NMP Unit 2 USAR

APPENDIX 2J

TEST PROCEDURES

APPENDIX 2J

TEST PROCEDURES

TABLE OF CONTENTS

APPENDIX 2J

TEST PROCEDURES

2J.1 UNIAXIAL COMPRESSION TEST PROCEDURE

2J.1.1 Introduction

The object of this set of tests was to determine values for the five independent elastic parameters that characterize a rock material having cross-anisotropic elastic behavior. The parameters to be evaluated were: Young's modulus and Poisson's ratio for a specimen loaded uniaxially in a direction perpendicular to the bedding, Young's modulus and Poisson's ratio for the specimen loaded uniaxially in a direction parallel to the bedding, and shear modulus of the rock.

The uniaxial compression test with strain measurements for elastic parameter determination is covered in Reference 1.

2J.1.2 Apparatus

Eight foil resistance strain gauges were fixed to each specimen with epoxy adhesive. The gauge length was 1.4 cm (0.55 in), at least 10 times the average grain size of the rock and 5 times the size of the largest grains beneath the gauge.

The strain gauge readout equipment (Vishay Model P350A) had a built-in calibration facility to allow a check on calibration at any time during the tests. Strain was recorded with a resolution of +1 microstrain, the overall accuracy of measurement being +5 microstrain or better.

The test machine was a Franall 226,800-kg (500,000-lb) capacity and the applied load was displayed on two gauges, one with a range 0 to 13,608 kg (30,000 lb) with 91 kg (200 lb) per division, and the other covering the full capacity of the testing machine. The 13,608-kg gauge was employed during the majority of the testing, the higher range of gauge being used only during loading to failure of the stronger rock specimens.

2J.1.3 Procedure

Rocks of the various formations onsite were sampled by drilling core approximately 13.2 cm (5.2 in) diameter, which was protected by encapsulation in metal cans and by reapplying a load perpendicular to the bedding planes sufficient to maintain the integrity of the specimen during storage and transportation. Test specimens were prepared from the samples by redrilling in directions at 90, 45, and 0 deg to the bedding.

Two different sizes of core bit were used in preparing the specimens. The larger size, producing a specimen of approximately 5 cm (2.0 in) diameter, was used for the stronger rocks such as sandstones and graywacke. The smaller size, producing specimens of approximately 3.8 cm (1.5 in) diameter, was used for the weaker rocks such as shale, in order to obtain the maximum number of specimens from the available samples in view of the high incidence of breakage and specimen loss that was encountered. The redrilled specimens were cut and lapped to give right circular cylinders with a ratio of length to diameter of approximately 2.0. The specimens were instrumented with electric resistance strain gauges, there being four pairs of gauges per specimen with pairs of gauges located at 90-deg intervals around the specimen circumference at mid-height. One gauge in each pair was oriented to measure axial compression and the other to measure circumferential expansion.

Specimen wiring was completed and initial readings taken of strain in each gauge. The curved surface (not the ends) of the specimen was waxed to retain water content, except in the case of sandstone specimens where waxing was considered unnecessary.

The specimen and spherical seating were positioned centrally in the testing machine, and the cross head lowered to apply a small (nominal) load. An initial set of strain gauge and temperature readings were taken at zero load.

Load was applied in approximately five equal increasing increments to a maximum of 60 to 70 percent of the estimated uniaxial compressive strength for the rock. Each load increment was applied in a period of approximately 2 to 5 min and the new load held constant while a complete set of reading was taken on all strain gauges. A further set of readings was taken if any one gauge showed a tendency to drift or to give an erratic readout. The time of each reading and the corresponding axial load were also recorded.

The load was then decreased in approximately five equal increments to a value sufficient to ensure that the specimen remained in place in the testing machine. Readings of strain and applied load were taken at each increment as previously specified. A further cycle of loading and unloading was then completed, with incremental values and maximum load similar to those for the first cycle.

After two load-unload cycles were completed, the specimen was loaded to failure in approximately five larger increments and readings were taken as before. Care was taken to record the failure load of the specimen from which the uniaxial compressive strength could be calculated, although the strains corresponding to this strength could not be measured.

2J.1.4 Calculations

The strain readings were processed, computing strain magnitudes by subtracting the initial (zero load) strain reading, and calculating average values for axial strain and circumferential strain in the x and y directions. The stress in the specimen was computed as the ratio of applied load to original cross-sectional area.

Values for Young's modulus and Poisson's ratio were computed from these. These elastic parameters are secant values, being based on only two sets of readings, one set at a stress close to zero and the other at a stress close to 141 kg/sq cm (2,000 psi). To compute the parameters, data points were selected as close as possible to these stress limits, separate values being calculated corresponding to the second cycle loading and unloading curves, and the third loading cycle.

2J.2 RING TEST PROCEDURE

2J.2.1 Introduction

The ring test was conceived with the object of measuring time dependent dimensional changes of rock specimens under three-dimensional confining pressure. In outline, the ring test employed a 13.2-cm (5.2-in) diameter cylindrical rock specimen grouted with molten sulphur into a thin-walled aluminum ring. The rock was sawed and ground flush with the ends of the ring, giving a 5-cm (2-in) high disc. Expansion of the rock in the horizontal (bedding plane) direction would result in an equal expansion of the ring, measured by four electric resistance strain gauges mounted on the outer surface of the aluminum with micrometer measurements as a check. Horizontal confining pressure would increase linearly in proportion to any expansion, with a known constant of proportionality deduced from the elastic properties and thickness of the ring.

Three types of ring tests were defined for purposes of this project: a swell strain test, where axial stress was maintained approximately constant at the overburden pressure, with measurement of axial (vertical) strain; a swell stress test where the axial load was adjusted to maintain an approximately constant specimen height, measuring the load required; and a creep strain test, similar to the swell strain test but with the specimen sealed to retain its initial water content. A total of 25 ring tests were performed, 13 of the swell strain type, 9 of the swell stress type, and 3 of the creep strain type.

2J.2.2 Apparatus

Rings of three different wall thicknesses, 0.25, 0.51, and 0.76 cm (0.1, 0.2 , and 0.3 in), were used in the testing program to provide three different confining pressure paths. Axial confining pressure was also provided using a simple two-column load frame. This load was applied by tightening nuts on the columns in order to transmit force to the rock specimen through ball seats and steel platens. The applied load was measured using electric resistance strain gauges mounted on the columns, with micrometer measurements as a check. Axial (vertical) strain of the specimen was measured between three pairs of steel balls fixed to the platens, using a micrometer.

The water content of the specimens was controlled. In some tests, the specimens were sealed with wax to retain their initial water content. In other tests, the specimens were allowed to dry or take up water. The loading platens were machined with concentric and radial grooves connected to a system of valves and tubes providing a supply of either dry nitrogen or distilled water to both upper and lower rock surfaces.

Tests were carried out in a temperature controlled environment. Initially, the tests were conducted in a site warehouse with temperature control in the range 18 ±2°C (64 ±3.6°F), then transferred in an insulated truck at a temperature of approximately 18 ±4°C (64 ±7.2°F) to a laboratory with a temperature of 18 ±1°C (64 ±1.8°F).

2J.2.3 Measuring Systems

Radial strain, proportional to radial stress acting on the aluminum ring, was measured using four foil resistance strain gauges mounted to measure circumferential strain at 90-deg intervals at mid-height on the outer surface of the ring. The overall accuracy of strain measurement was better than ±5 microstrain, with a resolution of ±1 microstrain. A check on radial strains was obtained by micrometer measurements between steel balls mounted in pairs on two orthogonal diameters of the rings, fixed to the ring with epoxy adhesive.

Axial strain of the rock was measured with a micrometer between three pairs of steel balls fixed with epoxy adhesive to the specimen platens. The micrometer resolution was 0.0003 cm (0.0001 in), with an overall measuring accuracy better than ±0.01 cm (±0.004 in).

Axial force on the specimen was measured using foil resistance strain gauges mounted in pairs on the central portion of each loading column. The gauges were mounted opposing each other and connected to the strain bridge so as to compensate for bending. The load in each column could be measured independently.

Micrometer measurements between steel balls fixed with epoxy adhesive to the top and bottom of each column served as a check on the applied load.

2J.2.4 Calibration

A load cell with range 0 to 2,270 kg (5,000 lb), accurate to ±1 percent was used to individually calibrate each load frame. Standard length gauges were used to calibrate all micrometers before the start of testing and at intervals during the progress of tests. The Toronto laboratory temperature was independently calibrated by the supplier of the control equipment. Before shipment to the field, each aluminum ring was checked using a dilatometer, taking readings of applied pressure, strain gauge output, and micrometer measurements.

2J.2.5 Test Procedure

The specimen was assembled in the load frame, positioning the grooved platens and spherical seats centrally on the top and the base of the rock faces. An initial set of zero readings was taken on all gauges before applying the axial load. The axial load prescribed for the specimen was then applied by tightening the two column nuts alternately and equally. A complete set of strain gauge and micrometer readings was taken on reaching the prescribed load.

Specimens other than those to be initially dried with nitrogen were then waxed to seal the exposed ring of rock and sulphur grout around the edge of upper and lower platens. Specimens for creep testing were further sealed by applying wax to completely fill platen inlet connectors.

Specimens to be tested unsaturated were weighed before assembly in the test frame. After applying the prescribed load, dry nitrogen was supplied to upper and lower faces of the specimen by opening the gas inlet valve. At intervals of approximately 30 to 60 min, the specimen was removed from the load frame and again weighed, replaced in the load frame, and the prescribed load reapplied. Periodic readings of time elapsed, axial pressure, and axial and radial strains were taken at intervals during the drying process.

Specimens to be tested saturated were flooded with water immediately after applying the prescribed axial load. Specimens to be tested unsaturated were flooded with water after a period of drying and after reapplying the prescribed load.

The reading procedure for swell strain tests was as follows: The initial prescribed axial pressure was applied and maintained constant, taking readings of time elapsed, the applied axial pressure, and axial and radial strains until swelling had stabilized to a steady log-time rate. The axial load was then reduced to one-half its initial value, maintained constant, and readings continued until swelling had again stabilized to a steady log-rate.

The axial load was then removed, with the exception of a small load (approximately 11 kg, 25 lb) due to the deadweight of the cross beam and upper platen. Readings were continued until swelling had again stabilized to a steady log-time rate. The specimen was then removed and cored to measure its final water content and density.

The program of loadings for creeping strain tests was identical to that for the swell strain tests.

For the swell stress tests, the prescribed axial load was applied and maintained constant, taking readings of all gauges until axial consolidation or shrinkage had changed to axial swelling or expansion. When expansion was detected, the height of specimen, measured as the average of micrometer readings between upper and lower platens, was maintained constant by increasing the axial load, tightening the column nuts by an amount sufficient to nullify any measured strain expansion increment. Readings were taken of elapsed time, the axial load required to main in the specimen height constant, and of radial strain, until the axial swell force and radial swell strain had stabilized to a steady log-time rate. On completion or testing the specimen was removed and redrilled to measure its final water content and density.

2J.2.6 Calculations

Radial confining pressure was computed from the circumferential ring strains by applying thin ring theory as follows:

$$S = \frac{2tE}{D} \varepsilon \qquad (2J\text{-}1)$$

Where:

S = Uniform radial stress in rock

t = Ring thickness

E = Young's modulus for aluminum, 10 x 10^6 psi

D = Internal diameter of ring

ε = Circumferential strain, measured

Axial strain of the rock specimen was computed directly as the average obtained from the three micrometer readings between upper and lower specimen platens, converting these readings to displacement and dividing by the specimen length.

2J.3 TRIAXIAL SWELL AND CREEP TEST PROCEDURE

2J.3.1 Introduction

The triaxial compression test and in particular the equipment used for purposes of this project have been described in a paper by Franklin and Hoek[2]. The purpose of the triaxial tests was to measure axial and radial swell strains as a function of time under controlled axial and lateral confining stress conditions.

2J.3.2 Apparatus

Three gauge rosettes were fixed at 120-deg intervals around the circumference of each specimen, with gauge elements aligned in the axial and circumferential directions.

The six gauges were wired to a switch and balance box and readout unit in such a way as to allow independent measurement of the strain in each gauge.

The strain readout equipment, Vishay Model P350A, had a built-in calibration facility to allow a check on calibration at any time during the tests. Strain was recorded with a resolution of ±1 microstrain, the overall accuracy of measurement being ±5 microstrain or better.

A supplementary axial extension measuring system was provided using a pair of steel balls fixed to the load transfer beams above and below the specimen, located on the specimen axis. The distance between these balls was measured using a micrometer.

The triaxial cell utilized was a Hoek-Franklin type cell complete with polyurethane rubber jacket and quick release outlets for hand pump and pressure gauge. Each cell was checked over an operating range of 3.5 to 141 kg/sq cm (50 to 2,000 psi) to ensure freedom from leakage of cell fluid.

Bourdon pressure gauges were used to measure the cell fluid pressure in the range 3.5 to 141 kg/sq cm (50 to 2,000 psi), with an accuracy ±2 percent of the measured - pressure. A loading frame consisting of two threaded columns with cross beams and channel supports was utilized. The load frame was designed and calibrated for loads in the range 0 to 45 kg (3,200 lb) force. Load was applied by tightening the column nuts using a sleeve wrench.

Force was transferred from the steel cross beams to the specimen through a spherical seat acting on the lower face of the specimen, and a water supply platen acting on its upper face. The spherical seat had a diameter of 4.2 cm (1.655 in) and a center of curvature coinciding with the center of the specimen end face. The upper water supply platen consisted of a steel cylinder with concentric and radial grooves at the specimen contact face.

2J.3.3 Calibration

A load cell with a range 0 to 2,270 kg (5,000 lb), accurate to ± 1 percent, was used to individually calibrate each load frame.

A standard length gauge was used to calibrate the axial extension micrometer before the start of testing and after its completion. Laboratory temperature was continuously recorded. The temperature record was checked using three independent thermometers positioned at various locations in the laboratory that had been independently calibrated by the supplier of the control equipment. The tests were conducted at a temperature of 18 ±1°C (64° ±1.8°F).

2J.3.4 Test Procedure

Specimens 3.8 cm (1.5 in) in diameter were prepared by drilling samples in a direction perpendicular to the bedding. The specimens were instrumented with three strain gauge rosettes mounted around the circumference at mid-height, each gauge consisting of two elements, one measuring in the axial and the other in the circumferential direction. The gauges were coated with waterproofing material and the specimen wrapped in blotting paper to allow access of water. The specimens were then assembled with spherical seats and inserted into the triaxial cells, applying an axial stress approximately equivalent to the overburden pressure. A confining pressure was then applied by hand pump. Specimens to be tested saturated were then flooded with water, introduced through the perforated upper platen.

Specimens to be tested for creep were sealed by application of wax to close the inlet port in the upper platen. Measurements were then taken of temperature, elapsed time, applied axial and cell pressure (constant), circumferential and axial strains on the rock specimen, and overall axial extension using a micrometer until the rates of swelling had stabilized to a constant log-time rate. The cell pressure was then reduced to approximately one-half the initial value, and readings were taken until steady log-time swelling had again been achieved. Finally the cell pressure was reduced to a small value sufficient to hold the cell in place, and readings were continued as before.

Specimens to be tested under swell conditions were then connected to the water reservoir by opening the water supply valve. Specimens to be tested under creep conditions were sealed by disconnecting the water supply valve and sealing the connector with wax.

The axial load prescribed for the specimen was then applied by tightening the two column nuts alternately and equally. A complete set of strain gauge and micrometer readings was taken on reaching the prescribed load.

The prescribed initial cell pressure was then applied using the hand pump. Readings of all gauges were again recorded.

The axial force and cell pressure were maintained as close to constant as possible for a period of several days, taking readings of all gauges at time intervals sufficient to adequately define the swelling or shrinkage characteristics of the specimen, until these dimensional changes appeared as straight lines on a graph of strain versus log-time.

The applied cell pressure was then reduced (usually to one-half the initial value) and readings continued until the strain rates again stabilized. Cell pressure was again reduced, this time to a nominal value sufficient to hold the cell in position, and strain readings were continued until swelling had stabilized.

2J.3.5 Calculations

The strain readings were processed, computing strain magnitudes by subtracting the initial (zero load) strain reading, and plotting graphs of individual strains versus time.

2J.4 TRIAXIAL COMPRESSION TESTING PROCEDURE

2J.4.1 Introduction

The triaxial compression tests were to determine the compressive strength of different rock types for different bedding inclinations. The tests were run at 3.5, 53, and 105 kg/sq cm (50, 750, and 1,500 psi) at 90-deg bedding inclination on one rock sample; and at 90, 45, and 0-deg bedding inclination on three other rock samples.

Data reduction was performed in accordance with equations and procedures described in Donath and Guven[3].

The tests were run on solid right cylindrical test specimens, 1.3 cm (0.5 in) in diameter by 2.5 cm (1 in) long, maintaining a specimen height to diameter ratio of approximately 2:1.

2J.4.2 Apparatus

The apparatus used in the triaxial compressive strength testing was a 2,110-kg/sq cm (30,000-psi) triaxial pressure vessel collar-coupled with a 18,144-kg (20-ton) holl-o-ram. Confining pressure and pore pressure were generated and measured by separate systems. Pore pressure was not used in this testing project, but the pore pressure piston was used to prevent pore pressure buildup in the saturated test specimen confining pressure was held constant during testing by a special pressure equalizer chamber mounted inside the hollow loading ram. Minor pressure adjustments were made by hand using the pressure generator throughout each test run to hold the pressure exactly at the required limit.

Axial force was generated by a loading ram system and was transferred through the bottom of the vessel to the test specimen by a loading piston. Loading was by a gear-driven hydraulic pump at a constant rate of strain of 10^{-4}/sec. The specimen assembly consisted of the test specimen solid right cylinder placed between the upper piston and a lower anvil and jacketed with clear, soft, flexible vinyl tubing. The jacket was sealed to the piston and anvil by 0-rings.

2J.4.3 Measurement and Recording

The 53- and 106-kg/sq cm (750- and 1,500-psi) confining pressures were measured by an auxiliary 0- to 3,515-kg/sq cm (50,000-psi) Heise gauge and the 50-psi confining pressure was read on a much smaller 0- to 11-kg/sq cm (160-psi) gauge. Confining pressure was continuously monitored and adjusted to the desired pressure with a variation of ±0.7±kg/sq cm (10 psi) for the Heise and ±1 for the smaller gauge.

Axial force being applied to the test specimen was continuously recorded on the Y axis of a Hewlett Packard Model 7001AM X-Y recorder. The recorded electrical signal was the output of the top plug load cell.

Axial shortening of the test specimen, measured as ram displacement relative to the top of the coupling collar, was continuously recorded on the X axis of the X-Y recorder. The electrical signal for the recorder was generated by an externally mounted Hewlett Packard Model 7DCDT-500 linear displacement transducer.

2J.4.4 Procedure

Specimen finishing (sawing to length and grinding) was done with precision on a machinist s tool and cutter grinder. Squareness and parallelism were maintained and checked to be within 0.0013 cm (0.0005 in) and length to diameter was maintained at 2:1 or greater. The specimen was inserted into the plastic jacket which was then placed into the pressure vessel. The vessel was sealed and made ready for testing. The confining pressure was then applied to the specimen. The specimen was loaded at 10-4 strain rate until failure.

2J. REFERENCES

1. International Society for Rock Mechanics. Suggested Methods for Determining the Uniaxial Compressive Strength and the Deformability of Rock Materials, 1978.

2. Franklin, J.A. and Hoek, E. Development in Triaxial Testing Techniques, Rock Mechanics 2, Springer Verlag, p 223-228, 1970.

3. Donath, F. and Guven. Data Reduction in Experimental Rock Deformation in Geology, Vol. 10, No. 2, 1971.

APPENDIX 2K

BORING LOGS

APPENDIX 2K

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont’d)

APPENDIX 2L

POPULATION DISTRIBUTION

APPENDIX 2L

LIST OF TABLES

APPENDIX 2L

LIST OF FIGURES

APPENDIX 2L

POPULATION DISTRIBUTION

Population distribution within a 50-mi radius of Nine Mile Point Unit 2 is listed by distance and direction in Tables 2L-1 through 2L-7. Population densities are listed in Tables 2L-8 and 2L-9. Figures 2L-1 and 2L-2 show the 10- and 50-mi areas with sector overlays corresponding to the tables.

Population distribution between 0 and 6 km (3.7 mi) was determined through a door-to-door survey conducted by SWEC May 9 through 13, 1982. Population distribution beyond 6 km (3.7 mi) was calculated using the same methods as those described in Section 2.1.3. Data from the 1980 U. S. Census of Population and the 1981 Canadian Census of Population provided the basis for the estimates.

Bibliography

1. Bureau of the Census. 1980 Census of Population, Advance Reports, U.S. Department of Commerce, New York, 1981.

2. New York Department of Commerce. 1978 Official Population Projections by Age and Sex for New York State Counties, September 1980.

3. Statistics Canada. Interim Population Counts for Census Divisions and Census Subdivisions, 1981, Ottawa, Canada, 1982.

4. Statistics Canada. Population: Geographic Distributions. 1976 Census, Census Divisions and Subdivisions: Ontario, Ottawa, Canada, June 1977.

5. Envirodata Corp. Digitized Maps of Area Within 50 Miles of Nine Mile Point, 1982.

6. Ministry of Treasury and Economics, Central Statistical Services, Ontario's Population Projections by Regions and Counties for years 1981, 1986, 1996, 2001, Toronto, Canada, February 1979.

7. Ministry of Treasury and Economics, Central Statistical Services, Ontario: Population Projections for Centers of 10,000 Population and Over (in 1976) 1981, 1986, 1991, 1996, 2001 (Concluded), Toronto, Canada, April 1980.

8. Statistics Canada, 1976 Final Population, 1981 Population and Dwellings, Canada, Provinces, Census Divisions and Subdivisions, Ottawa, Canada, 1982.

TABLE 2L-1

POPULATION DISRIBUTION FOR 1980
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	3	21	30	13	0	53	136	127	96	0	421	220	1,120
ESE	0	0	8	24	55	13	74	96	118	123	364	158	193	1,618	2,844
SE	0	0	0	45	50	82	65	66	13	44	197	79	131	180	952
SSE	0	0	0	25	101	87	17	109	249	110	115	107	191	176	1,287
S	0	0	0	7	45	22	81	132	60	56	176	212	229	217	1,237
SSW	0	0	8	4	36	75	147	146	196	180	436	172	758	1,817	3,975
SW	0	0	44	38	32	28	51	126	160	272	2,904	8,959	7,081	1,765	21,460
WSW	0	0	0	16	2	8	0	8	4	0	3	491	1,106	954	2,592
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	63	180	351	328	435	736	936	912	4,291	10,178	10,110	6,947	35,467

TABLE 2L-1 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	24	341	1,699	25,985	28,049
NNE	0	0	0	42	956	771	2,364	4,604	2,799	2,801	14,337
NE	0	56	396	711	1,911	3,872	2,199	21,085	15,349	6,910	52,489
ENE	232	2,282	1,061	2,130	879	449	242	176	1,086	5,554	14,091
E	703	1,343	729	760	1,393	758	421	615	1,086	1,895	10,823
ESE	1,024	1,069	1,210	881	1,549	1,976	3,518	5,103	11,287	22,726	53,187
SE	899	1,151	1,880	2,320	6,489	7,246	9,746	10,058	19,254	17,549	77,544
SSE	1,242	1,368	1,976	2,698	26,358	48,390	132,885	141,059	20,648	7,100	385,011
S	1,546	14,068	2,712	2,511	8,470	15,181	22,645	16,621	25,329	4,750	115,070
SSW	1,687	1,403	1,891	1,259	2,060	3,347	6,201	6,165	19,616	20,648	68,252
SW	1,482	1,234	767	929	3,121	4,062	3,541	7,089	9,583	18,091	71,359
WSW	15	0	0	0	0	31	1,404	4,286	6,496	10,308	25,132
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	164	323	487
NW	0	0	0	0	0	0	0	233	1,221	7,309	8,763
NNW	0	0	0	0	0	0	0	0	211	2,819	3,030
Total	8,830	23,974	12,622	14,241	53,186	86,083	185,190	217,435	135,828	154,768	927,624

TABLE 2L-2

POPULATION DISRIBUTION FOR 1986
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	3	23	33	15	0	58	150	141	107	0	467	244	1,241
ESE	0	0	9	27	61	14	82	107	131	136	403	175	214	1,791	3,150
SE	0	0	0	50	56	89	72	73	15	49	218	87	146	199	1,054
SSE	0	0	0	27	112	96	18	120	276	122	128	118	211	194	1,422
S	0	0	0	8	50	24	90	146	66	62	195	235	254	240	1,370
SSW	0	0	9	4	40	83	163	162	217	199	483	191	840	2,012	4,403
SW	0	0	49	42	35	31	56	140	177	302	3,216	9,923	7,842	1,956	23,769
WSW	0	0	0	18	2	9	0	9	4	0	3	544	1,224	1,057	2,870
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	70	199	389	361	481	815	1,036	1,011	4,753	1,273	11,198	7,693	39,279

TABLE 2L-2 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	24	352	1,762	26,337	28,475
NNE	0	0	0	43	990	797	2,443	4,760	2,895	2,895	14,823
NE	0	62	428	739	1,976	4,002	2,274	21,798	15,890	7,162	54,331
ENE	257	2,528	1,173	2,359	963	482	259	185	1,155	5,898	15,259
E	778	1,489	809	841	1,542	836	440	635	1,130	1,972	11,713
ESE	1,135	1,183	1,341	977	1,715	2,157	3,556	5,103	11,293	22,738	54,348
SE	995	1,275	2,082	2,569	7,141	7,648	10,274	10,679	20,778	18,925	83,420
SSE	1,376	1,515	2,188	2,983	27,775	50,483	138,635	147,163	21,544	7,426	402,510
S	1,712	15,581	3,005	2,780	8,837	15,827	23,593	17,204	25,850	4,863	120,622
SSW	1,869	1,554	2,094	1,371	2,092	3,393	6,317	6,281	19,807	20,319	69,500
SW	1,641	1,346	802	942	3,220	4,270	3,727	7,459	10,058	19,090	76,324
WSW	16	0	0	0	0	32	1,478	4,510	6,837	10,849	26,592
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	168	331	499
NW	0	0	0	0	0	0	0	240	1,253	7,504	8,997
NNW	0	0	0	0	0	0	0	0	216	2,904	3,120
Total	9,779	26,533	13,922	15,604	56,251	89,927	193,020	226,369	140,636	159,213	970,533

TABLE 2L-3

POPULATION DISRIBUTION FOR 1990
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	4	25	36	16	0	63	162	151	115	0	501	261	1,334
ESE	0	0	10	29	65	15	88	115	141	146	432	188	230	1,924	3,383
SE	0	0	0	53	60	97	77	78	16	52	234	94	156	214	1,131
SSE	0	0	0	29	120	103	20	129	297	131	137	127	228	209	1,530
S	0	0	0	8	54	26	96	157	71	67	209	252	273	258	1,471
SSW	0	0	10	5	43	89	175	173	233	214	519	205	903	2,161	4,730
SW	0	0	52	45	38	33	60	150	190	323	3,454	10,657	8,423	2,100	25,525
WSW	0	0	0	19	2	10	0	10	5	0	3	584	1,315	1,135	3,083
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	76	213	418	389	516	875	1,115	1,084	5,103	12,107	12,029	8,262	42,187

TABLE 2L-3 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	25	363	1,811	27,176	29,375
NNE	0	0	0	44	1,017	820	2,513	4,893	2,977	2,978	15,242
NE	0	67	453	761	2,032	4,115	2,340	22,416	16,352	7,373	55,909
ENE	277	2,715	1,261	2,532	1,027	508	273	195	1,205	6,151	16,144
E	836	1,599	869	903	1,657	896	458	655	1,166	2,037	12,410
ESE	1,218	1,271	1,439	1,047	1,842	2,299	3,626	5,169	11,437	23,030	55,761
SE	1,069	1,370	2,236	2,760	7,645	8,025	10,777	11,259	22,117	20,130	88,519
SSE	1,478	1,627	2,350	3,200	29,117	52,652	144,589	153,485	22,468	7,755	420,251
S	1,839	16,735	3,228	2,984	9,214	16,493	24,570	17,783	26,283	4,965	125,565
SSW	2,007	1,669	2,249	1,455	2,113	3,423	6,396	6,363	19,927	20,148	70,480
SW	1,762	1,433	827	949	3,294	4,435	3,871	7,748	10,432	19,869	80,145
WSW	17	0	0	0	0	34	1,536	4,685	7,103	11,271	27,729
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	170	335	505
NW	0	0	0	0	0	0	0	242	1,265	7,572	9,079
NNW	0	0	0	0	0	0	0	0	219	2,912	3,131
Total	10,503	28,486	14,912	16,635	58,958	93,700	200,974	235,256	144,932	163,702	1,010,245

TABLE 2L-4

POPULATION DISRIBUTION FOR 2000
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	4	28	41	18	0	71	184	173	131	0	572	299	1,521
ESE	0	0	11	33	75	18	101	131	161	167	494	214	262	2,197	3,864
SE	0	0	0	61	68	111	87	89	18	59	268	107	178	244	1,290
SSE	0	0	0	34	137	118	23	148	338	150	157	144	259	239	1,747
S	0	0	0	10	62	30	110	179	81	76	239	288	311	294	1,680
SSW	0	0	11	5	49	101	200	198	266	244	592	234	1,031	2,468	5,399
SW	0	0	60	51	43	38	69	171	217	370	3,944	12,167	9,616	2,398	29,144
WSW	0	0	0	22	3	11	0	11	5	0	4	667	1,501	1,296	3,520
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	86	244	478	445	590	998	1,270	1,239	5,829	13,821	13,730	9,435	48,165

TABLE 2L-4 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	25	361	1,824	27,272	29,482
NNE	0	0	0	44	1,014	817	2,506	4,881	2,970	2,971	15,203
NE	0	76	493	767	2,026	4,104	2,333	22,364	16,341	7,378	55,882
ENE	315	3,100	1,440	2,888	1,150	549	289	199	1,240	6,334	17,504
E	954	1,824	991	1,031	1,890	1,019	479	664	1,188	2,074	13,635
ESE	1,392	1,451	1,645	1,196	2,104	2,583	3,658	5,125	11,340	22,833	57,191
SE	1,221	1,562	2,553	3,150	8,676	8,756	11,714	12,231	24,172	21,893	97,218
SSE	1,687	1,857	2,683	3,646	31,719	56,769	155,897	165,485	24,225	8,371	454,086
S	2,099	19,104	3,684	3,404	9,936	17,765	26,447	18,985	27,539	5,226	135,869
SSW	2,292	1,905	2,568	1,635	2,199	3,559	6,703	6,677	20,597	20,236	73,770
SW	2,012	1,615	891	984	3,531	4,905	4,288	8,583	11,511	21,979	89,443
WSW	20	0	0	0	0	37	1,700	5,189	7,865	12,479	30,810
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	170	336	506
NW	0	0	0	0	0	0	0	243	1,271	7,607	9,121
NNW	0	0	0	0	0	0	0	0	219	2,926	3,145
Total	11,992	32,494	16,948	18,745	64,245	100,863	216,039	250,987	152,472	169,915	1,082,865

TABLE 2L-5

POPULATION DISRIBUTION FOR 2010
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	5	33	47	21	0	83	214	200	152	0	665	347	1,767
ESE	0	0	13	38	87	21	117	152	187	194	574	249	304	2,552	4,488
SE	0	0	0	71	79	128	101	104	21	69	311	124	207	284	1,499
SSE	0	0	0	40	160	137	27	172	393	174	181	169	301	278	2,032
S	0	0	0	11	71	35	128	208	95	88	278	334	362	342	1,952
SSW	0	0	13	6	57	118	232	231	309	284	688	271	1,197	2,867	6,273
SW	0	0	69	60	51	44	80	198	252	429	4,581	14,135	11,173	2,786	33,858
WSW	0	0	0	25	3	13	0	13	6	0	4	775	1,744	1,505	4,088
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	100	284	555	517	685	1,161	1,477	1,438	6,769	16,057	15,953	10,961	55,957

TABLE 2L-5 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	26	373	1,875	30,382	32,656
NNE	0	0	0	45	1,043	841	2,580	5,024	3,056	3,058	15,647
NE	0	89	552	798	2,085	4,225	2,401	23,022	16,833	7,607	57,612
ENE	366	3,600	1,673	3,353	1,314	609	316	209	1,297	6,632	19,369
E	1,110	2,121	1,152	1,198	2,196	1,181	522	697	1,246	2,176	15,366
ESE	1,617	1,686	1,909	1,389	2,442	2,971	3,902	5,400	11,948	24,056	61,808
SE	1,418	1,816	2,966	3,661	10,061	10,026	13,394	14,025	27,827	25,092	111,785
SSE	1,960	2,157	3,117	4,234	36,299	64,745	177,797	188,734	27,627	9,555	518,257
S	2,439	22,195	4,281	3,953	11,306	20,219	30,043	21,142	29,246	5,616	152,392
SSW	2,662	2,214	2,984	1,864	2,281	3,686	7,020	7,014	21,233	20,558	77,789
SW	2,337	1,849	967	1,018	3,808	5,493	4,809	9,627	12,873	24,655	101,294
WSW	23	0	0	0	0	42	1,908	5,821	8,823	13,999	34,704
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	165	325	490
NW	0	0	0	0	0	0	0	235	1,231	7,331	8,797
NNW	0	0	0	0	0	0	0	0	207	2,706	2,913
Total	13,932	37,727	19,601	21,513	72,835	114,038	244,718	281,323	165,487	183,748	1,210,879

TABLE 2L-6

POPULATION DISRIBUTION FOR 2020
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	5	38	55	24	0	96	247	231	175	0	767	401	2,039
ESE	0	0	15	44	101	24	135	175	215	223	662	287	351	2,945	5,177
SE	0	0	0	82	91	148	118	120	24	80	359	143	239	327	1,731
SSE	0	0	0	46	184	158	31	199	453	201	210	194	348	320	2,344
S	0	0	0	13	82	40	147	240	109	102	320	386	417	395	2,251
SSW	0	0	15	7	66	136	268	266	357	328	793	313	1,380	3,307	7,236
SW	0	0	80	69	58	51	93	229	291	495	5,285	16,304	12,886	3,212	39,053
WSW	0	0	0	29	4	15	0	15	7	0	5	894	2,012	1,736	4,717
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	115	328	641	596	792	1,340	1,703	1,660	7,809	18,521	18,400	12,643	64,548

TABLE 2L-6 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	26	381	1,910	34,863	37,180
NNE	0	0	0	47	1,068	861	2,639	5,140	3,127	3,128	16,010
NE	0	102	616	824	2,133	4,323	2,457	23,552	17,227	7,788	59,022
ENE	422	4,153	1,930	3,866	1,494	674	344	215	1,336	6,829	21,263
E	1,279	2,444	1,328	1,382	2,533	1,360	571	732	1,302	2,274	17,244
ESE	1,864	1,945	2,204	1,602	2,819	3,402	4,249	5,821	12,879	25,933	67,895
SE	1,635	2,095	3,421	4,222	11,608	11,601	15,482	16,219	32,117	28,821	128,952
SSE	2,261	2,489	3,595	4,885	42,005	74,977	205,894	218,560	31,994	11,064	600,068
S	2,813	25,601	4,938	4,558	13,061	23,364	34,654	23,884	31,342	6,101	172,567
SSW	3,071	2,553	3,441	2,118	2,375	3,831	7,387	7,409	21,992	21,252	82,665
SW	2,696	2,108	1,051	1,056	4,135	6,194	5,431	10,868	14,498	27,801	114,891
WSW	27	0	0	0	0	47	2,154	6,569	9,959	15,804	39,277
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	154	304	458
NW	0	0	0	0	0	0	0	220	1,148	6,780	8,148
NNW	0	0	0	0	0	0	0	0	183	2,314	2,497
Total	16,068	43,490	22,524	24,560	83,231	130,634	281,288	319,570	181,168	201,056	1,368,137

TABLE 2L-7

POPULATION DISRIBUTION FOR 2030
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	6	44	63	28	0	110	284	265	201	0	880	460	2,341
ESE	0	0	17	50	115	27	155	201	247	256	759	329	402	3,380	5,938
SE	0	0	0	94	105	171	135	137	27	91	412	165	274	375	1,986
SSE	0	0	0	52	211	182	35	228	520	230	240	222	399	367	2,686
S	0	0	0	15	94	46	169	276	125	117	368	443	478	453	2,584
SSW	0	0	17	8	75	157	307	305	409	376	911	359	1,585	3,795	8,304
SW	0	0	92	79	67	58	106	264	334	568	6,067	18,715	14,793	3,688	44,831
WSW	0	0	0	33	4	17	0	17	8	0	5	1,026	2,309	1,993	5,412
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	132	375	734	686	907	1,538	1,954	1,903	8,963	21,259	21,120	14,511	74,082

TABLE 2L-7 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	27	390	1,938	40,990	43,345
NNE	0	0	0	48	1,093	881	2,699	5,257	3,198	3,199	16,375
NE	0	118	686	853	2,182	4,421	2,513	24,095	17,621	7,965	60,454
ENE	485	4,768	2,215	4,435	1,696	744	374	219	1,361	6,965	23,262
E	1,468	2,806	1,525	1,587	2,909	1,560	631	772	1,364	2,378	19,341
ESE	2,139	2,233	2,529	1,840	3,235	3,891	4,712	6,417	14,201	28,594	75,729
SE	1,877	2,404	3,926	4,846	13,351	13,518	18,034	18,883	37,203	33,237	149,265
SSE	2,595	2,856	4,127	5,610	48,978	87,730	240,924	255,743	37,436	12,937	701,622
S	3,229	29,388	5,667	5,230	15,243	27,281	40,395	27,277	33,841	6,686	196,821
SSW	3,526	2,930	3,951	2,401	2,477	3,992	7,799	7,856	22,848	22,302	88,386
SW	3,095	2,394	1,144	1,096	4,508	7,006	6,150	12,307	16,389	31,433	130,353
WSW	31	0	0	0	0	53	2,438	7,441	11,278	17,897	44,550
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	137	270	407
NW	0	0	0	0	0	0	0	196	1,023	5,943	7,162
NNW	0	0	0	0	0	0	0	0	148	1,737	1,885
Total	18,445	49,897	25,770	27,946	95,672	151,077	326,696	366,853	199,986	222,533	1,558,957

TABLE 2L-8

POPULATION DENSITY FOR 1986
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	13	81	115	138	0	3,412	7,500	1,226	451	0	160	52	139
ESE	0	0	37	79	138	26	130	146	158	146	187	69	47	329	162
SE	0	0	0	146	127	165	113	99	18	53	101	34	32	37	55
SSE	0	0	0	79	254	178	28	163	331	131	119	99	46	36	85
S	0	0	0	23	113	44	141	198	79	66	90	92	56	44	71
SSW	0	0	37	12	91	154	255	220	260	213	224	75	184	369	227
SW	0	0	200	122	79	57	88	190	212	333	1,495	4,339	1,718	359	1,242
WSW	0	0	0	126	15	49	0	50	73	0	150	4,000	1,819	972	1,099
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	72	80	127	102	126	177	204	178	392	815	361	200	315

TABLE 2L-8 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	21	20	39	626	268
NNE	0	0	0	34	34	38	65	95	37	37	50
NE	0	55	45	44	45	74	36	296	190	77	124
ENE	70	200	74	128	22	11	4	3	14	65	35
E	72	110	51	48	37	17	7	9	14	21	25
ESE	103	88	84	58	51	40	56	73	139	246	115
SE	90	95	131	140	178	233	322	222	262	208	208
SSE	125	112	137	162	653	977	2,308	2,018	259	80	840
S	159	1,247	189	154	221	309	370	234	352	61	263
SSW	169	115	131	74	47	64	108	87	274	241	150
SW	152	104	63	78	97	86	63	101	121	205	166
WSW	148	0	0	0	0	57	473	178	162	195	205
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	32	34	33
NW	0	0	0	0	0	0	0	27	29	97	70
NNW	0	0	0	0	0	0	0	0	19	58	51
Total	122	249	104	100	143	195	339	312	149	142	201

TABLE 2L-9

POPULATION DENSITY FOR 2030
0- TO 50-MILE RADIUS

Distance	Distance (mi)														
	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.5	8.5-10.0	Total
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	25	155	219	257	0	6,471	14,200	2,304	848	0	302	98	262
ESE	0	0	69	146	260	50	246	275	297	274	351	129	88	620	306
SE	0	0	0	274	238	317	212	186	32	98	191	65	60	69	103
SSE	0	0	0	151	478	337	55	310	623	247	223	185	87	67	160
S	0	0	0	44	213	85	265	375	150	125	170	174	105	83	135
SSW	0	0	69	23	170	291	481	414	490	403	422	141	347	696	427
SW	0	0	375	230	152	107	166	359	400	626	2,821	8,183	3,240	677	2,342
WSW	0	0	0	231	29	93	0	95	145	0	250	7,544	3,431	1,832	2,072
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	136	151	239	194	237	334	385	335	739	1,537	682	377	594

TABLE 2L-9 (Cont'd.)

Direction	Distance (mi)										
	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	Total 0-50.0
N	0	0	0	0	0	0	24	23	42	975	409
NNE	0	0	0	37	37	42	72	105	41	41	56
NE	0	104	72	51	49	82	39	327	211	86	138
ENE	132	377	139	241	38	17	6	3	17	77	53
E	135	208	96	90	70	31	10	10	16	25	41
ESE	194	165	159	109	95	72	75	92	174	310	161
SE	170	179	246	263	333	411	566	393	469	365	372
SSE	235	212	259	305	1,151	1,698	4,011	3,506	450	139	1,464
S	301	2,352	357	290	381	533	633	371	460	83	429
SSW	319	217	248	130	56	75	133	108	316	265	191
SW	286	186	90	91	135	142	103	167	196	337	283
WSW	288	0	0	0	0	94	780	294	268	322	344
W	0	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	26	28	27
NW	0	0	0	0	0	0	0	22	24	77	56
NNW	0	0	0	0	0	0	0	0	13	35	31
Total	229	468	192	179	243	328	575	505	211	198	323

APPENDIX 2M

ADDITIONAL INFORMATION

ON

TRENCH 1

NOTE: HANDWRITTEN NOTES AND AFFIDAVITS ARE ON FILE IN FCMS.

TABLE OF CONTENTS

NOTE: A set of color slides showing the bedrock surface in Trench 1 was provided to the NRC by a letter from T. E. Lempges to A. Schwencer dated November 8, 1984.

NRC Site Visit 12/22/76 – Nine Mile Point Unit 2

Attendance list attached.

For full notes of conference, see notes of J. H. Mullin, CHOC, attached.

R. Jackson of NRC asked J. Peck of S&W what his opinion was in regard to the cooling tower trench fault being a seismic safety hazard to the existing plants. A lengthy response was given which concluded that, at the present state of knowledge concerning the feature, it does not constitute a seismic safety hazard to the existing plants. The major points covered in reaching that conclusion were the following:

1. Faulting in rock at cooling tower shows left lateral movement, horizontal slickensides, and 1-1/2 in of apparent vertical displacement. Rock surface in fracture zone is glacially rounded indicating pre-glacial age for bedrock faulting. Horizontal displacement not determined; based on dip of rock and all strike slip motion, vertical offset can be accounted for by 2-1/2 ft of horizontal movement.

2. Soil profile over bedrock fault shows discontinuous graben forming shears in lacustrine deposits overlying till. Maximum vertical offset is about 1 cm. The till shows no shearing. Peat soil overlies the lacustrine deposits and is not disturbed.

3. In the pit excavated about 40 ft NW of the cooling tower trench, the rock is fractured, shows horizontal slickensides and apparent left lateral movement of unknown amount. Horizontal slickensides are coated with crystalline calcite which is undisturbed. The fracture zone in rock is topographically low (about 6-10 in) compared to the undisturbed rock on either side and shows glacial polish and striations along edges of the zone.

4. The soil profile in the pit consists of till over rock, lake bed silts, rippled and cross-laminated sands, and peat soil. Small grabens occur in the lake bed deposits but not in the rippled sand or the till. Displacement is about 1 cm on gravity-type shears. Compaction folding over boulders in the till is shown in the lake bed silts but not in the rippled sands. The contact between lake bed deposits and rippled sand is an unconformity.

5. Trenches to the NW of the pit at 800 ft and 1600 ft along strike show no faulting in rock or soil disturbance. Some jointing is present.

6. In trench #3 (600 ft SW of cooling tower trench), the rock shows apparent vertical offset of at least 2-1/2 ft, possibly more, with south side down. The rock also shows a topographic low on the south side of the fracture zone which shows steep dip to the south and evidence of glacial plucking. The topographic relief is about 4-1/2 ft. The fracture zone shows horizontal and vertical slickensides with vertical younger than horizontal and crystalline calcite smeared into vertical slickensides. Rock surface dips gently north, north of the pulverized zone and steeply south, south of the zone. No clay gouge is evident but sandstone is brecciated and pulverized in a zone about 6 in to 1 ft wide and rock is badly fractured in a zone about 3 ft wide.

7. Soil overlying rock in trench #3 consists in ascending order of bouldery till, dark gray laminated lake bed silts, and light brown ripple marked sands and silty sands, with a dark brown peat soil capping the sand. Artifical fill covers the peat. The till, lake bed deposits and rippled sand show a monoclinal fold structure over the fracture zone in bedrock with reverse shears in the sand and the sand-lake bed contact. The displacement on these shears is a maximum of 2.5 in. The shears are discontinuous and become lower angle upward. Conelation of beds from south side to north on the monocline show that south side is 2-1/2 ft lower than north side. No thru-going shears in till, lake beds and sand are evident. No displacement of peat is evident. The contact between lake bed deposits and sand is an unconformity, and another unconformity within the sand is also evident. The peat soil is also unconformable on the sand; it does not conform to the fold below.

8. In trench #4 (about 700 ft southeast of trench #3), the bedrock shows a zone of brecciation and pulverized sandstone about 1 ft wide, trending N75°W and dipping steeply. The rock surface on the south side is about 3 ft lower than the rock surface on the north and dips about 25° south. Glacial plucking is evident south of the fracture zone. Glacial disturbance of large blocks of sandstone north of the zone has resulted in blocks surrounded with till but more or less in a normal open jointed configuration. That is, the joints are filled with till and till occurs under the blocks. The rock north of the zone dips slightly north. Vertical slickensides are present along joints parallel to the

broken zone south of the zone. Vertical displacement of the rock, if any, is not yet determined. Change in dip on both sides of crush zone would suggest some sort of near-surface buckling.

9. Soil profile overlying the bedrock in trench #4 is mostly till which shows irregular oxidation and includes pockets of structurally disturbed sand, silt and gravel south of the fracture zone in bedrock. Fold and shear structures of the sand bodies in the till indicate overriding by ice or other material. Within the till, no shear zones are evident over the bedrock zone. A large sandstone block is fractured and its north side moved up about 6 in relative to south side, but thin slab of sandstone beneath is not broken. The crack in the sandstone is filled with till in the upper open part. A wedge of post-till soil is present just to the north of the bedrock fracture zone on the west wall. The top of till is a pavement surface, very hard and smooth, dipping north at about 25°. Overlying the till pavement is a thin wedge of lake bed silt which shows a 1/2 in gravity shear with south down, coincident with a 2-1/2 in topographic feature on the till surface. Above the lake bed deposits are rippled sand and gravel deposits which appear to be unconformable on the lake bed silts, do not show shearing, and thicken northward. Unconformable on the sands is wood-bearing peat soil.

10. The relationships seen in the trenches and pits seem to indicate that a pop-up or glacial rebound feature has occurred along a pre-existing bedrock fault. The timing of the pop-up is uncertain but is either late glacial or early post-glacial. The condition of excavation walls and the history of plant construction, including tunnels at the Nine Mile and FitzPatrick sites indicate no obvious high rock stress condition. Therefore, it seems likely that conditions which could cause a repeat of the pop-up do not now exist at the plant site and that the feature does not constitute a seismic safety hazard to the existing plants.

Noted January 5, 1977 by J. H. Peck

NRC Meeting – 12/22/76

Meeting Attendance:

Name	Company
Norm Rademacher	Niagara Mohawk
J. Mullin	Stone & Webster
J. G. McWhorter	Dames & Moore
E. E. Fricks	Stone & Webster
S. H. Haybrook	Niagara Mohawk (Const)
Edward O'Donnell	NRC
John Kelleher	NRC
A. Seanor	Dames & Moore
J. J. Markham	Dames & Moore
R. B. McMullen	NRC
R. E. Jackson	NRC
John H. Peck	Stone & Webster
Jerry Szymanski	Dames & Moore
J. Edward Tillman	Dames & Moore
G. W. Page	Stone & Webster

Noted January 5, 1977 by J. H. Peck

Notes Copied from Field Notebook 76-2 of
John H. Peck, Stone & Webster
With Reference to Observations in "Trench #2"

Site Visit – 12/17/76

Trench in front of Nine Mile 1 switchyard was practically all cleaned but no indication of any faulting or joints parallel to the trench of the rock fractures to the SE. A few sets of closely spaced relatively tight joints trend N70°E $\pm$. No indication of any motion along these joints. May be part of regional set. Indications are that this trench is beyond any northwest extension of the cooling tower bedrock fault. This trench gives us a conservative northwest terminus of faulting. At this time, it is probably not necessary to trench closer to the cooling tower exposures to document the exact location of the terminus.

The new trench (trench #4) is one which shows brecciation in the bedrock along a trend about N73-75°W. Bedrock dips off to south and also somewhat less to north. Gives the

Copy made 10/15/84 – John H. Peck
Noted October 15, 1984 by John H. Peck

Meeting at Site – December 23, 1976

NMPC	NRC	D&M	S&W
Rademacher	Jackson	McWhorter	Peck
Haybrook	McMullen	Markham	Fricks
	O'Donnell	Szymanski	Mullin
	Kelleher	Seanor	Page
		Tillman	

1. Visit to RR trench, access road pit, circ. water ___
   Access pit destroyed, circ. water pit snow covered.

2. NRC given: 1) Plan showing trenches
   2) Sketch of access road ___

3. Markham discussed data to date
   RR pit shows tilling

3. Jackson – Is this a safety hazard to 3 units?
   While investigating – what about ___ FitzPatrick?
   Do we have a ___

___ Markham did not wish to discuss program without NMPC permission.

J. Szymanski – Hazard is not as great as looks
Postulates third "glacial" cause

___ NRC – What is mechanism?
J. Szymanski - ___ line theory

5. Rademacher – We have a program
   Cannot state safety hazard yet

6. McMullen – Is this related to heater bay?
   Peck – No.

7. Jackson – Seismic potential?
   McWhorter – Need to know geometry. Have not looked at it yet.
   NRC – Air ___
   McWhorter – Yes. Many lineations show on ___
   Mentioned teepee fold.
   Peck – Discussed FitzPatrick teepee, stress
   McMullin – Will stress be studied?
   Peck – Part of proposed program.
   Jackson – 90 ft hole indicates no stress, hasn't moved.
   Peck agreed.

Jackson - What is immediate feeling on safety hazard? 90 ft holes good indicator of stress. Have we studied it? NRC will have to report on it. Disagreed with isostatic adjustment theory. Area rising?
Peck – No, not here.
D&M – Same at Hudson Bay – 2mm/yr here.

Peck – Many problems in soil factors: 1) frost, 2) relation of soil deposits complex, 3) general discussion of rock movement, a) 2 motions - 1st horizontal, 2nd vertical. ??? in rock surface along pre-existing fracture which disturbed overlying soils and additional soils later deposited. Indicates movement early in post-glacial.

Rock excavation, FitzPatrick measurements indicate low stresses at site; low seismic hazard for initial appraisal. Jackson – This is what he wanted.

___ Schedules

Rademacher will inform.

Noted January 12, 1977 by J. H. Peck

NRC - Met Privately

NRC - McMullen

Send letter report summarizing John's interpretation. Also proposed program. Due two weeks from today.

Basis (to date) of not considering this a safety hazard. Short summary report of John Peck's argument. Main point.

More trending to SE. Total offset seems to be increasing; several feet of offset may work against glacial rebound.

Drill in cooling tower ___. (Probably included in scope.)

Useful to discuss consultants' setup of study.

Why it is reasonable to not take action now re: ___ FitzPatrick. Jackson needs a piece of paper.

Norm Rademacher - McMullen requested a look at Unit 1 ___. Norm will check.

AFFIDAVIT OF DOUGLAS E. ISLER

AFFIDAVIT of Douglas E. Isler, being duly sworn comes forward and states that the following is true and correct to the best of his knowledge, information and belief:

1. My name is Douglas E. Isler. My address is 5276 Church St., Mexico, New York.

2. During the period from 10/1/76 to 12/31/76 as an employee of Stone and Webster Engineering Corporation, I was engaged in the geologic mapping of excavations in so-called Trench 1 and Trench 2 at the Nine Mile Point Unit 2 site. Based upon the mapping which I performed, it is my professional opinion that such mapping did not reveal the so-called "cooling tower fault."

3. I have made all my logs, notes, photographs, written memoranda and evaluations of the trench features available to my employer, Stone and Webster, and I have no other information in my possession that was not previously provided that bears on the length or termination of the fault in question.

Douglas E. Isler

Sworn to before me this 24th day of October, 1984.

Amy L. Durant
Notary Public in the State of New York

(Signatures and notary seal on file in FCMS.)

AFFIDAVIT OF JOHN J. MARKHAM

John J. Markham, being duly sworn comes forward and states that the following is true and correct to the best of his knowledge, information and belief.

1. My name is John J. Markham. My address is 1901 Deer Hill Drive, Wayzata, Minnesota.

2. During the period September 1976 to February 1977 as an employee of Dames & Moore, I was engaged in the observation of Trenches 1 and 2 at the Nine Mile Point Unit 2 site as shown on Figure 2.5-28A of the FSAR. Based upon the observation which I performed, it is my professional opinion that the so-called “Cooling Tower Fault” was not revealed in these trenches.

3. I have made all of my logs, notes, photographs, memoranda and evaluations of the trench features available to Dames & Moore, and I have no other information in my possession, not previously provided, that bears on the length or termination of the fault in question.

John J. Markham

Sworn to before me this 1st day of November, 1984.

Gary D. Wilson
Notary Public in the State of New York

(Signatures and notary seal on file in FCMS.)

AFFIDAVIT OF JOHN H. PECK

AFFIDAVIT of John H. Peck of Amarillo, Texas, being duly sworn comes forward and states that the following is true and correct to the best of his knowledge, information and belief:

1. My name is John H. Peck. My address is 514 North Fillmore Street, Amarillo, Texas.

2. During the period from September 30, 1976 to December 22, 1976 as an employee of Stone & Webster Engineering Corporation I was engaged in geological consulation regarding mapping of the excavations and/or trenches at the Nine Mile Point 2 site and adjacent property to the west. Based upon the mapping of Trench No. 1 and No. 2 which I reviewed in the field; and based upon my observations in Trench No. 2, it is my professional opinion that such mapping did not reveal the so-called "cooling tower fault."

3. I have made all notes and written memoranda and evaluations of the Trench No. 1 and No. 2 observations available to my employer, Stone & Webster Engineering Corporation, and I have no other information in my possession that was not previously provided that bears on the western termination of the fault in question.

John H. Peck

Sworn to before me this 23rd day of October, 1984.

Michelle Goldsberg
Notary Public in the State of New York

Sworn to before me this 1st day of November, 1984.

Gary D. Wilson
Notary Public in the State of New York

(Signatures and notary seals on file in FCMS.)

APPENDIX 2N

RESPONSES TO NRC OPERATING LICENSE STAGE REVIEW QUESTIONS RELATED TO FSAR SECTION 2.5

QUESTION F230.2

The probability of exceeding the Operating Basis Earthquake during the operating life of the plant should be determined and stated.

RESPONSE

To quantify the risk of exceeding the Operating Basis Earthquake (0.075 g) during the planned life of Unit 2 (40 years), an existing probabilistic analysis has been reviewed. Algermissen, et al (1982) have presented probabilistic estimates of maximum accelerations in hard rock for the contiguous United States. For the area surrounding the site, their calculations show an expected acceleration of 0.05 g for a return period of 475 years, or about a 10 percent chance of this 0.05 g ground motion being exceeded during a 50 yr period. On this basis, the probability of exceeding the OBE (0.075 g) during the life of the plant would be somewhat less than 10 percent.

QUESTION F230.3

The staff's position has been that the largest historical earthquake, in terms of intensity, in the Central Stable Region which has not been associated with tectonic structure is the March 9, 1937, Anna, Ohio (maximum Modified Mercalli intensity VII-VIII) event. Using this controlling earthquake and following the Standard Review Plan, Section 2.5.2, results in a safe shutdown earthquake (SSE) characterized by a Regulatory Guide 1.60 design response spectrum with a high frequency anchor of 0.19g. This exceeds the SSE proposed for Nine Mile Point Nuclear Station Unit 2 in Section 2.5.2.6 of the Final Safety Analysis Report.

In recent operating license reviews, the staff has accepted the use of site specific response spectra developed from earthquake strong motion records of appropriate magnitude, distance and site conditions to characterize the response spectrum of the SSE. The staff has observed that the 1937 Anna, Ohio earthquake (magnitude (mb) 5.0-5.3) along with other central United States events have similar magnitudes. Therefore, for the Nine Mile Point Nuclear Station Unit 2 site, a site specific spectrum would be developed from a suite of strong motion records from magnitude 5.3 $\pm$ 0.5 earthquakes recorded at distances less than about 25 kilometers from the source at rock sites. It has been the staff's position that the appropriate representation of the response spectra as derived directly from real time histories is the 84th percentile level. A site specific spectrum may be computed directly or spectra from other appropriate sites may be utilized (see for example those used for Perry, Wolf Creek, and Limerick). Considering the staff's position, demonstrate the adequacy of the SSE by comparing it to either the Regulatory Guide 1.60 spectrum anchored at 0.19g or a suitable site specific spectrum.

RESPONSE

As described in FSAR Section 2.5.2.2.2, Unit 2 is located within the Eastern Stable Platform subprovince of the Central Stable Region. The Anna, Ohio earthquake of March 9, 1937 (maximum Modified Mercalli Intensity VII-VIII) is located at the confluence of three re-entrant zones of the Michigan, Illinois, and Appalachian Basins (outside of the site tectonic province). On the basis of detailed geophysical studies and focal mechanism construction from original records of the 1937 Anna earthquake, it is concluded that the 1937 Anna event is associated with basement geologic structure in the Anna, Ohio seismogenic zone and should not be assumed to occur at the site (FSAR, p. 2.5-107). The maximum intensity earthquake (FSAR Section 2.5.2.4) which has occurred in the site tectonic province and has not been associated with geologic structure was MMI VI, similar to the earthquakes of Lowville, New York, or Hamilton, Ontario. The safe shutdown earthquake has been designated as a random MMI VI event occurring adjacent to Unit 2, resulting in a peak horizontal ground motion of 0.07g (FSAR Section 2.5.2.6). A very conservative value of 0.15g was adopted, however, to represent the design basis acceleration and to be used as the zero period value in the horizontal and vertical design response spectra (FSAR Figures 2.5-83 and 2.5-84).

Considering the staff position regarding the 1937 Anna earthquake, as expressed in FSAR Question 230.3, a site specific response spectrum used by the NRC for a similar site (i.e., Limerick) is used for comparison to the SSE design response spectrum at Unit 2.

The available records for rock sites in the magnitude range of $m_b = 5.3 \pm 0.5$ at distances of 25 km or less were compiled by Lawrence Livermore Laboratory and used in a site specific response study for the Limerick site. When the based spectra (Limerick SER, Appendix F, August 1983) at the 84th percentile level (mean plus one standard deviation) is compared to the Unit 2 SSE design spectrum (FSAR Figure 2.5-83), the SSE spectrum is approximately equal to or larger than the 84th percentile of the site specific spectrum for the Limerick base case. Figure 230.3-1 presents this comparison.

The Unit 2 SSE design spectrum is, therefore, an adequate and appropriate representation of the ground motion for the site.

QUESTION F230.5

In Section 2.5.2.4 of the FSAR you assign a maximum Modified Mercalli (MM) intensity of VII to the Attica, New York earthquake of August 12, 1929 and state this suggests a MM intensity of IV at the site from this type event if it were to occur at the closest approach (100 km) of the associated structure

(Clarendon-Linden fault) to the site. Numerous seismological references report this earthquake as having had a maximum MM intensity of VIII or a maximum Rossi-Forel intensity of IX. Justify your downgrading of the intensity of this earthquake. Using the higher maximum intensity estimate the vibratory ground motion from this type event occurring at 100 km from the site. Determine if this will effect the seismic design for Nine Mile Point Unit 2.

RESPONSE

The Attica, New York earthquake of August 12, 1929 was originally described in a 1929 United States earthquake publication by the Coast and Geodetic Survey. The earthquake was classified as having a maximum Rossi-Forel Intensity (RFI) of IX. After publication of the Modified Mercalli Intensity (MMI) scale in 1931, the Attica earthquake was thereafter referenced as having maximum intensity of MMI VIII.

A detailed examination of original newspaper accounts, interviews with eyewitnesses, and analysis of original seismograph records of the 1929 Attica earthquake by Fox and Spiker (FSAR Reference 2.5-256) resulted in a proposed downgrading of the shock to a maximum intensity of MMI VII. In addition, at least one early reference[(1)] refers to the event as having an RFI of VIII, which would correspond to a MMI VII as a maximum. Historically, the site experienced a level of intensity equivalent to MMI III-IV from the 1929 Attica shock, which was described as "generally felt beds shook" in Oswego, New York[(2)]. Recent studies by Mitronovas (NYSGS, unpublished report) also support a maximum intensity of VII for the 1929 Attica earthquake. Notwithstanding the previous discussion regarding the maximum intensity of the 1929 Attica earthquake, the effect of assuming the occurrence of a MMI VIII earthquake on the closest approach (~100 km) of the Clarendon-Linden fault to the site has been evaluated.

An estimate of the magnitude of the 1929 Attica earthquake is described in FSAR Reference 2.5-256. Nuttli derived magnitudes for the event from several historical seismograph records that ranged from M_b = 4.5 (Chicago record) to m_b = 5.3-5.6 (Charlottesville record). Stevens estimated magnitudes ranging from m_b = 5.0 to 5.55 from the records of Ottawa, Seven Falls, Halifax, and Shawinigan Falls.

Using an m_b of 5.3 $\pm$ 0.5 for the equivalent of the 1929 Attica earthquake, and several recent attenuation equations for the eastern United States, Nuttli and Herrman[(3)] derived the following equation:

$$\ln a_p = 1.265 + 1.15m_b - 0.0044\Delta - 0.833 \ln\Delta \qquad (1)$$

A second attenuation equation was derived from MM Intensity distributions observed during a number of New England and

Canadian earthquakes[4]. The attenuation model was developed through regression analyses performed on more than 1,000 felt reports for the following earthquakes:

1. Cornwall-Massena; m_b = 5.8, I_o = VIII (September 5, 1944)

2. Ossippe, New Hampshire; m_b = 5.4, I_o = VII (December 20 and 24, 1940)

3. Quebec-Maine Border; 4.8 m_b, I_o = VI (June 15, 1973)

4. Southeastern Rhode Island; 3.5m_b, I_o = V (March 11, 1976)

The intensity relationship developed is:

$$I_s = -1.43 + 1.79m_b - 0.801n\Delta - 0.00184\Delta;\ \geq 10\text{ km} \qquad (2)$$

where I_s = site intensity (MM) at an epicentral distance Δ from the earthquake. The method used to convert I_s to a_p (McGuire, 1977) is:

$$\ln a_p = 1.45 - 0.359\ 1n\Delta + 0.68\ I_s \qquad (3)$$

This method recognizes that the transformation between site intensity and peak acceleration may be a function of epicentral distance. Equation (3) was derived for stiff soil sites and is assumed here to also apply to rock sites. Substituting Equation (2) into Equation (3) gives:

$$In\ a_p = 0.478 + 1.22m_b - 0.90\ In\Delta - 0.00125\Delta;\ \geq 10\text{ km} \qquad (4)$$

(where a_p = acceleration in cm/sec^2 and Δ = epicentral distance in km).

Ground motion experienced at the site from the occurrence of an m_b of 5.3 ± 0.5 event (equivalent to the 1929 Attica earthquake) on the closest approach to the site of the Clarendon-Linden Fault would range from less than 0.01g to 0.04g. It is clear that such an event would not have any effect on the seismic design for Unit 2 structures.

<u>References</u>

1. Earthquake Notes, Eastern Section. Seismological Society of America, Vol. 1, No. 2, October 25, 1929.

2. Heck, N. H. and Bodle, R. R. United States Earthquakes, 1929. United States Department of Commerce, Coast and Geodetic Survey, 1929.

3. Nuttli, O. W. and Hermann, R. B. Consequences of Earthquakes in the Mississippi Valley. Preprint 81-519, ASCE Meeting, St. Louis, Missouri, 1981.

4. Klimkiewicz, G. Personal Communication to R. K. McGuire regarding New England Attenuation, 1982.

QUESTION F231.4

The lengths of the three high angle faults, the Barge Slip, Drainage Ditch and Cooling Tower faults, as discussed on p. 2.5-54 of the FSAR, have not been conclusively determined.

a. Trench No. 2 beyond the northeast projection of the Cooling Tower fault appears too short to intersect the fault if there is the slightest deviation from a linear trend. Why was this trench not extended north and south, especially considering that the fault appears to change trend from a more northerly trend between Trenches 4 and 5 to slightly more westerly from Trench 4 to Trench 3 and Pit 1 according to Figure 2.5-28. If the fault turned slightly more west of Pit 1, the fault could be too far south to intersect the northwestern most Trench along the Cooling Tower fault.

b. On two separate occasions, in answer to question 361.26 and in Section 2.5.1.2.3 of the FSAR, the statement is made that it is difficult to determine precisely the east-southeast termination of the Cooling Tower fault. Since you postulate that this fault is the analog of the Drainage Ditch fault and therefore probably of the same length, please explain why a trench could not be dug near or beyond the postulated southeastern terminus, to verify the assumption?

c. Please explain the logic, including geometrical, mechanical, or physical principles, that justify the assumption stated in the last full paragraph on page 2.5-54 that "the length of the Cooling Tower fault is not significantly different from the length of its analog", and that all the faults extend to the same depth.

d. Inasmuch as the determined length of the Cooling Tower fault is based on assumption and not proven, what evidence precludes the possibility that the normal displacement increases with depth, as would be the case if there were recurrent movement through time?

RESPONSE

In general, the available data regarding the extent of the drainage ditch and cooling tower faults were considered sufficient to judge the lengths of these structures. The observed fault lengths are approximately one mile. Therefore, in keeping with 10 CFR, Part 100, Appendix A, the decision was made to carefully study the cooling tower fault to assess the possibility that it might be capable. The principal conclusion of the investigation was that the structure is not capable (FSAR Reference 2.5-94). Consequently, it was believed that further trenching to determine the extent of the fault was unwarranted.

a. Exposures of the cooling tower and drainage ditch faults, as described in the FSAR, revealed only one or two degrees variation in strike. The likelihood of the development of an en echelon splay along strike to the northwest from Pit 1 was considered minimal. Even if the fault strike does deviate or the structure splays at that location, the geological studies concluded that the fault is not a capable fault. Consequently, the possibility that the fault was not intersected in Trenches 2 or 1 is insignificant.

b. At the time of the investigation, additional trenching southeast of the trench for OC-2 (Figure 2.5-28) was considered unwarranted for reasons related to those stated in the foregoing paragraphs. On the basis of characteristics presented in c, it is believed that conditions along the fault are sufficiently known and understood that excavation of further trenches near or beyond the southeastern terminus of the fault would not yield information that would change the conclusion that these high angle faults are not capable.

c. The argument that the length of the cooling tower fault is not significantly different from the length of its analog was presented in detail in the response to Question 361.26, wherein it was shown that the extent of the drainage ditch fault (Tepee fold) is fairly well known. Since that response, excavations for the lake water tunnels for Unit 2 were completed. The drainage ditch fault was not encountered in these tunnels, indicating that it terminates between the tunnels and the drainage ditch. Therefore, the length of the fault is approximately 5,000 feet.

   The following six factors summarize the bases for our previous response that the drainage ditch and cooling tower faults are analogous:

   1. Magnitude of Displacement - The magnitude of displacements on both the barge slip and cooling tower faults is approximately 1 to 3 ft.

   2. Fault Zone Thickness - The fault zones are all characterized by the development of breccia with gouge as well as a density of mineralized

fractures near the fault decreasing perpendicularly away from the fault plane. The thicknesses of the brecciated zones are all of comparable magnitude.

3. Extent of Mineralization - The extent and thickness of vein mineralization along the fault and along fractures near the fault can be characterized as being very similar for the three high angle faults at Unit 2. This contrasts distinctively with the abundance and thickness of vein minerals of the same origin documented within the Demster Structural Zone.

4. Structural Attitude - The strike of the cooling tower fault is nearly identical to that of the drainage ditch and barge slip faults. Moreover, all the faults are steeply dipping. The linearity of the faults is also remarkable.

5. Structural Setting - Figure 361.26-3 suggests a possible scenario whereby the development of the Demster Structural Zone and gentle warping of sedimentary strata on either side of the zone could be spatially associated with the high angle faults in the vicinity of the site.

   As discussed in Appendix 2I of the NYSEG PSAR (FSAR Reference 2.5-81), a north-northeast trending broad syncline was inferred to occur just east of the J. A. FitzPatrick facility. The axis of the syncline appears to be located about midway between the interpreted extremities of the cooling tower and drainage ditch faults (Figure 361.26-1). This might suggest a possible causative relationship between the syncline and the faults.

   From Figure 361.26-3, it can be seen that such a relationship between the syncline and the high angle faults could account for the change in the character of deformation seen in the cooling, tower fault (from strike slip to normal). Such a change could be accounted for by a local clockwise rotation of the trajectory of greatest principal stress in response to continued shortening of the bedrock as the Demster Zone developed. Once rotated, the principal stress trajectory would be in a position close to the previously formed left lateral shear fracture, and conditions would then be compatible with development of normal faulting along this fracture (cooling tower fault).

6. Tectonic History - The sequence of deformation for the two north dipping faults is similar (see

Question 321.26). This interpretation, together with the aforementioned factors, strongly suggests that the faults have a common tectonic origin.

As described elsewhere in this response, additional exploration regarding the southeastern extent of the cooling tower fault was deemed unwarranted because geologic studies showed that the structure was not capable, according to Appendix A to 10CFR100. The principal conclusions regarding the noncapability of the cooling tower fault to generate vibratory ground motion are:

1. The possibility of the cooling tower fault generating vibratory ground motion in the future is extremely unlikely because the structure would have to enter into a renewed phase of unstable growth (buckling) below a depth of 140 ft below which only the $\lambda/2$ buckles are developed. For unstable growth to occur, a volume of rock sufficient to create another bedrock sliver or rotated limb would be required below the depth of initial amplification (140 ft) on the cooling tower fault (Section 8.1, FSAR Reference 2.5-94).

2. Stresses in the vicinity of the cooling tower fault are essentially relieved and the maximum stress orientation is parallel to the structure. It is highly improbable that this condition would change in the near future; thus, stress accumulation along the cooling tower fault is highly unlikely.

3. The maximum depth of development of reverse-slip deflection occurred when the crustal down warping from glaciation was at its maximum. Conditions at present, which are entirely different from the glacial maximum, would suggest that the potential for reverse slip deflection, and the recurrence of unstable growth folding and the potential for attendant vibratory ground motion, is a very unlikely possibility.

4. A growth fault is one which occurs contemporaneously with deposition in the sedimentary basin and is characterized by a) increasing throw with depth, and b) thicker strata on the downthrown side than the corresponding strata on the upthrow side. Growth faults tend to become less steep with depth near the bottom of a sedimentary basin.

   In the geologic investigation of the Cooling Tower fault (Volume 1, Appendix E, 1978; see report by H. L. Barnes, October 29, 1977), the possibility that this feature originated as a growth fault was raised. This origin is considered unlikely principally because of its apparent structural relationship to the Demster Structural Zone, as described in the response to

Question 361.26. It seems unlikely for two reasons that a large basement fault projects upward into sedimentary cover at the Unit 2 site such that normal-slip displacements of greater magnitude than 1 to 3 ft are present at depth. First, deformation of the site rocks would most likely be more intense, as is the case near the Demster Structural Zone. Second, the aeromagnetic and gravity signatures in the site area do not indicate the presence of a major fault at Unit 2.

QUESTION F231.5

What is the resolution of the magnetometer, i.e., how large does a basement offset have to be in order to be detected?

RESPONSE

The magnetometer is capable of detecting anomalies on the order of 1 gamma, but local, manmade noise limits the effective resolution to a few gammas.

The magnitude of basement offset which could be manifest in the magnetometer profiles depends upon various other factors, for example, depth to basement, magnetic susceptibility contrasts, and monopole versus dipole source. Based on the total field anomaly expressions given by Grant and West, 1965 (p. 323), for a fault step and susceptibilities typical of igneous rocks (e.g., Grant and West, 1965, p. 366), a basement offset ranging from about 2 to 10 m at a depth of 1,800 ft would produce a 1 gamma anomaly at the surface. Thus, for a resolution of a few gammas, basement offsets of over 10 m would be required to produce an observable anomaly.

The portable magnetometer profiles presented in the previous response to Question 321.26 revealed that where the maximum displacement occurs along the fault in the shallow bedrock, no anomaly was recorded. The profiles, however, are not long enough to detect an anomaly above the point where the site faults project to the basement because of the presence of Lake Ontario. On this basis, the ground magnetometer profile results would be indeterminate. However, examination of the aeromagnetic data for this area does not reveal any indication that these faults extend to the basement.

QUESTION F231.6

Please explain the basis for the assertion (p. 2.5-56) that the similarity of homogenization temperatures between the vein minerals of the fractures and the quartz clasts of the rock indicates that the deformation occurred after diagenesis. The logic is not obvious inasmuch as quartz clasts originate as igneous, or metamorphic minerals long before sedimentation, diagenesis, brittle fracture and vein mineralization.

RESPONSE

The statement in question is based upon the interpretation made by Dames & Moore's consulting geochemist, Dr. H. L. Barnes, in a report appended to Reference 94 (FSAR, Section 2.5.6). Dr. Barnes examined a number of primary fluid inclusions in quartz within the sandstone host rock exposed in the wall of a fracture filled with euxinic iron sulfides. From his examination, he reported that there were observed in samples of the host rock a succession of aged iron sulfides on bedding surfaces and fractures including mackinawite, troilite, pyrrhotite and pyrite which, because of the limited stability ranges of some of them, provided a mean upper limit to the maximum thermal effects of diagenesis of the host rocks. The presence of mackinawite, which is unstable above 155°C, provides good correlation with the primary inclusion temperatures in quartz in the host rock of 160°C, pressure corrected.

Studies of fluid inclusions from rocks and fracture filling minerals in the Manhattan Prong have yielded homogenization temperatures in the range of 200°C to 400°C (FSAR Section 2.5.6, Reference 166). Any inclusion which may have formed, potentially yielding homogenization temperatures in this range, must have been altered under conditions of long term deep (1.5 to 3 km) burial of the marine Paleozoic rocks at the site. On this basis, the recrystallization of the quartz in the host rock is believed to represent the maximum thermal effects of diagenesis of the host rock. The formation of the fractures and their subsequent filling with vein minerals is believed to be syn- to post-diagenetic in terms of relative age, as reflected in their temperature stability ranges. (Section 6.0 and Appendix I-E, FSAR Section 2.5.6, Reference 94).

QUESTION F231.7

On p. 2.5-60 the absence of mineralization in association with the buckling and reverse-slip displacement on the high angle faults is used to deduce the near surface origin of the structures and, by inference, their more recent development. Could the absence of mineralization be the result of continuous creep movements up to the present in a compressional regime which does not permit voids or extension along the structures?

RESPONSE

This question has two principal concerns: 1) the relationship of mineralization or the absence thereof to the reverse-slip deformation on the high angle faults, and 2) the potential for creep strain buildup on the high angle faults such that further reverse-slip might occur with a concomitant release of stored strain energy. This response treats each point separately.

1. During geologic exploration of the cooling tower, drainage ditch, and radwaste faults, dilational openings in the upper 200 ft of the site bedrock were conspicuous. For the brittle deformation and voids to develop at great depth it would be necessary to postulate that the fluid pressure would have been almost equal to the total vertical pressure. Such conditions are known to develop in the crust. However, not only must the fluid pressure be high, but there also must be sufficient quantities of fluid available to fill and support the void spaces. Thus, depending on temperature, pressure, and fluid chemistry of the system, vein minerals develop in the voids. In the majority of occurrences noted, however, the voids were not filled with epigenetic calcite and sulfides. It is true that some fractures along the high angle faults are filled with such minerals. These fractures all exhibit strike-slip or normal shear fabric. However, the reverse-slip deformational fabric associated with the voids consistently overprints the earlier deformation with high (above 75°C) homogenization temperature epigenetic minerals.

   A less pervasive form of calcite mineralization was recognized during the geologic investigation of the radwaste thrust structure. The mineralization has a distinctly different mode of origin because fluid inclusions in this material are rare and phase and filling temperature analysis indicates they formed at ambient surface temperatures. Under these conditions, it is obvious that the fluid pressure in the rock mass was much less, and that the paragenesis of the low temperature calcite is related to equilibrium conditions and fluctuations of the ground water table. Consequently, patches of this type of mineralization were found locally along bedding planes, joints, and even dilational openings associated with buckles. However, these brittle features were never completely filled with the low temperature calcite. This is important because it indicates that high confining pressure did not exist when the dilations were formed. Therefore, one must conclude that the buckles and thrusts have a near surface origin.

2. We do not consider the buckles of the cooling tower and drainage ditch faults to be locked. This term was used to characterize the rotation of the short limb of the buckle during the formation of the lower shear plane (see response to Question F231.10b) which progressed to a physical limit whereupon further strains were accommodated during the decelerating stabilization stage. It was concluded that minor adjustments may

occur within the buckle, but that they will occur at low strain rates, and be of limited extent.

This conclusion is based upon the limited energy available, the orientation of the stress tensor, and the geometry of the structure.

In the first and most important point, data from overcore borings RS-1, -2, and -3 show that very low normal stresses are present in the rock mass on the south side of the structural block bounded by the two north dipping high angle faults. Stress in excess of 2,000 to 3,000 psi would be required for the potential depth of reverse slip deflection to be greater than its observed depth of 200 ft. The stored strain energy required simply is not available, nor is it likely to become so 50 yrs from now.

In the second instance, stress measurements show that the maximum horizontal stress is oriented subparallel to the fault strike (and buckle axis trend). Inasmuch as these conditions are not likely to change during the lifetime of the plant, rock mass displacements will be small, without further buckling.

Third, the potential depth of reverse-slip deflection is controlled by the geometry of the uppermost buckle and the fault inclination, in addition to stress, as explained previously in the response to Question F361.30 (1980).

Therefore, we are confident that, although minor movements might occur, they would do so at a decelerating rate and would be localized. Moreover, they would be of small magnitude. Simply stated, creep strain buildup on the high angle faults and subsequent failure cannot occur.

However, in order to provide a means of monitoring any small movements of the rock mass, an extensive array of inclinometers, extensometers, piezometers and linear displacement sensors have been operational at the site over the last 5 yrs. Details regarding recorded data from this monitoring system are provided in response to Question F241.16.

QUESTION F231.9

What is the greatest depth at which bedding plane slip has been detected at or near the site?

RESPONSE

Bedding plane slip, as evidenced by the occurrence of slickensides along bedding plus the presence of breccia or gouge, was noted at a depth of 285 ft. However, the deepest hole drilled from the ground surface at the site is 300 ft (borings 809 and 810).

QUESTION 231.10

Mechanical theory of buckling (p. 2.5-63)

a. Summarize the reasons why the initial "deflection" in your discussion of the mechanical theory of the origin of the buckles is not simply drag effects of the earlier normal fault displacement on the high angle fault and therefore not related to the buckling superimposed on the earlier structures.

b. Considering that greater stress is required to cause a new fracture in rock than to cause slip along a pre-existing fracture, explain how, in going from the amplification to rotation stages of buckling, a new fracture is formed at almost the same angle to $\sigma 1$, as the pre-existing one. Also discuss the mechanical considerations that would allow a shear fracture to develop at such a high angle to $\sigma 1$ (considering the Coulomb-Mohr-Navier theory of shear fracture).

RESPONSE

The situation described in this question occurs when high lateral and vertical pressure exists. However, due to the low overburden stress during the buckling process, the lower fracture developed in association with rigid body rotation of the rock.

Our analysis of the buckling stated the importance of the initial deflection according to the theory of buckling. There was no interpretation as to the geological nature of this deflection, inasmuch as the magnitude of the initial deflection need be infinitesimally small. However, drag effects of the earlier normal fault displacement along the high angle fault is the best interpretation of the initial deflection geometry. This interpretation is supported by the fact that the buckling was found to occur along the entire length of the explored portion of the Cooling Tower and Drainage Ditch faults. In contrast, if the initial deflection had been related to lateral geometric variations owing to the lenticular nature of the bedding, then buckling might have been localized along certain portions of the high angle fault. Again, this was not the case.

The formation of the second (lower) fracture in the development of the fault controlled buckle is somewhat analogous to the development of a chevron style fold, where the lower fracture would be analogous to the axial plane of the fold. During upward slip of strata on the north side of the Cooling Tower Fault during the amplification stage of buckle development (FSAR, Section 2.5.6, Ref. 2.5-94, p. 7-11) the corresponding strata on the south side were subjected to a bending moment. The inability of these strata to deform by flexural slip because of gravitational loading from overlying strata and resistance to horizontal translation along bedding planes allowed shear stress to build up across the strata. Locally, stress concentrations within a layer undergoing bending can be well in excess of the tensile strength of the layer (Figure 231.10-1).

In the uppermost layer affected, once the shear stress accumulated to a point that satisfied the failure criterion, a tensile fracture developed below the neutral fiber. Once formed, the tensile fracture propagated upward as continued bending of the layer was accomplished. The fracture thus formed would be equivalent to the axial plane of a chevron style fold. As amplification of the buckle accelerated, each of the underlying strata was subjected to the same process of bending and development of tensile fractures. The eventual merging of the lower fracture plane (similar to the coalescing of the hinge line, or axial plane, of a chevron style fold) with the main (upper) fracture at a depth of about 140 ft can be attributed to a smaller bending moment (hence less shear stress across the strata) on layers south of the main shear plane.

F 231.10-1

FIBER STRESS
RELATED TO THE FORMATION OF THE LOWER
FRACTURE OF THE COOLING TOWER BUCKLE

QUESTION F231.11

The absence of evidence for reverse-slip deformation and buckling on the Barge Slip fault is attributed to its southerly dip, which is the only difference mentioned between this fault and the two parallel structures, the Cooling Tower and Drainage Ditch faults. The explanation is conjectural and not convincing. There is, however, another difference, which is present between the latter two faults of a low angle thrust with relatively young movement. Evaluate the likelihood that the reverse-slip and concomitant buckling of the Cooling Tower and Drainage Ditch faults are the result of tangential stresses exerted on the faults by movements of the Radwaste Thrust structure.

RESPONSE

Figure 231.11-1 is taken from a report on the geologic investigations performed of the barge slip fault at the J. A. FitzPatrick nuclear power plant prior to 1976 when the Cooling Tower Fault study began (FSAR Section 2.5.6, Reference 153). The map of a slot excavated across the barge slip fault indicates that bedding plane slip of the uppermost layers displaced this fault 1.5 ft to the south. This observation was attributed to glacial ice shove because of the presence of till like sediment along bedding planes in the upper few feet of the rock mass. The sense of displacement is consistent with that postulated for the development of layer parallel normal and shear stresses required to initiate buckling on the north dipping faults. If shear along the bedding is of the sense indicated in Figure 231.11-1, then buckling along the high angle fault could not occur.

Detailed field studies of the cooling tower and drainage ditch faults revealed nearly perfect parallelism of the two high angle faults. Therefore, slip along the intervening radwaste thrust structure between the two faults probably did not create a significant buildup of tangential stresses. The present state of stress, as determined from numerous measurements in several overcore borings throughout the structural block, suggests that slip along the radwaste thrust structure occurred after the development of the buckles. If, as the question implies, stress concentrations developed at the high angle faults because of thrust slip toward the west, then such stress concentrations should have been detected during the overcoring investigations at the site. In fact, the stresses were found to be almost totally relieved in adjacent to the cooling tower fault.

F 231.11-1

ROCK PIT - TRENCH B
JAMES A FITZPATRICK NUCLEAR POWER PLANT
POWER AUTHORITY OF THE STATE OF NEW YORK

QUESTION F231.12

Among the conclusions reached concerning the Cooling Tower fault, it is stated that minor subsurface adjustments may occur within the zone of buckling at a depth within the transition zone (50-200 ft). It is also asserted that these adjustments will not reach the surface because voids in the rock must first be closed. What estimates have been made as to how much movement (vertical or horizontal) may occur? What calculations have been made to determine the minimum vertical movement necessary to close the voids and then reach the surface? Also provide the justification for the estimates.

RESPONSE

On p. 2.5-61, it is stated that an estimation of the amount of expansion or dilation of the rock mass on the north side of the high angle fault is 2 to 3 percent. No estimates have been made as to how much movement may occur during the stabilization stage of the structure. Moreover, no calculations have been made to determine the minimum vertical movement necessary to close the voids for movement to occur at the surface. This calculation would require so many assumptions that the result would probably not be valid. Nevertheless, in view of the very low levels of stored strain energy in the rock in proximity to the buckle, any movements which might occur will be very small and insignificant with respect to the safety of the Unit 2 facility.

QUESTION F231.15

It is stated that the walls of the intake and discharge tunnels, which have exposed Radwaste type low angle thrust structures, will be bare and filled with water, with free standing pipes within. What will be the effects of the long term exposure of the faults to water on their stability. Is it likely to cause slip along planes of weakness (bedding or faults), locally?

RESPONSE

The thrust faults detected in the intake and discharge tunnels were previously, and will continue to be, beneath the level of the ground water table. During construction of the tunnels, they were locally dewatered and resaturated upon completion of the construction period. As discussed in the FSAR, the faults are not expected to move more than 1/4 in up dip (west northwest) on any individual shear. The engineered structures have been designed to withstand small movements during the next 40 yr.

It can be seen from the orientation of the stress tensor determined from measurements in the intake shaft that shear stress is stored along planes parallel to the thrust faults. It is very possible that changes in the vertical effective stress related to fluctuations of the ground water table could lead to very minor movements along the thrust faults. The amount of movement is related to the shear strength of the faults which can be described by Amonton's Law:

$$\tau = \mu\sigma_n$$

Where:

τ = Shear resistance

σ_n = Normal stress

μ = Coefficient of sliding friction

Thus, a decrease in the vertical effective stress may result in a decrease in shear resistance along the thrust fault. The amount of change in the vertical effective stress; that is, the smallest amount of vertical fluctuation of the water table that would result in slip along the thrust faults is related to the length of the fault. The length is not known with certainty. The effective length of the fault might extend only a few feet of the shaft excavation. Hence, changes in the vertical effective stress of a few pounds per square inch or a few tens of pounds per square inch may trigger minor adjustments along the faults. These adjustments, in conjunction with time-dependent displacements related to stress relief during excavation, have been taken into account in the design criteria that allow for a horizontal rock mass displacement at the shaft.

Fluid overpressure in the site rock of the magnitude thought to have developed during the drainage of Lake Iroquois will not occur in the near future. The level of the proglacial lake was about 300 ft above the present ground surface. Because Lake Ontario fluctuations are carefully controlled, a comparable situation cannot develop within the lifetime of the Unit 2 facility.

QUESTION F231.16

It is not clear from your discussions about the various structures at the site, what is concluded about the age of the bedding plane slip which is so prevalent. Although the discussions of both the Cooling Tower high angle fault and Radwaste Thrust fault attribute a role in this formation or deformation to bedding plane slip, the age of the bedding plane slip is not clearly stated, although the implications are that the slip is Pleistocene, either pre-Wisconsinan or related to the Lake Iroquois stage. Please expand your discussion of the bedding plane slip at the site and in the site region. Include in your discussion but do not limit it to:

(a) the significance of Fig. 3-3 of Appendix 2I which shows bedding plane slip surfaces with a northwestward (updip) sense of movement, being truncated by the Paleozoic high angle faults of the Demster Fault Zone;

(b) possible causes of the bedding plane slip.

(c) the possibility that the slip is Paleozoic in origin but renewed movement on preexisting weak gouge and brecciated surfaces provided the paths for glacial meltwater.

(d) in what ways the bedding plane slip may have influenced the structures to which they are related.

RESPONSE

The sedimentary rocks are primarily anisotropic because of exceedingly limited shear strength of the weaker shaly layers.

During the various stages of deformation in the geological history of the site bedrock, bedding plane slip was prevalent. Even so, bedding plane slip is now, and probably has been for the past 100 to 150 million years or so, the principal mechanism of deformation in the region of the Allegheny Plateau in upstate New York. This statement is based upon consideration of the evolution of the Lake Ontario homocline (FSAR p. 2.5-19). Since the late Paleozoic Era, the region has undergone broad regional warping, and a gentle southward gradient of 50 ft/mi of the bedding currently exists in the site area. Regional deformation of this nature imparts high shear strain, and the weakest layers must slip. In the area, this condition probably continues to the basement rock/sedimentary rock interface.

Tendencies for bedding plane slip were certainly enhanced by glaciation, and glacially induced deformation throughout the site region has been documented in FSAR Section 2.5.1.1.

Inasmuch as the contemporary maximum principal compressive stress at the site is subparallel to bedding, and of magnitudes in excess of the shear strength of certain beds, elastic and time dependent rock deformation is likely to be realized by bedding plane slip.

QUESTION F231.17

(a) Please provide a plot of the temperature/depth relationships of the minerals used to determine age of the joints and other structures. As there may be differing opinions concerning stability fields, etc., include a discussion justifying your choice of plot in depth determinations.

(b) The conditions of formation of the minerals within the faults or joints, not the joint itself, is postulated on the basis of homogenization temperatures. It is clear from some of the photos in Vol. 1 of the Fault Investigation (1978) that some of the structures formed in a compressional environment (subhorizontal slickensides) and experienced extension later (mineral coating with 3-dimensional undeformed crystals on the fracture surface). Please comment on the suggestion that the vein minerals have recorded changing stress regimes and suggest continuous or renewed movement through time on preexisting structures, rather than the conditions of formation of the faults, joints, slip planes, or voids.

RESPONSE

(a) Temperature/depth relations were established primarily through coupling two types of data. First, temperatures during development of the paragenetic sequence were determined from the homogenization temperatures of fluid inclusions. These temperatures were also tested against known thermal stability limits of associated sulfides. Secondly, geothermal gradients appropriate for deep sedimentary basins, such as the Appalachian Basin here, were used to correlate the determined temperatures with inferred depths. The bases for these two arguments are reviewed below.

1. The temperatures of homogenization of liquid and gas phases of fluid inclusions were measured by standard methods that have been well described in the literature (e.g., Roedder, 1979, Chapter 14, Geochemistry of Hydrothermal Ore Deposits, edited by H. L. Barnes, Wiley-Interscience, New York) and need not be summarized again. The measured temperature of homogenization must be pressure corrected to find the temperature of trapping the fluids, usually +10°C to +15°C for fluids in the 100-150°C range and basinal related (Roedder, ibid., p. 727).

   Two sulfides present in the paragenesis which have stability limits low enough to be of value in establishing thermal states are mackinawite, Fe_9S_8, and marcasite, FeS_{2-x}.

   It is not certain that mackinawite is ever an equilibrium mineral (Barton and Skinner, 1979, "Geochemistry of Hydrothermal Ore Deposits", page 359). However, it is known that mackinawite dissociates if heated above 140-150°C (Takeno, Zoka, and Niihava, 1970, Am. Mineralogist 55, 1639-1649; Vaughan and Craig, 1978, Mineral Chemistry of Metal Sulfides, Cambridge University Press, p. 284 and 391; Scott, 1974, Mineralogical Society of Am. Short Course Notes, Sulfide Mineralogy, 1, CS-21 to CS-40). Mackinawite is common as a primary iron sulfide where precipitated in euxinic, black, shaly sediments (Berner, 1971, Principles of Chemical Sedimentology, Chapter 10, McGraw-Hill, New York). During ageing, it normally inverts to smythite, Fe_9S_{11}, but smythite itself dissociates near 75°C (Barton and Skinner, ibid., p. 360). Consequently, the absence of smythite and the presence of mackinawite along bedding planes in these rocks indicates that they were heated, respectively, above 75°C but not appreciably above 150°C during their histories; these temperatures are in reasonable agreement with those of about 160°C found for the host rock inclusions.

   Marcasite is known to be metastable and to dissociate rapidly above 150°C (Rising, 1973, Phase Relations Among Pyrite, Marcasite, and Pyrrhotite: Unpublished Ph.d. thesis, The Pennsylvania State University, Department of

Geosciences; Barton and Skinner, ibid., p. 359-364; Murrowchick and Barnes, 1983, Geol. Soc. Am. Abstract for the Indianapolis Annual Meeting, The Role of Polysulfides in Pyrite and Marcasite Formation). This stability limit is again, within combined uncertainties, in agreement with the inclusion temperatures near 160°C. Two other types of thermal evidence, beyond the question being examined here, are the alteration index of local conodonts indicating 155°C, 2.4-3.0 km depth and the partially ductile and brittle textures of chalcopyrite suggesting deformation near 100-150°C, 2 km burial (Tillman and Barnes, 1983, Am. Assoc. Petrol. Geol. Bull. 67, 692-705). All four lines of evidence indicate similar values for maximum paleotemperatures during the paragenetic history of these rocks and their fractures.

2. The geothermal gradients used to estimate depths from the established temperatures are largely based on those now found along the Gulf Coast. The maximum geothermal gradient, about 40°C/km, corresponds with the highest hose rock temperatures (150-160°C here) and the basinal stage of maximum rate of sediment dewatering and heat transfer toward the earth's surface. This representative maximum gradient is taken from the Gulf Coast as analogous to the miogeosynclinal Appalachian Basin (e.g., Jones, 1975, Proc. First Geopress. Geothermal Energy Conf., Univ. Texas, 15-89; Isachsen, 1975, and Gabelman, 1975, Near Normal Geothermal Gradient Workshop, ERDA 76-11, 113-157). The gradient along the Gulf Coast gradually falls to 20-25°C/km after deep dewatering is completed. Possible mechanisms and rates of cooling are discussed by Tillman and Barnes (1983, Am. Assoc. Petrol. Geol. Bull 67, 692-705).

   Data on geothermal gradients in deep sedimentary basins elsewhere are in general agreement with the values taken for the Gulf Coast. Examples worldwide are found in Hunt (1979, Petroleum Geochemistry and Geology, W. H. Freeman, San Francisco, pp. 204, 244, 290, 292, 294, 296, 334, 373, and 521) where for 16 representative regions, gradients range from 11-55°C/km, average 33°C, and are most commonly between 20°C/km, and 40°C/km. Conybeare (1979, Litho stratigraphic Analysis of Sedimentary Basins, Academic Press, New York, p. 339 and p. 441) also finds 40°C/km and 20°C/km common for the hot, dewatering stage and post-dewatering, cool stage. The current gradient in central and western New York is about 25°C/km (Hodge, et. al., 1979, Preliminary geothermal investigations in New York State: Geothermal Resource Council Annual Meeting), again similar to the older Gulf Coast gradients.

The combining of the paleotemperatures and the appropriate geothermal gradients to derive depths of burial at each paragenetic stage is given in detail in the Barnes report of October 20, 1977, pages 9-11 and also in Tillman and Barnes (1983, ibid.) on pages 696-705.

(b) The vein minerals <u>have</u> recorded changing stress regimes with time as evidenced by the sequence of brittle deformation requiring changes in the stress tensor corresponding to four phases namely (in order of descending age):

1. Strike-slip

2. Normal-slip

3. Reverse-slip (buckle development)

4. Post-buckling bedding slip and thrust-fault-slip

The question seems to center on the timing of development of the initial fracture along which vein minerals were subsequently deposited. The field investigations revealed that the strike-slip fault was developed initially, but only in the massive Oswego Sandstone. The strike-slip fault is not present in the more ductile shales. Analysis of the calcite from the strike-slip fault reveals high homogenization temperatures. Lower temperatures were found in calcite-filled fractures known to be formed at the same time as the normal fault. Although the mineral studies do not provide any direct evidence of either absolute age of the site faults, nor of the possibility of movement on preexisting faults in the basement, they do indicate that the strike-slip faults were not tectonically inherited from basement discontinuities projecting upward into the passive cover beneath the site.

The maximum depth of the faults is not known, but has been addressed (see responses to Questions F231.4 and F231.5).

All investigations demonstrate that the buckles on the high angle faults are not related to tectonic movement generated from the basement.

QUESTION F231.18a

Inasmuch as complex folding and fracturing indicative of high stress concentration is inconsistent with a series of broad open folds, please explain how spacing alignment of the structure contour pattern indicates folding, rather than faulting, is the dominant process, as stated on p. 2.5-83.

RESPONSE

The spacing and alignment of the structure contour pattern of the Pulaski-Oswego boundary when viewed in plan as well as cross section (Fig. 2-4, 2-6, and 2-7, Appendix 2I) and in conjunction with detailed structural and stratigraphic mapping in Trench II indicate an asymmetrical fold with relatively small fault offset. Based on drilling, seismic refraction, and interpretation of the structure contour pattern, the fault and the offset on the fault appear to decrease and die out to the southwest.

The complex fracturing recognized in Trench II is the brittle response of the rock mass to multiple deformational events. At least three sequential structural styles are recognized and include: (1) tight folding, (2) reverse faulting associated with apparent northwest-southeast directed compression, and (3) subsequent normal faulting. The maximum measured stratigraphic offset due to faulting is approximately 15 feet of normal movement.

The stratigraphic relief from near the Demster Beach Anticline crest (R-2) to the New Haven Syncline trough (R-1) is approximately 140 ft. Thus, the maximum stratigraphic relief of the Pulaski-Oswego contact is related to folding as exemplified by the structure contour pattern.

QUESTION F231.18b

What information precludes the possibility of the Demster Fault Zone from having primarily left-lateral strike-slip displacement with a minor dip slip component? There are indications on the structure contour map (Fig. 2-4 of Appendix 2I) of a large left-lateral offset.

RESPONSE

Based on the structure contour map (Figure 2-4, Appendix 2I), one could speculate on the possibility of left lateral strike slip motion along the Demster Fault Zone. However, geologic data obtained from detailed mapping of Trench II indicate a lack of evidence to support an offset due primarily to a strike-slip displacement. The structural and stratigraphic data indicate reverse faulting followed by normal faulting. The evidence to support these conclusions follows:

1. The Zone 1, 2, and 3 strata in the southeast portion of Trench II (southeast structural domain) strike approximately N45°E and dip to the southeast 45° at the fault and flatten to 3-4° at the excavation limit. These strike and dip directions are interpreted as drag due either to folding or reverse faulting.

2. In the central structural domain (Figures 3-3 and 3-7, Appendix 2I) northeast trending asymmetric folds with northwest dipping axial planes and flexural slip are mapped. These structural elements and style are indicative of apparent northwest-southeast directed compression.

3. These folds (in the central structural domain) are cut by younger normal faults which are documented in Rock Pit I (Figure 3-7, Appendix 2I) and Rock Pit II (Figure 3-9, Appendix 2I). In addition, further evidence to document the normal faulting is shown by drag of the strata in Rock Pit II. No further cross cutting or structural style has been recognized younger than this normal faulting event.

4. No horizontal or near horizontal slickensides were mapped in the trench or any of the cored borings.

Based on combined geologic evidence, all observed or inferred movements have been dip-slip rather than strike-slip.

QUESTION F231.18d

Please provide a description of the criteria used to determine the top of Zone 1 of the Oswego Sandstone in developing the data for the structure contours of Fig. 2-4 of Appendix 2I. Specifically, core logs of Appendix 2C of the referenced PSAR for the New Haven site indicate interpreted formation and zonal contacts. The contacts at top of Zone 1 in different core logs do not appear to be consistent. Also, assuming R-13 of Fig. 2-9 is actually R-15, the contours bounding the boring location are off by 10 ft or one contour interval.

RESPONSE

Oswego Sandstone stratigraphic analysis and stratigraphic picks are based on the detailed and repeated examination of 144 cored borings, totalling more than 13,600 ft of Oswego core. The specific criteria for the stratigraphic subdivision of the Oswego in the New Haven site area and detailed subdivision of Oswego Zone 1 in the vicinity of the Demster Fault Zone are given in the NYSEG PSAR Sections 2.5I.2.24 and Appendix 2.5I.

Briefly stated, the criteria to determine the top of Oswego Zone 1 are based largely on the cumulative knowledge of the stratigraphic column in conjunction with systematic core logging downward. Each stratigraphic pick was, therefore, taken not only in context of lithologic and sedimentary property associations and the sequential stratigraphic relationships, but also correlation to nearby borings and gamma logs.

Generally, the top of a Zone 1 sedimentary cycle consists of a thin interval of siltstone and dark gray to black shale in sharp contact with the sandstone base of the next higher cycle. Evidence of soft sediment deformation is abundant in Zone 1. Slump structures occur elsewhere in the Oswego but are persistently present in and characteristic of Zone 1 only. Of stratigraphic significance to the Zone 1/Zone 2 boundary is a prominent shale that occurs about 10 ft below the Zone 2 boundary. This shale is 7 to 8 ft thick and either massive or interbedded with sandstone and siltstone Jaminae. This shale is underlain within several feet by two or three thin intervals of irregularly bedded fossils and shale clasts.

Northwestward, toward Nine Mile Point, the upper part of Zone 1 becomes increasingly shaly, presumably reflecting basinward facies change within the rock unit. Correlations of bore holes to the west (R-22, R-23, R-24, and R-25) and logs of Nine Mile Point borings (314, L-1, L-4, and L-8) indicate that this change is accomplished through gradation of siltstone and other intermediate rock types to dark gray to black shale.

The Zone 2 sedimentary cycle consists of a lower sandstone and an overlying black shale. The cycle has an average thickness of 4 to 5 ft, with an average sandstone/shale ratio of approximately 1.5. The Zone 1/Zone 2 boundary is the base of the lowest cycle conforming to Zone 2 criteria. Diagnostic criteria for Zone 2, in addition to its stratigraphic position, are:

1. Sandstone/shale couplets
2. Washout structures
3. Current bedded bioclastic deposits

On a local scale, particularly in Trench II, the Zone 1/Zone 2 boundary is unconformable. Locally the top of Zone 1 (Unit B, Section 2.5I.3.3 of Appendix 2.5I, NYSEG, 1979) has been partially removed, but stratigraphic relationships exposed in Trench II indicate the magnitude of the unconformity is small (approximately 5 ft maximum). Thus, in the Trench II area, the unconformity is marked by lenticular Zone 2 sandstones incised to various depths below the top of Unit B, and the Zone 1/Zone 2 boundary here is a sandstone/sandstone relationship.

With regard to the top of Zone 1 in boring R-15 as corrected from R-13 on Figure 2-9, Appendix 2I, the elevation is 171.5 ft, which is consistent with the contours on Figure 2-9. In addition, when the omitted borings R-23, R-25, R-24, and R-22 are placed in their appropriate locations, no change in the contour pattern is necessitated. The elevations for the top of Zone 1 in the corrected borings are:

Boring	Elevation
R-13	233.6'
R-15	171.8'
R-16	273.2'
R-22	243.0'
R-23	96.0'
R-24	210.2'
R-25	183.0'

QUESTION F231.18e

What information justifies bringing the structure contours into parallelism with the Demster Fault Zone? The sparse boring locations in the area do not appear to require such an interpretation.

RESPONSE

Several lines of complementary evidence were utilized to establish the pattern of structure contours relative to the Demster Fault Zone. The regional northwest strike and southwest dip of the gently folded Oswego Sandstone are verified by numerous borings to the southeast and northwest of the fault, at Nine Mile Point, and at the New Haven site. The addition of borings R-24, R-22, R-23, and R-25 (Figure 2-9, Appendix 2I) to the northwest supports the regional trends. However, to honor elevations of the Oswego Sandstone Zone 1/Zone 2 contacts established in borings on the southeast side of the fault zone, the contours must be drawn parallel. This is the case in a number of locations. For example, if the 200-ft contour is followed northwestward, it passes R-4 and R-1 before bending southwestward to pass between P1 and P2, adjacent to P4, between R-15 and P6, and then across the fault zone following the pattern established by borings R-20 and R-16. This pattern is reinforced on both sides of the fault zone by tracing other contours as developed from elevations in the four boring alignments that intersect the Demster Fault Zone at approximately right angles.

Within the trench, the attitude of bedding in the Demster Fault Zone was determined to be generally NE dipping southeast, corresponding to the interpreted structure contour pattern.

QUESTION F241.2 (SRP 2.5.4.1)

State the range and mean value of the core recovery and rock quality designation (RQD) ratios for each significant bedrock stratum at this site. What is the angle of bedding dip in the bedrock?

RESPONSE

The ranges and means of core recovery and rock quality designation (RQD) for each significant bedrock structure at Unit 2 are presented in Table 241.2-1. These values were calculated from 10 randomly selected borings from the 400-series boreholes and from borings GP-1 and GP-2. The 400-series boreholes were chosen for this study because they had been drilled prior to any excavation at Unit 2 and were not affected by the blasting activities. Borings GP-1 and GP-2 were added because they also sampled relatively unaffected bedrock and the 400-series did not produce enough core from Unit A of the Whetstone Gulf formation.

The bedrock at the site is essentially flat-lying. Regional dips are reported as approximately 40 ft/mi to the south. At Unit 2, the Oswego/Pulaski contact drops about 5.5 ft in elevation between boring SI-6 (located 395 ft north of the reactor centerline) and RS-2 (located 1,057.3 ft south of the reactor centerline).

TABLE 241.2-1

CORE RECOVERY AND ROCK QUALITY DESIGNATION
FOR SIGNIFICANT BEDROCK STRUCTURES
AT UNIT 2

Rock Unit	Core Recovery Standard			RQD Standard		
	Mean	Deviation	Range	Mean	Deviation	Range
Oswego (includes transition zone)	95.8	7.0	44 (56-100)	76.4	13.6	76 (21-97)
Pulaksi						
Unit A	98.2	3.5	40 (60-100)	85.8	11.4	100 (0-100)
Unit B	96.0	5.9	20 (80-100)	73.9	17.2	54 (46-100)
Unit C	98.0	2.9	13 (87-100)	82.6	13.1	48 (52-100)
Whetstone Gulf						
Unit A	100.0	0	0	92.6	2.1	9 (85-94)

QUESTION F241.16 (SRP 2.5.4.1, 2.5.4.6, 2.5.4.10)

Provide updated records of piezometers, settlement monuments, inclinometers, extensometers, and linear displacement sensors in graphical form. Discuss your findings and conclusions on the significance of this data and any bearing on the past and future performance of the seismic Category I facilities at the site.

RESPONSE

Results of the monitoring of instrumentation at the site have been provided in two previous submittals. In February 1980, in response to NRC Request for Addition Information 361.5, the results of the monitoring of instrumentation through March 1979 were presented. FSAR Section 2.5.4.13 updates the data presented in 361:5 and provides descriptions of additional instrumentation installed after March 1979. Generally, the FSAR provides data through December 1981. This current submittal provides instrumentation records and interpretation from the period of the last submittal to December 1982. The instrumentation discussed in this response includes:

1. Inclinometers in boreholes
2. Multipoint extensometers in boreholes
3. Borehole piezometer
4. Linear displacement sensors in structural gaps around the reactor complex.

Records of all other instrumentation are complete for their period of performance.

<u>Inclinometers</u>

During the course of investigations at Unit 2, 30 inclinometers have been installed to monitor bedrock displacements. In 1982, 23 of these inclinometers were monitored on an approximately monthly basis for all or part of the year. Three inclinometers were abandoned or became inaccessible for monitoring during the year. Table 241.16-1 provides a summary of the location, purpose, and status of each of the inclinometers constructed at the site. Figure 241.16-1 illustrates the general locations of these instruments in relation to the site excavations. Previous submittals have detailed the installation procedures and specifications for the instruments.

Because there were no significant movements recorded on any of the monitored inclinometers in 1982, the monthly plots are not provided. Instead, displacement plots for each instrument monitored are provided for the beginning (January 1982) and end (December 1982) of this reporting period (Figures 241.16-2 through 241.16-21). Because of ice blockage of some of the instruments in the winter months, it is not always possible to provide the displacement plots for the exact months of the beginning and end of this reporting period. In these cases, the next available plot is provided.

I-Series Inclinometers

The I-series inclinometers (I-1 through I-4) were installed in 1977 to monitor excavation performance. The inclinometers were relatively shallow installations located near piping trenches west of the reactor excavation. The results from monitoring I-1, I-2, and I-4 are ambiguous because of the uncertainty of the stability of the bottom of the inclinometers and, consequently, these instruments were abandoned. Because of the location of I-3 with respect to the screen wall shaft, monitoring is continuing, and the results of this monitoring through December 1982 are presented as Figure 241.16-2.

Radwaste Inclinometers (800-series)

Significant horizontal movement to date has been recorded at only two of the 800-series inclinometers: 803 and 805.

Since the 803 casing was installed (May 1980), southwesterly tilt has been recorded from near the bedrock surface (El 244 ft) down to approximately 45 ft below the collar. The movement has fluctuated in phase with changing seasons to a depth of 27 ft (El 222 ft). Moreover, the movement has been concentrated along two narrow zones: El 226 to 222 ft and El 214 to 208 ft. The slip vector orientation in each zone is the same, i.e., S46W (226± 6°), Figure 241.16-22; however, the slip vector magnitude is less in the lower zone. The estimated closure of the north face of the reactor excavation (north auxiliary bay) is approximately 0.03 in just above the north electric bench (El 212 ft) and 0.02 in below it. These amounts slightly exceed the closure predicted for the corresponding time period by a numerical modeling analysis of the time dependent displacement of the reactor excavation (Response F241.12). However, the model does not take into account, 1) the proximity of disturbed rock in the thrust fault to the northwest, and 2) relative displacements along discrete bedding zones within the section modeled in an axisymmetric fashion.

Significantly, in September 1981, the southwesterly displacements in 803 ceased. This cessation of movement corresponds temporally with the filling of the radwaste trench with concrete. It is obvious that the relatively small volume of concrete fill placed in the trench was insufficient to mechanically halt the rock mass movement; however, it can be postulated that the concrete sealed the open zones exposed in the exploratory trench that was full of water since the completion of the geological studies there and disrupted the hydrologic connection between the trench and the slip zones in 803. Water seeping from the trench along the radwaste slip zone to the vicinity of 803 appears to explain the pronounced seasonal temperature fluctuations that apparently have occurred in the rock even at a depth of nearly 30 ft below the ground. During 1982, no movements above the working limit accuracy of the instruments were detected in this zone (Figure 241.16-23).

Movements in 805 have been recorded at depths of 59 to 61 ft (El 203 to 201 ft). The slip vector is oriented west (273±6°) and has a magnitude of about 0.02 in. Because similar slip has not been detected in other inclinometers penetrating the radwaste thrust structure, it is suggested that the movements recorded in 805 are related to time dependent deformation around the excavation rather than a regional, tectonically induced slip that is little influenced by the excavation. It is not clear at this time whether the movements in 805 have stabilized or are progressing.

Reactor Excavation Inclinometers

For this reporting period, only one and a quarter year's data are available for SI-20, -21, -22, and -23 (Figures 241.16-11 through 241.16-14), and at least several months are required for bedding in. It appears, however, that no movements of significance have been recorded by these instruments for the reporting period.

Screenwell Shaft Inclinometers

As reported in previous submittals, the inclinometers in the screenwell shaft area have recorded elastic and time dependent displacements. The elastic displacements are directly related to the excavation activities in the shaft and tunnels and have been discussed in the FSAR. Notably, low angle thrust faults are present within the zones of maximum total displacement in the three inclinometers showing the greatest total displacement (SI-4, SI-5, and SI-6). Therefore, the higher magnitudes of total displacement appear to be, at least partly, related to the occurrence of these discontinuities near the levels that were excavated in the shaft and tunnels. These elastic displacements occurred during excavation activities in 1980 and have not been recorded during the current (1982) reporting period. Progressive time dependent deformation of the rock mass has only been observed in inclinometer SI-4. Relative movement between El 161 and 155 ft (Figure 241.16-24) occurs at the base of Unit B of the Pulaski formation. During the 1982 recording period, approximately 0.018 mm (0.007 in) of movement was recorded in this zone. Even assuming a linear extrapolation of this movement results in a very conservative estimate of movement in 40 yrs of 0.28 in. This is well within the design limit of 1 in of time dependent closure.

Extensometers

During the course of investigations of Unit 2, 11 extensometers have been installed to monitor vertical and horizontal strains

(Figure 241.16-1). Descriptions and specifications of the installations have been provided for all but one of the extensometers (HEX-2) in the previous NRC Request for Additional Information (Q361.5) and in the FSAR (Section 2.5.4.13.8). This response provides interpretation of readings through December 1982.

MPX-series

Readings from MPX-1 and MPX-2 were discontinued in June and August 1981, respectively. Consequently, the FSAR presents the latest information and interpretation available for these instruments.

EX-series

Extensometers EX-1 through EX-4 are located on the west side of the screenwell shaft and illustrate the effect of the dewatering of the shaft in December 1979. As discussed in the FSAR, all the extensometers near the shaft record a small contraction of the rock mass as a result of dewatering. Superimposed on this general contraction is a cyclic pattern of contraction and dilation that is the result of seasonal temperature fluctuations. This cyclic pattern records the differential thermal expansion between the rock and the steel rods of the extensometer. In the winter, cold contracts both the rock and the stainless steel rods, but the rod contracts more than the rock (stainless steel has a higher thermal expansion coefficient than the rock), yielding an apparent expansion of the rock. In the summer, the opposite effect occurs. These seasonal fluctuations are most prominent in the installations closest to the shaft and only marginally evident in the instrument furthest from the shaft (EX-1). Because of the seasonal fluctuations, it is difficult to determine with precision the amount of contraction that has occurred in the rock mass near the shaft. Additionally, only certain zones within the rock mass contract while others remain constant or even expand slightly. These differences are attributed to the differing swelling potentials of the rock units and the availability of ground water.

Because EX-1 is most isolated from temperature extremes, it perhaps affords the best measure of the amount of contraction that has occurred (Figure 241.16-25). Between December 1979 and December 1982, the total rock column measured in EX-1 (El 247 to 97 ft) contracted by 0.037 in/(0.012 in/yr). Similar comparisons with EX-2, EX-3, and EX-4 are difficult because of the fluctuations and the seasonal differences between one year and the next (Figures 241.16-26 through 241.16-28). However, similar contraction amounts and rates can be interpreted from EX-2, EX-3, and EX-4. Notable in the 1982 records of the installations close to the shaft is the sudden contraction in the December 1982 readings during a time when the reading values should have been increasing (based on past performance). This contraction is attributed to the pouring of the concrete liner in the screenwell shaft. The curing of the concrete added heat to the rock units (and extensometer rods), resulting in the reversal of the seasonal trend.

In the fall of 1981, three additional vertical rod extensometers were installed. Two (EX-5 and EX-6) were installed on the east bench of the screenwell shaft to replace MPX-1, and one (EX-20) was installed on the east side of the reactor excavation. During 1982, EX-5 (10 ft from the shaft) and EX-6 (20 ft from the shaft) displayed the seasonal fluctuation characteristic of the extensometer readings in general (Figures 241.16-29 and 241.16-30). Interestingly, because the rods from EX-5 and EX-6 are made from Invar steel, they have a different thermal expansion than the stainless steel rods, and the seasonal fluctuations are opposite to those observed from the original extensometers (EX-1 through EX-4). For the first 12 months of operation (December 1981 - December 1982), EX-5 and EX-6 showed almost no net change. The uppermost rock zone monitored (El 225 to 214 ft) reflected the seasonal temperature variations, and the zone between anchors 3 and 4 (El 173 to 133 ft) shows a small net contraction (0.005 to 0.007 in), but, overall,these two extensometers demonstrate a relatively stable period on the east bench.

Extensometer EX-20 is located approximately 25 ft east of the reactor excavation. It was installed in the fall of 1981 principally to monitor rock mass reaction to the planned temporary rewatering of the excavations. Like the other extensometers, EX-20 demonstrates a correlation with seasonal temperature fluctuations in the uppermost rock units (Figure 241.16-31). Otherwise, the readings are quite stable with the exception of a sharp expansion of 0.010 to 0.014 in in the spring of 1982 in the zone from El 92 to 54 ft. This zone is below the bottom of the reactor excavation and the expansion has not been correlated with any activities at the site.

Extensometer HEX-1 was installed into the east wall of the reactor excavation in the fall of 1981 at an orientation of N70E and at an inclination of 14 deg to 17 deg from the horizontal. HEX-1 was installed to monitor any horizontal movements along the Radwaste Fault that may occur in the area of the northeastern corner of the reactor excavation. Readings are taken with both a linear potentiometer and a sonic probe to monitor the relative displacements between anchors as well as thermistors to record the temperature changes (Figures 241.16-32, [a]-[c]). Since the initial readings in December 1981, the readings have been fairly stable, with 0.006 in of total expansion (as measured by the sonic probe) along the length of the extensometer up to December 1982. The linear potentiometer has recorded 0.001 in of movement in the same period of time.

In the fall of 1982, an inclined extensometer, HEX-2, was installed north of the reactor excavation. This instrument was oriented NE-SW and inclined at an angle of 15 deg from the horizontal to the SW in order to span the slip zone recorded in inclinometer 803. Initial readings were taken in December 1982. As more data become available, they will be reported.

Overall, the monitoring of extensometers at Unit 2 has produced a data set that is in accord with site design criteria for differential vertical movements. Moreover, the monitoring to December 1982 has provided a baseline for evaluating the effects of the temporary rewatering of the excavations in 1983.

Piezometers

Five pneumatic piezometers have been installed in the vicinity of the screenwell shaft. Four of the piezometers (PI-1 through PI-4) were installed in November 1979 and one (PI-5) in the fall of 1981. Additionally, two piezometers (PI-20 and PI-21) were installed on the east side of the reactor excavation in the fall of 1981 (Figure 241.16-1). The purpose of the inclinometers is to monitor water levels to relate to the performance of the rock mass as measured by the extensometers and inclinometers.

Table 241.16-2 presents the records of the piezometers through December 1982. Because PI-1 through PI-5 each contain two pore pressure transducers at different elevations, it can be seen that there are zones of perched water. With the layered, interbedded nature of the rock units at the site, flow along fracture planes and bedding is to be expected. The piezometers confirm this expectation.

Standpipe piezometers were installed in the vicinity of the reactor building. These are discussed in Section 2.5.4.6.5. Updated graphs of piezometer water levels versus time appear Figures 241.16-41 through 46.

Generally, the piezometers document the water level history of the shaft and reactor excavations while they are being pumped. From the records, it can be seen that the water level was allowed to rise in November and December 1982.

Linear Displacement Sensors

As part of the instrumentation program at Nine Mile Point, a suite of mechanical and electrical gauges has been installed at 11 locations surrounding the reactor building and auxiliary bays (Figure 241.16-33). The gauges were set in selected positions to permit monthly measurements of the structural gaps between the reactor containment and auxiliary bays versus the electric tunnels, the control building, and a service water pipe chase. As of December 1982, seven of the installations had been read for a sufficient time to report on the results (Figures 241.16-34 through 241.16-40). Five of the locations (G1-B, G2-B, G5-A, G5-B, and G6) have been read since November 1981 while two of them (G1-A and G2-A) have been read only since May 1982.

At each location, the measurements are recorded utilizing two different instruments: an oil filled dial gauge and a Vernier caliper gauge. At G1-B and G2-A, electric DCDT gauges are monitored simultaneously along with the mechanical gauges. The working accuracy of the dial gauge is ±0.001 in and the other gauges are accurate to within ±0.005 in. At each location, the 1982 measurements are predictably consistent, and there is good correspondence between the different measurement locations.

As noted on the plots, the measurements illustrate that the gap width oscillates in concert with seasonal temperature variations. It widens during the winter months and narrows during the summer months. The amplitude of the measured variation reaches a maximum of 0.18 in along the long axis of the reactor excavation (G5-A, G5-B), is smaller (0.16 in) along the short axis (G1-B, G2-B), and smallest (0.09 in) between the electric tunnel and the control building. The movement is attributed to the thermal response of the concrete structures and the majority of the movement is recoverable. Net displacement over a full annual cycle ranges from 0 to approximately 0.05 in. These results are within the design limits.

TABLE 241.16-1

INCLINOMEMTERS AT UNIT 2

Location	General Coordinates	Instrument Number	Dose	Length Monitored (ft.)	Casing Elevation	Date Installed	Date Abandoned
Trench 5 Rock slot	S 2400 E 1650	IT-1 IT-2 IT-3 IT-4 IT-5	Monitor excavation induced displacements Determine influence of cooling tower fault on excavation deformation	18 18 14 18 18	265-245	Mar 1977 Mar 1977 Mar 1977 Mar 1977 Mar 1977	Nov 1978 Nov 1978 Nov 1978 Nov 1978 Nov 1978
Circulating Water Piping Trenches	S 550 W 450 N 275 W 400	I-1 I-4 I-2 I-3	Locate and monitor time-dependent displacements near excavation	46 80 50 142	262-226 265-185 250-200 260-103	Mar 1977 Mar 1977 Mar 1977 Mar 1977	Aug 1982 Aug 1982 Aug 1982 N/A
Screenwell Shaft	N 335 W 300	SI-1 SI-2 SI-3 SI-4 SI-5 SI-6 SI-7 SI-8	Monitor effects of tunneling and ground water fluctuation Monitor time-dependent displacements of rock mass and thrust fault	146 152 150 156 156 166 146 146	222-76 263-91 235-79 234-72 250-72 222-72 222-76 222-76	Nov 1979 Nov 1979 Nov 1979 Nov 1979 Nov 1979 Nov 1979 Nov 1979 Oct 1981	Jan 1980 N/A Mar 1983 Mar 1983 Mar 1983 N/A Jan 1980 N/A
Reactor Excavation	N 005 E 140 S 60.W 80	SI-9 SI-10 SI-20 SI-21 SI-22 SI-23	Monitor time-dependent block mass displacements Monitor radwaste fault influence	142 166 194 190 190 152	222-74 250-74 252-54 255-56 262-60 237-51	Oct 1981 Oct 1981 Oct 1981 Oct 1981 Oct 1981 Oct 1981	N/A N/A N/A N/A N/A N/A
Radwaste Thrust Structure	N 200 W 005 N 080 E 400 N 300 E 075 S 1050 E 500	803 805 806 810 820 821 RS2	Monitor for radwaste fault displacements independent of rock squeeze closure at reactor excavation	126 158 286 284 186 186 78	249-117 262-88 261-(-)37 259-(-)37 252-52 254-52 264-172	May 1980 May 1980 May 1980 May 1980 Nov 1981 Nov 1981 May 1980	N/A N/A N/A N/A N/A N/A N/A

TABLE 241.16-2

PIEZOMETER DATA

Date	SHAFT	PI-1		PI-2		PI-3		PI-4	
	Water Level Elev.	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level
11/12/79		184.1	190.2	188.6	196.9			204.3	202.8
12/09/79	186.0	184.5	189.7	184.9	197.3	184.9	184.2	197.9	
12/12/79	177.0	178.3	185.6	182.1	197.8	180.8	185.6	207.8	198.6
12/17/79	143.5	151.3	184.2	164.6	196.9	155.8	184.2	189.1	Below 1940
12/19/79	142.0	150.4	184.2	162.2	196.4	155.4	184.7	189.1	
12/21/79	140.0	149.0	184.2	164.2	196.9	154.5	184.7	187.7	
12/28/79	140.0	149.5	183.8	164.2	195.5	156.5	184.7	188.2	
01/03/80	140.0	148.5	183.3	163.7	195.0	156.3	184.2	185.4	
01/7/80	136.0	138.8	Below 181.0	Below 160.0	195.5	141.5	184.7	185.4	
01/29/80	135.0	Below 131.0	--	--	206.1	136.9	Below 181.0	188.2	
02/11/80	130.0	--	--	--	209.6	139.6			
03/17/80	130.0	--	--	--	198.7	137.8	--	184.5	
04/14/80	130.0	--	--	--	198.3	136.0	--	184.0	
05/21/80	130.0	--	--	--	198.3	135.5	--	182.6	
06/18/80	130.0	--	--	--	201.0	136.0	--	183.1	
07/21/80	130.0	--	--	--	202.3	136.0	--		
09/04/80	130.0	--	--	--	202.0	135.5	--	183.1	
10/17/80	123.0	--	--	--	202.9	134.2	--	182.6	
12/01/80	123.0	--	--	--	202.0	132.3	--	181.3	195.8
01/14/81	123.0	--	--	--	202.6	132.1	--	181.7	196.1
02/18/81	123.0	--	--	--	202.3	134.2	--	182.2	
03/26/81	123.0	--	--	--	202.4	131.3	--	183.1	
05/07/81	123.0	--	--	--	202.0	132.8	--	181.7	
06/17/81	123.0	--	--	--	203.3	132.3	--	183.1	
08/04/81	123.0	--	--	--	205.6	133.0	--	183.1	196.3
09/15/81	123.0	132.8	--	--	206.1	133.2	--	182.2	

TABLE 241.16-2 (Cont'd.)

Date	SHAFT	PI-1		PI-2		PI-3		PI-4	
	Water Level Elev.	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level	"A" Sensor Water Level	"B" Sensor Water Level
11/04/81	123.0	--	--	--	--	133.2	--	183.1	197.2
12/22/81	123.0	--	--	--	204.3	--	--	183.1	196.3
01/13/82	123.0	--	--	--	205.2	132.3	--	183.1	196.3
03/04/82	123.0	--	--	--	204.3	--	--	183.1	
03/23/82	123.0	--	--	--	205.2	--	--	183.1	
04/29/82	123.0	--	--	--					
05/03/82	123.0	--	--	--	204.7	132.8	--	184.0	196.8
05/21/82	123.0	--	--	--					
05/25/82	123.0	--	--	--	205.2	133.2	--	184.5	197.2
06/23/82	130.0	--	--	--	205.6	132.8	--	184.5	197.2
06/28/82	130.0	--	--	--					
07/28/82	130.0	--	--	--	206.1	132.7	--	184.5	196.3
08/19/82	130.0	133.3	--	--	205.6	133.0	--	184.0	196.5
09/22/82	130.0	--	--	--	205.6	132.8	--	182.6	195.8
10/25/82		133.3	--	--	205.2	132.8	--	184.0	196.3
11/23/82		137.5	--	--	205.2	151.0	--	184.7	196.1
12/20/82		--	--	--	205.2	153.5	--	185.0	196.3
12/28/82		151.8	--	--	205.9	155.1	--	185.6	196.3

TABLE 241.16-2 (Cont'd.)

Date	SHAFT	PI-5		PI-20	PI-21
	Water Level Elev.	"A" Sensor Water Level	"B" Sensor Water Level	Sensor Water Level	Sensor Water Level
11/04/81		145.3	210.3	166.8	170.9
12/22/81		140.9	210.3	165.8	171.5
01/13/82		143.9	210.3		
03/04/81		143.0	210.3	168.6	
03/23/82		144.4	210.3	164.9	172.9
04/19/82		144.8	210.8	174.1	
05/03/82					175.6
05/21/82				172.7	
05/25/82		145.3	211.2		177.0
06/23/82		144.8	211.2	173.2	
06/28/82					174.7
07/28/82		144.8	210.8	167.7	
08/19/82		144.4	210.5	171.4	174.9
09/22/82		144.4	210.3	170.9	174.7
10/25/82		144.4	209.8	171.4	174.3
11/23/82		150.8	210.8	172.5	
12/07/82					173.6
12/20/82		150.6	211.2	168.8	
12/28/82		156.8	210.3	169.3	174.0

Notes: PI-1 "A" Sensor elev. is 131.0' "B" Sensor elev. is 181.0'
PI-2 "A" Sensor elev. is 160.0' "B" Sensor elev. is 189.5'
PI-3 "A" Sensor elev. is 130.0' "B" Sensor elev. is 181.0'
PI-4 "A" Sensor elev. is 160.5' "B" Sensor elev. is 194.0'
PI-5 "A" Sensor elev. is 122.7' "B" Sensor elev. is 202.0'
PI-20 Sensor elev. is 156.6'
PI-21 Sensor elev. is 155.8'

-- Water level is below sensor level

(blank) No reading

APPENDIX 2P

RESPONSES TO NRC OPERATING LICENSE STAGE REVIEW QUESTIONS RELATED TO FSAR SECTION 2.3

QUESTION F451.12 (2.3.4.3, SRP 2.3.4)

Short Term Dispersion Estimates

The transition from an unstable air mass over the lake to a stable air mass over the land occurs most often in fall and early winter, when the lake is still warm. How is this ac counted for in the short term diffusion model estimates?

RESPONSE

The short term diffusion estimates do not take into account the possible change in stability from unstable near the shoreline to a more stable condition farther inland during the fall and early winter. The meteorological data are not available from onsite or near site records for the 5 year period used in the accident diffusion calculations to make a conclusive determination if the transition is present, and if so to what extent and at what distances inland. Even without this consideration, the accident diffusion estimates presented with the model recommended in Regulatory Guide 1.145 conservatively estimate the highest 0.5 percent X/Q values for both ground level and elevated sources.

The accident diffusion estimates are extremely sensitive to those conditions which produce the highest hourly ground level concentrations. For a ground-level release, which is assumed for the accident assessment of the combined radwaste and reactor building vent, the 0.5 percent probability X/Q values for all distances are dependent upon the concentrations resulting from stable meteorology. A stability modification from unstable to stable conditions farther inland does not produce higher concentrations than the strictly stable cases with onshore flow. The initial dispersion of the effluent during unstable conditions significantly dilutes and widens the plume relative to that which would occur under strictly stable conditions. The transport of this wider plume under more stable conditions does not produce ground level concentrations which affect the upper percentiles of the probability distribution. Thus, if the incorporation of the transitional stability is accounted for, there would be no effect on the conservative accident ground level source assessment.

For an elevated release, such as the main stack, the accident X/Q values are solely dependent on the fumigation calculation for the 0-2 hour time scale. Furthermore, the fumigation X/Q value overwhelms the 0.5 percent probability X/Q value which is averaged with the fumigation value to obtain the 0-8 hour X/Q value. For the time periods longer than 0-8 hours, the accident X/Q value is determined by the interpolation between the 0.5-percent nonfumigation X/Q value and the annual X/Q value.

The 0.5-percent nonfumigation X/Q value for the main stack is dependent on very unstable, unstable and neutral conditions close to the stack and unstable to stable conditions farther inland.

The modification of some of these unstable hours to more stable conditions will not increase the conservative accident X/Q value which is obtained by enveloping. The use of steady state unstable conditions conservatively determines the limiting case for nearby distances since the concentrations are higher than those of neutral, stable or the transition from unstable to stable conditions. The farther from the source, the more important the stable and neutral conditions are in determining the upper percentiles of the concentrations distribution.

Therefore, the deletion of some unstable cases will not affect the frequencies associated with the upper percentile concentrations. It may be that the transition at some distances may influence the distribution, but the effect should be extremely minimal since the concentrations should be lower than strictly stable conditions but may approach those during neutral conditions.

QUESTION F451.13

Long-Term Dispersion Estimates (Wind speed)

Wind speeds measured at the 61 meter level of the Nine Mile Point meteorological tower are adjusted to the stack, vent or 10(m) release height using a power law relationship (FSAR Section 2.3.5.3.6).

1) Extrapolating wind speeds from 61(m) to higher elevations 130(m) can lead to erroneous results when compared to actual measured values. Justify the use of the power law extrapolation of wind speed in this type of coastal environment.

    a) Include in your discussion the estimated error incurred when applying the 10-61(m) layer stability to a much larger (10(m)-130(m)) layer for use in the power law extrapolation.

2) Demonstrate that, for very stable conditions, the power law coefficient (q=0.3) in equation 2.3-20 is more appropriate than other coefficients (q=0.55 or 0.60) recommended in other literature*. What conservative approximations have been made to prevent overestimation of wind speeds at the stack, vent and 10(m) level?

RESPONSE

1) The use of the power law equation is appropriate. Furthermore, the lack of stability measurements comparable with the height of the stack did not result in underestimates of annual X/Q values.

The extrapolation of wind speeds by the power law profile equation is recommended for heights of less than 200 m (656 ft)[1]. Demarrais has shown, based on measurements from a 481-m (1,578-ft) tower, that stability tends toward more stable conditions as one increases in height somewhere above 100 m (328 ft)[2]. Thus, the extrapolation of wind speeds up to the main stack height may have resulted in an underestimation of the actual wind speeds since the exponents used in the wind speed power law equation increase with increasing stability. To evaluate the possible effect on long-term X/Q calculations of this possible underprediction of wind speed at the top of the 130-m (429-ft) main stack, a test set of X/Q computations was made.

The first case duplicated the procedures and assumptions used in Section 2.3.5 with the 5-yr meteorological data base and stability determined from the 61-8 m (200-27 ft) temperature difference measurements. The second case conservatively assumed that all hours of each stability class were shifted one class toward the more stable conditions. In other words, all Stability A hours were considered as Stability B, all Stability B hours were made Stability C, etc., for use in determination of wind speed exponents, dispersion coefficients X/Q values. The 10 distances listed in Table 451.13-1 were evaluated with no terrain corrections.

A comparison of the X/Q values calculated with a one class stability shift were divided by those calculated with the unaltered 61-8 m (200-27 ft) stability. The ratio of the X/Q values are tabulated in Table 451.13-2. These ratios show that, except for four distance sector combinations, the use of the lower wind speeds (unaltered stabilities) estimated X/Q values conservatively for the stack since the ratios are less than 1.00.

The use of the power law exponent of 0.30 rather than 0.60 for very stable conditions (Stability G) does not result in substantial underestimates of annual X/Q values for either the main stack or the combined radwaste and reactor building vent. Although the literature has many recommendations concerning the proper power law exponents, EPA has reviewed most of its assumptions regarding stability, sigmas, etc., and its practice in diffusion modeling reflects the current state of the art. EPA has indicated that while modeling rural sources with its "benchmark" CRSTER model one should use a power law exponent of 0.30 for very stable conditions[3,4]. In addition, EPA has recommended the use of the 0.30 power law exponent for stable conditions in its Climatological Dispersion Model (CDM)[5].

To quantitatively assess the effect of using a 0.60 power law exponent instead of 0.30, a comparison of wind speeds used in the long term diffusion model described in Section 2.3.5 was made. The wind speeds were adjusted upward from 61 m (200 ft) to 130 m (429 ft) for the stack, slightly downward from 61 m (200 ft) to 57 m (187 ft) for the combined radwaste and reactor building vent, as well as downward from 61 m (200 ft) to 10 m (33 ft) for a ground level release. The extrapolated wind speed at top of the main stack, the vent, and at 10 m (33 ft) are shown in Table 451.13-3, as well as the difference in wind speeds due to the use of the two exponents. This table shows that the differences in wind speeds at the vent top are insignificant, while those at the stack top and at ground level might be significant. The ground level release wind speed adjustments are not used during light wind conditions since the vent plume is treated as an elevated rather than a ground level release. Although the magnitude of the wind speed differences is not especially large, the percentage difference is considerable for both the stack and the ground level release adjustments.

Therefore, two sets (one for the stack and one for the vent) of annual X/Q calculations were made to assess the effect of using the higher power law exponent for very stable conditions. The same model and meteorology described in Section 2.3.5 were again used at the 10 distances shown in Table 451.13-1 without terrain adjustments. The results of the comparison using the two power law exponents for the stack showed no difference at any distance in any sector. All ratios of X/Q using 0.60 compared to those derived with a 0.30 power law exponent were 1.00.

The calculations for the combined radwaste and reactor building vent showed, a small increase in X/Q values at most distances. Most of the ratios showed less than a 6 percent increase. There were larger increases noted over the lake at close in distances; however, these increases were not observed for land sectors. Table 451.13-4 lists the ratios of X/Q from the two sets of calculations for the vent.

The wind speed adjusted to the top of the main stack will not be overestimated using a 0.30 wind speed profile exponent compared to that obtained with a 0.60 exponent. This relative overprediction by the higher exponent is readily seen in Table 451.13-3. The minor height difference of 4 m (13 ft) between the top of the vent and the wind speed sensor elevation is not sufficient to cause any significant overestimate of wind speed, regardless of the wind speed profile exponent used. For those wind speed conditions when the vent release is treated as a ground level release, the use of the lower wind speed profile exponent may result in an overestimate of the wind speed.

However, this overestimate has been shown to result in a less than 5-percent increase in annual X/Q values, beyond 5,000 m (16,404 ft).

References

1. Hanna, S. R. et. al. Handbook on Atmospheric Diffusion. Atmospheric Turbulence and Diffusion Laboratory, NOAA, 1982.

2. DeMarrais, G. A. Atmospheric Stability Class Determinations on a 481 meter Tower in Oklahoma. Atmospheric Environment, Vol. 12, No. 10, 1978, p. 1957-1964.

3. U.S. Environmental Protection Agency. User's Manual for Single Source (CRSTER) Model. EPA-450/2-77-013, Monitoring and Data Analysis Division, Source Receptor Analysis Branch, Office of Air and Waste Management, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, July 1977:

4. Environmental Research and Technology, Inc. Addendum/Supplemental Information for Valley, CRSTER, ISC. EPA/DE-81-001e, The Aluminum Association, Inc., Washington, DC, December 1980.

5. Busse, A. D. and Zimmerman J., User's Guide for the Climatological Dispersion Model. EPA-R4-73-024, National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, December 1973.

TABLE 451.13-1

DISTANCES EVALUATED FOR COMPARISON
IN THE ANNUAL DIFFUSION CALCULATIONS

Distance	
m	(ft)
500	1,640
1,000	3,280
3,000	9,843
5,000	16,404
7,000	22,966
10,000	32,808
15,000	49,213
20,000	65,617
35,000	114,829
50,000	164,042

TABLE 451.13-2

RATIO OF ANNUAL X/Q VALUES DERIVED WITH A ONE CLASS SHIFT IN STABILITY AND THE UNALTERED STABILITY DISTRIBUTION FOR THE MAIN STACK

Distance		Sector Bearing															
m	(ft)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSE	W	WNW	NW	NNW	N
500	1,640	0.07	0.09	0.08	0.07	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.08	0.08	0.08	0.08
1,000	3,280	0.093	0.59	0.40	0.53	0.65	0.91	1.18	1.16	1.00	0.81	0.44	0.85	0.75	0.86	0.92	0.73
3,000	9,843	0.23	0.12	0.22	0.30	0.38	0.60	0.84	0.80	0.62	0.46	0.25	0.25	0.24	0.33	0.44	0.34
5,000	16,404	0.23	0.21	0.30	0.36	0.42	0.50	0.57	0.55	0.46	0.38	0.29	0.26	0.27	0.27	0.32	0.29
7,000	22,966	0.28	0.27	0.37	0.43	0.50	0.54	0.55	0.54	0.47	0.42	0.35	0.32	0.34	0.31	0.34	0.33
10,000	32,808	0.34	0.34	0.47	0.54	0.61	0.65	0.62	0.62	0.54	0.49	0.43	0.39	0.42	0.37	0.39	0.39
15,000	49,213	0.42	0.43	0.58	0.66	0.74	0.78	0.71	0.72	0.63	0.59	0.51	0.48	0.53	0.45	0.46	0.47
20,000	65,617	0.48	0.49	0.66	0.75	0.84	0.88	0.79	0.79	0.71	0.66	0.58	0.55	0.61	0.52	0.52	0.54
35,000	114,829	0.63	0.64	0.82	0.92	1.01	1.07	0.92	0.93	0.87	0.82	0.71	0.68	0.77	0.68	0.67	0.69
50,000	164,042	0.73	0.73	0.92	1.03	1.12	1.17	1.01	1.01	0.98	0.93	0.80	0.78	0.87	0.80	0.77	0.80

TABLE 451.13-3
WIND SPEED EXTRAPOLATED WITH DIFFERENT POWER LAWS
FOR VERY STABLE CONDITIONS (STABILITY G)

Wind Speed at Stack Height, 131 m (429 ft)							
Wind Speed at 61 m (200 ft)		Wind Speed Extrapolated with q = 0.30		Wind Speed Extrapolated with q = 0.60		Difference Between Col. 2 & 1	
m/sec	(mph)	m/sec	(mph)	m/sec	(mph)	m/sec	(mph)
0.45	1.0	0.57	1.28	0.71	1.59	0.14	0.31
0.89	2.0	1.12	2.51	1.41	3.15	0.29	0.65
2.46	5.5	3.09	6.91	3.89	8.70	0.80	1.79
4.47	10.0	5.62	12.57	7.07	15.82	1.45	3.24
6.93	15.5	8.71	19.49	10.95	24.50	2.24	5.01
9.39	21.0	11.81	26.42	14.84	33.20	3.03	6.78
15.65	35.0	19.68	44.03	24.74	55.35	5.06	11.32
Wind Speed at Vent Height, 57 m (187 ft)							
Wind Speed at 61 m (200 ft)		Wind Speed Extrapolated with q = 0.30		Wind Speed Extrapolated with q = 0.60		Difference Between Col. 2 & 1	
m/sec	(mph)	m/sec	(mph)	m/sec	(mph)	m/sec	(mph)
	1.0	0.44	0.98	0.43	0.96	-0.01	-0.02
0.89	2.0	0.87	1.95	0.85	1.90	-0.02	-0.04
2.46	5.5	2.41	5.39	2.36	5.28	-0.05	-0.11
4.47	10.0	4.38	9.80	4.21	9.42	-0.09	-0.20
6.93	15.5	6.79	15.19	6.66	14.90	-0.13	-0.29
9.39	21.0	9.20	20.58	9.02	20.18	-0.18	-0.40
15.65	35.0	15.34	34.32	15.03	33.62	-0.31	-0.69
Wind Speed at 10 m (33 ft)							
Wind Speed at 61 m (200 ft)		Wind Speed Extrapolated with q = 0.30		Wind Speed Extrapolated with q = 0.60		Difference Between Col. 2 & 1	
m/sec	(mph)	m/sec	(mph)	m/sec	(mph)	m/sec	(mph)
0.45	1.0	0.26	0.58	0.15	0.34	-0.11	-0.25
0.89	2.0	0.52	1.16	0.18	0.40	-0.34	-0.76
2.46	5.5	1.43	3.20	0.83	1.86	-0.60	-1.34
4.47	10.0	2.60	5.82	1.51	3.38	-1.09	-2.44
6.93	15.5	4.03	9.02	2.34	5.23	-1.69	-3.78
9.39	21.0	5.46	12.21	3.17	7.09	-2.29	-5.12
15.65	35.0	9.10	20.36	5.29	11.83	-3.81	-8.52

TABLE 451.13-4

RATIO OF ANNUAL x/Q VALUES DERIVED WITH POWER LAW EXPONENTS OF 0.60 AND 0.30
FOR THE COMBINED RADWASTE AND REACTOR BUILDING VENT

Distance		Sector Bearing															
m	(ft)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSE	W	WNW	NW	NNW	N
500	1,640	1.15	1.11	1.04	1.02	1.01	1.01	1.04	1.04	1.04	1.03	1.15	1.17	1.13	1.08	1.10	1.13
1,000	3,280	1.13	1.09	1.03	1.02	1.01	1.01	1.03	1.03	1.03	1.03	1.13	1.15	1.11	1.07	1.08	1.12
3,000	9,843	1.06	1.05	1.02	1.01	1.00	1.01	1.02	1.02	1.02	1.01	1.05	1.06	1.05	1.03	1.05	1.06
5,000	16,404	1.05	1.04	1.02	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.03	1.04	1.04	1.03	1.04	1.05
7,000	22,966	1.04	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.03	1.03	1.03	1.02	1.03	1.04
10,000	32,808	1.04	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.03	1.03	1.02	1.03	1.04
15,000	49,213	1.04	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.03	1.03	1.02	1.03	1.04
20,000	65,617	1.03	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.03	1.03	1.02	1.03	1.04
35,000	114,829	1.03	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.03	1.02	1.03	1.04
50,000	164,042	1.03	1.03	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.03	1.02	1.03	1.04

QUESTION F451.14

Long-Term Dispersion Estimates (Wind Direction)

The wind direction at the 61 meter level is used to represent conditions at the stack release height 130(m). Provide an analysis and/or data that show wind direction at the 61(m) level is representative of the stack release height of 130 (m). How is a wind direction reversal aloft, common in the spring and early summer with the onset of a lake breeze, accounted for in the dispersion modeling of both routine and non-routine stack release?

RESPONSE

The wind direction at 61 m (200 ft) represented the winds aloft at the top of the main stack, 130 m (429 ft) above grade. Since no onsite wind direction measurements existed above 61 m (200 ft) at Unit 2, theory or alternative data from another site must show the climatological representativeness of the 61-m (200-ft) winds of stack height winds.

Theory, specifically the Ekman Spiral, shows that the greatest directional change takes place closest to the ground. At most, theory predicts that the change in direction from the surface to the top of the frictional boundary layer, about 610 m (2,000 ft), significantly above the height of the stack, is between 15 deg and 30 deg for the terrain around Unit 2[1,2,3]. The smaller change is associated with the wind shear profile over Lake Ontario and the larger difference is associated with the change of direction with height over the land sectors.

The Ekman Spiral has already been substantiated in part at Unit 2. The difference in wind direction frequency distributions is noticeable between the 9-m (30-ft) and 30-m (100-ft) levels, but is reduced considerably between the 30-m (100-ft) and 61-m (200-ft) levels as shown in Table 2B-9. Thus, based on theory, the change in direction between the winds measured at 61 m (200 ft) and the top of the stack should be insignificant for onshore winds and should be quite small for the other wind directions since the largest change in direction has already been measured for the interval between the ground and 130 m (429 ft).

To further examine the change in direction with height, data from the Sterling tower, located west of Oswego, were plotted in wind rose format for three 1-yr periods in Figures F451.14-1 through F451.14-3[4]. Data from the 104-m (340-ft) level were compared with data from the 46-m (150-ft) level. Although there are some differences in wind frequencies in certain sectors, for the most part there are no significant differences in the wind roses.

The use of the 61-m (200-ft) wind direction to represent the climatological wind direction distribution is realistic and needs no uniform or identifiable shift to approximate the actual wind directions at the height of the stack. This is supported by theory, the winds measured at Unit 2, and the winds measured at the Sterling site.

References

1. Petterssen, S. Introduction to Meteorology. McGraw-Hill Book Company, Inc., Second Edition, 1958.

2. Sutton, O. G. Micrometeorology. McGraw-Hill Book Company, 1953.

3. Martin, J. R. Recommended Guide for the Prediction of the Dispersion of Airborne Effluents. The American Society of Mechanical Engineers, New York, Third Edition, 1979.

4. Burton, R. M. Letter to Mark Kramer, November 3, 1983.

QUESTION F451.15 (2.3.5.3.9, SRP 2.3.5, Regulatory Guide 1.111)

<u>Land/Lake Breeze Influence on Dispersion</u>

Modifications to the straight line Gaussian dispersion model (EQ 2.3-19) are necessary when the meteorological data available is unable to account for air flow characteristics of the site.

1) Provide estimates of seasonal (spring and summer) frequencies of lake breeze conditions at the NMP2 site using onsite meteorological data*. Present the criteria used to identify the onset of a lake breeze front.

2) Provide estimates of seasonal (spring, summer, fall, and winter) formations and frequency of, turbulent internal boundary layers (TIBLs). Theoretical predictions of characteristics of the TIBL are described by W. Lyons and several other authors in "Critical Review of Studies on Atmospheric Dispersion on Coastal Regions," NUREG/CR-2754.

3) Provide an estimate of the seasonal frequency of plume interception with the TIBL for routine and non-routine elevated releases from the primary vent and stack, and the basis for these estimates.

4) Spatial and temporal variations in air flow trajectories, particularly air flow reversals during the onset of the lake breeze and curved trajectories during the decay of the lake breeze, have not been explicitly incorporated into the annual average transport and diffusion model for the NMP2 site. Recent comparisons of the results of variable trajectory models with the results of the straight line model at coastal nuclear plants (e.g., Perry and St. Lucie) have indicated that the straight line model may underpredict

X/Q values by factors of two to four. Provide further justification for not modifying the results of the straight line model to consider spatial and temporal variations in air flow such as would be experienced during the onset and decay of the lake breeze.

RESPONSE

1. During a 5-month period in 1982, estimates of the frequency of lake breezes at Nine Mile Point were documented by meteorological measurements.[1]

   The onset of a lake breeze was identified by a significant wind direction shift from offshore to onshore during daylight hours in the absence of a frontal system or predominant gradient flow. Since the shoreline in the vicinity of Unit 2 is oriented primarily west-southwest to east-northeast, any hourly wind shift of greater than or equal to 25 deg or 45 deg within a 2-hr period, into a compass sector ranging from 270 deg (west) through 360 deg (north) to 45 deg (northeast) was considered evidence of a lake breeze front. Generally, one would expect the wind direction shift to occur at the shoreline first, with either concurrent or later shifts at locations further inland, depending upon the orientation of the lake breeze front. Therefore, a progressive shift in wind direction with distance inland from the shore also was used to document the occurrence of a lake breeze.

[1] Niagara Mohawk Inland Supplementary Meteorological Tower Study 1982.

   During the period of March 22 through August 15, 1982, a total of 21 lake breezes were identified in the Unit 2 area. This represents approximately 6 percent of the days in the year and 14 percent of the days in the 5 month period. A distribution of the lake breeze days is shown in the following table.

Number of Lake Breezes Days Identified

March	April	May	June	July	August	Total
1	1	5	2	8	4	21

   Of these 21 lake breeze occurrences, 19 cases (90 percent) showed that the lake breeze penetrated to distances of at least 9.6 mi (16 km), while on 14 occasions (67 percent of all cases) the lake breeze traveled as far inland as the

National Weather Service Office at Hancock Field (30.6 mi [51 km] from Unit 2).

2. An internal boundary layer forms whenever air flows across a surface discontinuity between land and water, such as the shoreline of Lake Ontario. The interface typically begins at the surface discontinuity and slopes upward in the direction of flow at a rate dependent on the wind speed, the characteristics of the original air mass over the water, and the properties of the downwind surface. Although the air flowing over the downwind surface starts to be modified immediately, some distance is required to obtain equilibrium.

   The thermal internal boundary layer (TIBL) has been discussed in several papers by Raynor, Michael and SethuRaman, Lyons and DiVecchio, Smith and Martin, among others[2-4]. All of these papers recognize the difficulty of accurately predicting the frequency and the height of the TIBL without direct continuous measurements. Formulations have been developed and have undergone limited validation, but even so, simplifying assumptions are generally necessary in order to predict TIBL formations and heights with routine meteorological tower measurements.

   Raynor et al derived an equation based on empirical data from aircraft and meteorological tower measurements on the south shore of Long Island[5]. According to the formulation, a TIBL will occur as long as a difference exists between the air temperatures over the land versus the water and the lapse rate of the air over the water is not isothermal.

   An extremely conservative approach has been used to compare the frequency of TIBL occurrences, regardless of height at Unit 2 and farther inland, with TIBLs predicted at the New Haven site. This approach assumed all onshore winds during daytime hours, 0800 through 1900 local standard time, would produce TIBLs. The number of hourly wind directions and the 30 ft (9.1 m) vane, regardless of stability and the wind speed, during the daytime are distributed by sector and season for two annual cycles in Table 451.15-1. The results for the 2 yr are quite similar. The corresponding frequencies are shown in Table 451.15-2. West winds account for approximately one third of all TIBL hours predicted by this overly simplified approach.

   A more refined estimate for the Unit 2 vicinity is obtained from data collected at the nearby New Haven site, approximately 1.8 mi (3 km) inland from the lake shore. The data have been previously anal zed and reported in the New Haven Environmental Report[6]. The analysis indicates that less than 3 percent of the year will have TIBL occurrences at this inland location. The monthly distribution of these

234 hr is reproduced as Table 451.15-3. This distribution shows the expected tendency of spring through fall TIBL's with monthly maxima in June. The criteria are more restrictive than those used in the conservative estimate for Unit 2 in that all wind speeds had to be less than 12 mph (19.3 kph), and the difference between the upper and lower temperature difference measurements had to be less than 31.6°F (-0.195°C). Furthermore, the lower temperature difference had to show neutral or unstable conditions.

3. The interception of the routine releases from the main stack and the combined radwaste and reactor building vent occurs whenever the effective height of each plume equals the height of the TIBL. The effective height of these plumes is dependent on the wind speed and stability and the characteristics of the release. These relationships have been thoroughly documented in Section 2.3.5. The transitional plume rise will be ignored in the following analysis since both plumes quickly reach their final rise with downwind distance.

During non-routine releases, the interception of the main stack plume with the TIBL must be assumed to occur at the height of the main stack, 429 ft (130.8 m) since no plume rise is assumed in accident evaluations. In the case of the combined radwaste and reactor building vent plume during an accident, the vent is treated as a ground level source with no plume rise. Therefore, the combined radwaste and reactor building vent plume will never intersect the TIBL.

The height cf the TIBL a function of the distance from the land/water discontinuity. The height has been shown to vary as the square root of the distance[7]. Expansion of this relationship using measured meteorological parameters, yields the expression by Raynor et al.[5]

$$H = \frac{u*}{\bar{u}} \left[\frac{f \left| (\theta_1 - \theta_2) \right|}{\left| \Delta T / \Delta Z \right|} \right]^{1/2} \tag{1}$$

where:

$u*$ = friction velocity over the downwind surface, m/sec

$\bar{u}$ = mean wind speed, m/sec

f = fetch, or distance over downwind surface, m

θ_1 = low-level potential air temperature over the source region, °K

θ_2 = temperature of downwind surface, °K

$|\Delta T/\Delta Z|$ = absolute value of the lapse rate over the source region or above inversion, °K/m

Since u* is not a routine meteorological measurement and must be derived from other measurements, several alternatives are available. Ruggles reports that u* = 0.4 u(10) for u(10) between 0-10 m/sec. Ruggles then related to u to the drag coefficient as follows:

$$C_D(z) = \left[\frac{u*}{u(z)}\right]^2 \qquad (2)$$

where:

$C_D(z)$ = the drag coefficient, dimensionless

z = the roughness height, m

This equation is dependent on the roughness height which varies with distance and sector at Unit 2, except over the lake.

In the absence of micrometeorological data of the flow over Lake Ontario, Equation 2 is modified by substituting $CD^{1}/^{2}$ for $u*/\bar{u}$, and using the expression:

$$10^3\ C_D = 0.05\bar{u} + 0.8 \qquad (3)$$

This equation is an interpolation between the lines of best fit for the relationships presented by Hicks (1972) based on Lake Michigan data and by Smith (1974) based on Lake Ontario data.(8,9) These relationships are selected because of the comparability with the site.

The use of Ruggles' transformation to derive u* has been tested by DiVecchio, Smith, and Martin for a site on the north shore of Long Island with limited data.(3,10) Correlation between the predicted TIBL height and the measured TIBL height is extremely good, 0.90, for the limited cases tested.

Therefore, setting the final effective height, H_e, equal to the height of the TIBL in Equation 1 and using Equations 2 and 3, the only parameter to be determined is the distance at which this occurs, f. Solving for the distance of plume interception with TIBL yields:

$$f = \frac{H_e^2}{\left[\frac{(0.05\overline{u} + .8)}{1000}\right] \cdot \left[\frac{(\theta_1 - \theta_2)}{\Delta T / \Delta Z}\right]} \tag{4}$$

In order to calculate the distance bat which the plumes intercept the TIBL in the vicinity of Unit 2, hourly meteorological data from the tower were employed, since other routine inland or over water measurements are not available. Since the temperature of the air over the water is not routinely measured, a climatological monthly average was used. This procedure has been recognized by NUREG CR-3351 as being a good approximation since the temperature of Lake Ontario, and therefore the temperature of the air over the lake, changes slowly relative to temperature changes of the air over the land. Mean monthly water temperatures from immediately offshore from Unit 2 were employed for March through December. Data from January and February were obtained from the work summarized by Yu and Brutsaert for Lake Ontario.[11]

Onshore wind directions and speeds were determined from the 30 ft (9.1 m) vane. The routine final rise of the main stack and the combined radwaste and reactor building vent plumes were calculated from the 200-ft (60.6-m) wind speed and the stability was determined from the 200-27 ft (60.6-8.2 m) delta temperature measurements. The ambient air temperature at 27 ft (8.2 m) was necessarily utilized for an indication of the air temperature over the land since land surface temperature data were not available. The lapse rate determined from the lower delta temperature, 100-27 ft (30.3-8.2 m) was employed.

The distance at which the plumes will intercept the TIBL was computed for all meteorological conditions except when the temperature of the air was equivalent to the monthly climatological values used to represent the temperature of the air over the water. The monthly air temperatures over the water are listed in Table 451.15-4. In addition, if the lapse rate was isothermal, the computation was not completed. These two situations represent a very small fraction of the 2-yr data base used (October 1978 through November 1980).

The seasonal distributions for the one non-routine release, the stack, and the two routine releases, the stack and the vent, are shown in Tables 451.15-5 through 451.15-7, respectively. The seasons have been defined as winter (December, January, and February); spring (March, April, May); summer (June, July, and August); and autumn (September, October, and November).

Table 451.15-5 shows that the interception with the main stack plume at a height of 429 ft (130:8 m) occurs most of the time beyond 12 mi (20 km) in all seasons. Less than 8 percent of the hours in each sector per season have the interception of the TIBL and the final effective height for the main stack occurring within 3 mi (5 km).

Table 451.15-6 shows that the interception of the routine stack plume with the TIBL occurs at even further distances downwind compared to the same hours for the non-routine stack data in Table 451.15-5. Again, the majority of the TIBL interceptions occur beyond 12 mi (20 km) from the stack.

The results in Table 451.15-7 for the routine releases from the combined radwaste and reactor building vent show that the interception generally occurs closer to the site than either of the stack releases due to the lower final effective height of the vent plume.

4. The routine diffusion modeling of the Unit 2 releases used 5 yr. of onsite meteorology to develop an onsite climatology for the annual X/Q and D/Q calculations. This approach adequately addresses the variations in meteorology since the concern is the annual average as opposed to any given hour(s). The use of 5 yr of meteorology assures that a climatological average is representative of the expected climatology and resultant X/Q and D/Q values in the future. Obviously, any given year may deviate from the resultant climatology, but the deviation should not significantly affect the conclusions drawn from the calculations.

References

1. Speiser, A. B.; Kramer, M. L.; Butler, M. J.; and Dupuis, L. R. Nine Mile Point Lake Breeze Study. Prepared for Niagara Mohawk Power Corporation, October 13, 1982.

2. Raynor, G. S.; Michael, P.; and SethuRaman, S. Meteorological Measurement Methods and Diffusion Models for Use at Coastal Nuclear Reactor Sites. Nuclear Safety Vol. 21-6, pp. 749-765, November-December 1980.

3. DiVecchio, R. A.; Smith, D. B.; and Martin, G. Performance of a Recent Formulation for Rate of Growth of Boundary Layers Near Shorelines. Presented at Conference on Coastal Meteorology, September 21-23, 1976, Virginia Beach, VA.

4. Lyons, W. A. Turbulent Diffusion and Pollutant Transport in Shoreline Environments. Lectures on Air Pollution and Environmental Impact Analyses, American Meteorological Society, 1975.

5. Raynor, G. S. et al. Studies of Atmospheric Diffusion from a Nearshore Oceanic Site. Journal of Applied Meteorology, Vol. 14, No. 6, pp. 1080-1094, September 1975.

6. New York State Electric and Gas Corporation, New Haven Nuclear Station, ER-CPS. Docket Nos. STN50-596 and STN50-597, March 1979.

7. Van Dop, H.; Steenkist, R.; and Nieuwstadt, F. T. Revised Estimates for Continuous Shoreline Fumigation. Journal of Applied Meteorology, Vol. 18, pp. 133-137.

8. Hicks, B. B.; Drinkrow, R. L.; and Grauze, G. Drag and Bulk Transfer Coefficients Associated With a Shallow Water Surface. Boundary Layer Meteorology, pp. 287-298, 1974.

9. Smith, S. D. Eddy Flux Measurements Over Lake Ontario. Boundary Layer Meteorology, pp. 235-256, 1974.

10. Ruggles, K. W. The Vertical Mean Wind Profile Over the Ocean for Light to Moderate Winds. Journal of Applied Meteorology, Vol. 9, No. 3, pp. 389-400, June 1970.

11. Yu, S. L. and Brutsaert, W. Estimation of Near-Surface Water Temperatures of Lake Ontario. Proceedings 11th Conference Great Lakes Research, pp. 512-523, 1968.

12. Athey, G. F.; Powell, D.C.; Ramsdell, J. V.; and Sandusky, W. F. Interim Report User's Guide to MESODIF-II (Version 2.0) PNL-4484, November 1982.

TABLE 451.15-1

SEASONAL DISTRIBUTION OF THE NUMBER OF HOURS WITH ONSHORE FLOW
AT THE 30-FT. (9.1-M) LEVEL FROM 0700 THROUGH 1900 LOCAL STANDARD TIME

	Wind Direction Sector (degrees)								
Season	270	292.5	315	337.5	360	22.5	45	Total	Missing
Winter									
12/78 - 2/79	81	144	129	39	40	36	59	528	5
12/79 - 2/80	78	146	124	51	57	52	52	560	108
Total	159	290	253	90	97	88	111	1,088	113
Spring									
3/79 - 5/79	156	76	57	42	74	34	69	508	18
3/80 - 5/80	205	97	70	60	51	41	34	558	2
Total	361	173	127	102	125	75	103	1,066	20
Summer									
6/79 - 8/79	247	78	55	23	71	43	39	556	16
6/80 - 8/80	258	94	62	17	42	47	37	557	8
Total	505	172	117	40	113	90	76	1,113	24
Fall									
11/78 & 9-10/79	115	112	62	17	45	66	48	465	21
11/79 & 9-10/80	159	101	60	24	26	26	34	430	41
Total	274	213	122	41	71	92	82	895	62
Annual									
11/78 - 10/80	1,299	848	619	273	406	345	372	4,162	219

TABLE 451.15-2

SEASONAL DISTRIBUTION OF THE NUMBER OF HOURS WITH ONSHORE FLOW
AT THE 30-FT. (9.1-M) LEVEL FROM 0700 THROUGH 1900 LOCAL STANDARD TIME

	Wind Direction Sector (degrees)								
Season	270 (%) *	292.5 (%)	315 (%)	337.5 (%)	360 (%)	22.5 (%)	45 (%)	Total (%)	Missing (%)
Winter									
12/78 - 2/79	3.8	6.7	6.0	1.8	1.9	1.7	2.7	24.4	0.2
12/79 - 2/80	3.6	6.7	5.7	2.3	2.6	2.4	2.4	25.6	4.9
Total	3.7	6.7	5.8	2.1	2.2	2.0	2.6	25.1	2.6
Spring									
3/79 - 5/79	7.1	3.4	2.6	1.9	3.4	1.5	3.1	23.0	0.8
3/80 - 5/80	9.3	4.4	3.2	2.7	2.3	1.9	1.5	25.3	0.1
Total	8.2	3.9	2.9	2.3	2.8	1.7	2.3	24.2	0.5
Summer									
6/79 - 8/79	11.2	3.5	2.5	1.0	3.2	1.9	1.8	25.2	0.7
6/80 - 8/80	11.7	4.3	2.8	0.8	1.9	2.1	1.7	25.2	0.4
Total	11.4	3.9	2.6	0.9	2.6	2.0	1.7	25.2	0.5
Fall									
11/78 & 9-10/79	5.3	5.1	2.8	0.8	2.1	3.0	2.2	21.3	1.0
11/79 & 9-10/80	7.3	4.6	2.7	1.1	1.2	1.2	1.6	19.7	1.9
Total	6.3	4.9	2.8	0.9	1.6	2.1	1.9	20.5	1.4
Annual									
11/78 - 10/80	7.4	4.8	3.5	1.6	2.3	2.0	2.1	23.7	1.3

* Percentage based on total number of hours in the season

TABLE 451.15-3

DISTRIBUTION AND FREQUENCY OF OCCURRENCE OF TIBL CONDITIONS
NEW HAVEN, NY*

Month	Hours of TIBL		Days of TIBL	
	Hours With TIBL Present	% of Total TIBL Hours	Days With TIBL Present	% of Total TIBL Hours
Jan	0	0	0	0
Feb	0	0	0	0
Mar	1	0.4	1	1.6
Apr	35	15.0	9	14.3
May	54	23.0	14	22.2
Jun	70	30.0	16	25.4
Jul	40	17.1	9	14.3
Aug	12	5.1	6	9.5
Sep	17	7.3	5	7.9
Oct	3	1.3	1	1.6
Nov	2	0.8	2	3.2
Dec	0	0	0	0
Totals	234	100.0	63	100.0

Hour of Day (LST)	Hours with TIBL Present	% of Total TIBL Hours
8	10	4.3
9	13	5.5
10	19	8.1
11	21	9.0
12	24	10.3
13	32	13.7
14	31	13.2
15	28	12.0
16	23	9.8
17	21	9.0
18	11	4.7
19	1	0.4
Totals	234	100.0

* Database - 4/1/77 through 3/31/78

TABLE 451.15-4

MONTHLY LAKE ONTARIO SURFACE WATER TEMPERATURE (C) MEASURED
IN THE NINE MILE POINT VICINITY

Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan (5)	Feb (5)
1976 (1)	HA	7.7	10.6	16.6	20.2	21.2	19.9	14.9	8.7	2.5		
1975 (2)	HA	3.3	10.2	15.4	23.5	21.6	17.0	14.4	10.7	6.2		
1974 (3)	0.9	2.1	8.5	14.2	20.2	22.1	18.9	12.5	8.5	4.6		
1973 (4)	NA	HA	HA	14.5	22.2	23.4	20.6	13.4	7.8	6.7		
Mean	0.9	4.4	9.8	15.2	21.5	22.1	19.1	13.8	8.9	5.0	2.8	1.8

NA: Not Available

(1) Source: Table IV-3; 1976 Nine Mile Point Aquatic Ecology Studies, May 1977, LMS Engineers for Niagara Mohawk Power Corporation.

(2) Source: Table IV-3; 1975 Nine Point Aquatic Ecology Studies, May 1976, LMS Engineers for Niagara Mohawk Power Corporation.

(3) Source: Table IV-5; 1974 Nine Mile Point Aquatic Ecology Studies, Dec 1975, LMS Engineers for Niagara Mohawk Power Corporation.

(4) Source: Table V-7; 1973 Nine Mile Point Aquatic Ecology Studies, Aug 1974, QLM Engineers for Niagara Mohawk Power Corporation.

Source: Yu and Brutsaert. Estimation of Near-Surface Water Temperatures of Lake Ontario, Proceedings 11th Conference Great Lakes Research, 1968, pages 512-523.

TABLE 451.15-5

WINTER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE NON-ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 12/78-12/79 AND 12/79-2/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	1	0.028	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	2	0.056	3	0.084	0	0.000	1	0.028	2	0.056	1	0.028	0	0.000
4	1	0.028	7	0.197	0	0.000	0	0.000	0	0.000	1	0.028	0	0.000
5	6	0.169	3	0.084	0	0.000	1	0.028	4	0.112	2	0.056	0	0.000
6	1	0.028	9	0.253	3	0.084	2	0.056	4	0.112	0	0.000	0	0.000
7	3	0.084	4	0.112	1	0.028	7	0.197	4	0.112	1	0.028	0	0.000
8	6	0.169	8	0.225	1	0.028	1	0.028	7	0.197	1	0.028	0	0.000
9	4	0.112	1	0.028	0	0.000	0	0.000	2	0.056	1	0.028	1	0.028
10	5	0.141	4	0.112	0	0.000	3	0.084	5	0.141	3	0.084	2	0.056
11	4	0.112	6	0.169	4	0.112	2	0.056	6	0.169	2	0.056	1	0.028
12	2	0.056	9	0.253	1	0.028	1	0.028	6	0.169	2	0.056	0	0.000
13	4	0.112	6	0.169	1	0.028	3	0.084	6	0.169	3	0.084	1	0.028
14	3	0.084	8	0.225	2	0.056	4	0.112	6	0.169	6	0.169	2	0.056
15	3	0.084	6	0.169	2	0.056	6	0.169	3	0.084	0	0.000	3	0.084
16	4	0.112	4	0.112	2	0.056	4	0.112	5	0.141	3	0.084	2	0.056
17	2	0.056	7	0.197	0	0.000	3	0.084	4	0.112	4	0.112	3	0.084
18	0	0.000	7	0.197	2	0.056	3	0.084	1	0.028	1	0.028	1	0.028
19	4	0.112	8	0.225	2	0.056	2	0.056	8	0.225	0	0.000	1	0.028
20	3	0.084	6	0.169	4	0.112	5	0.141	5	0.141	3	0.084	1	0.028
25	18	0.506	25	0.703	13	0.366	38	1.069	33	0.928	14	0.394	9	0.253
30	13	0.366	18	0.506	19	0.534	50	1.406	63	1.772	21	0.591	7	0.197
35	13	0.366	7	0.197	16	0.450	48	1.350	83	2.334	16	0.450	8	0.225
40	9	0.253	15	0.422	24	0.675	50	1.406	75	2.109	12	0.337	8	0.225
45	6	0.169	2	0.056	16	0.450	53	1.490	51	1.434	16	0.450	7	0.197
50	6	0.169	3	0.084	13	0.366	38	1.069	33	0.928	21	0.591	6	0.169
>50	27	0.759	32	0.900	77	2.165	120	3.375	105	2.953	48	1.350	25	0.703
	149	4.190	209	5.877	203	5.709	445	12.514	521	14.651	182	5.118	88	2.475

Missing 788
Total Hours 4344

TABLE 451.15-5 (Cont'd)

SPRING FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE NON-ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 3/79-5/79 AND 3/80-5/80

Distance LE (km)	Wind Direction Sector (degrees) 22.50 Count	Percent	45.00 Count	Percent	270.00 Count	Percent	292.50 Count	Percent	315.00 Count	Percent	337.50 Count	Percent	360.00 Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	2	0.052	0	0.000	0	0.000	0	0.000	1	0.026
6	1	0.026	1	0.026	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000
7	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
8	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
9	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
10	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
11	0	0.000	1	0.026	2	0.052	2	0.052	1	0.026	0	0.000	0	0.000
12	0	0.000	2	0.052	0	0.000	0	0.000	0	0.000	1	0.026	0	0.000
13	0	0.000	2	0.052	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
14	2	0.052	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
15	1	0.026	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
16	1	0.026	1	0.026	2	0.052	0	0.000	0	0.000	0	0.000	0	0.000
17	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
18	0	0.000	1	0.026	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000
19	1	0.026	0	0.000	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000
20	0	0.000	2	0.052	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000
25	1	0.026	2	0.052	10	0.261	2	0.052	3	0.078	2	0.052	0	0.000
30	2	0.052	7	0.183	10	0.261	3	0.078	1	0.026	2	0.052	2	0.052
35	1	0.026	5	0.130	12	0.313	4	0.104	6	0.156	6	0.156	3	0.078
40	0	0.000	6	0.156	12	0.313	8	0.209	4	0.104	2	0.052	3	0.078
45	2	0.052	7	0.183	9	0.235	11	0.287	8	0.209	3	0.078	2	0.052
50	2	0.052	4	0.104	19	0.495	18	0.469	12	0.313	3	0.078	1	0.026
>50	64	1.669	98	2.555	432	11.265	210	5.476	157	4.094	121	3.155	101	2.634
	80	2.086	142	3.703	514	13.403	262	6.832	192	5.007	140	3.651	113	2.947

Missing 581
Total Hours 4416

TABLE 451.15-5 (Cont'd)

SUMMER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE NON-ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 6/79-8/79 AND 6/80-8/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	1	0.025	0	0.000
6	0	0.000	0	0.000	0	0.000	4	0.101	0	0.000	1	0.025	0	0.000
7	0	0.000	0	0.000	3	0.075	0	0.000	0	0.000	0	0.000	0	0.000
8	0	0.000	1	0.025	1	0.025	1	0.025	0	0.000	0	0.000	1	0.025
9	1	0.025	3	0.075	1	0.025	1	0.025	1	0.025	0	0.000	0	0.000
10	0	0.000	3	0.075	2	0.050	1	0.025	0	0.000	0	0.000	0	0.000
11	1	0.025	3	0.075	2	0.050	3	0.075	1	0.025	1	0.025	1	0.025
12	1	0.025	1	0.025	2	0.050	0	0.000	0	0.000	1	0.025	0	0.000
13	0	0.000	1	0.025	3	0.075	0	0.000	0	0.000	0	0.000	0	0.000
14	1	0.025	0	0.000	5	0.126	2	0.050	0	0.000	1	0.025	0	0.000
15	1	0.025	0	0.000	2	0.050	2	0.050	1	0.025	0	0.000	1	0.025
16	0	0.000	3	0.075	4	0.101	1	0.025	0	0.000	0	0.000	0	0.000
17	1	0.025	0	0.000	1	0.025	2	0.050	2	0.050	0	0.000	0	0.000
18	1	0.025	1	0.025	3	0.075	1	0.025	0	0.000	0	0.000	0	0.000
19	1	0.025	0	0.000	3	0.075	1	0.025	2	0.050	0	0.000	0	0.000
20	0	0.000	1	0.025	2	0.050	2	0.050	2	0.050	0	0.000	0	0.000
25	3	0.075	2	0.050	16	0.403	7	0.176	4	0.101	0	0.000	0	0.000
30	4	0.101	3	0.075	15	0.377	16	0.403	4	0.101	0	0.000	1	0.025
35	2	0.050	3	0.075	27	0.679	12	0.302	3	0.075	2	0.050	2	0.050
40	0	0.000	2	0.050	29	0.730	5	0.126	2	0.050	0	0.000	0	0.000
45	5	0.126	5	0.126	23	0.579	10	0.252	3	0.075	1	0.025	2	0.050
50	3	0.075	6	0.151	20	0.503	6	0.151	3	0.075	0	0.000	0	0.000
>50	89	2.240	90	2.265	429	10.795	178	4.479	123	3.095	41	1.032	45	1.132
	114	2.869	128	3.221	593	14.922	255	6.417	151	3.800	49	1.233	53	1.334

Missing 442
Total Hours 4416

TABLE 451.15-5 (Cont'd)

FALL FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE NON-ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 11/78, 9/79-10/79 AND 11/79, 9/80-10/80

Distance LE (km)	22.50 Count	22.50 Percent	45.00 Count	45.00 Percent	270.00 Count	270.00 Percent	292.50 Count	292.50 Percent	315.00 Count	315.00 Percent	337.50 Count	337.50 Percent	360.00 Count	360.00 Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
6	0	0.000	4	0.110	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
7	3	0.083	2	0.055	1	0.028	0	0.000	0	0.000	0	0.000	0	0.000
8	1	0.028	3	0.083	0	0.000	1	0.028	0	0.000	0	0.000	0	0.000
9	7	0.193	4	0.110	2	0.055	0	0.000	0	0.000	0	0.000	0	0.000
10	0	0.000	1	0.028	0	0.000	0	0.000	0	0.000	0	0.000	1	0.028
11	0	0.000	3	0.083	1	0.028	2	0.055	1	0.028	0	0.000	1	0.028
12	0	0.000	3	0.083	3	0.083	2	0.055	0	0.000	0	0.000	0	0.000
13	1	0.028	4	0.110	0	0.000	0	0.000	3	0.083	0	0.000	0	0.000
14	3	0.083	2	0.055	1	0.028	5	0.138	0	0.000	0	0.000	0	0.000
15	0	0.000	1	0.028	0	0.000	2	0.055	0	0.000	1	0.028	0	0.000
16	2	0.055	5	0.138	0	0.000	0	0.000	2	0.055	0	0.000	0	0.000
17	0	0.000	5	0.138	3	0.083	1	0.028	2	0.055	0	0.000	0	0.000
18	3	0.083	3	0.083	1	0.028	0	0.000	1	0.028	0	0.000	0	0.000
19	2	0.055	3	0.083	1	0.028	4	0.110	2	0.055	0	0.000	0	0.000
20	2	0.055	0	0.000	2	0.055	3	0.083	3	0.083	0	0.000	0	0.000
25	14	0.386	7	0.193	19	0.524	29	0.800	29	0.800	4	0.110	4	0.110
30	7	0.193	4	0.110	38	1.049	30	0.828	25	0.690	1	0.028	1	0.028
35	6	0.166	3	0.083	38	1.049	19	0.524	23	0.635	8	0.221	1	0.028
40	1	0.028	7	0.193	37	1.021	26	0.718	41	1.132	7	0.193	0	0.000
45	1	0.028	10	0.276	12	0.331	25	0.690	15	0.414	6	0.166	3	0.083
50	5	0.138	7	0.193	8	0.221	25	0.690	15	0.414	4	0.110	1	0.028
>50	54	1.490	56	1.546	224	6.183	143	3.947	109	3.009	39	1.076	36	0.994
	112	3.091	137	3.781	391	10.792	317	8.750	271	7.480	70	1.932	48	1.325

Missing 745
Total Hours 4368

TABLE 451.15-6

WINTER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 12/78-2/79 AND 12/79-2/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
I	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	1	0.028	2	0.056	0	0.000	1	0.028	2	0.056	1	0.028	0	0.000
4	1	0.028	4	0.112	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	6	0.169	7	0.197	0	0.000	0	0.000	0	0.000	1	0.028	0	0.000
6	1	0.028	3	0.084	1	0.028	1	0.028	6	0.169	2	0.056	0	0.000
7	1	0.028	9	0.253	2	0.056	7	0.197	2	0.056	0	0.000	0	0.000
8	4	0.112	3	0.084	1	0.028	2	0.056	5	0.141	0	0.000	0	0.000
9	5	0.141	6	0.169	1	0.028	0	0.000	5	0.141	0	0.000	0	0.000
10	5	0.141	2	0.056	0	0.000	1	0.028	1	0.028	2	0.056	1	0.028
11	2	0.056	4	0.112	1	0.028	2	0.056	5	0.141	2	0.056	1	0.028
12	4	0.112	1	0.028	2	0.056	2	0.056	6	0.169	1	0.028	2	0.056
13	3	0.084	6	0.169	2	0.056	2	0.056	4	0.112	2	0.056	0	0.000
14	3	0.084	9	0.253	1	0.028	2	0.056	6	0.169	2	0.056	1	0.028
15	2	0.056	4	0.112	0	0.000	1	0.028	5	0.141	5	0.141	1	0.028
16	3	0.084	8	0.225	2	0.056	6	0.169	3	0.084	2	0.056	1	0.028
17	3	0.084	5	0.141	2	0.056	1	0.028	4	0.112	2	0.056	2	0.056
18	2	0.056	3	0.084	1	0.028	4	0.112	2	0.056	1	0.028	0	0.000
19	3	0.084	6	0.169	2	0.056	6	0.169	5	I 0.141	5	0.141	3	0.084
20	1	0.028	7	0.197	1	0.028	2	0.056	6	0.169	2	0.056	1	0.028
25	16	0.450	33	0.928	12	0.337	26	0.731	16	0.450	8	0.225	9	0.253
30	11	0.309	14	0.394	17	0.478	40	1.125	51	1.434	16	0.450	5	0.141
35	15	0.422	15	0.422	16	0.450	49	1.378	54	1.519	12	0.337	7	0.197
40	12	0.337	9	0.253	19	0.534	38	1.069	83	2.334	18	0.506	9	0.253
45	5	0.141	10	0.281	20	0.562	47	1.322	69	1.940	14	0.394	7	0.197
50	5	0.141	4	0.112	10	0.281	51	1.434	53	1.490	17	0.478	6	0.169
>50	35	0.981	35	0.984	90	2.531	154	4.331	128	3.600	67	1.884	32	0.900
	149	1.190	209	5.877	203	5.709	445	12.514	521	14.651	182	5.118	88	2.475

Missing 788
Total Hours 4344

TABLE 451.15-6 (Cont'd)

SPRING FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 3/79-5/79 AND 3/80-5/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
6	0	0.000	0	0.000	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000
7	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	1	0.026
8	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
9	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
10	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
11	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
12	0	0.000	0	0.000	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000
13	0	0.000	1	0.026	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000
14	0	0.000	0	0.000	1	0.026	0	0.000	1	0.026	0	0.000	0	0.000
15	0	0.000	0	0.000	1	0.026	0	0.000	0	0.000	1	0.026	0	0.000
16	0	0.000	3	0.078	2	0.052	0	0.000	0	0.000	0	0.000	0	0.000
17	2	0.052	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
18	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
19	0	0.000	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000
20	3	0.078	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
25	1	0.026	5	0.130	6	0.156	5	0.130	1	0.026	1	0.026	0	0.000
30	2	0.052	3	0.078	5	0.130	1	0.026	3	0.078	1	0.026	1	0.026
35	1	0.026	4	0.104	15	0.391	1	0.026	2	0.052	2	0.052	1	0.026
40	1	0.026	7	0.183	6	0.156	6	0.156	5	0.130	5	0.130	3	0.078
45	0	0.000	3	0.078	11	0.287	10	0.261	4	0.104	2	0.052	2	0.052
50	1	0.026	5	0.130	15	0.391	9	0.235	9	0.235	3	0.078	2	0.052
>50	67	1.747	107	2.790	447	11.656	227	5.919	167	4.355	125	3.259	103	2.686
	80	2.086	142	3.703	514	13.403	262	6.832	192	5.007	140	3.651	113	2.947

Hissing 581
Total Hours 4416

TABLE 451.15-6 (Cont'd)

SUMMER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 6/79-8/79 AND 6/80-8/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	1	0.025	0	0.000
6	0	0.000	0	0.000	0	0.000	4	0.101	0	0.000	1	0.025	0	0.000
7	0	0.000	0	0.000	3	0.075	0	0.000	0	0.000	0	0.000	0	0.000
8	0	0.000	1	0.025	1	0.025	0	0.000	0	0.000	0	0.000	1	0.025
9	1	0.025	3	0.075	1	0.025	1	0.025	1	0.025	0	0.000	0	0.000
10	0	0.000	3	0.075	2	0.050	1	0.025	0	0.000	0	0.000	0	0.000
11	1	0.025	3	0.075	2	0.050	3	0.075	1	0.025	1	0.025	1	0.025
12	1	0.025	1	0.025	2	0.050	0	0.000	0	0.000	1	0.025	0	0.000
13	0	0.000	1	0.025	3	0.075	0	0.000	0	0.000	0	0.000	0	0.000
14	1	0.025	0	0.000	5	0.126	2	0.050	0	0.000	1	0.025	0	0.000
15	1	0.025	0	0.000	2	0.050	2	0.050	1	0.025	0	0.000	1	0.025
16	0	0.000	3	0.075	4	0.101	1	0.025	0	0.000	0	0.000	0	0.000
17	1	0.025	0	0.000	1	0.025	2	0.050	2	0.050	0	0.000	0	0.000
18	1	0.025	1	0.025	3	0.075	1	0.025	0	0.000	0	0.000	0	0.000
19	1	0.025	0	0.000	3	0.075	1	0.025	2	0.050	0	0.000	0	0.000
20	0	0.000	1	0.025	2	0.050	2	0.050	2	0.050	0	0.000	0	0.000
25	3	0.075	2	0.050	16	0.403	7	0.176	4	0.101	0	0.000	0	0.000
30	4	0.101	3	0.075	15	0.377	16	0.403	4	0.101	0	0.000	1	0.025
35	2	0.050	3	0.075	27	0.679	12	0.302	3	0.075	2	0.050	2	0.050
40	0	0.000	2	0.050	29	0.730	5	0.126	2	0.050	0	0.000	0	0.000
45	5	0.126	5	0.126	23	0.579	10	0.252	3	0.075	1	0.025	2	0.050
50	3	0.075	6	0.151	20	0.503	6	0.151	3	0.075	0	0.000	0	0.000
>50	89	2.240	90	2.265	429	10.795	178	4.479	123	3.095	41	1.032	45	1.132
	114	2.869	128	3.221	593	14.922	255	6.417	151	3.800	49	1.233	53	1.334

Missing 442
Total Hours 4416

TABLE 451.15-6 (Cont'd)

FALL FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE MAIN STACK PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 11/78, 9/79-10/79 AND 11/79, 9/80-10/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
6	0	0.000	4	0.110	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
7	3	0.083	2	0.055	1	0.028	0	0.000	0	0.000	0	0.000	0	0.000
8	1	0.028	3	0.083	0	0.000	1	0.028	0	0.000	0	0.000	0	0.000
9	7	0.193	4	0.110	2	0.055	0	0.000	0	0.000	0	0.000	0	0.000
10	0	0.000	1	0.028	0	0.000	0	0.000	0	0.000	0	0.000	1	0.028
11	0	0.000	3	0.083	1	0.028	2	0.055	1	0.028	0	0.000	1	0.028
12	0	0.000	3	0.083	3	0.083	2	0.055	0	0.000	0	0.000	0	0.000
13	1	0.028	4	0.110	0	0.000	0	0.000	3	0.083	0	0.000	0	0.000
14	3	0.083	2	0.055	1	0.028	5	0.138	0	0.000	0	0.000	0	0.000
15	0	0.000	1	0.028	0	0.000	2	0.055	0	0.000	1	0.028	0	0.000
16	2	0.055	5	0.138	0	0.000	0	0.000	2	0.055	0	0.000	0	0.000
17	0	0.000	5	0.138	3	0.083	1	0.028	2	0.055	0	0.000	0	0.000
18	3	0.083	3	0.083	1	0.028	0	0.000	1	0.028	0	0.000	0	0.000
19	2	0.055	3	0.083	1	0.028	4	0.110	2	0.055	0	0.000	0	0.000
20	2	0.055	0	0.000	2	0.055	3	0.083	3	0.083	0	0.000	0	0.000
25	14	0.386	7	0.193	19	0.524	29	0.800	29	0.800	4	0.110	4	0.110
30	7	0.193	4	0.110	38	1.049	30	0.828	25	0.690	1	0.028	1	0.028
35	6	0.166	3	0.083	38	1.049	19	0.524	23	0.635	8	0.221	1	0.028
40	1	0.028	7	0.193	37	1.021	26	0.718	41	1.132	7	0.193	0	0.000
45	1	0.028	10	0.276	12	0.331	25	0.690	15	0.414	6	0.166	3	0.083
50	5	0.138	7	0.193	8	0.221	25	0.690	15	0.414	4	0.110	1	0.028
>50	54	1.490	56	1.546	224	6.183	143	3.947	109	3.009	39	1.076	36	0.994
	112	3.091	137	3.781	391	10.792	317	8.750	271	7.480	70	1.932	48	1.325

Missing	745
Total Hours	4368

TABLE 451.15-7

WINTER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE COMBINED RADWASTE AND REACTOR BUILDING VENT PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 12/78-2/79 AND 12/79-2/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	1	0.028	1	0.028	0	0.000	1	0.028	2	0.056	0	0.000	0	0.000
2	8	0.225	13	0.366	1	0.028	3	0.084	6	0.169	4	0.112	0	0.000
3	10	0.281	17	0.478	6	0.169	8	0.225	7	0.197	0	0.000	1	0.028
4	11	0.309	16	0.450	2	0.056	6	0.169	15	0.422	5	0.141	3	0.084
5	8	0.225	13	0.366	4	0.112	7	0.197	14	0.394	8	0.225	1	0.028
6	5	0.141	18	0.506	11	0.309	16	0.450	16	0.450	4	0.112	5	0.141
7	8	0.225	24	0.675	7	0.197	11	0.309	12	0.337	3	0.084	2	0.056
8	11	0.309	13	0.366	6	0.169	31	0.872	16	0.450	8	0.225	3	0.084
9	9	0.253	13	0.366	9	0.253	29	0.816	38	1.069	7	0.197	2	0.056
10	11	0.309	9	0.253	19	0.534	33	0.928	34	0.956	4	0.112	7	0.197
11	12	0.337	7	0.197	15	0.422	32	0.900	46	1.294	9	0.253	3	0.084
12	2	0.056	9	0.253	10	0.281	10	1.125	43	1.209	9	0.253	4	0.112
13	6	0.169	1	0.028	5	0.141	17	0.478	40	1.125	9	0.253	3	0.084
14	3	0.084	2	0.056	10	0.281	32	0.900	27	0.759	12	0.337	5	0.141
15	4	0.112	8	0.225	13	0.366	15	0.422	41	1.153	16	0.450	5	0.141
16	3	0.084	4	0.112	6	0.163	14	0.394	17	0.478	4	0.112	2	0.056
17	1	0.028	0	0.000	5	0.141	13	0.366	15	0.422	18	0.506	5	0.141
18	2	0.056	2	0.056	5	0.141	11	0.309	22	0.619	8	0.225	2	0.056
19	1	0.028	0	0.000	5	0.141	15	0.422	17	0.478	3	0.084	1	0.028
20	1	0.028	1	0.028	0	0.000	12	0.337	5	0.141	1	0.028	1	0.028
25	9	0.253	13	0.366	18	0.506	26	0.731	27	0.759	11	0.309	8	0.225
30	4	0.112	2	0.056	6	0.169	12	0.337	15	0.422	9	0.253	9	0.253
35	2	0.056	6	0.169	8	0.225	8	0.225	9	0.253	4	0.112	4	0.112
40	3	0.084	2	0.056	6	0.169	5	0.141	8	0.225	3	0.084	2	0.056
45	2	0.056	1	0.028	1	0.028	4	0.112	6	0.169	2	0.056	1	0.028
50	2	0.056	1	0.028	3	0.084	7	0.197	4	0.112	2	0.056	0	0.000
>50	10	0.281	13	0.366	22	0.619	37	1.040	19	0.534	19	0.534	9	0.253
	149	4.190	209	5.877	203	5.709	445	12.514	521	14.651	182	5.118	88	2.475

Missing 788
Total Hours 4344

TABLE 451.15-7 (Cont'd)

SPRING FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE COMBINED RADWASTE AND REACTOR BUILDING VENT PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 3/79-5/79 AND 3/80-5/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
(km)	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	2	0.052	1	0.026	0	0.000	0	0.000	0	0.000
3	1	0.026	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	1	0.026
4	0	0.000	2	0.052	0	0.000	1	0.026	0	0.000	0	0.000	0	0.000
5	0	0.000	1	0.026	3	0.078	1	0.026	0	0.000	0	0.000	0	0.000
6	1	0.026	2	0.052	4	0.104	2	0.052	1	0.026	1	0.026	0	0.000
7	2	0.052	4	0.104	1	0.026	1	0.026	0	0.000	0	0.000	0	0.000
8	1	0.026	1	0.026	7	0.183	3	0.078	1	0.026	1	0.026	1	0.026
9	2	0.052	1	0.026	4	0.104	1	0.026	2	0.052	0	0.000	0	0.000
10	2	0.052	2	0.052	4	0.104	2	0.052	0	0.000	2	0.052	1	0.026
11	0	0.000	2	0.052	10	0.261	3	0.078	3	0.078	1	0.026	0	0.000
12	1	0.026	3	0.078	7	0.183	6	0.156	2	0.052	0	0.000	1	0.026
13	0	0.000	5	0.130	11	0.287	9	0.235	4	0.104	1	0.026	0	0.000
14	0	0.000	2	0.052	2	0.052	7	0.183	10	0.261	3	0.078	1	0.026
15	0	0.000	3	0.078	9	0.235	20	0.522	6	0.156	3	0.078	2	0.052
16	1	0.026	3	0.078	6	0.156	10	0.261	11	0.287	3	0.078	0	0.000
17	0	0.000	1	0.026	6	0.156	14	0.365	1	0.026	0	0.000	1	0.026
18	1	0.026	2	0.052	6	0.156	7	0.183	3	0.078	0	0.000	0	0.000
19	1	0.026	3	0.078	9	0.235	5	0.130	0	0.000	2	0.052	1	0.026
20	1	0.026	6	0.156	7	0.183	1	0.026	2	0.052	1	0.026	1	0.026
25	5	0.130	11	0.287	52	1.356	23	0.600	14	0.365	12	0.313	8	0.209
30	2	0.052	8	0.209	28	0.730	12	0.313	13	0.339	3	0.078	4	0.104
35	4	0.104	9	0.235	28	0.730	8	0.209	11	0.287	7	0.183	5	0.130
40	5	0.130	1	0.026	20	0.522	6	0.156	5	0.130	2	0.052	5	0.130
45	2	0.052	2	0.052	19	0.495	6	0.156	1	0.026	2	0.052	3	0.078
50	2	0.052	2	0.052	20	0.522	5	0.130	3	0.078	3	0.078	1	0.026
>50	46	1.199	66	1.721	249	6.493	108	2.816	99	2.581	93	2.425	77	2.008
	80	2.086	142	3.703	514	13.403	262	6.832	192	5.007	140	3.651	113	2.947

Missing 581
Total Hours 4416

TABLE 451.15-7 (Cont'd)

SUMMER FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE COMBINED RADWASTE AND REACTOR BUILDING VENT PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 6/79-8/79 AND 6/80-8/80

Distance	Wind Direction Sector (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	2	0.050	0	0.000	0	0.000	2	0.050	0	0.000
3	0	0.000	1	0.025	2	0.050	4	0.101	1	0.025	0	0.000	0	0.000
4	1	0.025	6	0.151	12	0.302	3	0.075	1	0.025	3	0.075	1	0.025
5	2	0.050	4	0.101	2	0.050	2	0.050	2	0.050	0	0.000	0	0.000
6	1	0.025	1	0.025	6	0.151	4	0.101	2	0.050	0	0.000	1	0.025
7	1	0.025	2	0.050	6	0.151	2	0.050	3	0.075	0	0.000	0	0.000
8	0	0.000	3	0.075	5	0.126	4	0.101	2	0.050	0	0.000	0	0.000
9	3	0.075	0	0.000	6	0.151	13	0.327	3	0.075	0	0.000	0	0.000
10	1	0.025	0	0.000	8	0.201	12	0.302	2	0.050	0	0.000	0	0.000
11	1	0.025	1	0.025	9	0.226	8	0.201	3	0.075	0	0.000	0	0.000
12	0	0.000	2	0.050	14	0.352	3	0.075	1	0.025	1	0.025	0	0.000
13	0	0.000	0	0.000	9	0.226	2	0.050	2	0.050	1	0.025	0	0.000
14	1	0.025	0	0.000	19	0.478	4	0.101	1	0.025	1	0.025	2	0.050
15	1	0.025	0	0.000	13	0.327	4	0.101	0	0.000	0	0.000	1	0.025
16	1	0.025	1	0.025	14	0.352	3	0.075	0	0.000	0	0.000	0	0.000
17	1	0.025	2	0.050	21	0.528	2	0.050	1	0.025	0	0.000	1	0.025
18	0	0.000	3	0.075	9	0.226	8	0.201	1	0.025	0	0.000	0	0.000
19	2	0.050	2	0.050	5	0.126	2	0.050	0	0.000	0	0.000	0	0.000
20	1	0.025	1	0.025	11	0.277	0	0.000	1	0.025	0	0.000	0	0.000
25	9	0.226	10	0.252	26	0.654	3	0.075	8	0.201	0	0.000	0	0.000
30	0	0.000	10	0.252	22	0.554	7	0.176	7	0.176	1	0.025	3	0.075
35	6	0.151	4	0.101	23	0.579	7	0.176	9	0.226	0	0.000	2	0.050
40	5	0.126	4	0.101	14	0.352	7	0.176	5	0.126	1	0.025	1	0.025
45	2	0.050	5	0.126	14	0.352	7	0.176	2	0.050	2	0.050	1	0.025
50	0	0.000	4	0.101	17	0.428	3	0.075	4	0.101	0	0.000	1	0.025
>50	75	1.887	62	1.560	304	7.650	141	3.548	90	2.265	37	0.931	39	0.981
	114	2.869	128	3.221	593	14.922	255	6.417	151	3.800	49	1.233	53	1.334

Missing 442
Total Hours 4416

TABLE 451.15-7 (Cont'd)

FALL FREQUENCY DISTRIBUTION OF THE DISTANCES
WHERE THE ROUTINE COMBINED RADWASTE AND REACTOR BUILDING VENT PLUME INTERCEPTS THE TIBL
NINE MILE SITE METEOROLOGY: 11/78, 9/79-10/79 AND 11/79, 9/80-10/80

Distance	Wind Direction Sector, (degrees)													
LE	22.50		45.00		270.00		292.50		315.00		337.50		360.00	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
3	4	0.110	8	0.221	3	0.083	0	0.000	0	0.000	0	0.000	0	0.000
4	0	0.000	4	0.110	3	0.083	2	0.055	1	0.028	0	0.000	1	0.028
5	4	0.110	8	0.221	2	0.055	2	0.055	0	0.000	0	0.000	0	0.000
6	4	0.110	9	0.248	3	0.083	6	0.166	6	0.166	0	0.000	0	0.000
7	3	0.083	7	0.193	13	0.359	12	0.331	12	0.331	1	0.028	2	0.055
8	7	0.193	6	0.166	18	0.497	4	0.110	8	0.221	1	0.028	1	0.028
9	4	0.110	0	0.000	23	0.635	13	0.359	9	0.248	0	0.000	0	0.000
10	7	0.193	5	0.138	16	0.442	14	0.386	12	0.331	1	0.028	1	0.028
11	4	0.110	4	0.110	25	0.690	25	0.690	12	0.331	5	0.138	1	0.028
12	3	0.083	3	0.083	15	0.414	16	0.442	20	0.552	6	0.166	0	0.000
13	2	0.055	2	0.055	14	0.386	16	0.442	18	0.497	2	0.055	0	0.000
14	5	0.138	5	0.138	12	0.331	13	0.359	18	0.497	4	0.110	0	0.000
15	1	0.028	2	0.055	7	0.193	14	0.386	14	0.386	1	0.028	2	0.055
16	1	0.028	3	0.083	3	0.083	16	0.442	15	0.414	5	0.138	1	0.028
17	2	0.055	1	0.028	7	0.193	10	0.276	15	0.414	2	0.055	0	0.000
18	5	0.138	6	0.166	7	0.193	10	0.276	6	0.166	3	0.083	1	0.028
19	0	0.000	4	0.110	5	0.138	9	0.248	3	0.083	0	0.000	0	0.000
20	0	0.000	1	0.028	7	0.193	8	0.221	3	0.083	1	0.028	0	0.000
25	4	0.110	12	0.331	17	0.469	20	0.552	19	0.524	3	0.083	1	0.028
30	7	0.193	1	0.028	26	0.718	12	0.331	16	0.442	6	0.166	2	0.055
35	3	0.083	7	0.193	29	0.800	13	0.359	14	0.386	2	0.055	1	0.028
40	2	0.055	3	0.083	22	0.607	8	0.221	8	0.221	2	0.055	2	0.055
45	2	0.055	3	0.083	14	0.386	3	0.083	8	0.221	1	0.028	2	0.055
50	3	0.083	1	0.028	6	0.166	8	0.221	4	0.110	1	0.028	0	0.000
>50	35	0.966	32	0.883	94	2.595	63	1.739	30	0.828	23	0.635	30	0.828
	112	3.091	137	3.781	391	10.792	317	8.750	271	7.480	70	1.932	48	1.325

Missing 745
Total Hours 4368

APPENDIX 2Q

GEOLOGY ITEMS

(Derived from the US NRC Draft
Safety Evaluation Report, Section 2.5,
dated February 16, 1984)

GEOLOGY ITEMS

GEOLOGIC ITEM NO. 1

Genesis of Stresses at the Nine Mile Point Unit 2 Site

The NRC staff has requested[1] a recalculation of the changing stresses through time at the site, assuming less depth of burial than used originally in the calculations.

The staff has indicated a concern regarding the use of recorded maximum depths of burial for the sediments exposed in the near subsurface at Unit 2 for the purpose of estimating stress conditions extant at the time of initiation of normal faulting. The staff's concern lies with the use of the fluid inclusion studies as an indicator of maximum temperature of burial (when used with an assumed geothermal gradient) because they may lead to an assumption of greater burial depths and less conservative ages when assessing the capability of a fault.

The subsequent paragraphs provide the applicant's response to this request.

Conodont Color Alteration Index (CAI)

Harris, et al[2] and Epstein et al[3] have reported on the use of conodonts and their color alteration with increasing depth of burial (higher geothermal temperatures) as a means of assessing the thermal maturity of diagenesis within an active sedimentary basin. The staff has referred to a CAI in the site area indicating a maximum temperature of 60° to 100°C (140° to 212°F) for the Oswego Sandstone in the site region and a geothermal gradient of 35°C/km (95°F kilometer).[1] This would be interpreted as an estimated depth of burial of 1,220 to 2,440 meters (3,660 to 7,220 ft) of the sediments containing the conodonts at the time of maximum temperature. It should be noted that there have been no reported occurrences of conodonts, however, from high energy, clastic rocks such as the Oswego Sandstone in this region. The staff further refers to the CAI as not requiring interpretation, as the color of the conodont as found in the rock is a direct result of the maximum temperature ranges experienced by the rock, is independent of pressure, and is irreversible.[3] The staff, therefore, feels that the CAI is more reliable than fluid inclusion studies, which were used by the applicant for estimating the maximum depth of burial for sediments existing at Unit 2.

As shown in Table GI-1, which was obtained directly from Dr. A. Harris (personal communication, 1984), none of the counties surrounding Unit 2 has yielded any surface or drill hole samples (one sample) to be included in the CAI map of the Ordovician rocks in the northern Appalachian Basin. Those samples that have been studied from surrounding counties (underlined on each of the data sheets) are Siluvian and Devonian rocks which yielded a CAI of between 2 and 3. Utilizing the lower value (2) as representative of the CAI in the site area, the suggested approximate overburden depth at the time of fixing the color (maximum temperature) of the conodonts ranges from 8,000 to 12,000 ft (2,440 to 3,660 m). This is certainly consistent with the depth of burial estimates of 3.5 km (11,500 ft) reported in Section 7 of the FSAR.[4]

Although conodont color alteration is progressive, accumulative, and irreversible[2] and is time and temperature dependent, in discussions with Dr. Harris, it was found that recent studies by her and her colleagues have shown that the color alteration of conodonts is highly sensitive to the presence of mineralized solutions. Dr. Harris (personal communication, 1984) has estimated that the thermal maturity, as expressed in the color alteration index, may be retarded by as much as 50 percent in the presence of a closed system of circulating fluids. During and subsequent to the thermal maximum of diagenesis, the epigenetic sequence of sulfide mineralization observed at the site was deposited in a reducing (i.e., closed to the atmosphere) environment by circulating fluids.[5] Therefore, should the conodont color alteration index even be less than two in the site region, say 1-1/2 to 2, the presence of circulating fluids which is known to have occurred at the site should make any reported CAI number of conodonts found at the site most likely on the low side. This would suggest, therefore, that the depth of burial estimates deduced from the CAI would be conservative.

In consideration of the above, the applicant's position is that the very thorough and systematic study of the paragenetic relationship of observed mineralization and fluid inclusion study to the genesis of faults and fractures in the Unit 2 area has provided a conservative and thorough analysis of the stress genesis through time at Unit 2. Any recalculation of the stress history at the site would be unwarranted as the differences among the estimates of depth of burial between fluid inclusion analysis and the reported CAI would be only one to several hundred meters.

References - Genesis of Stresses

1. United States Nuclear Regulatory Commission, Draft Safety Evaluation Report, Section 2.5, Nine Mile Point Unit 2, Final Safety Analysis Report. February 16, 1984.

2. Harris, A. G.; Harris, L. D.; and Epstein, J. B. Oil and Gas Data From Paleozoic Rocks in the Appalachian Basin: Maps for Assessing Hydrocarbon Potential and Thermal Maturity (Conodont Color Isograds and Overburden Isopachs). Miscellaneous Investigation Series, Map I-917-E, U.S. Geological Survey. 1978.

3. Epstein, A. G.; Epstein, J. B.; Harris, L. B. Conodont Color Alteration - An Index to Organic Metamorphism. U.S. Geological Service, Prof. Paper 995, 27 p., 1977.

4. Niagara Mohawk Power Corporation, Final Safety Analysis Report, Vol. III, FSAR Reference 2.5-94, 1982.

5. Tillman, J. E. and Barnes, H. L. Deciphering Fracturing and Fluid Migration Histories in Northern Appalachian Basin. AAPG Bulletin, Vol. 67, No. 4, April 1983.

GEOLOGY ITEM NO. 2

Stresses Observed in Bedrock in the Region Surrounding the Nine Mile Point Site

The NRC Staff has generally agreed with the applicant that the latest movement on the cooling tower fault is nontectonic in origin and, therefore, noncapable in the meaning of Appendix A to 10CFR100. However, because they believe that this conclusion is not completely demonstrated by field data, they have requested additional information. Specifically, they have requested[(1)] "An evaluation of the significance of the decoupled regional stress regime" (SER Open Item No. 10). Subsequent paragraphs provide a discussion of the regional stress field around Unit 2.

The staff has discussed and summarized their observations regarding the regional stresses around Unit 2 on p. 2-35 to 2-37 in the Draft SER. In this summary, they have expressed several reservations about the orientation and magnitude of the regional stresses that they feel required additional clarification. These reservations include:

1. The omission of in situ stress measurements by overcoring and hydrofracturing at several localities on the north shore of Lake Ontario from the FSAR[(2)] and the apparent exclusion by the applicant of several deeper focal plant solutions in the regional data set and limiting stress and strain data observations to those in the upper 85 ft of the crust.

2. The impact and importance of deep hydrofracturing tests at the Darlington site, some 190 km west-northwest of Unit 2, on the north shore of Lake Ontario. The results of the deep hydrofracturing tests showed a maximum horizontal compressive stress of about 2,200 psi in the Ordovician rocks oriented N70°E and about 2,800 psi in the underlying crystalline Precambrian rocks, oriented N23°E[(2)].

3. A concern regarding the importance of the "decoupled" stress regime (as measured at Darlington) on the potential for vibratory ground motion at Unit 2.

The subsequent paragraphs provide a reiteration of data and discussions contained in the FSAR and FSAR references, as well as a discussion regarding new data available since the submission of the FSAR.

<u>Omission of Data in the FSAR</u>

The applicant presented a thorough discussion and analysis of the regional stress field operative in the region surrounding Unit 2 as of mid-1978 in Volume III of FSAR Reference 2.5-94. Data included in this analysis were all available measurements of both stress and strain indicators, such as deeper stress measurements (up to 1,700 ft) by hydrofracturing; shallower (up to 85 ft) measurements of stress by overcoring; earthquake focal mechanisms; pop-ups; and surface strain measurements.

Item 2 on p. 2-36 of the Draft SER describes the concerns of the NRC Staff regarding the omission off certain classes of in situ stress data from the FSAR. These included:

1. Excluding focal mechanisms from deeper foci earthquakes in the region.

2. Restricting observations of stress and strain data to the upper 23 m (85 ft) of the crust.

The applicant has include deeper focal mechanisms in its analysis. The event questioned by the staff was a swarm of small magnitude earthquakes which occurred near Blue Mountain Lake, New York, between May and November 1971. The authors of the paper(3) considered that the composite focal mechanism for the shallower foci (<2 km) events was more reliable than that of the deeper foci (between 2 and 3.5 km). The applicant did not consider the composite focal mechanism for the deeper swarm any further in its regional analysis. All of these data are reported in Table 2.3 of Volume III of FSAR Reference 2.5-94.

Additionally, it should be mentioned that the applicant has not restricted stress and strain data to the upper 24 m (85 ft) of the earth's crust in its regional analysis. The data reported in Tables 22 and 2.3 of Volume III of FSAR Reference 2.5-94 cover a range of depths for all types of stress and strain indicators from the surface (pop-ups of Quaternary age and surficial strain relief measurements) to over 20 km deep (focal mechanism solutions). Figure 2.5-20 in the FSAR provides additional focal mechanisms through 1982. All of these data show a remarkable consistency in orientation of the maximum horizontal compressive stress operative in the region, which is between N70°E and N80°E.

The data referred to by the staff as having been omitted from the FSAR analysis(2) do not change these observations.

<u>Additional Regional Stress Measurements and Focal Mechanisms</u>

Since the submission of the FSAR in January 1983, additional data have become available with which to compare earlier data. These are the October 7, 1983, Goodnow, NY earthquake and aftershocks (m_b = 5.2) and the results of deep (1.6 km) hydrofracturing in a test well at Auburn, NY, about 50 km SSE of Unit 2.

The focal mechanism available for the main shock of the Goodnow, NY sequence shows nodal planes striking NW to NNW with a mixed reverse/oblique sense of motion. The NNW striking plane, steeply dipping to the west, best fits the aftershock distribution. The axis of the maximum principal compressive stress is oriented ENE with a gentle plunge, in agreement with the available regional data.[4]

A composite focal mechanism available for a swarm of aftershocks of the Goodnow, NY main shock also strongly supports NW to NNW trending modal planes and a NE to ENE trend to the maximum horizontal stress. The solution also indicates a mixed reverse/oblique sense of faulting.[5]

A series of deep (1.6 km) hydrofracture tests was conducted in a geothermal exploration well in Auburn, NY, some 50 km SSE of the site. The results of the hydrofracturing indicate that:[6]

1. The minimum horizontal principal stress increases in a nearly linear fashion from 99 ± 2 bars at 593 meters depth to 306 ± 2 bars at 1,482 meters depth.

2. The maximum horizontal principal stress increases in a somewhat less regular fashion from 138 ± 10 bars to 490 ± 12 bars over the same depth range.

3. Orientation of hydraulic fractures induced at 593 m and 919 m indicate that the azimuth of the maximum horizontal principal stress is N83°E ± 15°. The total stress regime indicates conditions that would be favorable for strike-slip faulting, if stress levels were high enough.

4. None of the deviatoric stresses measured in this well were of a magnitude sufficient to cause failure along previously existing, favorably oriented fault planes.

The results at the Auburn site confirm what observations have already been made regarding the orientation of the horizontal maximum compressive stress for the region about the site. More important, the low deviatoric stresses observed throughout the 1.6 km deep well completely support the relatively aseismic nature of the region around the site.

<u>Observations Regarding Stress "Decoupling" and High Regional Stresses</u>

One of the staff's concerns regarding the regional stress regime around the Unit 2 site was the report[2] of a possible decoupling of stresses in the Paleozoic rocks from underlying Precambrian rocks as measured at the Darlington Nuclear Power Plant site, some 190 km WNW of Unit 2.

Stresses measured by the hydrofracturing method in a 300 m deep test hole at the Darlington site showed a consistent N70°E orientation of the maximum horizontal stress in Ordovician rocks with an average magnitude value of 2,200 psi. Several tests in the underlying Precambrian rocks showed, however, a counterclockwise rotation of the maximum horizontal stress orientation to about N23°E with an increase in magnitude of stress to about 2,800 psi. This difference in magnitude and orientation of the "principal stresses" has been attributed to a "decoupling" (presumably, a physical discontinuity) between the Ordovician and Precambrian interface. A plausible explanation given, but not elaborated on,[2] is simply that the current stresses measured at the Darlington site in the Precambrian rocks are the composite result of the superpositioned (through time) of two or more separate stress conditions.

Note that this situation is achieved with no restrictions or condition on the interface. It may be (but, more probably, is not) "decoupled." A decoupled condition may or may not exist equally if the stresses have:

1. The same orientation and/or

2. The same magnitude in both the Paleozoic and Precambrian rocks.

To date, there have been no reported observations of stress "decoupling" in the Unit 2 region. Furthermore, there is no reason to believe that decoupling of stresses, if in fact it exists, is necessarily associated with the release of stored strain. All that is required to satisfy the failure criterion is a stress field properly oriented and sufficient deviatoric stresses to overcome the strength of previously existing faults or fractures. This is not the case in the Unit 2 region, attested by the almost complete absence of perceptible seismic activity.

In various parts of the FSAR and principal FSAR references supporting conclusions reached in the FSAR regarding the nature and characteristics of the regional stress field, the applicant has made mention of the presence of "high horizontal rock stresses" in the region. High, in all cases, refers to stresses that exceed those expected from gravitational loading (lithostatic) alone. The stresses measured at the site are not anomalous with respect to stresses measured at similar depths in similar rocks within the region about the Unit 2 site. Essentially, all nearsurface (0 to 1.5 km) stress determinations indicate significant horizontal stresses (of the order of several hundred to several thousand psi). In North America and in other parts of the world, this condition is definitely more usual than a low horizontal stress condition. Thus, the existence of such horizontal stresses near the surface is not anomalous.

<u>References - Stresses Observed in Bedrock</u>

1. U.S. Nuclear Regulatory Commission. Draft Safety Evaluation Report. Section 2.5, Nine Mile Point Unit 2, Final Safety Analysis Report. February 16, 1984.

2. Haimson, B.C. and Lee, C. F. Hydrofracturing Stress Determinations at Darlington, Ontario. Proceedings, 13th Canadian Rock Mechanics Symposium (The H. R. Rice Symposium). Special Volume 22, p. 42-50, 1980.

3. Sbar, M. L.; Armbruster, J.; and Aggarwal, Y. P. The Adirondacks, NY, Earthquake Swarm of 1971 and Tectonic Implications. Bulletin of Seismic Society of America. Volume 62, No. 5, p. 1303-1317, 1972.

4. Lamont-Doherty, in LAMONT. A Close-up View of Intraplate Seismotectonics in the Adirondacks. 2 p, 1984.

5. Woodward-Clyde Consultants. Personal Communication with C. T. Statton, 1984.

6. Hickman, S. H.; Healy, J. H.; and Zoback, M.D. In-Situ Stress, Natural Fracture Distribution and Borehold Elongation at Depth in the Auburn Geothermal Well. Auburn, NY, 1983.

GEOLOGY ITEM NO. 3

The Origin of Diapiric Structures in the Region Surrounding Unit 2

As described on p. 2-54 of Item 3 of the Draft SER, the staff has requested "an assessment of sedimentary structures to determine if they are of seismic origin" (SER Open Item No. 11). The staff regards further evaluation of sedimentary structures observed at the Unit 2 site important bin further confirming the noncapability of the cooling tower fault.

The subsequent paragraphs discuss the observational character of the sediments and deformational structures at Unit 2 in comparison to other similar observations in the general site region. Additionally, the modes of origin of these types of structures, both seismic and aseismic, are presented.

Comparison of Overburden Sediments and Deformational Structures at Unit 2 to Similar Observations in the Region

As discussed in detail in Section 2.5.1.2.2 and in Section 4.5.2 of Volume I, FSAR Reference 2.5-94, the general characters of the overburden sediments where observed onsite consist of (from youngest to oldest):

1. Recent organic soil.

2. Massive, medium-gray silty sand.

3. Thin-bedded, rippled and cross-bedded silty fine sand of the Sandy Creek stage.

4. Lake Iroquois laminated, clayey silt.

5. Gray mottled proglacial lake fill grading downward to glacial till.

The diapiric or "flame" structures depicted on Figure 2.5-32 are found primarily within the massive or thinly bedded silty fine sands of the Sandy Creek stage sediments (deposited on top of the Lake Iroquois lake sediments). These sediments are shallow water deposits of thin bedded silt, fine to medium sand and clay. Bedding varies from planar to wavy rippled to ripple drift cross laminated.

The ripple drift cross laminations include totally preserved climbing ripples, which is indicative of rapid deposition from suspension and is attributed to turbidities, point bar deposits, and fluvial flood deposits (Vol. II, FSAR Reference 2.5-94). These sediments grade finer upward into a massive silty fine sand

and silt deposit, representing a fining upwards sequence during the Sandy Creek Stillstand.

The diapirs, or "flame" structures, occur very close to and below the gradational contact between the more permeable cross bedded and rippled fine sands and the upper, massive silts and silty fine sands. This gradational contact is seen as representing a permeability gradient within the sediments the permeability of the lower, fine silty sands being greater than the over lying massive silts and silty fine sands. Photographs taken of these diapirs during trenching of excavations at Unit 2 show the contacts between the fine sands intruded into the over lying silts are wispy and not well defined. This would indicate a very fluid type of flow under completely saturated conditions. It should be noted, however, that none of these structures is truncated or shows signs of significant erosion, indicating that the deformation did not take place at the water/sediment interface but rather at some depth where confining pressure and sediment permeability or viscosity gradients may have had more influence in forming the diapirs.

The deformational structures reported on by Hempton and Dewey (1983, Figures 1 and 2), although similar in form and appearance to those seen at Unit 2, have much sharper contacts between the sands intruded into finer grained silts and clays, which may be indicative of a greater vertical velocity of escape of the fluidized sediments. Additionally, they are much larger and many of the "flame" structures appear to be truncated, indicating that they were at or close to the surface when they were formed.

Observations of Similar Structures in the Region

A very well documented and thorough reconnaissance of deformed Quaternary sediments within the St. Lawrence lowlands in New York and parts of adjoining Canada was carried out in 1975 by an interdisciplinary team of geoscientists (Coates, 1975). The purpose of their reconnaissance was to "identify Quaternary sediments that meet the criteria for earthquake induced structures and to evaluate the applicability to the St. Lawrence lowland of studying the deformed features as a means of better defining earthquake recurrence rates" (Coates, 1975).

Their findings were that the St. Lawrence lowland contains a vast array of soft sediment deformation from folding and faulting, to diapirs, decollement structures, and fluidization features. A great majority of sedimentary structures they observed could be attributed to causes related to glaciation and deglaciation. However, after establishing certain minimum criteria that excluded causes by glaciation, they found that certain localities contained Quaternary deformation structures with the greatest promise of being related to seismic events (Coates, 1975; Figure 1). These areas were:

Alexandria Bay - This area was found to contain the maximum number of deformed structures observed at any locality visited in the St. Lawrence lowland. Because of the magnitude of deformation and its widespread continuity, diapirism of many units, thixotropy and form similarities with structures observed in seismically active areas (such as California), a reasonable hypothesis for their development must include triggering by vibratory ground motion.

Malone - Constable Area - Delta-type sediments and lake clays (lower most) are present in a road cut near Malone. Deformation structures observed were:

1. Widespread thixotropy of clay beds.
2. Diapirism.
3. Vertically directed deformation.

Canton Area - Coates (1975) feels that deformation structures observed in this area have the greatest possibility of having been induced by vibratory ground motion. The deformation is widespread and continuous through distances of several hundred feet in individual strata. The most convincing evidence was:

1. Truncation of diapirs, indicating that sediments were at the surface when deformed.
2. Widespread, vertically induced thixotropic structures.
3. Widespread continuity of deformation.

Colwell Gravel Pit, Watertown, NY - This pit contains deltaic deposits about 50 ft thick, with abundant cross bedded, ripple drift sand sequences and siltier units occurring below. Deformation structures observed were:

1. Truncated diapirs.
2. Thixotropic deformation structures.
3. Widespread, continuous deformation.

It is noted that because of the rapid deposition of the coarser grained topset beds, the lower finer-grained silts may not have reached sedimentary stability. The weight could have been sufficient to include the thixotropic structures. An earthquake related source for a casual mechanism could not be ruled out, however.

Modes of Origin of Diapiric Structures

Obviously, one of the potential causes of diapiric or "flame" structures being discussed here has to include a triggering mechanism caused by vibratory ground motion. Much discussed in the literature, liquefaction potential generally involves several characteristic criteria:

1. Grain size and sorting.

2. Void ratio.

3. Initial confining pressure.

4. Intensity and duration of ground shaking (Seed and Idriss, 1971).

Studies of the liquefaction process generally have been conducted on homogeneous, undrained noncohesive sediments. As Karcz and Enos (in Coates, 1975) have pointed out, problems that can develop on trying to attribute the origin of these diapiric structures to seismic shaking are:

1. How and at what rate pore pressures are dissipated in stratified systems.

2. How stratified systems of varying lithology and properties (i.e., porosity and permeability) behave or respond to pore pressure accumulation and dissipation at different rates.

Karcz and Enos (in Coates, 1975) further point out that in natural stratified systems, soft sediment deformation depends mainly on the stability of the sediment as well as the nature, magnitude, and rate of the deforming stress. The less stable a sediment is, the less energy is required to induce deformation. Fine grained sediments (i.e., silts), can gradually build up strain internally during deposition, and thus get to a critical metastable state if internal drainage is retarded during deposition. It is evident that any disturbing event need not be large at all to trigger soft sediment deformation. Such disturbing events can be a small, local earthquake or as innocuous as a pore pressure differential (water escape mechanism). Gillespie (1977) states that "seismicity, as a unique cause of deformation, can only be established if all other initiating causes can be eliminated."

Aseismic causes of soft deformation can be attributed to several different classes of physicochemical processes, including:

1. Settling and flow shear.

2. Inverse density stratification.

3. Consolidation and fluidization.

Settling - when a suspension of fine grained particles begins to settle out, the decline in settling velocity is caused by the upward moving fluid being displaced by the settling particles. As the sediment enters into a compression stage upon settling out, small scale convection (caused by the actual compression of consolidation or more complex physicochemical processes such as dilatancy or thixotropy) can occur, creating miniature diapirs or "mud volcanoes."

Flow - Many investigators have considered the effects of flow drag on deformation of soft sediments. Some attribute the deformation to the pressure difference between ripple crest and trough, leading to an upward suction on the crest (Keunen, 1968a, 1968b). Others suggest that fluid and sediment drag exerts sufficient shear to induce deformation.

Inverse Density Stratification - This process may occur through a number of ways, either through differences in lithology or differences in porosity and permeability. When a denser material overlies a less dense material, instability results. Once a certain threshold is exceeded, be it excess pore pressure, compact ion, etc., deformation begins. The final geometry depends on sediment properties and the continuity of the horizon. Figure 2-8 in Coates (1975) shows a remarkable similarity to the diapirs seen at Unit 2.

Consolidation and Fluidization - These processes can create deformation structures in soft sediments through the normal process of sediment dewatering during compaction. In certain fine grained sediments, rapid compaction (and liquefaction) will create an instability in the sediments when rapidly expelled fluids reach a critical velocity sufficient to start fluidization. Deformation structures such as diapirs, flow folds, etc., can result if the process is operative over a long enough time.

Comparisons of Unit 2 Diapiric Structures to Earthquake Induced Soft Sediment Deformation Criteria of Coates (1975)

As has been discussed in the previous pages, most of the deformational structures in soft sediments in the St. Lawrence lowlands can be explained as to their mode of origin by a variety of external causes, both seismic and aseismic. Coates (1975) most succinctly put it "the law of equifinality must be borne in mind at all times. . .that structures that visually appear to be almost identical may have been formed by different processes."

The diapiric and fluidization structures observed in Quaternary sediments in excavations made for the cooling tower fault investigation appear to be confined to the vicinity of the fault.

This is an apparent, not a casual association, because the sediments are only preserved in those portions of the site. The structures observed in the overburden sediments at the Unit 2 site may have been caused by vibratory ground motion; however, aseismic causes could have been equally (perhaps more plausibly) responsible for their information. Glacial processes or mechanism such as ice push or thrust, static loading and compacting, collapse by ice melt out, collapse near free standing ice margins or frozen ground phenomena could all have an integral part in the deformations observed at Unit 2.

As discussed in Volume I, Section 8.0 of FSAR Reference 2.5-94, the diapiric structures observed in Quaternary sediments at Unit 2 are believed to have formed due to abnormal pore pressure differentials existing in the bedrock and sediments after the rapid dewatering of Lake Iroquois to the Admiralty stage. The field evidence obtained during the investigation of the cooling tower fault does point to this as a plausible explanation, especially when viewed in light of Coates (1975) criteria of association of sedimentary structures to seismic disturbances in the St. Lawrence lowlands. A comparison of field observations at Unit 2 to the general criteria are: (Note: the underlined portions of the numbered items below are the general criteria established in Coates (1975) as being indicative of earthquake induced sediment deformation; the statements following each underlined criteria are field observations from Unit 2.).

1. <u>Diapirs, especially when truncated</u> - Diapirs occur in Sandy Creek stage sediments at a gradational contact between overlying massive silts and silty sands and underlying silty fine sands. They are not truncated, nor are they laterally continuous over large distances. They only occur at one horizont.

2. <u>Horizontal continuity of deformed units</u> - The deformed horizon is not continuous over large distances. Diapirs appear to be concentrated in the area near the cooling tower fault but do occur elsewhere in the sediments away from the fault.

3. <u>Presence of thixotropic features</u> - There are no observed thixotropic structures in association with the diapirs at the Unit 2 site. The deformation in the Sandy Creek stage sediments is confined to one horizon only.

4. <u>Vertically-directed distortion</u> - The nature of the diapirs or "flame" structures seen at Unit 2 give the indication that distortion was directed vertically.

5. <u>Absence of glacial processes</u> - The ice margin was far removed from the site when the Sandy Creek sediments were laid down.

6. <u>Character of overburden</u> - The massive silts and silty fine sands directly overlying the cross-laminated, rippled fine sands of Sandy Creek stage are thought to have provided both a viscosity and permeability gradient instability during or immediately following deposition.

If one were to look at the criteria established by Coates (1975) as being absolute, then the diapiric structures observed in Sandy Creek stage sediments at Unit 2 would most likely be associated with other external initiators than from vibratory ground motion as a triggering mechanism.

Gillespie (1977), one of Coates' students at S.U.N.Y. Binghamton, examined in detail two of the areas singled out by Coates' (1975) St. Lawrence report as having soft sediment deformation most likely originating from seismic activity in the St. Lawrence region. He studied both the Canton, NY Landfill and the Newberry Sand and Gravel Pits at Alexandria Bay, NY. These locations are about 91 and 58 miles distant from Unit 2, respectively. The Canton site has sediments of roughly correlative age to Unit 2 and a similar deltaic nature of depositional environment. The conclusions reached by Gillespie for this site (Canton) were that deformation structures (see Figures 33 and 34 in Gillespie, 1977) are most intense along the edges of distribuatory channels and areas of rapid point bar growth and primarily caused by water escape (as deduced at Unit 2). His most important conclusions, however, were:

1. That lateral continuity of deformation cannot be considered as an indicator of seismic triggering of deformation (one of Coates', 1975, criteria) as lack of deformation in one area might mean that the sediments there were not in an unstable state.

2. Seismicity, as a unique cause of soft sediment deformation, can only be established if all other external initiating causes can be eliminated.

In summary, the current state of the art does not allow us to readily differentiate between various external triggering mechanisms of soft sediment deformation in the region surrounding Unit 2, including seismic events. It is considered that the cooling tower fault, because of:

1. Its nature of development as a buckle of limited vertical extent.

2. Nonassociation with a basement-related tectonic structure.

3. Limited lateral extent was not responsible for the development of the diapiric structures as seen at the site.

While the diapiric structures observed at the site were of interest in unraveling the history of development of the sediments at the site, their significance to the likelihood of vibratory ground motion originating from the cooling tower fault is essentially meaningless.

GEOLOGY ITEM NO. 4

Cooling Tower Fault and Monitoring

The staff has recommended a monitoring program (No. 4, p. 2-54 of the Draft SER) of the cooling tower fault designed to ascertain the strain or displacement rate on the fault (SER Open Item No. 12).

The NRC Staff has agreed that the cooling tower fault is most likely nontectonic and, therefore, noncapable (Draft SER, p. 2-40). However, they continue to have several concerns relating to the interpretation and conclusion about the cooling tower and related faults. These concerns are as follows:

1. Neither the length nor the depth of the cooling tower fault has been completely explored or determined.

2. The mechanism postulated for reverse slip displacement, that of buckling, is not fully supported by field evidence.

3. The possibility that small, intrastratal diapiric structures in fine grained sediments overlying the cooling tower fault may have been formed as a direct result of vibratory ground motion.

These concerns have led the staff to recommend an extended period of monitoring the displacement on the cooling tower fault during plant licensing and operation.

Subsequent paragraphs provide a discussion and summary of available evidence regarding the latest history of movement on the cooling tower fault and the chronologic development of trench exposures of this structure. Discussions regarding the diapiric structures are found in the response to SER Open Item No. 11 and will not be repeated here.

Chronological Excavation and Investigation of the Cooling Tower Fault

In late September 1976, a nearly vertical apparent strike-slip fault trending about N70°W was discovered in the west wall of the cooling tower piping trench during bedrock surveillance mapping (routine examination of all bedrock exposures after excavation).

Pit was excavated approximately 50 ft west of the exposure of the cooling tower fault in the cooling tower piping trench between October 15 and 21, 1976. This was the first of the six manmade exposures designed to define the lateral extent of the cooling tower fault. Pit 1 was approximately 45 ft in diameter and exposed the cooling tower fault in the bedrock, with an observed orientation of about N77°W, some 7° variance to the exposure in the cooling tower piping trench (Fig. 2.5-28A).

Between October 21 and October 28, 1976, a 470-ft long, north-south oriented trench was excavated through the overburden to bedrock about 1,750 ft west of the cooling tower piping trench and was referred to as Trench 1. This trench, along with Pit 1, was observed by NRC Staff geologists during their site visit on November 4, 1976. The cooling tower fault was not observed in the Trench 1 exposure (see p. 1-4, FSAR Reference 2.5-94, Volume I). Trench 1 was excavated in such a fashion that the slight variation in orientation of the cooling tower fault between the cooling tower piping trench and Pit 1 could be accommodated in the length of Trench 1 so that the cooling tower fault would be observed if it were present (Fig. 2.5-28A).

Beginning about November 9, 1976, Trench 2 (Fig. 2.5-28A) as excavated about 700 ft west of and along the projected trend of the cooling tower fault as observed in the cooling tower piping trench. Again, the cooling tower fault was not observed either in the exposed bedrock or the over lying glacial sediments (see p. 1-4, FSAR Reference 2.5-94, Volume I).

In late November 1976, Trenches 3 and 4, located 5,200 ft and 1,300 ft farther southeast of the cooling tower piping trench, respectively, were excavated through the overburden to bedrock and both exposed the cooling tower fault. As seen in Fig. 2.5-28A, Trench 3 began to the south of the projected trend of the cooling tower fault and was excavated to the north until the fault was observed. Conversely, Trench 4 was begun to the north of the projected trend of the cooling tower fault and excavated in a southerly direction until the fault was exposed. In this manner, any minor change in orientation of the cooling tower fault, either in a northerly or southerly direction, would still have allowed the fault to have been observed.

Lastly, Trench 5 was excavated in January 1977, about 900 ft farther southeast of Trench 4, and also exposed the cooling tower fault.

<u>Development of the Buckle Associated with the Cooling Tower Fault</u>

The field evidence gathered in the various trenches and from drill holes that penetrated the cooling tower fault at the Unit 2 site all suggests that the youngest deformation at the site is the buckle that has produced reverse slip deformation on the cooling tower fault.

The evidence supporting buckling rather than reverse faulting in brittle rocks is overwhelming. This can be summarized as follows:

1. The latest high angle reverse slip movement is accompanied by displacement which increases upward (see Plates 5-4, 5-5, 5-6, and 5-7 of Vol. I, FSAR Ref. 2.5-94); if the displacements had been initiated in the underlying Precambrian rocks, they would have been, either constant or increasing downward.

2. The observed displacements have not resulted from frictional sliding on the structure.

Typical reverse faulting would have produced a relatively small amount of bedding plane dilation as compared to the accumulated displacement. What is observed is that dilation is 6 ft greater on the hanging wall than the same stratigraphic horizon on the footwall.

Additionally, displacement of strata on one side of the structure in relation to the corresponding stratigraphic horizon on the opposite site of the fault would not significantly decrease away from the structure. What is observed is that displacement progressively decreases and becomes smaller with depth between two points (see Plates 5-7 and 5-8 of Vol. I, FSAR Reference 2.5-94). This phenomenon occurs almost entirely within strata on the hanging wall.

Moreover, if the observed displacements were the result of reverse faulting, there would be, most likely, a continuous and relatively large shear displacement at the present bedrock surface. This is not observed, which indicates that the observed dilation in the hanging wall rocks is not a residuum of a larger and older reverse slip displacement eroded away to the present bedrock surface.

While the staff has considered all of the structures in the vicinity of the site (i.e., the cooling tower fault, the drainage ditch structure, and the barge slip fault) together as to their origin and significance, there is a distinct difference between the cooling tower fault and drainage ditch structure as compared with the barge slip fault in how they responded to the regional stress regime extant during glaciation. The orientation of the cooling tower and drainage ditch faults (700 dip to the north) to the stresses operative during glaciation and deglaciation in the site area provided shear stress resistance (not related to cohesion on the fault), thus allowing the development of buckling instability. The barge slip fault, because it was dipping to the south, was not in a favorable orientation to the regional stress regime, which is why buckling did not develop on this structure.

Although it was concluded that future small movements within the buckled zone of the cooling tower fault may occur (Section 8.6, Vol. I of FSAR Reference 2.5-94), the movements, if they occur, will involve only slow strain rates and only limited volumes of the rock mass (certainly not a rate or volume of rock that would sustain a seismic event). The cooling tower and all other structures onsite are sufficiently far removed from the cooling tower fault what would preclude any impact as the result of these small movements should they occur.

Additionally, the buckle developed on the cooling tower fault is not capable of generating movements sufficient to cause vibratory ground motion. Therefore, any program designed to monitor small adjustments in the rock mass and even if they were measured, would only be confirming what is potentially expected; it would not provide any evidence for, nor alter our conclusions regarding, the noncapability of the cooling tower fault.

Lastly, the cooling tower fault is not associated with basement related tectonic structure. Even if it were, the likelihood of the structure (because of its size and orientation to the stress regime extant in the eastern U.S.) being the locus of seismic energy release would be extremely small.

References - Cooling Tower Fault and Monitoring

U.S. Nuclear Regulatory Commission; Draft Safety Evaluation Report, Section 2.5, Nine Mile Point Unit 2, Final Safety Analysis Report, February 16, 1984.

Niagara Mohawk Power Corp., Final Safety Analysis Report, Vol. III, 1982, FSAR Reference 2.5-94.

Tillman, J. E. and Barnes, H. L. Deciphering Fracturing and Fluid Migration Histories in Northern Appalachian Basin, AAPG Bulletin, Vol. 67, No. 4, April 1983.

TABLE GI-1

GEOLOGIC DATA SHEETS

County*	Latitude/Longitude	System (Series)	Stratigraphic Unit	CAI
Montgomery	42°54′/74°36′	Ordovician (M)	Shoreham Formation	2.5-3
Niagara	42°55′/78°55′	Silurian (L)	Reynales Limestone	1.5
Oneida	43°16′15″/73°09′45″	Ordovician (M)	Trenton Group	3
Onondaga	42°57′30″/76°26′30″	Devonian (M)	Tully Limestone	2
Onondaga	42°50′48″/75°54′55″	Devonian (M)	Ludlowville Formation	2.5-3
Onondaga	42°55′04″/76°14′39″	Devonian (M)	Ludlowville Formation	2.5
Ontario	42°54′10″/77°22′10″	Devonian (M)	Ludlowville Formation	2
Ontario	42°45′/77°21′	Devonian (U)	Genesee Formation	2
Ontario	42°48′/77°30′	Devonian (U)	Genesee Formation	2
Ontario	42°49′/77°23′	Devonian (U)	Genesee Formation	2
Orange	41°16′04″/74°22′20″	Ordovician (L)	Halcyon Lake Calc-dolostone	5
Orange	41°15′07″/74°26′12″	Ordovician (M)	Balmville Limestone	5
Orange	41°28′08″/74°15′38″	Ordovician (M)	Balmville Limestone	5
Orange	41°29′36″/74°02′12″	Ordovician (M)	Balmville Limestone	4.5
Orange	41°30′/74°02′	Ordovician (M)	Balmville Limestone	4
Orange	41°27′/74°06′	Devonian (L)	Coeymans Formation	4.5
Orange	41°21′49″/74°39′53″	Devonian (L)	Kalkberg Formation	4.5-5
Otsego	42°48′/74°43′	Devonian (M)	Onondaga Formation	3
Rensselaer	42°49′47″/73°36′55″	Ordovician (L)	Deepkill Shale	4-4.5
Albany	42°28′20″/73°55′10″	Devonian (L)	Coeymans Formation	4
Albany	42°39′/74°01′	Devonian (L)	Coeymans Formation	4
Albany	42°39′/73°54′	Devonian (M)	Onondaga Formation	4

ABLE GI-1 (Cont'd.)

County*	Latitude/Longitude	System (Series)	Stratigraphic Unit	CAI
Cattaraugus	42°00'/78°30'	Devonian (U)	Oswayo Formation	1
Cattaraugus	42°13'/78°57'	Silurian (H/U)		2
Cayuga	42°49'/76°44'	Silurian (U)	Cobbleskill Limestone	2
Cayuga	42°43'39"/76°41'17"	Devonian (M)	Ludlowville Formation	2-2.5
Cayuga	42°47'37"/76°30'20"	Devonian (M)	Ludlowville Formation	2-2.5
Cayuga	42°48'24"/76°17'22"	Devonian (M)	Ludlowville Formation	2.5
Clinton	44°48'34"/73°26'46"	Ordovician (L)	Providence Island Dolostone	4
Clinton	44°47'47"/73°29'33"	Ordovician (L)	Spellman Formation	4-4.5
Clinton	44°50'54"/73°25'29"	Ordovician (M)	Day Point Limestone	4
Clinton	44°53'20"/73°26'15"	Ordovician (M)	Day Point Limestone	4
Clinton	44°47'/73°26'	Ordovician (M)	Glens Falls Limestone	4.5
Columbia	42°16'28"/73°43'14"	U.C/L.Ord.	Stuyvesant Falls Formation	3-3.5
Columbia	42°17'/73°31'	Ordovician (L)	Stockbridge Group	5
Columbia	42°22'48"/73°26'36"	Ordovician (L)	Stockbridge Group	5-5.5
Columbia	42°06'30"/73°32'30"	Ordovician (L)	Copake Limestone	4.5-5
Columbia	42°06'29"/73°32'26"	Ordovician (M)	Balmville Limestone	5-5.5

* In New York State.