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Atmospheric Dispersion Code Discussions

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Office of New Reactors

Division of Site Safety & Environmental Analysis

1ST RAMP USERS' MEETING
October 5th – 9th, 2015
North Bethesda, MD

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Atmospheric Dispersion Modeling Applications

Radiological Releases

1. Design Basis Accidents (PAVAN, ARCON96)
   - Control Room/Technical Support Center (intake, inleakage)
   - Offsite (exclusion area boundary, low population zone)
2. Routine Releases (XOQDOQ)
   - Site Boundary
   - Special Receptors (nearest resident, garden, milk/meat animal)
   - Population Dose (80 km radius)
3. Emergency Response (RASCAL)
4. Severe Accident Releases (MACCS)

Toxic Gas Releases (onsite and offsite)

5. Control Room (HABIT)

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Case Study

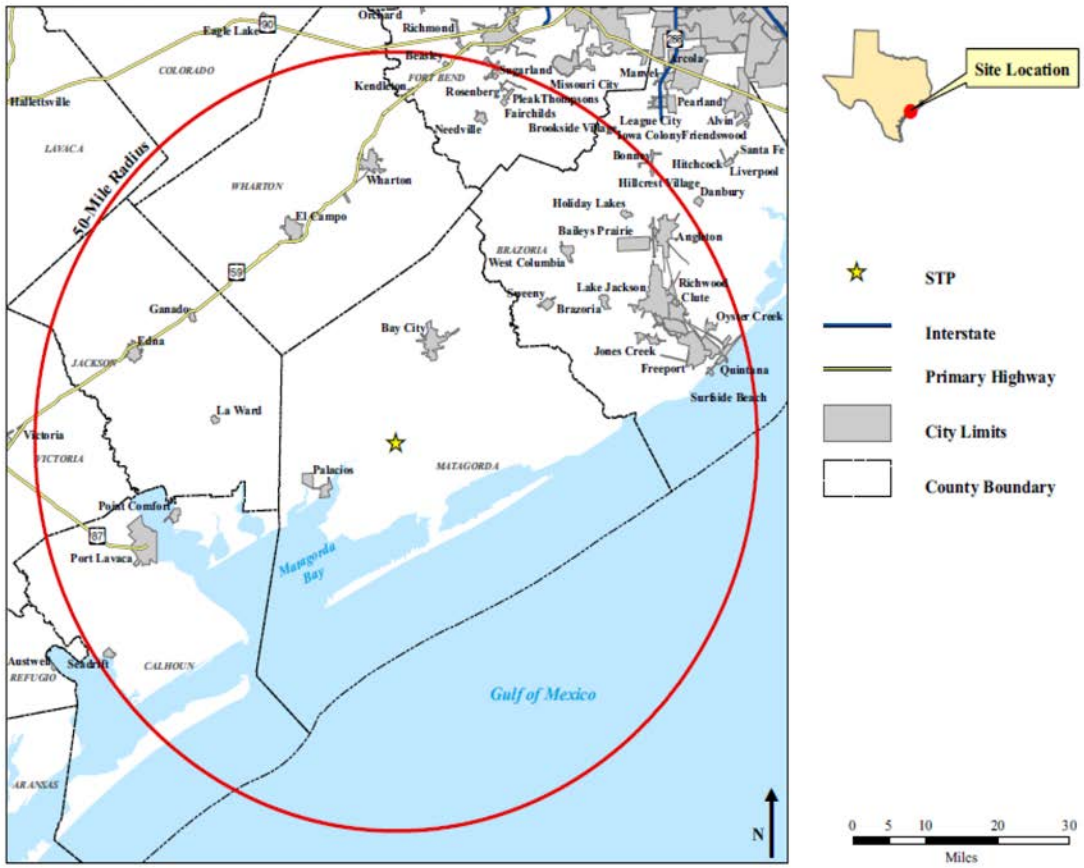

Figure 2.1-2 50-Mile Region

Combined License Application for South Texas Project, Units 3 and 4

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Case Study

Issued Design Certification - Advanced Boiling-Water Reactor (ABWR)

Who: General Electric (GE) Nuclear Energy

What: Application for Standard Design Certification for the U.S. Advanced Boiling-Water Reactor (ABWR), a 3926-MWt, single-cycle, forced-circulation, boiling-water reactor

When: General Electric submitted the Standard Design Certification Application in piecemeal format from September 29, 1987, through March 31, 1989. The U.S. Nuclear Regulatory Commission (NRC) issued a final rule certifying the design on May 12, 1997.

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Design Basis Accidents (ABWR)

- Instrument Line Break (8-hr)
- Main Steamline Break (2-hr)
- Loss of Coolant Accident (30-day)*
- Clean Up Water Line Break (2-hr)
- Radioactive Gas Waste System Leak or Failure Accident (30-min)
- Liquid Radioactive Tank Failure Accident (2-hr)
- Fuel Handling Accident (2-hr)
- Spent Fuel Cask Drop Accident (2-hr)

* The LOCA is the only accident for which Control Room doses are calculated

Reference: Tier 2, Chapter 15 of the ABWR DCD

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χ/Q Averaging Times for DBAs

Five Percent χ/Q Values		
EAB	**LPZ**	**CR/TSC**
0-2 hrs (1-hr avg)	0-8 hrs (8-hr avg) 8-24 hrs (16-hr avg) 1-4 days (72-hr avg) 4-30 days (624-hr avg)	0-2 hrs (1-hr avg) 2-8 hrs (6-hr avg) 8-24 hrs (16-hr avg) 1-4 days (72-hr avg) 4-30 days (624-hr avg)

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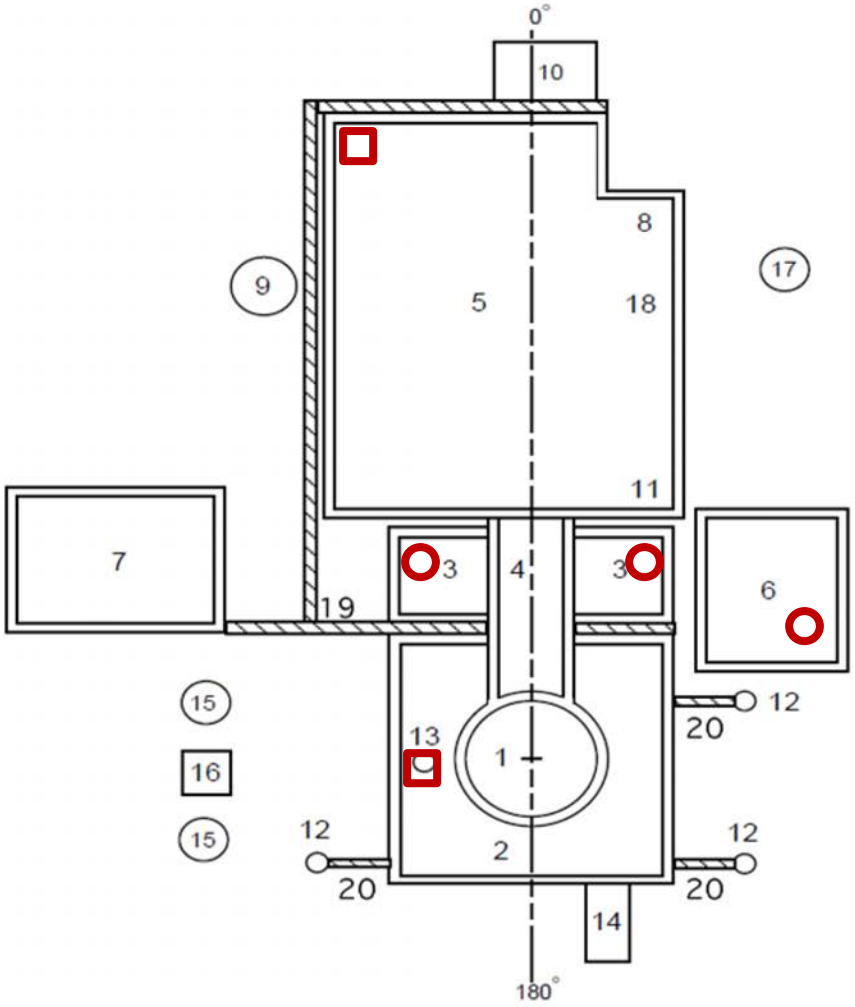
ABWR DBA Release and CR/TSC Receptor Locations



No.	FACILITY
1	REACTOR CONTAINMENT
2	REACTOR BUILDING
3	CONTROL BUILDING
4	MAIN STEAM/FEEDWATER TUNNEL
5	TURBINE BUILDING
6	SERVICE BUILDING
7	RADWASTE BUILDING
8	HOUSE BOILER
9	CONDENSATE STORAGE TANK
10	UNIT AUXILIARY TRANSFORMERS
11	NORMAL SWITCHGEAR
12	DIESEL OIL STORAGE TANK (3)
13	STACK
14	EQUIPMENT ENTRY LOCK
15	FIRE PROTECTION WATER STORAGE TANK (2)
16	FIRE PROTECTION PUMPHOUSE
17	BUNKER FUEL TANK
18	COMBUSTION TURBINE GENERATOR
19	RADWASTE TUNNELS RB, CB, TB
20	DG OIL TRANSFER TUNNEL (3)

Receptors ○
- CR and TSC Air Intakes

Release Points □
- Reactor Building Stack
- Turbine Building Doors

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DBA Releases to the CR and TSC

- Applicable NRC Regulations
  - 10 CFR Part 50, Appendix A, General Design Criterion 19 (GDC 19), *Control Room*
    - Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem (0.05 Sv) whole body, or its equivalent to any part of the body, for the duration of the accident
  - Paragraph IV.E.8 of Appendix E, to 10 CFR Part 50, *Emergency Facilities and Equipment*
    - Onsite emergency facilities be provided, from which effective direction can be given and effective control can be exercised during an emergency
    - Per SRP 15.0.3, TSC should provide the same level of protection against radiation that the control room provides

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DBA Releases to the CR and TSC

- Applicable NRC Guidance
  - RG 1.206, C.I.2.3.4: *Short-Term Atmospheric Dispersion Estimates for Accident Releases*
  - SRP 2.3.4: *Short-Term Atmospheric Dispersion Estimates for Accident Releases*
  - RG 1.194: *Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants (2003)*
  - NUREG/CR-6331: *Atmospheric Relative Concentrations in Building Wakes (1997)*
    - *ARCON96*

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ARCON96 Description

- Gaussian plume model
  - diffusion coefficients account for enhanced dispersion under low wind speed conditions and in building wakes
- χ/Q values are estimated for various time-averaged periods
  - 0-2 hrs, 2-8 hrs, 8-24 hrs, 1-4 days, 4-30 days
- Meteorological input consists of hourly values of wind speed, wind direction, and atmospheric stability class
- Hourly meteorological data are used to calculate hourly χ/Q values
  - Hourly χ/Q values are then combined to estimate concentrations ranging in duration from 2 hours to 30 days
  - Cumulative frequency distributions are prepared from the average χ/Q values
  - χ/Q values that are exceeded no more than 5 percent of the time for each averaging period are selected

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STP ARCON96 Inputs

INPUT SCREEN	INPUT PARAMETER	REACTOR BLDG PLANT STACK RELEASE			TURBINE BLDG TRUCK DOOR RELEASE		
		CR-C	CR-B	TSC	CR-C	CR-B	TSC
Source-Receptor Configuration	Release Mode	Gnd	Gnd	Gnd	Gnd	Gnd	Gnd
	Direction (deg from)	224	177	259	324	347	319
	Vertical Velocity (m/s)	0.0	0.0	0.0	0.0	0.0	0.0
	Stack Flow (m^3/s)	0.0	0.0	0.0	0.0	0.0	0.0
	Stack Radius (m)	0.0	0.0	0.0	0.0	0.0	0.0
	Distance (m)	73.2	52.9	60.3	131.5	108.5	132.1
	Intake Height (m)	8.8	8.8	10.2	8.8	8.8	10.2
	Release Height (m)	26.2	26.2	26.2	1.0	1.0	1.0
	Elevation Difference (m)	0.0	0.0	0.0	0.0	0.0	0.0
	Building Area (m^3)	2173.6	2173.6	2173.6	3813.5	3813.5	3813.5
Met Input	Wind Speed Units	mph	mph	mph	mph	mph	mph
	Lower Measurement Ht (m)	10.0	10.0	10.0	10.0	10.0	10.0
	Upper Measurement Ht (m)	60.0	60.0	60.0	60.0	60.0	60.0
Code Defaults	Surface Roughness (m)	0.2	0.2	0.2	0.2	0.2	0.2
	Wind Direction Window (deg)	90	90	90	90	90	90
	Minimum Wind Speed (m/s)	0.5	0.5	0.5	0.5	0.5	0.5
	Averaging Sector Width	4.3	4.3	4.3	4.3	4.3	4.3
	Initial σ_y (m)	0.0	0.0	0.0	0.0	0.0	0.0
	Initial σ_z (m)	0.0	0.0	0.0	0.0	0.0	0.0

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STP Resulting ARCON96 χ/Q Values (s/m^3)

Release Point	Receptor	0 – 2 hours	2 – 8 hours	8 – 24 hours	1 – 4 days	4 – 30 days
Reactor Building Plant Stack	CR Air Intake "C"	9.14E-04	4.98E-04	2.22E-04	1.68E-04	1.16E-04
	CR Air Intake "B"	2.03E-03	1.68E-03	5.88E-04	6.29E-04	5.59E-04
	TSC Air Intake	5.89E-04	4.50E-04	1.91E-04	1.27E-04	9.39E-05
Turbine Building Truck Doors	CR Air Intake "C"	3.38E-04	2.43E-04	1.16E-04	6.28E-05	5.43E-05
	CR Air Intake "B"	5.20E-04	4.18E-04	1.84E-04	1.18E-04	9.15E-05
	TSC Air Intake	3.28E-04	2.26E-04	1.06E-04	5.67E-05	4.99E-05

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DBA Releases to the EAB and LPZ

- Applicable U.S. NRC Regulations
  - 10 CFR 52.79(a)(1)(vi), *Contents of applications; technical information in final safety analysis report*
    - Perform an assessment assuming a fission product release from the core into the containment
      - An individual located at any point on the boundary of the EAB for any 2-hour period would not receive a dose in excess of 25 rem (0.25 Sv)TEDE
      - An individual located at any point on the outer boundary of the LPZ would not receive a dose in excess of 25 rem (0.25 Sv) TEDE during the entire period of the passage of the radioactive cloud

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DBA Releases to the EAB and LPZ

- Definitions (10 CFR 50.2 and 10 CFR 100.3)
  - Exclusion Area
    - The area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area …
      - *STP: Oval centered on STP Units 1 & 2, 1,430 m (0.9 mi) from each unit*
  - Low Population Zone
    - The area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident …
      - *STP: Circle centered on STP Units 1 & 2, 4,828 m (3 mi)*

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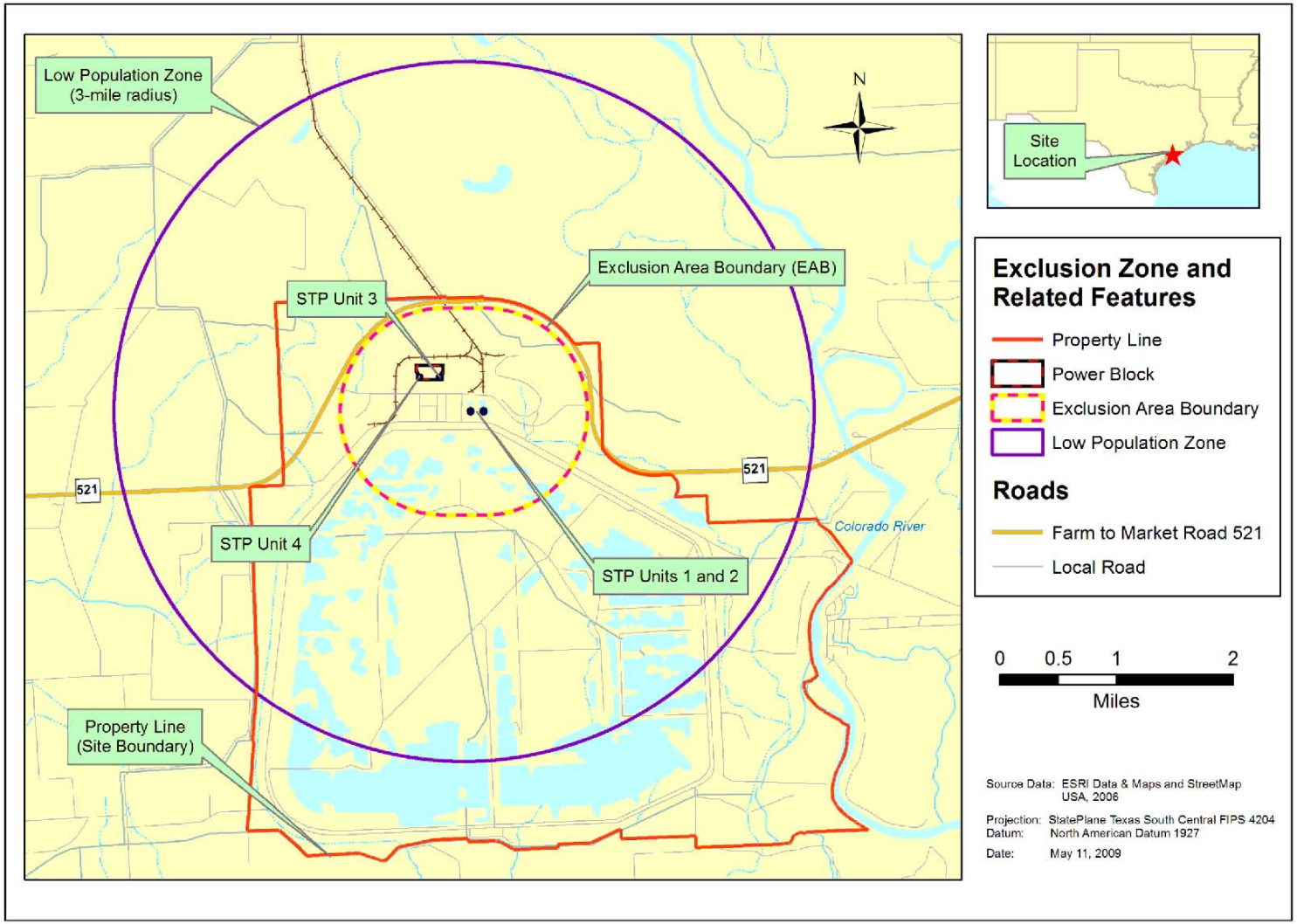
STP EAB and LPZ



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DBA Releases to the EAB and LPZ

- Applicable NRC Guidance
  - RG 1.206, C.I.2.3.4: *Short-Term Atmospheric Dispersion Estimates for Accident Releases*
  - SRP 2.3.4: *Short-Term Atmospheric Dispersion Estimates for Accident Releases*
  - RG 1.145: *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants (1983)*
  - NUREG/CR-2858: *PAVAN: An Atmospheric Dispersion Program for Evaluating Design-Basis Accident Releases of Radioactive Materials from Nuclear Power Stations (1982)*
  - NUREG/CR-2260: *Technical Basis for Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants" (1981)*

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PAVAN Description

- Gaussian plume model
  - for ground-level releases, diffusion coefficients modified to account for plume meander under low wind speed conditions and building wakes
- Estimates χ/Q values for various time-averaged periods
  - 0-2 hrs, 0-8 hrs, 8-24 hrs, 1-4 days, 4-30 days
- Meteorological input consists of a JFD of hourly values of:
  - wind speed (calms defined as below sensor threshold, historically ~ 1 mph)
  - wind direction (16 directions, 22.5 deg sectors, centered on true north)
  - atmospheric stability class (preferably based on delta-T)
- Building wake impacts on release height
  - release points less than 2.5 times the height of adjacent solid structures → *ground-level releases*
  - release points more than 2.5 times the height of adjacent solid structures → *elevated (stack) releases*
- Part-Time fumigation conditions assumed for stack releases

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STP JFD Table

Table 2.3S-10 Joint Frequency Distribution of Wind Speed and Wind Direction (10-Meter Level) by Atmospheric Stability Class for the STP 3 & 4 Site (1997, 1999, and 2000) (Continued)

Hours at Each Wind Speed and Direction

Period of Record: 1997, 1999, 2000 Total Period

Elevation: **Speed:** PT SPD10 **Direction:** PT DIR10 **Lapse:** PT DT60-10

Summary of All Stability Classes ΔT

	Wind Speed (m/s)												
Wind Direction (from)	0.23-0.50	0.51-0.75	0.76-1.00	1.1-1.5	1.6-2.0	2.1-3.0	3.1-5.0	5.1-7.0	7.1-10.0	10.1-13.0	13.1-18.0	> 18.0	Total
N	1	4	29	115	132	276	553	438	236	10	0	0	1794
NNE	0	5	31	153	237	358	712	236	58	0	0	0	1790
NE	1	9	35	208	277	418	483	138	18	0	0	0	1587
ENE	1	5	34	201	236	312	386	160	42	0	0	0	1377
E	0	7	24	175	216	372	423	250	129	7	0	0	1603
ESE	0	4	19	191	274	442	572	400	233	10	0	0	2145
SE	1	3	14	102	304	729	1076	937	300	10	3	0	3479
SSE	0	1	6	41	105	698	1401	1003	280	10	0	0	3545
S	0	1	5	18	58	346	1668	1012	131	3	0	0	3242
SSW	0	1	1	10	24	219	678	265	47	0	0	0	1245
SW	0	3	4	5	18	92	277	100	24	0	0	0	523
WSW	2	0	3	10	24	54	95	24	7	0	0	0	219
W	0	5	7	24	48	110	62	10	6	1	0	0	273
WNW	0	9	20	74	99	147	84	36	10	0	0	0	479
NW	0	2	20	76	121	166	173	130	79	2	0	0	769
NNW	0	4	19	90	109	206	395	318	193	21	0	0	1355
Totals	6	63	271	1493	2282	4945	9038	5457	1793	74	3	0	25425

Number of Calm Hours for this Table	0
Number of Variable Direction Hours for this Table	0
Number of Invalid Hours	879
Number of Valid Hours for this Table	25425
Total Hours for the Period	26304

Note: Stability class based on the vertical temperature difference (ΔT or lapse rate) between the 60-meter and 10-meter measurement levels.

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STP Wind Rose

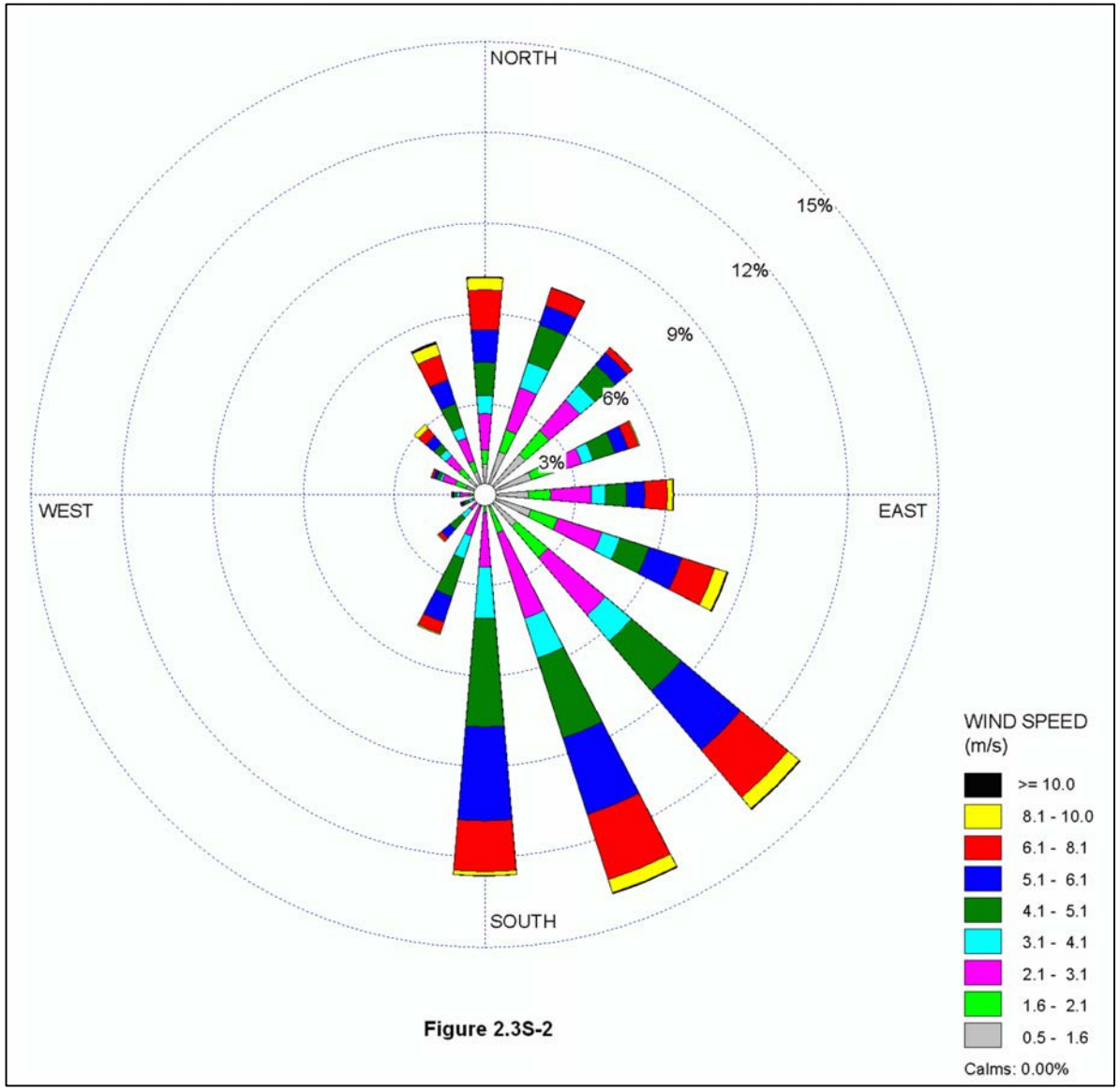

Figure 2.3S-2

Figure 2.3S-2
10-Meter Level
3-year Composite
Wind Rose -
Annual (1997,
1999, and 2000)

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PAVAN Description

- The larger of the following two calculated χ/Q values is selected to represent the χ/Q value for the 0–2 hour time interval.
  - 0.5-percent maximum sector value
  - 5-percent overall site value
- These calculated χ/Q values are based on 1-hour averaged data but are conservatively assumed to apply for 2 hours
- This procedure is repeated two times:
  - Once for the EAB
  - Once for the LPZ

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PAVAN Description

0.5-pecent Maximum Sector χ/Q Value

- For each of the 16 downwind direction sectors (N, NNE, NE, ENE, etc.), χ/Q values are calculated for each combination of wind speed and atmospheric stability at the appropriate downwind distance
- The χ/Q values calculated for each sector are then placed in order from the greatest to the smallest, and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and stabilities for each sector.
- An *upper envelope curve* is determined for each sector, based on the derived data (plotted as χ/Q versus probability of being exceeded), so that no plotted point is above the curve
- From this upper envelope, the χ/Q value, which is equaled or exceeded 0.5 percent of the total time (44 hrs) is obtained
- The maximum 0.5 percent χ/Q value from the 16 sectors becomes the 0–2 hour “0.5- percent maximum sector χ/Q value”

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PAVAN Description

5-percent Overall Site X/Q Value

- Using the same approach, all χ/Q values independent of wind direction are combined into one cumulative frequency distribution for the entire site.
- An upper envelope curve is determined, and the χ/Q value that equals or exceeds 5.0 percent of the total time (438 hours) is selected

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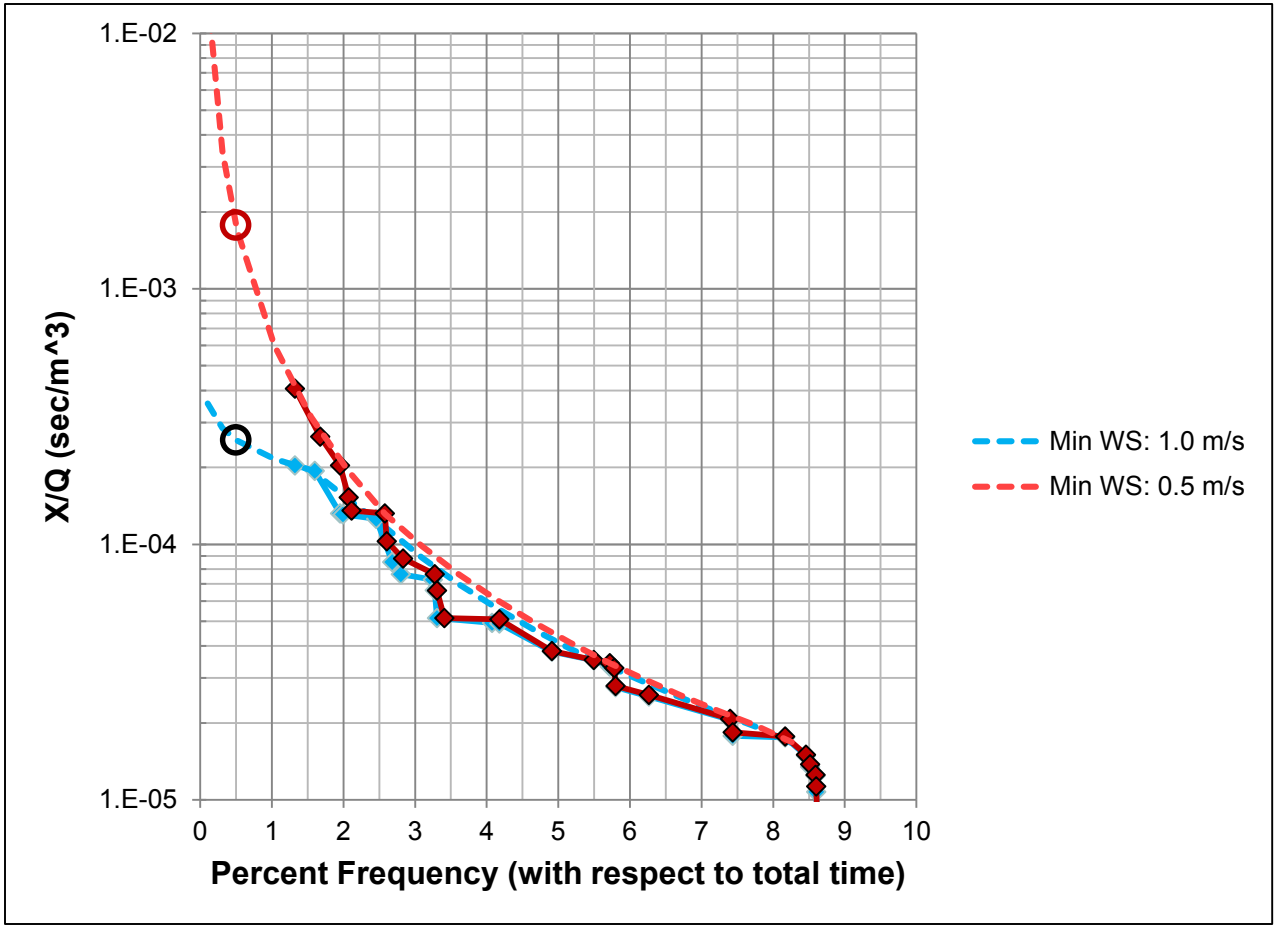
PAVAN Description

An upper envelope curve



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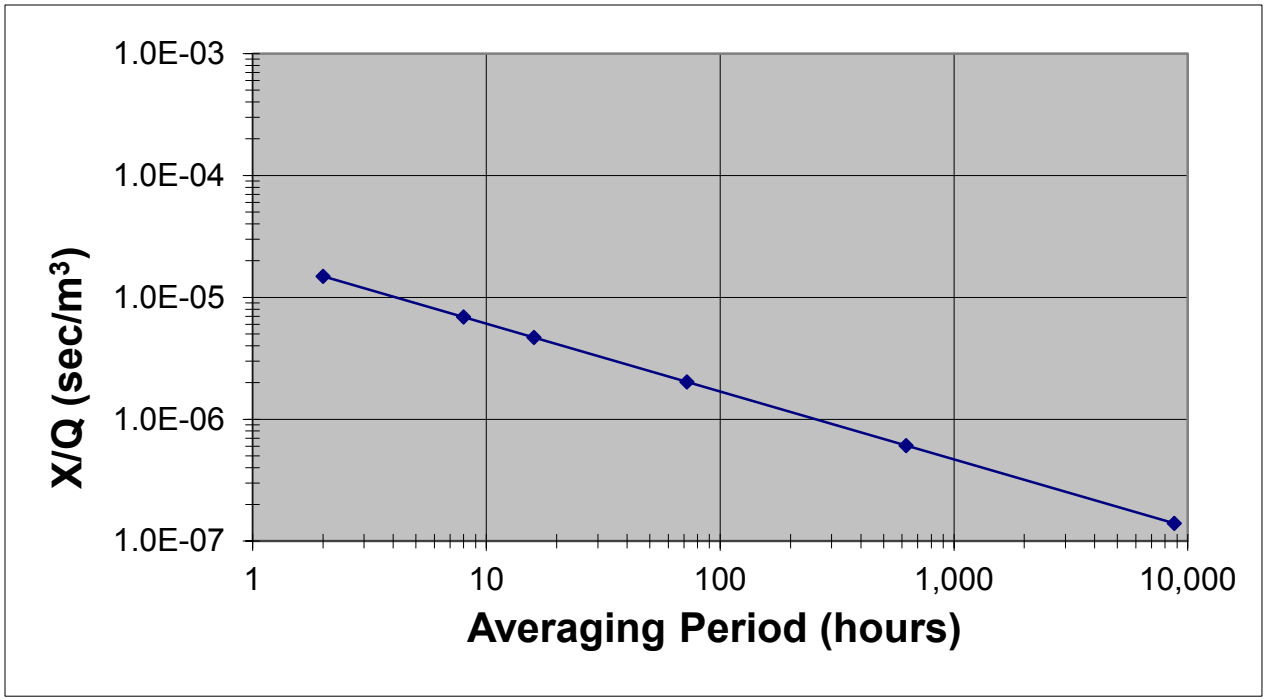
PAVAN Description



To determine LPZ χ/Q values for longer time periods (e.g., 0–8 hours, 8–24 hours, 1-4 days, and 4–30 days), PAVAN performs a logarithmic interpolation between the 0-2 hour χ/Q values and the annual average (8,760 hours) χ/Q values for each of the 16 sectors and the overall site. For each time period, the highest among the 16-sector and overall site χ/Q values is identified and becomes the short-term site characteristic χ/Q value for that time period.

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STP PAVAN Inputs

- One ground-level release point
- STP defined a power block envelope that encloses the STP 3 & 4 reactor buildings and turbine buildings
  - Determined the shortest distances from the power block envelope to the EAB and LPZ within 45-degree sectors centered on the compass directions of interest

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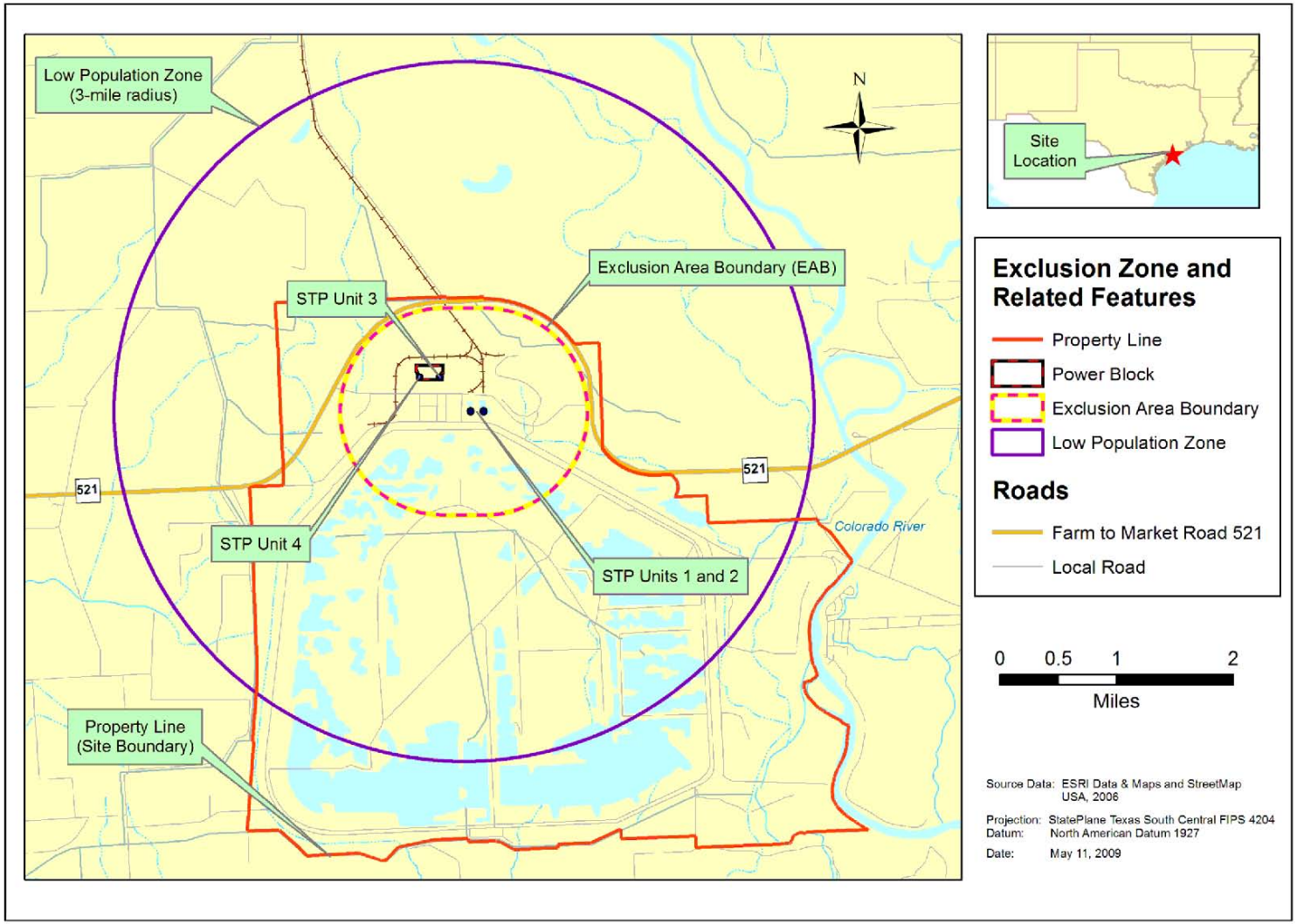
STP EAB and LPZ



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STP PAVAN Inputs

Table 2.3S-21 EAB and LPZ Distances

Distance from Envelope Surrounding STP 3 & 4				
Directional Sector	**To EAB (feet)**	**To EAB (meters)**	**To LPZ (feet)**	**To LPZ (meters)**
N	2503	763	13304	4055
NNE	2572	784	13684	4171
NE	2815	858	14183	4323
ENE	3691	1125	14941	4554
E	5098	1554	15912	4850
ESE	6335	1931	16765	5110
SE	6611	2015	17287	5269
SSE	6106	1861	17241	5255
S	5650	1722	16486	5025
SSW	4911	1497	15545	4738
SW	3825	1166	14350	4374
WSW	3084	940	13701	4176
W	2746	837	13182	4018
WNW	2343	714	12874	3924
NW	2251	686	12831	3911
NNW	2464	751	13156	4010

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STP PAVAN Output (LPZ)

RELATIVE CONCENTRATION (X/Q) VALUES (SEC/CUBIC METER)
VERSUS
AVERAGING TIME

DOWNWIND SECTOR	DISTANCE (METERS)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE	HOURS PER YEAR MAX 0-2 HR X/Q IS EXCEEDED IN SECTOR	DOWNWIND SECTOR
S	5025.	3.58E-05	1.59E-05	1.06E-05	4.40E-06	1.24E-06	2.65E-07	16.5	S
SSW	4738.	4.47E-05	2.06E-05	1.40E-05	6.06E-06	1.82E-06	4.17E-07	22.2	SSW
SW	4374.	5.16E-05	2.44E-05	1.67E-05	7.40E-06	2.30E-06	5.49E-07	40.4	SW
WSW	4176.	5.27E-05	2.45E-05	1.67E-05	7.30E-06	2.22E-06	5.15E-07	43.7	WSW
W	4018.	4.93E-05	2.34E-05	1.61E-05	7.18E-06	2.25E-06	5.43E-07	34.8	W
WNW	3924.	4.81E-05	2.35E-05	1.65E-05	7.57E-06	2.48E-06	6.34E-07	31.5	WNW
NW	3911.	4.34E-05	2.20E-05	1.56E-05	7.48E-06	2.59E-06	7.09E-07	24.3	NW
NNW	4010.	2.72E-05	1.41E-05	1.01E-05	4.97E-06	1.78E-06	5.08E-07	6.7	NNW
N	4055.	1.34E-05	7.06E-06	5.13E-06	2.56E-06	9.47E-07	2.80E-07	3.4	N
NNE	4171.	9.22E-06	4.45E-06	3.09E-06	1.40E-06	4.51E-07	1.12E-07	1.1	NNE
NE	4323.	6.35E-06	2.87E-06	1.93E-06	8.18E-07	2.38E-07	5.26E-08	2.7	NE
ENE	4554.	3.08E-06	1.45E-06	9.95E-07	4.40E-07	1.36E-07	3.25E-08	1.5	ENE
E	4850.	8.14E-06	3.67E-06	2.46E-06	1.04E-06	3.00E-07	6.58E-08	5.3	E
ESE	5110.	2.59E-05	1.08E-05	6.94E-06	2.67E-06	6.80E-07	1.27E-07	10.4	ESE
SE	5269.	2.36E-05	1.00E-05	6.54E-06	2.58E-06	6.81E-07	1.33E-07	7.9	SE
SSE	5255.	2.55E-05	1.11E-05	7.36E-06	3.00E-06	8.24E-07	1.70E-07	10.3	SSE
MAX X/Q		5.27E-05				TOTAL HOURS AROUND SITE:		262.6	
SRP 2.3.4	3911.	1.00E-04	4.43E-05	2.94E-05	1.21E-05	3.38E-06	7.09E-07		
SITE LIMIT		4.04E-05	2.07E-05	1.48E-05	7.18E-06	2.53E-06	7.09E-07		

0.5 PERCENT X/Q TO AN INDIVIDUAL IS LIMITING.
NOTE: VALUES ON THIS PAGE ARE APPROXIMATIONS ONLY.
CHECK THE REASONABLENESS OF THE ENVELOPES
COMPUTED FOR THE 0-2 HOUR VALUES. FOR ANY
FAULTY ENVELOPES, ADJUST THE ABOVE VALUES.

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Resulting PAVAN χ/Q Values for STP (s/m^3)

Receptor	Averaging Time	STP
EAB	0-2 hrs	2.74E-4
LPZ	0-2 hrs	5.27E-5
	0-8 hrs	2.45E-5
	8-24 hrs	1.67E-5
	1-4 days	7.57E-6
	4-30 days	2.59E-6
	Annual Average	7.09E-7

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Areas for Improvement RG 1.145 and PAVAN

- Update 1970's ATD algorithms
  - Turbulence based on stability classes derived from delta-T
  - Dispersion parameters (σ_y and σ_z)
  - Building wake
    - plume entrainment
    - enhanced dispersion
  - Low wind speed conditions
- Use hourly met data instead of JFD tables
- Implement sliding window approach instead of logarithmic interpolation for LPZ χ/Q values greater than 1 hour
- Consider upgrades to the computer code software
  - Implement a windows-based system
  - Resolve "code anomalies" reported by stakeholders
- Conclusion: Code is usable and conservative

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Draft PAVAN08

- PAVAN08: Staff evaluated new approach
- Gaussian plume model
- Improvements
  - Upgraded to a windows-based system
  - Uses hourly meteorological data
  - Uses sliding window approach
  - Implemented revised dispersion parameters for low wind speed and building wake similar to ARCON96 and RASCAL
- Remaining challenges
  - Handling low wind speed dispersion conditions
  - Addressing fumigation conditions
  - Results in significantly lower DBA χ/Q values

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PAVAN08 versus PAVAN DBA χ/Q Values

- For the PAVAN08 5% χ/Q values:
  - EAB 0-2 hr χ/Q value reduced the most (<10% of the PAVAN value)
  - LPZ values also reduced considerably
    - Greatest reductions for shortest time period
  - Reductions are a result of:
    - Low wind speed correction (Σ_y and Σ_z)
    - Sliding window approach (for intermediate averaging times)
  - hourly χ/Q values less sensitive to atmospheric stability
  - hourly χ/Q values generally increase with wind speed during stable (E-G) conditions
- Staff continues to evaluate possible alternate approaches

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Routine Operational Releases

- Applicable NRC Regulations
  - 10 CFR Part 20, Subpart D, *Radiation Dose Limits for Individual Members of the Public*
    - The annual average concentrations of radioactive material released in gaseous effluents at the boundary of the unrestricted area do not exceed the values specified in Table 2 of Appendix B to part 20
      - Intended to result in doses below 0.05 rem (0.5 mSv)
  - Appendix I of 10 CFR Part 50, *Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet ALARA Criterion for Radioactive Material in Reactor Effluents*
    - Section II.B: Unrestricted annual air dose < 10 mrad (0.1 mGy) gamma or 20 mrad (0.2 mGy) beta
    - Section II.C: Unrestricted annual individual organ dose from all pathways of exposure < 15 mrem (0.15 mSv)
    - Section II.D: radwaste system cost-benefit analysis based on population dose out to 50 miles

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Routine Operational Releases

- Applicable NRC Guidance
  - RG 1.206, C.I.2.3.5: *Long-Term Atmospheric Dispersion Estimates for Routine Releases*
  - SRP 2.3.5: *Long-Term Atmospheric Dispersion Estimates for Routine Releases*
  - RG 1.111: *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors (Revision 1, 1977)*
  - NUREG/CR-2919: *XOQDOQ Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations (1982)*

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XOQDOQ Description

- Gaussian plume model
  - plume horizontal distribution is assumed to be evenly distributed within the 22.5 deg downwind sector (sector-averaging)
  - for ground-level releases, plume vertical diffusion coefficient modified to account for building wake
- Meteorological input consists of a JFD of hourly values of:
  - wind speed (calms defined as ½ sensor threshold)
  - wind direction (16 directions, 22.5 deg sectors, centered on true north)
  - atmospheric stability class (preferably based on delta-T)
- Building wake impacts on release height
  - release points below adjacent solid structures → *ground-level releases*
  - release points higher than but less than 2 times higher than adjacent solid structures → *mixed-mode (part-time ground, part-time elevated) releases*
    - function of the ratio of plume vertical exit velocity to horizontal wind speed
  - release points higher than 2 times adjacent solid structures → *elevated releases*
    - calculates effective plume height

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XOQDOQ Description

- Allows adjustment of χ/Q and D/Q values to account for the effects of local air recirculation or stagnation using default or user-supplied site-specific correction factors

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XOQDOQ Description

- Dry depletion/deposition
- Annual estimates of χ/Q and D/Q values
  - No Decay/Undepleted χ/Q values: used to evaluate ground level concentrations of long lived noble gases (e.g., tritium and C-14)
  - 2.26-Day Decay/Undepleted χ/Q values: used to evaluate ground-level concentrations of short-lived noble gases (based on half-life of Xe-133m)
  - 8.00-Day Decay/Depleted χ/Q values: used to evaluate ground level concentrations of radioiodine and particulates assuming dry deposition (based on the half-life of I-131)
  - No Decay D/Q values
- Receptor locations
  - plant boundary
  - nearest resident, milk and meat animal, and vegetable garden
  - 22 standard radial distances out to 50 miles
  - 10 standard distance-segments out to 50 miles

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STP XOQDOQ Inputs

- Two ground-level release points (Unit 3 and 4 reactor building stacks)
  - The 249-ft reactor building stack qualifies as a mixed-mode (part-time ground/part-time elevated) release, but STP conservatively assumed ground-level releases
  - Distance from closest stack to each receptor was used
- Receptors of interest (based on land use census)
  - Site boundary, nearest resident, nearest meat animal, and nearest vegetable garden
  - No residential milk cows were identified within 8 km
  - STP assumed all residents have:
    - A vegetable garden
    - A calf for residential consumption

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STP XOQDOQ Inputs

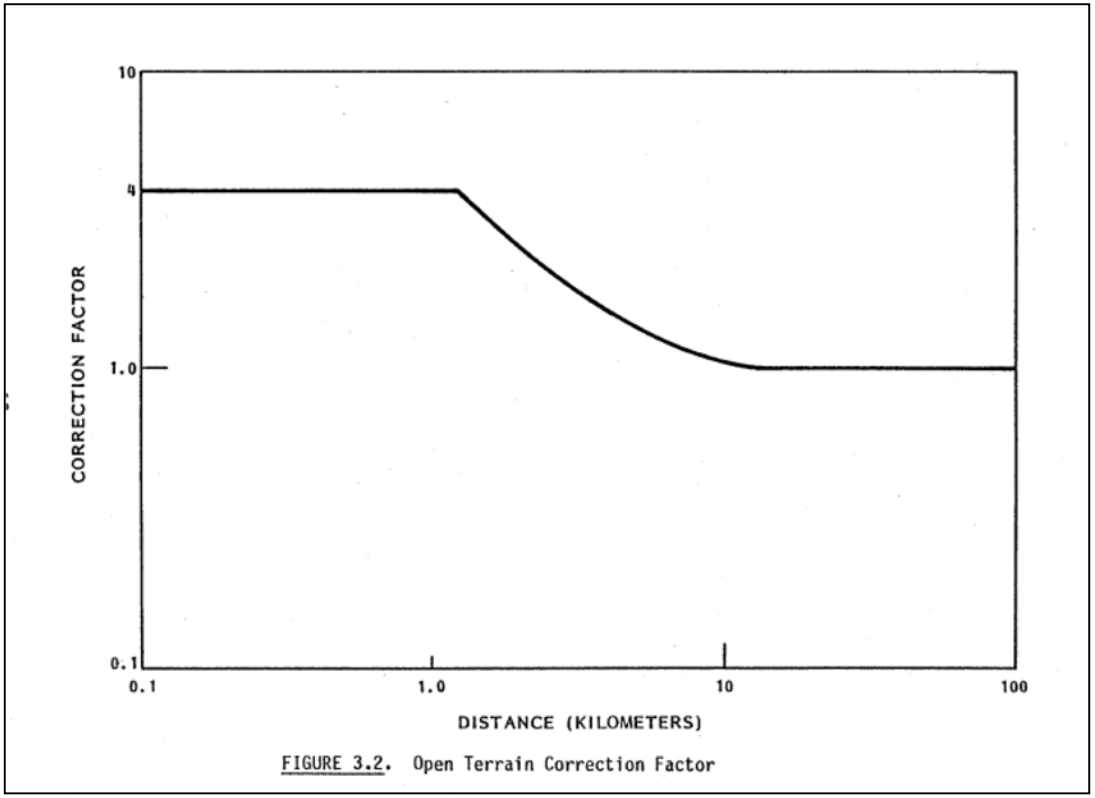

FIGURE 3.2. Open Terrain Correction Factor

Default XOQDOQ open terrain recirculation factors were used to adjust the results of the straight-line XOQDOQ model to account for sea breeze recirculation

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STP XOQDOQ Inputs

Table 2.3S-26b Distances from Release Points to the Site Boundary

Direction	From	Distance (m)
S	Unit 3	6380
SSW	Unit 4	4117
SW	Unit 4	2248
WSW	Unit 4	1916
W	Unit 4	1917
WNW	Unit 4	1917
NW	Unit 4	1295
NNW	Unit 4	1115
N	Unit 4	1098
NNE	Unit 3	1123
NE	Unit 3	1311
ENE	Unit 3	1649
E	Unit 3	2242
ESE	Unit 3	2309
SE	Unit 3	6180
SSE	Unit 3	6652

Table 2.3S-26 Distances from the Release Points to Sensitive Receptors

	Distance to Nearest Residence, Vegetable Garden, and Meat Animal (meters) from	Distance to Nearest Residence, Vegetable Garden, and Meat Animal (meters) from		Closest of two (meters)
Direction	Center of STP 1 & 2	STP 3	STP 4	STP 3 or 4
N	5600	5157	5193	5157
NNE	8000	7802	7932	7802
NE	8000	8083	8295	8083
ENE	7200	7549	7811	7549
E	8000	8557	8831	8557
ESE	5600	6287	6538	6287
SE	5600	6319	6517	6319
SSE	8000	8650	8768	8650
S	0	0	0	0
SSW	8000	8256	8177	8177
SW	7200	7185	7015	7015
WSW	4000	3734	3506	3506
W	7200	6673	6399	6399
WNW	7200	6521	6264	6264
NW	7200	6482	6292	6292
NNW	5600	4966	4884	4884

Note: For STP 1 & 2, if the distance is greater than 8,000 meters, then the distance is taken as 8,000 meters. If a pathway is not applicable, the receptor distance is 0 meters

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STP XOQDOQ Outputs

Table 2.3S-27 XOQDOQ-Predicted Maximum χ/Q and (D/Q) Values at Receptors of Interest

	Type of Location	Direction from Site	Distance (miles)	χ/Q (sec/m³)
No Decay	EAB	NW	0.52	1.50E-05
	Site Boundary	NNW	0.69	8.10E-06
	Resident	WSW	2.18	6.30E-07
	Meat Animal	WSW	2.18	6.30E-07
	Vegetable Garden	WSW	2.18	6.30E-07
	Unit 4 Reactor	WNW	0.17	8.30E-05
2.26 Day Decay	EAB	NW	0.52	1.50E-05
	Site Boundary	NNW	0.69	8.10E-06
	Resident	WSW	2.18	6.20E-07
	Meat Animal	WSW	2.18	6.20E-07
	Vegetable Garden	WSW	2.18	6.20E-07
	Unit 4 Reactor	WNW	0.17	8.30E-05
8 Day Decay	EAB	NW	0.52	1.40E-05
	Site Boundary	NNW	0.69	7.30E-06
	Resident	WSW	2.18	5.10E-07
	Meat Animal	WSW	2.18	5.10E-07
	Vegetable Garden	WSW	2.18	5.10E-07
	Unit 4 Reactor	WNW	0.17	8.00E-05
	Type of Location	**Direction from Site**	**Distance (miles)**	**D/Q (1/m²)**
	EAB	NW/NNW	0.52	1.00E-07
	Site Boundary	NNW	0.69	6.40E-08
	Resident	NNW	3.03	1.80E-09
	Meat Animal	NNW	3.03	1.80E-09
	Vegetable Garden	NNW	3.03	1.80E-09
	Unit 4 Reactor	WNW	0.17	3.40E-07

The receptors with the highest χ/Q and D/Q values are usually either the closest receptors and/or the receptors located in prevailing downwind sectors

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STP XOQDOQ Outputs

Table 2.3S-28 XOQDOQ-Predicted Annual Averate χ/Q Values at the Standard Radial Distances and Distance-Segment Boundaries

No Decay χ/Q at Various Distances											
RELEASE POINT - GROUND LEVEL - NO INTERMITTENT RELEASES NO DECAY, UNDEPLETED CORRECTED USING STANDARD OPEN TERRAIN FACTORS											
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED)											
	DISTANCE IN MILES FROM THE SITE										
Sector	.250	.500	.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	3.024E-05	9.780E-06	5.079E-06	2.601E-06	1.052E-06	5.737E-07	3.658E-07	2.567E-07	1.921E-07	1.504E-07	1.220E-07
SSW	4.092E-05	1.295E-05	6.688E-06	3.461E-06	1.420E-06	7.811E-07	5.015E-07	3.538E-07	2.659E-07	2.091E-07	1.701E-07
SW	4.526E-05	1.411E-05	7.274E-06	3.787E-06	1.565E-06	8.655E-07	5.577E-07	3.947E-07	2.974E-07	2.343E-07	1.909E-07
WSW	3.885E-05	1.214E-05	6.260E-06	3.256E-06	1.344E-06	7.423E-07	4.780E-07	3.380E-07	2.546E-07	2.005E-07	1.633E-07
W	3.799E-05	1.208E-05	6.311E-06	3.266E-06	1.338E-06	7.359E-07	4.722E-07	3.331E-07	2.502E-07	1.967E-07	1.600E-07
WNW	4.265E-05	1.383E-05	7.329E-06	3.766E-06	1.530E-06	8.360E-07	5.341E-07	3.754E-07	2.812E-07	2.205E-07	1.789E-07
NW	4.916E-05	1.643E-05	8.801E-06	4.462E-06	1.781E-06	9.619E-07	6.091E-07	4.251E-07	3.167E-07	2.471E-07	1.996E-07
NNW	3.826E-05	1.337E-05	7.195E-06	3.600E-06	1.413E-06	7.542E-07	4.735E-07	3.281E-07	2.430E-07	1.887E-07	1.517E-07
N	2.412E-05	8.121E-06	4.263E-06	2.104E-06	8.172E-07	4.335E-07	2.709E-07	1.871E-07	1.382E-07	1.070E-07	8.590E-08
NNE	1.015E-05	3.457E-06	1.819E-06	8.977E-07	3.486E-07	1.849E-07	1.156E-07	7.981E-08	5.893E-08	4.564E-08	3.664E-08
NE	5.005E-06	1.648E-06	8.572E-07	4.271E-07	1.679E-07	8.989E-08	5.656E-08	3.928E-08	2.915E-08	2.267E-08	1.827E-08
ENE	3.215E-06	1.088E-06	5.747E-07	2.885E-07	1.140E-07	6.122E-08	3.861E-08	2.686E-08	1.995E-08	1.554E-08	1.253E-08
E	6.872E-06	2.178E-06	1.131E-06	5.827E-07	2.379E-07	1.305E-07	8.360E-08	5.889E-08	4.421E-08	3.473E-08	2.823E-08
ESE	1.450E-05	4.452E-06	2.290E-06	1.191E-06	4.921E-07	2.720E-07	1.753E-07	1.240E-07	9.346E-08	7.365E-08	6.001E-08
SE	1.645E-05	5.201E-06	2.712E-06	1.396E-06	5.690E-07	3.117E-07	1.995E-07	1.405E-07	1.054E-07	8.273E-08	6.719E-08
SSE	2.145E-05	6.929E-06	3.598E-06	1.838E-06	7.415E-07	4.035E-07	2.570E-07	1.802E-07	1.347E-07	1.055E-07	8.545E-08

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Areas for Improvement RG 1.111 and XOQDOQ

- Update 1970's ATD algorithms
  - Turbulence based on stability classes derived from delta-T
  - Dispersion parameters (σ_z)
  - Building wake
    - plume entrainment
    - enhanced dispersion
- Address adequacy of Gaussian plume model out to 50 miles
  - spatial and temporal changing wind patterns
  - terrain and water influences
- Update dry deposition and depletion algorithms
- Add wet deposition and depletion algorithms
- Use hourly met data instead of JFD tables

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Any Questions?