameter values
  - Inputs found to be appropriate
- Staff and Southern results were similar

Radiological Impacts of Normal Operations — Results

Comparison of MEI Dose Estimates for a Single New Reactor Unit to 10 CFR Part 50, Appendix I, Design Objectives

Pathway / Type of Dose	Southern ER	Appendix I Design Objectives
Liquid Effluents		
Total body dose	0.00017 mSv/yr (adult)	0.03 mSv/yr
Maximum organ dose	0.00021 mSv/yr (child liver)	0.1 mSv/yr
Gaseous Effluents (noble gases only)		
Gamma air dose	0.0068 mGy/yr	0.1 mGy/yr
Beta air dose	0.0284 mGy/yr	0.2 mGy/yr
Total body dose	0.0056 mSv/yr	0.05 mSv/yr
Skin dose	0.0230 mSv/yr	0.15 mSv/yr
Gaseous Effluents (radioiodines and particulates)		
Organ dose	0.0591 mSv/yr (child thyroid)	0.15 mSv/yr

Radiological Impacts of Normal Operations — Conclusions

- Public
  - Doses within regulatory design objectives and dose standards
- Workers (onsite)
  - Occupational dose anticipated to be less than individual doses incurred at current operating LWRs
  - Compliance with 10 CFR 20.1201
  - ALARA
- Biota
  - Dose rate estimates less than NCRP and IAEA studies
- Staff conclusion – impacts would be SMALL

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Uranium Fuel Cycle Impacts

- Advanced Light Water Reactor Designs
  - Used impacts from Table S-3 (10 CFR 51.51(b))
  - Scaled impacts to AP1000 power level
  - Staff conclusion – impacts would be SMALL

Cumulative Radiological Impacts

- Considered contributions from:
  - Existing and proposed VEGP units
  - SRS releases (both historical and ongoing)
  - Other nearby nuclear facilities
  - Proposed Mixed Oxide Fuel Fabrication Facility
- Predicted doses to public and workers – meet regulatory standards
- Staff conclusion – cumulative radiological impacts would be SMALL

Conclusions

- Radiological Health Impacts During Construction – SMALL
- Radiological Health Impacts of Operation – SMALL
- Uranium Fuel Cycle Impacts – SMALL
- Cumulative Impacts – SMALL

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Radiological Impacts
(Accidents)

J. V. Ramsdell, Jr
Pacific Northwest National Laboratory
Richland, Washington

Reviewer Background

- MS in Meteorology, Oregon State University
- Atmospheric Transport and Dispersion Modeling at the Pacific Northwest National Laboratory since 1967
- Environmental Reviews since the 1970s (Maine Yankee, V. C. Summer)
- Accident Consequence Assessment Modeling since the 1980s
- Program Manager for Updating the Environmental Standard Review Plans in the 1990s
- EIS Accident Analyses for Clinton, Grand Gulf, and North Anna ESP Environmental Reviews

Environmental Review: Accident Consequence Assessment

- Design Basis Accidents
- Severe Accidents
- Severe Accident Mitigation Design Alternatives (SAMDAs)
  - These alternatives are the topic of a separate Staff presentation.

Design Basis Accidents

- Review Guidance
  - ESRP 7.1
  - SRP Chapter 15
  - Regulatory Guide 1.183
- Review Process
  - Exclusion Area and Low Population Zone Boundary Definitions
  - Atmospheric Dispersion Factors
  - Accident Selection
  - Dose Estimates

Design Basis Accidents

- Southern Analysis
  - Adjust Design Certification Analysis for Site Specific Information
- Staff Review
  - Consistency Check
  - Confirmatory Calculations

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Design Basis Accident Analysis Results

- Review Basis
  - AP1000 Rev. 15
  - Typical meteorology (50% X/Q)
- With respect to existing plants, the Commission has found that "*…the environmental impacts of design basis accidents are of small significance for all plants.*" (10 CFR Part 51 App. B)
- Safety criteria from SRP 15.0.3 provide context for considering DBA dose magnitudes
- DBA dose estimates were generally less than 10% of the safety criteria, the Loss-of-Coolant-Accident dose estimates were less than 15%.

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Design Basis Accident Conclusion

- Based on
  - Staff review of the Southern choice of design basis accidents and analysis of consequences of design basis accidents for an AP1000 reactor at the VEGP site
  - Staff independent evaluation of design basis accidents at the site
- Staff concludes that the VEGP site is suitable for operation of 2 reactors with parameters falling within the parameters of the AP1000 Rev. 15 design.

Severe Accidents

- Review Guidance
  - ESRP 7.2
  - Commission Safety Goals
- Review Process
  - Probabilistic Risk Assessment
  - Release Categories and Core Damage Frequency
  - MACCS2 Consequence Assessment
  - Risk Assessment

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Why MACCS2?

- ESRP 7.2 suggests the use of MACCS for assessing the consequences of severe accidents.
- MACCS2 was developed specifically for assessing severe accident consequences.
- MACCS2 is a component of the suite of computer models developed and maintained by Sandia National Laboratory for the NRC related to severe accidents.
- The atmospheric transport and dispersion components of MACCS2 have been evaluated by comparison with similar components of more elaborate models and found to give reasonable results.
- Using MACCS2 facilitates comparison of the consequence assessment for postulated reactors at the Vogtle site with consequence assessments performed for existing reactors and for new reactor designs at other sites.

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Severe Accident Review

- Southern Analysis
  - Design certification estimates of reactor source terms and core damage frequencies
  - MACCS2 consequence assessment using site specific input
  - Risk Assessment
- Staff Review
  - MACCS2 Options, Parameters, and Input
  - Confirmatory Calculations

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Severe Accident Analysis

- Review Basis:
  - AP1000 Rev. 15
  - VEGP Site meteorology, population, land use
- Severe Accident Risk Estimates
  - Population Dose 0.00028 person-Sv/Ryr
  - Fatalities 0.00000000019/Ryr
  - Economic Cost $48/Ryr
  - Farm Land 0.00036 ha/Ryr (~4 yd^2/Ryr)

Severe Accident Analysis Results

- With respect to existing plants, the Commission has found that "*The probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts from severe accidents are small for all plants.* " (10 CFR Part 51 App. B)
- The severe accident population dose risk of a postulated new reactor at the VEGP site is less than 10% of the severe accident risk for an existing unit.
- The average individual early fatality and population cancer fatality risks for the postulated new reactor are several orders of magnitude lower than the risk guidelines set forth in the Commission's Safety Goal Policy Statement (51 FR 30028).

Cumulative Risk

Source	**Population Dose** (Person-Sv/Ryr)
Normal Operations: Units 1 – 4	2.1×10^{-2}
Severe Accidents: Units 1 & 2	3.7×10^{-2}
Severe Accidents: Units 3 & 4	5.6×10^{-4}
Total Risk: Units 1 – 4	5.9×10^{-2}
Background Radiation	$2.4 \times 10^{+3}$

Severe Accident Conclusion

- The results of both the Southern analysis and the NRC staff's analysis indicate that the environmental risks associated with severe accidents for an AP1000 at the VEGP are small compared to the risks associated with operations of current reactors at the VEGP site and other sites and the Commission's Safety Goals.
- On these bases, the staff concludes that the environmental impact of probability-weighted consequences of a severe accident at the VEGP site would be of SMALL significance for an AP1000 reactor.

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