INSERTION INSTRUCTIONS FOR AMENDMENT 5

Remove old pages and insert Amendment 5 pages as instructed below (amendment pages bear the amendment number and date at the foot of the page).

Vertical bars (change bars) have been placed in the outside margins of revised text pages and tables to show the location of any technical changes originating with this amendment. Some pages bear a new amendment designation, but no change bars, because revisions on other pages in that section caused a text shift. A few unrevised pages have been reprinted because they fall within a run of closely spaced revised pages. No change bars are used on figures or on new sections, appendices, questions and responses, etc. Change bars from previous amendments have been deleted on pages revised by this amendment.

Transmittal letters along with these insertion instructions should either be filed or entered in Volume I of Part I, in front of any existing letters, instructions, distribution lists, etc.

LEGEND

Remove/Insert Columns

Entries beginning with "T" or "F" designate table or figure numbers, respectively. All other entries are page numbers:

T2.3-14 = Table 2.3-14 FG5-3 = Figure G5-3

2.1-9 = Page 2.1-9 EP2-1 = Page EP2-1 vii = Page vii

Pages printed back to back are indicated by a "/":

1.2-5/6 = Page 1.2-5 backed by Page 1.2-6

T2.3-14(5 of 5)/15(1 of 3) = Table 2.3-14, sheet 5 of 5, backed by Table 2.3-15, sheet 1 of 3

Location Column

Ch = Chapter, V = Volume, S = Section, Ap = Appendix

Remove	Insert	Location
	PART I, VOLUME 1	
None	MEP-1	before Ch1 tab
EP2-1 thru -11	EP2-1 thru -10	after Ch2 tab
T2.1-3(1 of 1)/blank	T2.1-3(1 of 1)/blank	after T2.1-2 (1 of 1)
T2.1-4(1 of 1)/blank	T2.1-4(1 of 1)/blank	
T2.1-5(1 of 1)/blank	T2.1-5(1 of 1)/blank	
T2.1-6(1 of 1)/blank	T2.1-6(1 of 1)/blank	
T2.1-7(1 of 1)/blank	T2.1-7(1 of 1)/blank	
T2.1-8(1 of 1)/blank	T2.1-8(1 of 1)/blank	
T2.1-9(1 of 1)/blank	T2.1-9(1 of 1)/blank	
	PART I, VOLUME 4	
2.5-i thru - x	2.5-i thru -x	after 2.5 tab

2034 261

7908310508

Remove	Insert	Location
2.5-1 thru -158	2.5-1 thru -174	
None	T2.5-14/blank	after T2.5-13 (1 of 1)
	PART I, VOLUME 5	
F2.5-9	F2.5-9	after F2.5-8
F2.5-16	F2.5-16	after F2.5-15
F2.5-17	F2.5-17	
F2.5-42	F2.5-42	after F2.5-41
F2.5-45	F2.5-45	after F2.5-44
F2.5-46	F2.5-46	
None	F2.5-70	after F2.5-69
	F2.5-71	
EP3-1/-2	EP3-1/-2	after Ch 3 tab
3-i thru -vii	3-i thru -vii	
	PART I, VOLUME 6	
3.6-7/-8	3.6-7/-8	after 3.6-6
T3.6-1(1 of 2)/-1(2 of 2)	T3.6-1(1 of 2)/-1(2 of 2)	after 3.6-9
T3.6-3(1 of 2)/-3(2 of 2)	T3.6-3(1 of 2)/-3(2 of 2)	
T3.6-4(1 of 1)/-5(1 of 1)	T3.6-4(1 of 1)/-5(1 of 1)	
EP4-1/-2	EP4-1/-2	after Ch4 tab
T4.1-15(1 of 1)/-16(1 of 1)	T4.1-15(1 of 1)/-16(1 of 1)	after T4.1-14 (3 of 3)
F4.1-13	F4.1-13	after F4.1-12
	PART I, VOLUME 8	
EP10-1	EP10-1	after Ch10 tab
10.2-1/-2	10.2-1/-2	after 10.2 tab
	PART I, VOLUME 13	
EP2.5I-1/-2	EP2.5I-1/-2	after 2.5I tab
2.5I-17/-18	2.5I-17/-18	
2.5I-31/-32	2.5I-31/-32	
2.5I-39/-40	2.5I-39/-40	
2.5I-45/-46	2.5I-45/-46	

2034 262

MASTER LIST OF EFFECTIVE PAGES
(Amendment 5, August 1979)

Chapter (and Pages)	Amendment Number
1 (2)	2
2 (11)	5
3 (2)	5
4 (4)	5
5 (2)	4
6 (2)	3
7 (1)	3
8 (1)	4
9 (1)	0
10 (1)	5
11 (1)	1
12 (1)	0
13 (1)	0
App 1.1A (1)	0
App 2.2A (2)	0
App 2.2B (1)	0
App 2.2C (1)	0
App 2.2D (1)	0
App 2.2E (1)	0
App 2.2F (1)	0
App 2.2G (1)	0
App 2.3A (1)	0
App 2.3B (1)	0
App 2.3C (1)	0
App 2.3D (1)	1
App 2.4A (1)	0
App 2.5A (1)	0
App 2.5B (1)	0
App 2.5C (4)	1
App 2.5D (1)	0
App 2.5E (1)	0
App 2.5F (1)	0
App 2.5G (1)	0
App 2.5H (1)	5
App 2.5I (1)	2
App 2.5J (1)	0
App 2.5K (1)	0
App 2.5L (1)	0
App 2.5M (1)	1
App 2.7A (1)	0
App 2.7B (1)	0
App 2.7C (1)	0
App 2.7D (1)	0
App 2.7E (1)	0
App 2.7F (1)	0
App 3.5A (1)	0
App 3.5B (1)	3
App 4.2A (1)	0
App 5.2A (1)	3
App 5.3A (1)	3
App 6.1A (1)	1

2034 243

LIST OF EFFECTIVE PAGES
(Amendment 5, August 1979)

Page, Table (T), or Figure (F)	Amendment Number
2.1-i thru 2.1-ii	1
2.1-iii thru 2.1-v	4
2.1-vii/-viii	3
2.1-1	0
2.1-2 thru 2.1-4a	4
2.1-5 thru 2.1-6	0
2.1-7 thru 2.1-14a	2
2.1-15 thru 2.1-16	0
2.1-17 thru 2.1-18a	4
2.1-19 thru 2.1-23	0
2.1-24 thru 2.1-24a	4
2.1-25 thru 2.1-27	0
2.1-28 thru 2.1-29	1
2.1-30 thru 2.1-31	3
2.1-32 thru 2.1-36	4
T2.1-1(1 of 1)	0
T2.1-2(1 of 1)	4
T2.1-3(1 of 1)	5
T2.1-4(1 of 1)	5
T2.1-5(1 of 1)	5
T2.1-6(1 of 1)	5
T2.1-7(1 of 1)	5
T2.1-8(1 of 1)	5
T2.1-9(1 of 1)	5
T2.1-10(1 of 1)	0
T2.1-11(1 of 1)	4
T2.1-12(1 of 1)	0
T2.1-13(1 of 1)	0
T2.1-14(1 of 1)	0
T2.1-15(1 of 1)	0
T2.1-16(1 of 1)	0
T2.1-17(1 of 1)	0
T2.1-18(1 of 1)	0
T2.1-19(1 of 1)	0
T2.1-20(1 of 3 thru 3 of 3)	0
T2.1-21(1 of 1)	2
T2.1-22(1 of 1)	0
T2.1-23(1 of 2 thru 2 of 2)	1
T2.1-23A(1 of 1)	1
T2.1-24(1 of 2 thru 2 of 2)	0
T2.1-24A(1 of 2 thru 2 of 2)	1
T2.1-25(1 of 1)	0
T2.1-26(1 of 9 thru 9 of 9)	0
T2.1-27(1 of 2 thru 2 of 2)	0
T.2.1-27A(1 of 2 thru 2 of 2)	2
T2.1-28(1 of 2 thru 2 of 2)	0
T2.1-29(1 of 1)	0
T2.1-30(1 of 1)	0
2.1-32 thru 2.1-36	4
T2.1-31(1 of 4 thru 4 of 4)	0
T2.1-32(1 of 3 thru 3 of 3)	0
T2.1-33(1 of 1)	0
T2.1-34(1 of 1)	1
T2.1-35(1 of 1)	1
T2.1-36(1 of 1)	0
T2.1-37(1 of 1)	0
T2.1-38(1 of 1)	0
T2.1-39(1 of 1)	0
T2.1-40(1 of 1)	0

2034 264

Page, Table (T), or Figure (F)	Amendment Number
T2.1-41(1 of 2 thru 2 of 2)	0
T2.1-42(1 of 1)	0
T2.1-43(1 of 1)	0
T2.1-44(1 of 1)	1
T2.1-45(1 of 2 thru 2 of 2)	0
T2.1-46(1 of 16 thru 5 of 16)	0
T2.1-46(6 of 16 thru 16 of 16)	1
T2.1-47(1 of 1)	3
T2.1-48(1 of 1)	3
F2.1-1 thru 2.1-6	0
F2.1-6A	1
F2.1-7 thru 2.1-9	0
F2.1-9A	2
F2.1-16	1
F2.1-17 thru 2.1-18	0
F2.1-19 thru 2.1-26	3
2.2-i thru 2.2-iii	1
2.2-iv	2
2.2-v thru 2.2-xxix	1
2.2-1 thru 2.2-15	0
2.2-16	3
2.2-17 thru 2.2-36	0
2.2-37 thru 2.2-38	1
2.2-39 thru 2.2-84	0
2.2-85 thru 2.2-86a	1
2.2-87 thru 2.2-99	0
2.2-100 thru 2.2-100a	1
2.2-101 thru 2.2-111	0
2.2-112 thru 2.2-112a	1
2.2-113 thru 2.2-132	0
2.2-133 thru 2.2-134b	1
2.2-135 thru 2.2-150	0
2.2-151 thru 2.2-152b	1
2.2-153 thru 2.2-162	0
2.2-163 thru 2.2-164a	3
2.2-165 thru 2.2-180	0
2.2-181 thru 2.2-188	1
2.2-189	1
2.2-190 thru 2.2-190a	3
2.2-191 thru 2.2-192	1
2.2-193	0
2.2-194 thru 2.2-198	1
2.2-199 thru 2.2-200	0
2.2-201 thru 2.2-208a	1
2.2-209 thru 2.2-219	0
2.2-220 thru 2.2-220a	1
2.2-221 thru 2.2-223	0
2.2-224 thru 2.2-224a	1
2.2-225 thru 2.2-232	0
2.2-233 thru 2.2-234a	1
2.2-235 thru 2.2-236	0
2.2-237 thru 2.2-238	3
2.2-239 thru 2.2-242	0
T2.2-1(1 of 2 thru 2 of 2)	0
T2.2-2(1 of 5 thru 5 of 5)	0
T2.2-3(1 of 1)	0
T2.2-4(1 of 1)	0
T2.2-5(1 of 1)	0
T2.2-6(1 of 2 thru 2 of 2)	0
T2.2-7(1 of 2 thru 2 of 2)	0
T2.2-8(1 of 1)	0
T2.2-9(1 of 11 thru 11 of 11)	0

2034 245

Page, Table (T), or Figure (F)	Amendment Number
T2.2-10 (1 of 1)	0
T2.2-11 (1 of 1)	0
T2.2-12 (1 of 1)	0
T2.2-13 (1 of 1)	0
T2.2-14 (1 of 1)	0
T2.2-15 (1 of 1)	0
T2.2-16 (1 of 1)	0
T2.2-17 (1 of 1)	0
T2.2-18 (1 of 1)	0
T2.2-19 (1 of 1)	0
T2.2-20 (1 of 1)	0
T2.2-21 (1 of 1)	0
T2.2-22 (1 of 1)	0
T2.2-23 (1 of 1)	0
T2.2-24 (1 of 1)	0
T2.2-25 (1 of 1)	0
T2.2-26 (1 of 1)	0
T2.2-27 (1 of 1)	0
T2.2-28 (1 of 1)	0
T2.2-29 (1 of 1)	0
T2.2-30 (1 of 1)	0
T2.2-31 (1 of 1)	0
T2.2-32 (1 of 1)	0
T2.2-33 (1 of 1)	0
T2.2-34 (1 of 1)	0
T2.2-35 (1 of 1)	0
T2.2-36 (1 of 1)	0
T2.2-37 (1 of 1)	0
T2.2-38 (1 of 1)	0
T2.2-39 (1 of 1)	0
T2.2-40 (1 of 1)	0
T2.2-41 (1 of 1)	0
T2.2-42 (1 of 1)	0
T2.2-43 (1 of 1)	0
T2.2-44 (1 of 1)	0
T2.2-45 (1 of 1)	0
T2.2-46 (1 of 1)	0
T2.2-47 (1 of 1)	0
T2.2-48 (1 of 1)	0
T2.2-49 (1 of 1)	0
T2.2-50 (1 of 1)	0
T2.2-51 (1 of 1)	0
T2.2-52 (1 of 1)	0
T2.2-53 (1 of 1)	0
T2.2-54 (1 of 1)	0
T2.2-55 (1 of 1)	0
T2.2-56 (1 of 1)	0
T2.2-57 (1 of 1)	0
T2.2-58 (1 of 1)	0
T2.2-59 (1 of 1)	0
T2.2-60 (1 of 1)	0
T2.2-61 (1 of 1)	0
T2.2-62 (1 of 1)	0
T2.2-63 (1 of 1)	0
T2.2-64 (1 of 1)	0
T2.2-65 (1 of 1)	0
T2.2-66 (1 of 1)	0
T2.2-67 (1 of 1)	0
T2.2-68 (1 of 1)	0
T2.2-69 (1 of 1)	0
T2.2-70 (1 of 1)	0
T2.2-71 (1 of 1)	0
T2.2-72 (1 of 1)	0

2034 266

Page, Table (T), or Figure (F)	Amendment Number
T2.2-73 (1 of 1)	0
T2.2-74 (1 of 1)	0
T2.2-75 (1 of 1)	0
T2.2-76 (1 of 1)	0
T2.2-77 (1 of 1)	0
T2.2-78 (1 of 1)	0
T2.2-79 (1 of 1)	0
T2.2-80 (1 of 1)	0
T2.2-81 (1 of 1)	0
T2.2-82 (1 of 1)	0
T2.2-83 (1 of 1)	0
T2.2-84 (1 of 1)	0
T2.2-85 (1 of 1)	0
T2.2-86 (1 of 1)	0
T2.2-87 (1 of 1)	0
T2.2-88 (1 of 1)	0
T2.2-89 (1 of 1)	0
T2.2-90 (1 of 1)	0
T2.2-91 (1 of 1)	0
T2.2-92 (1 of 1)	0
T2.2-93 (1 of 1)	0
T2.2-94 (1 of 1)	0
T2.2-95 (1 of 1)	0
T2.2-96 (1 of 1)	0
T2.2-97 (1 of 1)	0
T2.2-98 (1 of 1)	0
T2.2-99 (1 of 1)	0
T2.2-100 (1 of 1)	0
T2.2-101 (1 of 1)	0
T2.2-102 (1 of 1)	0
T2.2-103 (1 of 1)	0
T2.2-104 (1 of 1)	0
T2.2-105 (1 of 1)	0
T2.2-106 (1 of 1)	0
T2.2-107 (1 of 1)	0
T2.2-108 (1 of 1)	0
T2.2-109 (1 of 1)	0
T2.2-110 (1 of 2 thru 2 of 2)	0
T2.2-111 (1 of 2 thru 2 of 2)	0
T2.2-112 (1 of 2 thru 2 of 2)	0
T2.2-113 (1 of 2 thru 2 of 2)	0
T2.2-114 (1 of 10 thru 10 of 10)	0
T2.2-115 (1 of 11 thru 11 of 11)	0
T2.2-116 (1 of 7 thru 7 of 7)	0
T2.2-117 (1 of 9 thru 9 of 9)	0
T2.2-118 (1 of 7 thru 7 of 7)	0
T2.2-119 (1 of 10 thru 10 of 10)	0
T2.2-120 (1 of 1)	0
T2.2-121 (1 of 2 thru 2 of 2)	0
T2.2-122 (1 of 1)	0
T2.2-123 (1 of 10 thru 10 of 10)	0
T2.2-124 (1 of 1)	0
T2.2-125 (1 of 1)	0
T2.2-126 (1 of 1)	0
T2.2-127 (1 of 1)	0
T2.2-128 (1 of 1)	0
T2.2-129 (1 of 1)	0
T2.2-130 (1 of 1)	0
T2.2-131 (1 of 3 thru 3 of 3)	0
T2.2-132 (1 of 1)	0
T2.2-133 (1 of 2 thru 2 of 2)	0
T2.2-134 (1 of 1)	0
T2.2-135 (1 of 3 thru 3 of 3)	0

2034 247

Page, Table (T), or Figure (F)	Amendment Number
T2.2-136 (1 of 1)	0
T2.2-137 (1 of 2 thru 2 of 2)	0
T2.2-138 (1 of 2 thru 2 of 2)	0
T2.2-139 (1 of 3 thru 3 of 3)	0
T2.2-140 (1 of 1)	0
T2.2-141 (1 of 2 thru 2 of 2)	0
T2.2-142 (1 of 1)	0
T2.2-143 (1 of 3 thru 3 of 3)	0
T2.2-144 (1 of 3 thru 3 of 3)	0
T2.2-145 (1 of 2 thru 2 of 2)	0
T2.2-146 (1 of 1)	0
T2.2-147 (1 of 1)	0
T2.2-148 (1 of 1)	0
T2.2-149 (1 of 2 thru 2 of 2)	0
T2.2-150 (1 of 1)	0
T2.2-151 (1 of 2 thru 2 of 2)	0
T2.2-152 (1 of 1)	0
T2.2-153 (1 of 2 thru 2 of 2)	0
T2.2-154 (1 of 1)	0
T2.2-155 (1 of 1)	0
T2.2-156 (1 of 1)	0
T2.2-157 (1 of 1)	0
T2.2-158 (1 of 1)	0
T2.2-159 (1 of 1)	0
T2.2-160 (1 of 1)	0
T2.2-161 (1 of 1)	0
T2.2-162 (1 of 1)	0
T2.2-163 (1 of 1)	0
T2.2-164 (1 of 1)	0
T2.2-165 (1 of 1)	0
T2.2-166 (1 of 1)	0
T2.2-167 (1 of 1)	0
T2.2-168 (1 of 1)	0
T2.2-169 (1 of 1)	0
T2.2-170 (1 of 1)	0
T2.2-171 (1 of 1)	0
T2.2-172 (1 of 1)	0
T2.2-173 (1 of 1)	0
T2.2-174 (1 of 1)	0
T2.2-175 (1 of 1)	0
T2.2-176 (1 of 1)	0
T2.2-177 (1 of 1)	0
T2.2-178 (1 of 1)	0
T2.2-179 (1 of 1)	0
T2.2-180 (1 of 1)	0
T2.2-181 (1 of 1)	0
T2.2-182 (1 of 1)	0
T2.2-183 (1 of 1)	0
T2.2-184 (1 of 1)	0
T2.2-185 (1 of 1)	0
T2.2-186 (1 of 1)	0
T2.2-187 (1 of 1)	0
T2.2-188 (1 of 1)	0
T2.2-189 (1 of 1)	0
T2.2-190 (1 of 1)	0
T2.2-191 (1 of 6 thru 6 of 6)	0
T2.2-192 (1 of 1)	0
T2.2-193 (1 of 1)	0
T2.2-194 (1 of 1)	0
T2.2-195 (1 of 1)	0
T2.2-196 (1 of 1)	0
T2.2-197 (1 of 2 thru 2 of 2)	0
T2.2-198 (1 of 1)	0

2034 248

Page, Table (T), or Figure (F)	Amendment Number
T2.2-199(1 of 1)	0
T2.2-200(1 of 1)	0
T2.2-201(1 of 1)	0
T2.2-202(1 of 1)	0
T2.2-203(1 of 1)	0
T2.2-204(1 of 1)	0
T2.2-205(1 of 2 thru 2 of 2)	0
T2.2-206(1 of 1)	0
T2.2-207(1 of 1)	0
T2.2-208(1 of 1)	0
T2.2-209(1 of 1)	0
T2.2-210(1 of 1)	0
T2.2-211(1 of 1)	0
T2.2-212(1 of 1)	1
T2.2-213(1 of 1)	0
T2.2-214(1 of 2 thru 2 of 2)	0
T2.2-215(1 of 4 thru 4 of 4)	0
T2.2-216(1 of 2 thru 2 of 2)	0
T2.2-217(1 of 3 thru 3 of 3)	0
T2.2-218(1 of 1)	0
T2.2-219(1 of 1)	0
T2.2-220(1 of 1)	0
T2.2-221(1 of 1)	0
T2.2-222(1 of 1)	0
T2.2-223(1 of 2 thru 2 of 2)	0
T2.2-224(1 of 2 thru 2 of 2)	0
T2.2-225(1 of 1)	0
T2.2-226(1 of 1)	0
T2.2-227(1 of 3 thru 3 of 3)	0
T2.2-228(1 of 1)	0
T2.2-229(1 of 1)	0
T2.2-230(1 of 1)	0
T2.2-231(1 of 1)	0
T2.2-232(1 of 1)	3
T2.2-233(1 of 1)	0
T2.2-234(1 of 3 thru 3 of 3)	0
T2.2-235(1 of 1)	0
T2.2-236(1 of 1)	0
T2.2-237(1 of 1)	0
T2.2-238(1 of 1)	0
T2.2-239(1 of 2 thru 2 of 2)	0
T2.2-240(1 of 1)	0
T2.2-241(1 of 1)	0
T2.2-242(1 of 1)	0
T2.2-243(1 of 1)	0
T2.2-244(1 of 1)	0
T2.2-245(1 of 1)	0
T2.2-246(1 of 1)	0
T2.2-247(1 of 1)	0
T2.2-248(1 of 1)	0
T2.2-249(1 of 1)	0
T2.2-250(1 of 1)	0
T2.2-251(1 of 1)	0
T2.2-252(1 of 1)	0
T2.2-253(1 of 1)	0
T2.2-254(1 of 4 thru 4 of 4)	0
T2.2-255(1 of 1)	0
T2.2-256(1 of 1)	0
T2.2-257(1 of 1)	0
T2.2-258(1 of 2 thru 2 of 2)	0
T2.2-259(1 of 3 thru 3 of 3)	0
T2.2-260(1 of 5 thru 5 of 5)	0
T2.2-261(1 of 2 thru 2 of 2)	0

2034 269

Page, Table (T), or Figure (F)	Amendment Number
T2.2-262(1 of 2 thru 2 of 2)	0
T2.2-263(1 of 3 thru 3 of 3)	0
T2.2-264(1 of 1)	0
T2.2-265(1 of 1)	0
T2.2-266(1 of 1)	0
T2.2-267(1 of 1)	0
T2.2-268(1 of 1)	0
T2.2-269(1 of 1)	0
T2.2-270(1 of 1)	0
T2.2-271(1 of 1)	0
T2.2-272(1 of 1)	0
T2.2-273(1 of 2 thru 2 of 2)	0
T2.2-274(1 of 1)	0
T2.2-275(1 of 1)	0
T2.2-276(1 of 1)	0
T2.2-277(1 of 7 thru 7 of 7)	0
T2.2-278(1 of 1)	0
T2.2-279(1 of 3 thru 3 of 3)	0
T2.2-280(1 of 1)	0
T2.2-281(1 of 2 thru 2 of 2)	1
T2.2-282(1 of 1)	0
T2.2-283(1 of 1)	0
T2.2-284(1 of 1)	0
T2.2-285(1 of 1)	0
T2.2-286(1 of 1)	0
F2.2-1	1
F2.2-2 thru 2.2-84	0
F2.2-85	2
F2.2-86 thru 2.2-87	0
F2.2-88	2
F2.2-89 thru 2.2-107	0
2.3-i thru 2.3-xi	1
2.3-xiii	1
2.3-1	0
2.3-2 thru 2.3-2a	1
2.3-3 thru 2.3-14	0
2.3-15	0
2.3-16 thru 2.3-16a	1
2.3-17 thru 2.3-26	0
2.3-27 thru 2.3-28	1
2.3-29 thru 2.3-34	0
T2.3-1(1 of 2 thru 2 of 2)	0
T2.3-2(1 of 1)	0
T2.3-3(1 of 1)	0
T2.3-4(1 of 1)	0
T2.3-5(1 of 1)	0
T2.3-6(1 of 1)	0
T2.3-7(1 of 1)	0
T2.3-8(1 of 1)	0
T2.3-9(1 of 1)	0
T2.3-10(1 of 1)	0
T2.3-11(1 of 1)	0
T2.3-12(1 of 1)	0
T2.3-13(1 of 1)	0
T2.3-14(1 of 1)	0
T2.3-15(1 of 1)	0
T2.3-16(1 of 1)	0
T2.3-17(1 of 1)	0
T2.3-18(1 of 1)	0
T2.3-19(1 of 1)	0
T2.3-20(1 of 1)	0
T2.3-21(1 of 1)	0

2034 270

Page, Table (T), or Figure (F)	Amendment Number
T2.3-22 (1 of 1)	0
T2.3-23 (1 of 1)	0
T2.3-24 (1 of 1)	0
T2.3-25 (1 of 1)	0
T2.3-26 (1 of 1)	0
T2.3-27 (1 of 1)	0
T2.3-28 (1 of 1)	0
T2.3-29 (1 of 1)	0
T2.3-30 (1 of 1)	0
T2.3-31 (1 of 1)	0
T2.3-32 (1 of 1)	0
T2.3-33 (1 of 1)	0
T2.3-34 (1 of 1)	0
T2.3-35 (1 of 1)	0
T2.3-36 (1 of 1)	0
T2.3-37 (1 of 1)	0
T2.3-38 (1 of 1)	0
T2.3-39 (1 of 1)	0
T2.3-40 (1 of 1)	0
T2.3-41 (1 of 1)	0
T2.3-42 (1 of 1)	0
T2.3-43 (1 of 1)	0
T2.3-44 (1 of 1)	0
T2.3-45 (1 of 1)	0
T2.3-46 (1 of 1)	0
T2.3-47 (1 of 1)	0
T2.3-48 (1 of 1)	0
T2.3-49 (1 of 1)	0
T2.3-50 (1 of 1)	0
T2.3-51 (1 of 1)	0
T2.3-52 (1 of 1)	0
T2.3-53 (1 of 1)	0
T2.3-54 (1 of 1)	0
T2.3-55 (1 of 1)	0
T2.3-56 (1 of 1)	0
T2.3-57 (1 of 1)	0
T2.3-58 (1 of 1)	0
T2.3-59 (1 of 1)	0
T2.3-60 (1 of 1)	0
T2.3-61 (1 of 1)	0
T2.3-62 (1 of 1)	0
T2.3-63 (1 of 1)	0
T2.3-64 (1 of 1)	0
T2.3-65 (1 of 1)	0
T2.3-66 (1 of 1)	0
T2.3-67 (1 of 1)	0
T2.3-68 (1 of 1)	0
T2.3-69 (1 of 1)	0
T2.3-70 (1 of 1)	0
T2.3-71 (1 of 1)	0
T2.3-72 (1 of 1)	0
T2.3-73 (1 of 1)	0
T2.3-74 (1 of 1)	0
T2.3-75 (1 of 1)	0
T2.3-76 (1 of 1)	0
T2.3-77 (1 of 1)	0
T2.3-78 (1 of 1)	0
T2.3-79 (1 of 1)	0
T2.3-80 (1 of 1)	0
T2.3-81 (1 of 1)	0
T2.3-82 (1 of 1)	0
T2.3-83 (1 of 1)	0
T2.3-84 (1 of 1)	0

2034 271

Page, Table (T), or Figure (F)	Amendment Number
T2.3-85(1 of 1)	0
T2.3-86(1 of 1)	0
T2.3-87(1 of 1)	0
T2.3-88(1 of 1)	0
T2.3-89(1 of 1)	0
T2.3-90(1 of 7 thru 7 of 7)	0
T2.3-91(1 of 7 thru 7 of 7)	0
T2.3-92(1 of 1)	0
T2.3-93(1 of 7 thru 7 of 7)	0
T2.3-94(1 of 1)	0
T2.3-95(1 of 1)	0
T2.3-96(1 of 1)	0
T2.3-97(1 of 1)	0
T2.3-98(1 of 1)	0
T2.3-99(1 of 1)	0
T2.3-100(1 of 1)	0
T2.3-101(1 of 1)	0
T2.3-102(1 of 1)	0
T2.3-103(1 of 1)	0
T2.3-104(1 of 1)	0
T2.3-105(1 of 1)	0
T2.3-106(1 of 1)	0
T2.3-107(1 of 1)	0
T2.3-108(1 of 1)	0
T2.3-109(1 of 1)	0
T2.3-110(1 of 1)	0
T2.3-111(1 of 1)	0
T2.3-112(1 of 1)	0
T2.3-113(1 of 1)	0
T2.3-114(1 of 1)	0
T2.3-115(1 of 1)	0
T2.3-116(1 of 1)	0
T2.3-117(1 of 1)	0
T2.3-118(1 of 1)	0
T2.3-119(1 of 1)	0
T2.3-120(1 of 1)	0
T2.3-121(1 of 1)	0
T2.3-121A(1 of 1)	1
T2.3-122(1 of 1)	0
T2.3-123(1 of 1)	0
T2.3-124(1 of 1)	0
T2.3-125(1 of 1)	0
T2.3-126(1 of 1)	0
T2.3-127(1 of 1)	0
T2.3-128(1 of 1)	0
T2.3-129(1 of 1)	0
T2.3-130(1 of 1)	0
F2.3-1 thru 2.3-14	0
2.4-i thru 2.4-vii	1
2.4-1 thru 2.4-6	0
2.4-7	1
2.4-8 thru 2.4-30	0
2.4-31	1
2.4-32 thru 2.4-32a	3
2.4-33 thru 2.4-36	1
2.4-36a	3
2.4-37 thru 4-43	0
2.4-44	1
2.4-45 thru 2.4-52	0
T2.4-1(1 of 1)	0
T2.4-2(1 of 1)	0
T2.4-3(1 of 1)	0

2034 272

Page, Table (T), or Figure (F)	Amendment Number
T2.4-4(1 of 1)	0
T2.4-5(1 of 6 thru 6 of 6)	0
T2.4-6(1 of 2 thru 2 of 2)	0
T2.4-7(1 of 8 thru 8 of 8)	0
T2.4-8(1 of 1)	0
T2.4-9(1 of 1)	0
T2.4-10(1 of 1)	0
T2.4-11(1 of 3 thru 3 of 3)	0
T2.4-12(1 of 1)	0
T2.4-13(1 of 1)	0
T2.4-14(1 of 2 thru 2 of 2)	0
T2.4-15(1 of 3 thru 3 of 3)	0
T2.4-16(1 of 2 thru 2 of 2)	0
T2.4-17(1 of 1)	0
T2.4-18(1 of 1)	0
T2.4-19(1 of 1)	0
T2.4-20(1 of 1)	0
T2.4-21(1 of 1)	0
T2.4-22(1 of 4 thru 4 of 4)	0
T2.4-23(1 of 1)	0
T2.4-24(1 of 1)	1
T2.4-25(1 of 1)	1
F2.4-1 thru 2.4-2	0
F2.4-3	1
F2.4-4 thru 2.4-6	0
F2.4-7	3
F2.4-8 thru 2.4-11	0
F2.4-12 thru 2.4-13	3
F2.4-14 thru 2.4-62	0
F2.4-63	1
2.5-i thru 2.5-v	5
2.5-vii thru 2.5-ix	5
2.5-0	0
2.5-1 thru 2.5-175	5
T2.5-1(1 of 55 thru 55 of 55)	0
T2.5-2(1 of 3 thru 3 of 3)	0
T2.5-3(1 of 4 thru 4 of 4)	0
T2.5-4(1 of 1)	0
T2.5-5(1 of 1)	1
T2.5-6(1 of 1)	1
T2.5-7(1 of 4 thru 4 of 4)	1
T2.5-8(1 of 1)	1
T2.5-9(1 of 1)	1
T2.5-10 delete notice	1
T2.5-11(1 of 1)	1
T2.5-12(1 of 3 thru 3 of 3)	2
T2.5-13(1 of 1)	2
T2.5-14(1 of 1)	5
F2.5-1 thru 2.5-5	0
F2.5-5A thru 2.5-5B	1
F2.5-6 thru 2.5-8	0
F2.5-9	5
F2.5-10 thru 2.5-11	0
F2.5-12 thru 2.5-13A	1
F2.5-14	1
F2.5-15	0
F2.5-16 thru 2.5-17	5
F2.5-18 thru 2.5-48	0
F2.5-49 thru 2.5-62	1
F2.5-63	0

2034 273

Page, Table (T), or Figure (F)	Amendment Number
F2.5-64	1
F2.5-65 thru 2.5-66	0
F2.5-67 thru 2.5-69	2
F2.5-70 thru 2.5-71	5
2.6-i	2
2.6-iii	1
2.6-1 thru 2.6-2	0
2.6-3	3
2.6-4 thru 2.6-4a	4
2.6-5 thru 2.6-6	1
2.6-7 thru 2.6-10	2
F2.6-1 thru 2.6-16	0
2.7-i	1
2.7-iii	1
2.7-v	1
2.7-1 thru 2.7-5	0
T2.7-1(1 of 2 thru 2 of 2)	0
T2.7-2(1 of 2 thru 2 of 2)	0
T2.7-3(1 of 2 thru 2 of 2)	0
F2.7-1 thru 2.7-10	0
2.8-i	1
2.8-iii	1
2.8-v	1
2.8-1 thru 2.8-4	0
T2.8-1(1 of 1)	0
T2.8-2(1 of 2 thru 2 of 2)	0
T2.8-3(1 of 1)	0
T2.8-4(1 of 1)	0
T2.8-5(1 of 3 thru 3 of 3)	0
T2.8-6(1 of 1)	0
T2.8-7(1 of 1)	0
F2.8-1 thru 2.8-3	0

2034 274

1970 POPULATION AND POPULATION DEN

Direction from Site	0 to 1 Mi from Site: Number of Inhabitants	0 to 1 Mi from Site: Inhabitants per Sq Mi	1 to 2 Mi from Site: Number of Inhabitants	1 to 2 Mi from Site: Inhabitants per Sq Mi	2 to 3 Mi from Site: Number of Inhabitants	2 to 3 Mi from Site: Inhabitar per Sq N
N	24	122.2	27	45.8	38	38.7
NNE	16	81.6	70	118.8	127	129.5
NE	11	56.1	51	86.6	116	118.2
ENE	8	40.8	35	59.4	84	85.7
E	11	56.1	43	73.0	60	61.2
ESE	2	10.2	35	59.4	86	87.8
SE	22	112.2	16	27.2	33	33.7
SSE	8	40.8	27	45.8	27	27.6
S	19	96.9	14	23.8	35	35.7
SSW	11	56.1	29	49.2	35	35.7
SW	19	96.9	54	91.7	35	35.7
WSW	119	606.1	24	40.7	2	2.0
W	29	147.7	97	164.7	24	24.5
WNW	14	71.4	122	207.1	70	71.4
NW	6	30.6	113	191.9	111	113.1
NNW	2	10.2	68	115.4	208	211.9
Total for Each Annular Ring	321	102.3	825	87.5	1,091	69.5

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6, 56

2034 275

BLE 2.1-3

SITY, BY SECTOR, WITHIN 10 MILES OF THE SITE

ts i	3 to 4 Mi from Site Number of Inhabitants	3 to 4 Mi from Site Inhabitants per Sq Mi	4 to 5 Mi from Site Number of Inhabitants	4 to 5 Mi from Site Inhabitants per Sq Mi	5 to 10 Mi from Site Number of Inhabitants	5 to 10 Mi from Site Inhabitants per Sq Mi	Total Population 0 to 10 Mi from Site
	*	*	*	*	*	*	89
	60	43.7	*	*	*	*	273
	392	285.3	124	70.2	216	14.7	910
	60	43.8	51	28.9	673	45.7	911
	89	65.0	73	41.3	996	67.8	1,272
	816	593.7	223	126.2	909	61.8	2,071
	113	82.2	73	41.3	867	59.0	1,124
	41	29.9	175	99.0	559	38.0	837
	46	33.6	29	16.4	1,511	102.6	1,654
	68	49.6	127	71.9	692	47.1	962
	38	27.6	60	34.0	2,066	140.3	2,272
	60	43.8	182	103.0	4,461	302.9	4,848
	113	82.2	179	101.3	5,492	373.1	5,934
	103	74.9	132	74.7	*	*	441
	118	85.9	173	97.9	*	*	521
	*	*	*	*	*	*	278
	2,117	96.3	1,601	56.7	18,442	78.3	24,397

2034 276

PROJECTED POPULATION AND POPULATION DENSIT

Direction from Site	0 to 1 Mi from Site Number of Inhabitants	0 to 1 Mi from Site Inhabitants per Sq Mi	1 to 2 Mi from Site Number of Inhabitants	1 to 2 Mi from Site Inhabitants per Sq Mi	2 to 3 Mi from Site Number of Inhabitants	2 to 3 Mi from Site Inhabita per Sq
N	33	168.1	39	66.2	54	55.1
NNE	22	112.0	99	168.1	179	182.5
NE	15	76.5	72	122.2	162	165.3
ENE	11	56.1	49	83.2	118	120.4
E	15	76.5	60	101.9	84	85.7
ESE	3	15.3	49	83.2	121	123.5
SE	31	157.9	22	37.4	47	48.0
SSE	11	56.1	39	66.2	39	39.8
S	26	132.4	19	32.3	49	50.0
SSW	15	76.5	41	69.6	49	50.0
SW	26	132.7	75	127.3	49	50.0
WSW	166	846.9	33	56.0	3	3.1
W	41	209.2	136	230.9	33	33.7
WNW	19	96.9	172	292.0	98	100.0
NW	8	40.8	158	268.3	155	157.9
NNW	3	15.3	95	161.3	292	297.7
Total for Each Annular Ring	445	141.9	1,158	122.9	1,532	97.5

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 277

1

E&G ER
EN-NUCLEAR

E 2.1-4

Y, BY SECTOR, WITHIN 10 MILES OF THE SITE, 1991

ts	3 to 4 Mi from Site		4 to 5 Mi from Site		5 to 10 Mi from Site		Total Population
i	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	0 to 10 Mi from Site
	*	*	*	*	*	*	126
	84	61.1	*	*	*	*	384
	549	399.6	174	98.5	302	21.6	1,274
	82	60.0	72	40.7	944	64.2	1,276
	125	91.0	103	58.3	1,397	95.0	1,784
	1,144	832.6	327	185.1	1,275	86.7	2,919
	158	115.3	100	56.6	1,216	82.7	1,574
	58	42.3	246	139.2	784	53.3	1,177
	65	47.4	41	23.2	2,119	144.1	2,319
	95	69.3	179	101.3	970	66.0	1,349
	54	39.4	84	47.5	2,897	197.1	3,185
	84	61.3	255	144.3	6,256	425.6	6,797
	158	115.3	252	142.6	7,703	523.1	8,323
	145	105.8	186	105.3	*	*	620
	165	120.0	242	137.0	*	*	728
	*	*	*	*	*	*	390
	2,966	134.9	2,261	80.0	25,863	109.8	34,225

2034 278

of 1

PROJECTED POPULATI[illegible]N AND POPULATION DENSIT

Direction from Site	0 to 1 Mi from Site: Number of Inhabitants	0 to 1 Mi from Site: Inhabitants per Sq Mi	1 to 2 Mi from Site: Number of Inhabitants	1 to 2 Mi from Site: Inhabitants per Sq Mi	2 to 3 Mi from Site: Number of Inhabitants	2 to 3 Mi from Site: Inhabitan[ts] per Sq [Mi]
N	34	173.5	40	67.9	55	56.0
NNE	23	117.3	102	173.2	184	187.4
NE	15	76.5	74	125.6	167	170.4
ENE	11	56.1	50	84.9	121	123.5
E	15	76.5	62	105.3	87	88.8
ESE	3	15.3	50	84.9	124	126.5
SE	32	163.3	23	39.0	48	49.0
SSE	11	56.1	40	67.9	40	40.8
S	27	137.8	20	34.0	50	51.0
SSW	15	76.5	42	71.3	50	51.0
SW	27	137.8	77	130.7	50	51.0
WSW	171	872.4	34	57.7	3	3.1
W	42	214.3	140	237.7	34	34.7
WNW	20	102.0	177	300.5	102	104.1
NW	8	40.8	163	276.7	160	163.0
NNW	3	15.3	98	166.4	301	307.1
Total for Each Annular Ring	457	145.7	1,192	126.5	1,576	100.3

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 279

LE 2.1-5

Y, BY SECTOR, WITH 10 MILES OF THE SITE, 1993

ts Mi	3 to 4 Mi from Site Number of Inhabitants	3 to 4 Mi from Site Inhabitants per Sq Mi	4 to 5 Mi from Site Number of Inhabitants	4 to 5 Mi from Site Inhabitants per Sq Mi	5 to 10 Mi from Site Number of Inhabitants	5 to 10 Mi from Site Inhabitants per Sq Mi	Total Population 0 to 10 Mi from Site
	*	*	*	*	*	*	129
	87	63.3	*	*	*	*	396
	565	411.1	179	101.3	311	21.1	1,311
	85	62.0	85	48.1	972	66.1	1,324
	129	94.2	105	59.4	1,438	97.8	1,836
	1,178	857.4	337	190.7	1,313	89.3	3,005
	163	119.0	103	58.3	1,252	85.2	1,621
	60	43.8	253	143.2	807	54.9	1,211
	67	48.9	42	23.8	2,182	148.4	2,388
	98	71.5	184	104.1	999	68.0	1,388
	55	40.1	87	49.2	2,983	202.9	3,279
	87	63.5	262	148.3	6,443	438.3	7,000
	163	119.0	259	146.6	7,932	538.9	8,570
	150	109.5	191	108.1	*	*	640
	170	123.7	250	142.0	*	*	751
	*	*	*	*	*	*	402
	3,057	139.0	2,337	82.7	26,632	113.0	35,251

2034 280

PROJECTED POPULATION AND POPULATION D

Direction from Site	0 to 1 Mi from Site		1 to 2 Mi from Site		2 to 3 Mi from Sit	
	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabita per Sq
N	38	193.9	44	74.7	61	62.1
NNE	25	127.6	112	190.2	203	206.8
NE	17	86.7	82	139.2	184	187.8
ENE	13	66.3	55	93.4	133	135.7
E	17	86.7	68	115.4	95	96.9
ESE	3	15.3	55	93.4	137	139.8
SE	36	183.7	25	42.4	53	54.1
SSE	13	66.3	44	74.7	44	44.9
S	30	153.1	22	37.4	55	56.1
SSW	17	86.7	46	78.1	55	56.1
SW	30	153.1	85	144.3	55	56.1
WSW	189	964.3	38	64.5	3	3.1
W	46	234.7	154	261.5	35	3[illegible].7
WNW	22	112.2	194	329.4	112	[illegible]
NW	9	45.9	180	305.6	176	179.
NNW	3	15.3	108	183.4	331	337.2
Total for Each Annular Ring	508	161.7	1,312	139.2	1,732	110.1

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 281

BLE 2.1-6

ENSITY, BY SECTOR, WITHIN 10 MILES OF THE SITE
2000

	3 to 4 Mi from Site		4 to 5 Mi from Site		5 to 10 Mi from Site		Total Population
ts Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	0 to 10 Mi from Site
	*	*	*	*	*	*	143
	95	69.1	*	*	*	*	435
	623	453.3	197	111.5	343	23.3	1,446
	93	67.9	82	46.4	1,070	72.8	1,446
	142	103.6	116	65.6	1,584	107.8	2,022
	1,297	943.9	[illegible]71	210.0	1,446	98.4	3,309
	180	131.4	[illegible]	64.5	1,379	93.8	1,787
	66	48.2	[illegible]78	157.3	888	60.4	1,333
	74	54.0	46	26.0	2,403	163.5	2,630
	108	78.8	[illegible]	114.9	1,100	74.8	1,529
	61	44.5	[illegible]	53.8	3,285	223.5	3,611
	95	69.3	[illegible]	163.6	7,095	482.7	7,709
	180	131.4	285	161.3	8,735	593.4	9,435
	165	120.4	211	119.4	*	*	704
	188	136.8	275	155.6	*	*	828
	*	*	*	*	*	*	442
	3,367	153.1	2,562	90.6	29,328	124.5	38,809

2034 282

TABLE

PROJECTED POPULATION AND POPULATION DENS
2(

Direction from Site	0 to 1 Mi from Site		1 to 2 Mi from Site		2 to 3 Mi from Site	
	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabita per Sq M
N	43	219.4	50	84.9	69	70.3
NNE	28	142.9	127	215.6	230	234.3
NE	19	96.9	93	157.9	209	213.3
ENE	15	76.5	62	105.3	151	154.1
E	19	96.9	77	130.7	108	110.2
ESE	3	15.3	62	105.3	155	158.2
SE	41	209.2	28	47.5	60	61.2
SSE	15	76.5	50	84.9	50	51.0
S	34	173.5	25	42.4	62	63.3
SSW	19	96.9	52	88.3	62	63.3
SW	34	173.5	96	163.0	62	63.3
WSW	214	1,091.8	43	73.0	4	4.1
W	52	265.3	175	297.1	39	39.8
WNW	25	127.6	220	373.5	127	129.6
NW	10	51.0	204	346.3	200	203.7
NNW	3	15.3	123	208.8	375	382.0
Total for Each Annular Ring	574	183.0	1,487	157.8	1,963	125.0

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 283

2.1-7

ITY, BY SECTOR, WITHIN 10 MILES OF THE SITE
)10

	3 to 4 Mi from Site		4 to 5 Mi fr... ?ite		5 to 10 Mi from Site		Total Population
ts Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	0 to 10 Mi from Site
	*	*	*	*	*	*	162
	108	78.6	*	*	*	*	493
	706	513.7	223	126.2	389	26.4	1,639
	105	76.6	93	52.6	1,213	82.5	1,639
	161	117.5	132	74.7	1,796	122.2	2,293
	1,314	956.0	421	238.3	1,640	111.6	3,595
	204	148.9	129	73.0	1,564	106.4	2,026
	75	54.7	315	178.3	1,007	68.5	1,512
	84	61.3	52	29.4	2,725	185.4	2,982
	123	89.8	230	130.2	1,247	84.8	1,733
	69	50.4	108	61.1	3,725	253.4	4,094
	108	78.8	328	185.6	8,046	547.3	8,743
	204	148.9	323	182.8	9,905	672.6	10,698
	187	136.5	239	135.3	*	*	798
	213	155.0	312	176.6	*	*	939
	*	*	*	*	*	*	501
	3,661	166.5	2,905	102.7	33,257	141.1	43,847

2034 284

PROJECTED POPULATION AND POPULATION D

Direction from Site	0 to 1 Mi from Site		1 to 2 Mi from Site		2 to 3 Mi from Site	
	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabita per Sq
N	49	250.0	57	96.8	78	79.
NNE	32	163.3	144	244.5	261	265.
NE	22	112.2	105	178.3	237	241.
ENE	17	86.7	70	118.8	171	174.
E	22	112.2	87	147.7	122	124.
ESE	4	20.4	70	118.8	176	179.
SE	46	234.7	32	54.3	68	69.
SSE	17	86.7	57	96.8	57	58.
S	39	199.9	28	47.5	70	71.
SSW	22	112.2	59	100.2	70	71.
SW	39	199.0	109	185.1	70	71.
WSW	243	1,239.8	49	83.2	4	4.
W	59	301.0	198	336.2	44	44.
WNW	28	142.9	249	422.8	144	146.
NW	11	56.1	231	392.2	227	231.
NNW	4	20.4	139	236.0	425	433.
Total for Each Annular Ring	654	208.5	1,684	178.7	2,224	141.

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 285

LE 2.1-8

NSITY, BY SECTOR, WITHIN 10 MILES OF THE SITE
2020

nts	3 to 4 Mi from Site		4 to 5 Mi from Site		5 to 10 Mi from Site		Total Population
Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	0 to 10 Mi from Site
5	*	*	*	*	*	*	184
9	122	88.8	*	*	*	*	559
8	801	582.8	253	143.2	442	29.9	1,859
5	119	86.9	105	59.4	1,376	93.6	1,858
5	183	133.1	150	84.9	2,037	138.6	2,601
6	1,490	1,084.4	477	269.9	1,860	126.5	4,077
4	231	168.6	146	82.6	1,774	120.7	2,297
2	85	62.0	357	202.0	1,142	77.7	1,715
4	95	69.3	59	33.4	3,090	210.2	3,381
4	139	101.5	261	147.7	1,414	96.2	1,965
4	78	56.9	122	69.0	4,224	287.3	4,642
1	122	89.1	372	210.5	9,124	620.7	9,914
9	231	168.6	366	207.1	11,232	763.1	12,130
9	212	154.7	271	153.4	*	*	904
2	242	176.1	354	200.3	*	*	1,065
2	*	*	*	*	*	*	568
6	4,150	188.8	3,293	116.5	37,714	160.1	49,719

2034 286

TABLE 2

PROJECTED POPULATION AND POPULATION DEN
20

Direction from Site	0 to 1 Mi from Site: Number of Inhabitants	0 to 1 Mi from Site: Inhabitants per Sq Mi	1 to 2 Mi from Site: Number of Inhabitants	1 to 2 Mi from Site: Inhabitants per Sq Mi	2 to 3 Mi from Sit: Number of Inhabitants	2 to 3 Mi from Sit: Inhabit per Sq
N	56	285.7	65	110.4	88	89
NNE	36	183.7	163	276.7	296	301
NE	25	127.6	119	202.0	269	274
ENE	19	96.9	79	134.1	194	198
E	25	127.6	99	168.1	131	133
ESE	4	20.4	79	134.1	200	204
SE	52	265.3	36	61.1	77	78
SSE	19	96.9	65	110.4	65	66
S	44	224.5	32	54.3	79	80
SSW	25	127.6	67	113.8	79	80
SW	44	224.5	124	210.5	79	80
WSW	276	1,408.2	56	95.1	5	5
W	67	341.8	225	382.0	50	51
WNW	32	163.3	282	478.8	163	166
NW	13	66.3	262	444.8	257	261
NNW	5	25.5	155	263.2	475	483
Total for Each Annular Ring	742	236.6	1,908	202.5	2,507	159

NOTE:

*Lack of population indicates entire area covered by Lake Ontario

SOURCES:

References 3, 6

2034 287

SITY, BY SECTOR, WITHIN 10 MILES OF THE SITE
30

e ants Mi	3 to 4 Mi from Site		4 to 5 Mi from Site		5 to 10 Mi from Site		Total Population 0 to 10 Mi from Site
	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	Number of Inhabitants	Inhabitants per Sq Mi	
.6	*	*	*	*	*	*	209
.5	138	100.4	*	*	*	*	633
.5	908	660.6	287	162.4	500	34.0	2,108
.0	135	98.5	119	67.3	1,560	106.1	2,106
.7	207	151.1	170	96.2	2,310	157.1	2,942
.1	1,690	1,230.0	541	306.2	2,109	143.5	4,623
.6	262	191.2	166	93.9	2,012	136.9	2,605
.3	96	70.1	405	229.2	1,295	88.1	1,945
.6	108	78.8	67	37.9	3,504	238.4	3,834
.6	158	115.3	296	167.5	1,603	109.0	2,228
.6	88	64.2	138	78.1	4,790	325.9	5,263
.1	138	100.7	422	238.8	10,347	703.9	11,244
.0	262	191.2	415	234.9	12,737	865.3	13,756
.3	240	175.2	307	173.7	*	*	1,024
.8	274	199.4	401	226.9	*	*	1,207
.8	*	*	*	*	*	*	635
.6	4,704	213.9	3,734	132.1	42,767	181.5	56,362

2034 288

TABLE OF CONTENTS

SECTION 2.5

SITE CHARACTERISTICS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

2034 291

TABLE OF CONTENTS (Cont'd)

2034 292

LIST OF TABLES

2034 293

LIST OF FIGURES

2034 294

LIST OF FIGURES (Cont'd)

2034 295

LIST OF FIGURES (Cont'd)

2034 296

LIST OF FIGURES (Cont'd)

2034 297

2.5 GEOLOGY AND SEISMOLOGY

The site is located near the southern shore of Lake Ontario, approximately 2 mi south of Mexico Bay in New Haven, NY, as shown in Figure 2.5-7. The site is situated in the Central Lowland physiographic province[1] and is in an area of essentially flat-lying undeformed sedimentary rocks of Ordovician age. The station structures are underlain by gently southwestward-dipping sedimentary rocks of the Oswego Sandstone. Extensive surface and subsurface geologic investigations indicate that the sedimentary strata at the site have not experienced any major orogenic deformation. Broad, low folds occur areally and trend N 50 deg E. The Demster Beach anticline with associated fault zone over 3 mi long is located 1 1/2 mi northwest of the site (Appendix 2.5I).

An earthquake data base was compiled from published catalogs, as well as from original sources such as newspapers, town histories, etc, for a region extending more than 200 mi radially from the site. Prominent trends or clusters of seismic activity were identified, assessed, and, where possible, correlated with other geologic and geophysical data. Based on the spatial distribution of historical activity and also on the locations of the most recent reliable instrumental epicenters, the site is considered to be located in a region of very low seismicity.

Considering that the site intensities associated with the largest historical events, both outside and within the site province, do not exceed an Intensity VI, the selection of an Intensity VII at the site is considered to be a conservative assessment of the maximum earthquake potential. From a conservative analytical assessment of the seismicity, a peak horizontal ground acceleration of 0.15 g is adequately conservative under Appendix A to 10CFR100, Seismic and Geologic Siting Criteria. It has been decided by NYSE&G that a value of 0.2 g peak horizontal ground acceleration will be adopted for this site.

There is no known hazard of surface faulting at the site. There has been no mining activity, petroleum, natural gas recovery, or any other subsurface withdrawal activity at the site which would cause settlement or ground subsidence, nor is any anticipated. The abandoned Pulaski gas field, approximately 8 mi northeast of the site, is the closest occurrence of subsurface withdrawal other than private and municipal water wells.

All safety related station structures will be founded on bedrock. Core borings and Trench I at the site indicated no evidence of significant bedrock weathering, cavities, or faults which might affect the safety or integrity of station structures. There are no steep slopes, unstable ground, or other geologically hazardous conditions which affect the suitability of the site. There are no major aquifers at or near the site; overburden deposits are generally of low permeability and ground water flow occurs primarily at the bedrock-soil interface.

The geologic, geophysical, and seismic investigations described in Sections 2.5.1, 2.5.2, and 2.5.3 were carried out by Weston Geophysical Research Inc. Geotechnical engineering and ground water studies described in Sections 2.5.4

and 2.5.5 were conducted by Stone & Webster Engineering Corporation. In addition, a number of consultants and subcontractors' personnel performed aspects of work as described below:

1. The regional geology and site area investigations were carried out by Weston Geophysical personnel with the direction of Dr. George A. Kiersch, geologic consultant to Weston. The field program was supplemented by the special studies of Professor Ernest Muller, Syracuse University, who mapped the surficial geology of the site area; and John R. Rand, consulting geologist, who provided part of text and map materials on the regional geology and seismotonics

2. Sprague and Henwood, Inc. of Scranton, Pa, under the direction of of Weston Geophysical, drilled test borings, sampled soil, cored rock, performed pressure tests, installed piezometers, and performed permeabilility tests

3. Peter Kiewit and Sons' Company of Omaha, Neb, excavated a 982-ft trench onsite, a 200-ft trench for fault investigation, and provided machinery for test pit excavations.

4. Goldberg, Zoino, Dunnicliff & Associates, Inc. of Newton, Mass, performed laboratory tests to determine compressive strength and slake durability for representative core samples.

5. Warren George, Inc., of Jersey City, New Jersey, under the direction of Stone & Webster, performed test borings in Lake Ontario.

Information contained in this report was obtained from the following sources:

1. Review of published geologic literature and maps, and private reports and data for the site and regional areas

2. Field mapping (bedrock and surficial) at a scale of 1:24,000 within a 5-mi radius of the site

3. Surficial map of the site at a scale of 1:4,800

4. Interpretation of aerial photographs, earth resources technology satellite imagery, and gravity and aeromagnetic maps

5. Geological reconnaissance of selected features and stratigraphic units within the region

6. Soil and rock borings and analysis of sampled raterials

7. Detailed mapping of two exploratory trenches that exposed Oswego Sandstone across the site and at fault zone located 1.5 mi from the site

2034 299

8. Onsite geophysical surveys, including seismic refraction surveys, in situ velocity measurements, borehole logging, and seismic reflection, gravity, and VLF studies within the site area and region

9. Laboratory testing of representative soil and rock samples

10. Piezometer installations and ground water monitoring

11. In situ borehole permeability tests in soil and pressure tests in rock

2.5.1 Basic Geologic and Seismic Information

This section is presented in two parts. The first covers the geology of the entire region, followed by a description of the geology in the site area and site.

2.5.1.1 Regional Geology

The region is defined by a 200-mi radius from the site.

2.5.1.1.1 Regional Physiography and Geomorphology

2.5.1.1.1.1 Introduction

The site is situated in the Erie-Ontario Lowland section of the Central Lowland physiographic province[1]. Physiographic provinces and sections which lie within 200 mi of the site are shown in Figure 2.5-1 and include:

PROVINCE	SECTION
Central Lowland	Erie-Ontario Lowlands
Appalachian Plateaus	Catskill Section Appalachian Uplands Allegheny Mountain Section Kanawha Section Tug Hill Upland Mohawk Section
Adirondack	
Valley and Ridge	Hudson Valley Section Middle Section
Laurentian Highlands	
St. Lawrence Lowlands	Champlain Section
New England	Connecticut Valley Lowland Green Mountain Section

2034 300

	Taconic Section
	Reading Prong-Hudson Highlands
Piedmont	Piedmont Lowlands Section
Coastal Plain	Embayed Section

2.5.1.1.1.2 Central Lowland Province (Site Province)

The Erie-Ontario Lowlands encompass the relatively low, flat areas lying south of Lake Erie and Lake Ontario. From the lake levels of 570 ft and 244 ft, respectively, the land rises gently eastward and southward. The maximum elevation, (1,000 to 1,500 ft) occurs along the Portage escarpment, the boundary with the Appalachian Uplands to the south (Figure 2.5-1). In the Ontario Lowland, east-west escarpments are formed by the Onondaga limestone and Lockport dolomite. The province is underlain by a nearly flat-lying (minor southward dip) sequence of shale, sandstone, and limestone of Early to Middle Paleozoic age. The simple erosional topography has been modified by glacial action with deposition of drumlin fields, moraines, and shoreline deposits.

2.5.1.1.1.3 Appalachian Plateaus Province

The Catskill Mountain section lies west of the Hudson Valley and extends as a salient into the Appalachian Plateaus. This area of mountainous relief consists of a maturely dissected, slightly higher plateau which reaches an elevation of approximately 4,000 ft. The underlying bedrock sedimentary formations of Middle and Upper Paleozoic age, are more deformed than those of the uplands to the west. The mountains owe their prominent relief to a resistant coarse sandstone and conglomerate caprock (Catskill Formation). The area has been glaciated, and glacial deposits abound in the deep and prominent steep sided valleys.

The Appalachian Uplands (the northern extreme of the Appalachian Plateaus) were formed by dissection of the uplifted but flat-lying sandstones and shales of the Devonian Catskill delta. Relief is moderate to high. Westward, the Uplands surface is represented by flat topped divides. Drainage is generally southwest into the Allegheny, Susquehanna, and Delaware River systems, except for Cattaraugus Creek, the Genessee River, the Finger Lakes, and minor streams along the Catskill front.

The northern edge of the province is cut by the Finger Lake troughs, which are glacially modified valleys of preglacial rivers[3]. At least two of the lakes (Cayuga and Seneca) have bedrock floors below sea level. Glacial cover is generally thin, although some very thick deposits occur in some north-south valleys. The major east-west drainage divide of central New York the Valley Heads moraine, is a recessional moraine south of the present Finger Lakes (Figure 2.5-2).

The Allegheny Mountain section in northern Pennsylvania is a dissected plateau on mildly folded sedimentary rocks of Middle to Upper Paleozoic ages. Erosion

of the gently folded rocks has resulted in a pattern of crude topographic belts which trend northeasterly. Mountain surfaces rise to el 2,900, assumed to reflect a level of the Schooley peneplain. Lower surfaces dissected into the plateau at approximately el 2,000 may reflect a later peneplain development.

The Tug Hill Upland is an isolated section at the eastern end of the Erie-Ontario Lowlands. Elevation is approximately 2,000 ft and relief is very low. The Tug Hill Plateau results from a resistant caprock of Oswego Sandstone (of Ordovician age), resting on a thick series of sandy shales. These shales, in turn, overlie Trenton and Black River limestones (Figure 2.5-6). The low slope of the caprock and the thin cover of glacial deposits have caused poor drainage and many swamps which result in a desolate landscape.

The Mohawk section, a lowland resulting from erosion along an outcrop belt, lies between the Adirondacks and the Helderberg escarpment. The belt is commonly of low elevation and relief, underlain by relatively nonresistant Ordovician shales which have been exposed by early large scale erosion, stripping away the overlying Silurian and Devonian sandstones, and by Pleistocene glacial action. T Mohawk Valley is largely blanketed by deposits of Late Pleistocene ou ash, deltas, and lake clays[3].

2.5.1.1.1.4 Adirondack Province

The highest mountains within the site region occur in the Adirondack Province, a glaciated uplift area in which peaks are largely well rounded by erosion and many reach altitudes above 4,000 ft; two peaks are over 5,000 ft in elevation. The province merges into the plains of the St. Lawrence Valley to the north and west, and the Mohawk Valley to the south. Eastward to the Champlain Lowlands, the slope is more abrupt.

Ancient Precambrian crystalline rocks of schist, quartzite, marble, and granitic intrusives, similar to the Canadian shield, underlie the Adirondacks. The mountains are transected by long, northeast-southwest lineaments, and some represent shear zones or major faults[4]. The lineaments frequently control drainage and the landforms. Many lakes follow geologic contacts, or are in valleys along weak rock units. Young glacial deposits clog the normal radial drainage and lower areas are dotted with lakes, ponds, and swamps.

2.5.1.1.1.5 Valley and Ridge Province

The Hudson Valley section is a lowland resulting from erosion along an outcrop belt of relatively nonresistant shales and slates, lying between the more resistant sedimentary rocks of the Catskill Mountains and Helderberg escarpment to the west (Figure 2.5-1), and the harder metamorphic rocks of the Taconic Mountains to the east. Most of the section has both low elevation and relief, and is underlain primarily by Ordovician shales which have been exposed by recent glacial action and earlier large scale erosion which stripped off the Silurian and Devonian limestones. The northern part of the Hudson Valley is largely blanketed by Late Pleistocene deposits of glacial outwash, deltas, and glacial lake clays. South of Albany, the valley narrows

gradually and becomes gorgelike between abrupt uplands of hard metamorphic rocks, near Poughkeepsie, New York.

The Middle section in the site region is characterized by a more typical northeasterly-elongate topographic pattern of valleys and ridges resulting from differential erosion of folded sedimentary rocks, commonly with the more resistant sandstones supporting the ridges. Along its southeastern margin, the Middle section is characterized by a lowland underlain by Early Paleozoic limestone and shale, bounded by the abrupt slopes of the Reading Prong-Hudson Highlands.

2.5.1.1.1.6 Laurentian Highlands Province

The Highlands within 200 mi of the site are characterized by low relief, with numerous lakes filling the lower ground between gentle northeast-trending ridges of peneplained Precambrian (Grenville) crystalline rocks. Elevations range to about 700 ft. Much of the area is blanketed by a veneer of Late Wisconsinan glacio-lacustrine and glacio-marine silt and clay deposits.

2.5.1.1.1.7 St. Lawrence Lowlands Province

The northeastern physiographic province in the site region includes the St. Lawrence River Valley, the low hills south of the river valley, and the Lake Champlain Valley. The underlying rocks, Cambrian and Ordovician sandstones, dolomites, and limestones, dip gently away from the Adirondacks. Relief is approximately 100 ft. Streams draining the northern and eastern slopes of the Adirondacks flow across the province. The shoreline of Lake Champlain is largely controlled by north-south and east-west faults which have broken the Paleozoic sandstones and carbonates into large blocks[4]. Bedrock of the St. Lawrence Valley is blanketed by fine-grained glacio-marine and glacio-lacustrine sediments of Late Pleistocene age.

2.5.1.1.1.8 New England Province

The physiographic fabric of the land area in the New England region within 200 mi of the site is characterized by a series of subparallel belts, elongate to the northeast, of lowlands, uplands, and mountain ranges or groups. These northeast-trending physiographic belts largely reflect regional variations in the structure or lithology of the underlying bedrock, which ranges in age from Precambrian to Mesozoic. These differences are further accentuated by differential weathering and erosion. The topography has been rounded or subdued by the scouring action of continental glaciation which moved over the region intermittently during the Pleistocene epoch.

The New England Upland (Figure 2.5-1) is a maturely dissected plateau ranging in elevation from about 500 to 2,000 ft, underlain largely by Silurian and Devonian eugeosynclinal metasedimentary rocks which were folded, recrystallized, and consolidated in a broad northeast striking foldbelt during the Acadian Orogeny (Devonian time). Monadnocks rising above the Upland terrane are commonly composed of metamorphic bedrock of Acadian age; however, some of the more prominent of these are supported by discordant intrusive

bodies of Middle and Late Mesozoic age. These Mesozoic intrusive bodies are scattered from southwestern Maine and southeastern New Hampshire along a zone trending north-northwest across New Hampshire into southern Quebec. In southwestern New Hampshire and west-central Massachusetts, the New England Upland is largely supported by north-trending granitic domes of the Lower Paleozoic Bronson Hill anticlinorium and by Precambrian rocks of the Berkshire Uplands and Merrimack synclinorium.

The Connecticut Valley Lowland, a distinctive low elevation physiographic and geologic element, trends northward into the New England Upland for about 100 mi through central Connecticut and west-central Massachusetts. The valley, formed by crustal rifting in Early Mesozoic time, contains easily eroded sandstones and shales of Triassic and Jurassic age(5), locally interlayered with resistant diabase flows which form prominent ridges.

The narrow belt of the Green Mountain section (Figure 2.5-1) ranges in elevation from about 1,000 to 3,000 ft, and reflects closely the continuous north-trending fabric of fairly open anticlinal folding and west-directed thrust faulting of crystalline Precambrian basement masses and overlying Lower Paleozoic miogeosynclinal sedimentary rocks(6).

The Taconic section, some 150 mi east of the site, is characterized by a mountaneous terrane supported by quartzite, schist, and phyllite metamorphic rocks, with a prominent valley on the east underlain by relatively non-resistant marble bedrock. The north-trending alignment of the section reflects the underlying bedrock fold and fault structure which developed in Taconic and Acadian Oroganies (Paleozoic time) by westerly directed crustal compression(7,8).

The Reading Prong-Hudson Highlands section, a narrow southwestward extension of the upland terrane of the New England province, is underlain mainly by Precambrian crystalline rocks related to those of the Green Mountain and Berkshire Uplands. The section is characterized by elevations ranging to about 1,200 ft, cut by deep, structurally controlled valleys trending parallel to the section. The section boundaries with the middle section to the northwest, and with the Triassic sedimentary rocks of the Piedmont Lowlands to the southeast are abrupt.

2.5.1.1.1.9 Piedmont Province

The Piedmont Lowlands in the site region are underlain by relatively non-resistant Triassic shales and sandstones with interlayered resistant diabase flows. The section is bounded on the northeast and north by a prominent escarpment of the Palisades diabase sill, on the northwest by the Ramapo fault and other border faults of Mesozoic rifting derivation, and on the southeast by the overlap of Coastal Plain sediments of Cretaceous age. The Palisades are the outstanding feature of the section, forming the west bank of the Hudson River from Nyack, NY, southward. Here, the Hudson River follows the contact of the Triassic shales with the underlying and enclosing crystalline basement rocks. Southward, beyond the 200 mi region, the Precambrian and

Early Paleozoic basement of metamorphic rocks and igneous intrusives is cut by other Triassic sediment filled basins.

2.5.1.1.1.10 Coastal Plain Province

The Atlantic Coastal Plain, extending from the Gulf of Maine through southeastern New Jersey forms the continental shelf beneath the Atlantic Ocean to the continental rise. The province is a low elevation section composed of loosely consolidated sediments of Cretaceous and Cenozoic age resting on basement rocks which constitute the on-strike extensions of the Precambrian, Paleozoic, and Mesozoic terranes of the upland areas. Beneath Long Island, Coastal Plain sediments underlie locally thick deposits derived from Pleistocene glaciations. The Coastal Plain section is characterized by a series of seaward dipping sedimentary formations which thicken toward the continental slope[9].

2.5.1.1.1.11 Physiographic Development

The development of the physiographic features characterizing the site region was initiated at the close of the Mesozoic era. Following peneplanation, the region was elevated and subjected to subareal weathering, erosion, and dissection of the peneplain surface. Sediments transported from the landmass during this time were carried seaward to form the Coastal Plain sedimentary deposits. Crystalline basement rocks underlying the elevated landmass in New England were deeply weathered, with the fine grained metamorphic rocks generally undergoing more extensive weathering than the intrusive plutonic rocks.

Following the long period of Cenozoic weathering and degradation of the landmass, successive advances of continental glaciation occurred during the Pleistocene epoch. The ice sheets removed the residual soils and loose weathered bedrock surface, and upon withdrawal/melting deposited a ground moraine of generally stony till on the scoured bedrock surface. Locally, the morainal deposits are overlain by ice contact and outwash deposits. Depression of the landmass by the weight of thick glacial ice, combined with a rise of sea level due to the melting of the ice sheets, resulted in submergence of wide areas of the lowlands. Rock flour released from the melting ice was deposited on the undulating surface of the submerged lowlands and valleys as a blanket of marine clay-silt, or as lake deposits along the major river valleys. Crustal rebound, following the removal of the last glacial ice, elevated the upper surface of the marine clay-silt blanket and lake water-plane deposits above sea level by as much as several hundreds of feet[10].

2.5.1.1.2 Regional Surficial Geology

2.5.1.1.2.1 Introduction

The distribution of surficial deposits in the region is shown in Figure 2.5-2, and throughout the site area is shown in Figure 2.5-18. The following discussion of the regional surficial deposits is generalized and subdivided

into two informal sectors, although the deposits, therein, are generally similar. No geologic, seismic, or manmade hazards of significance as to the safety of the site are known or inferred to relate to the regional surficial geologic features. There are no areas near the site that are currently undergoing intense erosion.

2.5.1.1.2.2 New England Sector

The surficial deposits throughout the New England sector (Figure 2.5-2), except for a small area of residual soils in New Jersey, are glacially derived and cover the landmass[1],[2]. They were deposited primarily by the Late Wisconsinan continental ice sheet and the meltwaters of the receding ice. The upland and mountain areas are characterized by a thin veneer of glacial till with interspersed bedrock exposures. Ice contact and outwash sands and gravel, deposited locally along valleys in this sector, are sometimes associated with clay-silt deposits, 9,000 to 10,000 years old. The Seaboard Lowlands are characterized by extensive deposits of glacio-marine clay-silt (rock flour) and by extensive deposits of ice contact and outwash sands overlying till. Seismic reflection surveys in offshore areas indicate that till, ice contact, outwash, and glacio-marine clay-silt deposits are also distributed throughout the northern marine sector. The southern terminus of the last glacial advance is defined along the southern New England coast and Long Island by east-west elongate deposits of terminal moraine tills. To the south of the glaciated region, the continental shelf is blanketed by a veneer of Holocene clastic sediments, with local occurrences of deep channel fillings on an irregular pre-Pleistocene erosion surface[9].

2.5.1.1.2.3 New York/Great Lakes Sector

Surficial deposits in the New York/Great Lakes sector of the site region are glacially derived and cover the entire landmass (Figure 2.5-2), except for the areas of steep relief such as parts of the Hudson Valley, Adirondack Mountains, and Helderberg escarpment (Figure 2.5-1). The deposits were largely deposited by Late Wisconsinan continental ice sheet and associated meltwaters. The following description of features is after LaFleur[13].

At maximum extent, the last major continental ice sheet covered most of New York state and New England, north of Long Island and Staten Island. Ice thickness in the site area may have exceeded 3,000 ft, while sea level stood about 350 ft below that at present, exposing much of the continental shelf. The burden of the glacial mass produced regional downwarp of the earth's crust to the extent that the land surface in southern Quebec was depressed to some 1,000 ft below where it stands today. The periphery, or zero isobase of this depressed crustal zone, tended to coincide with the position of the ice margin at maximum extent (i.e., the latitude of New York City). As the glacier backwasted northward, meltwaters drained slowly through the lower Hudson Valley to a rising Atlantic Ocean. A thin glacial till is overlain locally by ice contact and outwash sands and gravels, throughout much of the sector.

A series of glacial lakes accompanied the wasting ice margin through the Hudson and Champlain Lowlands. The earliest was Lake Hackensack, confined

2034 306

south of the Hudson Highlands. Lakes Albany and Vermont followed, and a thick series of lacustrine clays were deposited in the basins. Lake Albany covered most of the Hudson River Valley. The ice sheet broke apart in the St. Lawrence Lowland, as the sea level continued to rise in that depressed basin. Marine waters then invaded much of the Champlain Lowland from the north. Continued crustal uplift of the St. Lawrence Lowland eventually drained the Champlain sea, and the present Lake Champlain came into existence (Section 2.5.1.1.1.7). Since Late Wisconsinan times, the Lake Albany clays have been eroded and redeposited in topographically low areas where they have been subsequently dissected by streams and tributaries. This cycle is common throughout the site area.

The surficial deposits of the Adirondacks are characterized by a thin veneer of glacial till with interspersed bedrock exposures. Throughout the valley areas, such as the Mohawk and Hudson Rivers, ice contact and outwash sands with numerous hanging delta deposits are common, along with a till blanket. The widespread lake clays of ancestral Lake Albany occur within the central Hudson River Valley. In central and western New York State, the bedrock is concealed by thin to thick deposits of glacial till and/or gravels. Surface features such as drumlins, eskers, and glacially-scoured lakes are common. The major east-west drainage divide of central New York, the Valley Heads moraine, is a recessional moraine south of the present Finger Lakes (Figure 2.5-2). The glacial tills and gravelly deposits of northern Pennsylvania were laid down by the earlier Wisconsinan ice sheets.

2.5.1.1.3 <u>Regional Bedrock Geology</u>

2.5.1.1.3.1 <u>Introduction</u>

The site is underlain by undeformed Ordovician sandstone and shales of the Eastern Stable Platform province. The regional bedrock geology surrounding the site is shown in Figure 2.5-3; a diagrammatic regional geologic profile showing major bedrock and structural elements is shown in Figure 2.5-4; and regional tectonic elements and provinces are shown in Figure 2.5-5. Discussions herein of the bedrock geology are segmented according to the tectonic provinces shown in Figure 2.5-5. Maps were compiled from many diverse sources which are on file with the project.

2.5.1.1.3.2 <u>Eastern Stable Platform (Site Province)</u>

The Eastern Stable Platform consists of two distinct geologic terranes: the Precambrian Grenville basement of the Frontenac Arch sector and southern Canada; and the overlying, essentially undeformed, nearly flat-lying series of Cambrian to Devonian sedimentary rocks (Figure 2.5-3). The Grenville basement rocks are described in Section 2.5.1.1.3.6.

In New York State, the Platform is characterized by east-west trending belts of relatively undisturbed Paleozoic rocks consisting of sandstones, siltstones, limestones, shales, and evaporite beds. The sedimentary series dips 40 to 50 ft per mi to the south in a homoclinal structure, and progressively younger beds crop out southward. The southward sloping

Precambrian basement surface produces an increase in the thickness of the Paleozoic rocks to approximately 18,000 ft[14] in southern New York State. A northeast trending belt of folds occur in the Auburn-Pulaski sector of the Platform (Appendix 2.5I).

A significant tectonic feature of the Platform within 200 mi of the site is the Clarendon-Linden structure that consists of near surface folds which become faults at 800 to 1,000 ft below the surface (Figure 2.5-5). No evidence for young deformation or Quaternary movement has been reported[15]. Several north-trending and west trending faults are known in central New York State; all are very old in age (Figure 2.5-5). For example, a number of small faults in Devonian rocks near Syracuse strike N70degW and exhibit a maximum displacement of 40 ft; they were apparently formed during the regional tilting and broad folding of central-southern New York State during mid-to-Late Paleozoic time.

The Platform province is the location of many small-scale folds, popups, and anticlinal features that occur throughout the upper St. Lawrence River sector and along the southern and western shore of Lake Ontario in New York State and in the Toronto-Hamilton area of Canada (Appendix 2.5A, 2.1). Most of the features are postglacial in origin; some were partly to wholly formed prior to the last ice advance.

2.5.1.1.3.3 Appalachian Plateau Province

The main Appalachian Plateau province consists primarily of a gently folded synclinal basin filled with sediments of Cambrian to Permian age that overlie the Grenville-like, Precambrian basement[16]. East of the site area, the Catskill Basin and Helderberg Highlands are local features within the broad province (Figure 2.5-1 and Section 2.5.1.1.1.3). In the New York State sector, the structure is part of the regional homocline that continues southward from the Eastern Stable Platform.

The northern and northwestern boundary of the Appalachian Plateau province is broadly marked by the Portage escarpment and, to the south, by gentle folds and some small faults (Figure 2.5-5). These features trend east-west, normal to the regional dip that continues southward from the Eastern Stable Platform (Section 2.5.1.1.3.5). The base of the folded and faulted sequence in central New York State is the Salina Formation (Silurian) consisting of several hundred feet of interbedded rock salt and dolomite. Prucha[17] suggests that the folding and faulting of the overlying strata are due, in part, to sliding or adjustment and decollement slip of the Appalachian Plateau that includes the southern part of New York State as confirmed by structures in the Cayuga Salt Mine in the core of the Fir Tree anticline near Ithaca. Movement within the evaporite beds near the top of the Salina Formation and decollement slip in the Appalachian Plateau Province has been further documented by the investigations of Engelder and Engelder[18].

The southern and eastern boundary of the Plateau province is the Appalachian Structural Front, the limit of highly deformed rocks in the Northern Valley and Ridge province (Figure 2.5-5 and Section 2.5.2.2.2).

The youngest known tectonic features in the province are Cretaceous mafic dikes and associated structures in central New York State[19]. Subsequent epirogenic uplift in Tertiary time occurred due to the great removal of sediment from the entire Appalachian system within the Plateau sector. The Ancestral streams were reactivated and began downcutting below the old peneplained surface. The Pleistocene ice sheets further sculptured and carved the surface bedrock into the present topography (Section 2.5.1.1.2.2).

2.5.1.1.3.4 Adirondack Mountains

The Adirondack Mountains represent a transitory phase in a geological history spanning at least 1,100,000,000 years. On the basis of the rocks exposed, it is impossible to reconstruct the entire sequence of Precambrian events; much of the record has been obscured or destroyed by many cycles of dynamic geological processes. Only the deep root zone of an ancestral mountain system remains, and some areas of critical structures are buried beneath glacial deposits and alluvium. However, from this fragmentary evidence, a reasonable reconstruction of the Precambrian geological history has been formulated[19].

Sometime earlier than 1,100,000,000 years ago (perhaps much earlier), all of eastern North America was the site of a long, narrow trough covered by a shallow sea. In this geosyncline, sediments were deposited from an adjacent landmass on the west and probably a continental mass on the east (ancestral Africa before drift).

With the passage of time, the ancient geosyncline became loaded with sediments (i.e., submarine lavas and volcanic ash-falls, sand, mud, and calcium carbonate). The growing accumulation of debris caused the geosyncline to sag slowly, and the sediments gradually were compacted and cemented into rock. The prism of sedimentary rock in the geosyncline ultimately reached a thickness of perhaps 40,000 ft. At that time, tectonic forces began buckling and thrusting the wedge of sediments to form a high-standing, deep-rooted mountain system.

Throughout the ancestral mountain system, the deformation profoundly folded and disrupted the original sediments. As a result of extremely high temperatures and intense pressures in the mountain root zone, the rocks recrystallized into gneisses, marbles, and other metamorphic rock types, while some units became mobile and flowed. Others, such as granite, melted and invaded adjoining rocks. The Precambrian crystalline rocks are similar to those of the Canadian Shield/Grenville province.

The early Precambrian mountain range was reduced to sea level by erosive forces. The Adirondack region was subsequently subjected to at least one, and possibly two or more, Precambrian mountain building episodes. The mountains of today represent a rebirth of part of the ancient, bevelled Precambrian root zone as a result of doming in Paleozoic and later time. At the beginning of Cambrian time, some 600,000,000 years ago, the Adirondacks were rather high mountains supplying sediments to the surrounding sectors. DeWaard[20] estimated that the crystalline rocks exposed in the Adirondacks have been

uplifted as much as 19 to 22 mi. The Paleozoic rocks thicken in all directions away from the circular outcrop of the Adirondacks.

The Adirondack Mountains were strongly deformed in Early and Middle Paleozoic time by the Taconic and Acadian Orogenies of at least 435,000,000 and 350,000,000 years ago, respectively. Many of the large scale faults and regional structures formed during these Paleozoic Orogenies are prominent features today and can be traced several miles into the onlapping sedimentary rocks (Figure 2.5-3) as long, northeast-southwest lineaments; they frequently control drainage and landforms. The Adirondacks are covered in large part by widespread glacial deposits (Section 2.5.1.1.2.2).

2.5.1.1.3.5 <u>Frontenac Arch Sector of Eastern Stable Platform</u>

The portion of the Frontenac Arch Sector within the 200-mile region is characterized by a metamorphosed complex of Lower and Middle Proterozoic gneisses and migmatites, quartzites, marbles, and other metasediments that are locally intruded by granites and syenites of Grenville age. The rocks of the Grenville series have radiometric ages of some 1,100,000,000 years, and are the oldest rocks in the region[18].

The Grenville series was formed by marine deposition of thick deposits of mud, sand, and calcareous materials (over 1,100,000,000 years ago). The sediments were lithified into a sequence of shale, sandstone, and limestone which reaches a maximum thickness of about 9,400 ft in the sector north of Lake Ontario. The rocks subsequently underwent three periods of folding with local intrusions of mafic and felsic igneous rocks and diabase dikes. One protracted period of regional/ dynamic metamorphism occurred. These events represent the last major Precambrian orogeny in northeastern North America[21].

The Grenville Orogeny was followed by a long interval of geologic time during which erosion bevelled the Precambrian (Proterozoic) rocks to a low-lying topography. During Paleozoic time, at least part of the terrane was covered by sedimentary rocks which have since been stripped away.

2.5.1.1.3.6 <u>Western Quebec Seismic Zone</u>

The Western Quebec Seismic Zone is characterized by a central, closely faulted sequence of Cambrian-Ordovician sandstones, shales, and limestones and a broad belt of Precambrian Grenville-age rocks which are bordered to the north and south by highly deformed Grenville-type Precambrian rocks of the Laurentian and Adirondack Mountains[22].

Cambrian-Ordovician strata in the Western Quebec Seismic Zone include the following rock units within New York State and Canada: Potsdam Sandstone, Beekmantown Dolomite, Chazy Limestone and Sandstone, Black River Dolomite, Trenton Limestone, Canajoharie/Utica Shale, and the Lorraine and Queenston Shales and Sandstones. These rock units range from 10 to 1,000 ft thick.

Intruded into this Cambrian-Ordovician sequence are a series of Mesozoic alkaline intrusions, which locally result in doming of the adjacent strata. Compositionally, these intrusions range from carbonatite to alkaline gabbro to syenite[23].

Grenville-type rocks consist of a series of compositionally and structurally complex Proterozoic rocks, as described in Section 2.5.1.1.3.6. Within the province, the metamorphosed complex of the Laurentian Mountains are variable and consist of anorthosite, gabbro, charnockite, amphibolite, granodiorite, and granite migmatite. The Adirondack uplift sector is also underlain by Grenville age rocks, as described in Section 2.5.1.1.3.4.

The Western Quebec Seismic Zone is marked by numerous high angle faults (i.e., Ottawa-Bonnechere graben), including the Winchester Springs and the Gloucester faults (Appendix 2.5A) with maximum displacement of some 1,700 ft[22]. Faults trend predominately northwest and swing to the northeast near Montreal. Associated with faulting are numerous deep seated alkaline intrusives, carbonatites, mica peridotite pipes, and diatreme breccias. Alkaline intrusions form a series of alignments subparallel to this fault system. Larger alkaline intrusions are exposed or inferred at many junctions of the alignments.

The Western Quebec Seismic Zone is marked by alkaline magmatic activity ranging from Precambrian to Cretaceous in age[24,25]. Widespread normal faults are the youngest known tectonic events, as described in Section 2.5.2.2.11 and are post-Ordovician in age.

2.5.1.1.3.7 <u>Northern Valley and Ridge Province</u>

The Northern Valley and Ridge province within the region is characterized by the main folding and thrust-faulting of the Appalachian system (Figure 2.5-3 and Section 2.5.1.1.4.2). The Paleozoic rocks of Cambrian Devonian age (and younger to the south) are deformed into a major northeast- to northward-trending series of anticlines and synclines and/or thrust ridges. Today, they occur as parallel or subparallel ridges and valleys with 1,000 to 2,000 ft of local relief. The Cambro-Ordovician limestones and shales occur beneath the deeply scoured valleys, and the ridges are generally composed of more resistant Middle and Upper Paleozoic sandstones and conglomerates southward in Pennsylvania.

Rocks of the province are part of the series that comprise the Appalachian geosynclinal sedimentary history (Figure 2.5-6). Deposition which began in Cambrian time and continued throughout much of the Paleozoic resulted in the formation of shales, sandstones, conglomerates, and limestones. Deformation progressed throughout the Paleozoic, beginning with the Taconic Orogeny (450,000,000 to 500,000,000 years) with further activity during the Acadian Orogeny (350,000,000 to 400,000,000 years ago) and Pennsylvanian and Permian time (230,000,000 to 260,000,000 years). This activity included the development of a strong angular unconformity, some gravity sliding of large blocks/slices of allochthon (slope sequence rocks) along with low-grade metamorphism, granite and ultramafic intrusions, and further faulting during

the Taconic Orogeny; medium- to high-grade metamorphism, granite intrusions and a reactivation of faulting with one episode and, in some places, two separate episodes. In the southern and western edge of the province further folding and faulting occurred as the youngest compressional deformation activity, the Alleghenian Orogeny, near the end of Paleozoic time. In the Valley and Ridge province final extensional faulting occurred during Early Mesozoic time[7].

The geologic history of the province within the site area, from the initiation of the Precambrian landmass on the east through the Taconic and Acadian tectonic activity and resulting structural features, is described in Section 2.5.1.2.5.2.

Deformation of the near-surface Paleozoic rock sequence and the relationship of the underlying Precambrian basement has been interpreted in two different ways, as described in Section 2.5.1.1.4.7.

The province was subjected to prolonged erosion throughout Mesozoic time. Broad uplift of the Appalachian system in Tertiary time reactivated streams which downcut below the ancient peneplained surface and formed the young topography[7]. The Pleistocene ice sheets scoured and further modified the surface, as described in Section 2.5.1.1.1.2.

The dashed zone in Figure 2.5-5 is one interpretation[7] of the boundary between the Piedmont and the Northern Valley and Ridge provinces which, on its northeastern end, essentially coincides with the series of small en echelon normal faults of the Ramapo Fault system in northeastern New Jersey. A second interpretation[26,27] places the province boundary at the base of a steep regional gravity gradient as shown by a solid line in Figure 2.5-5.

2.5.1.1.3.8 New England-Maritime Province

The New England Foldbelts

The fabric of the bedrock structure in the New England province is grossly characterized by a series of elongate belts of folded and faulted metamorphic rocks with included plutonic masses of Early to Middle Paleozoic age. The most western rock groups strike as discrete anticlinoria and synclinoria from southern Connecticut northerly through Massachusetts and Vermont. The more easterly of these belts are north-trending in eastern Connecticut and central Massachusetts, and swing gradually to the northeast through New Hampshire to Maine.

The westernmost of these foldbelts, the Green Mountain anticlinorium, contains a folded/faulted core of Precambrian (Grenville age) basement rocks enclosed by Early Paleozoic sedimentary rocks. It is delimited along its eastern edge by a discontinuous chain of ultramafic intrusive rocks which may reflect the location of an Early Paleozoic continental edge. Roughly parallel to the western edge of the anticlinorium is a steep gravity gradient (Figure 2.5-5) which defines the boundary between the crustal plate of the New England foldbelts and that of the central craton[26].

2034 312

Foldbelts to the east of the Green Mountain anticlinorium contain Early to Middle Paleozoic eugeosynclinal metamorphic rocks, with locally included domes of Ordovician plutonic and volcanic rocks and elongate bodies and irregular masses of Middle Devonian granitic intrusives. Foldbelts to the west of the Merrimack synclinorium (Figure 2.5-5) first experienced fold and thrust deformation by westerly directed compression during the Taconic Orogeny in Ordovician time, with the last orogenic deformation occurring there at the time of crustal consolidation of geosynclinal sediments in the Merrimack synclinorium, during the Acadian Orogeny of Early Devonian time[6].

The Connecticut Valley contains shales and sandstones of continental origin, interbedded with diabase flows. These formations were deposited in a rifted basin structure, formed during Triassic and Jurassic time, by continental separation and the final opening of the Atlantic Ocean. The subsequent fracture deformation of the basin is interpreted to have been by left lateral faulting oriented toward the north-northeast[5].

The Merrimack synclinorium, largest of the several foldbelts, ranges up to 75 mi in width across a belt from southwestern Maine to northwestern New Hampshire, in a "hinge" zone where the overall strike of the belt swings from a north to a northeasterly trend. The bedrock fold structure in this "hinge" zone is commonly transverse to the regional northeast fabric of the foldbelt, with local areas of northwest striking bedrock folds, northwest-oriented plutonic masses of Devonian age, and a north-northwest-oriented pattern of emplacement of central complex intrusives of Permo-Triassic to Middle Cretaceous ages (the White Mountain plutonic series)[28].

2.5.1.1.3.9 Piedmont Province

The Piedmont Province in the site region is characterized by Precambrian basement and early Paleozoic metamorphic rocks intruded by Paleozoic plutons. The basement rocks are deformed into a northeast trending fabric and within the complex of metamorphic rocks are many structural basins of Triassic siltstones, sandstones, shales, and conglomerates that occur from New Jersey to Georgia. The province is generally blanketed by a residual mantle of weathered rock, saprolite, which increases in thickness southward. The principal tectonic features and ages are described in Section 2.5.1.1.4.9.

The dashed line in Figure 2.5-5 is an interpretation[7] of the boundary between the Piedmont and the Northern Valley and Ridge provinces as described in Section 2.5.1.1.3.2.

2.5.1.1.4 Regional Tectonics

2.5.1.1.4.1 Introduction

The major tectonic elements of the site region are shown in Figure 2.5-5, as are as are the boundaries by which the region can be subdivided into provinces having distinctive structural characteristics or origins. These provinces were formed by fundamental tectonic episodes which occurred at times in the geologic past ranging from about 100,000,000 years ago to more than

500,000,000 years ago, in response to stress regimes which are not active today. Some of the provinces have undergone major deformational effects from two or more different stress regimes; some have experienced only minor or localized tectonic modifications in the course of as much as 1,000,000,000 years.

Each province appears to have a reasonable degree of consistency relative to specific structural features impressed upon it by ancient compressional or tensional stress regimes (or lack thereof). Although the provinces as shown in Figure 2.5-5 are reflective of ancient stress regimes, they are probably not related to modern, relatively low magnitude crustal stresses in any demonstratable way. Of more importance is the orientation of the present day stress field relative to zones of weakness or other mechanical discontinuities (density, rigidity, geometry) which may result in localized stress concentrations within a province.

2.5.1.1.4.2 Eastern Stable Platform (Site Province)

The Eastern Stable Platform is bounded on the north, east, and south by the Frontenac Arch Sector and the Adirondack and Appalachian Plateau provinces, respectively. The western boundary of the Platform is defined by the subsurface trend of the Grenville Front, which passes southerly from the west end of Georgian Bay, Ontario (300 mi west-northwest of the site), beneath Lake Huron, through eastern Michigan, west-central Ohio (about 420 mi west-southwest of the site), and into northern Kentucky[29] where it is apparently displaced to the west on the Kentucky River fault zone[30]. To the east of the Front, basement rocks are of Grenville age and to the west, the basement is largely of Hudsonian age (about 1,700,000,000 years), with evidence of further broad deformation in Elsonian time (1,350,000,000 years) and crustal rifting and volcanism in Keweenawan time (about 1,100,000,000 years[21]).

The buried surface of the Grenville basement in the Eastern Platform is relatively elevated in the northwestern part of the province along the Algonquin axis and Findlay arch, in southwestern Ontario and west-central Ohio, respectively, and slopes gently to the south and east from these topographic highs. Overlying the gently sloping basement surface throughout the province are essentially undeformed, nearly flat-lying sedimentary rocks which range in age from Cambrian to Permian. Faulting is localized, having been identified from surface exposures in northwestern Ohio and southwestern Ontario, and interpreted at depth from drillhole data in western New York, south of Lake Ontario (Figures 2.5-3 and 2.5-5) and exposures in excavations.

The principal structural feature of the central New York sector of the Eastern Stable Platform is the southward-dipping homocline which continues uninterrupted into the Appalachian Plateau Province. Origin and characteristics of the regional dip and associated folding/faulting are described in Section 2.5.1.1.4.3, as both features have been investigated more extensively within the Appalachian Plateau Province.

2034 314

Within 200 mi of the site, normal faulting has displaced sedimentary rocks of the Platform in several areas in New York[31] and one area in southern Ontario, on the south and north sides of Lake Ontario. In the two areas to the south of Lake Ontario and west-northwest of the site, south-trending normal faults are interpreted to pass beneath, but not displace Lower Silurian rocks. The significant tectonic feature of the Platform approximately 85 mi west of the site is the Clarendon-Linden structure and a number of small faults described in Section 2.5.1.1.3.2. Broad low folds are common in the Paleozoic rocks such as the Demster Point anticline and New Haven syncline of the Auburn-Oswego/Mexico-Pulaski sector (Figure 2.5-5A). Sometimes modest scale faulting is associated with these feactures, such as the Demster Structural Zone (Figure 2.5-5A).

Another notable structural feature is the Colton-Carthage mylonite zone of Precambrian mylonite, augen gneiss, and ultramylonite[32] that extends in a sinuous manner from Carthage to Colton, New York (Figure 2.5-5A). This northwest-dipping zone is a fundamental boundary and contact/fault zone[33] between contrasting Precambrian rock types: the northwestern lowland of amphibolite-grade, Grenville series and metasediments of the Eastern Stable Platform; and the high-grade granulite facies, gneisses, plutonic rocks, and associated metasediments of the Adirondacks.

Garnet-cordierite gneiss, marble and calc-silicate of the Grenville Series in the St. Lawrence lowlands have undergone four periods of folding while the meta-igneous rocks have undergone three folding phases across the Colton-Carthage zone[34]. There is no major post-intrusive displacement along the Colton-Carthage zone[33]; strike-slip and other fault movements occurred in Precambrian time.

The Colton-Carthage zone appears as a prominent aeromagnetic linear on the U.S. Geological Survey aeromagnetic map[36] (Figure 2.5-5B). The magnetic signature of the Colton zone dies out north of the site area to the north of Pulaski, New York. The geophysical anomaly is due to the contrasting rock types/structures that comprise the Colton Zone.

2.5.1.1.4.3 <u>Appalachian Plateau Province</u>

The Appalachian Plateau province in the site region consists primarily of a homoclinal structure of southward-dipping Paleozoic rocks that rest on the Grenville-like, Precambrian basement. The main Plateau province in Pennsylvania and southward is a broad synclinal basin feature characterized by a thick mass of red shale and sandstone.

The northern and northwestern boundaries of the Appalachian province is broadly marked by the southern limit of the known Paleozoic faults that extend south from the Adirondack Mountains, the Portage escarpment, and the northern extent of gentle folds and small faults that occur on an east-west trend normal to the regional dip (Section 2.5.1.1.3.3); gentle northeast trending folds occur northward in the Eastern Stable Platform. The southern and eastern boundary of the Plateau province is the Appalachian Structural Front

and the highly deformed rocks of the Northern Valley and Ridge province (Figure 2.5-5).

Origin of Folding

The general features relevant to the regional dip and the superimposed folding of central-southern New York were recognized many years ago by Vanuxem[37] and Hall[38]. Sherwood[39] traced some of the Pennsylvania folds into New York State, such as the Crooked Creek (Pine Creek) syncline, the Sabinsville anticline, and the Cowanesque syncline (Figure 2.5-5A). Williams[40] described the parallel folds which decrease in strength northwest from Pennsylvania.

The most complete discussion on the folds and geologic structure of south-central New York is by Wedel[41]. He located, mapped, interpreted their probable relation, and suggested an origin. His work is the basis for the major fold structures shown in Figure 2.5-5A and is a principal source of information on the folds.

Prucha[17] confirmed decollement slip movement as a principal cause of deformation for some of the folding in his investigation of structures in the Salina salt beds and in the Cayuga Rock Salt mine located in the core of the Firtree Point anticline (Figure 2.5-5A). Below the well-defined base of thin-skinned folding within the thick salt beds (Salina Group of Late Silurian) at 1,000 ft underground, the rock units are undeformed and show only a southward regional dip.

Rodgers[7] prepared a map of the Appalachian foreland and delineated the folds of New York, southwestward across Pennsylvania and West Virginia.

Earlier in 1963, Rodgers[42] described the decollement slip movement responsible for the folding of Burning Springs anticline, a fold in the foreland of the Appalachian Plateau of West Virginia. Furthermore, he speculated that the salient folds of central New York (Figure 2.5-5A) may be due to a similar origin: a shift of large blocks along strike-slip faults.

Engelder and Engelder[18] have investigated the origin of the folds of the Appalachian Plateau with respect to large-scale decollement slip. They have calculated a 10-percent shortening of upstate New York normal to the fold trend. Other investigators have yet to accept this explanation for large-scale shortening (Prucha[43] and Wallick[44]).

An impressive feature of the Appalachian Plateau fold structures is the departure from the general trend of the folding, which may be a reflection of inherent weaknesses in the rock column, localized adjustments at the time of deformation, or structural weaknesses in the basement. The change in trend of the large continuous folds in south-central New York (Figure 2.5-5A) is related spatially and, apparently, in origin to the salients of the appalachians.

2034 316

The southward-dipping regional homocline of the Appalachian Plateau and Eastern Stable Platform provinces was formed in mid- to late-Paleozoic time by one or more possible causes. Generally, investigators relate the tilting of Paleozoic strata to phases of the folding/faulting of the Alleghenian orogeny.

Regional Dip and Folding

The regional dip of the strata is generally consistent throughout central-southern New York (both the Eastern Stable Platform and Appalachian Plateau Sectors). The Paleozoic formations crop out in bands that trend east-west, but in the western part, the younger formations swing southward.

The prominent regional dip of Paleozoic beds may have originated in one of three periods relative to the time of the main thin-skinned folding and deformation of mid- to late-Paleozoic:

1. Tilting occurred before folding
2. Tilting occurred contemporaneous with folding as a result of the same forces
3. Tilting occurred after folding

The relatively uniform formational thicknesses and the evidence that tilting did not occur before Devonian time eliminates the concept of the dip originating as a function of sedimentation.

Kindle[45] suggested that the first possible origin of regional tilting was produced by the Canadian uplift, presumably near the close of the Devonian. Uplift of the Adirondacks could likewise be suggested as a similar source for tilting in the eastern sector (Hypothesis No. 4, Appendix 2.5I.6.4). The Precambrian basement surface generally dips uniformly southward throughout central-southern New York.

If post-Devonian sediments were absent over most of central New York and deposition largely ceased at the close of the Devonian, then differential uplift could have occurred during this period, thereby tilting the strata southward (related to Hypothesis No. 3, Appendix 2.5I.6.4).

This proposed origin of the tilt would physically accentuate the dip to the southwest in New York due to down-sinking of the overall Appalachian basin, the site of continuing sedimentary accumulation on through the Pennsylvanian time southward in Pennsylvania. Formations in the rock column are essentially parallel and of equal thickness over a wide area. Evidence indicates tilting did not occur before the end of Devonian time.

Furthermore, if tilting occurred before folding, then the gentle folds of south-central New York (Figure 2.5-5A) were superimposed on a preexisting regional tilt. The folding logically occurred as part of the Alleghenian orogeny (Mississippian-Triassic). Yet, another objection to tilting first concerns the regional dip, which does not increase to the north or northeast

as the center of the Canadian uplift or Adirondack uplift is approached. However, there are examples of regional dips on a large scale with no definite known center of uplift, as the Prairie Plains monocline of Kansas, Oklahoma, and Texas.

A second possible origin for the regional tilting is that it occurred at about the same time as the folding. Deposition in south-central New York may have ceased by the end of Devonian time or soon thereafter (Figure 2.5-6); deposition ceased in the Rochester area at the end Devonian time according to Kinsland[46], Dott and Batten[47], and Seyfert and Sirkin[48]. However, in the southwestern part of the basin in New York/Pennsylvania, sediments of Mississippian and even Pennsylvanian ages were deposited. An estimate of the thickness of overlying Devonian sediments removed in the site area (approximately 5,500 ft) is shown on Figure 2.5-6 and assumes non-deposition of some Silurian carbonates that occur in western New York. Peneplains developed after the folding; Cretaceous erosion surfaces have been traced from Pennsylvania northward into New York and suggest that a considerable amount of overburden has been eroded[49]. If the regional dip was impressed on central-southern New York at the time of the folding, it was by differential stresses, at least part torsional in nature.

A third possible time of regional tilting is after the folding. However, if the regional dip was produced after folding ceased, the tilting was completed before the Cretaceous peneplains were developed[49]; these peneplains can be traced into Pennsylvania at an average slope of only a few feet to a mile. Furthermore, the broad folds of the site area (Figure 2.5-9), such as the Demster Beach anticline, do not exhibit features of tilting subsequent to folding.

A westward component in the regional dip causes Paleozoic formations in southwestern New York to dip southwest. Thinning alone is not of sufficient magnitude, nor in the right direction to account for this marked change. The increase in the westward component of regional dip becomes evident around the Seneca Lake sector where the marked change in trend of the fold axes occurs (Figure 2.5-5A).

An obvious possibility for the southwest dip is irregular doming in the northeastern part of New York. However, this cause alone would not form the consistent and uniform regional homoclinal structure of central-southern New York.

If the tilting of beds and westward component of dip was caused by basin-wide subsidence (Hypothesis No. 3, Appendix 2.5I.6.4), this activity could have contributed to the buildup of stresses ultimately responsible for the widespread folding throughout central-southern New York and northern Pennsylvania (Appalachian Plateau Province).

Post-Folding Events

Extended erosion bevelled the ancestral Appalachian mountains and reduced the surface to a flat plain in Tertiary time. The removal of the thick cover was

accompanied by some normal faulting and igneous activity, probably during Jurassic-Cretaceous time (in central New York State). This activity included emplacement of the ultramafic dikes and some small structures.

Widespread regional uplift occurred again a few million years ago, and the province has undergone a rejuvenation of the erosion cycle since that time. No tectonic deformation is known to have occurred within the past tens of millions of years in the province. Small-scale, nontectonic deformation associated with the glacial history/features is common (Appendix 2.5A).

2.5.1.1.4.4 Adirondack Mountains

The Adirondack Mountains represent only the deep-root zone of an ancestral Precambrian mountain system. Some important structural features are buried beneath glacial deposits and alluvium. The tectonic province is here defined as bounded on the north by the Western Quebec Seismic Zone; on the south by the Northern Valley and Ridge province; and on the south and west by the Appalachian Plateau, and the Eastern Stable Platform and the Frontenac Arch Sector. The geologic history is described in Section 2.5.1.1.3.4.

A Precambrian geosyncline became the location of sediment deposition at least 1,100,000,000 years ago and subsequently tectonic forces deformed the wedge of sediments to form a high-standing, deep-rooted mountain system. The early Precambrian mountain range was reduced to sea level by erosive forces and the Adirondack region was subjected to at least one, and possibly two or more, Precambrian mountain-building episodes.

The Adirondack Mountains were strongly deformed in Early and Middle Paleozoic time by the Taconic and Acadian Orogenies of 435,000,000 and 350,000,000 years ago, respectively. Many of the large scale faults and regional structures formed during these Paleozoic orogenies are prominent features today and some can be traced and inferred many mi into the onlapping sedimentary rocks (Figure 2.5-3) as long, northeast-southwest lineaments; they frequently control drainage and landforms. Studies of recent ERTS-1 imagery have delineated a series of linears and/or joint patterns throughout the Adirondack domal uplift(50). However, to date, no tectonic features younger than Acadian are known. Some investigators have suggested younger activity and even that the Adirondack Mountains are rising(51). However, field data to support this hypothesis and the possibility of Cenezoic faulting in the Lake George sector was analyzed. The Lake George anomaly was not substantiated (Appendix 2.5B) as a young fault. Furthermore, possible evidence for Quaternary seismic events in the northwestern sector of the province and the St. Lawrence Lowland by Coates(52) was analyzed in the field, and the reported features were determined to be glacial in origin and not seismically induced (Appendix 2.5A.3).

The limits of the Adirondack Mountain province along the south and west are arbitrary; some locate the boundary at the outcrop of the Precambrian basement(1), others at the Helderberg escarpment south of the Mohawk River, and other at known limits of the Paleozoic faults that extend south of the Mohawk River. The latter interpretation of the Adirondack province boundary

2034 319

has been used in this report (Figure 2.5-5) and, thus, the province borders on the Appalachian Plateau province.

2.5.1.1.4.5 Frontenac Arch Sector of Eastern Stable Platform

The Frontenac Arch Sector in the site region is characterized by a metamorphosed complex of Lower and Middle Proterozoic gneisses and migmatites, and sediments locally intruded by granites and syenites of the Grenville age, all now having a radiometric age around 1,00,000,000 years. Here, the tectonic province is defined as bounded on the northwest by the Grenville Front, about 270 mi northwest of the site; on the northeast by the graben structure of the Western Quebec Seismic Zone; and on the southeast by the Highlands Boundary Fault[21]. To the south, Grenville rocks slope gently beneath an increasingly thick cover of essentially undeformed sedimentary formations of Paleozoic age, and form the basement for the Eastern Stable Platform.

2.5.1.1.4.6 Western Quebec Seismic Zone

The Western Quebec Seismic Zone is characterized by a central, sequence of Cambrian-Ordovician sandstones, shales, and limestones and a broad belt of Precambrian Grenville age rocks, bordered to the north and south by highly deformed Grenville-type rocks of the Laurentian and Adirondack Mountains.

The zone is marked by numerous, high-angle faults (i.e., Ottawa-Bonnechere graben), including the Winchester Springs and the Gloucester faults (Appendix 2.5A). Maximum displacement along the faults is approximately 1,700 ft[22]. Faults trend predominantly northwest and swing to the northeast near Montreal. Associated with faulting are numerous mantle-derived alkaline intrusives, carbonatites, mica peridotite pipes, and diatreme breccias. Alkaline intrusions form a series of alignments subparallel to this fault system. Larger alkaline intrusions are exposed or inferred at many junctions of the alignments. Geophysical studies by Diment[26], King[53], and Williams[22], along with investigations reported in Appendix 2.5A have verified the existence of these fault alignments.

The Western Quebec Seismic Zone is marked by alkaline magmatic activity ranging from Precambrian to Cretaceous in age[24,25]. Cretaceous, nonorogenic alkaline magnetism and widespread normal faulting are the youngest known tectonic events. Kumarapeli[54] recognizes three phases of normal movement (i.e., Pre-Ordovician, Ordovician, and Post-Ordovician). However, Beland[55] citing geophysical evidence, indicates no important movement since Ordovician time.

Generalized mapping[56] has precluded the possibility of extending the so-called St. Lawrence rift up the St. Lawrence River to Lake Ontario, which had been postulated by Kumarapeli and Saull[57].

Sbar and Sykes[40] and Saull and Williams[59] believe that the region is now in compression with the maximum principal stress oriented east to northeast. Release of such a stress would result in wrench faulting along preexisting

northeast- and northwest-trending normal faults. Stress data are scattered and insufficient to make a meaningful interpretation of the stress regime throughout the zone. There is no evidence of surface displacement accompanying any historical earthquake.

The close, spatial relationship between the Massena earthquake epicenter and the Gloucester fault, suggests a possible structural correlation (Figure 2.5-25).

2.5.1.1.4.7 Northern Valley and Ridge Province

The folded and thrust faulted Northern Valley and Ridge province is a major structural belt of the Appalachian system[7]. The province is bounded on the east by the New England-Maritime province, on the southeast by the Piedmont province, on the west and northwest by the Appalachian Plateau, the Adirondack Mountains, and the Western Quebec Seismic Zone. The Paleozoic rocks of the province are underlain by the Precambrian basement rocks similar to those in the adjoining Piedmont province.

The prominent northeast-trending folds and thrusted structures have long been described as the result of strong pressure from the southeast which folded the great anticlines and synclines, and in places overturned them toward the northwest. Deformation has been considerably more intense than in adjoining regions, and investigators have long argued over two possible causes:

1. Deformation is primarily in the underlying basement and the structures observed in the overlying strata are merely a reflection of that in the basement[60,61,62].

2. The original concept that all deformation is largely confined to the Paleozoic rocks overlying the basement[63].

Deformation of the province rocks progressed throughout Early-Middle Paleozoic time beginning with the Taconic Orogeny (450,000,000 to 500,000,000 years), and with further activity during the Acadian Orogeny (360,000,000 to 400,000,000 years)[64]. The youngest activity occurred during Pennsylvanian and Permian time (230,000,000 to 260,000,000 years), in a sector to the south. Final extensional faulting occurred during Early Mesozoic time (190,000,000 to 180,000,000 years). By one interpretation[7], the Ramapo fault in northeastern New Jersey forms the southeastern boundary of the province. By another interpretation[26,27], the Ramapo fault system lies near the central part of the province.

2.5.1.1.4.8 New England-Maritime Province

The gross character of the New England province is that of a series of north-to northeast-trending foldbelts formed by two periods of orogenic compression in Ordovician and Devonian times. From west to east, these major foldbelts are the Green Mountain anticlinorium and the Connecticut Valley synclinorium[65]. The predominant trend of faulting parallels the foldbelts. Many of these longer faults were initially formed as a result of orogenic

forces. Some, such as the border fault of the Connecticut Valley and the Ammonocosuc fault may represent older Paleozoic fault structures which were reactivated during Late Paleozoic continental translation or Mesozoic crustal extension.

2.5.1.1.4.9 Piedmont Province

The Piedmont Province in the site region is characterized by a Precambrian basement and Early Paleozoic metamorphic rocks intruded by Paleozoic plutonic rocks[7]. Within the basement rocks are structural basins of Triassic sediments (Section 2.5.2.2.11). The Piedmont is a relic structural province of Paleozoic-Mesozoic time. The tectonic province is herein defined as bounded in the east by the Northern Coastal Plain and on the west-northwest by the Northern Valley and Ridge province. The Piedmont province may terminate near the northern New Jersey state line (dashed line in Figure 2.5-5), or near the easternmost corner of Pennsylvania (solid line in Figure 2.5-5) against the southwestern projection of the southern boundary of the New England-Maritime province.

The youngest tectonic structures in the province are the Triassic-Jurassic faults associated with the Triassic basin features[66]. Last movement on the faults of at least 135,000,000 years has been determined by extensive studies within the Piedmont, south of the region (Section 2.5.2.2).

The Ramapo fault is a prominent feature in the province in the vicinity of northern New Jersey. The fault system has been extensively studied and investigations report that last movement has occurred since the Triassic sediments lithified and prior to Cretaceous time[67,68,69]. The Ramapo system may either coincide with the northern boundary of the Piedmont province[7], or may lie to the north of the Piedmont rocks in the Northern Valley and Ridge province (Figure 2.5-5).

2.5.1.1.5 Regional Geologic History

2.5.1.1.5.1 Introduction

The bedrock of the site region (Figure 2.5-3) ranges in age from Precambrian Y (roughly 1,000,000,000 years old) to Middle Cretaceous (about 100,000,000 years old), and in lithology from predominantly crystalline metamorphic and igneous rocks in the Piedmont, New England, Adirondacks, and Precambrian provinces to unmetamorphosed sedimentary rocks lying on a buried Precambrian cratonic basement in the Appalachian Plateau and Eastern Stable Platform areas (Figure 2.5-3). In New England and the Piedmont, Juro-Triassic continental deposits occur in supracrustal rift basins, and on the Southeastern New England Platform, continental deposits of Carboniferous age occur in intermontane and fault-bound basins on a Late Precambrian (550,000,000 to 650,000,000 years ago) Z basement terrain. In southeastern New Jersey and in offshore areas, the basement rock is covered by loosely consolidated sediments of Late Cretaceous to Tertiary age (about 100,000,000 to 20,000,000 years old). Much of the northern three-quarters of the region is covered by a

relatively thin veneer of loose, unconsolidated sediments of Pleistocene and Recent age (commonly less than about 25,000 years old).

The major historical episodes which have created the present structural configuration are described by ages. (The principal references used in developing the historical summary include: Ballard[70]; Billings[71]; Bird and Dewey[72]; Cameron and Naylor[73]; King[10]; King and Beckman[74]; Rodgers[7]; Sloss[75]; Woodward[76].)

2.5.1.1.5.2 Paleozoic

By the close of Precambrian time in the region surrounding the site, much of the Precambrian craton, including the Canadian Shield and its broad southern extension into the area of middle North America, had been reduced by a long period of subareal erosion to a low, broad landmass. Around the borders of this North American craton, the land was subsiding to initiate the development of geosynclines which were to constitute the mobile belts and the site of major orogenic activity throughout Paleozoic time.

Cambrian

By the start of the Cambrian period, the northeast-trending Appalachian geosyncline had formed in the proto-Atlantic Ocean which filled the gap between continental plates. The outer miogeosynclinal zone was receiving clastic shelf sediments at this time and fine-grained sediments were deposited in the eugeosynclinal deep to the east. Gradual submergence of the interior platform to the west continued through Cambrian time, with deposition of basal quartz sands, followed by carbonate deposition as the sea deepened across the craton. In upstate New York and Pennsylvania, a shallow sea was receiving sediments from an eastern landmass.

Ordovician

Depositional patterns of the Late Cambrian continued through Early Ordovician time with the deposition of predominantly calcareous materials in the miogeosyncline and onto the interior platform, and with argillaceous sedimentation in the eugeosyncline to the east. The first sequence of Paleozoic continental submergence ended at the close of Early Ordovician time with the widespread emergence and erosion of the interior landmass.

By Middle Ordovician time, orogenic activity and uplift in the eastern geosyncline created a landmass along the eastern edge of the continent. The Taconic Orogeny of this period (435,000,000 to 455,000,000 years ago) was initiated by a convergence of crustal plates in western New England, with development of an island arc along the zone of the present Bronson Hill anticlinorium; with the westward-directed compression raising blocks of Precambrian Y basement (1,100,000 to 840,000,000 years ago) upward to the west on imbricate thrust planes[77]; and with the transporting of masses of the overlying eugeosynclinal deposits to the higher areas of the uplift, from which they migrated as submarine gravity slides downslope farther to the west, thus forming the Taconic allochthon[78].

With gradual subsidence of the craton to the west, clastic sediments from the eastern uplift were deposited in shallow seas to the west as sand, shale, and carbonate deposits over the early Middle Ordovician erosional surface of the interior platform. Subsidence of the interior craton at this time was not geographically uniform, and the development of broad basins and intervening arches on the basement in east-central United States was initiated. Throughout Upper Ordovician time, continued erosion of the eastern uplands and gradual subsidence of the interior platform spread shaly sediments westerly from the eastern uplands to the Mississippi River area.

Silurian

Carbonate deposition predominated throughout the Silurian, with the development of a wide, shallow sea over the interior platform. In Middle Silurian time, carbonate reef formation was widespread, enclosing broad restricted basins where in Upper Silurian time salt, anhydrite, and gypsum accumulated in areas subject to rapid evaporation. The broad tectonic basins and intervening topographic arches which had begun to form on the inner craton during Ordovician time increased in size and number. By the end of Late Silurian time, the interior seas had shrunk to expose wide areas to subareal erosion.

Continued orogenic activity from place to place in the eastern geosyncline maintained discontinuous land areas along the eastern edge of the continent, which provided clastic sediments to the miogeosynclinal zone during Middle and Upper Silurian time, following Latest Ordovician Early Silurian block faulting in the Mohawk and Champlain Valleys[64]. The eugeosyncline was an intermittently active zone of volcanism, uplift, and subsidence.

Devonian

In Early Devonian time, a transgressing sea permitted the deposition of carbonate rocks over the Silurian carbonates of the miogeosyncline and adjacent submerged platform areas. In the interior platform, the first Devonian sediments to be deposited in many areas were Middle Devonian shales, deposited on a widespread erosional unconformity on Middle Silurian rocks.

In the New England province during Early Devonian time, thick, predominantly sedimentary deposits entered a eugeosynclinal trough along the zone of the Merrimack synclinorium. A renewed crustal plate convergence in later Early Devonian time compressed the region toward the northwest, folded and uplifted the island arc chain into the Bronson Hill anticlinorium, and culminated with folding, metamorphism, faulting, and widespread plutonic activity in the New England province approximately 380,000,000 years ago. The Acadian Orogeny resulted in the final consolidation of the province as a discrete crustal block, welded to the North American continent.

In the eastern part of the site region, the effects of the Acadian Orogeny included metamorphism, folding of earlier-developed Taconic cleavage, overturned folding to the west, and high-angle reverse faulting. Uplift resulting from the orogenic deformation led to rapid erosion, with the

building westward of the clastic wedge of the Catskill Mountains during Middle and Late Devonian time.

At this time in the region's history, the Southeastern New England Platform was not located in its present position to the southeast of the New England province[79,80].

Carboniferous

In Early Mississippian time, sedimentary deposition blanketed the interior platform to the Mississippi River area, predominantly in the form of black shales. These clastic sediments were derived from the upland tectonic landmass formed by Devonian orogenic activity along the eastern border of the continent. In Middle Mississippian time, clastic deposition on the interior platform gave way to carbonate deposition as the eastern crystalline landmass was gradually worn down by erosion. By the end of the Mississippian period, the interior platform largely emerged from the sea and was subjected to subareal erosion over wide areas.

In Early Pennsylvanian time, part of the interior platform was elevated above the sea, and sedimentary deposits are mainly restricted to the original eastern miogeosynclinal zone with some deposition westward. Toward Middle Pennsylvanian time, basin areas of the interior platform again were submerged with the deposition of marine limestones and shales as well as nonmarine clastic rocks. Sedimentary formations in the southwestern part of the site region are mostly nonmarine, shales, sandstones, and coal seams, with a few thin limestone members.

The long history of geosynclinal subsidence and orogenic activity along the eastern border of the continent was brought to a close in the later part of Early Permian time by the Alleghenian orogeny. Permian sedimentary rocks are restricted to a small area beyond 200 mi from the site, in southeastern Ohio, southwestern Pennsylvania, and northwestern West Virginia, and consist of shales, sandstones, and thin coal seams which reflect the same general nonmarine depositional environment as the underlying Pennsylvanian rocks.

For the region to the east of the site region during this time, the tectonic history of the Carboniferous is characterized largely by southwesterly directed, right-lateral, strike-slip faulting (Middle Devonian to Late Carboniferous time), involving rocks along the present coastal zone[81,82]. The Southeastern New England Platform is interpreted to have migrated southwesterly into the general location of its present position at this time. Late Devonian to Carboniferous continental sediments were deposited in intermontane basins on the Precambrian and older Paleozoic crystalline and sedimentary basement rocks of the Southeastern Platform.

The close of the Paleozoic in the eastern region is characterized tectonically by the collision of North Africa against the northern Appalachians[80] and the development of the thrust fault complex along the boundary between the Southeastern Platform and the New England-Maritime foldbelt in Middle Permian time (Public Service Company of New Hampshire, Seabrook PSAR[83]), and

finally, by right lateral transform faulting and locally intense metamorphism along the southern New England coast as Africa, south of the South Atlas fault, is interpreted to have slid westward to collide with North America, south of New York[80,84].

It is not known whether the final Paleozoic tectonic events produced deformation in the site area. In the southern part of the site region and beyond in the region to the south, Cambrian through Pennsylvanian, sedimentary rocks of the miogeosyncline are highly folded in the Valley and Ridge province. These rocks are sometimes overturned to the northwest, and thrust-faulted, with subparallel folds and faults striking northeasterly. The gentle tilting and broad folding of the Paleozoic rocks throughout central New York State and probably the site area/region occurred as part of the main Appalachian system deformation. However, whether the site/area and related fold/fault features were formed earlier than the main Appalachian activity or as part of the Alleghenian orogeny is unclear on the basis of the available information.

2.5.1.1.5.3 Mesozoic

During the Mesozoic era, the site area was elevated above sea level and subjected to subareal erosion. There is no record of geologic history for the site area during this time.

Along the zone of the old eastern geosyncline on the eastern edge of the continent, a discontinuous series of linear rift basins developed in the uplifted eastern landmass during Triassic time, trending northeasterly from Alabama to Nova Scotia. These basins locally accumulated more than 20,000 ft of terrestrial clastic sediments including coal seams, and basin development was accompanied by extrusions of basalt flows and intrusions of basalt and diabase dikes and sills.

During most of Triassic and Jurassic time, the landmass which had been formed along the eastern margin of the continent by Late Paleozoic orogenic events was subjected to erosion and base leveling, and by late Jurassic time, a low platform had been developed along the margin of the continental land area. In Early Cretaceous time, the area of the present Appalachian highlands was subjected to a series of broad arching uplifts aligned parallel to the northeasterly-trending Paleozoic fabric of deformation, while the low Coastal Plain platform subsided with each successive epeirogenic uplift. Clastic sediments of both terrestrial and marine origin were laid down in the gradually subsiding Paleozoic basement to form a thick wedge shaped series of Coastal Plain formations which dip gently seaward.

Whitten[85] has shown that a period of particularly rapid crustal subsidence occurred on the Atlantic coastal plain between 102,000,000 and 108,000,000 years ago, continuing less strongly to about 90,000,000 years ago, and has related this to Middle Cretaceous periods of rapid subsidence and marine transgressions on cratonal areas in Siberia, Russia, western Canada, the United States Rocky Mountains and Gulf Coast, and Brazil.

The compressional stress regimes of the older Paleozoic orogenic events and the later Paleozoic strike slip and thrust faulting in the eastern and southern quadrants of the site region gave way to regional extensional stress early in Mesozoic time, as the final separation of Africa from North America was initiated, about 200,000,000 years ago[86]. Rift basins were formed intermittently along the eastern Appalachians from Alabama to the Canadian Maritime provinces, and the region was widely intruded by mafic dikes. McHone[23] has examined data on more than 900 mafic dikes primarily in southeastern Quebec, Vermont, central and northern New Hampshire, and central western Maine. These data suggest most early Mesozoic dikes were emplaced under conditions of least horizontal stress directed southeast-northwest; whereas, later Mesozoic dikes (Middle Cretaceous) may have been emplaced under conditions of least horizontal stress directed approximately S15 deg W-N15 deg E. Kimberlite dikes of Early Cretaceous age in the Ithaca and Syracuse areas of New York[87] tend to strike slightly west of north, suggesting an eastwest least horizontal stress for emplacement control in that area at that time.

Essentially simultaneously (100,000,000 to 120,000,000 years ago) with emplacement of the younger White Mountain series plutons in south-central New England and with the intrusion of the younger west-northwest-trending mafic dikes, more than 15 plugs and alkaline complexes of the Monteregian Hills plutonic series were emplaced in southeastern Quebec, 300 km (200 to 220 mi) northeast of the site. The Monteregian intrusives are distinctly more alkaline than the White Mountain series rocks, and are interpreted to have been emplaced much more rapidly and forcefully than the White Mountain series intrusives. The Monteregian Hills plutons occur along a 120-km (75 mi) zone which trends east-southeasterly through Montreal, and is located near the eastern edge of the Western Quebec Seismic Zone and nearby the steep gravity gradient (crustal boundary) as shown in Figure 2.5-5.

The distribution throughout the site region of evidence of Mesozoic extensional stress regimes in the form of rift basins, central complex intrusives, and mafic dikes, coupled with evidence of a synchronous global geodynamic episode in Middle Cretaceous time[85], suggests that the earlier stress regimes in the site region must have been dissipated by Late Mesozoic time.

2.5.1.1.5.4 Cenozoic

At the close of the Mesozoic era, the landmass of the region is postulated to have been roughly comparable, physiographically, with that of today. For the past 70,000,000 years the region has been subjected tectonically only to broad arching uplifts followed by deep weathering and erosion. Evidence in Coastal Plain deposits of intermittent erosional cycles is indicative of periods of emergence of these formations, possibly related more to fluctations in sea level than to tectonic uplift[88]. The Appalachian Mountains were largely reduced by erosion before Tertiary time (some 65,000,000 years ago). The removal of this great amount of sediment from the mountain system was accompanied by further uplift and doming. In central New York, erosion continued uninterrupted during Cenozoic time and developed a large river system flowing to the south on a featureless plain[2]. As a result of a

general doming of eastern North America, during Middle to Late Tertiary time, the whole peneplained region was uplifted 1,000 to 2,000 ft and the drainage reversed, allowing the pre-Finger Lakes Rivers to become north flowing tributaries of the Late Tertiary system.

The last episode in the geologic history of the region was a succession of continental glaciations during Quaternary time (the last 500,000 to 1,000,000 years before present). These several periods of glaciation scoured away the older Cenozoic residual soils to fresh bedrock, and replaced them with deposits of till, ice contact sands and gravels, sandy outwash deposits, and finally, postglacial marine and lacustrine clay-silt deposits.

No evidence has been reported to suggest that any tectonic fault displacement has occurred in Quaternary deposits in the region. The landmass of the region has, however, experienced differential upwarping or rebound, as a result of unloading after the melting and removal of the continental ice[89,90,91].

2.5.1.2 <u>Site Geology</u>

The site area is defined by a 5-mi radius from the station.

2.5.1.2.1 <u>Physiography of Site Area</u>

The site is located in the Ontario Lowlands physiographic province[1] 2 mi south of Mexico Bay-Lake Ontario. The site area is within the limits of continental glaciation and the higher ancestral level of Lake Ontario (Lake Iroquois), which had shorelines south and east of the site area. The site area is generally flat with low relief, but the terrain is interrupted by a number of steep sided, flat-topped hills. Typical of the Ontario Lowland, the land surface rises to the south from a lake shore elevation of +246 ft (msl) to over +400 ft (msl) at the southern edge of the site area. The bedrock surface in the site area slopes to the south at 30 ft/mi. The rock surface is rather flat and controls only the general elevations of the area. The detailed landforms at the site result from Wisconsinan glaciation and postglacial erosion (Figure 2.5-7).

The most striking feature of the site area is the strong north-northwest orientation of drainage and topography which reflects the direction of glacial advance. South of Route 104, a swarm of flat topped drumlin hills clearly shows the glacial trend. The drumlins rise 60 to 70 ft above the surrounding land and most top out at the 470-ft elevation. The southern part of the site area is poorly drained with only three through flowing, low gradient streams. The interdrumlin zones are generally swamps that occur at elevations of 400 to 410 ft.

An irregular, 5-sq mi, plateau-like feature east of Scriba is the highest sector of the site area. Elevations in the center of this feature increase to 510 ft.

North of Route 104, elevations decrease sharply from +400 ft to +350 ft, and from this point, the ground slopes uniformly to the lake shore. The glacial

trend is subdued, but still evident in several small drumlins. The topography is generally of very low relief with small rolling hills. This subdued glacial trend, below el 400, reflects the influence of a higher ancestral stand of Lake Ontario. Sutton, et al[92] describe some effects of the ancestral Lake Ontario levels as bevelling of glacial features and the distribution of young sand deposits which they call the Dune stage. Consequently, many of the glacial features prominent south of the plant site are masked or modified within parts of the site area and northward.

The area north of Route 104 is well drained with more than ten through flowing streams. The streams diverge from the glacial trend and flow more northerly toward Lake Ontario. The streams are incised 10 to 20 ft.

The Lake Ontario shore at Nine Mile Point is unprotected and has the erosional character of a high energy shoreline. The rim of Mexico Bay, east of Nine Mile Point, shows features of an inundated shoreline, such as bay mouth bars, beach ridges, and associated estuarian swamps.

2.5.1.2.2 Stratigraphy of Site Area and Site

2.5.1.2.2.1 Introduction

The site area (5-mi radius of the site) is underlain at depth by Grenville-like crystalline rocks of the Precambrian basement. These terranes are overlain by about 2,000 ft[93] of Cambrian and Ordovician strata, the youngest of which are Cincinnatian in age. Several types of glacial deposits, including lake sediments, immediately overlie the glacially scoured bedrock surface; rock exposures are rare. Figure 2.5-8 illustrates the stratigraphic setting of the site area and that part of the rock column investigated during this study. The sedimentary sequence rests upon a southward sloping basement surface (30 ft/mi). The combination of a southerly sloping basement surface and a northerly sloping bedrock surface produces an increase in thickness of the homoclinal Paleozoic section of rocks to the south and southwest. None of the major units are known to pinch out or lose their identity within or near the site area.

The basement is a complex series of Grenville-like metamorphic rocks, apparently similar lithologically to equivalent strata exposed on the Canadian Shield and Adirondack dome. The basement probably is mantled by Cambrian Sandstones (Potsdam and/or Theresa), but the section consists predominantly of Ordovician strata. The Ordovician units are, from oldest to youngest, Black River Limestone, Trenton Limestone, Utica Shale, Whetstone Gulf Shale, Pulaski Shale, and the Oswego Sandstone (Figure 2.5-8). The entire succession changes in gross aspect from limestone through shale into sandstone; its progradational character is complete with inclusion of the Late Ordovician portion of Queenston Formation, a sequence of red beds overlying the Oswego to the south and west of the site area.

Within the site area, that part of the Ordovician sequence investigated by direct methods consists of the lower two-thirds of the Oswego Sandstone and the uppermost strata of the Pulaski Shale (Figure 2.5-8). The upper third of

2034 329

the Oswego Sandstone, the Oswego-Queenston transition zone, and the Queenston Formation are not present within the site area; strata lower than the uppermost Pulaski Shale were not investigated, except in Boring G-75, near Demster Point (intake pumphouse). Here the lowermost 50 ft of strata are assigned provisionally to the Whetstone Gulf Shale.

2.5.1.2.2.2 Pulaski-Oswego Formational Boundary

The principal purpose of the stratigraphic investigations was division of the site area section into a number of mappable rock units. Because the section represents a continuum of marine deposition, unit boundaries are assumed to have been essentially horizontal as deposited, except on a very local scale, and, therefore, are considered reliable key horizons. Structure contour maps of the unit boundaries, or key horizons, were constructed and examined for evidence of structural trends. The Pulaski-Oswego boundary was selected as the primary key horizon because of its formational rank and established mappability, based on marked lithologic differences with the Oswego.

Borings R-1, R-2, R-3, and R-4 were analyzed and compared on the basis of lithologic properties to exposures of the Pulaski on the Salmon River in Pulaski, New York, and along Route 81, east of the village, and to exposures of the Oswego Sandstone above Bennett Bridge in the Salmon River gorge (Figure 2.5-13), and within the site area (Figure 2.5-9). All four borings bottom in rock that correlates with the type Pulaski, on the basis of an association of distinctive properties including: sandstone color, thickness, and bedding characteristics; sedimentary structures; sandstone-shale ratios; and the frequency of occurrence, thickness, and position within the sandstones of faunal zones.

The upper boundary of the Pulaski with the overlying Oswego Sandstone does not crop out along Salmon River, but occurs in the covered interval between the village of Pulaski and Bennett Bridge (Figure 2.5-13); intermittent exposures within that interval indicate that the boundary is transitional(94). This description of the boundary is consistent with the shaly aspect of the lowermost Oswego immediately upstream of Bennett Bridge. Westward and southwestward, however, the lower Oswego is predominantly sandstone and the boundary is distinctly mappable, provided that a sufficient section is recovered to firmly establish the identity of the Pulaski shale.

Accordingly, each borehole drilled for the purpose of broad stratigraphic control was advanced several tens of ft into the Pulaski in verification of the boundary.

Identification and description of the Pulaski and the Pulaski-Oswego boundary are based on an aggregate thickness of 3,200 ft of Pulaski section from 39 boreholes in which an average of 82 ft and a maximum of 286 ft of Pulaski were penetrated. The distribution of these borings is shown in Figure 2.5-9, a site area base map, and in Figure 2.5-14, a structure contour map of the unit.

Structurally, the top of the Pulaski Shale is a gently sloping surface consistent with the marine conditions of its deposition, as modified by

subsequent regional tilting. Within the areal limits of stratigraphic control, from Boring R-6 on the east to Nine Mile Point on the west (Figure 2.5-9), the Pulaski appears to strike west-northwestward and dips to the south-southwest at about 60 ft/mi. The plant site overlies a gently sloping, mildly negative, ramp-like structural element whose south-southwest dip reflects the local New Haven synclinal feature.

The contour pattern northwest of the site (Figure 2.5-14), based on closely spaced Pulaski control points, indicates abrupt changes in the strike, dip, and dip direction of the Pulaski-Oswego boundary. These changes, together with the pronounced lineation and compression of the pattern, are generally accepted as evidence for faulting. Additional inclined borings in the zone of suspected faulting traversed a crushed zone several tens of ft wide, including a number of intervals of gouge and breccia and confirmed the occurrence of a fault zone. The contour pattern and boring data thus define the position and orientation of the northeastward-trending Demster Structural Zone that occurs on the eastern limb of the Demster Beach anticline; the full extent of both features is unknown. Demster Structural Zone was exposed by Trench II and further investigated by additional borings. The results are discussed in Appendix 2.5I.

Southward deflections of the contour pattern occur west-northwest and east-southeast of the site. To reestablish the regional strike and correlate with stratigraphic control at Nine Mile Point (Borings 314, L-1, L-4, L-8, T-4-12), the structural contours must turn again to the north (Figure 2.5-14). Stratigraphic control west of the site indicates a repeated pattern somewhat similar to the southwest trending zone, delineated in Figure 2.5-14. The contour pattern is sinous along regional strike. The Pulaski-Oswego boundary has been shaped into a series of broad, low amplitude folds normal to the strike that trend northeastward and plunge southward. The N 50°E trending fault zone associated with the folding breaks this areal contour pattern (Figure 2.5-14).

2.5.1.2.2.3 Pulaski Shale

The Pulaski is a monotonous alternating sequence of black fissile, commonly pyritic shales, and mediumgray to pale-gray, fine - to very fine-grained well sorted sandstones and coarse grained siltstones. Alternations are thinly laminated to medium bedded, but thin to very thin bedding is characteristic. Individual sandstones thicker than 2 ft are rare. The sandstone-shale ratio of most cycles and the unit in general is <1.0. The predominance of shale and the absence of green coloration in sandstone are diagnostic of the Pulaski; the latter suggests a fundamental compositional difference between the Pulaski and Oswego Formations and most probably corresponds to change in content of chloritic matter and metamorphic rock fragments.

Dark gray silty shale and gray to bluish-gray siltstone are subordinate rock types. These occur mainly as lenses and laminae within black shales, or constitute transitional intervals between gray sandstones and overlying black shales.

Each cycle described in the boring logs begins at the sharp interface between a prominent gray sandstone, as thin as 0.5 ft, and the black shale top of the underlying cycle. Generally, the interface is planar and near-horizontal, but grooves, load casts, shale rip-ups, shale plumes, disrupted bedding, sandstone intrusions, or washouts mark the base of many cycles. These are all small scale features, reflecting a relative increase in the energy of the system at the time of their formation. The basal sandstone is gray and fine to very fine grained, but ranges to medium-grained with increasing bed thickness; it may be uniformly textured and megascopically structureless, finely laminated, cross laminated, or interrupted by wavy shale laminae. Both basal sandstones and thinner sandstones higher in the cycle are commonly fossiliferous, and extremely fossiliferous sandstones are quite common. Fossils typically are concentrated at the bases of sandstones, associated with irregular bedding, small shale clasts, and small shale flasers. Beds of closely packed fossils, about 0.1-ft thick, occur locally within the black shales. The faunal assemblage includes crinoid columnals, brachiopods, pelecypods, bryozoans, gastropods, and possibly ostracods; the larger forms commonly are recrystallized, and geode-like structures are not uncommon.

The basal sandstone of each cycle may grade upward through a finely laminated zone into a thin to very thin bedded alternating sequence of shale, with lenses, laminae, and minute load structures of sandstone and siltstone. In any case, shale beds increase in thickness and frequency of occurrence up cycle at the expense of sandstone. Pyrite is ubiquitous in the black shale interval, and commonly occurs as laminae, nodular masses and fossil replacements. Non-pyritized fossils, mainly brachiopods, are present but quite obscure. The top of the cycle is consistently a sharp boundary with the overlying basal sandstone.

In summary, the properties upon which identification of the Pulaski is based are:

1. Sandstone-shale ratios <1.0

2. Gray, finely textured and structured, commonly fossiliferous sandstones

3. Pyritic, black, fissile shale

4. Relatively high natural radioactivity

This association of properties, together with the cyclic sequence, served to firmly establish the identity of the Pulaski Shale and its boundary with the Oswego Sandstone.

The lithologic aspect of the Pulaski is relatively constant, both areally and stratigraphically, and no systematic changes or bases for subdivision were discerned.

2034 332

2.5.1.2.2.4 Oswego Sandstone

Within the site area, all strata between the top of the Pulaski and the base of the glacial sediments are referred to the Oswego Sandstone. Three hundred ft of Oswego recovered in Boring R-19 is the thickest sequence known to occur within 5 mi of the site, and is about 80 percent of the estimated total thickness of the formation[95]. At the site, directly eastward along strike, the section is only slightly thinner, and any of several deep borings there may be considered reference sections (Figure 2.5-10).

The southward dip of the strata and northward slope of the erosion surface bring progressively older beds into subcrop from south to north. This combination of geomorphologic and regional structural trends determined the extent of subsurface mapping. North of the site, lower stratigraphic horizons lie at higher elevations, and borings are collared at lower elevations; control on the lower horizons is relatively dense, but the upper units have been removed by erosion. Onsite and southward, most boreholes did not intersect the lower stratigraphic horizons. However, control on the upper horizons is dense because of the expanded section. Therefore, structure contour maps of the upper, more thoroughly documented horizons were prepared for the site, while the more areally extensive lower stratigraphic horizons were selected to illustrate the structure of the site area. A map of the bedrock surface (Figure 2.5-20) or any expression of the external geometry of the total Oswego is of limited value for stratigraphic and structural analyses of the area.

Stratigraphic analysis of the Oswego Sandstone is based on the examination of more than 13,600 ft of Oswego core from 144 boreholes, including the 39 Pulaski penetrations (Section 2.5.1.2.2.2). The formation is divided according to associations of lithologic and sedimentary properties and on the basis of sequential relationships into five mappable rock- stratigraphic units or zones. They are defined by four selected intraformational marker horizons. The following zones are recognized.

Oswego Sandstone - Zone 1

This unit conformably overlies the Pulaski Formation throughout the site area and, in turn, is conformably overlain by Zone 2. Twenty-three complete sections of Zone 1 provide a range in thickness of about 60 to 90 ft and an average thickness of about 80 ft; the unit thins gradually to the north and subcrops beneath the till as indicated in Figure 2.5-12.

Zone 1 consists of a medium to very thick bedded succession of pale gray to green sandstones, pale green, dark green, and olive siltstones, and dark gray shales commonly arranged as graded beds up to 10 ft or more in thickness. The basal sandstone typically is predominant within a sedimentary cycle, and ratios of sandstone to siltstone + shale average 2.5; these contrast sharply with those of the Pulaski which rarely exceed 1.0. Intermediate rock types such as silty shale, shaly siltstone, and sandy siltstone are present as sequential components of many graded cycles but occur also as distinct units bounded by planar surfaces.

2034 333

Zone 1 sandstones are mainly fine to medium grained and commonly become slightly coarser toward the base. Pale gray sandstones tend to be harder and more calcitic than green sandstones, which tend to be soft, clayey, and noncalcitic. Zone 1 sandstones are typically monotonous structurally but are interrupted locally by wavy to broken shale laminae, very thin distinct zones of siltstone, and thin bedding parallel zones of shale intraclasts. Pronounced cross bedding, lenticular bedding, and other structures relatable to high energy levels are uncommon, particularly in the lower part of the zone, while evenly laminated to thinly laminated beds are quite common throughout. Generally, the top of the Zone 1 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. Sandstone lenses, laminae, load structures, and wavy bedding characterize these intervals.

Evidence of soft sediment deformation is abundant in Zone 1. Features observed include slump folds, overturned slump folds, slump blocks and breccia, contorted banding, broken laminae, and large load casts and sandstone pillows. Slumping involved all lithologic types but is especially prominent in the siltstones. Slump structures occur elsewhere in the Oswego but are persistently present in and characteristic of Zone 1 only.

Individual beds or intervals of potential stratigraphic significance include 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 sandstone- and siltstone-laminated; it is underlain within several feet by two or three thin intervals of irregularly bedded fossils and shale clasts. The sequence is fairly persistent throughout the site area. In several borings, the basal 10 ft of Zone 1 consists, in part, of one or two thick beds of dark greenish-gray, slump folded, shaly siltstone. In core logging downward, the appearance of these siltstones is followed within a very few ft by the disappearance of greenish beds, a marked decrease in the sandstone-shale ratios and bedding thickness, the reappearance of fossils, and, in most borings, a distinct shift in the gamma log (Borings R-1, R-3, R-11, and R-14). These changes indicate the position of the Pulaski shale-Oswego Zone 1 boundary.

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 boreholes to the west (R-22, R-23, R-24, and R-25) and logs of Nine Mile Point borings (314, L-1, L-4, L-8) (Appendix 2.5I) indicate that this change is accomplished through replacement of siltstone and other intermediate rock types by dark-gray to black shale. Bedding thickness, bed-forms, and the overall aspect of the lower part of the unit remain relatively constant throughout the site area.

Oswego Sandstone - Zone 2

This zone conformably overlies Zone 1 and is overlain by Zone 3. With the exception of Boring R-6, where an anomalously thin section of 14 ft suggests an eastward thinning of the unit, Zone 2 is quite uniform in thickness, with a range of 25 to 38 ft and an average thickness of 29 ft.

2034 334

Zone 2 sedimentary cycles consist basically of a lower sandstone and an overlying black shale. The cycles have an average thickness of 4 to 5 ft and an average sandstone shale ratio of about 1.5. Siltstone and related transitional rock types are generally more subordinate, except as lenses, laminae, and very thin bands. Zone 2 comprises several such cycles and the Zone 1-Zone 2 boundary is the base of the lowest cycle conforming to Zone 2 criteria. The sequence is obviously regressive on Zone 1, but the boundary is conformable on all but a small scale.

The base of each cycle coincides with the sharp, erosional contact between a prominent sandstone and an uppermost shale of the next lower cycle or, where cycles are incomplete, between sandstone and siltstone or sandstone and sandstone. Interrupted cycles and abrupt changes in mode of deposition are revealed where sandstone and shale are in sharp contact along steeply inclined, grooved, or rippled surfaces. These features indicate that Zone 2 has a complex internal geometry.

Zone 2 sandstones are gray, pale greenish-gray, or yellowish-gray, fine to medium grained, typically hard and slightly calcitic. A high percentage, including thin beds in the upper shaly part of each cycle, are fossiliferous and commonly extremely fossiliferous. Bioclastic deposits are particularly evident at the base of thicker sandstones, associated with inclined lenticular bedding, relatively coarse sandstone matrix, ragged shale clasts, clay galls, and mud flasers. Many sandstones, up to 3 ft thick, are fossiliferous throughout; more commonly, they consist of several zones, alternately fossiliferous and barren. The upper, more finely textured part of the thicker sandstones may be siltstone laminated, gradational through dark gray or greenish gray siltstone into black shale, or contain several planar, wavy, or broken shale laminae.

The well developed Zone 2 cycle ends in an interval of black fissile shale with laminae and lenses of gray sandstone and greenish gray siltstone.

Bedding is typically wavy to lenticular, and load structures are common. Pyrite is prominent at many sandstone shale boundaries.

Diagnostic criteria for Zone 2, in addition to its stratigraphic position, are:

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

The Zone 2-Zone 3 boundary is placed at the top of the highest prominently fossiliferous cycle in this sequence.

2034 335

Oswego Sandstone - Zone 3

This unit consists of a sequence of strata with neither the fossiliferous aspect of Zone 2 nor the burrowed aspect of Zone 4. It has no uniquely diagnostic features, but is defined mainly by its stratigraphic position and the absence of bioclastic and bioturbated bed forms. Given a section in which Zones 2 and 4 are recognizable, Zone 3 becomes mappable.

Zone 3 is lithologically similar to Zone 2, consisting mainly of gray to greenish-gray, fine grained, hard sandstones and black shales, with a sandstone-shale ratio of about 1.5. Bedding and other sedimentary structures are as described for Zone 2, with the exception of features relatable to channel formation which are relatively uncommon in Zone 3. The definition of the base or this zone is approached from down section by determining the top of Zone 2.

Borings on the site indicate an average thickness of about 10 ft for Zone 3. The unit maintains this thickness within a 2-mi radius of the site, but could not be differentiated in Boring R-3 and appears to lose its identity southward. The combined thickness of Zones 3 and 2, however, remains constant (about 37 ft) and the loss of the Zone 3-Zone 2 boundary presents no problem in extending correlations southward from the site. To the northeast (Boring R-6), Zone 3 thickens to approximately 25 ft at the expense of Zone 2. Here, too, the combined thickness of Zones 3 and 2 is 37 ft and the Zone 3-Zone 2 interval is the designated unit. Northwestward, at Boring 314 (FitzPatrick Nuclear Power Station), the stratigraphic interval bounded by Zone 4 and Zone 1 is about 55 ft thick and considerably more shaly. Criteria for recognition of the Zone 3-Zone 2 boundary are not applicable and the designated unit is the total interval, as at Boring R-3. North of the site, most borings collar in Zones 1 or 2, as the younger units have been removed by erosion.

Oswego Sandstone - Zone 4

Zone 3 is overlain conformably throughout the site area by Zone 4, a sequence of thin to medium bedded strata identified on the basis of its bed forms and biogenic structures. Zone 4 is overlain by Zone 5, and the Zone 4-Zone 5 boundary, marked by pronounced changes in bedding properties and sandstone shale ratios, is considered a highly reliable and readily mappable marker horizon.

The Zone 4-Zone 5 boundary is a broadly undulating conformity, as shown in Figure 2.5-16. On a more local scale, as revealed in Figure 2.5-17, the boundary is somewhat more intricate. The features revealed by the smaller contour interval, specifically the closed lows, are most likely directly related to processes active during Zone 5 deposition. This conclusion is entirely consistent with the interpretation of Zone 5, based on both surface and subsurface data.

Zone 4 consists mainly of very thin to medium bedded cyclic repetitions of sandstone, siltstone, and shale. Bedding thickness and the cyclicity set this

sequence apart from Zones 3 and 5. Zone 4 sandstone/shale ratios generally lie between 1.0 and 2.0, a range similar to that of Zone 3 but considerably less than the majority of Zone 5 ratios. Additionally, the prevalence of burrowed strata and indistinct lithologic boundaries makes this unit identifiable even out of stratigraphic context. Because of its distinctive association of properties and high stratigraphic position, Zone 4 provides reliable stratigraphic control at relatively shallow depths.

The average thickness of Zone 4, based on a large number of complete sections of the unit, is 45 to 50 ft; its range of thickness is quite small, and no systematic variation in Zone 4 thickness is apparent. Consequently, reconstruction of the top of Zone 4 beyond the limit of Zone 5 cover is considered valid. Figure 2.5-15 shows the distribution of Zone 4, both in subsurface and subcrop, as well as its absence in the vicinity of Borings R-2, R-5, R-9, and R-16 where a local structural feature has resulted in the removal of Zone 4 by erosion (Section 2.5.1.2.2.2). The wide extent of Zone 4 in subcrop is consistent with its appreciable thickness, high stratigraphic position, and the relationship between regional dip and bedrock slope. Similarly, the shape and position of the Zone 4-Zone 5 boundary in subcrop are consistent with the regional dip, bedrock slope, and structural shape of the boundary.

The entire zone may be described in terms of five to ten major cycles of sedimentation, each beginning at the sharply defined base of a prominent sandstone bed. Typically, this sandstone is greenish gray, fine grained, slightly calcitic, and contains one or more very thin zones of bedded shale clasts. Even, wavy, and disrupted laminae of black shale are also common, as are somewhat wider intervals of thin lamination, cross-stratification, and lenticular bedding. Fossils do occur associated with irregular bedding and shale clasts, but are relatively rare.

Each major sandstone passes upward through thinly bedded rhythmic alternations of sandstone, siltstone, and shale to the base of the next higher major cycle. The transition is accomplished through a gradational increase in the thickness and frequency of occurrence of the finer clastics at the expense of the sandstone. Bedding in the upper part of the cycle may be quite distinct, revealing several thin sequences of greenish-gray sandstone, dark gray to dark greenish-gray siltstone, and black fissile shale. Characteristic sedimentary structures include ripple-marked surfaces, broken shale laminae, small shale ripups, load structures, small scale slump structures, and wavy, lenticular, and flaser bedding. The uppermost black fissile shale is typically very thin and in sharp irregular contact with the basal sandstone of the next higher major cycle; obviously some shale and siltstone has been removed from the top of each cycle.

The well bedded Zone 4 cycle is less typical than the cycle in which much of the internal detail has been destroyed by burrowing organisms. In this case, the cycle consists of a basal sandstone, as described above, overlain by alternations of sandstone and intervals of burrow mottled and thoroughly mixed sandstone, siltstone, and shale; these mixed zones might well be described as sandy mudstones. Organic activity and the effect that it probably had on the

2334 337

formation of load structures have resulted in diffusion of all bedding surfaces except those at the base of the thicker sandstones. The burrowed sequence occurs locally elsewhere in the Oswego, but is nowhere developed to any great extent except in Zone 4. In core logging down section, the top of Zone 4 corresponds to an abrupt decrease in the sandstone/shale ratio, a decrease in bedding thickness, and the appearance of burrow mottled strata.

Structure contours on the top of Zone 4 (Figures 2.5-16 and 2.5-17) show a pattern virtually identical to those drawn on the Pulaski boundary and on the top of Zone : (Figures 2.5-14 and 2.5-15). The surface is broadly undulating throughout the site area and similarly irregular on the site scale as determined by closely spaced borings on and in the immediate vicinity of the plant site. The pattern revealed on the site might reasonably be expected to characterize the entire site area.

Oswego Sandstone - Zone 5

All strata between the top of Zone 4 and the base of the glacial deposits are designated as Zone 5. This unit lies conformably upon Zone 4 and the boundary is a reliable marker horizon; Figure 2.5-15 shows the boundary configuration. Figure 2.5-17, drawn on a 5-ft contour interval and based on closely spaced control points, demonstrates the detailed configuration of the Zone 4-Zone 5 interface. This expression of the external form of Zone 5 is entirely consistent with its internal geometry as seen in the site trench (Appendix 2.5H and Figure 2.5-33), the few scattered exposures (Figure 2.5-9), and an extensive core record.

The approximate areal extent of Zone 5 is defined in Figure 2.5-16. All borings on and southward of the plant site collar in this unit. The top of rock map (Figure 2.5-20), therefore, illustrates the results of erosion and glaciation of Zone 5. Northward of the site, where more thinly bedded strata subcrop, relief on the rock surface appears to be much less pronounced.

The maximum known thickness (142 ft) of Zone 5 occurs about 1.6 mi west of New Haven at Boring R-19. However, thickness data for this unit have little stratigraphic significance because the unit is incomplete. An average sandstone shale ratio is relatively meaningless for the same reason. Typical ratios for the explored part of Zone 5 range from 5.0 to 10.0 and ratios of 25.0 and greater are not uncommon.

Basically, Zone 5 is a sequence of thick to massive sandstone units ranging in color from dark greenish-gray through pale greenish-gray and pale gray to white, and texturally from fine to medium grained. The darkest colored units are at once the most silty, the softest, and the least calcitic, while pale gray and white sandstones tend to be medium grained, hard to very hard, moderately calcitic, and cross stratified.

Sandstone beds of these various aspects are arranged in sequences up to 35 ft thick, interrupted by no more than a few widely spaced thin zones of siltstone, or intervals of shale intraclasts; these commonly delimit sandstones of a given aspect but just as commonly occur within a bed. Each

2034 338

sequence of sandstone beds ends (upward) in an interval, generally thinner than 2 ft, of dark greenish-gray siltstone and black fissile shale or olive blocky shale. The shaly top of the sequence is normally irregularly bedded, with laminae, lenses, and load structures of sandstone; the top of the shale is typically a sharp sculptured boundary with the next higher sandstone sequence. In places, the shale has been scoured out and the sequence ends in siltstone.

Zone 5 sandstones show many process related primary structures. Of these, cross stratification of various magnitudes is most prominent, from that which appears as angular planar bedding in core, to microcross laminae and irregular, lenticular bedding. Closely associated with these bed forms, and particularly with lenticular bedding, are increases in grain size to medium or coarse, shale-clast and clay-gall accumulations, rounded pebbles of sandstone and siltstone, and bioclastic deposits. Lag deposits of this description define channels and washout structures which, in turn, define the base of sedimentary cycles.

Siltstone laminated to finely laminated sandstone is equally as common as cross stratification; these intervals are fine grained and horizontally bedded to very slightly inclined. Inclined opposed bedding planes are not uncommon and indicate vectoral changes in the process of sedimentation. Slump folding occurs locally, involving siltstone and silty sandstones, as do thin zones of burrowed dark gray siltstone; neither feature is common in Zone 5. Dolomite occurs as pink to tan laminae, wavy bands, and irregular and ovoid masses throughout Zone 5. The irregular and ovoid masses are arranged in bedding parallel zones but are transected by bedding; thus, they appear to be secondary in origin. Dolomite is confined to Zone 5 and is diagnostic of the unit.

Additional structures observed in the site trench (Appendix 2.5H) and in outcrop include: sedimentary troughs, commonly several ft across, with current rippled surfaces; massive sandstone lenses of comparable magnitude; interference ripples and flat-topped current ripples; orthocone cephalopods, both as bioclastic concentrations of small individuals and as solitary forms up to 3 ft in length; large-scale cross stratification; and shale clast conglomerates and shale pinchouts. The higher points on the Zone 5 bedrock surface are glacially striated, and the till and derivative clayey silt have been injected well into the bedrock along joints, fractures, and bedding surfaces.

2.5.1.2.2.3 <u>Stratigraphic Summary</u>

The principal aspects of the stratigraphy of the site area and their implications for its geologic history are as follows:

The Pulaski Formation, immediately underlain by the Whetstone Gulf Shale and at greater depth by a thick sequence of marine shelf carbonates and shales, is the highest major unit in which sandstone is subordinate. Its black pyritic shales, rhythmic bedding, finely detailed textural and structural features, and benthonic faunal assemblage identify the Pulaski as a proximal marine

2034 339

shelf sequence which received frequent contributions of fine to medium grained sand. As uplift and marine regression accelerated, the basal strata of the Oswego Formation began to offlap the Pulaski, the transition corresponding to the appearance in Zone 1 of thick bedding, green coloration, an overall increase in grain size, and the virtual disappearance of fossils. The prevalence of slump structures and poorly sorted lithologic types indicate that the basal Oswego was deposited rapidly as an influx of terrigenous detritus on the shallow marine shelf. Marine processes were not entirely effective in distributing the materials because of high rates of deposition, and adjustments to the depositional slope were effected by slumping of the unconsolidated deposits. This process generated turbidity flows from which sediment was redeposited as graded sequences, with settlement from suspension as an important mode of deposition.

These strata were offlapped in turn by those of Zones 2 and 3. The appearance in the section of this sequence corresponds to a further increase in overall grain size and reflects a substantial increase in energy levels. Current bedded coquinites, shale clast conglomerates, washout structures, and a rarity of siltstone identify the dominant mode of deposition as bed load transport. Intercalated shale beds possibly are related to periodic advances of the strand, or to changes in the availability of sand size detritus. Zones 2 and 3 probably were deposited in a shallow subtidal setting characterized by frequent variations in current vectors and velocities. Zone 3 reflects a somewhat less rigorous setting than Zone 2 and is transitional to and offlapped by Zone 4.

Zone 4 consists largely of thin to medium beds of sandstone and burrow-mottled mudstone in cyclic arrangement, with a variety of process related structures to indicate alternating periods of high energy and low energy in which bed load transport alternated with settlement from suspension as the depositional mode. These strata are interpreted as mixed tidal flat deposits on the basis of bedding patterns and biogenic and sedimentary structures.

With continued retreat of the shoreline, the mixed tidal flat environment was replaced in the section by a thick sandstone sequence with complex internal geometry imparted by small and large scale primary structures. These include cross stratification, plunging troughs, washouts, scour pits, ripple marked surfaces, shale clast carpets, lensoid channel fillings, and various combinations of these structures; in association, these features describe an intertidal setting characterized by shoaling conditions in which sedimentary materials were acted upon by waves, fluvial currents, and tidal flow.

Additional strata of Zone 5 aspect and origin were deposited and then offlapped by the Queenston fluvial sequence, completing the transition from marine to nonmarine sedimentation. The Oswego-Queenston transition is not preserved in the vicinity of the site area but is well exposed along the lake shore farther to the west.

The local section is progradational from bottom to top and records the progressive marine withdrawal from the site area and surroundings in Late Ordovician time. According to Patchen[76], continental replacement of the

marine basin was accomplished by westward migration of the strand as the source lands shifted northwestward. Project investigations substantiate this interpretation.

2.5.1.2.3 Structural Geology Site Area and Site

2.5.1.2.3.1 Introduction

Earlier studies of the Oswego Sandstone by Patchen[94,95] and investigations by Dames and Moore for the Nine Mile Point Nuclear Units 1 and 2 and the J. A. FitzPatrick Nuclear Plant (1964-1975) concluded that the geology of the Oswego-Mexico area is essentially undeformed, and flat-lying strata of the Oswego Sandstone occur beneath the glacial cover. Locally, minor folds, popups, and small scale faults are known as in the Nine Mile Point area[91,96,97,98]. Stone & Webster[97,98]. Initial regional studies undertaken for the project included four core borings throughout the site area to provide of an areal stratigraphic correlation, indications of unsuspected bedrock structures, and an aid in placing the site borings in the site area stratigraphic column.

A detailed analysis of rock core was the basis for establishing the Pulaski/Oswego formational boundary in Borings R-2, R-3, and R-4 (Section 2.5.1.2.2). The boundary is a relatively uniform, southerly dipping surface over much of the site area (Figures 2.5-11 through 2.5-13). Stratigraphic correlation of core obtained from the four initial site area borings (R-1 through R-4), combined with mapping of scattered bedrock outcrops (Figure 2.5-9), recognized approximately 120 ft of elevation differential of the Oswego/Pulaski boundary between Borings R-1 and R-2 (Figure 2.5-13); this elevation differential could represent a fault, a fold, or a formational pinchout. Boring R-2 is on the up side of a feature, and further investigations were desirable.

Data on the cooling tower fault zone, located at the Nine Mile Point Nuclear Plant[91], indicated that this small fold and associated fault might extend eastward; if the zone continued on trend, it would occur in the general vicinity of Boring R-2 (Figure 2.5-9). Consequently, to clarify whether this possible fault or an en echelon system traversed the site area, and also to establish additional control points on the Oswego/Pulaski boundary, five additional borings (R-5 through R-9) were drilled south and east of Boring R-2 (Figure 2.5-9). All five borings penetrated the boundary and provided additional data on the areal structure, rock column, and the areal strike and dip of the Oswego/Pulaski beds. These data, combined with information from outcrops in the Tug Hill sector, subsurface borings from the Nine Mile Point project (Borings 314, L-1, L-4, L-8 in Figure 2.5-9), and the site area, provided the basis for the west-east Section C-C' shown in Figure 2.5-13.

A stratigraphic analysis of all available boring data throughout the site area and site, confirmed an elevation differential between the Oswego/Pulaski boundary in Borings R-1 and R-2. Data from Borings R-5 through R-9 eliminated the possibility of an east-west-trending structure (continuation of Cooling Tower fault or zone at Nine Mile Point), and provided a more comprehensive

understanding of the subsurface geometry of the various stratigraphic zones as described in Section 2.5.1.2.2.2. The interpretation of the new data established that a northeast-trending feature must account for the stratigraphic offset.

Further confirmation of the feature, trend/origin of the stratigraphic offset, and geometry of this structural zone is under investigation and discussed in Appendix 2.5I.

Additional borings (some inclined) and geophysical measurements (gamma logs) have subsequently identified a steep northwestward-dipping fault zone approximately 50 ft wide consisting of two known offsets with the west side up, which together with broad folding has resulted in a net stratigraphic displacement of approximately 120 ft (Figures 2.5-13 and 2.5-16). This deformation is herein designated the Demster Structural Zone associated with the Demster Beach anticline (Figure 2.5-9).

2.5.1.2.3.2 Tectonic Structures

Subsurface stratigraphic correlation, coupled with bedrock exposure, indicate a general bedding strike of N60°W to N70°W and a regional dip of about one-half degree to the southwest. This is analogous with strikes and dips reported by Patchen[94,95] and Dames and Moore[96]. Section C-C' (Figure 2.5-13) parallels this regional strike, while Section A-A' (Figure 2.5-11) closely parallels the regional dip direction.

An analysis of the Oswego/Pulaski boundary structural contour map (Figure 2.5-14) demonstrates that the regional strike and dip is somewhat variable (Section 2.5.1.2). Contours were also constructed for the top of the Oswego Sandstone Zones 1, 3, and 4. The contour maps of the Oswego/Pulaski boundary and the top of Zones 1 and 4 are included herein (Figures 2.5-14 through 2.5-16).

The structural contour maps indicate the three-marker horizons: Oswego/Pulaski boundary, top of Zone 1, and top of Zone 4 are sinuous and delineate southwestward-plunging synclines and anticlines. The New Haven and Nine Mile sites are on similar structural contour embayments. The subsurface contours demonstrate the near-horizontal altitude of the beds beneath the plant site (Figure 2.5-17) on the top of Zone 4.

Northwest of the site, in the vicinity of Demster and parallel to the northeast alignment of a portion of Catfish Creek, the Oswego/Pulaski boundary structural contours show a marked deviation from the regional trend. All four marker horizons in the overlying Oswego Sandstone show a similar clustering of the contours. Subsurface data show a marked strike change, i.e., from northwest to northeast, and also a change in dip direction from southwest to southeast. This structural feature, the Demster Structural Zone, is discussed in Appendix 2.5I.

Stratigraphic correlation with borehole data from the Nine Mile Point and FitzPatrick Nuclear stations (borings L-1, L-4, L-8, and 314) show that both

2034 342

the New Haven site and the Nine Mile site overlie approximately the same structural contours for each contoured horizon (Figures 2.5-14 through 2.5-16). Consequently, the northeast-trending Demster Structural Zone was investigated by cored borings for a counterpart structure of similar trend on the west between Nine Mile Point and the New Haven site (Borings R-2, R-5, R-16, and P-5).

The resultant structural contour maps and cross-sections (Figures 2.5-13 through 2.5-16) do not indicate the existence of a fault zone on the western limb of the Demster Beach anticline.

The site area joint pattern shown in Figure 2.5-9 indicates two primary joint sets: N45degW and N70degE, with vertical dips, and a secondary joint set N50degE, also with vertical dip. Mineralized joints are rare and occur only in the core of borings in vicinity of the Demster Structural Zone. At Nine Mile point, two joint sets, similar to the primary joints at the New Haven site are recognized: N25degW to N50degW and N69degE to N80degE, with high angle dips. Joints exposed at the top of Oswego sandstone (Zone 5) in the Trench I Excavation (Appendix 2.5H) exhibit trends of N66degE, N03degE and N30degW to N50degW; they are predominantly vertical and generally widely spaced. Joints, in general, are widely spaced, and only locally, such as at Pleasant Point and the Mack Road Quarry, does the intensity increase. Joints do not persist with depth; within the Oswego Formation they are usually confined to individual sandstone beds. Rarely do joints traverse shale layers; however, in the shaly zones, horizontal partings are common. Within the Demster Structural Zone jointing commonly traverses individual sandstone, siltstone, and shale beds.

In the Pulaski Formation, cropping out along the Salmon River, primary joints trend N44degE and N48degW with high-angle dip. Secondary joint trends were N90degE and N73degW. Joints are generally continuous from sandstone to shale. Calcite mineralization occurs locally, filling joints and associated small-scale faults.

Joints in the site area are generally related to the areal folding/faulting such as the Demster Point anticline and New Haven syncline (Figure 2.5-9). Joint Set (II) N50degE and Set (III) N45degW are parallel and perpendicular, respectively, to the main folding trend and originated due to extensional forces. Joint Set (I) N70degE and Set (IV), N03degE, (most abundant joints, Trench I) probably originated due to shearing forces. The joint set trending N73degW recognized at Nine-Mile Point and at Salmon River (Pulaski Formation) is a minor trend and apparently unrelated to the main N50degE deformational trend.

Cored borings (S- and G- series) throughout the site (Figure 2.5-33) intersect typical joints as known in the Oswego and Pulaski beds. No tectonic offsets or fault zones were encountered in the onsite borings and none are suspected on the basis of subsurface structural contour maps and detailed stratigraphic cross sections (Figures 2.5-14 through 2.5-17).

2034 243

Mapping of Trench I across the site (Appendix 2.5H) showed no faults, slickensided joint surfaces, mineralized joints, or small-scale nontectonic folds at the rock surface of the Oswego Sandstone.

Cored borings (S- and G- series) throughout the site (Figure 2.5-33) intersect typical joints as known in the Oswego and Pulaski beds. No significant tectonic offsets or fault zones were encountered in the onsite borings and none are suspected on the basis of subsurface structural contour maps and detailed stratigraphic cross sections (Figures 2.5-14 through 2.5-17).

Mapping of Trench I across the site (Appendix 2.5H) showed no faults, slickensided joint surfaces, mineralized joints, or small-scale nontectonic folds at the rock surface of the Oswego Sandstone.

2.5.1.2.3.3 Minor Geologic Structures

Minor tectonic and/or nontectonic structural features are recognized along the southern shore section of Lake Ontario and in the site area. Several such features have been the basis of detailed geological investigations over the past decade. The features have been termed popups, pressure ridges or buckles, folds, and postglacial brittle deformation. The significance and occurrence of the features were reviewed in the Site Confirmation Reports[99,100] and described as structural features requiring further study in the site area. An explanation of the features and their probable origin is given in Appendix 2.5A.2.

Within the site area, three minor geologic structures are known from earlier investigations at the J. A. FitzPatrick and Nine Mile Point Nuclear Power Plants. All of these features in the vicinity of Nine Mile Point trend approximately N78degW and are shown on Figure 2.5-9.

At the J. A. FitzPatrick Nuclear Power Plant, a Teepee Fold striking N78degW was exposed in the foundation excavation of the Oswego Sandstone[97]. This feature predates the last ice advance and has experienced no movement since the retreat of the ice. Evidence of residual stresses was absent or negligible[97]. The Teepee Fold has also been called the Drainage Ditch fault (feature, structure) in Dames & Moore's 1978 report, and is categorized as being similar in age and movement to the Cooling Tower fault[91].

The Intake/Discharge fault[97] and the Barge Slip fault[98] are part of the same structure or are en-echelon structures located north of the J. A. FitzPatrick Nuclear Power Plant (Figure 2.5-9). Conclusions resulting from a detailed investigation of the Intake/Discharge fault by Stone & Webster[97] are:

1. Total displacement on the fault is approximately 17 inches with up to 4 inches of gouge

2. The fault displacement dies out within approximately 1,500 ft and resolves into a set of joints

3. The absence of montmorillonite or halloysite in the fault gouge and adjoining shale strongly suggest that there has been no hydrothermal alteration as would be expected if the fault was associated with deep-seated tectonic activity

4. The secondary calcite deposited in joints along the fault is not sheared or crushed

An investigation of the Barge Slip fault by Stone & Webster[98] indicated the following:

1. The Barge Slip fault, a normal fault, is part of an en echelon system (70 to 100 ft wide) that trends N73deg-80degW and is at least 2,000 ft long

2. The faults have a very minimum of offset (6 inches to 3.5 ft)

3. The overlying glacial deposits are not tectonically deformed;

4. The fluid trapped as inclusions in calcite suggest a burial depth of 1.7 km or greater

5. The faulting apparently occurred during Middle-Paleozoic time

During excavation for the Cooling Tower at Nine Mile Point Unit No. 2 in 1976-1977, Dames & Moore reported finding a small scale monoclinal fold with fault displacement along the crestal axis. This fault trends about N77degW and has a displacement of up to 3 ft which reportedly persists to some 200 ft in depth[91]. The fold amplitude decreases eastward as does the fault displacement and becomes rather insignificant in a test pit located south of the FitzPatrick plant. This feature, called the Cooling Tower fault zone by Dames & Moore, was investigated in great detail by borings, trenching, mapping, in situ measurements, and laboratory studies during 1976-1978. The extensive investigations by Dames and Moore on the Cooling Tower fault and Drainage Ditch fault resulted in the following conclusions[91]:

1. Both strike-slip and normal fault movement occurred along the Cooling Tower fault

2. Displacements are due to very old geologic processes

3. Buckling along the Cooling Tower fault is attributed to changes in the bedrock stress field induced by glacial loading and facilitated by the anisotropy of the bedrock

4. Minor deformation of the young, unconsolidated glacial sediments is attributed to a high fluid pressure in the bedrock related to changes in the level of Lake Iroquois. Differential pore pressure in bedrock promoted bedding plane slip and local buckling which was reflected in the overlying glacial sediments

2034 345

5. None of the geologic structures known at the site represent a seismic hazard

All three minor structural features at Nine Mile Point and FitzPatrick Nuclear Plants are concluded to be old, inactive, not capable in accordance with Appendix A, 10CFR100[98], and of no effect on the plant design[93,98]. Some implications of this fault/fold trend (approximately N78degW) were investigated at the New Haven site as described in Section 2.5.1.2.3.1 and Appendix 2.5H. No similiar features or indication of such features (folds/pop-ups, small normal or strike-slip faults) were recognized during the extensive New Haven site investigations nor were any such features exposed in the 982-ft long bedrock inspection Trench I exposing the Oswego Sandstone (Appendix 2.5H). This trench was aligned N38degE, across the trend of the Nine-Mile Point features.

At Pleasant Point on Lake Ontario, unusual crescentic joint patterns and closely spaced joints trending N70degW occur. No offsets or slickensides were observed; some surface blocks of the Oswego Sandstone are tilted. A somewhat similar type of feature occurs along the west side of Little Salmon Creek, south of Arthur, New York (Figure 2.5-9). The sandstone blocks are tilted and closely jointed in a manner similar to those near a popup, however, these features are only partially exposed in stream beds and may not be in place; glacial debris of the bank masks the trend and possible extension. No deformation of the thin overburden is evident at either the Pleasant Point or Arthur site.

Both the Oswego and Pulaski Formations contain many primary sedimentary structural features. These structures are well preserved and are excellent indicators of paleoflow and depositional environment[94,95]. These data were referred to in dividing the Oswego into five zones in the site area (Section 2.5.1.2.2.4). Paleocurrent studies[94] demonstrate a strong northward paleocurrently trend for this prograding environment.

2.5.1.2.4 Surficial Geology

2.5.1.2.4.1 Site Area

The distribution of rock and soil materials in the site area is shown in Figure 2.5-18. Bedrock outcrops are rare, and the Oswego Sandstone is concealed by loose to compacted sediments mainly deposited during the latest recession of the continental ice sheet (some 12,000 years ago). These sediments consist primarily of lodgment and ablation till, sand and gravel deposited by meltwater streams, and sand, silt, and clay deposited in proglacial lakes. These units are discussed in sequence of deposition.

Stratified Sediments Beneath Till

Several borings encountered as much as 12 ft of stratified drift lying directly on bedrock and beneath the glacial till. No surface exposures of such material were recognized. In the subsurface, they are presumed to be discontinuous but common, particularly in shallow bedrock basins or otherwise

2034 346

protected locations. The ice sheet readvanced into imponded proglacial lake waters, and erosion of the lake sediments was extensive, but was not complete everywhere.

Glacial Till

In addition to shaping the bedrock topography, glaciation accounted for most of the drift, either directly as glacial till, or indirectly as stratified drift. The character of glacial till is determined by its grain-size distribution, composition, and mode of deposition. Stratigraphic and sedimentologic studies that relate tills in the nearby region to patterns described in the site area include the work of Kaiser[101,102], Salomon[103], and Moore[104].

An extensive cover of lodgment till mantles most of the site area and is widely exposed at the surface. This material consists of rock fragments (mostly local origin) and glacial flour which was deposited beneath actively moving ice. Due to this process of deposition and subsequent glacial loading, lodgment till is typically firm, dense, and impermeable.

As revealed in deep exposures, the unweathered till is gray with a sandy, silty matrix and contains about 10-percent clay. Rock fragments in the till reflect the terrane traversed by the ice shortly before reaching the point of deposition. Consequently, the till variations tend to involve a downflow blurring of bedrock contacts. On the site, fragments of Oswego Sandstone dominate with very minor proportions of red sandstone, carbonate, and metamorphic rocks. In the southern part of the site area, the proportion of red sandstones increases markedly, giving the till a characteristic red color.

Postglacial weathering has penetrated 12 to 20 ft producing a characteristic weathering profile. In this zone, the till is oxidized, with a yellow-brown to brown color. Calcium carbonate has been leached from the uppermost few ft of the profile by downward circulating ground water.

Lodgment till is marked by distinctly drumlinized topography, involving long, parallel, elliptical hills composed primarily of lodgment till. These drumlins are part of a drumlin field in central New York, which has been the subject of studies by Fairchild[105], Salter[106], Miller[107,108], Muller[109], and Grieco[110]. Drumlin orientations indicate that the last ice sheet to cover the site area spread southeast out of the Ontario basin with flow lines diverging toward the Oneida basin.

Subsequent deposition covered the lodgment till in extensive interdrumlin areas. The surficial map pattern (Figure 2.5-18) of lodgment till clearly indicates the dominance of drumlin topography. Subsequent erosional and depositional processes modified the form of many of the drumlins. Notably, drumlins that stood above the wave base in proglacial Lake Iroquois were subjected to winnowing. The result is that many drumlins in the southern part of the site area are relatively flat-topped in the elevation range at about 470 ft above sea level, and are fringed by a lee-side skirt of stratified sand and gravel.

A veneer of ablation till was deposited in places upon the lodgment till by melting of the transporting glacial ice. Ablation till is thick and dominant in areas of end moraine, deposited near the edge of the ice sheet. Areas of ablation till and end moraine curve obliquely across the drumlinized landscape in discontinuous arcs that record the oscillatory shifting of the glacier terminus during wastage of the ice sheet. The ablation till tends to be coarser, less firm, and somewhat more permeable than the associated lodgment till. The action of glacial melt water caused a limited amount of sorting and washing which produced local pockets of stratified drift (Figures 2.5-18). Topography is irregular and undulatory, involving scattered low knobs and ridges that tend to be elongate parallel to the former ice margin.

Several belts of morainal deposits are shown in Figure 2.5-18. Belts north of the site seem to reflect a minor readvance of the glacier, as indicated by a significant change in the direction of ice flow from that recorded to the south. In these areas of end moraine, throughout the northern part of the site, large blocks of Oswego Sandstone are notable components of the till. This is predictable because the ice sheet here flowed over a gently scarped landscape of Oswego Sandstone. In places, however, the abundance of large blocks is abnormal and suggests the possibility that short-lived deglaciation, prior to the final readvance, permitted unloading and dilation of rock joints, thus facilitating quarrying when the ice readvanced.

Outwash and Kame Gravel

Gravel was deposited by streams flowing from the ice margin throughout the site area. However, due to impounding at the ice margin, no typical outwash plain is developed. Rather, proglacial deltaic gravels are of limited extent, such as south of Jones Corners in Scriba (Figure 2.5-18). Steeply-dipping foreset beds are well developed, consisting of clean, well sorted pebble to cobble gravel, in places interbedded with coarse sand. Locally, ground water has firmly indurated the gravels with calcium carbonate cement.

Lake Sediments

Withdrawal of the ice sheet from the site area was followed by impounding of proglacial melt water. Until the ice sheet withdrawal permitted escape of melt waters north of the Adirondack Mountains, the outflow was eastward into the Mohawk River near Rome. The former lake, controlled by this outlet, was one of the last in a succession of lake stages ancestral to present Lake Ontario and is called Lake Iroquois. Because of postglacial rebound following removal of the ice sheet, shore features of Lake Iroquois now stand several hundred ft above their original level and rise in elevation northward.

The Lake Iroquois shoreline is marked by beach deposits just east of the site area, and by scattered bars and shoal deposits to the south in Volney and Palermo Towns. Except for these features, the entire site area was below the upper limit of Lake Iroquois and, therefore, subject to erosional and depositional modification by wave processes.

2034 348

Erosional activity of Lake Iroquois is recorded by surf-winnowed, flat topped, gravel-skirted drumlins in the southern part of the site area. The Lake Iroquois sediment accumulation is widely represented by a blanket of well sorted and stratified sand, silt, and clay deposited in the interdrumlin lowlands. This material tends to be sandy on the lower drumlin slopes, while at a distance from the slopes and from former ice margins, sand interfingers with laminated silt and clay.

Withdrawal of the ice border, north of the Adirondacks, resulted in an ephemeral lake stage lower than Lake Iroquois, identified by Sutton et al[92] as the Sandy Creek stage (12,000 years B.P.). Because of postglacial rebound of the Lake Iroquois outlet, shoreline features of the Sandy Creek stage, which are well above the present Lake Ontario near the outlet, pass below the present Ontario shoreline in the south. Limited remnants of the Sandy Creek stage are mapped southwest of Pulaski in the northeastern corner of the site area. Other beach deposits comprise baymouth barriers and spits along the present Ontario shoreline and a series of parallel beach ridges on the outer margin of Butterfly Swamp (Figure 2.5-18).

Wind-deposited Sand

Drainage of Lake Iroquois left extensive areas of loose sand exposed to the wind. Consequently, many soil profiles possess a thin cap of structureless silt loess and fine sand deposited by the wind. However, only in the exposed east shore areas bordering Lake Ontario was the sand supply sufficiently enduring or the wind source capable of constructing dunes large enough to be shown in Figure 2.5-18. Because the sand source for some of the dunes at the southeast corner of Lake Ontario seems to have been beyond the present shoreline, Sutton et al[92] inferred that the older dunes record a time of lower lake level in the Ontario Basin (called the Dune stage) before uplift of the outlet to its present level.

Peat and Muck

Upwarping of the Ontario Basin, with uplift of the outlet in the interval since the Dune stage, has resulted in inundating the mouths of rivers along the south shore of Lake Ontario. The action of long-shore currents has closed off many of these basins and the result is development of estuarine swamps. More extensive, however, are the partly enclosed basins between drumlins isolated by kames and end moraine arcs, which are vestiges of former Lake Iroquois. A few contain small ponds, but most have passed from a lake phase to a muckland phase because of the combination of basin filling and either natural or artificial deepening of outflow channels. Organic sediments overlying lake sediments in these basins range from a few ft to a few tens of ft of peat and muck that record the succession of postglacial environments.

Alluvial Deposits

Most streams/creeks in the site area occupy courses which were determined by inherited glacial topography. Postglacial time has been adequate for only minor modification of stream patterns. Only the larger streams have developed

sufficiently extensive alluvial flats to be shown in Figure 2.5-18. The stream deposits generally reflect the local materials. The courses of most streams have cut into areas of ablation and lodgment till, but only rarely to bedrock (Figure 2.5-9). Consequently, the alluvial deposits tend to be coarse lag gravels derived directly from the till and transported only under flood conditions.

2.5.1.2.4.2 Site

The types and distribution of the surficial deposits on site are shown in Figure 2.5-19. With the exception of embankment fills and recent stream alluvium, the surficial deposits are of glacial origin. Most of the major classes of glacial deposits are represented, including lodgement and ablation tills, ice contact and deltaic sands and gravels, and lacustrine silts and clays as described for the site area (Section 2.5.1.2.4.1). The predominant surficial deposit on the site is glacial till with lodgement and ablation tills about equally represented.

Lodgement Till

Lodgement till generally overlies bedrock and consists of a very dense, relatively impermeable, skip-graded material ranging from sandy and gravelly silt to silty and gravelly fine sand. It is the principal constituent of several small drumlins and many drumlinoid knobs and ridges. Most of the latter features, have a core of lodgement till and are blanketed with ablation till.

Locally stratified fluvial and lacustrine deposits occur sandwiched between the base of the lodgement till and the top of rock. The origin of these deposits is discussed in Section 2.5.1.2.4.1. At the site, these stratified materials were encountered in Borings S-2, S-8, S-26, B-3, and B-5 and consisted of interbedded fine sand, silt, and silty clay up to 12 ft thick.

Ablation Till

The ablation deposits overlie lodgement till at lower ground surface elevations and generally underlie lake or kame deposits. Abalation till ranges from 3 to 15 ft thick, and in shallow bedrock areas, such as in the vicinity of the trench, is found directly overlying bedrock (Appendix 2.5H). Ablation till is less dense and more granular than the lodgement till, nonstratified, brown in color rather than gray-brown or gray, and ranges in composition from silty coarse to fine sand with up to 25-percent silt to a sandy gravel with as little as 10-percent silt.

Areas of cobble and boulder concentrations are common in the ablation till and locally occur as nests in a sand or silty sand matrix. Boulders and slabs are principally tabular to rectangular blocks of Oswego Sandstone, and their origin is discussed in Section 2.5.1.2.4.1.

2034 350

Glacial Lake Deposits

Deposits of at least two short lived glacial lakes occur within the site. The relations of these lakes to late glacial, low level stages of glacial Lake Iroquois are discussed in Section 2.5.1.2.4.1. The higher level lake had a wave base in the range of el 350 to 360 (msl). Stagnant ice occupied much of the site during the high-level stage so that the lake deposits are confined to the borders of the lake basin. These sediments consist of silty fine sand and stiff to hard interbedded silt and silty clay.

Shallow water deposits of silt and fine sand were lain down during the melting of the stagnant ice associated with the high level lake stage. The lake level gradually fell to the low level stage during this melting, maintaining a shallow pond bordering the ice margin in which the silts and fine sands were deposited.

The low level lake deposits consist of a typical glacial lake sequence of graded sediments. The coarser materials at the top consist of fine sand and silty fine sand, with materials becoming increasingly finer with depth, grading from sandy silt to a soft, silty clay at the base.

Kame Deposits

Several kame and related ice contact deposits occur on the site, as shown in Figure 2.5-19. A special effort was made to locate kame deposits to be utilized as sources of onsite granular borrow materials.

Kame terraces occur along the west side of the valley of Butterfly Creek and are associated with the high level lake stage. Although included as lake deposits on the broad site area map (Figure 2.5-18), the materials are partly kame deposits and consist primarily of fine sand with some silt and contain no clays; the deposits display characteristic kame terrace forms as shown in Figure 2.5-19.

Just west of the northern kame terrace is a feature mapped as a kame delta (Figure 2.5-19), also associated with the high level lake stage. Because the delta was bounded by ice on the south and by an actively melting ice mass on the north during deposition, it was unable to develop into a normal deltaic form. The bottomset beds of the delta merge with the lake deposits to the west. Postglacial erosion by the unnamed creek flowing through the site has destroyed the former continuity between these bottomset beds and the foreset beds of the delta proper.

Apparently, the stream that supplied the delta with sediments flowed through the topographic saddle between the northern kame terrace and the delta. Coarse gravels occur at this location.

Several small kames occur at scattered locations in the northern portion of the site. Two were explored by test pits. The kame adjacent to the delta bottomset deposit consists primarily of fine sand. The kame noted in Figure

2034 351

2.5-19 as a potential source of granular borrow contains clean sandy gravel and coarse to fine sand. The gravelly material is cemented with calcite.

Loess

Loess occurs as a nearly ubiquitous layer that blankets most of the site. It consists of a yellow-brown, silty-fine sand or sandy-coarse silt from 2 to 3 ft thick (Section 2.5.1.2.4.1). The loess has been significantly altered since deposition. A humus layer (topsoil) has been developed in the upper part in the woods and fields. Locally, frost action has worked gravel and even cobbles and boulders into the lower parts. When saturated, loess experiences a dramatic loss in strength and trafficability.

Embankment fill and stream alluvium constitute a very small proportion of the total surficial deposits (Figure 2.5-19).

2.5.1.2.5 Geologic History

2.5.1.2.5.1 Introduction

The Ordovician rock units exposed on site are part of a southward-thickening veneer of Cambrian-Ordovician sandstones and shales which unconformably overlies Precambrian Grenville-like gneisses and quartzites. Bedrock is largely concealed by a thin to moderately thick cover of young glacial deposits. Bedrock units were not adversely affected by the Paleozoic Appalachian deformation that formed a regional southward homoclinal dip and a few broad folds with small scale faults.

2.5.1.2.5.2 Site Area

The basement gneisses and quartzites of the Canadian Shield, Frontenac Axis, Adirondack Mountains, Green Mountains, and Taconic Mountains were formed during the Grenville Orogeny (1,100,000,000 years ago) of Precambrian time[1]. The exact nature of this orogenic event is unknown, but it is believed to have involved deep burial and high temperatures resulting in the formation of gneisses, marbles, charnockites, granulites, and monzonites. Erosion combined with isostatic uplift exposed these deep-seated rocks by the start of the Cambrian, creating a surface which sloped radially away from the central uplift.

The only Cambrian and Early Cambrian deposition occurred east of the Adirondacks, which provided a source for a eastward-thickening, shelf basin sequence of rocks which are now located in eastern New York and western Massachusetts (Taconic section). This sequence of rocks encroached westward upon the massif and, by Late Cambrian time, marine deposition occurred radially around the Adirondacks throughout the greater portion of present-day New York State. This deposition is recorded north of the site area by the Potsdam sandstone, a beach strand deposit. Continued transgression resulted in the deposition of the alternating sand dolomite and orthoquartzite sandstone of the Theresa Formation (Figure 2.5-8).

2034 352

A stable marine environment continued until Early Ordovician time, when the region emerged and erosion eliminated part of the sedimentary sequence. This was followed by a period of submergence which initiated a long period of Early Middle Ordovician sedimentation resulting in deposition of the carbonate shelf deposits of the Black River and Trenton formations. In Middle Ordovician time, a period of regional uplift occurred as a result of compression from east of the Adirondacks. This resulted in the rising of the land to the east and southeast. Initially, the site area was an area of deep water, but continued uplift created regression of the strand line in a northwesterly direction. During deposition of the middle part of the Oswego Sandstone, shelf and shallow water conditions prevailed. The upper part of the Oswego consists of near-shore shelf and tidal deposits indicating that the site area was in the immediate vicinity of the paleo shoreline.

Deposition of the overlying Queenston Formation is considered to have been continuous with the sequence consisting of both shallow water lagoonal and/or tidal flat deposits. The culmination of the Ordovician period is marked by the Queenston Formation.

By the beginning of Silurian time, the site area was entirely dry land. Eventually, marine deposition resumed and resulted in the Medina delta, recorded in the red, green, and mottled sandstones of the Grimbsy Formation.

Through the remainder of Silurian and Devonian time, deposition continued to the south in the form of fine to coarse clastic sediments from exposed lands to the east. This records the effects of the Acadian Orogeny in eastern New York.

Through the rest of the Paleozoic, northern New York probably received some sediments from the exposed landmass, while, to the south, marine and continental deposition ensued, forming a southward-thickening wedge of sediment. The extent of depth of Paleozoic deposition is conjectural; Colton[(11)] outlines an Appalachian Basin of deposition that extends north of Lake Ontario and covered the site area with several thousand ft of Mid to Late Paleozoic sediments. The Appalachian Orogeny in the Late Paleozoic folded and faulted the rocks in eastern New York (Valley and Ridge Province), and effected the tilting and folding of the rocks of central and western New York southward into the regional east-west-trending homoclinal structure that exists today (Section 2.5.1.1.4.3). Erosion has removed all Silurian and younger Paleozoic strata from the site area, leaving the Oswego Sandstone as the youngest rock unit at the site.

The most recent geologic events are the several stages of Pleistocene glaciation, which scoured the bedrock and then, in receding northward, contributed a veneer of till, glacio-fluvial, glacio-lacustrian, and other periglacial sediments to the site area.

2.5.1.2.6 <u>Site Engineering Geology</u>

The foundation rock at the site has not been adversly affected by deformational events throughout geologic history. These events tilted the

rocks gently southward in low dip, and formed a pronounced joint pattern. There is no evidence of faults, shears, folds, or major discontinuties occurring in the rock beneath Seismic Category I structures. Joints below the top few ft of oxidized and frost-wedged rock are generally tight, unweathered and moderately to widely spaced (Section 2.5.1.2.3.2).

Seismic Category I structures will be founded on fresh rock. The sandy clay/silt glacial lake deposits, any thin zone of weathered bedrock, or any slabs at the top of rock dislodged by ice shove will be removed during foundation preparation. Deep excavation slopes in the glacial deposits (till and lake deposits) which could become unstable will require appropriate design for stability. The local deposits of relict stratified sediments may be very permeable and unstable in deep cut slopes. Engineering properties of soil and rock at the site are discussed in detail in Section 2.5.4.

The coarse to fine-grained, silica-cemented sandstone bedrock is not susceptible to solution action. There are no major empoundments in the area which induce loading or unloading effects on the site. The only subsurface fluid withdrawal in the area is by domestic wells which will have no effect on the foundation rock beneath the Seismic Category I structures. The past withdrawal of natural gas from the old Pulaski field (8 mi north of the site) or the proposed production from three to four wells, located 5 to 6 mi east-northeast of the site (Well no. 12447, 12399, 12406, or 12398)[84]) is not considered a cause for subsidence in the area (Figure 2.5-9). Production from the Trenton beds at around 1,500 ft below the surface is reported to be of short duration. Gas is produced commercially for a few months or 1 to 2 years, and then tails off very quickly to a very low flow.

Minor gas seeps are known in the foundation of the nearby Nine Mile Point Nuclear Plant, Unit No. 2.

The very small natural gas occurrences/pockets in the Oswego Sandstone can be safely controlled by venting. Because the excavation is shallow and is high in the Oswego section, there is little potential for the occurrence of gas.

2.5.1.2.7 Site Ground Water Conditions

The site ground water conditions are discussed in Sections 2.4 and 2.5.4.

2.5.1.2.8 Mineral Resources

2.5.1.2.8.1 Site and Local Resources

Geologic mapping and subsurface investigations located no unreported mineral resources within the 5-mi area or the site. Glacial materials are widespread (Figure 2.5-18) and fair quality sand and gravel deposits occur within the area. A few pits are operated for local use, such as the Rose Pit south of New Haven, and Phelix, Meany, and Lazarek Pits some 5 mi to the southwest.

Natural gas has been and is being produced from the Trenton Limestone (Figure 2.5-8) throughout parts of central and western New York State. Some small

natural gas reserves are known within 6 mi of the plant site. However, all past production has been of short duration (for months or up to 2 years only), and then the gas tails off very quickly to a very low flow[112]. Pockets of natural gas were encountered in Oswego during exploration and the subsequent excavation for the Nine Mile Point No. 2 Unit, located some 5 mi northwest of the site (Figure 2.5-9). The gas is 93 percent methane and is probably generated in the underlying Pulaski and Trenton beds. The gas flows dissipated within a few days. A few cored borings at the site encountered some pockets of gas which dissipated (lost pressure) within a few days (Section 2.5.1.2 and Appendix 2.5C).

The wells that supply water for domestic purposes in the site area are normally shallow dug wells in till, or deeper drilled wells in rock. The dug wells are low yield, large diameter installations which rely primarily on well storage. The shallow wells are subject to decreasing yields, or may even go dry during the summer months. The deeper drilled wells also are low yield. The best source of high yielding wells are the glacial outwash sand and gravel deposits. The nearest known deposit capable of producing yields sufficient for public supply is located in Mexico, 4 mi southeast of the site. There are no deposits onsite that are potential sources for high yield wells. Ground water use is discussed in detail in Section 2.4.13 of the PSAR and Section 2.1.3.8 of the Environmental Report.

The Oswego Sandstone was quarried for dimension stone prior to the 1960's, but this use is currently uneconomic. Local use of this material for riprap and breakwater stone is common.

2.5.1.2.8.2 Local Mineral Extraction Activities

Mineral extraction activities within the area consist of ground water withdrawal for domestic purposes and quarrying a few small sand and gravel deposits for local uses. Construction of the station would have no effect on these operations.

2.5.1.2.8.3 Summary and Conclusions

Geologic mapping and subsurface investigations throughout the 5-mi area and detailed investigations of the site located no previously unreported mineral resources. Small pockets of natural gas are known; a principal ground water aquifer for domestic purposes occurs in the glacial deposits; and the Oswego Sandstone is a potential source for construction/building stone.

Construction of the station would have no effect on any of the local mineral extraction activities.

2.5.1.2.9 Geologic Hazards

There is no record of a seismic or aseismic (geologic) event causing damage within 25 mi of the site.

2.5.2 Vibratory Ground Motion

2.5.2.1 Seismicity

2.5.2.1.1 Local and Regional Seismicity

The relatively low level of local seismicity at the site is clearly illustrated by the cumulative seismicity map (Figure 2.5-21) compiled for a large region of eastern United States and Canada. Superimposed on this map is the site location and 50-, 100-, and 200-mi radius circles around the site area that show the spatial relationship of the site to the various zones of historical seismic activity. These zones of concentrated activity are clearly distinguishable from the almost aseismic background.

The listing of available earthquake parameters describing all plotted events is presented in Table 2.5-1. Recommended thresholds, i.e., magnitudes greater than 3.0 and modified Mercalli (MM), intensities greater than III have been followed. Table 2.5-2 lists all known parameters of earthquakes not well enough defined to be plotted in Figure 2.5-21. There is no historical record of a seismic or aseismic (geologic) event having caused damage within 25 mi of the site.

Three symbols are used to plot epicenters: an octagon, a square, and a square with two diagonal lines. The first symbol is used for intensity, the second for magnitude, and the third for magnitudes of events which have occurred since 1968. The size of all symbols is proportional to the size of the events; the proportionality is not linear and attempts to indicate the increasing importance of larger events. All of the preinstrumental era events are plotted with the intensity symbol.

Events of the early part of the instrumental era are also plotted with the intensity symbol. From 1928 to 1968, MM intensity values are used when available; if not, the M values are used, but the size symbol is slightly reduced to correct for the bias signaled by Stevens[113]. Some larger events for which the magnitude has been reexamined conclusively are also plotted with the magnitude symbol. From 1968 on, the magnitude symbol is used exclusively. This is done because most of the magnitude values are calculated according to Nuttli's scale (m_{blg}), which is more applicable for the eastern region than the Richter local magnitude scale used previously. Such m_{blg} values are considered more characteristic of the events than other magnitude or intensity values. The third symbol (square with diagonals) is used to differentiate the more recent events (last decade) from the others, and to suggest that both epicentral locations and magnitude values are likley to be more accurate for reasons to be discussed later.

2.5.2.1.1.1 Data Base

Sources

The cumulative historical seismicity, as presented here, is taken from Weston Geophysical's earthquake data base. This data base contains a set of

parameters for each earthquake, selected on the basis of a comparative review and evaluation of available listings, supplemented by extensive historical research. A parallel compilation was made of all entries contained in major earthquake catalogs and listings. These include the United States Earthquakes Series; The Earthquake History of the United States; the Publications of the Dominion Observatory (Canada) a the Seismological Series of the Earth Physics Branch (Canada); the Bulletins of the Lamont-Doherty Observatory and the New England Seismological Association; as well as listings by Mather and Godfrey, Brigham, Brooks, Pomeroy, etc. This compilation facilitated the detection of typographical errors, and signaled discrepancies to be investigated. By keeping in mind the chronological order of important listings, such as those of Mather and Godfrey, Brigham, Brooks, Eppley, Coffman and von Hake, Smith, Pomeroy, etc., and by returning to quoted references, it was possible, in many cases, to weigh the quality and significance of these listings and also detect some misinterpretations. The investigation of historical sources, such as newspapers, scientific bulletings, town histories, private diaries, etc., has contributed important earthquake information and led to the revision of some older historical events. This is illustrated in the Historical Seismicity of New England[114] published as part of the PSAR of the Pilgrim II site.

Completeness and Reliability

The cumulative seismicity presented in this analysis needs to be discussed in terms of completeness and reliability. Its internal value for the seismic risk assessment is tied to these qualities.

Even though major historical catalogs carry entries dating back to more than three and one-half centuries, in no way should the coverage of this long period be considered homogeneous. On closer examination of the spatial, temporal, and size distribution of the reported events, it appears that the completeness and reliability of the data set is intrinsically related to the quality of the population distribution and, later, of the seismographic network coverage. Accuracy of epicentral coordinates and assigned maximum intensities must be cautiously evaluated; focal depth information is simply absent.

For many of the earlier historical events, epicenters may have been located incorrectly near dense settlements due to the absence of felt reports from the true epicentral area. Construction practices, especially of chimneys in the earlier centuries, were certainly not those envisaged in the Modified Mercalli scale; if historical damage reports are interpreted without due consideration, they may result in overestimated intensities. The tendency of early settlers to build near rivers, where soil conditions amplify ground motion, may have resulted in a biased sampling of the earthquake damages and lead to overestimated intensities.

Figures 2.5-22 and 2.5-23 show the progressive migration of the population, in the eastern United States and Canada. These figures indicate that for a long period of the historical record, the population distribution was such that the seismological information on events located outside the major concentrations of population was biased.

2034 357

Seismological information for the instrumental era (post-1900) must also be accepted with caution. Seismic instrumentation made its beginning in the early 1900's, both in the United States and Canada, the quality of the earthquake data improved very slowly with time. Epicentral locations were still based on felt reports; they were only complemented and somehow controlled by instrumental data. For much of this era, from the start of the century and up to the sixties, several seismographs operated simultaneously in the northeast, both in the United States and Canada. These few stations were part of regional networks operated by the Jesuit Seismological Association (JSA), the Canadian government, and some American colleges and universities. In these early decades, numerous factors, such as the type of instrumental response, lack of accurate time control, awkward configuration, use of graphical method, and limited knowledge of crustal velocities, were potential sources of errors and large uncertainties in the epicentral coordinates. In the sixties, some improvements in the coverage came about with the operation of the World Wide Standard Station Network (WWSSN), the Long Range Seismic Monitoring Program (LRSM), and the expansion of the Canadian Network for the Upper Mantle Project. The operational characteristics and station distributions of these networks were primarily oriented towards recording large regional and teleseismic events and studying the internal structure of the earth. The uncertainty to be associated with many local epicenters during the sixties can still reach tens of kilometers.

Since the 1960's, increased interest in understanding the local seismicity has resulted in the implementation of dense seismograph networks. Presently, seismic data in the northeastern United States are gathered by the Northeastern United States Seismic Network (NEUSSN) and reported in its bulletin. This agency, incorporated in 1975 and funded by the Nuclear Regulatory Commission (NRC), the United States Geological Survey (USGS), the National Science Foundation (NSF), the New York State Energy and Resource Development Authority, and the New York State Science Services, reports earthquake hypocentral locations and magnitudes determined through cooperation of the following institutions: Weston Observatory of Boston College (WES), Massachusetts Institute of Technology (MIT), University of Connecticut (UCT), Lamont-Doherty Geological Observatory (LDO), Pennsylvania State University (PSU), Delaware Geological Survey (DGS), and the Maine Geological Survey (MGS).

Seismicity data for adjacent eastern Canada are reported in the annual Canadian Earthquakes Seismological Series of the Earth Physics Branch (EPB) of Canada.

A recent configuration of seismographic stations, operating in the area confined by the 39deg and the 50degN parallels and the 67deg and 80degW meridians at the beginning of 1977, is presented in Figure 2.5-24. It includes the following numbers of seismograph stations: LDO-29, WES-20, MIT-8, EPB-5, PSU-4, and DGS-1.

These 67 seismograph stations, operated by NEUSSN and the EPB, is supplemented by dense micro-networks funded by power utility companies. These arrays include 13 stations in southeastern New York, supported by Consolidated Edison

Company, and 5 stations in central New Hampshire, supported by Boston Edison Company. These micro-networks are not shown in Figure 2.5-24. It should be noted that the present seismograph configuration may be slightly different than that shown, as new stations are being implemented and others moved or deactivated.

The cumulative historical seismicity data, interpreted in the light of careful review, yields valuable information on the spatial and temporal distribution of the larger significant events and the location of zones of concentrated seismic activity. It has been pointed out that the distribution of recent epicenters obtained through a denser network[115] appears to be a reliable indicator of the major seismicity patterns. Granting that a correlation of epicenters with surface geologic features is more likely to be made using the more accurate data obtained in the last few years than with the older and less reliable data, it is a fact that only the historical record, complete for more than two centuries at or above a significant threshold, e.g., Intensity VII, MM, can yield information on the temporal continuity of these seismic zones. The understanding of causative mechanisms, based on fault plane solutions and focal depths, depends on the more accurate data recently acquired. The definition of the upper bounds which characterize major seismic zones and the approximate location of these events can only be obtained through seismic records of a sufficient time span and information on the nature, size, extent, etc. of structure(s) which may cause earthquakes.

Another important point to be made is that all the large historical events are spatially coincident with the few zones of activity revealed by recent networks having a lower threshold of detection. This suggests that tectonic forces relatively homogeneous over large regions of the continent must give rise to stress concentrations and strain releases in those specific areas where seismic activity has been evident for centuries. In this context, the occurrence of large earthquakes becomes spatially predictable. If large earthquakes can not be predicted in time, their occurrence in space is not random but confined to these continuously active areas.

2.5.2.1.1.2 <u>Recent Revision of Some Historical Events</u>

<u>The September 16, 1732 Event</u>

This event was the object of additional historical research because of its importance as one of the larger events which occurred within the Western Quebec Seismic Zone. The true intensity and exact location of this event have been often questioned in recent years, both in Canada and United States. In review, the following intensity values were published: Mather and Godfrey[116] assigned a Rossi Forel Intensity IX (Intensity VIII-IX(MM)) to the event; the two references quoted were Brigham, and Lewis and Newhall. Heck and Eppley[117], in their Earthquake History of the United States, assigned an Intensity VIII(MM). Brooks[118] also assigned an intensity VIII(MM). Smith[119] was the first to assign an Intensity IX(MM); his references do not indicate any new research beyond already published sources. The reason for his adopting an Intensity IX(MM) is not explicitly given. Smith presents some supporting material and quotes only one reference in

full: it is an abstract of the letter of Mother Duplessis of St. Helen. Coffman and von Hake[120], in their revised edition of Earthquake History of the United States, assigned an Intensity IX citing Brigham and Smith as references. No reason was given for the change.

All of the above references were based on very limited data to arrive at their conclusions: a few descriptions of damages in Montreal were not written in Montreal. Some descriptions dealt primarily with effects along the coast of New England with only secondary mention of what was heard to have occurred in Montreal. The basic reference used, that of Mother Duplessis of St. Helen, superior of the Hospital Hotel Dieu in Quebec, is a friendly letter to a female friend in France. It is written with the contemporary colorful style of the epoch and a touch of religious piety, particularly evident in the original French text. It is probable that Smith assigned the Intensity IX(MM) to account for the large number of broken chimneys and the dramatic description of the religious fear that resulted both from the main shock and its long sequence of aftershocks.

At this point, it should be noted that E. A. Hodgson[121], in an appendix to his major study of the La Malbaie 1925 event, (cited Smith[119]) questioned both the intensity and location of the 1732 event on the basis of the available evidence. He also called explicitly for further research in order to solve the problem (Appendix 2.5F.1).

In this present study, the 1732 event is assigned an Intensity VIII(MM) on the basis of new material uncovered and a review of the entire context from which some former evidence had been abstracted. In particular, the description written by Sister Cuillerier, a historian of the religious community in charge of the Hospital Hotel Dieu in Montreal, is given prime consideration. The earthquake effects, e.g., broken chimneys, falling stones, disturbed wells, and fears described in this text are adequately covered by an Intensity VIII(MM), as interpreted in the Richter[122] commentary of the Modified Mercalli scale. A corresponding Magnitude 6 at or very near Montreal could account for the described damages, particularly if the soil conditions of the city and the poor quality of masonry are taken into consideration. Clark[123] states "that the greater part of the Montreal area is covered by deposits of Pleistocene and Holocene ages. These, in part, are of glacial origin, and, in part, deposits made in the seas of the Champlain submergence." A building inventory taken in 1731 shows that at least one half of the houses were built of wood; in this case, the chimneys were not as well supported as in the case of stone buildings and, thus, are more vulnerable to horizontal ground motion. In addition, the letter of the Montreal Hotel Dieu Superior, Sister Le Vasseur, to the Colony Intendant, Mr. Hocquart, with the object of asking for compensatory monies, does carry clear references to damages of the Intensity VIII(MM) range, but has no dramatic overtone. In fact, reference to previous fires and fear of frost wedging are suggested as potential causes of future structural damages, underlining the urgency of repairs. It should be noted that an Intensity VIII(MM) in Montreal would be in better agreement with the Intensity III-IV(MM) that can be assigned to Quebec City, on the basis of Hocquart's comment that the shock "amounted to not much in Quebec." An Intensity IX(MM) in Montreal would, according to the attenuation curves,

account for an Intensity V-VI(MM) report in Quebec, certainly not in agreement with the Hocquart report. Similarly, an Intensity VIII(MM) in Montreal would be in good agreement with the Intensity III-IV(MM) observed in eastern Massachusetts. Appendix 2.5F.1 presents the original texts of some newly uncovered materials used in the reevaluation as well as that of the most pertinent ones already available.

As far as the location is concerned, clearly, the present epicentral coordinates should be accepted, with some uncertainty of at least 30 mi. The suggestion of E. A. Hodgson, that the event could have occurred further down the river, is not accepted here for two reasons. First, the felt report for Quebec City and eastern Massachusetts would show a greater discrepancy with predicted intensity values. Judging by the census for 1739, as presented by Sulte[124], it appears that the distribution of settlements around Montreal, down the river, was such that an epicenter substantially outside Montreal would likely have been recognized as such. Second, Hodgson's reasoning that the long duration points to a somewhat distant epicenter is not entirely convincing. Discrepancies on observed duration as well as the possibility of aftershocks immediately after a main shock are arguments that can be made against using duration.

The December 18, 1867 Event

The epicentral coordinates of 44degN and 73degW as in Smith[119], Coffman and von Hake[120], and others following them, placed an event with an assigned Intensity VII(MM) in the area between the Western Quebec Zone and the New England White Mountain Plutonic Series (Zone A, Boston Edison Company, Pilgrim II SER). To a certain extent, this event, as originally (mis-) located, may explain in part why the Boston-Ottawa trend was conjectured..

Extensive historical research was performed to clarify and improve the data set which supported the original location. Possibly, the earlier researchers were aware of the broad felt area, but could not (or did not) succeed in drawing an isoseismal around an area of distinct highest intensity. From the descriptions of people awakened in Burlington, Vermont, (given as supporting material) it remains hard to understand how an Intensity VII(MM) was assigned.

New material gathered from local newspapers was evaluated and assigned local intensities mapped. Numerous places far apart showed an Intensity V(MM); a single region, centered in Canton, New York, reported a long sequence of aftershocks; also, disturbances of well waters were exclusive to that area. An Intensity VI(MM) is a conservative estimate for this region, considering that no structural damage was reported. The proposed relocation is 44.65degN and 75.15degW, near the center of the aftershocks. Relevant new material is presented in Appendix 2.5F.2.

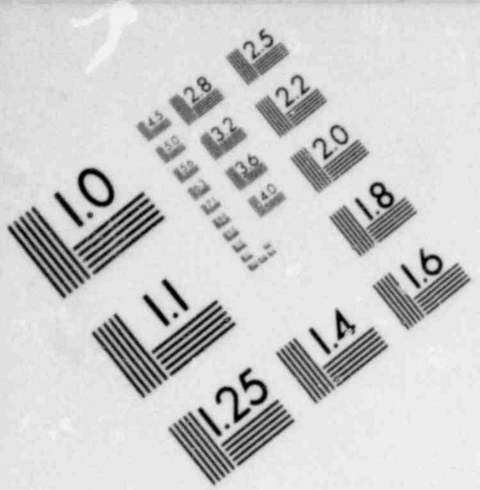
The November 4, 1877 Event

This earthquake is listed by Smith[119] and Coffman and Von Hake[120] as an Intensity VII(MM) event located at 44.5degN and 74.0degW. Brooks[118] assigned epicentral coordinates further north at 45.0degN and 74.0degW, while

2034 341

IMAGE EVALUATION TEST TARGET (MT-3)

6″



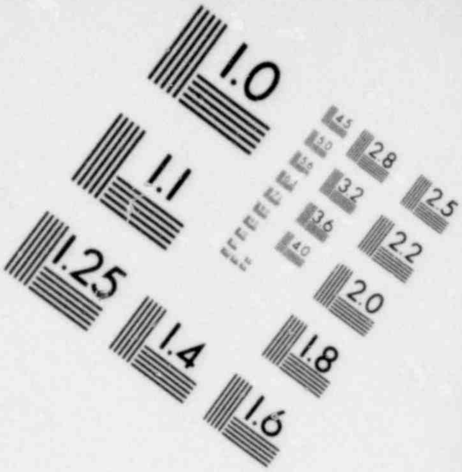
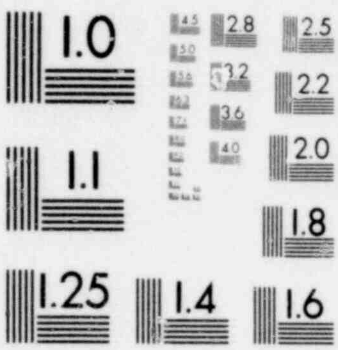
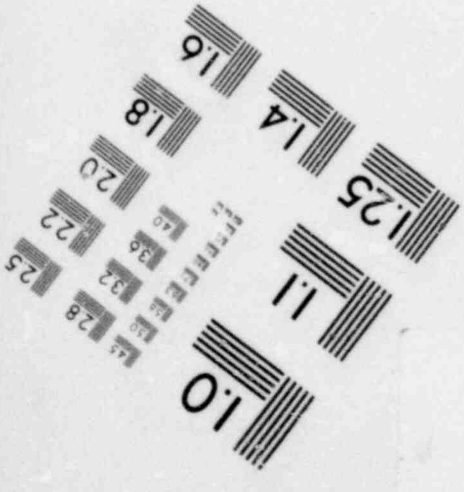
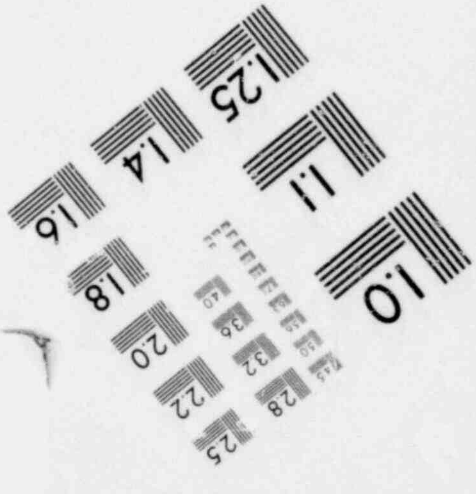


IMAGE EVALUATION TEST TARGET (MT-3)



6″





retaining the Intensity VII(MM) parameter. Considering this uncertainty in the location, numerous original newspaper accounts were collected to reanalyze this event; these are presented in Appendix 2.5F.3.

Accounts of the earthquake's effects for localities between Massena, New York, and Montreal, Quebec, although containing a few references to damaged chimneys, are best evaluated with an epicentral Intensity VI(MM). As in the case of the 1867 earthquake, the characterization of this event as an Intensity VII(MM) by previous authors is not realistic, due to the lack of structural damage.

Although the case for a reevaluation of this event to an epicentral Intensity VI(MM) is well justified by the newly uncovered reports, the epicentral location is not as well defined by them. However, several items in an account from Huntingdon, Quebec, suggest that this locality may be situated near the earthquake's source. The report at Huntingdon indicates a short, impulsive duration of shaking in the range of 6 to 12 sec, and also mentions the possible occurrence of two slightly felt aftershocks. Recent instrumental earthquake locations show a cluster of epicenters just northeast of Huntingdon. Based on this fact and the previously-discussed historical data, the following parameters have been adopted for the 1877 event: epicentral coordinates 45.4degN, 73.9degW, Intensity VI(MM). Some uncertainty should continue to be attached to the revised epicenter.

The February 10, 1914 Event

The epicentral location (44deg59'N, 76deg55'W), given to this event by Smith[114] and numerous others who have simply copied his catalog, resulted in an isolated Intensity VII(MM) completely outside of the southwestern boundary of the Western Quebec Zone. Smith discussed nonetheless another location (46degN15'n, 74deg46'W) that Dr. O. Klotz, seismologist at the Dominion Observatory had calculated, at the time of the earthquake. Dr. A. E. Stevens[125] indicated that Dr. Klotz's location could be the correct one. Just recently, Basham[126], in a risk analysis for the Gentilly nuclear site, used a revised epicenter, 46degN and 75degW, the position adopted by Weston Geophysical.

2.5.2.1.2 Zones of Concentrated Seismic Activity

The cumulative historical seismicity map (Figure 2.5-21) reveals the presence of several distinct areas of concentrated seismic activity. These are addressed individually in terms of location, areal extent, level of historical seismicity, and their tectonic framework as inferred from current research.

The Western Quebec Zone

The largest concentration of seismic activity is located in a northwesterly trending zone, consisting of a large portion of southwestern Quebec and the upper part of northern New York State, located between the St. Lawrence River and the New York-Vermont border. Starting near Kirkland Lake, Ontario, the southwestern boundary of this zone is almost coincident with the Ottawa River,

2035 001

from Timiskaming to Ottawa, suggesting a possible major tectonic relationship. From there, it heads towards Cardinal and enters New York State, where it curves to the east at about 44deg20'N. Formerly considered a part of the Boston-Ottawa trend[58] which was thought to be continuous through New England, the Western Quebec Zone appears now, on the basis of more recent and reliable seismicity data, to terminate in New York, abutting on an apparent aseismic zone in central and northern Vermont. Basham[126] has clearly left the Blue Mountain Lake Activity out of the zone. He has estimated the total area of the elliptical zone to be 1.6 x 10^5 sq km, and dashed its entire boundary to indicate that the definitive tectonic control is not well known. The zone is fairly broad, close to 200 mi to the northwest and more than 100 mi to the southeast. Basham considers the western Quebec zone to be the most active area in eastern Canada, on the basis of the 1971 to 1975 data. Sbar and Sykes[115] have partially corrobrated this in defining northern New York the most active area in state. Horner et al[127] have calculated fault plane solutions for the Maniwaki, Quebec, July 1975 event, as the most northerly located event in the zone with a known mechanism. The fault planes oriented north-northwest are almost parallel to the zone trend. This is somewhat similar to the solution for the Altona earthquake of June 1975[128], located near the southeastern limit. Thrust faulting and nearly horizontal deviatoric pressure axes are consistent with the observations by Sbar and Sykes[58] of maximum compressive stress, nearly horizontal, oriented in a northeasterly direction.

Besides the frequent occurrences of relatively small earthquakes in the magnitude range of 2 to 4 the zone is characterized in the instrumental era by two earthquakes with magnitudes near 6. The first one occurred near Timiskaming, Quebec, on November 1, 1935, and was given an epicentral Intensity VII(MM). It had a rather large felt area, near 1,000,000 sq mi. E. A. Hodgson[129,130,131] studied the event in detail. The second event had its epicenter in the Cornwall-Massena area and occurred on September 5, 1944; its maximum intensity was VIII(MM). The magnitude 5.9 that was originally given to the event has been reviewed by A. E. Stevens[125], Street and Turcotte[illegible], and Basham[126], who suggest that an m closer to 5.6 could be more realistic. In the preinstrumental era, the historical event of September 16, 1732, placed near Montreal, stands out as the largest event. Smith[119] assigned an Intensity IX(MM), on the basis of reports which did not, strictly speaking, originate in Montreal. In Section 2.5.2.1 and Appendix 2.5F.1, it is suggested, on the basis of additional evidence, that an Intensity VIII (MM) could adequately correspond to the reported observations.

Activity in Western New York

Historical reports and recent instrumental data from dense seismograph networks, indicate the present of a diffuse zone of seismic activity extending from the Dale-Attica region of western New York to the area of the Niagara Peninsula between eastern Lake Erie and western Lake Ontario. Surrounding this zone of relatively minor activity is a wide region than can be described as a seismic, based on available data.

2035 002

The Intensity VIII Attica earthquake of 1929 is the largest known earthquake located in this area. Analysis of the several available seismograms of this event have yileded a magnitude 5.2 m_{bLg}[132]. Herrmann[133] suggests that the high intensity resulting from this relatively low magnitude can be explained by a shallow focal depth. Fox and Spiker[134] have proposed a reclassification of this event to an Intensity VII(MM).

The 1929 event, along with other felt earthquakes in 1966, 1967, and 1973, and recently detected microearthquake swarms, which are apparently related to salt mining, can be spatially correlated to the Clarendon-Linden fault system[135,115]. Some of the earthquake activity appears to be spatially correlated only to a segment of the Clarendon-Linden fault. The entire fault extends from near the New York-Pennsylvania border, northward into Lake Ontario[135], where activity was recently recorded. The fault appears to be the eastern terminus of a weak alignment of earthquakes from the Niagara Peninsula, eastward.

Focal mechanism solutions of two Attica earthquakes, by Herrmann[133], and a composite focal mechanism solution of earthquake swarms near Attica, by Fletcher and Sykes[135], indicate reverse faulting on a nodal plane parallel to the northerly trend of the Clarendon-Linden system. Focal depths of the analyzed events are restricted to the upper 1 to 3 km of the crust.

Activity in Southeastern New York and Northern New Jersey

Seismic activity in southeastern New York, eastern Pennsylvania, and New Jersey is characterized by several repeated occurrences of Intensity VII(MM) earthquakes. Three events occurred near New York City in 1737, 1884, and 1927, and two others occurred in southwestern New Jersey in 1840 and 1871. Several Intensity VI(MM) events are also distributed throughout this area of low level activity.

Recent investigations by Aggarwal, et al[136] and Sbar and Sykes[115] propose a spatial correlation of instrumentally recorded, small earthquakes to the Ramapo fault system, which extends in a northeasterly direction, parallel to the Appalachian trend in this region. Available focal mechanism solutions for this area, by Aggarwal[128], suggest high angle reverse faulting along planes that parallel mapped or inferred segments of the northeast trending Ramapo system.

Activity in the Adirondack Mountains

The more significant historic seismic activity in the region of the Adirondack Mountains is restricted to their margins near or within adjoining physiographic provinces. Activity to the north is associated with the southernmost extension of the previously discussed Western Quebec zone. The Intensity VII, Lake George earthquake of 1931 is located at the southeast margin of the Adirondacks, near the western boundary of the Valley and Ridge province. Two other Intensity VI(MM) events, one near Utica, New York, in 1840 and another near Lowville in 1853, are located at the western edge of the

Adirondacks, near the boundary with the Eastern Stable platform. No other significantly felt earthquakes are known for the Adirondacks.

Since the implementation of recent networks, microearthquake swarms in the vicinity of Blue Mountain Lake, in the central Adirondacks, have been reported[137]. These events, ranging in magnitudes to 3.6 m_{blg}, have characteristically very shallow focal depths, down to 3.5 km[137,138]. Focal mechanisms for the Blue Mountain Lake events exhibit reverse faulting along planes oriented north-northwest[115,138].

Aggarwal[128] suggests that earthquakes in the Adirondacks occur at shallow depths, preferentially along northwest trending faults and not along the predominant northeast striking features known for this region.

Activity in Central New Hampshire and Northeastern Massachusetts

The area of central New Hampshire and northeastern Massachusetts, including the Cape Ann area, once considered to be a segment of a continuous Boston-Ottawa seismic trend[58], is now interpreted as a separate seismic region. Recently, Sbar and Sykes[115] have recognized the presence of a seismicity gap in Vermont and western New Hampshire.

Extensive regional investigations, geological and geophysical, conducted for the PSAR of the Pilgrim II Unit, have stressed the individual entity of this seismic zone. The largest events to affect this region are the Intensity VIII, Cape Ann earthquake of 1755, and the three Intensity VII events; one near Cape Ann in 1727 and two near Ossipee, New Hampshire, on December 20 and 24, 1940. Street and Turcotte[132] recommend a magnitude of 5.4 m for the Ossipee events, based on reanalysis of several seismograms. The larger earthquakes in the Ossipee and Cape Ann areas have been individually correlated to certain plutons of the White Mountain series in combination with anomalous country rock faulting by the Applicant of the Pilgrim II Unit. The Nuclear Regulatory Commission has associated these earthquakes with a larger structural zone of White Mountain intrusives and the United States Geological Survey, following Hadley and Devine[139], correlates the earthquakes with the northeastern Massachusetts zone of deformation defined by a series of northeast trending faults.

Recent activity in this region, including central New Hampshire and the Cape Ann area, appears to be low. Only several events ranging in magnitudes to just over 3.0 m have been reported in the last decade.

Activity in Southern New England

Areas of central Connecticut, near East Haddam and Moodus, and the region near Narragansett Bay in Rhode Island and southeastern Massachusetts have experienced a level of activity lower than that previously described for the central New Hampshire and eastern Massachusetts region, but appreciably above the adjacent aseismic regions as seen in Figure 2.5-21. The largest event for this region is the Intensity VI-VII, East Haddam earthquake of 1791. More

recent activity is restricted to several events ranging in magnitude to approximately 3.5 m_b.

Activity in Maine and Adjacent Eastern Canadian Provinces

The seismicity of Maine, characterized by a maximum Intensity VI, is spatially distributed in the central and west-central regions, the New Brunswick border area and the Quebec border region, near northern New Hampshire.

Two Intensity VI(MM) earthquakes, one located at sea off Portland in 1957 and the other near the Maine-Quebec border in 1973, are both assigned magnitudes of 4.8 m . Wetmiller[140] determined, for the 1973 event, an oblique strike-slip focal mechanism with nodal planes oriented N40degE and N37degW. This solution is the first available for Eastern Canadian or New England earthquakes.

The La Malbaie, Quebec Zone

This zone, located northeast of Quebec City, is completely outside of the 200-mi radius circle around the site. It is briefly discussed because, of all the zones included in Figure 2.5-21, it is the most important in terms of energy released. Historically, numerous large events have occurred in this zone (Table 2.5-1) with intensities ranging from VIII to X. Some of these events are listed in Section 2.5.2.4 as felt at the site. There are reasons to suggest that the epicentral distribution, as presented on the cumulative map, shows a large scattering of smaller events which are not real, but result from population and network biases[141]. The tighter distributions of microearthquakes located during the 1970 and 1974 field surveys[141,142], coinciding with the epicenters of the larger shocks, are probably more indicative of the true areal dimensions of the seismic activity. A conjunction of the Charlevoix meteoritic impact structure and Logan's tectonic structure has been presented as a likely cause of localized strain release[141]. Fault plane solutions for some small events agree with northeasterly-oriented faults present on the north shore of the St. Lawrence, parallel to Logan's line; they suggest, in general, a thrusting motion. The significance of these features for the understanding of the regional tectonics should be minimized until further data from larger shocks are acquired.

2.5.2.2 Geologic Structures and Tectonic Activity

2.5.2.2.1 Introduction

The site is located in the eastern portion of the Eastern Stable Platform Tectonic Province (Figure 2.5-5). Geologically, the province consists of undeformed Cambrian through Permian shales, sandstones, and carbonates which lie unconformably on a peneplained surface of highly deformed Precambrian gneisses of the Grenville basement[19]. To the north, the province projects up slope to the Frontenac Arch, whose northern boundary coincides with the southewestern edge of the Western Quebec Seismic Zone. To the east, the Eastern Stable Platform is bounded by the Adirondack Mountains, consisting of Grenville-age crystalline rocks. To the south, the Eastern Stable Platform

province is bounded by the south-southwest trending Appalachian Plateau province consisting of deformed Cambrian through Permian carbonates, sandstones/quartzites, and shales which thicken to the south.

Within a 200-mi radius of the site, the following tectonic provinces or parts of tectonic provinces are found: the Eastern Stable Platform (site province), the Appalachian Plateau province, the Adirondack Mountains, the Frontenac Arch, the Northern Valley and Ridge province, and the New England Maritime province. Also included is part of the seismotectonic province currently called the Western Quebec Seismic Zone. A seismotectonic province is a region characterized by a relative consistency of the geologic structural features of the earth associated with or revealed by earthquakes.

2.5.2.2.2 <u>Eastern Stable Platform province</u>

The Eastern Stable Platform is characterized by a sequence of very slightly deformed, nearly flat lying sedimentary rocks of Cambrian to Permian age which rest on a gentle southward sloping peneplained surface underlain by crystalline rocks of Grenville age. The youngest known, tectonically derived structures in the province are kimberlite and ultramafic dikes of Early Cretaceous age[19].

The only faulting in the province which some investigators assume to be active is on the Clarendon-Linden fault zone, near Attica, New York[135]. Seismic activity spatially correlated with the central portion of this fault system is discussed in Section 2.5.2.1.2. No evidence for young deformation or Quaternary movement has been reported[5].

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.2, 2.5.1.1.4.2, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5.

The distribution of earthquakes and tectonic and seismotectonic provinces within 200 mi of the site are presented in Figure 2.5-25. Not included in Figure 2.5-25 is a cluster of events in southeast-central Ohio, 400 to 450 mi southwest of the site, where several events with intensities ranging from V to VII(MM) have been reported[142]. No geologic structural discontinuities are mapped for the area, where some 6,000 ft of nearly flat lying Paleozoic sedimentary rocks rest on a Grenville basement surface which slopes gently to the east-southeast at about 80 ft per mi. The epicenters are within the Central Ohio Magnetic Belt[144], a 90 mi wide, north-trending zone of distinctive magnetic and gravity anomalies in the basement which is bounded on the west by the Grenville Front.

2.5.2.2.3 <u>Frontenac Arch Sector of the Eastern Stable Platform</u>

The Frontenac Arch Sector is a peneplained complex of Proterozoic metamorphic rocks extruded by granitic rocks, all with Grenville radiometic ages of approximately 1,100,000,000 years. The sector in the 200 mi region is the exposed up-slope basement extension of the Eastern Stable Platform.

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.5, 2.5.1.1.4.5, and 2.5.1.1.5. The generalized geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5.

Historical data suggest that the Frontenac Arch Sector is virtually aseismic.

2.5.2.2.4 <u>Appalachian Plateau Province</u>

The Appalachian Plateau province is a broad, gently synclinal basin containing rocks which range from Cambrian to Permian in age (to the south). The nearly flat lying sedimentary rocks rest on a peneplained surface of Precambrian crystalline rocks. The province has two subdivisions, the Allegheny Plateau on the north and the Cumberland Plateau on the south (Figure 2.5-5).

The youngest known tectonic structures in the province are mafic dikes of Early Mesozoic age[7].

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.3, 2.5.1.1.4.3, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5. The distribution of earthquake epicenters within the province appears in Figure 2.5-25. Historical data suggest that this region is virtually aseismic.

2.5.2.2.5 <u>Adirondack Mountains Province</u>

The Adirondack Mountains province is characterized by a Precambrian basement of the Grenville-type metamorphic rocks intruded by various types of plutonic rocks. The Adirondacks have persisted as a structural high throughout a great portion of geologic time[19] and represent an ancient mountain root system which has been periodically uplifted[145] as erosion gradually reduced the super incumbent load. DeWard[146] estimated that the crystalline rocks exposed to the Adirondacks have been uplifted as much as 19 to 22 mi. The Paleozoic rocks thicken in all directions away from the circular outcrop of the Adirondacks. The youngest known major tectonic structures in the province are a system of faults that radiate from the Precambrian rocks of the Adirondack uplift and can be traced several mi into the onlapping sedimentary rocks; they were active during the latest tensional phases of the Taconic Orogeny (at least 435,000,000 years ago), and in the Hudson Valley sector, active during the Acadian Orogeny (at least 350,000,000 years ago)[87]. No capable faults have been identified in the province. Limited local stress data have been obtained from microearthquake studies[137,138] in the Blue Mountain area, but are inadequate for an understanding of the present regional stress regime of the province.

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.4, 2.5.1.1.4.4, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5. The distribution

of earthquake epicenters within the province appear in Figure 2.5-25. The discussion of seismicity is presented in Section 2.5.2.1.2.

2.5.2.2.6 Northern Valley and Ridge Province

The Northern Valley and Ridge province is characterized by the folded and thrust-faulted structural system of the Appalachian Mountains. The prominent geomorphic and northeasterly-trending tectonic features consist of parallel or subparallel ridges and valleys. The province consists of rocks that range from Cambrian to Pennsylvanian in age. The main valleys are due to the weakness of the Cambro-Ordovician limestones and shales, while the ridges are composed of very resistant Middle and Upper Paleozoic sandstones and conglomerates. Two classic theories have been advanced for the origin of the structures:

1. Deformation was essentially in the underlying basement and reflected in the overlying sediments

2. Deformation is largely confined to the sedimentary rocks

The youngest known tectonic structures in the province are mafic dikes of Mesozoic age[7], and extensional faults of Triassic age. No capable faults have been identified in the province. From several focal mechanism solutions, it appears that the present maximum compressive stress direction is largely uniform and trends east-southeast[128].

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.7, 2.5.1.1.4.7, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-2 and the tectonic elements and province boundaries are shown in Figure 2.5-5. The distribution of earthquake epicenters appears in Figure 2.5-25. The earthquake activity in southeastern New York and northern New Jersey is discussed in Section 2.5.2.1.2.

The distribution of earthquake epicenters in the remainder of the province is diffuse and of low frequency, with a maximum epicentral Intensity of VI(MM).

2.5.2.2.7 New England-Maritime Province

In this PSAR, the New England and Maritime provinces are combined as a single tectonic province. Whether they are considered as a single province or two separate provinces has no effect upon the site. Clusters of seismic activity occur within this province. Some of these areas can be defined as tectonic subprovinces, while others are related to tectonic structures[23].

The New England-Maritime province is characterized by a systematic pattern of north to northeast trending Paleozoic foldbelts, faults, and granitic intrusives, transected in the eastern New Hampshire region by a north-northwesterly elongate clustering of central complex plutons of Mesozoic age, and in central Massachusetts and Connecticut by a north trending rift basin containing Juro-Triassic continental sediments and volcanic flows. The

2035 008

youngest known tectonic structures in the province are mafic plutons of Middle Cretaceous age, dated at about 110,000,000 to 120,000,000 years. No capable faults have been identified in the province. There are no definitive data by which the present stress regime can be deduced.

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.8, 2.5.1.1.4.8, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5. The distribution of earthquake epicenters appears in Figure 2.5-25.

The distribution of earthquake epicenters in the province is not uniform; there is a marked tendency for epicenters to cluster:

1. In southwest-central Maine where a southeast trending Paleozoic foldbelt is intersected and cut off by a southwest trending, postmetamorphic fault system

2. In central New Hampshire where five Mesozoic central complex plutons are enclosed by an apparent collapsed caldera structure, and to the south where geologic structures and aeromagnetic patterns trend northwesterly, transverse to the regional northeasterly fabric of the province

3. In northeastern Massachusetts where a zone of extreme fault deformation of Late Paleozoic age marks the boundary of the New England province with the Southeastern Platform, and where a cylindrical mafic pluton of apparent Mesozoic age has intruded this fault complex in its offshore extension north of Cape Ann

4. In central Connecticut where the Juro-Triassic rocks are closely faulted and a northwest-trending structural pattern to the south is cut off by the southwest trending fault boundary of the province, and in southwestern Connecticut and south easternmost New York along the projection of that boundary

For a discussion of the seismicity in Maine, central New Hampshire, northeastern Massachusetts, and southern New England, refer to Section 2.5.2.1.2.

2.5.2.2.8 <u>Western Quebec Seismic Zone</u>

The Western Quebec Seismic Zone is characterized by a central, fairly closely faulted sequence of Cambrian-Ordovician sandstones, shales, and limestones which are bounded to the north and south by highly deformed, Grenville-type rocks of the Laurentian and Adirondack Mountains, respectively. The zone is marked by numerous, somewhat anastomosing high-angle faults, that include the Ottawa-Bonnechere graben, and the Winchester Springs and the Gloucester faults. The faults trend predominately west-northwest and swing to the northeast near Montreal[22].

2035 009

Numerous deep seated alkaline intrusions, carbonatities, mica peridotite pipes, and diatreme breccia (the Monteregian plutonic series) are associated with the faults, and are frequently exposed or inferred at the junction of fault alignments. Geophysical studies have verified the extent and alignment of the faults (Appendix 2.5A). This zone is marked by alkaline magmatic activity ranging from Precambrian to Cretaceous in age. Widespread normal faults are the youngest known tectonic events and are post-Ordovician in age. Earthquake epicenters may correlate with one or more of the faults within the zone.

For further details of the bedrock geology, tectonic elements, and geologic history of the province, refer to Sections 2.5.1.1.3.6, 2.5.1.1.4.6, and 2.5.1.1.5. The bedrock geology is shown in Figure 2.5-3 and the tectonic elements and province boundaries are shown in Figure 2.5-5. The distribution of earthquake epicenters in the zone is somewhat uniform, is shown in Figure 2.5-25 and the seismicity is discussed in Section 2.5.2.1.2.

2.5.2.3 Correlation of Earthquake Activity with Geologic Structures or Tectonic Provinces

2.5.2.3.1 Limitations on Possible Correlations

In Section 2.5.2.1, various concentrations of seismic activity were selected from a rather aseismic background. The spatial stability through historical times of these active zones was presented as indicative of localized strain releases, likely associated with structural inhomogeneities. Logically, this seismic activity can be related to the interaction of the present stress regime with tectonic structures that may or may not be surficially evident. In the latter case, these inhomogeneities of lithology and/or structure can only be inferred through geophysical investigations which can detect the variations of the physical properties in crustal and mantle rocks. On the basis of geological and geophysical data presently available, only a limited number of correlations of earthquakes with goelogic structures can be made. These are enumerated in this section.

2.5.2.3.2 Correlations with Structures

Many of the larger earthquakes that have affected the site (Table 2.5-1) are located in the La Malbaie, Quebec zone where the conjunction of the Charlevoix meteorite impact crater and Logan's line is suggested to constitute a zone of crustal inhomogeneity. In the presence of a regional stress field, this local structure becomes ideally suited to concentrate and periodically release tectonic strain[141],[142].

The events in the Montreal area, in particular the one that occurred in 1732, which is important in determining the likely upper bound of the Western Quebec Seismic Zone, can be associated with the Mount Royal intrusive, one of the Monteregian plutons.

The southwestern boundary of the Western Quebec Seismic Zone coincides with a long section of the Ottawa River (Figure 2.5-25) suggesting the likelihood of

a tectonic control. The Cornwall-Massena earthquake, Intensity VIII and Magnitude near 5.6, appears to be spatially related to the Gloucester Fault.

The Attica, NY event of 1929, and other nearby repeated activity, have been correlated with the Clarendon-Linden structure[135,115].

The largest New England earthquake at Cape Ann in 1755 is correlated with a tectonic structure, the Cape Ann pluton, in a thrust fault complex[23], or with a broader tectonic structure encompassing the White Mountain Mesozoic pluton series[147], or with a restricted tectonic province, i.e., the northeastern Massachusetts thrust fault complex[147].

Similarly, two large earthquakes near Ossipee, New Hampshire, in 1940 and other nearby activity, have been associated specifically with the Ossipee pluton and fault structures[23], or with the White Mountain plutons in general[147].

In the area of southern New York State, it is suggested that some minor earthquake activity is associated with the Ramapo fault or fault system[148,128].

The Lake George earthquake of 1931 occurred near the southeastern region of the Adirondack Mountains tectonic province. The possibility exists that this event, as well as some other smaller events apparently located at the periphery of the province, could be related to stresses associated with the periodic uplifting described in Section 2.5.2.2.4.

2.5.2.3.3 Interpretations of Gravity and Its Possible Relationships to Earthquakes and Deep Seated Structures

2.5.2.3.3.1 Data Base

Variations in the earth's gravitational field can be used for regional tectonic analysis. Gravity data have been examined for an extensive area in the northeastern United States and the southeastern part of Canada. Gravity interpretations are based on the total Bouguer anomaly map, a smoothed version of the total Bouguer anomaly, and a regional and residual Bouguer anomaly map.

Data were obtained from two sources for this study. The Defense Mapping Agency (DMA) provided approximately 20,000 stations for the United States and the Earth Physics Branch (EPB) provided approximately 5,000 stations for Canada. No independent check of the data was done for the present study; however, for two other recent studies[149,23], it was found that the observed gravity values at most stations were correct to within 2 milligal. Those stations for which the observed gravity differs significantly from the values of nearby stations can be readily recognized from the resulting defect in the contoured gravity map, and have been blanked out or graphically interpolated.

2035 011

2.5.2.3.3.2 Procedures and Interpretation

One method of analyzing gravity data is to use a uniform grid of observations. The method of least squares was used to produce a regular grid of gravity values from the random spatial distribution of field observations supplied by the DMA and EPB. This grid was used to produce the contoured gravity maps.

The total Bouguer gravity anomaly map is shown in Figure 2.5-26. A smooth version is shown in Figure 2.5-27; it has the effect of removing very local density contrasts and, to a certain extent, topography and noise by averaging values over a 20-km square.

The total Bouguer gravity anomaly includes effects from mass distribution at all depths in the earth. In order to distinguish the gravity anomalies associated with those masses near the surface from the anomalies due to more deeply buried masses, the total Bouguer anomaly map was filtered. The regional Bouguer anomaly map was obtained by contouring average values taken at the center of a square with a side of 80 km. The residual gravity anomaly was taken to be the difference between the total Bouguer anomaly and the regional Bouguer anomaly.

The regional Bouguer anomaly map is shown in Figure 2.5-28. It is due mainly to mass distributions that occur at considerable depths in the earth's crust and upper mantle, and it is reflective of regional tectonic structures.

The residual gravity anomaly map is shown in Figure 2.5-29. It is due mainly to near surface mass distribution, and it is useful for the interpretation of local features.

In Figure 2.5-27, epicenters are shown superimposed on the smoothed Bouguer gravity anomaly maps. In many regions, there appears to be a spatial correlation between certain distributions of epicenters and certain features in the regional gravity field. For example, between Concord, NH, and Madison, Me, the epicenters occur along relatively steep gravity gradients. In the general vicinity of Montreal, Canada, and Massena, NY, the epicenters appear to be correlated with a high in the regional gravity field. The physical basis for such correlations have been suggested previously[149], namely, the stresses produced by the anomalous masses. In northeastern United States and Canada, the total anomalies are smaller in amplitude than in the state of Washington and adjacent British Columbia. The correlation of epicentral locations and gravity gradients is not as well defined, since the stresses due to gravitational loading are smaller, and it is probable that regional stresses are smaller for the northeastern United States and adjacent Canada. However, the correlation between the number of earthquakes and the azimuthal direction of the gravity gradient is reasonably well defined in the northeastern United States. The form of the relation is:

$$N = A + B \sin 2\theta$$

2035 012

where:

N = the number of earthquakes per increments of θ

θ = the trend of the gravity measured counterclockwise from east.

For θ = 15deg, A = 35 and B = -20. The trend of the gravity gradient is the direction along which the magnitude of gravity is changing most rapidly. The largest number of earthquakes occur in the gradient direction of N45degW and the minimum is the gradient direction of N45degE.

One physical model with several possible variants appears to account for the observed correlation. The regional Bouguer gravity and its gradient are reflective of large through-going geologic structures. The earthquakes occur on such structures because of several possible mechanism:

1. The structures are faults, the locations of long continued earthquake activity

2 Stress due to anomalous mass (which is greatest in the region of highest gravity gradient) adds to tectonic stress and localizes the earthquakes to those regions in which the combined stress is greatest

3. Tectonic stress is amplified by any mismatch in the elastic moduli of rocks, the amount of amplification depends on the relative direction of the greatest principal tectonic stress and the direction of the interface between pairs of rock masses.

Therefore, for a given tectonic stress direction, some orientation of the interface will be more favorable than other orientation for the generation of the necessary stress for earthquakes to occur.

2.5.2.4 Maximum Earthquake Potential

The determination of the maximum earthquake potential at the site is made in two stages. As a first approximation, actual site intensities resulting from larger historical earthquakes are determined. In a second stage, the maximum potential site intensities resulting from hypothetical events are calculated. These events are specified as the largest earthquakes known for a zone of activity, these largest earthquakes are then assumed to potentially occur anywhere zone and specifically at a point of closest approach to the site.

Table 2.5-3 lists the location, epicentral intensity, distance to the site, and site intensity for the larger historical earthquakes located in the various zones of concentrated activity, discussed in Section 2.5.2.1.2. Three methods were used to determine the effects at the site. The first and most reliable method was to infer site intensities from newspaper accounts of earthquake effects at localities near the site. The location of the felt report with respect to the site and epicenter (i.e., whether the reporting locality is nearer to or further from the epicenter than from the site) is noted in the "remarks" column of Table 2.5-3. The documented felt reports are

presented in Appendix 2.5F.4. Secondly, site intensities were read from available published isoseismal maps. these are complied in Appendix 2.5F.5. Finally, theoretical site intensities were determined using the conservative attenuation relationship of Gupta and Nuttli[150]. This curve is compared in Figure 2.5-30 to four others derviced using eastern North American intensity data. The highest intensity at the site resulting from earthquakes plotted in Figure 2.5-21 is in the range of V to VI.

In order to account for the possibility of a large epicentral uncertainty, especially for events occurring in the first two centuries of the historical record, the largest known earthquakes were attenuated to the site from the points of nearest approach of the several zones of concentrated activity, using the conservative relationship of Gupta and Nuttli[150]. Justification for this procedure is that, although some individual epicenters within a zone may be mislocated, the zone itself is well defined by repeated historical activity and especially by accurate locations of earthquakes occurring in the past ten years (Section 2.5.2.1.2). The following are theoretical intensities at the site, resulting from hypothetical earthquakes specified as the largest earthquake known for a zone of concentrated activity occurring at the zone's nearest approach to the site.

An Intensity VIII event in the Western Quebec Zone, 80 to 90 mi from the site, would result in a site intensity of VI; an Intensity VII in the Adirondack Mountains, 30 to 40 mi from the site, would produce a site intensity of V-VI; an Intensity VIII in central New Hampshire, 200 to 210 mi from the site, would result in a site intensity of IV-V; an Intensity VII in southeastern New York, 170 to 180 mi from the site, would produce Intensity III-IV effects at the site.

The 1929 Attica event associated with the Clarendon-Linden fault system occurred at a distance of 110 to 115 mi from the New Haven site. A repeat of this event would produce a site intensity of V.

Finally, an Intensity X earthquake in the La Malbaie cluster, at a distance of 410 to 420 mi from the site, would produce a site intensity of V-VI(MM). It is reiterated that these extrapolated values are based on a conservative attenuation relationship and a conservative distance.

Seismic activity in the Eastern Stable Platform, the province in which the site is located, is at a very low level, with the exception of the activity in western New York (Section 2.5.2.1.2) and activity further to the southwest in Ohio. The concentration of anomalously high activity in western New York, relative to the aseismic remainder of the Eastern Stable Platform, is spatially correlated with the Clarendon-Linden fault system[135,115]. Recent seismic monitoring has confirmed the presence of microearthquake activity in this area[135].

Considering that the maximum historical site intensity from distant earthquakes does not exceed VI(MM), and the fact that historical data as well as recent instrumental data show no seismic activity near the site, selection of an Intensity VII for the maximum earthquake potential at the site is

conservative. From the preceding analysis, it is apparent that no event from the other zones of concentrated activity has resulted in such a site intensity.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

The plant foundations will rest on bedrock consisting of the Oswego Sandstones. Compressional wave velocities of the sandstone materials range from 13,950 to 16,300 fps, and shear wave velocities range from 6,750 to 7,300 fps, indicating a competent bedrock. Table 2.5-4 is a summary of the seismic velocities and the resultant modulus values, as determined by Weston Geophysical. The complete report of the in situ velocity measurements is included as Appendix 2.5E.

There are no unusual conditions at this site which would affect seismic wave transmission.

2.5.2.6 The Safe Shutdown Earthquake

The maximum intensity at the site is a VII(MM) with a corresponding acceleration range of 0.06 to 0.13g (Figure 2.5-32). The larger value of this range is taken from an intensity-acceleration relationship developed by Trifunac & Brady[151]. From the conservative analytical assessment of Section 2.5.2.4 above, a peak horizontal ground acceleration of 0.15g is adequately conservative under Appendix A of 10CFR100.

It has been decided by NYSE&G that a value of 0.20g peak horizontal ground acceleration will be adopted for this site.

The PWR Reference Plant seismic design envelopes are defined by the smoothed response spectra given in SWESSAR-P1, Section 3.7. There are no adverse site specific conditions that would influence the shape or the amplitude of these spectra. The duration of the stronger ground motion associated with the Intensity VII earthquake is estimated at 5 sec using an assumed threshold acceleration of 0.05 g[152].

2.5.2.7 Operating Basis Earthquake

An operating basis earthquake (OBE) of 0.1g, will be used for this site.

2.5.3 Surface Faulting

No recent surface faulting has been recognized within the immediate area of the site. Bedrock and structural features were exposed in a 982-ft inspection Trench I across the plant site area. No evidence of faulting/folding was observed (Section 2.5.1.2 and Appendix 2.5H). Within the 5-mi radius, a stratigraphic anomaly in the elevation of the contact between the Oswego and Pulaski Formations is due to broad folding and an associated Demster Structural Zone (over 3 mi long) located 1 1/2 to 3 mi northwest of site. This structure was investigated by geological/geophysical and core boring techniques and the fault zone exposed in a Trench II and rock pits. A

discussion of the Demster Structural Zone is presented in Section 2.5.1.2.3 and Appendix 2.5I.

Minor tectonic and/or nontectonic structural features are recognized within the site area or nearby. Three such occurrences have been investigated at the Nine Mile Point and J.A. FitzPatrick Nuclear Power Plants (Section 2.5.1.2.3.3 and Figure 2.5-8). All three structural features are concluded by Dames & Moore[96,91] to be old, inactive, and of no effect on the design.

No significant postglacial offsets have been observed within the immediate plant site area. No evidence of offset due to tectonic causes has been observed along any of the prominent sets of joints in the bedrock. Glacial unloading of the rock column has formed minor rebound features in the bedrock of the region. No evidence of surface faulting was observed in cored borings or the Trench I exposure at the site. Minor faults in the region last moved during the Alleghenian orogeny (250,000,000 years ago).

There has been no subsurface mining or natural gas recovery, or other activities that could cause subsidence and/or ground rupture at the site. Ponds/swamps at or near the site are small, and their surface loading effects need not be considered.

2.5.3.1 <u>Geologic Conditions of the Site</u>

The regional and site geologic conditions are presented in Sections 2.5.1.1, 2.5.1.2, and 2.5.4.1.

2.5.3.2 <u>Evidence of Fault Offset</u>

Based on a geologic investigation and a study of Landsat Environment Resources Technology Satellite imagery and low-altitude air photos (scales of 1:24,000 and 1:7,200), there is no evidence of recent fault offset on the site. Postglacial offsets were observed on the ground but are minor, and their origin is probably due to glacial rebound (Sectoin 2.5.1.2). Faults and associated folding within the site area are discussed in Section 2.5.1.2.3 and Appendix 2.5H.

2.5.3.2.1 <u>Lineament and Linear Features - Region and Site Area</u>

2.5.3.2.1.1 <u>Introduction</u>

High altitude ERTS, intermediate-altitude NASA U-2 imagery and low-altitude black and white photographs of the New Haven site area and region were examined for linears. Various workers, Saunders, et al[153], Short[154], Isachmen and McKendree[31] have demonstrated a relationship between some linears and geologic structure. In certain cases, linear alignments are suggestive of regional lineaments representing near-vertical basement faults[155].

In this analysis, linears are defined as: straight/uniform or gently curved alignments of topographic features, glacial effects, and tonal changes, or

2035 016

outcrop effects identified on the imagery and probably unrelated to geologic structure.

Lineaments are defined as: generally uniform alignments of tonal or fabric changes identified on the imagery, and likely related to geologic structure.

Available photographs and imagery were reviewed (Table 2.5-12 and Figure 2.5-67) and the following, area/regional coverage was selected on the basis of quality for this study; black and white aerial photographs (scale 1 in. - 2,000 ft.) of April 1967; LANDSAT (ERTS) imagery of October 25, 1973 (MSS band 4) and October 11, 1972 (MSS band 5); and intermediate-altitude color infrared NASA U-2 imagery (scales of 1:64,135 and 1:128,000) of June 5, 1972 (scene ID 620500290064) and August 20, 1972 (Scene ID 5720006323299), respectively. Cloud cover was always less than 10 percent with imagery quality 8 or greater.

Examination of the selected photographs/imagery (Figures 2.5-68 and 2.5-69) provided the data and interpretations compiled on the accompanying maps. Linears interpreted were analyzed with respect to features shown on the topographic maps, the site area bedrock and surficial geology maps. Based on these observations, cultural features such as roads, rail lines, fence lines, transmission lines, and pipelines were eliminated. A statewide study of ERTS imagery by Isachsen and McKendree[31] indicated no lineaments in the New Haven site area.

2.5.3.2.1.2 Examination of Imagery

Linears and lineaments interpreted on ERTS/U-2 imagery of the region and site area are plotted on Figures 2.5-68 and 2.5-69. Linear and lineament occurrences can be divided into three broad domains based on the style, orientation, and relationship to underlying bedrock.

Domain 1 - These lineaments consist of generally uniform alignments directly related to the complex bedrock structure (folds and faults) of the underlying Precambrian metamorphics of the Frontenac Arch, portions of the Western Quebec Zone, and the Adirondack tectonic elements (Figure 2.5-5). The Frontenac Arch lineaments trend dominantly northeastward, but swing to the northwest near Ottawa in the Western Quebec Zone.

The St. Lawrence River follows a prominent northeastward-trending feature which Saunders and Hicks[155] termed the St. Lawrence geomorphic lineament (Figure 2.5-68). However, project investigations (Appendix 2.5A), detailed mapping by Dames and Moore[156] and published geologic maps of Ontario (Map 2197[157]), and of New York[4] indicate no evidence to support a geologic structure as the cause of the St. Lawrence linear.

The Colton-Carthage mylonite zone (Lineament No. 2, Figure 2.5-68) is a major contact zone with associated Precambrian faulting (Section 2.5.1.1.4.2). The mylonite zone also appears as a prominent southwest-trending aeromagnetic linear that dies out south of the

Adirondacks beneath the Paleozoic cover. Regionally, the dominant aeromagnetic trend follows this northeastward trend over a wide sector east of the site area. However, no significant lineaments parallel this geophysical trend.

Domain II - These linears occur in the sector to the south of the Frontenac Arch (Figure 2.5-5) and in the vicinity of Lake Ontario. Features are primarily straight but of somewhat variable trends. North of Lake Ontario, the features trend essentially northeast and appear to be related to the underlying Cambric-Ordovician sandstones and limestones. However, to the south of Lake Ontario, linears trend to the northwest and are due to the parallel alignments of glacial effects, particularly drumlins. This sector is largely underlain by non-resistant interbedded sandstones and shales. Observed easterly trends, south of Lake Ontario and near Oneida Lake, are lines parallel to the strike of the strata controlled by lithology. Saunders and Hicks[155] indicate a major geomorphic alignment to the east of the site area which is coincident with the Salmon River Reservoir. This linear could not be traced eastward across New York State by project investigations and is not recognized by Isachsen and McKendree[31]. Also, the continuation southwestward of the St. Lawrence trend, shown by Saunders and Hicks[4,31] could not be identified.

Domain III - Lineaments and linears occur in a sector throughout central New York (Figure 2.5-68). Three lineament trends (N55 deg east, N25 deg west, and N5 deg west) are manifested by the dominant drainage pattern (Lineament No. 5, Table 2.5-13). Similar analysis of LANDSAT imagery by Pohn et al[158] in south-central New York indicates that the observed alignments are more closely related to the direction of glacial movements rather than to the strike of the major joint sets. Within the limits of Domain III, shown on this imagery, no major-mapped folds or faults are reported[4,31]. However, an investigation of the Salina salt beds in central New York[159] reports the existence of two strike-slip faults of Alleghenyan age (Lineament Nos. 7 and 8, Table 2.5-13) as shown on Figure 2.5-68.

The site area was investigated utilizing U-2 infrared imagery at two different scales. The 1:128,000 imagery is shown in Figure 2.5-69. Analysis at this scale and of the 1:64,135 imagery delineated three trends of northwest, west-northwest and northeast orientations. The northwest trend occurs mainly to the west and south of the New Haven site. A correlation of field observations, topographic map data, and black and white photographs indicated that this trend is due to the parallel alignment of drumlins and peat-filled inter-drumlin valleys. North of the site, these features are subdued or absent due to the reworking and bevelling of the drumlins by ancestral higher-level stages of Lake Iroquois. Below an elevation of 300 ft, the glacial features are largely modified and/or buried by a surficial cover of lake sediment deposits of the Sandy Creek Stage[92]. The west-northwest trends occur east of Nine Mile Point and are expressed topographically as a series of parallel drainage alignments. No outcrops were observed in these drainages, but alignments are parallel to one set of site area joints (Appendix 2.5I).

The northeast trend is very subtle and coincides with jointing and fracturing of bedrock in the central structural domain of the Demster Structural Zone (Figure 2.5-9). This alignment parallels Catfish Creek for approximately 4,000 ft and appears to continue northeastward as a series of aligned, low-lying, bogs. Beyond the bogs, to the northeast, the trend is indistinct; south of Catfish Creek the alignment is also indistinguishable. Detailed bedrock and surficial and mineralogical studies (Appendix 2.5I) concluded that the Demster Structural Zone is a Paleozoic structure.

2.5.3.2.1.3 Conclusions

An analysis and evaluation of both high-altitude ERTS imagery and intermediate altitude U-2 imagery was made throughout both the site area and the region. No major throughgoing regional lineaments are recognized in the site area nor are any projections inferred therein from the surrounding region. A subtle lineament is recognized coincident with jointing and fracturing of bedrock associated with the Demster Structural Zone of Paleozoic age (Appendix 2.5I).

Imagery evaluation coupled with surficial mapping (Section 2.5.1.2.4 and Figures 2.5-18 and 2.5-19) and two inspection trenches (Appendices 2.5H and 2.5I) show no evidence of stream, terrace or glacial drift offsets. Minor linears recognized in the site area are related to glacial effects.

2.5.3.3 Earthquakes Associated with Capable Faults

There are no known capable faults.

2.5.3.4 Investigation of Capable Faults

As discussed in Sections 2.5.1.2 and 2.5.2.2, there is no evidence of any capable faults.

2.5.3.5 Correlation of Epicenters with Capable Faults

There are no known capable faults.

2.5.3.6 Description of Capable Faults

There are no known capable faults.

2.5.3.7 Zone Requiring Detailed Faulting Investigation

There are no known capable faults, therefore, no detailed fault investigations, as defined in Appendix A, 10CFR100, are required.

2.5.3.8 Results of Faulting Investigation

There are no known capable faults.

2035 019

2.5.4 Stability of Subsurface Materials

The stability of the subsurface materials underlying the site was evaluated using the results of detailed field and laboratory investigations. Descriptions of the various investigations and their results are presented in this section and associated appendices.

2.5.4.1 Geologic Features

Generally, flat lying sedimentary rock and glacially deposited overburden comprise the geologic environment of the site. There are no features to indicate uplift, subsidence, or collapse. The coarse and fine grained silica cemented bedrock is not susceptible to solution from changes in level or composition of groundwater. The only withdrawal of subsurface fluids near the site is for individual domestic water supplies, and this does not cause settlement at the site.

The site surficial deposits are discussed in Section 2.5.1.2.4. The basal overburden stratum is lodgement glacial till. This till was subjected to pressure from the overriding ice and is very dense. A younger, less dense, and somewhat permeable ablation till was deposited by the melting ice. Glacial deposits above the tills were deposited in proglacial lakes. These materials were consolidated during drainage of the glacial lakes and fluctuations in the level of Lake Ontario. The compressible surficial deposits on the site, glacial lake silts and clays, loess, and recent alluvium will be removed during foundation preparation, as will all glacial materials beneath Category I structures.

Paleozoic and Mesozoic deformational events have jointed and tilted the site bedrock strata similar to the conditions throughout the site area shown in Figure 2.5-9. This deformation has not caused faults, folds, shears, or crushed zones in the site bedrock which would constitute structural weakness. Closely spaced jointing is confined to the top few feet of rock where frost wedging and ice shove have accentuated the site area joint pattern. Weathering is limited to the near surface zone. Highly jointed and broken bedrock will be removed during foundation preparation. Below the top few feet of bedrock, joints are moderate to widely spaced, subvertical, closed, and only slightly weathered.

A low to moderate level of in situ stress exists in the bedrock at the site. Average values, interpreted from measurements onsite (Appendix 2.5M) are 700 psi and 500 psi, respectively, for the maximum and minimum compressive stresses in the horizontal plane. The average maximum horizontal stress is directed N45 deg W. As discussed in Appendix 2.5M, these stresses will not have a significant effect on station excavations or structures.

No pop-up features, small folds, or faults were found onsite during investigations which included detailed mapping of a bedrock trench (Section 2.5.1.2.3.3 and Appendix 2.5H). The compressive strength of the rock at the site (Appendix 2.5J) is more than ten times greater than the largest measured horizontal stress. Reduction of vertical stress during excavation

2035 020

will be minor (less than 50 psi). Therefore, pop-up features, or other significant rock deformation, is not anticipated due to excavation unloading.

2.5.4.2 Properties of Subsurface Materials

Detailed field and laboratory investigations were conducted to determine the properties of site subsurface materials. Section 2.5.4.3 discusses the scope of these investigations. Figures 2.5-33 and 2.5-34 show the location of test borings, pits, and trenches completed in the site area. Descriptions of the subsurface materials are presented in the boring logs (Appendix 2.5C). Test pit logs and trench logs and maps are presented in Appendices 2.5G and 2.5H, respectively. Site subsurface profiles (Figures 2.5-35 through 2.5-39) have been developed through proposed locations of Seismic Category I and other major plant structures. Figure 2.5-34 shows the location of the profiles with respect to the plant structures.

The following subsections summarize the physical and engineering properties of the major subsurface materials encountered on site: recent alluvium, glacial lake deposits, kame deposits, glacial till, and bedrock.

2.5.4.2.1 Recent Alluvium

Recent alluvial soils are deposited in low lying valleys trending north-south along Butterfly Creek and along the unnamed tributary to Catfish Creek (Figure 2.5-19). The alluvium is a minor deposit on site. It ranges from a narrow strip where drumlin ridges abut the creeks to approximately 300 ft in width where the creek beds flatten. Being situated in areas of low topography, the alluvium is relatively thin and usually not more than 15 ft thick. The alluvium is underlain by either bedrock or a thin layer of glacial till. These deposits will not comprise significant slopes in the plant area. No station structures will be founded on the alluvium.

Classification and index tests were conducted on split spoon samples recovered from borings taken in alluvial soils (Appendix 2.5K). In general, these soils are interbedded brown and gray silts and silty sands. The silts are non to slightly plastic and soft, with Standard Penetration Test (SPT) blow counts usually less than 10 blows/ft. The silty sands are usually compact with blow counts ranging from approximately 20 to 40 blows/ft. The higher values indicate the effect of both density and gravel content.

Compressional wave velocities for these deposits range from approximately 500 to 1,500 fps (Appendix 2.5D).

2.5.4.2.2 Glacial Lake Deposits

Glacial lake deposits occur in low lying areas situated extensively though randomly throughout the site (Figure 2.5-19). In the immediate plant area, these deposits are found trending north-south along the unnamed tributary of Catfish Creek. To the west of the plant area, the deposits extend between the high topography of drumlins and kame deposits. Further to the west along several small drainage tributaries, the lake deposits are extensive and

comprise most of the overburden in this portion of the site. To the northeast encompassing the abandoned railroad, and on both sides of Butterfly Creek to the southeast, these deposits are also extensive. The lake deposits overlie both bedrock and glacial tills. The maximum thickness of lake deposits in the plant area is about 10 ft.

Glacial lake deposits will not support any major plant structures but may support roadways, railways, and small switchyard facilities. Excavated slopes uncovering these deposits in the area of Category I structures will be minor. The degree of such slopes is discussed in Section 2.5.4.5.1.

The glacial lake deposits consist primarily of brown-gray soft to very soft silts and clays (Figure 2.5-40). In the lower elevations, the deposits are primarily slightly plastic clays. In the higher elevations, greater percentages of fine sands and silts are present causing increased penetration resistance. The fine sands and silts are sometimes interbedded.

Undisturbed samples of the glacial lake deposits were recovered from borings G-36, G-37, G-40, and G-43 (Figure 2.5-34). Representative specimens from these borings were tested for consolidation and strength characteristics. The results are summarized in Table 2.5-5 and shown graphically in Figure 2.5-41. The consolidation test results (Appendix 2.5K) show that the glacial lake deposits are overconsolidated with an overconsolidation ratio (OCR) ranging from approximately 20 near ground surface to approximately 2 at depth. The overconsolidation is probably due to dessication. When loaded to a level above its preconsolidation stress, the soil is moderately compressible.

The shear strength characteristics of the glacial lake silts and clays are indicative of past consolidation. The undrained shear strength values decrease with depth at a rate similar to the decrease of maximum past pressures (Figure 2.5-41). The effective angle of shearing resistance, ϕ , decreases from approximately 35 deg in the upper part of the deposit to approximately 25 deg in the lower part (refer to the triaxial test reports in Appendix 2.5K). The pore pressures generated in the specimens during testing are also indicative of past consolidation. The heavily overconsolidated specimen dilated when subjected to shear stress, resulting in a negative pore pressure parameter. The slightly overconsolidated specimen dilated very little upon loading as evidenced by a minor initial reduction of the pore pressure parameter. The specimen tested under normal consolidation generated pore pressures during loading in excess of the applied shear stress. This effect is typical of a normally consolidated sand-clay matrix undergoing particle rearrangement during shear. Since the glacial lake deposits are overconsolidated throughout the site, particle rearrangement and the associated high degree of sensitivity are unlikely during loading. The values of sensitivity derived from laboratory vane and penetration testing generally range from 1 to 3 (Figure 2.5-41).

Greater percentages of sand are present in the lake sediments deposited in shallower water. The typically flat oedometer plot of boring G-37, Sample 2B, (Appendix 2.5K) is representative of such deposits.

2035 022

Field permeability tests performed in glacial lake deposits indicate low coefficients of permeability (less than 10^{-4} cm/s). Field permeability test results are summarized in Table 2.5-6.

Compressional wave velocities of these deposits range from approximately 500 to 2,000 fps (Appendix 2.5D).

2.5.4.2.3 Kame Deposits

The kame features originate from terrace, delta, and outwash plain modes of deposition. They form a narrow strip trending northwesterly through the center of the site (Figure 2.5-19) and are commonly found in areas of high topography surrounded by glacial tills. The kame deposits are rather thick (up to 40 ft) and underlain directly by bedrock in the higher topography near the center of the site. They are much thinner (5 to 10 ft) and underlain by silty glacial lake deposits in areas of lower topography near Butterfly Creek and the tributary to Catfish Creek.

The kame deposits consist predominantly of brown stratified fine sands, silty sands, and silts. Immediately north of the plant is a coarser, well graded mixture of sand and gravel. The finer sands are generally medium dense with SPT blow counts ranging from 15 to 25 blows/ft. The coarser sands and gravels exhibit more variable density with SPT blow counts from 20 to 60 blows/ft. Test pits TP-14 and TP-15 were excavated in the latter deposit. This material is a potential onsite source of select granular backfill (refer to the test pit logs in Appendix 2.5G and the gradation curve in Appendix 2.5K).

Estimates of the coefficient of permeability are made for the kame deposit soils on the basis of soil particle size. From the boring logs (Appendix 2.5C) and grain size analyses of borings and test pit samples (Appendix 2.5K) the coefficients of permeability are estimated to range from 1×10^{-2} cm/s for the coarse clean sand and gravel mixtures to 1×10^{-5} cm/s for the stratified silty sands and silts.

Compressional wave velocities of these deposits range from approximately 1,000 to [illegible],000 fps (Appendix 2.5D).

2.5.4.2.4 Glacial Tills

Glacial tills onsite consist of lodgement and ablation depositional types, and constitute the majority of soil overburden onsite (Figure 2.4-19). Lodgement till is found primarily on the high ridges near Route 104 in the southern portion of the site, on random drumlin features, and on the high topography just east of Butterfly Creek. Ablation till is the slightly more prevalent of the two types and constitutes the hummocky ground moraine found throughout the site.

The high density of the lodgement tills is indicative of the effect of ice pressure and SPT blow counts are commonly over 100 blows/ft. This is a result of both high density and the gravel, cobble, and boulder content of the till. It was often necessary to core the till since boulders up to several feet in

diameter were encountered. Excavation of the test pits was difficult in this material. The lodgement till is a highly variable, widely graded mixture of coarse and fine grained soil sizes. Often it exists as a group of platey or angular sandstone boulders embedded in a silt and clay matrix. The fine grained soils present in the matrix are nonplastic.

The composition of the ablation till is highly variable. Due to its mode of deposition, the ablation till is less dense than the lodgement till. During excavation of the exploratory trench (Figure 2.5-34), it was noted that the ablation till becomes loose and remolded when saturated and exposed for long durations. This characteristic of the ablation till makes it suitable for use only as random backfill during construction. Ablation tills are located only beneath nonsafety-related structures at the periphery of the plant area (Figure 2.5-19).

Field percolation testing indicated both the lodgement and ablation tills to be of low permeability (Table 2.5-6) with coefficients of permeability ranging from about 10^{-3} cm/s to 10^{-5} cm/s. A few tests yielded higher permeabilities and minor seepage was noted in several of the test pits within till (Appendix 2.5G). However, this seepage is believed to be a result of localized pockets of coarse material or to the formation of drainage paths within the boulder till.

Compressional wave velocities for the tills range from approximately 5,000 to 8,000 fps. The higher velocities correspond to the denser lodgement till.

2.5.4.2.5 Bedrock

Bedrock in the site area consists of the Oswego formation, a greenish-gray to light gray, thin bedded, fine grained sandstone interbedded with siltstone and shale. The stratigraphy of this unit is contained in Section 2.5.1.2 and detailed descriptions are given on the boring logs (Appendix 2.5C).

The bedrock surface at the site is fairly regular and slopes gently to the north at a gradient of about 70 ft/mi. Over much of the site, the uppermost 5 to 10 ft of bedrock is moderately to highly jointed. From trench observations (Appendix 2.5H) this zone appears as large blocks and slabs bounded by joints or breaks. It is shown on the boring logs as a zone of low rock quality designation (RQD) (usually averaging less than 50 percent) with recoveries significantly less than 100 percent. Although the range of permeability derived from field testing is great, this zone yields the highest permeability of the major substrata at the site (Tables 2.5-6 and 2.5-11)[160,161,162,163]. The high permeability is evident also by the loss of drilling fluid at or near the top of bedrock in about 10 percent of the site borings. Below this zone the sandstone is more massive. Core recovery ranged from 90 to 100 percent with RQD greater than 80 percent.

Seventeen intact rock specimens from vertical cores were tested for unconfined compressive strength, elastic moduli, and slaking resistance. These specimens were chosen from borings in the two reactor containment areas. The test results are presented in Appendix 2.5J and results are differentiated for

2035 024

sandstones, shales, and siltstones. Unconfined compressive strengths and elastic moduli (secant modulus at 50 percent of ultimate strength) of the sandstone are fairly consistent, ranging from 20.5x10^3 to 31.8x10^3 psi and 2.36x10^6 to 4.68x10^6 psi, respectively. The strengths of siltstone and shale specimens averaging 20.8x10^3 psi and 18.0x10^3 psi, respectively, are somewhat lower than those for the sandstone. Young's modulus for biaxial loading in the horizontal plane was determined during the in situ stress measurement program (Appendix 2.5M). These measurements agree closely with the laboratory results and indicate that the siltstones and sandstones are approximately isotropic in three dimensions.

Of the rock types tested, only the shales were affected significantly by the cyclic wet-dry slaking tests. The shale structures decomposed along bedding planes into thin wafer-like fragments. The effect of such slaking on the stability of the rock excavation is discussed in Sections 2.5.4.5 and 2.5.4.12.

Unit weights were determined for each specimen. These ranged from 156.2 pcf to 168.3 pcf. The average unit weight of all specimens is 163 pcf.

Direct shear tests were conducted on natural and polished joints in shale specimens. The results are included in Appendix 2.5J. The tests on the polished joints were intended to minimize the effects of joint roughness and consequently were anticipated to yield conservatively low values of shear strength parameters. The tests on natural joints were intended to yield representative parameters of in situ shear strength.

Results of the direct shear tests can be characterized by two types of shear force versus displacement curves. The curves typical of polished joints were flat. During shear, the polished joints contracted normal to the shear plane. The shear strengths of two of the three polished specimens increased slightly with increasing displacement. A particle of rock sliding within the joint of the third specimen caused a high residual strength in that test. The range of values for peak and residual angles of shearing resistance, ϕ , for the polished joints was from 23.7 to 26.7 deg, respectively. The mean value for both peak and residual ϕ was approximately 25 deg.

The curves typical of the natural joints generally showed shear strength peaks at less than 3 mm of displacement. More pronounced peaks and generally greater shear strengths were developed with higher normal pressures. During shear, the natural joints expanded normal to the shear plane. Peak values of ϕ for natural joints ranged from 24.8 to 39.1 deg. The mean value was 29.8 deg. Residual values of ϕ for natural joints ranged from 18.2 to 30.1 deg with a mean value of 25.0 deg. The latter value was used in the slope stability analysis (Section 2.5.5) and is conservative since it also equals the average values resulting from the polished joint tests.

In situ compressional and shear wave velocity measurements for bedrock at the site are presented in Appendix 2.5E and summarized in Table 2.5-4. Average values of elastic moduli calculated from the seismic velocity measurements are given below:

El From	To	Young's Modulus (E)	Shear Modulus (G)	Poisson's Ratio (Y)
320	240	4.60×10^6 psi	1.69×10^6 psi	0.36
240	90	4.85×10^6 psi	1.76×10^6 psi	0.38

From the seismic refraction surveys (Appendix 2.5D), compressional wave velocities were determined to range from 8,000 to 10,000 fps within the jointed rock and from 10,000 to 16,000 fps within the sound rock.

2.5.4.3 Exploration

Field investigations were conducted to determine subsurface conditions and the properties of subsurface materials. These included geologic mapping, soil and rock borings, borehole permeability and water pressure tests, observation well installations, seismic refraction surveys, in situ seismic velocity measurements, in situ rock stress measurements, a series of test pits, and an exploratory trench to bedrock. The laboratory testing of site soils (Appendix 2.5K) included classification and index property tests and determination of strength and consolidation characteristics. Rock samples were tested to determine index properties, compressive and shear strengths, elastic moduli, and slaking resistance. Laboratory rock testing results are presented in Appendix 2.5J.

The results of the geologic mapping are presented in detail in Section 2.5.1.2.

A total of 162 test borings were drilled in the soil and rock at and near the site. Five of these were drilled offshore along the location of the makeup water tunnel. The boring locations are illustrated in Figures 2.5-33 and 2.5-34. Table 2.5-7 is a listing of all boring coordinates, elevations, and special testing performed in the boreholes. Complete boring logs are presented in Appendix 2.5C. The logs include the soil or rock types, the location and type of samples recovered, the standard penetration resistance of the soils, and the core recovery and RQD of the rock. Subsurface profiles (Figures 2.5-35 through 2.5-39) illustrate the horizontal and vertical extent of subsurface stratigraphy together with the SPT blow counts for the soils and the RQD of the rock. The subsurface profile locations are shown in Figure 2.5-34. The relation of plant foundations to subsurface stratigraphy is shown in the excavation profiles (Figure 2.5-42 through 2.5-46). The locations of groundwater observation wells are indicated in Figure 2.5-48 and Table 2.5-7.

A seismic refraction survey was conducted to determine average compressional wave velocities and depths to major soil strata and bedrock. The location of the refraction lines and the report of this field investigation are presented in Appendix 2.5D.

Seismic crosshole techniques were employed in order to measure the in situ compressional and shear wave velocities of the site bedrock. The boring locations selected for the crosshole seismic survey are noted in Table 2.5-7 and shown in Figure 2.5-34. The report on this phase of testing is presented

in Appendix 2.5E. Measurements of the in situ rock stress were made in these three test borings. The report of these tests is presented in Appendix 2.5M.

An exploratory trench was excavated through the site overburden to allow detailed examination of the bedrock surface. Figure 2.5-34 shows the trench location. Detailed trench maps and a discussion of the trench bedrock geology are presented in Appendix 2.5H.

A series of test pits were excavated into the site overburden to aid interpretation of the site surficial geology, and to locate potential sources of granular backfill. The test pit locations are shown in Figure 2.5-34 and listed in Table 2.5-8. Detailed test pit logs are presented in Appendix 2.5G.

2.5.4.4 Geophysical Surveys

Seismic profiles, including compressional wave velocity values and a bedrock contour map, based on the seismic profiles and test boring data, are presented in Appendix 2.5D.

Table 2.5-4 and Appendix 2.5E provide in situ compressional and shear wave velocity measurements, along with the corresponding elastic moduli values.

2.5.4.5 Excavations and Backfill

2.5.4.5.1 Excavations

The extent, depths, and slopes of the excavations for Seismic Category I and other major plant structures are shown in the Excavation Plan (Figure 2.5-47) and the Excavation Profiles (Figures 2.5-42 through 2.5-46).

Excavation in rock will be accomplished by controlled blasting in a manner consistent with acceptable construction techniques and in accordance with local, state, and federal requirements. The blasting will be monitored to minimize effects on nearby structures during construction, and to limit rock wall overbreak. Local overexcavation or dental work will be required if jointed, weathered, or weak rock zones are encountered at founding levels.

The monitoring program will provide data for the development of blast criteria in the form of vibration envelopes. Envelopes will be developed for confined and open-face blasting methods and for both surface and deep excavation blasting.

The blast envelope developed at Nine Mile Point - Unit 2 will be used as a guideline for the initial rock excavation. Upper bedrock stratigraphy is similar at the two sites. The early site blasts will be monitored at variable distances from the blast source in order to develop a site specific envelope.

During the later stages of excavation, blasts will be planned using the site envelope such that the maximum particle velocity at a concrete structure will be limited with respect to concrete set time as follows.

Concrete Set Time (hr)	Particle Velocity (in/sec)
C 3	4.0
3-11	1.5
11-24	2.0
?4-48	4.0
over 48	7.0

Blasts will be monitored at the location of nearby structures and fresh concrete pours to confirm compliance with the above criteria and to provide a basis for updating the blast envelope as may be necessary.

In the plant area, the upper 5 to 10 ft of rock is moderately to highly jointed with detached rock slabs occuring randomly at the bedrock surface. Excavations will be through the upper 5 to 10 ft zone of slabs and into sound rock beneath several of the Seismic Category I structures (the reactor containments, annulus buildings, service water cooling towers, fuel oil storage tanks and pump houses, and the solid waste and decontamination buildings). Installation of the foundations for these structures will require the removal of all overburden and up to 35 ft of rock. The deepest excavations will exist beneath the service water cooling towers where founding level is approximately el +296 ft (msl). The largest excavations will exist beneath the containment structures and annulus buildings where excavations will average 20 ft into rock. Excavations will be taken to the top of sound rock beneath all other Seismic Category I structures and beneath the fuel buildings, reactor plant tank areas, turbine pedestals, main steam manifolds, and the ultrasonic cleaning and normal switchgear rooms. Excavations beneath the exterior Category I pipelines and ductlines will be taken to sound bedrock or to other stable subgrade. The locations of such pipelines are shown in Figure 2.5-70. Analyses will be performed to ensure that the piping and ducts do not exceed acceptable limits of settlement or motion relative to fixed structures. The bases for these analyses are given in Section 2.5.4.11.

In view of the shallow depth of excavations, low to moderate in situ compressive stresses, and nearly isotropic elastic behavior of the rock (Appendix 2.5M and Section 2.5.4.2.5); time dependent inward movement of excavation walls is not expected to occur. If any time dependent movement does occur, it will be detected and monitored as discussed in Section 2.5.4.13.

As shown in the excavation profiles and the excavation plan, an approximate 5 ft working space will be provided between the excavated rock faces and the walls of plant structures.

The degree of rock slopes is based on stability analyses discussed in Section 2.5.5. Generally, rock excavations will have vertical side slopes, but wherever thin wedges of potentially unstable rock are found the walls will be cut back to a stable configuration.

2035 028

Generally, permanent excavations in overburden will have side slopes of 2.0 (horizontal) to 1.0 (vertical). Temporary slopes during construction and permanent slopes cut in glacial till will be 1.5 (horizontal) to 1.0 (vertical). There are no permanent soil slopes in the area of Category I structures.

Slaking test data (Appendix 2.5J) indicate that the shale beds encountered in the excavation will deteriorate when exposed during construction. Although the rock excavations will be predominantly in sandstone, the weathering of shale beds may cause loosening of small blocks of rock at the excavation face. Local use will be made of wire mesh, steel dowels, and gunite as necessary to protect the rock faces during construction.

The excavations for Category I structures will extend below normal ground water levels. Seepage into the excavations will come primarily from the jointed zone at the top of the bedrock side walls. The quantity of seepage is such that dewatering can be accomplished as needed by pumping from sumps. In the unlikely event that this method of pumping is insufficient to dewater the actual seepage encountered, other means will be employed. The NRC will be notified of any such occurrence and significant design changes will be reported. Since excavations below the ground water table are relatively shallow, and the founding rock is characterized by a high compressive strength (Appendix 2.5J), hydrostatic uplift pressures are not expected to cause instability in the excavation floors.

During the test boring program, natural gas was detected in several holes, some within the Category I structure area usually at depths greater than 50 ft into rock. The borings which encountered gas are noted in Table 2.5-7. As discussed in Section 2.5.1.2.8.1, most of the gas encountered in the site borings is generated in the Pulaski Shale which exists approximately 250 ft below plant founding levels. Although the excavations will be no deeper than 35 ft into rock, the random occurrence of gas in small quantities and at low pressures may be anticipated. Much of this gas will be dissipated quickly through joints opened by blasting. During construction in open excavations the gas will be vented adequately without special measures being required. In confined excavations and tunnels, ventilation systems will be employed as needed. If gas seepage continues and can be detected by personnel at the time that foundation mats are to be poured, a lift of porous concrete will be placed on the excavation floor. This concrete will be used to channel the gas to vents located at the excavation perimeter.

All rock excavations for Category I structures and pipelines will be geologically mapped in detail. The mapped surfaces will include the excavation walls and floors. Rock excavations for other than Category I structures and pipelines will be mapped similarly where warranted and significant for the interpretation of the site geology. All rock excavations will be inspected and evaluated to confirm soundness for bearing. The inspection will be made by a geologist or engineer who is familiar with the foundation design criteria and the geologic and engineering properties of the rock mass. Mapped excavations will be subject to appropriate quality control and quality assurance to ensure the accuracy of recorded data. Federal and

state regulatory staffs will be informed of excavation and mapping progress so that they may schedule site visits to observe the mapped surfaces. Any feature that could pose a potential hazard to safe operation of the plant will be reported.

2.5.4.5.2 Backfill

Beneath those Seismic Category I structures not founded directly on sound rock, lean concrete backfill will be required to bring the excavated subgrade up to designated founding grade. The extent and slopes of the lean mix backfill are shown in the Excavation Profiles (Figures 2.5-42 through 2.5-46). The lean mix concrete will be designed with a 28-day minimum compressive strength of 1,000 psi. The frequency and type of quality control testing of the concrete will be in accordance with ANSI 45.2.5. Around Category I structures, backfill will consist of a lean concrete mix, and a layer of compressible material placed against the outer structural walls (Section 2.5.4.10). The thickness and compressibility of this material will be selected to accommodate any time-dependent lateral movement of excavation walls that is predicted from survey measurements. As shown in Figures 2.5-42 through 2.5-46, the working space around structures will be of sufficient size to allow alternate backfill schemes.

Exterior Category I pipelines and ductlines will be founded on either lean mix concrete or compacted select granular backfill. Such pipelines are the Units 1 and 2 service water lines and the diesel generator fuel oil lines. The safety related electrical ducts will follow approximately the same paths as those for the pipelines as shown in Figure 2.5-70. To represent the support of these lines and ducts, a typical bedding cross section of the service water pipelines is provided in Figure 2.5-71. The gradation distribution of the granular pipe bedding will be governed by pipe manufacturer's specifications.

Potential onsite sources of select backfill are encountered in the kame deposits (test pits TP-14 and TP-23, Appendix 2.5K). Offsite sources are also available within 15 mi of the site. Descriptions of potential offsite borrow and estimates of its availability are provided in Appendix 2.5L. During the evaluation of offsite sources of borrow, it was noted that several of the area borrow pits were in use. Some of these sources will not be available when site backfill operations begin. Therefore, the selection of offsite sources, if necessary, will be made later. A laboratory comparison of compaction criteria will be performed subsequent to selection of the select material. The criteria will be based on either relative density or moisture-density relationships. The fill will be compacted to at least 75 percent relative density as determined by ASTM D2049 or to 95 percent of the maximum dry density as determined by ASTM D1557. The test method will be employed which yields the highest value of maximum dry density and yet provides the most appropriate criteria with respect to the specific fill material. The basis for this method will be reported to the NRC prior to backfilling.

Backfill placed above bedrock and within 5 ft of structures will be compacted by tampers and hand operated vibrators in 4-inch lifts (loose lift thickness).

2035 030

Backfill placed beyond 5 ft from structures will be compacted by light compaction equipment in lifts not to exceed 10 inches. Field inspection and testing will be performed during placement to ensure proper gradation, moisture content, and compacted density. Tests for gradation, in place density, and the limits of maximum - minimum density will be performed for each 1,000 cu yd of backfill.

Prior to placement of the backfill, the excavated areas will be dewatered and cleaned thoroughly. If necessary, the rock surfaces will be scaled of loose rock.

Excavated soil and rock will be transported directly to onsite fills or stockpiled for onsite use. The excavated rock will be used for general site grading and for slope protection in designated areas. The glacial tills will be used for random fills and for general site grading. The silts and clays will be stockpiled in spoil areas or used for site grading.

2.5.4.6 Groundwater Conditions

Site groundwater levels were monitored in observation wells installed at the locations listed in Table 2.5-7 and shown in Figure 2.5-48. The observation wells consist of a 1 7/8-inch dia porous tip connected to a 2-inch od polyvinyl chloride (PVC) riser pipe. The tips are embedded in sand backfill at or near the top of rock. Two of the observation wells are sealed off from the rock as a check for separate aquifers. At ground surface the riser pipe is protected by a steel casing set in concrete. The water level measurements taken in the observation wells were used to prepare a site ground water contour map (Figure 2.5-48). Seasonal variation in ground water level measurements are plotted in Figures 2.5-49 through 2.5-62.

In situ permeabilities of the overburden soils and jointed bedrock were determined from constant and falling head percolation tests conducted in several borings. Table 2.5-7 lists the borings where these tests were performed. Both the open-hole and open-end techniques were used. Water pressure flow tests were conducted in rock at approximately 15 ft intervals. The results of field permeability and water pressure tests are given in Table 2.5-6 and 2.5-9, respectively. The permeability, effective porosity, in situ density, and grain size characteristics of the major site aquifers are summarized in Table 2.5-11.

The groundwater table at the site slopes to the north and is locally modified by topography with highs occurring under the drumlin ridges. Groundwater flow occurs primarily in the upper 5 to 10 ft zone of broken, jointed rock at the bedrock surface. The rate of flow in this zone is variable and dependent on the extent of openings, type of soil overburden, and the hydraulic gradient. Inflow from this zone into the exploratory trench at the site was relatively minor due to the dense till overburden which often filled the joint and fracture openings.

The groundwater table varies between el +329 and el +340 in the vicinity of the excavations required for the plant (Figure 2.5-48). The deepest

2035 031

excavations will be to approximately el +296. Since overburden onsite is shallow most of the excavation will be in rock. No major dewatering problems are anticipated during excavation and backfill operations. Seepage into excavations is expected to occur primarily along joints and fractures, particularly in the upper 5 to 10 ft of rock. Seepage will be removed by sump pumps installed within the excavations. Sediment detention basins will be used for clarification prior to discharge to surface water. Seepage into the excavations will have limited effect on ground water levels at the site due to the low permeability of the overburden materials and limited depth of excavation. Section 2.5.4.5 discusses the dewatering and excavation methods to be used.

The groundwater level associated with the probable maximum flood (PMF) is taken to be plant grade (el +340) and is the basis for design static water uplift and loadings on safety related structures. Maximum groundwater levels due to seasonal fluctuations (Figure 2.5-48 through 2.5-62) may be modified slightly due to stream diversion and final site grading (Figure 2.5-64). Maximum levels anticipated during the life of the station are less than el +335 and el +340, respectively, beneath Unit 1 and Unit 2 structures. In order to provide a conservative and uniform analysis for equivalent structures of both units, the design basis groundwater level for dynamic loadings is also taken to be plant grade (el +340).

There is no requirement for the temporary or permanent control of groundwater during plant operation.

Subsurface geologic and groundwater conditions encountered during construction will be documented and compared with original preoperational input. If differences exist, the impact on operational conditions will be evaluated and discussed in the FSAR.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

The bedrock shear moduli derived from field crosshole shear wave velocity measurements are given in Table 2.5-4. The founding of Category I structures, pipelines, and ductlines are discussed in Section 2.5.4.5. Subgrade - structure interaction analyses will not be performed for those structures founded on bedrock or backfill concrete since both foundation materials are stable under SSE loading.

As discussed in Section 2.5.4.5, the pipelines and ductlines founded on select granular backfill will be analyzed to ensure that acceptable limits of settlement or motion relative to fixed structures are not exceeded.

Compaction specifications for select granular backfill are discussed in Section 2.5.4.5.2.

2.5.4.8 Liquefaction Potential

All Seismic Category I structures will be founded on bedrock or backfill concrete. The working spaces between these structures and the rock excavation walls will be backfilled with lean concrete and a layer of compressible material (Section 2.5.4.5.1). Select granular backfill used around buried exterior Category I pipelines and ductlines will be placed in thin lifts and compacted as necessary to preclude liquefaction under SSE loading.

The resistance of a soil backfill to liquefaction is largely a function of the soil gradation and degree of compaction. As shown in Figure 2.5L-2, the soils available for select backfill are coarse, well-graded mixtures of sand and gravel. Laboratory and field studies by others have indicated that such soils typically have a high resistance to liquefaction. Laboratory studies[164,165] show that under cyclic undrained loading, soils with larger grains have higher shear strength. The soil sizes identified[164] as most susceptible to liquefaction are uniform medium and fine sands.

A study of the 1964 Alaska earthquake[166] provides evidence of the ability of saturated gravelly soils to withstand earthquake shaking. Wong, Seed, and Chan[165] conclude from this study that the capacity to dissipate induced pore pressures is the "...reason for lower susceptibility of gravelly soils to earthquake-induced liquefaction." The fine grained portion of the New Haven site select granular backfill is less than 8 percent by weight (Figure 2.5L-2) and is such that pore water drainage will not be impeded.

It is generally recognized that soil liquefaction is also dependent on in-place void ratio or relative density. Evidence[167,168] of well documented earthquakes in Japan has shown that liquefaction was extensive in sandy soils where the relative densities were about 50 percent, and undetected where relative densities exceeded 75 percent. A review[169] of numerous sites of known earthquakes also shows that soils exhibiting relative densities in excess of 75 percent have been sufficiently dense to preclude liquefaction at ground accelerations equal to the SSE for the New Haven site. Accordingly, the select granular backfill used around Category I pipelines, and ductlines, will be compacted to at least 75 percent relative density.

2.5.4.9 Earthquake Design Basis

The earthquake for which the stability of the subsurface materials is evaluated is the safe shutdown earthquake (SSE) which corresponds to a maximum horizontal bedrock acceleration of 0.20 g.

2.5.4.10 Static Stability

The rebound of the bedrock due to excavation will be essentially elastic. Its magnitude is a function of the weight of overburden and rock removed during excavation. Since excavations for the Category I and other major plant structures will be taken to sound bedrock, will be relatively shallow, and since the bedrock deformation modulus is high, the rebound will be negligible.

Calculated rebounds and settlements are based on a modulus of deformation for the site rock mass. This modulus is a reduced value of the modulus of elasticity and is more realistic for static design since it includes the effects of compressing microfissures, joints, and bedding planes. Coon and Merritt[178] determined that for sandstones with RQD values greater than 80 percent, the deformation modulus is approximately one-half the elastic tangent modulus calculated at 50-percent compressive strength. The average tangent modulus derived from laboratory unconfined compression tests is 4.2 x 10^6psi. Studies by Deere, et al[177], indicate that a similar reduction is warranted for elastic modulus derived from seismic crosshole surveys. The average elastic modulus derived from seismic surveys in the upper 100 ft of bedrock is 4.6 x 10^6psi. Accordingly, a modulus of deformation equal to 2.1 x 10^6 psi is used for calculation of heave and settlement.

The containment structures and annulus buildings impose the largest pressures (approximatly 8 ksf) on the excavation floor. The net settlements associated with these pressures are calculated to be less than 0.1 inch and are considered negligible. In addition, these pressures are only a small percentage of the ultimate compressive strength of the rock. The minimum value of strength, derived from laboratory compression tests and reported in Appendix 2.5J is 2,045 ksf (14,200 psi).

The design hydrostatic loads on Category I structures are based on the site groundwater level associated with the probable maximum flood. This level is taken to be plant grade for each structure (el +340). The distribution of hydrostatic loading is discussed in Section 2.5.4.11.

The lateral earth pressures generated in the backfill around structures will depend upon the allowable structural deflection, backfill materials, compactive effort and adjacent surcharge loads. The basis for and distribution of these pressures is discussed in Section 2.5.4.11.

As discussed in Section 2.5.4.13, instrumentation will be installed in and around the walls of the deeper site excavations to monitor horizontal movements of the excavation rock walls. Movements in excess of short-term elastic relief are not anticipated. If continuous rock creep is detected over a period of several months, predictions will be made of the magnitude, distribution, and time rate of long-term movement. The impact of such movement or structural walls and backfill materials will be assessed. As discussed in Section 2.5.4.5.2, the backfill scheme within the excavation working spaces around Category I structures will consist of loan concrete with a layer of compressible material placed against the outer structural walls. The design of the structural walls and the backfill scheme will accommodate horizontal movements in the compressible material of up to 1 in. The NRC will be notified if movements are predicted to exceed 1 in. (Section 2.5.4.13). If necessary, changes in the compressible material will be implemented. Such changes would likely incorporate the use of a greater thickness or a different type of compressible material.

2.5.4.11 Design Criteria

The results of static bearing and settlement analyses for Category I foundations are discussed in Section 2.5.4.10. All Category I foundations will bear on sound rock. The settlement analysis is based on elastic theory and uses a reduced value of elastic modulus to account for in situ rock properties. The maximum structural bearing pressures are a small fraction of the shear strength of the rock.

The static and dynamic lateral earth pressures generated above the top of bedrock by backfill placed against structural walls are distributed on structures, as shown in Figure 2.5-63. The static pressures are based on Coulomb and Rankine theories. The dynamic earth pressures are computed according to the analysis described by Saed and Whitman[172]. The static and dynamic water pressures acting on structural walls are also distributed as shown in Figure 2.5-63. The hydrodynamic pressures are based on Westergaard[173].

Coefficients for earth pressures induced on Category I pipelines will be based on studies by Terzaghi[174], and Audibert and Nyman[175]. Connected structural components and piping will be designed to accommodate relative motions corresponding to the SSE and determined by methods given by Christian[176].

The stability of Category I excavation rock slopes is analyzed using computer methods described by Hendron, et al[177]. Permutations of possible rock wedge tetrahedrons are considered under static, dynamic, and surcharge loads. A more detailed description of the computer analysis is described in Section 2.5.5.

The minimum design factors of safety are as follows:

Bearing capacity	- 3.0 for all loading conditions
Sliding and overturning	- 1.5 for all permanent and OBE loading conditions
	- 1.1 for SSE loading conditions
Hydrostatic uplift	- 1.1 for probable maximum flood (PMF) levels and SSE loadings
Slope stability	- 1.5 for all permanent loading conditions
	- 1.2 for SSE loading conditions and for construction slopes

2.5.4.12 Techniques to Improve Subsurface Conditions

Bedrock is relatively shallow in the plant area (Figure 2.5-21). Where weak or potentially unstable soils exist beneath non-safety-related structures, the soils will be excavated.

As discussed in Section 2.5.4.2.5, the top of bedrock throughout much of the site is highly jointed to a depth of 5 to 10 ft. Where zones of this or other weak rock exist at the bottom of excavations for Category I structures, the

zones will be removed or cleaned and pressure grouted where practicable. All over-excavation will be backfilled to the designated founding grade with lean concrete backfill.

Results of the static and dynamic slope stability analyses discussed in Section 2.5.5 indicate minor wedges of potential instability. These wedges are long and thin and are formed from the intersection of high angle joints. Field mapping will be performed in the excavations to determine the in situ joint orientations and the extent of actual wedges. An analysis will then be performed and the wedges determined to be unstable under temporary loading conditions imposed during construction will be removed and the excavation walls cut back to a stable slope. The wedges determined to be unstable under permanent loading conditions during the plant design life will either be removed or a structural wall will be designed and constructed to withstand the loads imposed by the wedges.

Although the rock excavation walls will be predominantly in sandstone, some thin shale beds will be encountered. When exposed, these beds will deteriorate and minor amounts of rock will become loose. A gunite coating and/or steel dowels and wire mesh will be used locally as required to prevent the loosened rock from falling into the excavations. Rock scaling will be performed prior to placing backfill against the excavation walls. Once sound rock is encountered, the excavation floors will weather only slightly when exposed, and during construction the rock surface will remain suitable for founding.

2.5.4.13 Surface and Subsurface Instrumentation

Approximately two years prior to site excavation, at least four primary monuments will be installed in boreholes outside the plant area for vertical and horizontal survey control. These monuments will provide permanent reference for all secondary monuments and other site instrumentation requiring high orders of accuracy. The monuments will consist of steel pipes grouted into boreholes taken to sound bedrock. The pipes will be installed within larger diameter casing to preclude interference caused by movements in the surrounding soil. Survey traverses will be performed at a frequency sufficient to determine and account for the effects of seasonal variation and construction activity on the monuments. These checks will be made for the duration of plant construction.

Secondary monuments will be installed around the deeper excavations to detect and monitor any rock movements due either to slope instability or time dependent creep of excavation walls. These monuments will be installed approximately two years prior to excavation. Survey checks for horizontal and vertical drift will be as frequent as those for the primary monuments and may be more frequent during the monitoring of excavation instrumentation. Additional secondary monuments may be added, as needed, to monitor features of particular interest or to replace those monuments which become inaccessible during construction.

2035 036

Heave monitoring points will be installed in the deeper site excavations prior to blasting. The monitoring points will consist of steel pins grouted into boreholes taken about 10 ft below final excavation grade. Casing will be installed within the borehole from initial ground level to bedrock. The elevation of the pin will be monitored by inserting a calibrated survey rod into the casing and by using optical survey methods. The heave monitoring points will be read when installed, following removal of overburden, and after completion of rock excavation. Readings will continue as long as changes are measurable or until construction activities interfere with monitoring. As discussed in Section 2.5.4.10, values of heave should be negligible. The order of accuracy of optical survey control may indicate zero heave. However, if heave is measurable, the data will provide the basis for estimates of any recompression settlement expected during structure loading.

Settlement monitoring points will be installed to monitor the settlement of all safety-related structures. The initial settlement monitoring points will consist of metal plates embedded within the foundation mat. Vertical rods mounted above the plate and encased within a guard pipe will be used to permit optical survey at a higher elevation. These plates will be located at the level of the bottom of the mat. During construction of the structure walls, the settlement monitoring points will be transferred to metal plates or pins embedded at higher elevation in the structure concrete surfaces. Settlement monitoring points will be surveyed on a weekly basis during concrete placement and on a monthly basis thereafter until major structural loads have been applied and settlement has ceased. As predicted in Section 2.5.4.10, net settlements for major site structures should not exceed 0.1 inch. The order of accuracy of optical survey control will be sufficient to allow measurement of such movements. Actual values of settlement will be compared to this predicted amount and will be presented in the FSAR. Values of differential settlements will be computed and compared to the acceptable design limits for the plant structures and interconnecting piping.

Groundwater conditions during construction will be compared with those conditions encountered during site exploration. The design basis groundwater levels will be assessed to include the new data. Changes in design levels, if observed, will be presented in the FSAR. Groundwater levels will be monitored monthly to provide general data on site groundwater levels during excavation dewatering. Readings will be taken in those existing observation wells (Figure 2.5-48) not affected by construction activities. Wells presently located within the plant structure or construction facility areas will be abandoned. Additional wells will be installed as needed in areas of specific interest in order to determine or verify design groundwater levels and drawdown due to excavation dewatering.

In addition to the control provided by the secondary monuments, excavation wall movements due either to slope instability or time dependent creep will be measured by subsurface instrumentation installed adjacent to the deeper excavations for Category I structure. This instrumentation will consist of multiple point extensometers in horizontal boreholes and/or borehole slope inclinometers in vertical boreholes.

2035 037

The extensometers will consist of pretensioned strain measuring wires anchored at variable locations within a horizontally drilled borehole. Each borehole will be oriented to follow a competent sedimentary bed into the rock wall and to cross high angle joints which may affect slope stability. The extensometers will be installed in the walls at different elevations along a vertical line in order to measure displacement relative to individual beds. Relative movements of the anchors will be transmitted to the sensor head where the strains will be measured electrically or mechanically.

Slope inclinometers will be installed in vertical boreholes drilled near the excavation face. These boreholes will be drilled to a depth of at least 10 ft below final excavation grade. The bottom of the inclinometer casing will be grouted into rock.

Readings of inclinometers and extensometers will be taken at the time of installation and at minimum monthly intervals thereafter. Results of the monitoring program will be used to confirm predictions (Sections 2.5.4.5.1, 2.5.4.10, and Appendix 2.5M) that long term time dependent rock movements will not occur and that excavation slopes are stable. As discussed in Section 2.5.4.10, if measurements indicate that time dependent movements can exceed 1.0 inch, the NRC will be notified, and the composition of backfill and/or compressable materials surrounding the structural walls will be redesigned to accommodate predicted movements.

Table 2.5-14 summarizes the scope of the geotechnical instrumentation program. A manual describing the installation procedures, monitoring frequencies and techniques, and data analysis for all site instrumentation, will be developed prior to the start of installation activities. If the use of other monitoring techniques are indicated during the construction period, the instrumentation manual will be updated as necessary.

2.5.4.14 Construction Notes

To be supplied in FSAR.

2.5.5 Slope Stability

The existing site area varies in elevation from +246 ft msl at Lake Ontario to +420 ft msl at the top of a hill located approximately 0.5 miles southwest of the Unit 2 centerline. The topography (see Figure 2.5-7) is hummocky and characteristic of an area underlain by ground moraine and outwash material (Figure 2.5-18). There are no significant natural slopes in the immediate vicinity of safety related plant structures.

No permanent rock slopes will be created by the plant construction. Removal of bedrock will be limited to foundation excavations. Sections 2.5.5.1.1 and 2.5.5.2.1 discuss the construction slopes resulting from rock excavation for the containment, annulus, and service water cooling tower structures.

Figure 2.5-64 illustrates the entire site layout including permanent soil slopes and embankments associated with the switchyard and the site perimeter

2035 038

landscape landforms. These slopes are sufficiently distant from the main station area that their failure will not affect the Seismic Category I structures.

2.5.5.1 Slope Characteristics

2.5.5.1.1 Rock Cuts

Figures 2.5-47 and 2.5-42 through 2.5-46 show temporary rock cuts created during construction excavation. The deepest cut (35 ft) is created by the Unit 2 service water cooling tower excavation. The stability of the excavation walls is controlled by discontinuities such as rock joints and bedding surfaces. Joint sets considered in the stability analysis were determined from mapping of the exploratory trench as described in Section 2.5.1.2 and Appendix 2.5H. Figure 2.5-65 is an equal area plot of 103 joints obtained from the exploratory trench. These data are interpreted to show two nearly vertical joint sets. Average orientations for each set were used in the stability analysis as follows: N60E, 90 degree; and N03E, 82SE to 85NW. Bedding is essentially horizontal at the site.

Six NQ core sections containing natural bedding joints and three sawed, lapped surfaces in shale were subjected to direct shear tests to determine the peak and residual angles of shearing resistance (Appendix 2.5J). The data show some scatter with peak values of the angle of shearing resistance ranging from 23.7 to 39.0 deg. The higher (30 deg +) values appear to be associated with larger asperities on the joint surfaces in some shale samples. For the stability analysis the peak angle of shearing resistance was taken to be 25 deg and all surfaces were assumed to have zero cohesion.

2.5.5.1.2 Soil Slopes and Embankments

No permanent or temporary soil slopes or embankments which affect Seismic Category I structures will be created by the plant construction. Figure 2.5-64 shows the location of permanent soil slopes and embankments. Fill material for the site perimeter landscape landforms will be obtained primarily from sands and gravels, glacial tills, and rock excavated in the main plant, natural draft cooling tower, and switchyard areas.

Temporary construction slopes exposed during excavations in soil will consist of sands and gravels, glacial lake deposits, and dense glacial tills (Figure 2.5-35 through 2.5-39). These slopes will be constructed to factors of safety consistent with the design criteria given in Section 2.5.4.11.

2.5.5.2 Design Criteria and Analyses

2.5.5.2.1 Rock Cuts

The stability of rock cuts associated with the containment structure and annulus building and service water cooling tower excavations is analyzed using the SWARS-2P computer program[178,179]. This program uses methods described by Hendron et al[177] to perform a vector analysis of rock tetrahedrons formed

by the intersection of two planar discontinuities, the excavation face, and the rock surface. The analysis calculates factors of safety for the various possible rock wedges under static and SSE loading conditions and includes the effects of surcharge and hydrostatic pressure. The input parameters are the excavation configuration (Figure 2.5-47), the joint orientations and angle of shearing resistance discussed in Section 2.5.5.1.1, and the ground water elevations for static loading conditions (el +340 - Section 2.5.4.6). Both the static and the dynamic analysis indicate many minor wedges which are potentially unstable. These wedges are generally long and thin due to the high angle joints and will be removed by overexcavation as they are encountered during construction.

Since the SWARS-2P computer program is unable to analyze cases with a low angle bedding plane parameter, a manual calculation was performed to analyze both a narrow and a wide block formed by the intersection of a low angle bedding plane with the excavation face and a near vertical joint. Figure 2.5-66 shows the calculation and the input parameters used. The results of this calculation show that there are no stability problems due to blocks formed by low angle bedding planes and high angle joint sets.

Slaking test data (Appendix 2.5J) indicate that the shales are highly susceptable to deterioration when exposed to alternate wetting and drying. The shale beds at the site are generally thin and are protected by resistant layers of sandstone which predominate the upper section (Zone 5) of the Oswego formation. Local use will be made of wire mesh and gunnite as may be necessary to protect rock faces during construction.

Excavation faces will be mapped in detail during construction and the observed system of joints and bedding will be subjected to a final analysis. If necessary, permanent reinforcement will be designed to meet the criteria for permanent slopes given in Section 2.5.4.11. No significant slope stability problems have been reported at any of the area's numerous quarries and construction excavations in Oswego sandstone.

2.5.5.2.2 Soil Slopes and Embankments

Section 2.5.4.11 gives design criteria factors of safety for slope stability. As stated in Section 2.5.5.1.2, there are no permanent or temporary soil slopes that can affect safety related structures.

2.5.5.3 Logs of Core Borings

The location of test borings are shown in Figures 2.5-33 and 2.5-34. Boring logs for all soil and rock test borings are contained in Appendix 2.5C.

2.5.5.4 Compaction Specifications

Although none of the soil slopes and embankments are safety related, a laboratory test program will be performed on typical fill materials prior to the start of construction activities. This program will be used to establish

2035 040

the compaction specifications for placement of fill in plant slopes and embankments.

2.5.6 References for Section 2.5

2.5.6.1 Cited References

1. Fenneman, N. M. Physiography of Eastern United States. McGraw-Hill Book Company, NY, 1938.

2. von Englen, O. D. Origin and History of the Finger Lakes Region, New York. Cornell Press, Ithaca, NY, 1962.

3. LaFleur, R. Sequence of Events in Eastern Mohawk Lowland Prior to Waning of Lake Albany Geological Society of American Abstracts, Vol 7, No. 1, 1975, p 875.

4. Isachsen, Y. W. and D. W. Fisher. Geologic Map of New York: Adirondack Sheet. New York Geological Survey, State Museum and Science Service, Map and Chart Series No. 15, Albany, NY, 1970.

5. Robinson, P.; Hubert, J. F.; Wise, D. V.; and Hall, L. M.; The Juratrias of Emerson (1898) on the New Massachusetts Geologic Map. Geological Society of America Northeastern Section Meeting, Abstracts with Program, Vol 10, No. 2, 1978.

6. Cady, W. M. Regional Tectonic Synthesis of Northwestern New England and Adjacent Quebec. Geological Society of America Memoir 120, 1969.

7. Rodgers, J. The Tectonics of the Applachians. John Wiley & Sons, NY, 1970, 271 p

8. King, P. B. The Evolution of North America, Revised Edition. Princeton University Press, Princeton, NJ, 1977, 197 p

9. New England Power. Units 1 and 2, Preliminary Safety Analysis Report, 1978.

10. King, P. B. Tectonics of Quaternary Time in Middle North America. The Quaternary of the United States, Princeton University Press, Princeton, NJ, 1965, p 831-870.

11. Flint, R. F.; Colton, R. B., Goldthwait, R. P.; and William , H. B. Glacial Map of the United States East of the Rocky Mountains. Geological Society of America, Boulder, Colo, 1959.

12. Prest, V. K. Retreat of Wisconsin and Recent Ice in North America. Geological Survey of Canada Map 1257A, 1969.

13. LaFleur, R. Glacial Lake Albany in Pine Bush - Albany's Last Frontier. Lane Press, Albany, NY, 1976, Chapter I, p 1-10.

14. Fisher, D. W. Highlights in New York's Tectonic History. Geological Society of America, Abstracts with Programs, Vol 7, No. 1, March 1975, p 57 and 58.

15. Fakundiny, R. H. Clarendon-Linden Fault System of Western New York: Longest and Oldest Active Fault in Eastern United States. Geological Society of America Northeastern Section Meeting, Boston, Mass, 1978, p 42.

16. King, P. B. Tectonic Map of North America. U. S. Geological Survey, Scale 1:5,000,000, 1969.

17. Prucha, J. J. Salt Deformation and Decollement in the Firtree Point Anticline of Central New York. Tectonophysics, Vol. 6, No. 4, 1968, p 273-299.

18. Engelder, T. and Engelder, R. Fossil Distortion and Decollement Tectonics of the Appalachian Plateau. Geology, Vol 5, No. 8, 1977, p 457-460.

19. Broughton, J. G.; Fisher, D. W.; Isachsen, Y. W.; and Rickard, L. V. Geology of New York, A Short Account. New York State Museum and Science Service, Educational Leaflet No. 20, 1966.

20. De Waard, D. Precambrian Geology of the Adirondack Highlands: A Reinterpretation. Geologische Rundschau, Vol 56, No. 2, 1967, p 596-629.

21. King, P. B. Precambrian Geology of the United States: An Explanatory Text to Accompany the Geologic Map of the United States. U. S. Geological Survey, Professional Paper No. 902, 1976.

22. Williams, D. A. Faults and Alignments of the Montreal-Ottawa Region. Montreal-Ottawa Region. Geological Map, Plate 3, Doctor of Philosophy Thesis, McGill University, Montreal, 1976.

23. Boston Edison Company, Pilgrim Unit 2, Preliminary Safety Analysis Report, BESG-7603, Geologic Investigations, Docket No. 50-471, 1976.

24. Doig, R. and Barton, J. M., Jr. Ages of Carbonates and Other Alkaline Rocks in Quebec. Canadian Journal of Earth Science, Vol. 5, 1968, p 1401-1407.

25. Doig, R. An Alkaline Rock Province Linking Europe and North America. Canadian Journal of Earth Sciences, Vol 7, 1970, p 22-28.

26. Diment, W. H. Gravity Anomalies in Northwestern New England. Studies of Appalachian Geology, Northern and Maritime, E. Zen et al (ed), John Wiley & Sons, NY, 1968.

27. Rankin, D. W. Appalachian Salients and Recesses: Late Precambrian Continental Breakup and the Opening of the Iapetus Ocean. Journal of Geophysical Research, Vol 81, No. 32, 1976.

28. Englund, E. J. The Bedrock Geology of the Holderness Quadrangle, New Hampshire. New Hampshire Department of Resources and Economic Development, Bulletin No. 7, 1976.

29. Bayley, R. W. and Muehlberger, W. R. Basement Rock Map of the United States. U. S. Geological Survey, Washington, DC, 1968.

30. Heyl, A. V. The 38th Parallel Lineament and Its Relationship to Ore Deposits. Economic Geology, Vol 67, 1972, p 879-894.

31. Isachsen, Y. W. and McKendree, W. G. 1977, Preliminary Brittle Structures Map of New York. New York State Museum Map and Chart Series No. 31, Scale 1:500,000, 1977.

32. Buddington, A.F. and Leonard, B.F. Regional Geology of the St. Lawrence County Magnetite District. Northwest Adirondacks, New York. U.S. Geological Survey Professional Paper 376, 196?.

33. King, P.B. Precambrian Geology of the United States; An Explanatary Text to Accompany the Geologic Map of the U.S. Geological Survey Professional Paper 902, 1976.

34. Dill, D.B. and de Lorraine, W. Structure, Stratigraphic Controls, and Genesis of the Balmaf Zinc Deposit. Northwest Adirondacks New York. U.S. Geological Survey. Abstracts with Programs Vol 10, 1978, p 389.

35. Wiener, R.W. Intrusion, Cataclasis, and Multiple Folding Along the Adirondack Highlands. Northwest Lowlands Boundary. Geological Society of America. Abstracts with Programs, Vol 10, 1978, p 516.

36. United States Geological Survey. Areomagnetic Map of Parts of the Rochester and Utica 1° by 2° Sheets New York. USGS Open File Report 77-553, 1977.

37. Vanuxem, L. Fourth Annual Report of the Geological Survey, Part III, Survey of the Third District. New York State Museum. 1842.

38. Hall, J. Geology of New York, Part 4. Comprising the Survey of the Fourth Geological District. 1843.

39. Sherwood, A. Report of Progress in Bradford and Tioga Counties, Part I, and Areal Map. Second Geological Survey of Pennsylvania. 1878.

40. Williams, H.S. The Undulations of the Rock Mass Across Central New York. Proceedings of the American Association for the Advancement of Science. Vol. 31, 1882.

41. Wedel, A.A. Geologic Structure of the Devonian Strata of South Central New York. New York State Museum Bulletin 294, 1932.

42. Rodgers, J. Mechanics of Appalachian Foreland Folding in Pennsylvania and West Virginia. American Association of Petroleum Geologists, 1963.

43. Prucha, J.J. Personal Communication, 1978.

44. Wallick, T.L. Personal Communication, 1978.

45. Kindle, E.M. Geologic Structure in Devonian Rocks, in Description of the Watkins Glen-Catatonk District. U.S. Geological Survey Folio 169, 1909, p 13-15.

46. Kingland, G.L. Formation Temperature of Flourite in the Lock Port Dolomite in Upper New York State as indicated by Fluid Inclusion Studies, with a Discussion of Heat Sources. Economic Geology 72, 1977, p 849-854.

47. Dott, R.H. and Batten, R.L. Evolution of the Earth. New York, McGraw-Hill, 1971.

48. Seyfert, C.K. and Sirkin, L.A. Earth History and Plate Tectonics. New York, Harper and Row, 1973.

49. Fridley, H.M. General Geology of the Gaines Quadrangle (Pa) U.S. Geological Survey Folio 93, 1929.

50. Isachsen, Y.W. Utilization of ERTS-1 Imagery in a Tectonic Sequency Synthesis of New York State. Geological Society of America Abstracts, Vol 5, No. 1, 1974, p 40.

51. Isachsen, Y. W. Contemporary Doming of the Adirondack Mountains, New York. American Geophysical Union Transactions, Vol 57, No. 4, 1976, p 325.

52. Coates, D. R. Identification of Late Quaternary Sediment Deformation and Its Relation to Seismicity in the St. Lawrence Lowland, New York. New York State Energy Research and Development Authority, NY, NY, No. NYSERDA-75/14, 1975.

53. King, W. F. Studies of Geologic Structures with the VLF Method. McGill University, Montreal, Quebec, Unpublished Master of Science Thesis, 1971.

54. Kumarapeli, P. S. The St. Lawrence Rift System, Some Related Ore Deposits of the Carbonatite Association and Models of Appalachian Evolution. Geologic Association of Canada, Mineralogical Association of Canada Annual Meeting, Abstracts from Programs, 1974.

55. Beland, J. La Tectonique des Appalaches du Quebec, Geoscience Canada, Vol 1, No. 4, 1974, p 26-32.

56. Dames and Moore, Regional Geologic and Tectonic Study of the St. Lawrence River Valley. Proposed Fast Breeder Reactor Site Near Waddington, NY, 1974.

57. Kumarapeli, P. S. and Saull, V. A. The St. Lawrence Valley System: A North American Equivalent of the East African Rift Valley System. Canadian Journal of Earth Sciences, Vol 3, No. 5, 1966, p 639-658.

58. Sbar, M. L. and Sykes, L. R. Contemporary Compressive Stress and Seismicity in Eastern United States. Geological Society of America Bulletin, Vol 84, 1973, p 1861-1882.

59. Saull, V. A. and Williams, D. A. Evidence for Recent Deformation in the Montreal Area. Canadian Journal of Earth Sciences, Vol 11, No. 12, 1974, p 1621-1624.

60. Cooper, B. N. Grand Appalachian Field Excursion. Virginia Polytechnical Institute, Geological Society of America, Guidebook for Field Trips, 74th Annual Meeting, 1961.

61. Cooper, B. N. Relation of Stratigraphy to Structure in the Southern Appalachians. W. D. Lowry (ed.), Tectonics of the Southern Appalachians: Virginia Polytechnical Institute, Department of Geology, Science Memoir 1, 1964, p 81-114.

62. Cooper, B. N. Profile of the Folded Appalachians of Western Virginia. University of Missouri at Rolla, Journal No. 1, 1968, p 27-64.

63. Keith, A. Stratigraphy and Structure of Northwestern Vermont. Journal of the Academy of Science, Vol 22, 1932, p 257-379, 393-406.

64. Fisher, D. W. and McLelland, J. M. Stratigraphy and Structural Geology in Mt. Amenia-Pawling Valley, Dutchess County, New York. Northern Connecticut and Adjacent Areas of New York, New England Intercollegiate Geological Conference, Guidebook for Field Trips in Western Massachusetts, 67th Annual Meeting, City College of C.U.N.Y., New York, 1975, p 280-312.

65. Cady, W. M. Tectonic Setting and Mechanism of the Taconic Slide. American Journal of Science, Vol 266, 1968, p 563-578.

66. De Boer. Paleomagnetic Differentiation and Correlation of the Late Triassic Volcanic Rocks in the Central Appalachians (with Special Reference to the Connecticut Valley). Geological Society of America Bulletin, Vol 79, No. 5, 1968, p 609-626.

67. Dames and Moore. Nuclear Regulatory Commission, Indian Point Testimony. 1976, p 4301-4362.

68. Ratcliffe, N. M. Contrasting Styles of Deformation of Precambrian Basement Rocks in Western New England: Implications for Taconian Paleogeography and Tectonism. Geological Society of America, Abstracts with Program, Vol 8, No. 2, 1976, p 252.

69. Davis et al. Nuclear Regulatory Commission, Indian Point Testimony, 1976, p 4309, Line 22; p 4310, Line 1.

70. Ballard, N. Stratigraphy and Structural History of East-Central United States. American Association of Petroleum Geologists Bulletin, Vol 22, No. 11, 1938, p 1519-1559.

71. Billings, M. P. 1956, The Geology of New Hampshire - Part II Bedrock Geology. Department of Resources and Economic Development, Concord, NH.

72. Bird, J. M. and Dewey, J. F. Lithosphere Plate-Continental Margin Tectonics and the Evolution of the Appalachian Orogen. Geological Society of America Bulletin, Vol 81, 1970, p 1031-1060.

73. Cameron, B. and Naylor, R. S. General Geology of Southeastern New England, Geology of Southeastern New England, NEIGC. Guidebook for Field Trips, 68th Annual Meeting, 1976.

74. King, P. B. and Beckman, H. M. The Cenozoic Rocks: A Discussion to Accompany the Geologic Map of the United States. U. S. Geological Survey Professional Paper No. 904, 1978.

75. Sloss, L. L. Sequences in the Cratonic Interior of North America. Geological Society of America Bulletin, Vol 74, 1963, p 93-114.

76. Woodward, H. F. Preliminary Subsurface Study of Southeastern Appalachian Interior Plateau. American Association of Petroleum Geologists Bulletin, Vol. 45, No. 10, 1961. p 1634-1655.

77. Ratcliffe, N. M. and Harwood, D. C. Blastomylonites Associated with Recumbent Folds and Overthrusts at the Western Edge of the Berkshire Massif, Connecticut and Massachusetts. A preliminary report, Tectonic Studies of the Berkshire Massif, Western Massachusetts, Connecticut and Vermont. U. S. Geological Survey Professional Paper No. 888-A, 1975, p 1-19.

78. Zen, E. Time and Space Relationships of the Taconic Allochthon and Authochthon. Geological Society of America Bulletin Special Paper 97, 1967.

79. Schutts, L. D.; Brecher, A.; Hurley, P. M.; Montgomery, C. W.; and Krueger, H. W. A Case Study of the Time and Nature of Paleomagnetic Resetting in a Mafic Complex in New England. Canadian Journal of Earth Sciences, Vol 13, 1976, p 898-907.

80. Dewey, J. F. and Kidd, W. S. F. Continental Collisions in the Appalachian Caledonian orogenic Belt: Variations Related to Complete and Incomplete Suturing. Geology, Vol 2, 1974, p 543-546.

81. Belt, E. S. Post-Acadian Rifts and Related Facies, Eastern Canada," Studies of Appalachian Geology: Northern and Maritime. John Wiley & Sons, New York, NY, 1968.

2035 046

82. Wones, D. R. and Stewart, D. B. Middle Paleozoic Regional Right-Lateral Strike Slip Faults in Central Coastal Maine. Geological Society of America Annual Meeting, Abstracts with Program, Vol 8, No. 2, 1976, p 304.

83. Public Service Company of New Hampshire, Seabrook Preliminary Safety Analysis Report, 1975.

84. McKerrow, W. S. and Ziegler, A. M. Paleozoic Oceans. Nature, Physical Sciences, Vol 240, 1972, p 92-94.

85. Whitten, E. H. T. Cretaceous Phases of Rapid Sediment Accumulation, Continental Shelf, Eastern United States. Geology, Vol 4, 1976, p 237-240.

86. Pittman, W. C. and Talwani, M. Sea-Floor Spreading in the North Atlantic. Geological Society of America Bulletin, Vol 83, No. 3, 1972, p 619-646.

87. Rickard, L. V. and Fisher, D. W. "Geologic Map of New York: Finger Lakes Sheet. New York Geological Survey, State Museum and Science Service, Map and Chart Series No. 15, Albany, NY, 1970.

88. King, L. H. Relation of Plate Tectonics to the Geomorphic Evolution of the Canadian Atlantic Provinces. Geological Society of America Bulletin, Vol 83, 1972, p 3083-3090.

89. Flint, R. F. Glacial and Pleistocene Geology. John Wiley & Sons, New York, NY, 1957.

90. Walcott, R. I. Late Quaternary Vertical Movements in Eastern North America: Quantitative Evidence of Glacio-Isostatic Rebound", Review of Geophysics and Space Physics, Vol 10, p 849-884.

91. Dames and Moore. Nine Mile Point Nuclear Station, Geologic Investigation, Three Volumes, Niagara Mohawk Power Corporation, Syracuse, NY, 1978.

92. Sutton, R. G.; Lewis, T. L.; and Woodrow, D. L. Post-Iroquois Lake Stages and Shoreline Sedimentation in Eastern Ontario Basin. Journal of Geology, Vol 80, 1972, p 346-356.

93. Kreidler, W. L.; Van Tyne, A. M.; Jorgensen, K. M. Deep Wells in New York State. New York State Museum and Science Service, Bulletin 418A, 1972.

94. Patchen, D. G. Petrology of the Oswego, Queenston, and Grimsby Formations, Oswego County, New York. M.A. Thesis, State University of New York at Binghamton, NY, 1966.

95. Patchen, D. G. Depositional Environments of the Oswego Sandstone, Oswego County, New York . Geological Society of America, Abstracts with Program, Vol 7, No. 1, 1975, p 103-104.

96. Dames and Moore. Preliminary Safety Analysis Report, Nine Mile I Nuclear Power Station. Niagara Mohawk Power Corporation, Syracuse, NY, 1968.

2035 047

97. Stone & Webster Engineering Corp. Final Safety Analysis Report, FitzPatrick Nuclear Station, Power Authority of the State of New York, Scriba, NY, 1971.

98. Stone & Webster Engineering Corp. Report of Fault Investigation at FitzPatrick Nuclear Power Plant. Power Authority of the State of New York, Scriba, NY, 1978.

99. Kiersch, G. A. Regional Geology Confirmation Report, New Site Generation Project Phase I Investigation: 4-3-11 Site (New Haven). New York State Electric & Gas, Binghamton, NY, 1976, (additions January 28, 1977).

100. Geotechnical Engineers, Inc. Confirmation Study of Site 4-3-11, New York State Electric & Gas Corporation New Site Project, Figures and Appendices, 1976.

101. Kaiser, R. The Composition and Origin of Glacial Till in the Mexico and Kasoag Quadrangles, New York. Unpublished Master of Science Thesis, Department of Geology, Syracuse University, 1938.

102. Kaiser, R. Composition and Origin of Glacial Till, Mexico and Kasoag Quadrangles, New York. Journal of Sedimentary Petrology, Vol 32, 1962, p 602.

103. Salomon, N. L. Stratigraphy of Glacial Deposits Along the South Shore of Lake Ontario, New York. Unpublished Master of Science Thesis, Department of Geology, Syracuse University, 1976.

104. Moore, W. S. et al. Episodic Growth of Ferromanganese Nodules in Oneida Lake, New York. Geological Society of America, Abstract with Program, Vol 8, No. 6, 1976, p 1017-1018.

105. Fairchild, H. L. New York Drumlins. Rochester Academy of Sciences Proceedings, Vol 7, 1929, p 1-37.

106. Slater, G. The Structure of Drumlins Exposed on the South Shore of Lake Ontario. New York State Museum Bulletin, Vol 281, 1929, p 1-23.

107. Miller, J. W. Drumlins in the Oswego, Weedsport, and Auburn, New York Quadrangles. Doctor of Philosophy Dissertation. Department of Geography, Syracuse University, 1970.

108. Miller, J. W. Variations in New York Drumlins. Annual Association of American Geology, Vol 62, 1972, p 418-423.

109. Muller, E. H. Origin of Drumlins, Glacial Geomorphology. Geomorphology, D. R. Coates (ed.). State University of New York at Binghamton, NY, 1974.

110. Grieco, M. Till Fabric Analyses in the Intepretation of Drumlin Origins. Unpublished Master of Science Thesis. Department of Geology, Syracuse University, NY, 1977.

2035 048

111.Colton, G. W. The Appalachian Basin - Its Depositional Sequences and Their Geologic Relationships. Studies of Appalachian Geology, Central and South, G. W. Fisher, F. J. Pettijohn, K. N. Weaver, and J. C. Reed, Jr., (eds). John Wiley & Sons, New York, NY, 1970.

112.Van Tyne, A. Personal Communications, 1978.

113.Stevens, A. E.; Milne, W. G.; Wetmiller, R. J.; and Leblanc, G. Canadian Earthquakes - 1967. Seismological Series of the Earth Physics Branch, Seismological Service of Canada, No. 65, 1973.

114.Boston Edison Company. BESG-7601, Historical Seismicity of New England. Docket No. 50-471, 1976.

115.Sbar, M. L. and Sykes, L. B. Seismicity and Lithospheric Stress in New York and Adjacent Areas. Journal of Geophysical Resources, Vol 82, No. 36, 1977, p 5571-5786.

116.Mather, K. F. and Godfrey, H., assisted by Hampson, K., The Record of Earthquakes Felt by Man in New England. Copy of the manuscript of a paper presented to the Eastern Section of the Seismological Society of America, 1927.

117.Heck, N. H. and Eppley, R. A. Earthquake History of the United States. United States Department of Commerce, Coast and Geodetic Survey, Washington, DC, 1958.

118.Brooks, John E. A Study in Seismicity and Structural Geology (Parts I and II). Bulletin de Geophysique, Observatoire de Geophysique, College, Jean-de-Brebeuf, Montreal, Quebec, No. 6 and 7, 1960.

119.Smith, W. E. T. Earthquakes of Eastern Canada and Adjacent Areas, 1534-1927. Publication of the Dominion Observatory, Ottawa, Canada, Vol 26, No. 5, 1962.

120.Coffman, J. L. and von Hake, C. A. Earthquake History of the United States, Publication No. 41-1, U. S. Department of Commerce/NOAA, Boulder, Colo, 1973.

121.Hodgson, Ernest A. The Saint Lawrence Earthquake, March 1, 1925. Publication of the Dominion Observatory, Ottawa, Vol 7, No. 10, 1950.

122.Richter, C. F. Elementary Seismology. W. H. Freeman and Company, San Franciso, Calif, 1956.

123.Clark, T. H. Region de Montreal Raffort Geologique, Ministere des Rechesses Naturelles. Quebec, No. 152, 1972.

124.Sulte, B. Histoire Des Canadiens-Francais. Wilson 8 cie, (ed.) 1882.

125.Stevens, A. Unpublished, 1976.

2035 049

126.Basham, P. W. A Regional Evaluation of the Seismicity of Eastern Canada for Purposes of Estimating Seismic Design Parameters for a Nuclear Power Plant Site at Gentilly, Quebec. Seismological Service of Canada Internal Report 77-1, Department of Energy, Mines, and Resources, Ottawa, Canada, 1977.

127.Horner, R. B.; Stevens, A. E.; Hasegawa, H. S.; and Leblanc, G. Focal Parameters of the 12 July, 1975, Maniwaki, Quebec, Earthquake - An Example of Intraplate Seismicity in Eastern Canada. Seismological Society of America Bulletin, in press, 1978.

128.Aggarwal, Y. P. Study of Earthquake Hazards in New York and Adjacent Areas. Phase IV-Annual Technical Report. New York State Energy Research and Development Authority, USNRC, NSF, and USGS, 1977.

129.Hodgson, E. A. Preliminary Report of the Earthquake of November 1, 1935. Earthquake Notes, Vol 7, No. 4, 1936a, p 1-4.

130.Hodgson, E. A. The Timiskaming Earthquake of November 1, 1935. Journal of the Royal Astronomical Society of Canada, Vol 30, N9. 4, 1936b, p 113-123.

131.Hodgson, E. A. Timiskaming Earthquake - Data and Time-Distance Curves for Dilatational Waves. American Geophysical Union Transactions, Vol 18, 1937, p 116-118.

132.Street, R. L. and Turcotte, F. T. A Study of Northeastern North American Spectral Moments, Magnitudes, and Intensities. Seismological Society of America Bulletin, Vol 67, No. 3, 1977, p 599-614.

133.Hermann, R. B. A Seismological Study of Two Attica, New York Earthquakes. Bulletin of the Seismological Society of America, Vol 68, No. 3, 1978.

134.Fox, F. L. and Spiker, C. T. Intensity Rating of the Attica (New York) Earthquake of August 12, 1929 - A Proposed Earthquake Reclassification. Earthquake Notes, Vol 48, No. 1-2, 1977, p 37-46.

135.Fletcher, J. B. and Sykes, L. R. Earthquakes Related to Hydraulic Mining and Natural Seismic Activity in Western New York State. Journal of Geophysical Resources, Vol 82, No. 26, 1977, p 2767-2780.

136.Aggarwal, Y. P.; Yang, J. P.; and Cranswick, E. Seismological Investigation on the Adirondacks and Environs, 1977. Geological Society of America Abstract Program, Vol 9, 1977, p 234.

137.Sbar, M. L.; Armbruster, J.; Aggarwal, Y. P.; and Sykes, L. R. Adirondack Earthquake Swarm of 1971 and Tectonic Stresses in Northeastern United States. Geological Society of America Abstracts, Vol 4, No. 3, 1972, p. 231.

2035 050

138. Anderson, J. G. and Fletcher, J. B. Source Properties of a Blue Mountain Lake Earthquake. Seismological Society of America Bulletin, Vol 66, No. 3, 1976, p 677-683.

139. Hadley, J. B. and Devine, J. F. Seismotectonic Map of the Eastern United States. United States Geological Survey, Miscellaneous Field Studies Map, MF-620, 1974.

140. Wetmiller, R. J. 1975, The Quebec-Maine Border Earthquake, 15 June 1973. Canadian Journal of Earth Sciences, Vol 12, p 1917-1928.

141. Leblanc, G. and Buchbinder, G. Second Microearthquake Survey of the St. Lawrence Valley Near La Malbaie, Quebec. Canadian Journal of Earth Sciences, Vol 14, No. 12, 1977, p 2778-2789.

142. Leblanc, G.; Stevens, A. E.; Wetmiller, R. J.; and Duberger, R. A Microearthquake Survey of the St. Lawrence Valley Near La Malbaie, Quebec. Canadian Journal of Earth Sciences, Vol 10, 1973, p 42-53.

143. von Hake, C. A. Earthquake History of Ohio. Earthquake Information Bulletin, Vol 8, No. 1, 1976, p 28-30.

144. Zietz, I., et al, Crustal Study of a Continental Strip from the Atlantic Ocean to the Rocky Mountains. Geological Society of America Bulletin, Vol 77, 1966, p 1427-1488.

145. Isachsen, Y. W. Contemporary Vertical Movements Associated with the Adirondack Mountains Dome, An Anomalous Uplift on the North American Craton. Geological Society of America Abstracts, Vol 7, Albany, NY, 1975, p 1127-1128.

146. De Waard, D. The Occurrence of Garnet in Granulite - Facies Terrance of the Adirondack Highlands and Elsewhere, and Amplification and a Reply. Journal of Petrology, Vol 8, 1967, p 210-232.

147. Boston Edison Company. Pilgrim Unit 2, SER NRC postion, 1976.

148. Sykes, L. R. Testimony on Capability of Ramapo Fault Before Atomic Safety Licensing Appeal Board, 1976.

149. Washington Public Power Supply System Preliminary Safety Analysis Report, Amendment 23, WNP 1 and 4. 1976.

150. Gupta, I. and Nuttli, O. W. Spatial Attenuation of Intensities for Central U.S. Earthquakes. Seismological Society of America Bulletin, Vol 65, No. 1, 1976, p 139-162.

151. Trifunac, M.D. and Brady, A.G. On the Correlation of Seismic Intensity Scales With the Peaks of Recorded Strong Ground Motion. Seismological Society of America Bulletin. Vol. 65, No. 1, 1976, p 139-152.

2035 051

152.Bolt, B. A. Duration of Strong Ground Motion. Proceedings Fifth World Conference on Earthquake Engineering, Edigraf, Rome, Italy, Vol 1, 1973, p 1304-1308.

153.Saunders, D.F., Thomas, G.E., Kinsman, F.E., and Beatly, D.F. 1973, "ERTS Imagery Use in Reconnaissance Prospecting" Final Report NASA Contract NAS5-21796. Texas Instuments.

154.Short, N.M., 1974, "Mineral Resources, Geological Structure, and Landform Survey: Freden, S.C., and Mercanti, E.P., eds., Third Earth Resources Technology Satellite Symposium III Discipline Summary Reports, NASA, SP-357 Goddard Space Flight Center, Greenbelt, Md, p 33-51.

155.Saunders, D.F., and Hicks, D.E., 1976, "Regional Geomorphic Lineaments on Satellite Imagery - Their Origin and Applications," 2nd International Conference on the New Basement Tectionics, Newark, Del.

156.Dames and Moore, 1974, "Seismo-Tectonic Conditions in the St. Lawrence River Valley Region," Report to New York State Atomic and Space Development Authority.

157.Ontario Department of Mines and Northern Affairs, 1970, Ontario Geologic Map.

158.Pohn, H.A., Podwysocki, M.H., and Merin, I.S., 1979, "The Relationship Between Lineaments, Stream Valleys, Glaciation and Joints in South-Central New York. Abstracts with Programs, Geological Society of America, 11, p 49.

159.Murphy, P.J., 1979, "Structure and Stratigraphy - Appalachian Basin," Abstracts with Programs, Geological Society of America, 11, p 46.

160.Hough, B. K. Basic Soils Engineering. Ronald Press Co, 1969.

161.Todd, D. K. Groundwater Hydrology, John Wiley & Sons, Inc. New York, NY, 1959, p 336.

162.Terzaghi, K. and Peck, R. B. Soil Mechanics in Engineering Practice. John Wiley & Sons, Inc., New York, NY, 1967, p 28.

163.Jumikis, A. R. Foundation Engineering. Intext Educational Publishers, Pa, 1971, p 39.

164.Lee, K. L. and Fitton, J. A. Factors Affecting the Cyclic Loading Strength of Soil. Vibration Effects of Earthquakes on Soils and Foundations, ASTM STP 450, 1969.

165.Wong, R. T., Seed, H. B., and Chan, C. K. Cyclic Loading Liquefaction of Gravelly Soils. Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 101, No. GT6, 1975.

2035 052

166. Ross, G. A., Seed, H. B., and Migliaccio, R. R. Bridge Foundations in Alaska Earthquake. Journal of the Soil Mechanic and Foundations Division. American Society of Civil Engineers, Vol. 95, No. SM4, 1969.

167. Kishida, H. Characteristics of Liquified Sands during Mino-Owari, Tohnankai, and Fukui Earthquakes. Soil and Foundation, Vol. 9, No. 1, 1969.

168. Seed, H. B. and Idriss, I. M. Analysis of Soil Liquefaction: Niigata Earthquake. Journal of the Soil Mechanics and Foundations Division. American Society of Civil Engineers, Vol. 93, No. SM3, 1967.

169. Seed, H. B. Evaluation of Soil Liquefaction Effects on Level Ground during Earthquakes. Liquefaction Problems in Geotechnical Engineering. American Society of Civil Engineers' National Convention, 1976.

170. Coon, R. F., and Merritt, A. H. Predicting In Situ Modulus of Deformation Using Rock Quality Indexes. ASTM STP 477, American Society of Testing Materials, 1970, p 154-173.

171. Deere, D. U.; Hendron, Hr., A. J.; Patton, F. D.; and Cording, E. J. Design of Surface and Near Surface Construction in Rock. Proceedings of the Eighth Symposium on Rock Mechanics, Minneapolis, Minn, 1966, p 237-303.

172. Seed, H. D., and Whitman, R. V. Design of Earth Retaining Structures for Dynamic Loading. American Society of Civil Engineers. Speciality Conference on Lateral Stresses and Design of Earth Retaining Structures, Ithaca, NY, 1970, p 103-147.

173. Westergaard, H. M. Water Pressures on Dams During Earthquakes. Transactions of American Society of Civil Engineers, Vol 98, 1933, p 418-433.

174. Terzaghi, K. Evaluation of Coefficients of Subgrade Reaction. Geotechnique, Vol 5, No. 4, 1955, p 297-326.

175. Audibert, J. M. and Nyman, K. J. Coefficient of Subgrade Reaction for the Design of Buried Piping. Structural Design of Nuclear Plant Facilities, Vol 1-A, New Orleans, 1975, p 109-141.

176. Christian, J. T. Relative Motion of Two Points During an Earthquake. Journal of the Geotechnical Division, American Society of Civil Engineers, Vol 102, No. GR11, Nov 1976.

177. Hendron, A. J.; Cording, E. J.; and Aiyer, A. K. Analytical and Graphical Methods for the Analysis of Slopes in Rock Masses. NCG Technical Report No. 36, U.S. Army Corps of Engineers, Vicksburg, Miss, 1971.

2035 053

178.Campbell, D. S. Analytical Method for Analysis of Stability of Rock Slopes. (SWARS-2P). Unpublished Masters Thesis, MIT, Cambridge, Mass. Sept 1974.

179.Campbell, D. S., Christian, J. T., and Ernstein, H. H. Computerized Analysis of Rock Slope Stability. Rock Engineering for Foundations and Slopes, American Society of Civil Engineers, Geotechnical Engineering Division, 1976.

2.5.6.2 Bibliography for Geology, Seismology, and Geotechnical Engineering

Aerial Photograph (site 4-3-11, Scale 1" = 400') approximately 3'x4', black and white, prepared by Kucera and Associates for United Engineers & Constructors, Inc., also aerial photo indexes of site 1, (Scale 1:7920, 2) Scale 3960.

Aerial Photographs (Site 4-3-11), 1968, Lockwood Mapping, Inc., Rochester, New York, 29 9"x9", Black and White, Stereo Air Photos, Scale approximately 1"=2,000'.

Aggarwal, Y.P., 1977, "Study of Earthquake Hazards in New York and Adjacent States," New York State Energy Research and Development Authority, Annual Technical Report, Phase IV, p 39.

Aggarwal, Y.P., 1978, "Earthquakes, Faults and Nuclear Power Plants in Southern New York - Northern New Jersey," Lamont-Doherty Geology Department. to be submitted to the B.S.S.A., p 26.

Aggarwal, Y.P., L.R. Sykes, J. Armbuster, and M. Sbar, 1973, "Premonitory Changes in Seismic Velocities and Prediction of Earthquakes," Nature, Vol. 241, p 010-104.

Aggarwal, Y.P., J.P. Yang, and E. Cranswick, 1977, "Seismological Investigation on the Adirondacks and Environs, 1977," Geological Society of America Abstract with program, Vol. 9, p 234.

Aggarwal, Y.P., and J.P. Yang, 1978, "Seismic Activity and Lithospheric Stresses in Northeastern North America," Geological Society of America Abstracts with program, Vol. 10, No. 2, p 29.

Airmag Surveys, 1974, "Aeromagnetic Survey of Ogdensburg, New York Area," 15 Sheets, 1 Index Map.

Albee, A.L. and E.L. Boudette, 1972, "Geology of the Attean Quadrangle, Somerset County, Maine, with a Section on Geologic Interpretation of the Aeromagnetic Map by J.W. Allingham and A.L. Albee," U.S. Geological Survey, Bulletin 1287.

Albert, R.L., et al, October 1977, "Gravity Studies of Earthquake-Related Structures in Northern New York," Seismological Society of America, 49th Annual Meeting, Eastern Section.

Allen, J.R.L. and P.F. Frient, 1968, "Deposition of the Catskill Facies, Appalachian Region, With Notes on Some Old Red Sandstone Basins," Geological Society of America Special Paper 106.

Alvord, D.C., M.H. Pease, Jr., and R.J. Fahey, 1976, "The Pre-Silurian Eugeosynclinal Sequence Bounded by the Bloody Bluff and Clinton-Newbury Faults, Concord, Billerica, and Westford Quadrangles, Massachusetts," N.E.I.G.C. Guidebook for Field Trips, 68th Annual Meeting, p 315-333.

American Society for Testings and Materials, 1977, "1977 Annual Book of A.S.T.M. Standards, Soil and Rock; Building Stones; Peats," American Society for Testing and Materials, Lukens, R.P. (chief ed.), part 19.

Anderson, J.G. and J.B. Fletcher, 1976, "Source Properties of a Blue Mountain Lake Earthquake," Seismological Society of America Bulletin, Vol. 66, No. 3, p 677-683.

Andrews, J.T., 1970, "Present and Postglacial Rates of Uplift for Glaciated Northern and Eastern North America Derived from Postglacial Uplift Curves," Canadian Journal of Earth Sciences, Vol. 7, p 703-715.

Audibert, J.M. and K.J. Nyman. 1975, Coefficient of Subgrade Reaction for the Design of Buried Piping. Structural Design of Nuclear Plant Facilities, Vol. 1-A, New Orleans, La, p 109-141.

Ballard, N., 1938, "Stratigraphy and Structural History of East-Central United States." American Association of Petroleum Geologists Bulletin, Vol. 22, No. 11, p 1519-1559.

Balsley, J.R. and A.F. Buddington, 1960, "Magnetic Susceptibility, Anisotropy and Fabric of Some Adirondack Granites and Orthogenesis," American Journal of Science, Vol. 185A, p 6-20.

Banff Oil, Ltd., 1969, Quebec Ministry of Natural Resources, "Final Report on Vibroseis Survey in Montreal Lowlands Quebec."

Barker, F., 1964, "Reaction Between Mafic Magmas and Pelitic Schist," Cortlandt, NY, American Journal of Science, Vol 263, p 614-634.

Barrell, J. November 1913, "The Upper Devonian Delta of the Appalachian Geosyncline, Part I: The Delta and Its Relation to the Interior Sea," American Journal of Science - Fourth Series, Vol. 36, No. 215.

Barrell, J., 1913, "The Upper Devonian Delta of the Appalachian Geosyncline, Part II: Factors Controlling the Present Limits of the Strata," American Journal of Science - Fourth Series, Vol. 36, p 429-472.

Barton, Brown, Clyde & Loguidice - Consulting Engineers, 1967, "Report on the Oswego County Water Supply Study," sponsored by the New York State Department of Health, North Syracuse, NY.

2035 055

Basham, P.W., 1977, "A Regional Evaluation of the Seismicity of Eastern Canada for Purposes of Estimating Seismic Design Parameters for a Nuclear Power Plant Site at Gentilly, Quebec," Seismological Service of Canada Internal Report 77-1, Department of Energy, Mines and Resources, Ottawa, Canada.

Bates, C.C., September 1953, "Rational Theory of Delta Formation," Bulletin of the American Association of Petroleum Geologists, Vol. 37, No. 9, p 2119-2162.

Bayley, R.W. and W.R. Muehlberger, 1968, "Basement Rock Map of the United States," U.S. Geological Survey, Washington, D.C.

Beland, J., 1962, "Ste Perpetua Area," Quebec Department of Natural Resources, Geological Report 98.

Beland, J., 1974, "La Tectonique des Appalaches du Quebec," Geoscience Canada, Vol 1, No. 4, p 26-32.

Belt, E.S. 1968, Post-Acadian Rifts and Related Facies, Eastern Canada, Studies of Appalachian Geolcgy: Northern and Maritime. John Wiley & Sons, Inc. NY.

Belyea, H.R., 1952, "Deep Wells and Subsurface Stratigraphy of Part of the St. Lawrence Lowlands, Quebec," Canada Department of Mines and Technical Surveys, Geological Survey of Canada Bulletin 22.

Ben-Menahem, A. July 15, 1975, "Dating of Historical Earthquakes by Mud Profiles of Lake-Bottom Sediments," Nature, Vol. 262, p 200-202.

Berry, W.B.N., 1963, "Ordovician Correlations in the Taconic and Adjacent Regions," see J.M. Bird, 1963, Geological Society of America Bulletin, Guidebook No. 3.

Berry, W.B.N., 1968, "Ordovician Paleography of New England and Adjacent Areas Based on Grapotolites," in Zen, E. et al (eds.) Studies of Appalachian Geology: Northern and Maritime, Interscience Publishers, Inc., p 23-34.

Bickford, M.E., 1970, "Rb-Sr Geochronology of Genisses in Structural Domes, Southeastern Adirondack Mountains, New York," Geological Society of America Abstracts with program, Vol. 2, No. 7, p 495.

Bickford, M.E. and B.B. Turner, 1971, "Age and Probable Anatectic Origin of the Brant Lake Gneiss, Southeastern Adirondack Mts., N.Y.," Geological Society of America Bulletin, Vol. 82, p 2333-2342.

Billings, M.P., 1956, "The Geology of New Hampshire - Part II Bedrock Geology," Department of Resources and Economic Development, Concord, NH.

Billings, M.P., J. Rodger, and J.B. Thompson, Jr., 1952, "Geology of the Appalachian Highlands of East-Central New York, Southern Vermont and Southern New Hampshire," Geological Society of America Guidebook to New England.

Birch, F., R.F. Roy, and E.R. Decker, 1968, "Heat Flow and Thermal History in New England and New York," in Zen-Ean, Studies of Appalachian Geology, Northern and Maritime, Interscience Publications, p 437-451.

Bird, J.M. and J.F. Dewey, 1970, Lithosphere Plate - Continental Margin Tectonics and the Evolution of the Appalachian Oregen. Geological Society of America Bulletin, Vol. 81, p 1031-1060.

Blackburn, W.H., 1968, "The Spatial Extent of Chemical Equilibrium in Some High Grade Metamorphic Rocks from the Grenville of Southeastern Ontario," Contract Mineral and Petroleum, Vol 19, p 72-92.

Bloomer, R.O., September 1965, "Precambrian Grenville or Paleozoic Quartzite in the DeKalb Area of Northern New York," Geological Society of America Bulletin, Vol. 76, p 1015-1026.

Bofinger, V.M. and W. Compston, 1967, "A Reassessment of the Age of the Hamilton Group New York, and Pennsylvania and the Role of Inherited Radiogenic Sr. 87," Geochimica et Cosmochimica Acta., Vol. 31, p 2353-2359.

Bolt, B.A., 1973, "Duration of Strong Ground Motion," Proceedings Fifth World Conference on Earthquake Engineering, Edigraf, Rome, Italy, Vol. 1, p 1304-1308.

Bond, I.J. and R.G. Greggs, 1976, "Revision of the Oxford Formation (Arenig) of Southeastern Ontario and Northern New York State," Canadian Journal of Earth Sciences, Vol. 13, p 19-26.

Bonini, W.E., "Bouguer Gravity Anomaly Map of New Jersey," New Jersey Geological Survey, Geologic Report Series No. 9, 10 p, and plates, Loc: BECO.

Boone, G.M., 1973, "Metamorphic Stratigraphy, Petrology and Structural Geology of the Little Bigelow Mountain Map Area, Western Maine," Maine Geological Survey Bulletin, No. 24, 136 p, 1 plate.

Bostock, H.S., 1969, "Physiographic Regions of Canada," Geological Survey of Canada Map 1254A, Scale 1:5,000,000.

Boston Edison Company, 1976, BESG-7601, Historical Seismicity of New England, Docket No. 50-471, 641 p.

Boston Edison Company, 1976, Pilgrim Unit 2, Preliminary Safety Analysis Report, EBSG-7603, Geologic Investigations, Docket No. 50-471.

Boston Edison Company, 1976, Pilgrim Unit 2, SER NRC Position.

Bott, M.H.P., 1953, "Negative Gravity Anomalies Over Acid 'Intrustions' and Their Relation to the Structure of the Earth's Crust," Geological Magazine, Vol. 90, p 257-267.

2035 057

Bott, M.H.P. and S.B. Smithson, 1967, "Gravity Investigations of Subsurface Shape and Mass Distribution of Granite Batholiths," Geological Society of America Bulletin, Vol. 78, No. 7, p 859-878.

Boucot, A.J., 1968, "Silurian and Devonian of the Northern Appalachians," in Zen, E., et al (eds.) Studies of Appalachian Geology - Northern and Maritime, Interscience Publisher, Inc., p 83-94.

Boucot, A.J., 1969, "Geology of the Moose River and Roach River Synclinoria, Northwestern Maine," Maine Geological Survey Bulletin, No. 21, 117 p, 21 maps.

Boudette, E.L., 1973, "Geology of the Kennesage Lake Quadrangle, Maine," Maine Geological Survey Open File Maps.

Boulton, N.S., 1963. "Analysis of Data From Non-Equilibrium Pumping Tests Allowing for Delayed Yield From Storage," Proceedings Institute of Civil Engineers (London) Vol. 26, No. 6693.

Bower, D.R., A. Lambert, and J. O'Brien, 1976, "Tidal Gravity Measurements at Ottawa and Alberta, 1967-1974," Earth Physics Branch of the Department of Energy, Mines and Resources, Canada, Geodynamics Series Bulletin No. 67, 65 p.

Bower, M.E., 1960, "Geophysical Interpretation of the Magnetic Anomaly at Marmora, Ontario," Geological Survey of Canada, Department of Mines and Technical Surveys Paper 59-4.

Bownocker, J.A., 1965, "Geologic Map of Ohio," Division of Geological Survey, Department of Natural Resources, Columbus, Ohio.

Brocoum S., 1970, "Structural and Metamorphic History of the Major Precambrian Gneiss Belt, Northwest Adirondacks, New York," Geological Society of America Abstracts with program, Vol. 2, No. 7, p 502-503.

Brocoum, S.J., (Abstract), 1974, "Structural and Metamorphic History of the Major Precambrian Gneiss Belt in the Hailesboro-West Fowler-Balmal Area, Adirondack Lowlands, New York," Dissertation Abstracts International, Vol. 34, No. 12, Part 1, p 6065B.

Brooks, J.E., 1960, "A Study in Seismicity and Structural Geology (Parts I and II)," Bulletin de Geophysique, Observatoire de Geophysique, College, Jean de Brefeuf, Montreal, Quebec, Nos. 6 and 7.

Bromry, R.W., 1967, "Simple Bouguer Gravity Map of Massachusetts," GP-612, Loc. GP File.

Broms, B.B., "Lateral Earth Pressures Due to Compaction of Cohesionless Soils," Proceedings, Fourth Conference on Soil Mechanics, Budapest, 1971, p 373-384.

2035 058

Broms, B.B. and I. Ingelson, 1971, "Earth Pressure Against the Abutments of a Rigid Frame Bridge," Geotechnique, Vol. 21, No. 1, p 15-28.

Booker, E.W. and H.O. Ireland, February 1965, "Earth Pressures at Rest Related to Stress History," Canadian Geotechnical Journal, Vol. II, No. 1.

Broughton, J.G.; D.W. Fisher, Y.W. Isachsen, and L.V. Rickard, 1966, "Geology of New York, A Short Account." New York State Museum and Science Service, Educational Leaflet No. 20.

Brown, J.S., 1967, "Precambrian Grenville or Paleozoic Quartzite in the Dekalb Area in Northern New York: Discussion," Geological Society of America Bulletin, Vol 78, No. 7, p 921-930.

Brown, J.S., 1973, "Sulfur-Isotopes of the Precambrian Sulfates and Sulfides in the Grenville of New York and Ontario," Economic Geology, p 362-370.

Brown, J.S. and A.E.J. Engle, 1956, "Revision of the Grenville Stratigraphy and Structure in the Balmat-Edwards District, Northwest Adirondacks, New York," Geological Society of America Bulletin, Vol. 67, p 1599-1622.

Brown, L.D. and J.E. Oliver, 1976, "Vertical Crustal Movements from Leveling Data and their Relation to Geologic Structure in the Eastern United States," Reviews of Geophysics & Space Physics, Vol. 14, No. 1.

Brown, S.P., 1967, "Anatomy of A Refold: An Empirical Approach," New York State Museum Geogram, Vol. 5, No. 1, p 9-14.

Buddington, A.F. and B.F. Leonard. 1962, "Regional Geology of the St. Lawrence County Magnetite District. Northwest Adirondacks, New York." U.S. Geological Survey Professional Paper 276.

Buddington, A.F., (Abstract), 1966, "The Occurrence of Garnet in the Granulite-Facies Terrane of the Adirondack Highlands," Journal of Petrology, Vol. 7, p 331-335.

Buehler, E.J. and I.H. Tesmer, 1963, "Geology of Erie County, N.Y.," Buffalo Society of Natural Science Bulletin, Vol. 21, No. 3.

Burger, D., 1967, "Distribution and Origin of Parent Soil Materials in Part of the Ottawa and Bonnechere River Valleys, Ontario," Canadian Journal of Earth Sciences, Vol. 4, p 397-411.

Burke, K. and J.F. Dewey, 1973, "Plume Generated Triple Junctions: Key Indicators in Applying Plate Tectonics to Old Rocks," Journal of Geology, Vol. 81, p 406-431.

Cady, W.M., 1968, "Tectonic Setting and Mechanism of the Taconic Slide," American Journal of Science, Vol. 266, p 563-578.

2035 059

Cady, W.M., 1969, "Regional Tectonic Synthesis of Northwestern New England and Adjacent Quebec," Geological Society of America Memoir 120.

Caley, J.F., 1940, "Paleozoic Geology of the Toronto-Hamilton Area," Geologic Survey of Canada Memoir 224.

Caley, J.F., 1941, "Paleozoic Geology of the Brantford, Area, Ontario," Geologic Survey of Canada Memoir 226.

Calkin, P.E., 1970, "Strand Lines and Chronology of the Glacial Great Lakes in Northwestern New York," Ohio Journal of Sciences, Vol. 70(2), p 78-96.

Calvert, W.L., 1964, Oil and Gas Fields of Ohio, Ohio Division of Geological Survey.

Cameron, B.W., 1971, "Stratigraphy and Sedimentary Environments of Lower Trentonian Series (Middle Ordovician) in Northwestern New York and Southeastern Ontario," Dissertation Abstracts International, Vol. 32, No. 3, p 1736-1737.

Cameron, B. and R.S. Naylor, 1976, "General Geology of Southeastern New England," Geology of Southeastern New England, N.E.I.G.C. Guidebook for Field Trips, 68th Annual Meeting.

Cameron, C.C., 1970, "Peat Deposits of Southeastern New York," U.S. Geological Survey Bulletin 1317-B, p 32.

Campbell, D.S. September 1974, "Analytical Method for Analysis of Stability of Rock Slopes." (SWARS-2P), Unpublished Masters Thesis, MIT, Cambridge, Mass.

Campbell, D.S., J.T. Christian, and H.H. Ernstein. 1976, "Computerized Analyses of Rock Slope Stability. Rock Engineering for Foundation and Slopes," American Society of Civil Engineers, Geotechnical Engineering Division.

Candy, W., 1967, "Geosynclinal Setting of the Appalachian Mountains in Southeastern Quebec and Northwestern New England." Appalachian Tectonics, Royal Society of Canada Special Publication 10, p 57-68.

Caquot, A. and J. Kerisel, 1949, Traite de Mechanique Des Sols, Gautheir Villars, Paris.

Card, K.D., 1969, "Geology and Geochronology of the Southern Province of the Canadian Shield," Geological Society of America Abstracts with program, p 6-7.

Carl, J.D. and B.B. VanDiver, 1975, "Precambrian Grenville Alaskite Bodies As Ash Flows Tuffs, Northwest Adirondacks, New York," Geological Society of America Bulletin, Vol. 86, p 1691-1707.

Cartography Service, 1969, "Geologic Map of Parts of Eastern Canada."

Castle, R.O., H.R. Dixon, E.S. Grew, A. Griscom, and I. Zietz, 1976, "Structural Dislocations in Eastern Massachusetts," U.S. Geological Survey Bulletin 1410, 39 p, 1 plate.

Chadwick, G.H., 1909, "Downward Overthrust Fault at Saugerties, New York," New York State Museum Bulletin, Vol. 140, p 157-160.

Champion, D., E. Oaskford, G. Palmer, D. Hodge, and P. Calkin, 1972, "Gravity Delineation of the Preglacial Casenovia River Valley Western New York," Geological Society of America Abstracts with Programs, Vol. 4, No. 1, p 9.

Chapple, W.M., 1975, "The Role of Gravity in Thin-Skinned Stress Transmission Problem in the Central Appalachians:" Northeastern Section, 10th Annual Meeting, Geological Society of America Abstract, Vol. 7, No. 1, p 38-39.

Charbonneau, B.W., 1973, "A Grenville Front Magnetic Anomaly in the Megiscane Lake Area, Quebec," Geological Survey of Canada Paper 73-29, Department of Energy, Mines, and Resources, 20 p.

Chenoweth, P.A., 1952, "Statistical Methods Applied to Trentonian Stratigraphy in New York," Geological Society of America Bulletin, Vol. 63, p 521-560.

Chesworth, W., May 1972, "Metamorphic Facies in the Grenville Province of Ontario," Tectonophysics, Vol. 14, No. 1, p 71-78.

Christensen, M.N., February 1963, "Structural Analysis of Hoosac Nappe in Northwestern Massachusetts," American Journal of Science, Vol. 261, p 97-107.

Christian, J.T., November, 1976, "Relative Motion of Two Points During an Earthquake," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 102, No. GT11.

Chute, N.E., 1969, "Structural Features in the Syracuse Area," Prucha J.J. (ed.), New York State Geological Association, 36th Annual Meeting Guidebook to Field Trips, p 74-77.

Clark, G.S. and J.L. Kulp, December 1968, "Isotopic Age Study of Metamorphism and Intrustion in Western Connecticut and Southeastern New York," American Journal of Science, Vol. 266, p 865-894.

Clark, S.K. and J.S. Royds, 1948, "Structural Trends and Fault Systems in Eastern Interior Basin," American Association of Petroleum Geologists Bulletin, Vol. 32, No. 9, p 1728-1749.

Clark, T.H., June 1951, "New Light on Logans Line," Transactions of the Royal Society of Canada, Vol. 45, Series III, p 11-22.

Clark, T.H., 1954, "Geologic Map, St. Jean, Quebec," Scale 1 mile = 1 inch or 1:63,360 blueline, to accompany Geological Report No. 66, Department of Mines, Province of Quebec.

Clark, T.H., 1955, "St. Jean-Beloeil Area: Iberville, St. Jean, Napieroille Rouville, Chambly, St. Hyacinth, et at. Counties," Quebec Department of Mines Geologic Report No. 66, 1 map of 2, 83 p.

Clark, T.H., 1962, "Breccia Localities," NEIGC Guidebook 54th Annual Meeting, McGill University, Montreal, Quebec, p 95-104.

Clark, T.H., 1964, "Yamaska-Aston Area: Nicolet, Yamaska, Berthier, Richelieu and Drummond Counties," Quebec Department of National Resources Geological Report 102, 191 p.

Clark, T.H., 1964, "St. Hyacinthe Area (West Half): Bagot, St. Hyacinthe and Shefford Counties," Quebec Department of Natural Resources, Geologic Report 101, 128 p.

Clark, T.H., 1964, "Upton Area, Bagot, Drummond, Richlieu, St. Hyacinthe, and Yamaska Counties," Quebec Department of Natural Resources, Geologic Exploration Service Geologic Report 100, 37 p.

Clark, T.H., 1972, "Region de Montreal Area", Geologic Report No. 152, Ministere des Rechesses Naturelles, p 244.

Clark, T.H., E.H. Kranck, and A.R. Philpotts, 1967, "Ile Ronde Breccia, Montreal," Canadian Journal of Earth Sciences, Vol. 4, p 507-513.

Cloos, E., 1966, (Abstract), "Appalachenprofil," Geological Society of America Bibliography and Index of Geology.

Coates, D.R., 1975, "Quaternary Sediment Deformation as a Seismic Indicator in the St. Lawrence Lowland, New York," Geological Society of America Abstracts with program, Vol. 7, No. 7, p 1030-1031.

Coates, D.R. Dr., September 1975, "Identification of Late Quaternary Sediment Deformation and Its Relation to Seismicity in the St. Lawrence Lowland, New York," New York State Energy Research and Development Authority, NY, No. NYSERDA-75/14.

Cochran, J.R. and M. Talwani, 1974, "Gravity and Magnetic Studies on the Continental Shelf Off New York," Geological Society of America Annual Meetings Abstract with program for 1974, Vol. 6 No. 7, p 691.

Cohee, G.V., 1948, "Cambrian and Ordovician Rocks in Michigan Basin and Adjoining Areas." American Association of Petroleum Geologists Bulletin, Vol. 32, No. 3, p 1417-1443.

Cohee, G.V. (Chairman), et al, 1962, Tectonic Map of the United States, U.S. Geological Survey and American Association of Petroleum Geologists.

Cohen, P. and C.N. Durfor, 1966, "Design and Construction of a Unique Injection Well on Long Island, New York," U.S. Geological Survey, Professional Paper No. 550-D, p D253-D257.

Cohen, B.P., 1975, "Beach Modification by Ice Eastern Shore of Lake Ontario," Geological Survey Association Abstracts, Vol. 7, No. 1, p 40-41.

Cohen, B.P. and J.E. Robinson, 1976, "A Forecast Model for Great Lakes Water Levels," Journal of Geology, Vol 84, p 455-465.

Coffman, J.L. and C.A. von Hake, 1973, Earthquake History of the United States, Publication No. 41-1, U.S. Department of Commerce/NOAA, Boulder, Col.

Coleman, A.P., 1936, "Geology of the North Shore of Lake Ontario," 45th Annual Report of Ontario Department of Mines, Part 7, p 37-74.

Coles, R.L., 1976, "A Review of Large Scale Magnetic Anomolies Over Canada and Artic Regions," American Geophysics and Resources.

Colton, G.W., 1970, "The Appalachian Basin - Its Depositional Sequencies and Their Geologic Relationships," Studies of Appalachian Geology: Central and Southern, John Wiley and Sons, Inc., NY, p 5-47.

Connally, G.G., 1964, "Garnet Ratios and Provenance in the Glacial Drift of Western New York," Science, Vol. 144.

Coon, R.F. and A.H. Merritt, 1970, "Predicting In Situ Modulus of Deformation Using Rock Quality Indexes", ASTM STP477, American Society of Testing Materials, p 154-173.

Cook, J.H., December 1942, "Geology of the Catskill and Kaaterskill Quadrangles," New York State Museum Bulletin, No. 331, p 187-237.

Cooper, B.N., 1961, "Grand Appalachian Field Excursion," Virginia Polytechnical Institute, Geological Society of America, Guidebook for Field Trips, 74th Annual Meeting, 187 p.

Cooper, B.N., 1964, "Relation of Stratigraphy to Structure in the Southern Appalachians," W.D. Lowry (ed.), Tectonics of the Southern Appalachians: Virginia Polytechnical Institute, Department of Geology, Science Memoir 1, p 81-114.

Cooper, B.N., 1968, "Profile of the Folded Appalachians of Western Virginia," University of Missouri at Rolla, Journal, No. 1, p 27-64.

Cushing, H.P., 1916, "Geology of the Vicinity of Ogdensburg," New York State Museum Bulletin, No. 191.

Cushing, HP., et al, December 15, 1910, "Geology of the Thousand Island Region," New York State Museum Bulletin, No. 485, p 4-187.

Dames and Moore, 1968, Preliminary Safety Analysis Report, Nine Mile I Nuclear Power Station, Niagara Mohawk Power Corporation, Syracuse, NY.

2035 063

Dames and Moore, 1971, "Regional Geologic and Tectonic Study of the St. Lawrence River Valley," Proposed Fast Breeder Reactor Site Near Waddington, New York.

Dames and Moore, 1973, "Report, Site Suitability Geotechnical Studies, Lloyd, New York," New York State Atomic and Space Development Authority.

Dames and Moore, 1974, "Seismo-Tectonic Conditions in the St. Lawrence River Valley Region, Phase 1, 1973 Geologic Investigations Report to NYSASDA."

Dames and Moore, 1974, "Regional Geologic and Tectonic Study of the St. Lawrence River Valley." Proposed Fast Breeder Reactor Site near Waddington, NY.

Dames and Moore, 1974, "Seismo-Tectonic Conditions in the St. Lawrence River Valley Region," Report to New York State Atomic and Space Development Authority.

Dames and Moore, 1975, "Report of Geologic Investigation, Lloyd, New York," prepared for New York State Energy, Research, and Development Authority.

Dames and Moore, 1976, Nuclear Regulatory Commission, Indian Point Testimony, p 4301-4362.

Dames and Moore, 1978, Nine Mile Point, Nuclear Station, Geologic Investigation, Three Volumes, Mohawk Power Corporation, Syracuse, NY.

Darton, N.H. and J.F. Kemp, 1895, "A Newly Discovered Dike at De Witt near Syracuse, New York," American Journal of Science, 3rd Series, Vol. 149, p 456-462.

Davis, J.F., 1962, "Field Guide to the Central Portion of the Southern Adirondacks," State Museum and Science Service, Educational Leaflet Series No. 12, Albany, NY.

Davis, et al, 1976. Nuclear Regulatory Commission, Indian Point Testimony, p 4309, Line 22; p. 4310, Line 1.

De Boer, J., 1968, "Paleomagnetic Differentiation and Correlation of the Late Triassic Volcanic Rocks in the Central Appalachians (with Special Reference to the Connecticut Valley)," Geological Society of America Bulletin, Vol. 79, No. 5, p 609-626.

De Waard, D., 1967, "Precambrian Geology of the Adirondack Highlands: A Reinterpretation," Geologische Rundschau, Vol. 56, No. 2, p 596-629.

De Waard, D., 1967, "The Occurrence of Garnet in the Granulite-Facies Terrance of the Adirondack Highlands and Elsewhere, and Amplification and a Reply," Journal of Petrology, Vol. 8, p 210-232.

2035 064

DeWitt, D.B. and E.J. Essene, 1974, "Sphalerite Geobarometry Applied to Grenville Marbles," Geological Society of America Abstract, Vol. 6, No. 7, p 709-710.

Deere, D.U., A.J. Hendron, Jr., F.D. Patton, and E.J. Cording, 1966. Design of Surface and Near Surface Construction in Rock. Proceedings of the Eighth Symposium on Rock Mechanics, Minnepolis, Minn., p 237-303.

Deland, A.N., 1974, "Geology of the North Bank of the Ottawa River Between Carillion and Grenville, Argenteuil County," Quebec Department Natural Resources, Preliminary Report, No. 528 12 p. 1 map.

Dennen, W.H., 1975, Preliminary Bedrock Geologic Map of the Marblehead North Quadrangle, Massachusetts, U.S. Geological Survey Open File Report 75-543.

Dennen, W.H., 1975, Preliminary Bedrock Geologic Map of the Ipswich Quadrangle, Massachusetts, U.S. Geological Survey Open File Report 75-544.

Dennen, W.H., 1975, Prelimary Bedrock Geologic Map of the Rockport Quadrangle, Massachusetts, U.S. Geological Survey Open File Report 75-545.

Dennen, W.H., 1975, Preliminary Bedrock Geologic Map of the Gloucester Quadrangle, Massachusetts, U.S. Geological Survey Open File Report 75-546.

Dennis, J.G., 1968, "Isotopic Ages of the Appalachians and Their Tectonic Significance-Discussion," Also Comment by C.T. Harper in Response to the Article, Canadian Journal of Earth Sciences, Vol. 5, No. 4, p 959-962.

Department of Energy, Mines and Resources, 1971, Gravity Map of Toronto-Ottawa Area Gravity Map Series No. 133, Scale 1:500,000 Earth Physics Branch, Canada.

Department of Energy, Mines and Resources, 1971, Gravity Map of the Upper Ottawa River Area. 1:500,000 Gravity Map Series No. 134.

Department of Energy, Mines and Resources, 1971, Gravity Map of the Parent-Trois Rivers Area, Quebec. 1:500,000 Gravity Map Series No. 135.

Department of Energy, Mines and Resources, 1971, Gravity Map of the Ottawa-Montreal Area. 1:500,000 Gravity Map Series No. 136.

Department of Energy, Mines and Resources, 1971, Gravity Map of the Windsor-Toronto Ontario Area. 1:500,000 Gravity Map Series No. 137.

Department of Energy, Mines and Resources, 1974, Bouguer Anomaly Map of Canada Gravity Map Series 74-1, 1 sheet, 1:500,000.

Department of Energy, Mines and Resources, 1977, "Gravity Data For New Brunswick," Earth Physics Branch Open File Report No. 77-4, Bouguer Anomaly Map, Scale 1:500,000.

2035 065

Dewey, J.F. and W.S.F. Kidd, 1974, "Continental Collisions in the Appalachian - Caledonian Orogenic Belt: Variations Related to Complete and Incomplete Suturing," Geology, Vol. 2, p 543-546.

Dill, D.B. and W. de Lorraine. 1978, "Structure, Stratigraphic Controls, and Genesis of the Balmaf Zinc Deposit. Northwest Adirondacks, New York." U.S. Geological Survey Abstracts with program, Vol 10, p 389.

Diment, W.H., 1953, Notes on a Partial Bibliography For: "A Regional Gravity Survey in Vermont, Eastern New York, and Western Massachusetts," Ph.D. Thesis, Harvard University, 219 p.

Diment, W.H., 1968, "Gravity Anomalies in Northwestern New England," Studies of Appalachian Geology, Northern and Maritime, E. Zen et al (eds.), John Wiley & Sons, Inc., NY.

Diment, W.H. and T.C. Urban, et al., (Abstract), 1974. "Speculations About the Precambrian Base nt of New York and Pennsylvania From Gravity and Magnetic Anomalies," Geological Society of America Abstracts, Vol. 6, No. 7, p 711.

Dineen, R., 1975, "Geology and Land Uses in the Pine Bush, Albany County, New York Area," New York State Museum and Science Service Circular No. 47, 27 p.

Doig, R., 1970, "An Alkaline Rock Province Linking Europe and North America," Canadian Journal of Earth Sciences, Vol. 7, p 22-28.

Doig, R., and J.M. Barton, Jr., 1968, "Ages of Carbonates and Other Alkaline Rocks in Quebec," Canadian Journal of Earth Sciences, Vol. 5, p 1401-1407.

Doll, C.G, W.M. Cody, J.B. Thompson, and M.P. Billings, 1961, Centennial Geologic Map of Vermont, Maine Geological Survey, Scale 1:250,000.

Dott, R.H. and R.L. Batten. 1971, Evolution of the Earth. McGraw-Hill. New York.

Douglas, R.J.W., 1969, Geological Map of Canada, Geological Survey of Canada Map 1250A, Scale 1:5,000,000.

Doyle, R.G., R.S. Young, and L.A. Wing, 1961, "A Detailed Economic Investigation of Aeromagnetic Anomalies in Eastern Penobscot County, Maine," Maine Geological Survey Special Economic Studies Series No. 1, excluding map, 69 p 5 plates.

Doyle, R. G. and A.M. Hussey II, 1966, Preliminary Geologic Map of Maine, Maine Geological Survey.

Dreimanis, A. and P.F. Karrow, 1972, "Glacial History of the Great Lake - St. Lawrence Region, the Classification of the Wisconsin(an) Stage and its Correlatives," 24th IGC, Section 12, 10 p.

2035 066

Dreimanis, A. and R.P. Goldthwait, 1973, "Wisconsin Glaciation in the Huron, Erie, and Ontario Lobes," Geological Society of America Memoir 136, The Wisconsin Stage., p 71-106.

Dufresne, C., December 1947, "Faulting in the St. Lawrence Plain," Thesis for Master of Science at McGill University, 216 p.

DuQuette, G., 1960, "Preliminary Report on the Gould Area, Wolfe and Compton Electoral Districts, Quebec," Quebec Department of Mines and Mineral Deposits Briefing, Preliminary Report 432, 10 p.

Elink, L.S. 1973, "Middle Ordovician Fish Bearing Beds From the St. Lawrence Lowlands of Quebec," Canadian Journal of Earth Sciences, Vol. 10, p 954-960.

Elson, J.A., 1962, "Pleistocene Geology of the Saint Lawrence Lowland," NEIGC Guidebook 54th Annual Meeting, McGill University, Montreal Quebec, p 15-24.

Elson, J.A., 1962, "Pleistocene Geology Between Montreal and Covey Hill," NEIGC Guidebook 54th Annual Meeting, McGill University, Montreal, Quebec, p 61-66.

Emercon, B.K., 1971, "Geology of Massachusetts and Rhode Island," U.S. Geological Survey Bulletin 597, 289 p.

Engle, A.E.J. and C.G. Engle, 1953, "Grenville Series in the Northwest Adirondack Mountains, New York, Part I, General Features of the Grenville Series," Geological Society of America Bulletin, Vol. 64, p 1013-1048.

Engle, A.E.J. and C.G. Engle, September 1953, "Grenville Series in the Northern Adirondack Mountains, New York Part II: Origin and Metamorphism of the Major Pargneiss,", Geological Society of America Bulletin, Vol. 64, p 1049-1098, 11 figures, 2 plates.

Engle, A.E.J. and C.G. Engle, November 1958, "Progressive Metamorphism and Granitization of the Major Paragneiss, Northwest Adironack Mountains, New York, Part I: Total Rock," Geological Society of America Bulletin, Vol. 69, p 1369-1414, 7 figures, 4 plates.

Engle, A.E.J., et al, 1961, "Variations in Properties of Horneblendes Formed During Progressive Metamorphism of Amphibolities, Northwest Adirondack Mountains, New York," Short Paper in the Geologic and Hydrologic Sciences, 262 p C313-C316.

Engle, A.E.J. and C.G. Engle, 1962, "Hornblende Formed During Progressive Metamorphism of Amphibolites, Northwest Adirondack Mountains, New York," Geological Society America Bulletin, Vol. 73, p 1499-1514.

Engle, A.E.J. and C.G. Engle, 1963, "Metasomatic Origin of Large Parts of the Adirondack Phacoliths," Geological Society of America Bulletin, Vol. 74, p 349-352.

2035 067

Engle, A.E.J. and C.G. Engle, 1964, "Mineralogy of Amphibolite Interlayers in the Gneiss Complex, Northwest Adirondack Mountains, New York," Journal of Geology, Vol. 72, p 131-156.

Engelder, T. and M.L. Sbar, 1976, "Determination of Regional Stress Patterns in New York State and Adjacent Areas by In-Situ Strain Release Measurements," Lamont-Doherty Geological Observatory, Palisades, NJ.

Engelder, T. and M.L. Sbar, June 10, 1976, "Evidence for Uniform Strain Orientation in the Potsdam Sandstone, Northern New York, From In-Situ Measurements," Journal of Geophysical Research, Vol. 81, No. 17, p 3013-3017.

Engelder, T. and R. Engelder, 1977, "Fossil Distortion and Decollement Tectonics of the Appalachian Plateau," Geology, Vol. 5, No. 8, p 457-460.

Engelder, T. and M.L. Sbar, 1977, "Strain Relaxation Measurements in the Vicinity of New York State Using Surface Overcoring Techniques," New York State Energy Research and Development Authority, Annual Technical Report for July 1976 to June 1977, 38 p.

Engelder, T. and M.L. Sbar, 1977, "The Relationship Between In Situ Strain Relation and Fractures in the Potsdam Sandstone, Alexandria Bay, New York," Vol. 115.

Englund, E.J., 1976, "The Bedrock Geology of the Holderness Quadrangle, New Hampshire," New Hampshire Department of Resources and Economic Development Bulletin No. 7.

Fairchild, H.L., 1907, "Drumlins of Central Western New York," New York State Museum Bulletin, No. 111, p 443.

Fairchild, H.L., March 25, 1913, "Pleistocene Geology of New York State," Geological Society of America Bulletin, Vol. 24, p 133-162.

Fairchild, H.L., 1916, "Pleistocene Uplift of New York and Adjacent Territory," Geological Society of America Bulletin, Vol. 27, p 235-262.

Fairchild, H.I., 1929, "New York Drumlins," Rochester Academy of Sciences Proceedings, Vol. 7, p 1-37.

Fairchild, H.L., 1932, "Closing Stage of New York Glacial History," Geological Society of America Bulletin, Vol. 43, p 603-626.

Fakundiny, R.H., 1974, "Photogeologic Features of ERTS-1 Linears in Southeastern New York: A Preliminary Phase of Regional Tectonic Analysis," Geological Society of America Abstracts with program, Vol. 5, No. 1, p 24.

Fakundiny, R.H., 1978, "Clarendon-Linden Fault System of Western New York: Longest and Oldest A .ive Fault in Eastern United States," Geological Society of America, Northeastern Section Meeting, Boston, Mass., p 42.

Farmer, I.W., 1968. Engineering Properties of Rocks, London, E. and F.N. Spon Ltd., p 180.

Farrand, W. F., 1962, "Post Glacial Uplift in North America," American Journal of Science, Vol. 260, p 181-199.

Fenneman, N.M., 1938, Physiography of Eastern United States, Mc-Graw-Hill Book Company, NY.

Finks, R.M., 1968, "Taconian Islands and the Shores of Appalachia," New York State Geologic Association Guidebook 40th Annual Meeting, Trip E., p 117-153.

Finn, W.D.L. and P.M. Byrne, May 1976. "Estimating Settlements in Dry Sands During Earthquakes," Canadian Geotechnical Journal, J. 13.335.

Fisher, D.W., January 1954, "Lower Ordovician (Canadian) Stratigraphy of the Mohawk Valley, New York," Geological Society of America Bulletin, Vol. 65, p 71-96.

Fisher, D.W., September 1954, "Stratigraphy of Medinan Group, New York and Ontario," Bulletin of American Association of Petroleum Geologists, Vol. 38, No. 9, p 1979-1996.

Fisher, D.W., 1965, "Mohawk Valley Strata and Structure," Field Trip No. 1, New York State Museum and Science Service, Educational Leaflet No. 18.

Fisher, D.W., Y.W. Isachsen, and L.V. Pickard, 1970, Generalized Tectonic - Metamorphic Map of New York, New York Geological Survey Map and Chart Series No. 15, Sheet 6.

Fisher, D.W., March 1975, "Highlights in New York's Tectonic History," Geological Society of America Abstracts with program, Vol. 7, No. 1, p 57 and 58.

Fisher, D.W. and J.M. McClelland, 1975, "Stratigraphy and Structural Geology in the Amenia-Pawling Valley, Dutchess County, New York," New England Intercollegiate Guidebook 67th Annual Meeting. p 280-312.

Fisher, J.A. and J.G. McWhorter, (Abstract), March 1975, "The Clarendon-Linden Fault: Seismotectonic Impact on Siting Critical Facilities in Western New York State," Geological Society of America Abstracts with program, Vol. 7, No. 1, p 5.

Flagler, C.W., (Abstract), 1966, "Subsurface Cambrian and Ordovician Stratigraphy of the Trenton Group Precambrian Interval in New York State - New York State Museum and Science Service Map and Chart," Series No. 8, 57 p, Abstracts of North American Geology, p 1176.

Flawn, P.T. (Chairman), 1967, Basement Map of North America, American Association of Petroleum Geologists and U.S. Geological Survey, Scale 1:5,000,000.

2035 069

Fletcher, J.B. and L.R. Sykes, 1977, "Earthquake Related to Hydraulic Mining and Natural Seismic Activity in Western New York State." Journal of Geophysical Research, Vol. 82, No. 26, p 2767-3780.

Flint, R.F., 1957, Glacial and Pleistocene Geology, John Wiley & Sons, Inc., NY, 535 p.

Flint, R.F., R.B. Colton, R.P. Goldthwait, and H.B. Willman, 1959, Glacial Map of the United States East of the Rocky Mountains, Geological Society of America.

Fluhr, T.W., 1962, "New York Bay - Bedrock Profile," Geological Society of America Bulletin, Vol. 73, p 261-262.

Foose, M.P., 1975, "The Structure and Stratigraphy of the Bigelow Area, Northwest Adirondacks, New York," Geological Society of America Abstracts ith program, Vol. 7, No. 1, p 60.

Foose, M.P., 1976, "A Structural and Stratigraphic Synthesis of Part of the Northwest Adirondacks, New York," Geological Society of America Abstracts, Vol. 8, No. 2, p 176.

Foose, M.P. and C.E. Brown, 1959, "A Preliminary Synthesis of Structural, Stratigraphic and Magnetic Data From Part of the Northwest Adirondacks, New York," United States Geological Survey Open File Report 76-281, 24 p, and Maps.

Forster, S., 1971, "Pleistocene Geology of the Carthage 15 Minute Quad, N.Y. State," Ph.D. Thesis, Syracuse University.

Foster, B.P. and P.H. Reitan, 1972, "Kiberlite Dike Emplacement in the Central Finger Lakes Region, New York," Geological Society of America Abstracts, Vol. 4, No. 1. p 17.

Fox, F.L. and C.T. Spiker, 1977, "Intensity Rating of the Attica (New York) Earthquake of August 12, 1929 - A Proposed Earthquake Reclassification," Earthquake Notes, Vol. 48, Nos. 1-2, p 37-46.

Fridley, H.M. 1929. "General Geology of the Gaines Quadrangle (Pa)" U.S. Geological Survey Folio 93.

Frieco, M., 1977, "Till Fabric Analyses in the Interpretation of Drumlin Origins," Unpublished, Master of Science Thesis, Department of Geology, Syracuse University.

French, C.A., 1931, "Magnetic Surveys of the Hull-Gloucester and Hazeldean Faults," Geological Survey of Canada, Memoir No. 165, p 210-227.

Frohlich, R.K., et al, 1975, "Ground Magnetic Anomalies Over the Narragansett Pier Granite, Rhode Island." Geological Society of America Abstracts with program, Northeastern Section, Vol. 7, No. 1, p 61.

Gableman, J.W., 1973, "Possible Translated Segments in the Appalachians," Geological Society of America Abstracts, Vol. 5, No. 2 p 162-163.

Gadd, N.R., 1960, "Surficial Geology of Becancour Map-Area, Quebec," Geological Survey of Canada Department of Mines and Technical Surveys, Paper 59-8, 34 p, incomplete.

Gadd, N.R., 1964, "Moraines in the Appalachians Region of Quebec," Geological Society of America Bulletin, Vol. 75, p 1249-1254.

Gadd, N.R., 1971, "Pleistocene Geology of the Central St. Lawrence Lowland," Geological Survey of Canada Department of Energy, Mines, and Resources Memoir 359, Ottawa, Canada.

Gadd, N.R., B.C. McDonald, and W.W. Shilts, 1972, "Deglaciation of Southern Quebec," Geologic Survey of Canada, Department of Energy, Mines and Resources Paper 71-47, 19 p.

Gamache Exploration and Mining Co., Ltd., 1955, "Reports on a Geological Survey of Part of Anticosti Island," P.Q. Summer, Report GM-27783.

Gates, T. and J. Combs, 1970, "Geophysical Investigation in the Northern Adirondacks," New York Geologic Association Guidebook 42nd Annual Meeting, Healslip, W.G. (ed.).

Geological Survey of Canada, "Aeromagnetic Maps of Southern Ontario," 54 maps along Canadian Border.

Geological Survey of Canada, 1969, "Principal Mineral Areas of Canada," Geological Survey of Canada, Mineral Resources Branch Map 400A, 1' =120 miles.

Geological Survey of Canada Geophysical Series (Aeromagnetic) Scale 1' = 1 mi.

Geological Survey of Canada, Geophysical Four Mile Sheets - Aeromagnetic. Southern Ontario - Quebec Area, Scale 1" = 4 miles.

Geological Survey of Canada, "Great Lakes-Ottawa River," Aeromagnetic Compilation Map, p 800.

Geological Survey of Canada, 1977, "Magnetic Anomaly Map of Canada," 1:500,000 Geological Survey of Canada Map 1255A, 3rd ed.

Geometrics - Site 4-3-11, 1874, "Aeromagnetic Map of Westernmost New York State," Scale 1:250,000.

Geotechnical Engineers Inc., 1976, "Confirmation Study of Site 4-3-11, New York State Electric & Gas Corp. New Site Project," Project No. 76265, December 23, 1976, Document No. 72, Revised February 8, 1977.

Geotechnical Engineers Inc., 1976, "Report on Site 4-3-11 (Drill Notes)."

Geraghty, E.P., D. De Waard, and B. Turner, 1975, "Preliminary Correlation of Stratigraphy Between the Eastern and Central-Adirondack Highlands Portion of the Grenville Province," Geological Society of America Abstract, Vol. 7, No. 1, p 63-64.

Gibb, R.A., et al, 1969, "A Preliminary Analysis of the Gravity Anomaly Field in the Timmins-Senneterre Mining Area," Gravity Map Series No. 58 of the Dominion Observatory 25 p 1 plate.

Gilman, R. A., March 1967, "Core-In-Core Concretions from Western New York," Journal of Sedimentary Petrology, Vol. 39, No. 1, p 87-95.

Goddard, E.N., Chairman, et al, 1965, Geologic Map of North America, North American Geologic Map Committee, U.S. Geological Survey.

Goldthwait, R.P., G.W. White, and J.L. Forsyth (1967) Glacial Map of Ohio, U.S. Geological Survey Miscellaneous Geologic Investigations Map I-316.

Gray, C., et al, 1969, Geologic Map of Pennsylvania, Pennsylvania Geological Survey, Map 1, Scale 1:250,000.

Green, D., 1957, Trenton Structure in Ohio, Indiana and Northern Illinois," American Association of Petroleum Geologists Bulletin, Vol. 41, No. 4, p 627-642.

Greenslate, J., November 8, 1974, "Manganese and Biotic Debris Associations in Some Deep-Sea Sediments," Science, Vol. 186.

Greggs, R.G. and I.J. Bond, 1971, "Conodonts from the March and Oxford Formations in the Brockville Area, Ontario," Canadian Journal of Earth Sciences, Vol. 8, p 1453-1471.

Greggs, R.G. and I.J. Bond, 1972, "A Principal Reference Section Proposed for the Nepean Formation of Probable Tremadocian Age Near Ottawa, Ontario," Canadian Journal of Earth Sciences, Vol. 9, p 933-941.

Griscom, A. and R.W. Bromery, 1968, "Geologic Interpretation of Aeromagnetic Data for New England, Studies of Appalachian Geology, Northern and Maritime, Zen, E. (ed.), John Wiley & Sons, Inc., NY. p 425-436.

Griswold, R.E, 1951, "The Ground water Resources of Wayne County, New York," State of New York Department of Conservation Bulletin GW-27, 61 p, 2 maps.

Guidotte, C.V., 1965, "Geology of the Bryant Pond Quadrangle, Maine," Maine Geological Survey Bulletin No. 16.

Gupta, I. and O.W. Nuttli, 1976, "Spatial Attenuation of Intensities for Central U.S. Earthquakes," Seismological Society of America Bulletin, Vol. 66, No. 3, p 743-751.

2035 072

Guzowski, R.V., (Abstract), March 1975, "Structural Evidence for Multiphase Deformation in the Black Lake Region of the Northwest Adirondacks, New York," Geological Society of America Abstracts with program, Vol. 7, No. 1, p 67.

Gwinn, V.E., September 1964, "Thin-Skinned Tectonics in the Plateau and Northwestern Valley and Ridge Provinces of the Central Appalachians," Geological Society of America Bulletin, Vol. 75, p 863-900.

Hadley, J.B. and J.F. Devine, 1974. Seismotectonic Maps of the Eastern U.S. U.S. Geological Survey Map Series, 3 maps, scale 1:50,000,000, Map MF-620, 8 p.

Hager, D, 1949, "Tectonics of North-Central States," American Association of Petroleum Geologists Bulletin, Vol. 33, No. 7, p 1198-1205.

Hagni, R.D., 1968, "Titanium Occurrence and Distribution in the Magnetite Hematite Deposit at Benson Mines, New York," Economic Geology, 63, p 151-155.

Hagner, A. and L.G. Collins, 1967, "Magnetite Ore Formed During Regional Metamorphism, Ausable Magnetite District New York," Economic Geology, p 1034-1071.

Hall, J. 1843, "Geology of New York, Part 4," Comprising the Survey of the Fourth Geological District.

Halley, R.B., 1971, "Cryptagal Limestones of the Hoyt (Upper Cambrian) and Whitehall (Upper Cambrian to Lower Ordovician) Formations of New York State," Geological Society of America Abstracts, Vol. 3, No. 1, p 35.

Hansen, E., et al., September 1961, "Decollement Structures in Glacial-Lake Sediments," Geological Society of America Bulletin, Vol. 72, p 1415-1418.

Hardin, B. O. and W.L. Black, March 1969, "Vibration Modulus of Normally Consolidated Clay," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 94, No. SM2.

Hardin, B.O., and V.P. Drnevich, July 1972, "Shear Modulus and Damping Soils: Design Equations and Curves," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 95, No. SM7.

Hardin, B.O. and V.P. Drnevich, June 1972, "Shear Modulus and Damping in Soils: Measurement and Parameter Effects," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 95, No. SM6.

Harding, W.D., 1931, "The Relations of the Grenville Sediments and the Potsdam Sandstone in Eastern Ontario," America Mineralogist, No. 16, p 430-436.

Harper, C.T., 1968, "Isotopic Ages From the Appalachians and Their Tectonic Significance," Canadian Journal of Earth Sciences, Vol. 5, p 49-59.

2035 073

Harper, J.D., 1969, "Development of Near-Shore and Coastal Carbonate Environments, Late Silurian-Early Devonian, New York State," Geological Society of America Annual Meeting, Abstracts with program.

Harrison, W.P. and E.T. Misiaszek, 1971, "Some Aspects of Engineering Geology in the St. Lawrence Valley and Northwest Adirondack Lowlands," Van Diver B., ed., New York State Geologic Association Guidebook 43rd Annual Meeting, p C1-C43.

Hartnagel, C.A., 1907, "Geologic Maps of the Rochester and Ontario Beach Quadrangles," New York State Museum Bulletin, No. 114, p 35, 1 map.

Hatheway, R.B., 1971, "Evidence for Major Faulting in South Central Maine," Geological Society of America Bulletin, Vol. 82, p 253-258.

Hawkes, H.E., et al., 1946, "Aeromagnetic Map Showing Total Intensity 1,000 Feet Above the Surface of Part of the Oswegatche Quadrangle," U.S. Geological Survey, Geophysical Investigations Map No. 1

Haworth, R.T., 1977, "Interpretation of Geophysical Data in the Northern Gulf of St. Lawrence and Relevance to Lower Paleozoic Geology," Geological Survey of Canada Manuscript.

Heath, R.C. and E.H. Salvas, 1961, "Some Geochemical Aspects of Groundwater in Northern St. Lawrence County, New York," Short Papers in the Geologic and Hydrologic Science, No. 251, p C283-C286.

Heath, R.C., 1964, "Groundwater in New York," State of New York Water Resources Commission Bulletin, GW-51.

Heck, N.H. and R.A. Eppley, 1958, "Earthquake History of the United States," United States Department of Commerce, Coast and Geodetic Survey, Washington.

Heckel, P.H., 1966, "Stratigraphy, Petrography and Depositional Environment of the Tully Limestone (Devonian) in New York State and Adjacent Region," Dissertation Abstracts, Vol. 27, No. 4, p 1185B-1186B.

Henderson, E.P., 1972, "Surficial Geology of Kingston (31C N1/2) Map Area, Ontario:" Geological Survey of Canada Paper 72-48, 6 p.

Hendron, A.J., 1963 "The Behavior of Sand in One-Dimensional Compression," Ph.D. Thesis, Department of Civil Engineering, University of Illinois, Urbana.

Hendron, A.J., E.J. Cording, and A.K. Aiyer, 1971, "Analytical and Graphical Methods for the Analysis of Slopes in Rock Masses," NCG Technical Report No. 36, U.S. Army Corps of Engineers, Vicksburg, Miss.

Herrmann, R.B., 1978 "A Seismological Study of Two Attica, New York Earthquakes," Seismological Society of America Bulletin, Vol. 68, No. 3, p 641.

2035 074

Hewitt, D.F., 1956, "The Grenville Region of Ontario," The Grenville Problem, J.E. Thompson, (ed.), Royal Society of Canada Special Publications, p 22-41.

Hewitt, D.F., 1957, "The Grenville Province," Royal Society of Canada Special Publication, No. 2, p 132-140.

Hewitt, D.F., 1972, "Paleozoic Geology of Southern Ontario," Ontario Division of Mines Geologic Report 105, 18 p.

Heyl, A.V., 1972, "The 38th Parallel Lineament and its Relationship to Ore Deposits," Economic Geology, Vol. 67, p 879-894.

Higgins, M.W., 1973, "Superimposition of Folding in the Northeastern Maryland Piedmont and its Bearing on the History and Tectonics of the Central Appalachians," American Journal of Science, Vol. 273-A, p 150-195.

Hobbs, W.H., 1905, "Examples of Joint Controlled Drainage From Wisconsin and New York," Journal of Geology, Vol. 13, p 363-374.

Hodgson, E.A., 1936, "Preliminary Report of the Earthquake of November 1, 1935," Earthquake Notes, Vol. 7, No. 4, p 104.

Hodgson, E.A., 1936, "The Timiskaming Earthquake of November 1, 1935," Journal of the Royal Astronomical Society of Canada, Vol. 30, No. 4, p 113-123.

Hodgson, E.A., 1937, "Timiskaming Earthquake - Data and Time-Distance Curves for Dilatational Waves," American Geophysical Union Transactions, Vol. 18, p 116-118.

Hodgson, E. A., 1950, "The Saint Lawrence Earthquake, March 1, 1925," Publication of the Dominion Observatory, Ottawa, Vol. 7, No. 10.

Hodgson, J.J., 1956, "Les Tremblements de Terre Au Canada," Publications of the Earth Physics Branch, Reprint From: Le Jeune Scientifique, Vol. 4, p 108-118.

Hodgson, J.S. (ed.), 1970, "Symposium on Recent Crustal Movements," Canadian Journal of Earth Sciences, Vol. 7, p 553-734.

Holmes, C.D, 1952, "Drift Dispersion in West-Central New York," Geological Society of America Bulletin, Vol. 63, p 993-1010.

Honkura, Y., E.R. Niblett, and R.D. Kurtz, 1976, "Changes in Magnetic and Telluric Fields in a Seismically Active Region of Eastern Canada, Preliminary Results of Earthquake Prediction Studies," Tectonophysics, Vol. 34, p 219-230.

Hood, P.J., 1977, "Magnetic Anomaly Maps of the Atlantic Provinces," Three maps at 1:1,000,000, Sepias, Geological Survey of Canada Open File 496.

2035 075

Horner, R.B., A.E. Stevens, H.S. Hasegawa, and G. Leblanc, 1978, "Focal Parameters of the 12 July, 1975, Maniwaki, Quebec, Earthquake - An Example of Intraplate Seismicity in Eastern Canada," Seismological Society of America Bulletin, in press.

Horowitz, D. H., 1966, "Evidence for Deltaic Origin of an Upper Ordovician Sequence in the Central Appalachians," Deltas in Their Geologic Framework, Houston Geological Society, p 159-169.

Hosain, I., 1965, "Gravity Survey in the St. Lawrence Lowlands," Thesis for Masters of Science at McGill University, 60 p, and map.

Houde, M. and T.H. Clar, 1962, "Geologic Map of St. Lawrence Lowlands," Department of Natural Resources, Province of Quebec, No. 1407.

Hough, B.K., 1969, Basic Soils Engineering. Ronald Press Co.

Hubert, C., J. LaJoie, and M.A. Leonard, 1970, Deep Sea Sediments in the Lower Paleozoic Quebec Supergroup," Flysch Sedimentology in North America, Geologic Association of Canada Special Paper No. 7, La Joie, ed., p 103-126.

Hudson, G. H., 1931, "Dike Invasions of the Champlain Valley, New York," New York State Museum Bulletin, Vol. 286, p 81-117.

Husch, J., 1975, "Anorthositic Rocks in the Southern Adirondacks: Basement or Non-Basement," Geological Society of America Abstracts with program, Vol 7, No. 1, p 78.

Hussey, A. M. II, 1971, "Geologic Map of the Portland Quadrangle, Maine," Maine Geological Survey Map GM-1, 19 p, and 1 map.

Hussey, A. M. II, 1971, "Geologic Map and Cross Sections of the Orrs Island 7 1/2' Quadrangle and Adjacent Area, Maine," Maine Geological Survey Map GM-2, 18 p, and 1 map.

Hussey, A. M. II, 1972, "Generalized Geologic Map of Maine," Maine Geological Survey.

Hussey, A.M. II and K.A. Pankiwskyj, 1976, "Preliminary Geologic Map of Southwestern Maine," Maine Geological Survey Open File Map, 1976-1.

Hvorslev, M.J., 1951, "Time Lag and Soil Permeability in Ground water Observations," Bulletin No. 36, Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss.

Ichihara, M. and H. Matsuzawa, December, 1973, "Earth Pressure During Earthquake," Japanese Society of Soil Mechanics and Foundations, Vol. 13, No. 4.

2035 076

Isachsen, Y.W., 1964, "Extent and Configuration of the Precambrian in Northeastern United States," Transactions of New York Academy of Sciences Series II, Vol. 26, p 812-829.

Isachsen, Y.W. and D.W. Fisher, 1970, "Geologic Map of New York: Adirondack Sheet," New York Geological Survey, State Museum and Science Service, Map and Chart Series No. 15, Albany, NY.

Isachsen, Y.W., 1973, "Geological Features and Spectral Anomalies in Satellite Imagery of the Adirondack Mountain Region," Geological Society of America Abstracts, Vol. 5, No. 2, p 180-181.

Isachsen, Y.W., 1974, "Utilization of ERTS-1 Imagery in a Tectonic Sequency Synthesis of New York State," Geological Society of America Abstracts, Vol. 5, No. 1, p 40.

Isachsen, Y.W., 1975, "Possible Evidence for Contemporary Doming in the Adirondack Mountains, New York and Suggested Implications for Regional Tectonics and Seismicity," Tectonophysics, Vol. 29, p 169-181. Also, Geological Survey of America Abstracts with program, Vol. 7, No. 7

Isachsen, Y.W., 1975, "Contemporary Vertical Movements Associated with the Adirondack Mountains Dome, an Anomalous Uplift on the North American Craton," Geological Society of America Annual Meetings, Abstracts with program, p 1127-1128.

Isachen, Y.W., March 1975, "Anorthosite Contact Relationships in the Adirondacks and Their Implications for Geological History," Geological Society of America Abstracts with program, Vol. 7, No. 1, p 78.

Isachsen, Y.W., 1975, "Contemporary Vertical Movements Associated with the Adirondack Mountains Dome, An Anomalous Uplift on the North American Craton," Geological Survey, New York State Museum and Science Service, Albany, NY.

Isachsen, Y.W., 1976, "Contemporary Doming of the Adirondack Mountains, New York," American Geophysical Union Transactions, Vol. 57, No. 4, p 325.

Isachsen, Y.W., and W.G. McKendree, 1976, "Preliminary Brittle Structure Map of New York State," New York Geological Survey Map and Chart Series No. 31E.

Isphording, W. C., September 1970, "Petrology, Stratigraphy, and Re-Definition of the Kirkwood Formation (Miocene) of New Jersey," Journal of Sedimentary Petrology, Vol. 40, No. 3, p 986-997.

Jacob, C.E., 1944, "Notes on Determining Permeability by Pumping Tests Under Water Table Conditions," U.S. Geological Survey Mimeographed Report in Walton (3).

Jacoby, C.H., 1968, "Structural Aspects of Salina Salt Series in the Eastern Appalachian Basin," Geology of Saline Deposits, Procedings Hanover Symposium 1968, UNESCO 1972, No. 7, p 205.

Jaffe, H.W. and E.B. Jaffe, 1967, "Structure and Petrology of the Precambrian Allochthon and Paleozoic Sediments of the Monroe Area, New York," in Waines, R.H. (ed.), Guidebook to Field Trips, New York State Geological Association, 39th Annual Meeting, SUNY College at New Paltz, NY, p F1-F17.

Jaky, J., 1944, "The Coefficient of Earth Pressure at Rest," Journal of the Society of Hungarian Architects and Engineers, p 355-358.

Jumikis, A.R., 1971, "Foundation Engineering," Intext Educational Publishers, Penn, p 39.

Kaiser, R.F., 1962, "Composition and Origin of Glacial Till, Mexico and Kasoag Quadrangles of New York," Journal of Sedimentary Petrology, Vol. 32, p 502-513.

Kaiser, R.F., 1978, "The Composition and Origin of Glacial Till in the Mexico and Kasoag Quadrangles of New York." Unpublished Master of Science Thesis, Department of Geology, Syracuse University.

Kane, M.F. and R.W. Bromery, 1966, Simple Bouguer Gravity Map of Maine 1:500,000 GP-580.

Kane, M.F., D.S. Harwood, and N.L. Hatch, Jr., 1971, "Continuous Profiles Near Ground Level as a Means of Discriminating and Correlating Rock Units," Geological Society of America Bulletin, Vol. 82, No. 9, p 2449-2456.

Kane, M.F., 1972, "Bouguer Gravity and Generalized Geologic Map of New England and Adjoining Areas," 1:1,000,000 GP-839.

Kane, M.F., M.J. Yellin, K.B. Bell, and I. E. Zietz, 1972, "Gravity and Magnetic Evidence of Lithology and Structure in the Gulf of Maine Region," U.S. Geological Survey Professional Paper 726-B, 22 p, and 2 plates.

Kane, M.F., G. Simmons, W. Diment, Fitzpatrick, Joyne, and R.W. Bromery, 1972, "Bouguer Gravity and Generalized Geologic Map of New England and Adjoining Areas," U.S. Geological Survey, Map GP-839.

Kane, M.F., 1977, "Correlation of Major Eastern Earthquake Centers with Mafic/Ultramafic Basement Masses," United States Geological Survey Open File Report, p 77-134.

Kantrowitz, I.H., 1970, "Ground water Resources in the Eastern Oswego River Basin, N.Y." State of New York Conservation Department Water Resources Commission Basin Planning Report ORB-2.

Karcz, I.A., J. Morreale, and F. Porebski, 1975, "Vertical Crustal Movements in New York and Pennsylvania-Neotectonics or Benchmark-Instability," Geological Society of America Abstracts, Vol. 7, No. 7, p 113-139.

Karrow, P.F., et al., 1961, "The Age of Lake Iroquois and Lake Ontario," Journal of Geology, Vol. 69, p 659-667.

2035 078

Katz, S., 1954, "Seismic Study of Crustal Structure in Pennsylvania and New York," Seismological Society of America Bulletin, Vol. 45, No. 4, p 303-325.

Kay, M.G., April 1, 1942, "Ottawa-Bonnechere Graben and Lake Ontario Homocline," Geological Society of America Bulletin, Vol. 53, p 585-646.

Kay, M.G., November 1, 1942, "Development of the Northern Allegheny Synclinorium and Adjoining Regions," Geological Society of America Bulletin, Vol. 53, p 1601-1658.

Kay, M.G., 1953, "Geology of the Utica Quadrangle," New York State Museum Bulletin No. 347, p 9-117.

Kay, M.G., June 21, 1974, "Closing of the Protocadic Ocean and Intraplate Basins," Nature, Vol. 249, p 751-752.

Kay, M.G., 1975, "Ottawa-Bonnechere Graben: Tectonic Significance of an Aulacogen," Geological Society of America Abstract, Vol. 7, No. 1, p 82.

Kearey, P., 1978, "An Interpretation of the Gravity Field of the Morin Anorthosite Complex, Southwest Quebec," Geological Society of America Bulletin, Vol. 89, p 467-475.

Keen, C.E. and M.J. Keen, "The Continental Margins of Eastern Canada and Baffin Bay," Geology of Continental Margins, Burke and Drake, (ed.).

Keith, A., 1932, "Stratigraphy and Structure of Northwestern Vermont," Washington, D.C., Academy Science Journal, Vol. 22, p 357-379, 393-406.

Kemp, J.F., 1888, "A Diorite Dike at Forest of Dean, Orange County, New York," American Journal of Science, 3rd Series, Vol. 135, p 331-332.

Kemp, J.F. and V.F. Marster, 1893, "The Trap Dikes of the Lake Champlain Region," United States Geological Survey Bulletin 107, 62 p.

Kiersch, G.A., 1976, "Regional Geology Confirmation Report, New Site Generation Project Phase I-Investigation: 4-3-11 Site (New Haven)," New York State Electric & Gas, Binghamton, NY, 17 p, Four Figures (additions January 28, 1977).

Kilgour, W.J., 1963, "Lower Clinton (Silurian) Relationships in Western New York and Ontario," Geological Society of America Bulletin, Vol. 74, p 1127-1142.

Kindle, E.M. 1909, "Geologic Structure in Devonian Rocks, in Description of the Watkins Glen - Catatonk District." U.S. Geological Survey Folio 169, p 13-15.

Kindle, E.M. and L.D. Burling, July 23, 1915, "Structural Relations of the Precambrian and Paleozoic Rocks North of the Ottawa and St. Lawrence Valleys," Canadian Museum Bulletin No. 18, p 23.

2035 079

King, L.H., 1972, "Relation of Plate Tectonics to the Geomorphic Evolution of the Canadian Atlantic Provinces," Geological Society of America Bulletin, Vol. 83, p 3083-3090.

King, P.B., 1965, "Tectonics of Quaternary Time in Middle North America," The Quaternary of the United States, Princeton University Press Princeton, NJ, p 831-870.

King, P.B., 1969, "Tectonic Map of North America," U.S. Geological Survey, Scale 1:5,000,000.

King, P.B., 1969, "The Tectonics of North America. A Discussion to Accompany the Tectonic Map of North America," U.S. Geological Survey Professional Paper 628.

King, P.B., 1970, "Tectonic Map of the Central and Southern Appalachians," Studies of Appalachian Geology: Central and Southern, John Wiley & Sons, Inc., NY.

King, P.B., 1976, "Precambrian Geology of the United States: An Explanatory Text to Accompany the Geologic Map of the United States," U.S. Geological Survey Professional Paper 902.

King, P.B., 1977, "The Evolution of North America," Revised Edition, Princeton University Press, Princeton, NJ, 197 p.

King, P.B. and H.M. Beckman, 1978, "The Cenozoic Rocks: A Discussion to Accompany the Geologic Map of the United States," U.S. Geological Survey Professional Paper, No. 904.

King, W.F., 1971, "Studies of Geological Structures with the VLF Method," McGill University, Montreal, Quebec, Unpublished Master of Science Thesis, 270 p.

Kinsland, G. L., 1977, "Formation Temperature of Flourite in the Lockport Dolomite in Upper New York State as Indicated by Fluid Inclusion Studies - With a Discussion of Heat Sources," Economic Geology, p 849-854.

Kirwan, J.L., 1963, "The Age of the Nepean (Potsdam) Sandstone in Eastern Ontario," American Journal of Science, Vol. 261, p 108-110.

Kishida, H., 1969, "Characteristics of Liquified Sands During Mino-Owari, Tohnankai, and Fukui Earthquakes," Soil and Foundation, Vol. 9, No. 1.

Klugman, M.A. and P. Chung, 1976, "Slope Stability Study of the Regional Municipality of Ottawa - Carleton, Ontario, Canada," Ontario Geological Survey Miscellaneous Paper, MP-68, p 13.

Krall, D.B., 1972, "Till Stratigraphy and Olean Ice Retreat in East-Central New York," Dissertation Abstracts International, Vol. 33B, p 1619B.

2035 080

Krall, D.B., 1975, "Glacial Geology of the Appalachian Plateau South of Utica, New York," Geological Society of America Abstract, Vol. 7, No. 1, p 86.

Kranck, E.H. and P.R. Eakins, 1962, "The Laurenthian Area North of Montreal," NEIGC Guidebook 45th Annual Meeting, McGill University, Montreal, Quebec, p 25-33.

Kreidler, W.L., A.M. Van Tyne, and K.M. Jorgensen, 1972, "Deep Wells in New York State," New York State Museum and Science Service, Bulletin 418A, 335 p.

Krogh, T.E. and G.L. Davis, (Abstract), 1970, "Two Periods of Metamorphism and Deformation 1700, and 100, M.Y. Ago in the Grenville Province, Ontario," Transactions of American Geophysical Union (EOS), Vol. 51, p 434.

Kroll, R., October 1976, "Barndoor Diabase Intrusions, North-Central Connecticut," Geological Survey of America Bulletin, Vol. 87, p 1449-1454.

Krumin, P.O., W.H. Smith, R.A. Brant, and F. Amos, 1952, "The Meigs Creek No. 9 Coal Bed in Ohio," Report of Investigations, No. 17, Ohio Division of Geological Survey.

Kulhawy, F.H. and A. Ninyo, 1977, "Earthquakes and Earthquake Zoning in New York State," Association of Engineering Geology Bulletin, Vol. No. 2, p 69-87.

Kumarapeli, P.S., 1974, "The St. Lawrence Rift System, Some Related Ore Deposits of the Carbonatite Association and Models of Appalachian Evolution," Geologic Association of Canada-Mineralogical Association of Canada Annual Meeting, Abstracts for program.

Kumarapeli, P.S. and V.A. Saull, 1966, "The St. Lawrence Valley System: A North American Equivalent of the East African Rift Valley System," Canadian Journal of Earth Sciences, Vol. 3, No. 5 p 639-658.

Kumarapeli, P.S. and B. Sharma, 1969, "A Gravity Profile Across the Shield Margin in the Vicinity of St. Jerome, Quebec," Canadian Journal of Earth Sciences, Vol. 6, p 1301-1306.

Kummel, B, 1970, The History of the Earth, 2nd Edition, W.H. Freeman and Co., San Francisco, Calif.

Kuo, J.T., M. Ottaviani, and S. K. Singh, 1969, "Variations of Vertical Gravity Gradient in New York City and Alpine, New Jersey," Geophysics, Vol. 34, No. 2, p 235-248.

LaFleur, R.G., 1975, "Sequence of Events in Eastern Mohawk Lowland Prior to Waning of Lake Albany," Geological Society of America Abstracts, Vol. 7, No. 1, p 875.

LaFleur, R.G., 1976, Glacial Lake Albany in Pine Bush-Albany's Last Frontier, Lane Press, Albany, NY, Chapter I, p 1-10.

Lahr, J.C., L.R. Sykes, P.B. Fletcher, and Cormier, 1971, "Seismicity and Recent Tectonic Activity in New York," American Geophysical Union Transactions (EOS), Vol. 52, No. 4, p 277.

Lambe, T.W., and R.V. Whitman, 1969 "Soil Mechanics," John Wiley & Sons, Inc., NY, p 105-166.

Lamborn, R.E., C.R. Austin, and D. Schaaf, 1938, "Shales and Surface Clays of Ohio, Fourth Series," Bulletin 39, Geological Survey of Ohio.

Lamont-Doherty Geological Observatory, October 19, 1977, "Symposium on the Geological Development of the New York Bight."

Laporte, L.F., 1969, "Paleozoic Carbonate Facies of Central Appalachian Shelf," American Association of Petroleum Geologists, Vol. 53, No. 3, p 728.

Laporte, L.F., 1969, "Recognition of a Transgressive Carbonate Sequence Within an Epeiric Sea: Helderberg Group (Lower Devonian) of New York State," Society of Economic Paleontologists and Mineralogists Special Publication 14, p 98-119.

Larrabie, D.M., 1971, Map Showing Distribution of Ultramafic and Intrusive Mafic Rocks from New York to Maine, U.S. Geological Survey Map I-676, 2 sheets, Scale 1:500,000.

Leake, B.E., 1963, "Origin of Amphibolites from Northwest Adirondacks, New York," Geological Society of America Bulletin, Vol. 74, p 1193-1202.

Learman, A. and R.R. Weiler, 1970, "Diffusion and Accumulation of Chloride and Sodium in Lake Ontario Sediment," Earth and Planetary Science Letter, Vol. 10, p 150-156.

Leblanc, G., A.E. Stevens, and R.J. Wetmiller, et al., 1973, "A Microearthquake Survey of the St. Lawrence Valley Near LaMalbaie, Quebec," Canadian Journal of Earth Sciences, Vol. 10, p 42-53.

Leblanc, G. and G. Buchbinder, 1977, "Second Microearthquake Survey of the St. Lawrence Valley Near LaMalbaie, Quebec," Canadian Journal of Earth Sciences, Vol. 14, No. 12, p 2778-2789.

Lee, K.L. and A. Albaisa, April, 1974, "Earthquake Induced Settlements in Saturated Sands," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 100, No. GT4.

Lee, P.H. and C.G. Winder, 1967, "Fabric of a Middle Ordovician Limestone at Colborne, Ontario," Canadian Journal of Earth Sciences, Vol. 4, p 529-540.

Lee, K.L. and J.A. Fitton, 1969, "Factors Affecting the Cyclic Loading Strength of Soil," Vibration Effects of Earthquakes on Soils and Foundations, American Society for Testing and Materials, ASTM STP 450.

Leitzke, P.A., (Abstract 1974, "Discontinuity in Fold Structures Between the Adirondack Highlands and Lowlands," Geological Society of America Abstracts, Vol. 5, No. 1, p 47.

Leonard, B.F. and A.F. Buddington, 1964, "Ore Deposits of the St. Lawrence County Magnetite District, Northwest Adirondacks, New York," U.S. Geological Survey Professional Paper 377, 259 p, and 21 plates.

Lewis, J.R., (Abstract), 1970, "Structure and Stratigraphy of the Rossie Complex, Northwest Adirondacks, New York," Dissertation Abstracts, Vol. 30, No. 12, p 55-56B.

Lewis, J.V. and H.B. Kummel, 1910-1912, "Geologic Map of New Jersey," State of New Jersey Department of Conservation and Economic Development, Scale 1:250,000, revised 1950.

Liberty, B.A., 1960, "Belleville and Wellington, Map Areas Ontario," Geological Survey of Canada, Department of Mines and Technical Surveys, Paper 60-31.

Liberty, B.A., 1960, "Rice Lake, Port Hope and Trenton Map Areas," Geological Survey of Canada, Department of Mines and Technical Surveys, Paper 60-14.

Liberty, B.A., 1963, "Geology of Tweed, Kaladar, and Bannockburn Map Areas," Geologic Survey of Canada, Department of Mines and Technology Paper 63-14.

Liebling, R.S., May 1973, "Clay Minerals of the Weathered Bedrock Underlying Coastal New York," Geological Society of America Bulletin, Vol. 84, No. 5, p 1812.

Lilley, W.D. and S. Smith, 1977, "The History and Production of the Pulaski Gas Field," New York Department of Public Service, 13 p.

Long, L.E. and J.L. Kulp, 1962, "Isotopic Age Study of the Metamorphic History of the Manhattan and Reading Prongs," Geological Society of America Bulletin, Vol. 73, p 969-996.

Longwell, C.R., 1943, "Geologic Interpretation of Gravity Anomalies in the Southern New England-Hudson Valley Region," Geological Society of America Bulletin, Vol. 54, p 555-590.

Lowe, K.E., 1950, "Storm King Granite at Bear Mountain New York," Geological Society of America Bulletin, Vol. 61, p 137-190.

Lowman, S.W., 1961, "Some Aspects of Turbidite Sedimentation in the Vicinity of Troy, New York," New York State Geologic Association Guidebook 33rd Annual Meeting, p 31-B15.

Lowman, S.W., 1962, "Various Types of Breccias, Upper Ordovician to Lower Cambrian, Near Troy, New York," and "Sedimentary Environment of the Deepkill 'Blackshale' (Beekmantown) at the Type Locality, Grant Hollow, New York,"

Geological Society of America Bulletin Abstracts Special Paper, 68, p 220-221.

Lucier, W.A., (Abstract), 1966, "The Petrology of the Middle and Upper Devonian Kiskatom and Kaaterskill Sandstones, a Vertical Profile," Dissertation Abstracts International, Vol. 27B, No. 5, p 1515.

Lumsden, D.N. and B.R. Pelletier, 1969, "Geology of the Grimsby Sandstone (Lower Silurian) of Ontario and New York," Journal of Sedimentary Petrology, Vol. 39, No. 2, p 521-530.

MacClintock, P. and D.P. Stewart, 1965, "Pleistocene Geology of the St. Lawrence Lowlands," New York State Museum and Science Service Bulletin No. 394, p 148.

MacIntyre, R.M., D. York, and W.W. Moorehouse, 1967, "K-AN Age Determinations in the Madoc-Bancroft Area in the Grenville Province of the Canadian Shield," Canadian Journal of Earch Sciences, Vol. 4, p 815-828.

MacNish, R.D., et al., 1960, "Bibliography of the Groundwater Resources of New York through 1967," State of New York Conservation Department Water Resources Commission Bulletin 65, 186 p.

Manheim, F.T. and R.E. Hall, 1976, "Deep Evaporitic Strata Off New York and New Jersey - Evidence from Interstitial Water Chemistry of Drill Holes," Journal of Research of the U.S. Geological Survey, Vol. 4, No. 6, p 697-702.

Manspeizer, W., 1969, "The Catskill Delta Complex: Distributaries in the Bradford Subdelta," Geological Society of America Abstracts, No. 1, p 39.

Marcuson, W.F. and W.A. Bieganousky, October, 1976, "Laboratory Standard Penetration Tests on Fine Sands," Symposium on Soil Liquefaction, American Society of Civil Engineers National Convention, Philadelphia.

Martens, J.H.C., 1924, "Igneous Rocks of Ithaca, New York and Vicinity," Geological Society of America Bulletin, Vol. 35, p 305-320.

Martin, G.R., W.D.L. Finn, and H.B. Seed, May, 1975, "Fundamentals of Liquefaction Under Cyclic Loading," Journal of the Geotechnical Engineering Division. American Society of Civil Engineers, Vol. 101, No. GT5.

Martini, I.P., June 1971, "Grain Orientation and Paleocurrent Systems in the Thorold and Grimsby Sandstones (Silurian), Ontario and New York," Journal of Sedimentary Petrology, Vol. 41, No. 2, p 425-434.

Martini, I.P., 1971, "Regional Analysis of Sedimentology of Medina Formation (Silurian), Ontario and New York," American Association of Petroleum Geologists Bulletin, Vol. 55, No. 8, p 1249-1261.

2035 084

Mather, K.F. and H. Godfrey, assisted by K. Hampson, 1927, "The Record of Earthquakes Felt by Man in New England," Copy of the manuscript of a paper presented to the Eastern Section of the Seismological Society of America.

Matheus, E.B., 1933, Geologic Map of Maryland, Maryland Geological Survey, Scale 1:380,160.

Matson, G.C., 1905, "Peridotite Dikes Near Ithaca, New York," Journal of Geology, p 264-275.

May, R.W. and A. Dreimanis, 1973, "Differentiation of Glacial Tills in Southern Ontario, Canada, Based on their Cu, Zn, Cr. and Ni Geochemistry," Geological Society of America Abstract 136, The Wisconsin Stage, p 221-278.

Mazzullo, S. J., 1973, "Sedimentary Structures and Trace Fossils as Criteria for Distinguishing Peritidal Deposits: Hamilton Grope (Middle Devonian), New York State," Journal of Sedimentary Petrology, Vol. 43, No. 2, p 569-572.

McAlester, A.L., 1963, "Pelecypods as Stratagraphic Guides in the Appalachian Upper Devonian," Geological Society of America Bulletin, Vol. 74, p 1209-1224.

McBride, E.G., March 1962, "Flysch and Associated Beds of the Martinsburg Formation (Ordovician) Central Appalachians," Journal of Sedimentary Petrology, Vol. 32, No. 1, p 39-91.

McCann, T.P., N. Privtasky, F. Stead, and J. Wilson, November 12, 1966, "Possibility for Disposal of Industrial Wastes in Subsurface Rocks on North Flank of Appalachian Basin, New York."

McCave, I.N., January 1969, "Correlation of Marine and Nonmarine Strata with Example from Devonian of New York State," American Association of Petroleum Geologists, Vol. 53/1, p 155-162.

McCave, I.N., 1973, "The Sedimentology of a Transgression: Portland Point and Cooksburg Members (Middle Devonian) New York State," Journal of Sedimentary Petrology, Vol. 43, No. 2, p 484-504.

McConnell, R.B., 1972, "Geological Development of the Rift System of Eastern Africa," Geological Society of America Bulletin, Vol. 83, No. 9, p 2549-2572.

McCormick, G.R., 1961, "Petrology of Precambrian Rocks of Ohio," Report of Investigations, No. 41, Ohio Division of Geological Survey, Columbus, Ohio.

McDonald, B.C. and W.W. Shilts, 1971, "Quaternary Stratigraphy and Events in Southeastern Quebec," Geological Society of America Bulletin, Vol. 82, p 683-698.

McDonald, B.C. and W.W. Shilts, 1973, "Interpretation of Faults in Glaciofluvial Sediments in Glaciofluvial and Glaciolacustrine Sedimentation,"

2035 085

Society of Economic Paleontologists and Mineralogists, Special Publication 23, p 123-131.

McElhinney, M.W., 1973, "A Paleomagnetic Study of the Trenton Limestone (New York State)," American Geophysical Union Transactions (EOS), Vol. 54, No. 4, p 248.

McElhinney, M.W. and N.D. Opdyke, 1973, "Remagnetization Hypothesis Discounted - A Paleomagnetic Study of the Trenton Limestone, New York State," Geological Society of America Bulletin, Vol. 84, p 3697-3708.

McKerrow, W.S. and A.M. Ziegler, 1972, "Paleozoic Oceans," Nature, Physical Sciences, Vol. 240, p 92-94.

McLelland, J., 1969, "Geology of the Southernmost Adirondacks," New England Intercollegiate Guidebook.

McLelland, J., November 1974, "Structure Geology and Stratigraphy of the Southern Adirondacks," Geological Society of America Abstracts with Programs, Vol. 6, No. 7, p 265.

Mencher, E., November 1, 1939, "Catskill Facies of New York State," Bulletin of the Geological Society of America, Vol. 50, p 1761-1794.

Merkel, R.H., 1972, "Earthquake Distribution in the Adirondacks," American Geophysical Union Transactions, Vol. 53, No. 4, p 442.

Mesolella, K.J., 1966, "Collophane Associated with the Unconformity at the Base of the Devonian Onondaga Limestone in New York State," Journal of Sedimentary Petrology, Vol. 36, p 260-262.

Meyer, H.O.A., 1976, "The Kimberlites of the Continental United States: A Review," Journal of Geology, Vol. 84, p 377-407.

Miller, H.J. (Abstract), 1971, "Lake Ontario-Rochester Marine Geophysical Survey," New York Geologic Association Guidebook, 43rd Annual Meeting, Van Diver, ed.

Miller, J.W., 1970, "Drumlins in the Oswego, Weedsport and Auburn, New York Quadrangles," Doctor of Philosophy Dissertation, Department of Geography, Syracuse University, 162 p.

Miller, J.W., (Abstract), 1971, "Drumlins in Oswego, Weedsport, and Auburn, New York Quadrangles," Dissertation Abstracts International, Vol. 32, No. 1, p 370B.

Miller, J.W., 1972, "Variations in New York Drumlins," Annual Association of American Geology, Vol. 62, p 418-423.

Miller, W.J., 1909, "Geology of the Remsen Quadrangle," New York State Museum Bulletin No. 126, Albany, NY.

2035 086

Miller, W.J., December 1, 1916, "Geology of the Blue Mountain, New York Quadrangle," New York State Museum Bulletin No. 192.

Mills, H.C. and P.D. Wells, March 1974, "Ice Shove Deformation and Glacial Stratigraphy of Port Washington, Long Island, New York," Geological Society of America Bulletin, Vol. 85, No. 3.

Milne, W.G. and A.G. Davenport, 1969, "Distribution of Earthquake Risk in Canada," Bulletin of the Seismological Society of America, Vol. 59, No. 2, p 729-754.

Ministry of the Environment, "Overburden and Bedrock Well Yields," Map 5926-1 and 5926-2, Scale 1:500,000.

Mooney, C.N., et al, 1919, "Soil Survey of Oswego County, New York," U.S. Department of Agriculture, 45 p.

Moore, S. July 1948, "Crustal Movement in the Great Lakes Area," Geological Society of America Bulletin, Vol. 59, p 697-710.

Moore, W.S., et al, 1976, "Episodic Growth of Ferromanganese Nodules in Oneida Lake, New York," Geological Society of America Abstracts with program, Vol. 8, No. 6, p 1017-1018.

Morgan, B.A., 1972, Metamorphic Map of the Appalachians, U.S. Geological Survey Map I-724, 10 p, and 1 map, Scale 1:2,500,000.

Morgenstern, M.R. and N. Einstein, 1970 "Methods of Estimating Lateral Loads and Deformations," Specialty Conference on Lateral Stresses in the Ground and Design of Earth-Retaining Structures, American Society of Civil Engineers, New York, NY.

Morner, N.A., 1973, "The Erie Interstate," Geological Society of America Memoir 136, The Wisconsin Stage, p 107-134.

Moss, J.H. and D.F. Ritter, 1962, "New Evidence Regarding the Binghamton Substages in the Region Between the Finger Lakes and Catskills, New York." American Journal of Science, Vol. 260, p 81-106.

2035 087

Mozola, A.J. 1951, "The Ground water Resources of Seneca County, New York." State of New York Department of Conservation, Water Power and Control Commission Bulletin GW-26, 57 p, 3 maps.

Muller, E.H., 1964, "Quaternary Section of Otto, New York," American Journal of Science, Vol. 262, p 461-478.

Muller, E.H., (Abstract), 1972, "Syracuse Channels Revisited," Geological Society of America Abstracts with program, Vol. 4, No. 1, p 35.

Muller, E.H., 1974, "Origin of Drumlins, Glacial Geomorphology," Geomorphology, D.R. Coates (ed.), State University of New York at Binghamton, 398 p.

Murphy, P.J., 1979, "Structure and Stratigraphy - Appalachian Basin," Abstracts with program Geological Society of America, Vol. 11, p 46.

Mutch, T.A., J.W. Head III, and R.S. Saunders, 1967, "Photographic Interpretation of Catskill Front Stratigraphy Southeastern New York State," Journal of Sedimentary Petrology, Vol. 38, No. 1, p 259-269.

Nagy, D. 1977, "Bouguer Anomaly Map of Canada," The Canadian Cartographer, Vol. 14, No. 1, p 59-66.

Nathan M. Newmark Consulting Services, January, 1976, "Statistical Studies of Horizontal and Vertical Earthquake Spectra," NUREG 0003, Report prepared for the NRC.

Neale, E.R., J. Beland, R.R. Potter, and W.H. Poole, 1961, "A Preliminary Tectonic Map of the Canadian Appalachian Region Based on Age of Folding," Transactions of the Canadian Institute of Mining and Metals, Vol. 52, p 231-242.

Nelson, A.E., et al, 1956, "Geologic Map of the Chateaugay Quadrangle, New York," U.S. Geological Survey Map I-168, Scale 1:62,500.

Nelson, A.E., 1968, "Geology of the Ohio Quadrangle, Southwestern Part of Adirondack Mountains, New York," U.S. Geological Survey Bulletin 1251-F, 46 p, map not included.

N.E.I.G.C., 1977, "Appalachian, Platform and Precambrian Geology Near Quebec City, Canada," Field Trip Outline, N.E.I.G.C. Annual Meeting.

New England Power, 1978, Units 1 and 2, Preliminary Safety Analysis Report.

New York Geological Survey and United States Geological Survey, 1974, Aeromagnetic Maps, 15 minute quadrangles of most of the St. Lawrence Lowlands. 35 maps, list on back of card, Scale, 1:62,500, Sepias

2035 088

New York Geological Survey and U.S. Geological Survey, 1975, Aeromagnetic Map of the Ogdensburg, New Jersey Area. 1:250,000 Contour Internal 50,250 gammas, Sepia, Loc. Roll File.

New York Geological Survey and U.S. Geological Survey, 1975, Aeromagnetic Map of Westernmost New York, Covers West of 77 deg 45'. Scale 1:250,000, Contour Internal 0,50,250 gammas, Sepia, Loc Roll File.

New York State Museum and Science Service, 1975, "Geogram," Vol. 11, No. 2, 22 p.

Newmark, N.M., J.A. Blume, and K.K. Kapur, November 1973, "Seismic Design Spectra for Nuclear Power Plants," Journal of the Power Division, American Society of Civil Engineers, Vol. 99, No. PO2.

Newmark, N.M. and W.J. Hall, 1977, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," Nuclear Regulatory Commission, Division of Operating Reactors, Contract No. AT(49-24)-0116.

Nielson, D.L., R.G. Clark, J.B. Lyons, E.J. England, and D.J.. Borns, 1976, "Gravity Models and Mode of Emplacement of the New Hampshire Plutonic Series," Studies in New England Geology, Geological Society of America Memoir 146, P.C. Lyons, and A.H. Brownlow (eds.), p 301-318.

Norling, D.L., 1958, "Geology and Mineral Resources of Morgan County, Ohio," Bulletin 56, Ohio Division of Geological Survey.

Norris, D.K., 1967, "Structural Analysis of the Queensway Folds, Ottawa, Canada," Canadian Journal of Earth Sciences, Vol. 4, p 299-321.

Ohio Division of Geological Survey, Physiographic Sections of Ohio, one 8 1/2 x 11 sheet, Ohio Department of Natural Resources.

Oliver, J., April-May 1969, "Earthquakes in New York State," The Conservationist.

Oliver, W.A., Jr., 1954, "Stratigraphy of the Onondaga Limestone (Devonian) in Central New York," Geological Society of America Bulletin, Vol. 65, p 621-652.

Ontario Department of Mines, Ontario Geological Maps.

Ontario Department of Mines, Geologic Map, Gananoque Area, Ontario.

Ontario Department of Mines, 1946, "Part of Southeast Ontario Showing Distribution of Potsdam Sandstone," Map No. 1946-9.

Ontario Department of Mines, 1961, Geologic Map of District of Algoma, Ontario.

Ontario Department of Mines, 1964, Geologic Map, Madoc Area.

Ontario Department of Mines and Northern Affairs, 1970, Ontario Geologic Map.

Ontario Division of Mines, 1973-1975, Quaternary Geologic Map Series, Scale 1:50,000, Southern Ontario.

Ontario Division of Mines, 1973-1975, Drift Thickness Map Series, Southern Ontario, Scale 1:50,000.

Ontario Division of Mines, 1973-1975, Bedrock Topography Series, Scale 1:50,000.

Ontario Division of Mines, Mineral Potential Maps, 1976, Ontario Geological Survey.

Osberg, P.H., 1968, "Stratigraphy, Structural Geology, and Metamorphism of the Waterville-Vassalboro Area, Maine," Maine Geological Survey Bulletin No. 20.

Osberg, P.H., 1973, Preliminary Lithologic Map of Maine, Maine Geological Survey Open File Map.

Osborne, F.F., August-September 1956, "Geology Near Quebec City," Le Naturaliste Canadien, Vol. 83, Nos. 8-9, p 157-223.

Osborne, F.F., FRSC, 1967, "Appalachian Region of Quebec: Some Aspects of its Divisions and Geology," Appalachian Tectonics, Royal Society of Canada Special Publication 10, p 18-24.

Osborne, F.F. and T.H. Clark, 1960, "New Glasgow-St. Lin Area," Quebec Department of Mines, Geological Report No. 91, 41 p, 2 maps.

Osborne, F.F. and M. Morin, 1962, "Tectonics of Part of the Grenville Subprovince in Quebec," Geology of the Atlantic Region, Royal Society of Canada Special Paper No. 4, p 118-143.

Owens, G.L., 1967, "The Precambrian Surface of Ohio," Report of Investigations No. 64, Ohio Division of Geological Survey.

Owens, G.L., 1970, "The Subsurface Silurian-Devonian 'Big Lime' of Ohio," Report of Investigations No. 75, Ohio Division of Geological Survey.

Paige, S., 1956, "Cambro-Ordovician Age of the 'Inwood Limestone' and 'Manhattan' Schist near Peekskill, New York," Geological Society of America Bulletin, Vol. 67, p 391-394.

Palmer, A.R., (Abstract), 1969, "Stratigraphic Evidence for Magnitude of Movement on the Champlain Thrust," Geological Society of America Abstract No. 1, p 47-48.

Parker, J.M. III, 1942, "Regional Systematic Jointing in Slightly Deformed Sedimentary Rocks," Geological Society of America Bulletin, Vol. 53 p 381-409.

Patchen, D.G., 1966, "Petrology of the Oswego, Queenston, and Grimsby Formations, Oswego County, New York," Master's Thesis, State University of New York at Binghamton.

Patchen, D.G., March 1975, "Depositional Environments of the Oswego Sandstone, Oswego County, New York," Geological Society of America Abstracts with program.

Patchen, D.G., 1977, "Depositional Environments of the Oswego Sandstone (Upper Ordovician), Oswego County, New York," Oil and Gas Section of West Virginia Geological Survey. Vol. 7, No. 1, p 103-104.

Payne, J.G., 1968, "Geology and Geochemistry of the Blue Mountain Nepheline Syenite," Canadian Journal of Earth Sciences, Vol. 5, p 259-273.

Peterson, D.N. and M.P. Wilson, 1972, "Geophysical Investigation of the Ancestral Walnut Creek Valley, Western New York," Geological Society of America Annual Meetings Abstracts for 1972, Vol. 4, No. 1, p 39.

Pettijohn, F.S., P.E. Potter, and R. Siever, 1973, Sand and Sandstone, Springer-Verlag, NY, 618 p.

Pirtle, G.W., 1932, "Michigan Structural Basin and its Relationship to Surrounding Area," American Association of Petroleum Geologists Bulletin, Vol. 16, No. 2, p 145-152.

Pitman, W.C. and M. Talwani, 1972, "Sea-Floor Spreading in the North Atlantic," Geological Society of America Bulletin, Vol. 83, p 619-646.

Platt, L.B., 1962, "Observations on the Taconic Problem," New York Academy of Science Transactions, Series II, Vol. 24, p 621-629.

Pluhowski, E.J., "Hydrologic Interpretation Based on Infrared Imagery of Long Island, New York," U.S. Geological Survey Water Supply Paper 2009-B.

Pohn, H.A., M.H. Podwysocki, and I.S. Merin, 1979, "The Relationship Between Lineaments Stream Valleys, Glaciation, and Joints in South Central New York." Abstracts with program Geological Society of America, Vol. 11, p 49.

Pomeroy, P.W., et al, 1974, "Earthquakes Triggered by Surface Quarrying in the Wappinger Falls, New York," New York State Science Service Journal Series No. 189, Lamont Safety Contribution 0000.

Pomeroy, P.W., 1975, "Preliminary Studies of Seismic Hazard in New York State," Geological Society of America Abstracts with program, Vol. 7, No. 1, p 107-108.

Pomeroy, P.W., W. Simpson, and M.L. Sbar, 1975, "The Wappinger Falls, New York Earthquake of June 7, 1974, and its Aftershocks," Geological Society of America Abstracts, Vol. 7, No. 7, p 1331.

Pomeroy, P.W., and R.H. Fakundiny, 1976, "Seismic Hazard Evaluation in the New York State Based Upon Tectonic History, Structural Geology and Seismology," Geological Society of America Abstracts with Program, Vol. 8, No. 2, p 247-248.

Pomeroy, P.W., et al, 1978, "Clarendon-Linden Fault System of Western New York, A Vibroseis Seismic Study," New York State Geological Survey, New York State Museum Manuscript, 37 p, 30 minutes.

Poole and Rodgers, 1972, "Appalachian Geotectonic Elements of the Atlantic Provinces and Southern Quebec," International Geologic Congress, Montreal 1972 Guidebook 63, 200 p, p 179-191.

Postel, A.W., 1956, "Geologic Map of the Malone Quadrangle, New York,"

U.S. Geological Survey, Miscellaneous Geological Investigation Map No. I-167.

Potter, D.B., 1963, "Stratigraphy and Structure of the Hoosick Falls Area," Geological Society of America Guidebook to Field Trips, p 58-67, (See Bird, J.M.).

Potter, D.B. and E. Potter, 1971, "Seismic Study of Bedrock Topography Beneath Drumlins, Central New York," Geological Society of America Abstracts, Vol. 3, No. 1, p 48-49.

Prest, V.K., 1969, "Retreat of Wisconsin and Recent Ice in North America," Geological Survey of Canada Map 1257A.

Prickett, T.A., 1965, "Type-Curve Solution to Aquifer Tests Under Water Table Conditions," Ground Water, Vol. 3, No. 3.

Prowell, D.C., (Abstract), 1976, "Implications of Cretaceous and Post-Cretaceous Faults in the Eastern United States," Geological Society of America Abstracts, Vo. 8, No. 2, p 249-250.

Prucha, J.J., 1968, "Salt Deformation and Decollement in the Firtree Point Anticline of Central New York," Tectonophysics, Vol. 6, No. 4, p 273-299.

Prucha, J.J. Personal Communication, 1978.

Public Service Company of New Hampshire, Seabrook Preliminary Safety Analysis Report, 1975.

Pyke, R., H.B. Seed, and C.K. Chan, April, 1975. "Settlement of Sands Under Multi-Directional Shaking," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 101, No. GT4.

Quinn, A.W., 1933, "Normal Faults of the Lake Champlain Region," Journal of Geology, Vol. 41, No. 2, p 113-143.

2035 092

Randall, A.D., 1978, "A Contribution to the Late Pleistocene Stratigraphy of the Susquehanna River Valley of New York," Empire State Geogram, Vol. 14, No. 2, p 2-15.

Rankin, D.W., 1975, "The Continental Margin of Eastern North America in the Southern Appalachians: The Opening and Closing of the Proto Atlantic Ocean," American Journal of Science, Vol. 275, p 236-298.

Rankin, D.W., November 10, 1976, "Appalachian Salients and Recesses: Late Precambrian Continental Breakup and the Opening of the Iapetus Ocean," Journal of Geophysical Research, Vol. 81, No. 32.

Ratcliffe, N.M., 1969, "Structural and Stratigraphic Relations Along the Precambrian Front in Southwestern Massachusetts," New England Intercollegiate Geological Conference Guidebook 21 p.

Ratcliffe, N.M., (Abstract), 1976, "Contrasting Styles of Deformation of Precambrian Basement Rocks in Western New England: Implications for Taconian Paleogeography and Tectonism," Geological Society of America Abstracts with program, Vol. 8, No. 2, p 252.

Ratcliffe, N.M., (Abstract), 1976, "Paleozoic Age of 'Triassic' Border Fault at Northern End of Newark Basin in New York State." Geological Society of America Abstracts, Vol. 8, No. 2, p 252-253.

Ratcliffe, N.M. and D.S. Harwood, 1975, "Blastomylonites Associated with Recumbent Folds and Overthrusts at the Western Edge of the Berkshire Massif, Connecticut and Massachusetts," a preliminary report, Tectonic Studies of the Berkshire Massif, Western Massachusetts, Connecticut and Vermont, U.S. Geological Survey, Professional Paper 888-A, p 1-19.

Reed, J.C., 1934, "Geology of the Potsdam Quadrangle," New York State Museum Bulletin, No. 297, 65 p.

Rehnman, S.E., and B.B. Broms, 1972, "Lateral Earth Pressures on Basement Wall, Results from Full-Scale Tests," Procedures 5th European Conference Soil Mechanics and Foundation Engineering, Madrid, Vol. 1, Theme 2, p 189-197.

Reinhardt, E.W. and A.E. Wilson, 1973, "Geology of Carleton Place, Ontario," Geological Survey Map No. 1362A, Scale 1:50,000.

Rensselaer County Health Department, 1961, "Water Resources in Rensselaer County, An Environmental Health Study," Rensselaer County Health Department, Troy, NY, 276 p.

Revetta, F.A., 1970, "A Regional Gravity Survey of New York and Eastern Pennsylvania," Ph.D. Thesis, University of Rochester, Rochester, NY.

Revetta, F.A. and W.H. Diment, 1969, "A Regional Gravity Survey of New York and Eastern Pennsylvania," Geological Society of America, Annual Meetings Abstract for 1969, Vol. 1, No. 7, p 187.

2035 093

Revetta, F.A. and W.H. Diment, 1971, "Simple Bouguer Gravity Anomaly Map of Western New York," New York State Map and Chart Series No. 17, 4 maps.

Revetta, F.A. and W.H. Diment, 1971-1973, "Simple Bouguer Anomaly Maps of New York," Scale 1:250,000, U.T.M. Projection; Western N.Y., Northern N.Y. East-Central N.Y., Southeastern N.Y., New York State Map and Chart Series 17, Loc, Roll File, 4 maps.

Richart, F.E., J.R. Hall, and R.D. Woods, 1970, Vibrations of Soils and Foundations, Prentice-Hall, Inc., Englewood Cliffs, NJ, p 168.

Richter, C.F., 1956, Elementary Seismology, W.H. Freeman and Company, San Francisco, Calif.

Rickard, L.V., 1964, "Correlation Chart of the Devonian Rocks in New York State," New York State Museum and Science Map and Chart Series, No. 4.

Rickard, L.V., 1967, "Stratigraphy of the Upper Silurian Group, New York, Pennslyvania, Ohio, and Others," New York State Museum and Science Service Map and Chart Series No. 12, 57 p, 14 plates.

Rickard, L.V. and D.W. Fisher, 1970, "Geologic Map of New York: Finger Lakes Sheet," New York Geological Survey, State Museum and Science Service, Map and Chart Series No. 15, Albany, NY.

Rickard, L.V., 1973, "Stratigraphy and Structure of the Subsurface Cambrian and Ordovician Carbonates of New York," New York State Museum and Science Service Map and Chart Series No. 18, 26 p.

Rickard, M.J., May 1965, "Taconic Orogeny in the Western Appalachians: Experimental Application of Microtextural Studies to Isotopic Dating," Geological Society of America Bulletin, Vol. 76, p 523-536.

Riva, J., 1969, "Utica and Canajoharie Shales in the Mohawk Valley," NEIGC Guidebook 61st Annual Meeting, Bird, J.M., ed., p 13-1 - 13-7.

Roberson, H.E., and K. Elchenlaub, 1971, "Origin of Coloration in Upper Devonian Catskill Facies, New York," American Association of Petroleum Geologists Bulletin, Vol. 55, No. 12, p 360.

Robinson, P., J.F. Hubert, D.V. Wise, and L.M. Hall, 1978, "The Juratrias of Emerson (1898) on the New Massachusetts Geologic Map," Geological Society of America, Northeastern Section Meeting, Abstracts with program, Vol. 10, No. 2.

Robinson, S.D. and W.K. Fyson, 1976, "Fold Structures, Southern Stake Mountain Area, Eastern Townships, Quebec: Taconic or Acadian?" Canadian Journal of Earth Sciences, Vol. 13, p 66-74.

2035 094

Rocheleau, M. and J. LaJoie, 1974, "Sedimentary Structures in Residemented Conglomerate of the Cambrian Flysch L'Islet, Quebec Appalachians," Journal of Sedimentary Petrology, Vol. 44, No. 3, p 826-836.

Rodgers, J., November 1, 1937, "Stratigraphy and Structure in the Upper Champlain Valley," Geological Society of America Bulletin, Vol. 48, p 1573-1588.

Rodgers, J. 1963, "Mechanics of Appalachian Foreland Folding in Pennsylvania and West Virginia." American Association of Petroleum Geologists.

Rodgers, J., May 1967, "Chronology of Tectonic Movements in the Appalachian Region of Eastern North America," American Journal of Science, Vol. 265, p 408-427.

Rodgers, J. 1967, "Unusual Features of the New York Sector of the Appalachian Mountains," New York State Geologic Association Guidebook 3[illegible] Meeting.

Rodgers, J. 1970, The Tectonics of the Applachians, John Wiley & Sons, Inc., NY, 271 p.

Roe, L.N. II, 1975, "A Three Dimensional View of Portions of the Catskill Delta Complex in New York State," Geological Society of America Abstracts, Vol 7, No. 1, p 112.

Roliff, W.A., 1967, "A Stratigraphic Analysis of the Subsurface Data Relating to the Chazy Group in the St. Lawrence Lowland of Eastern Canada," Canadian Journal of Earth Sciences, Vol. 4, No. 3, p 579-595.

Ross, M.H., 1949, (Abstract) "Source and Correlation of the Deepkill Conglomerates," Geological Society of America Bulletin, p 1973.

Ross, G.A., H.B. Seed, and R.R. Migliaccio, 1969, "Bridge Foundations in Alaska Earthquake," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 95, No. SM4.

Rudman, A.J., C.H. Summerson, and W.J. Hinze, 1965, "Geology of Basement in Midwestern United States," American Association of Petroleum Geologists Bulletin, Vol. 49, p 894-904.

Sabourin, [illegible].J.E., 1965, "Bristol-Masham Area, Pontiac and Gatineau Counties," Quebec Department of Natural Resources, Geological Report No. 110, 44 p, 1 map.

St. Julien, P., 1970, "Geology of Disraeli Area (Eastern Half): Frontenac, Wolfe, and Megantic Counties, Quebec Department of Natural Resources, Mines Branch, Preliminary Report 587, p 20.

St. Julien, P. and C. Hubert, 1975, "Evolution of the Taconian Orogen in the Quebec Appalachians," American Journal of Science, Vol. 275-A, p 337-362.

2035 095

Salomon, N.L., 1976, "Stratigraphy of Glacial Deposits Along the South Shore of Lake Ontario, New York," Unpublished, Master of Science Thesis, Department of Geology, Syracuse University, 78 p.

Sandhu, B.S., December 1974, "Earth Pressure on Walls Due to Surcharge," Civil Engineering, American Society of Civil Engineers.

Sangrey, D.A., 1970, "Evidence of Glacial Readvance Over Soft-Layered Sediments Near Kingston, Ontario," Canadian Journal of Earth Sciences, Vol. 7, p 1331-1339.

Saull, V.A. and D.A. Williams, 1974, "Evidence for Recent Deformation in the Montreal Area," Canadian Journal of Earth Sciences, Vol. 11, No. 12, p 1621-1624.

Saunders, D.F., G.E. Thomas, F.E. Kinsman, and D.F. Beatly, 1973, "ERTS Imagery Use in Reconnaissance Prospecting." Final Report NASA Contract NAS5-21796. Texas Instruments.

Saunders, D.F. and D.E. Hicks, 1976, "Regional Geomorphic Lineaments of Satellite Imagery - Their Origin and Applications," 2nd International Conference on the New Basement Tectonics, Newark, Del.

Sbar, M.L., J. Armbruster, Y.P. Aggarwal, and L.R. Sykes, 1972, "Adirondack Earthquake Swarm of 1971 and Tectonic Stresses in Northeastern United States," Geological Society of America Abstracts, Vol. 4, No. 3, p 231.

Sbar, M.L. and L.R. Sykes, 1973, "Contemporary Compressive Stress and Seismicity in Eastern United States," Geological Society of America Bulletin, Vol. 84, p 1861-1882.

Sbar, M.L., et al., 1975, "In-Situ Stress Measurement Program Field Results," New York Energy Research and Development Authority P.B.-243 538.

Sbar, M.L., et al., 1977, "Study of Earthquake Hazards in New York and Adjacent States," Lamont-Doherty Geological Observatory of Columbia University, Palisades, NJ.

Sbar, M.L. and L.R. Sykes, 1977, "Seismicity and Lithosphere Stress in New York and Adjacent Areas," Journal of Geophysical Research, Vol. 82, No. 36, p 5771-5786.

Schoen, R., 1964, "Clay Minerals of the Silurian Clinton Ironstones New York State," Journal of Sedimentary Petrology, Vol. 34, No. 4, p 855-863.

Schoenberg, M.E., 1975, "Structural Development of the Adirondack Lowlands East of Gouverneur, New York," Geological Society of America Abstracts, Vol. 7, No. 1, p 116.

Schutts, L.D., A. Brecher, P.M. Hurley, C.W. Montgomery, and H.W. Krueger, 1976, "A Case Study of the Time and Nature of Paleomagnetic Resetting in a

Mafic Complex in New England," Canadian Journal of Earth Sciences, Vol. 13, p 898-907.

Scotford, D.M., 1956, "Metamorphism and Aerial-Plane Folding in the Pound Ridge Area, New York," Geological Society of America Bulletin, Vol. 67, p 1155-1198.

Seed, H.B. and I.M. Idriss, 1967, "Analysis of Soil Liquefaction: Niigata Earthquake," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 93, No. SM3.

Seed, H.B. and I.M. Idriss, January 1969, "Influence of Soil Conditions on Ground Motions During Earthquakes," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 94, No. SM1.

Seed, H.B. and I.M. Idriss, December 1970, "Soil Moduli and Damping Factors for Dynamic Response Analyses," Report No. EERC 70-10, University of California, EERC, Berkeley, Calif.

Seed, H.B. and R.V. Whitman, 1970, "Design of Earth Retaining Structures for Dynamic Loads," American Society of Civil Engineers Special Conference, Lateral Stresses in the Ground and the Design of Earth Retaining Structures, p 103-147.

Seed, H.B. and I.M. Idriss, September 1971, "A Simplified Procedure for Evaluating Soil Liquefaction Potential," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 97, No. SM9.

Seed, H.B. and M.L. Silver, April 1972, "Settlement of Dry Sands During Earthquakes," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 98, No. SM4.

Seed, H.B., I. Arango, and C.K. Chan, October 1975, Evaluation of Soil Liquefaction Potential During Earthquakes, EERC, Report No. EERC 75-28, Berkeley, Calif.

Seed, H.B., 1975, "Earthquake Effects on Soil-Foundation Systems," Foundation Engineering Handbook, ed. by Winterkorn and Fang.

Seed, H.B., C. Ugas, and J. Lysmer, February 1976, "Site-Dependent Spectra for Earthquake-Resistant Design," Bulletin of the Seismological Society of America, Vol. 66, No. 1.

Seed, H.B., P.P. Martin, and J. Lysmer, April 1976, "Pore-Water Pressure Changes During Soil Liquefaction," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 102, No. GT4.

Seed, H.B., September 1976, "Evaluation of Soil Liquefaction Effects on Level Ground During Earthquakes," Liquefaction Problems in Geotechnical Engineering, American Society of Civil Engineers National Convention, Philadelphia, Penn, Preprint 2725.

Selleck, B.W., 1975, "Paleoenvironments and Petrography of the Potsdam Sandstone, Thersea Formation and Ogdensburg Dolomite (Upper Cambrian - Lower Ordovician) of the Southwestern St. Lawrence Valley, New York," Ph.D. Thesis, University of Rochester, 196 p.

Senechal, R.G., 1973, "Metamorphic Resetting of Rb-Sr Systems in Dutchess County, New York," American Geophysical Union Transactions (EOS), Vol. 54, No. 4, p 494.

Seyfert, C.K. and L.A. Sirkin, 1973, Earth History and Plate Tectonics, New York. Harper and Row.

Shannon & Wilson, Inc., and Agbabian Jacobsen Associates, 1972, "Soil Behavior Under Earthquake Loading Conditions," report to USAEC.

Shearrow, G.G, 1957, "Geologic Cross Section of the Paleozoic Rocks from Northwestern to Southeastern Ohio," Report of Investigations No. 33, Ohio Division of Geological Survey.

Shell Quebec Limited, 1970, "Report on Exploration Activities on Mineral Exploration License," No. 197 for the 1969/70 License Year, GM-26204

Shen, J., "Characteristics of Seisches on Oneida Lake, New York," U.S. Geological Survey Short Papers in the Geologic and Hydrologic Sciences, Article 36, p B8-B81.

Sherwood, A., 1978, "Report of Progress in Bradford and Tioga Counties, Part I, and Aerial Map," Second Geological Survey of Pennsylvania.

Shilts, W.W., 1973, "Glacial Dispersal of Rocks, Minerals, and Trace Elements in Wisconsinan Till, Southeastern Quebec, Canada," Geological Society of America Memoir 136, The Wisconsin Stage, p 189-219.

Short, N.M., 1974, "Mineral Resources, Geological Structure, and Landform Survey: S.C. Freden, and E.P. Mercanti, eds., Third Earth Resources Technology Satellite Symposium III Discipline Summary Reports, NASA, SP-357 Goddard Space Flight Center, Greenbelt, Md., p 33-51.

Shride, A.F., 1971, "Igneous Rocks of the Seabrook, New Hampshire - Newbury, Massachusetts Area," in NEIGC Guidebook for Field Trips in Central New Hampshire and Contiguous Areas.

Silver, M.L. and H.B. Seed, September 1971, "Volume Changes in Sands During Cyclic Loading," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 97, No. SM9.

Simmons, E.C. and Y.W. Isachsen, (Abstract), 1975, "Petrogenesis of an Anorthosite-Charnokite Suite From the Adirondack Mountains, New York Based on Rare Earth Elements," EOS.

2035 098

Simmons, G., February 1964, "Gravity Survey and Geological Interpretation, Northern, New York," Geological Society of America Bulletin, Vol. 75, p 81-98.

Simpson, D.W., 1974, "Upper Crustal Structure and Active Dilatancy Monitoring at Blue Mountain Lake (BML), New York," American Geophysical Union Transactions (EOS), Vol. 55, No. 4, p 354.

Sissons, J.B., 1960, "Subglacial, Marginal and Other Glacial Drainage in the Syracuse-Oneida Area, New York," Geological Society of America Bulletin, Vol. 71, p 1575-1588.

Skehan, J.W., 1968, "Fracture Tectonics of Southern New England as Illustrated by the Wachusett-Marlborough Tunnel, East-Central Massachusetts," Studies of Appalachian Geology: Northern and Maritime, Zen, E. (ed.), John Wiley and Sons, Inc., NY.

Skehan, J.W., 1969, "Tectonic Framework of Southern New England and Eastern New York," "North Atlantic Geology and Continental Drift," American Association of Petroleum Geologists Memoir No. 12, p 793-814.

Skehan, J.W., 1975, "Puddingstone Drumlins and Ancient Volcanoes," A Geologic Field Guide Along Historic Trails of Boston, Boston College Bicentennial Celebration Publication.

Slater, G., 1929, "The Structure of Drumlins Exposed on the South Shore of Lake Ontario," New York State Museum Bulletin, Vol. 281, p 1-23.

Sloss, L.L., 1963, "Sequences in the Cratonic Interior of North America," Geological Society of America Bulletin, Vol. 74, p 93-114.

Smith, B., 1909, "Dikes in the Hamilton Shale Near Clintonville, Onondaga County, New York," Science, Vol. 30, p 724.

Smith, W.E.T., 1972, "Earthquakes of Eastern Canada and Adjacent Areas, 1534-1927," Publication of the Dominion Observatory, Ottawa, Canada, Vol. 26, No. 5.

Sobczak, L.W., "Gravity Surveys in the Alexandria Area, Eastern Ontario," Publication of the Dominion Observatory, Ottawa, Canada, Vol. 39(G), p 155-173.

Sorauf, J.E., September 1965, "Flow Rolls of Upper Devonian Rocks of South-Central New York State," Journal of Sedimentary Petrology, Vol. 35, No. 3, p 553-563.

Sowers, G.G. and G.T. Sowers, 1970, Introductory Soil Mechanics and Foundations, 3rd Edition, MacMillan, NY, p 556.

Stearn, C.W., 1962, "Geology of Mount Royal," NEIGC Guidebook 45th Annual Meeting, McGill University, Montreal, Quebec, p 35-59.

Stevens, A.E., W.G. Milne, R.J. Wetmiller, and G. Leblanc, 1973, "Canadian Earthquakes - 1976. Seismological Series of the Earth Physics Branch," Seismological Service of Canada, No. 65.

Stevens, A., 1976, Unpublished.

Stickney, W.F., et al, May 1965, "A Detailed Economic Investigation of Geochemical and Aeromagnetic Anomalies, North Central Maine," Maine Geological Survey Special Economic Studies, series No. 4.

Stockwell, C.H., 1967, "A Tectonic Map of the Canadian Shield," Royal Society of Canada Special Paper No. 4, p 6-15.

Stockwell, C.H., 1969, Tectonic Map of Canada, Geological Survey of Canada Map 1251A, Scale, 1:5,000,000.

Stone, D.S., 1957, "Origin and Significance of Breccias Along the Northwest Side of Lake Champlain," Journal of Geology, Vol. 65, p 85-96.

Stone & Webster, 1971, Final Safety Analysis Report, FitzPatrick Nuclear Station, Power Authority of the State of New York, Scriba, NY.

Stone & Webster, 1978, "Report of Fault Investigation at FitzPatrick Nuclear Power Plant," Power Authority of the State of New York, Scriba, NY.

Stout, W., et al, 1932, "Structural Contours on the Trenton Limestone of Western Ohio, on the Clinton Sand of the Central Area and on the Pittsburgh Coal of the Eastern Part of the State," Ohio Geological Survey Structure Map No. 2.

Stout, W. and G.F. Lam, 1938, "Physiographic Features of Southeastern Ohio," Ohio Journal of Science, Vol. 38, No. 2.

Street, J.S., 1971, "Some Pleistocene Features of St. Lawrence County, New York," New York Geologic Association Guidebook 43rd Annual Meeting, Van Diver, p E0-E4.

Street, R.L. and F.T. Turcotte, 1977, "A Study of Northeastern North American Spectral Moments, Magnitudes, and Intensities," Seismological Society of America Bulletin, Vol. 67, No. 3, p 599-614.

Stupavsky, M., D.T.A. Symons, and C.P. Gravenor, 1974, "Paleomagnetism of the Port Standly Till, Ontario," Geological Society of America Bulletin, Vol. 85, p 141-144.

Sulte, B., 1882, "Histoire Des Canadiens-Francais," Wilson 8 cie, (ed.) 88 p.

Sumner, J.R., et al, 1976, "Principal Facts for Gravity Stations in the Newark-Gettysburg Triassic Basin, Pennsylvania and Adjacent States," United States Geological Survey Open File Report No. 76-302.

2035 100

Sutton, R.G., (Abstract), 1969, "Sedimentary Structures and Their Environmental Significance in the Marine Catskill Delta of New York," Geological Society of America Abstracts, No. 1, p 58.

Sutton, R.G., 1970, "Marine Shelf-Environments of the Upper Devonian Sonyea Group of New York," Geological Society of America Bulletin, Vol. 81, p 2978-2992.

Sutton, R.G., T.L. Lewis, and D.L. Woodrow, 1972, "Post-Iroquois Lake Stages and Shoreline Sedimentation in Eastern Ontario Basin," Journal of Geology, Vol. 80, p 346-356.

Sutton, R.G., T.L. Lewis, and D.L. Woodron, 1974, "Sand Dispersal in Eastern and Southern Lake Ontario," Journal of Sedimentary Petrology, No. 44, p 705-715.

Sutton, R.G. and G.R. Ramsayer, December 1975, "Association of Lithologies and Sedimentary Structures in Marine Deltaic Paleoenvironments," Journal of Sedimentary Petrology, Vol. 45, No. 4, p 799-807.

Swinnerton, A.C., 1932, "Structural Geology in the Vicinity of Ticonderoga, New York," Journal of Geology, Vol. 40, p 402-416.

Sykes, L.R., 1971, "Post-Glacial Faulting in Competent Rock in the St. Lawrence Seismic Zone of New York State," Abstracts of Seismological Papers, Earthquake Notes, Vol. 42, No. 3-4, p 15.

Sykes, L.R., 1976, Testimony on Capability of Ramapo Fault Before Atomic Safety Licensing Appeal Board.

Sykes, L.R., et al., 1974, "Seismic Investigations in the St. Lawrence Valley and Adjacent Areas," Lamont-Doherty Geological Observations, Palisades, NJ.

Sykes, L.R., et al., 1975, "Seismicity in New York State, January 1974-1975," Lamont-Doherty Geological Observatory, Columbia University, Palisades, NJ.

Tanner, J.G. and R.A. Bibb, "Gravity Measurements in Canada, January 1, 1967 to December 31, 1970," Publication of the Earth Physics Branch, Canada, Vol. 42, No. 2.

Taylor, M.E. and R.B. Halley, 1974, "Systematics, Environment, and Biogeography of Some Late Cambrian and Early Ordovician Trilobites From Eastern New York State," U.S. Geological Survey Professional Paper, No. 834, 37 p.

Telford, W.M., et al., 1976, "V.L.F. Mapping of Geological Structure," Geological Society of Canada Paper 75-25.

Teng, W.C., 1962, Foundation Design, Prentice-Hall, Englewood Cliffs, NJ, p 88-91.

2035 101

Terasme, J., 1960, "Surficial Geology of Cornwall Map-Area Ontario and Quebec," Geological Society of Canada Paper 60-28.

Terasme, J., 1965, "Surficial Geology of the Cornwall and St. Lawrence Seaway Project Areas, Ontario," Canadian Geological Survey Bulletin, No. 121, 54 p.

Terzaghi, K., 1934, "Large Retaining-Wall Tests, I: Pressure of Dry Sand," Engineering News-Record, Vol. 112, p 136-140.

Terzaghi, K., 1954, "Anchored Bulkheads," Transactions, American Society of Civil Engineers, CXIX, p 1243.

Terzaghi, K., 1955, "Evaluation of Coefficients of Subgrade Reaction," Geotechnique, Vol. 5, No. 4, p 297-326.

Terzaghi, K. and R.B. Peck, 1967, Soil Mechanics in Engineering Practice, John Wiley & Sons, Inc., NY, p 28.

Theis, C.V., 1935, "The Relation Between the Lowering of Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground water Storage," Transactions of the American Geophysical Union, 16th Annual Meeting Part 2.

Theokritoff, G., 1968, "Cambrian Biogeography and Biostratigraphy in New England," Studies of Appalachian Geology, Northern and Maritime, Zen, E. John Wiley & Sons, Inc., NY, p 9-22.

Thomas, R.L., (Abstract), 1970, "The Distribution and Characteristics of Lake Ontario Surface Sediments," Geological Society of America Abstracts, Vol. 2, No. 7, p 703.

Thomas, R.L., A.L.W. Kemp, and C.E.M. Lewis, "Distribution, Composition and Characteristics of the Surficial Sediments of Lake Ontario," Journal of Sedimentary Petrology, Vol. 42, No. 1, p 66-84.

Thomas, R.L., J.F. Kemp, and C.E.M. Lewis, 1972, "Report on the Surficial Sediment Distribution of the Great Lakes," Pt. I., Geological Survey of Canada, Department of Energy, Mines and Resources Paper 72-17, 52 p.

Thompson, J.B. Jr., 1968, "Nappes and Gneiss Domes in West-Central New England," Studies of Appalachian Geology: Northern and Maritime, Zen, E. (ed.), John Wiley and Sons, Inc., NY.

Thompson, L.G.D. and A.H. Miller, 1958, "Gravity Measurements in Southern Ontario," Publications of the Dominion Observatory Department of Mines and Technical Surveys Dominion Observatories, Ottawa, Canada, Vol. 19, No. 9, 2 maps, p 321-378.

Thompson, M., (Abstract), 1973, "Large-Scale Superposed Structures in the Northern Green Mountains, Bakersfield and Waterville, Vermont," Geological Society of America Abstracts, Vol. 8, No. 2, p 286.

2035 102

Thonis, M., (Abstract), 1973, "Strain in Adirondack Lowland Migmatite," Geological Society of America Abstracts, Vol. 5, No. 2, p 227-228.

Thornbury, W.D., 1965, Regional Geomorphology of the United States, John Wiley & Sons, Inc., NY.

Thyssen-Bornemisza, S., June 1970, "Discussion on Variations of Vertical Gravity Gradient in New York City and Alpine, New Jersey," Geophysics, Vol. 35, No. 3, p 521-522.

Todd, D.K., 1959, Ground Water Hydrology, John Wiley & Sons, Inc., NY, p 336.

Trainer, F.W., March-April 1973, "Formation of Joints in Bedrock by Moving Glacial Ice," Journal of Research of the U.S. Geological Survey, Vol. 1, No. 2, p 229-235.

Treesh, M.I., (Abstract), 1973, "The Syracuse Formation (Upper Silurian) of New York State: A Case for Salt Deposition," Geological Society of America Abstracts, Vol. 5, No. 2, p 229.

Trifunac, M.D. and A.G. Brady, 1976, "On the Correlation of Seismic Intensity Scales With the Peaks of Recorded Strong Ground Motion," Seismological Society of America Bulletin, Vol. 65, No. 1 p 139-162.

Turner, B.B., (Abstract), 1968, "Configuration and Petrogenesis of a Geologically Critical Area in the Southeastern Adirondack Mountains, New York," Dissertation Abstracts International, Vol. 28, No. 8, p 3346B.

Turner, B.B., (Abstract), 1971, "Structural-Stratigraphic Relationships Among Metasedimentary, Metaigneous, and Other Gneissic Rocks, Southeastern Adirondack Mountains, New York," Geological Society of America Abstracts, Vol. 3, No. 1, p 58.

Turner, B.B., 1971, "Metavolcanic Rocks and Their Origin, Southern Adirondack Mountains, New York," Bulletin Volcanologique, Vol. 34, No. 4, p 777-791.

Uchupi, E., 1965, Map Showing Relation and Land and Submarine Topography, Nova Scotia to Florida, U.S. Geological Survey Map I-451, Scale, 1:1,000,000.

Ulreich, E.O., 1911, "Revisions of the Paleozoic Systems," Geological Society of America Bulletin, Vol. 22, p 281-680.

U.S. Department of the Interior, Bureau of Reclamation (1960), "Earth Manual."

U.S. Department of the Navy, Naval Facilities Engineering Command (1971), "Design Manual, Soil Mechanics, Foundations, and Earth Structures," DM-7.

U.S. Geological Survey, 1946-present, "Geophysical Investigations," Maps covering New York and New England.

2035 103

U.S. Geological Survey, 1950, "Compilation of Records of Surface Waters of the United States Through September, 1950," Part 1-B, North Atlantic Slope Basins, New York to York River U.S. Geological Survey Water Supply Paper 1302.

U.S. Geological Survey, 1958, "Compilation of Records of Surface Waters of the United States Through September, 1950," Part 4. St. Lawrence River Basin, U.S. Geological Survey Water Supply Paper 1307.

U.S. Geological Survey, 1964, "Compilation of Records of Surface Waters of the United States, October 1950 to September 1960," Part 1-B. North Atlantic Slope Basins, New York to York River, U.S. Geological Survey Water Supply Paper 1722.

U.S. Geological Survey, 1964, "Compilation of Records of Surface Waters of the United States, October 1950 to September 1960," Part 4. St. Lawrence River Basin, U.S. Geological Survey Water Supply Paper 1727.

U.S. Geological Survey, 1970, Shaded Relief Map of Ohio.

U.S. Geological Survey, 1970, "Index of Surface Water Records to September, 30, 1970," Part 4. St. Lawrence River Basin, U.S. Geological Survey Circular 654.

U.S. Geological Survey, 1973, "Water Resources Investigations in New York."

U.S. Geological Survey, 1974, "Aeromagnetic Map of Parts of the Scranton and Newark 1° by 2° Quadrangles, Pennsylvania," U.S. Geological Survey Open File Report 74-15.

U.S. Geological Survey, 1974, "Aeromagnetic Map of Parts of the Warren and Buffalo 1° by 2° Quadrangle, Pennsylvania," U.S. Geological Survey Open File Report 74-16.

U.S. Geological Survey, 1974, "Aeromagnetic Map of Part of the Williamsport 1° by 2° Quadrangle Pennsylvania," U.S. Geological Survey Open File Report 74-17.

U.S. Geological Survey, 1976, "Aeromagnetic Map of the Bristol Quadrangle, Bristol, Kent, Newport, and Providence Counties, Rhode Island," 1 plate at 1:24,000, Cont. Int. 20 gamma, U.S. Geological Survey Open File Report 76-224.

U.S. Geological Survey, 1976, "Aeromagnetic Map of the Coventry Center Quadrangle, Kent and Providence Counties, Rhode Island," 1 plate at 1:24,000 Cont. Int 20 gamma and 100 gamma, U.S. Geological Survey Open File Report 76-225.

U.S. Geological Survey, 1976, "Aeromagnetic Map of the Compton Quadrangle, Kent and Providence Counties, Rhode Island," 1 plate at 1:24,000 Cont. Int. 20 gamma U.S. Geological Survey Open File Report 76-226.

U.S. Geological Survey, 1976, "Aeromagnetic Map of the East Greenwich Quadrangle, Kent, Washington, Providence, and Newport Counties, Rhode Island,"

1 plate at 1:24,000 Cont Int 20 gamma, U.S. Geological Survey Open File Report 76-227.

U.S. Geological Survey, 1976, "Aeromagnetic Map of Atlantic Continental Margin Quadrangle," U.S. Geological Survey Maps MF-752A through E, Scale: 1:250,000.

U.S. Geological Survey, 1977, "Aeromagnetic Map of Parts of the Rochester and Utica 1° x 2° Quadrangles, New York," U.S. Geological Survey Open File Report 77-553.

U.S. Geological Survey, 1978, "Aeromagnetic Map of the Eastern Part of the Adirondacks Mountains, New York," U.S. Geological Survey Open File Report 78-279. Scale 1:250,000.

U.S. Naval Oceanographic Office, 1964-1966, Total Magnetic Intensity: United States Atlantic Coastal Region (Project Magnet). U.S.N.O.D. Aeromagnetic Survey, 1:500 gamma contour interval, sepias, sheets 1-4.

U.S. Naval Oceanographic Office Aeromagnetic Survey, 1:500,000, Flight Altitude 500' ASL, 500 gamma contour interval, sepias, sheets 1-4.

University of Rochester, May 4-6, 1956, "Guidebook to Field Trips in Western New York, Chronological Wastage of Ice in New York State," New York State Geological Association 28th Annual Meeting, p 47-59.

Van Tyne, A.M., 1975, "Subsurface Investigation of the Clarendon-Linden Structures," New York State Museum and Science Service Open File Report, 12 p, 2 maps of 8.

Van Tyne, A., 1978, Personal Communication.

Vanuxem, L. 1842, "Fourth Annual Report of the Geological Survey, Part III, Survey of the Third District." New York State Museum.

Vidale, R., "Metamorphic Differentiation Layering in Pelitic Rocks of Dutchess County, New York," Geochemical Transport and Kinetics Carnegie Institute, Washington, DC.

Vidale, R.J., 1974, "Vein Assemblages and Metamorphism in Dutchess County New York," Geological Society of America Bulletin, Vol. 85, p 303-306.

Voight, B., 1965, "Structural Relationships of the Sudbury Nappe to the Subadjacent Middlebury Synclinorium and Superadjacent Taconic Allochthon in West-Central Vermont," Geological Society of America Special Paper No. 82.

Voight, B., 1966, "Interpretation of In Situ Stress Measurements," Proceedings of the International Congress of the Society of Rock Mechanics, Vol. III, p. 332-348.

2035 105

Voight, B., 1969, "Evolution of North Atlantic Ocean: Relevance of Rock-Pressure Measurements," North Atlantic Geology and Continental Drift, Kay, M. (ed.), American Association of Petrology Geologic Memoir 12, p 955-962.

Von Englen, O.D., 1962, Origin and History of the Finger Lakes Region, New York, Cornell Press, Ithaca, NY.

von Hake, C.A., 1976, "Earthquake History of Ohio," Earthquake Information Bulletin, Vol. 8, No. 1, p 28-30.

Waananen, A.O., 1961, "Hydrologic Effects of Urban Growth - Some Characteristics of Urban Runoff," Short Papers in the Geologic and Hydrologic Sciences No. 275, p C353-C356.

Walker, K.R., (Abstract), 1970, "The Stratigraphy, Environmental Sedimentology and Community Ecology of the Middle Ordovician Black River Group, of New York State," Dissertation Abstracts International, Vol. 31, No. 3, p 1353B-1354B.

Walker, R.G., December 1967, "Quantitative Analysis of Turbidites in the Upper Devonian Sonyea Group, New York," Journal of Sedimentary Petrology, Vol. 37, No. 4, p 1012-1022.

Walker, R.G., December 1967, "Upper Flow Regime Bed Forms in Turbidites of the Hatch Formation, Devonian of New York State," Journal of Sedimentary Petrology, Vol. 37, No. 4, p 1052-1058.

Wallick, J.L. Personal Communication, 1978.

Walton, W.C., 1970, Ground Water Resource Evaluation, Mc-Graw Hill Co., NY.

Washington Public Power Supply System, 1976, Preliminary Safety Analysis Report, Amendment 23, WNP 1 and 4.

Weaver, C.E., 1970, "General Geology of Western New York State and Detailed Geology of West Valley Area," Union Carbide Corporation, Nuclear Division Subcontract No. 7009 Under U.S. Government Contract No. W-7405 56 p.

Webb, G.W., 1969, "Paleozoic Wrench Faults in Canadian Appalachians, North Atlantic-Geology and Continental Drift," American Association of Petroleum Geology Memoir No. 12, p 754-786.

Wedel, A.A. 1932, "Geologic Structure of the Devonian Strata of South Central New York," New York State Museum Bulletin 294.

Westergaard, H.M., 1933, "Water Pressures on Dams During Earthquakes," Transcripts of American Society of Civil Engineers, Vol. 98, p 418-433.

Weston Geophysical Research, Inc., 1976, "Aeromagnetic Map of Southeastern New England and the Western Gulf of Maine," prepared for Boston Edison Company Plate 2C-1.

2035 106

Weston Geophysical Engineers, (Site 7-11-6), 1976, "Site Confirmation Study," "Seismic Survey," "Regional Geology,"

Wetmiller, R.J., 1975, "The Quebec-Maine Border Earthquake, 15 June 1973," Canadian Journal of Earth Sciences, Vol. 12, p 1917-1928.

Whitten, E.H.T., 1976, "Cretaceous Phases of Rapid Sediment Accumulation, Continental Shelf, Eastern United States," Geology, Vol. 4, p 237-240.

Whipple, J.M., 1972, "Remote Sensing of New York Lakes," U.S. Geological Survey Professional Paper 800-C, p C243-C247.

White, W.S., 1968, "Generalized Geologic Map of the Northern Appalachian Region," Studies of Appalachian Geology, Northern and Maritime, Zen, E., et al (eds.), Interscience Publishers, Inc., p 453-454.

Whitham, K., W.G. Milne, 1972, "Protection of the Public From Earthquake Hazards in Canada," EMO National Digest, Vol. 12, No. 5, 6 p.

Whitham, K. and H.S. Hasegawa, 1975, "The Estimation of Seismic Risk in Canada - A Review," Publications of the Earth Physics Branch, Ottawa, Vol. 45, No. 2, p 137-162.

Whitten, E.H.T. 1978, "Cretaceous Phases of Rapid Sediment Accumulation, Continental Shelf, Eastern United States," Geology, Vol. 4, p 237-240.

Wiener, R.W. 1978, "Intrusion, Cataclasis, and Multiple Folding Along the Adirondack Highlands - Northwest Lowlands Boundary," Geological Society of America Abstract with program, Vol. 10, p 516.

Wiesnet, D.R. and T.H. Clark, 1966, "The Bedrock Structure of Covey Hill and Vicinity Northern New York and Southern Quebec," U.S. Geological Survey Professional Paper No. 550-D, p 35-38.

Wiitala, S.W., 1965, "Magnitude and Frequency of Floods in the United States," Part 4, St. Lawrence River Basin, U.S. Geological Survey Water Supply Paper 1677.

Williams, D.A., April 1976, "Faults and Alignments of the Montreal-Ottawa Region," Doctor of Philosophy Thesis, McGill University, Montreal.

Williams, G.H., (Abstract), 1890, "Note on the Eruptive Origin of the Syracuse Serpentine," Geological Society of America Bulletin, No. 1, p 533-534.

Williams, H.S., 1882, "The Undulations of the Rock Mass Across Central New York," Proceedings of the American Association for the Advancement of Science, Vol. 31.

Wilson, A.E., 1940, "Geology of Nepean, Ontario and Quebec," Geological Survey of Canada, Map No. 588A, Scale 1:126,720.

2035 107

Wilson, A.E., 1941, "Geology of Maxville, Ontario and Quebec," Geological Survey of Canada Map No. No. 661A, Scale 1:126,720.

Wilson, A.E., 1941, "Geology of L'Orignal, Ontario and Quebec," Geological Survey of Canada Map. No. 662A, Scale 1:126,720.

Wilson, A.E., 1941, "Geology of Valleyfield, Quebec and Ontario," Geological Survey of Canada Map No. 660A, Scale 1:126,720.

Wilson, A.E., 1946, "Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec," Geological Survey of Canada Memoir No. 241, 65 p.

Wilson, A.E., 1946, "A Buried Channel of the St. Lawrence River," American Journal of Science, Vol. 244, No. 8, p 557-562.

Wilson, J.T., April 1949, "Some Major Structures of the Canadian Shield," Transactions of the Canadian Institute of Mining and Metals, Vol. 52, p 231-242.

Wing, L.A., August 1959, "An Aeromagnetic and Geologic Reconnaissance Survey of the Sidney-Augusta and Gardiner Areas, Kennebec County, Maine," Maine Geological Survey GP and G No. 5, 18 p, plus several small maps.

Wissig, G.C., Jr., 1970, "Bedrock Geology of the Ossining, New York Quadrangle," Ph.D. Thesis, Syracuse University, 230 p.

Wolcott, R.I. 1972, "Late Quaternary Vertical Movements in Eastern North America: Quantitative Evidence of Glacio-Isostatic Rebound", Review of Geophysics and Space Physics, Vol. 10, p 849-884.

Wones, D.R. and D.B. Stewart, 1976, "Middle Paleozoic Regional Right-Lateral Strike Slip Faults in Central Coastal Maine," Geological Society of America Annual Meeting, Abstracts with program, Vol. 8, No. 2, p 304.

Wong, R.T., H.B. Seed, and C.K. Chan, 1969, "Cyclic Loading Liquefaction of Gravelly Soils," Journal of the Soils Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 101, No. GT6.

Woodward, H.P., 1961, "Preliminary Subsurface Study of Southeastern Appalachian Interior Plateau," American Association of Petroleum Geologists Bulletin, Vol. 45, No. 10, p 1634-1655.

Woolard, G.P., 1948, "Gravity and Magnetic Investigations in New England," Transactions of American Geophysical Union (EOS), Vol. 51, p 434.

Woolard, G.P., 1948, "Recent Regional Gravity Surveys," Transactions of American Geophysical Union (EOS), Vol. 29, No. 5, p 727-738.

Wynne-Edwards, H.R., 1957, "Structure of the Westport Concordant Pluton in the Grenville, Ontario," Journal of Geology, Vol. 65, p 639-649.

2035 108

Wynne-Edwards, H.R., 1967, "Senneterre-St. Jerome, A Cross Section Through the Grenville Province," Geological Association of Canada, Mineralogical Association of Canada, 20th Annual Meeting, Kingston, Ontario.

Wynne-Edwards, H.R., 1967, "Westport Map Area, Ontario: With Special Emphasis on the Precambrian," Geological Society of Canada Memoir 346.

Young, D.A., 1972, "A Quartz Syenite Intrusion in the New Jersey Highlands," Journal of Petrology, Vol. 13, No. 3, p 511-528

Young, J.R. and G.W. Putman, "The Puzzle of Saratoga - An Old Solution With a New Twist," Empire State Geogram, Vol. 14, No. 2, p 17-31.

York, J.E. and J.E. Oliver, 1976, "Cretaceous and Cenozoic Faulting in Eastern North America," Geological Society of America Bulletin, Vol. 87, No. 7.

Zartman, R.E., 1976, "Geochronology and its Tectonic Implications in the Northern Appalachians Between 41° and 43° Latitude," Geological Society of America Abstracts with rogram Vol. 8, No. 2, p 306-307.

Zartman, R.E., et al, 1967, "K-Ar and Rb-Sr Ages of Some Alkalic Intrusive Rocks," American Journal of Science, Vol. 265, p 848-870.

Zartman, R.E. and R.F. Marvin, 1971, "Radiometric Age (Late Ordovician) of the Quincy, Cape Ann and Peabody Granites From Eastern Massachusetts," Geological Society of America Bulletin, Vol. 82, p 937-958.

Zen, E., 1959, "Stratigraphy and Structure in Central Vermont and Adjacent New York," NEIGC Guidebook to Field Trips 51st Annual Meeting.

Zen, E., 1961, "Stratigraphy and Structure at the North End of the Taconic Range in West-Central Vermont," Geological Society of America Bulletin, Vol. 72, p 293-338.

Zen, E., 1963, "Structural Relations in the Southern Taconic Region: An Interpretation," Geological Society of America, Albany, NY.

Zen, E., 1963, "Age and Classification of Some Taconic Stratigraphic Units on the Centennial Geologic Map of Vermont: A Discussion," American Journal of Science, Vol. 261, p 92-94.

Zen, E., 1964, "Taconic Stratigraphic Names, Definitions, and Synand Synonymies," United States Geological Society of America Bulletin No. 1174, 95 p.

Zen, E., 1967, "Time and Space Relationships of the Taconic Allochthon and Autochthon," Geological Society of America Bulletin Special Paper 97, 107 p.

Zen, E., 1968, "Nature of the Ordovician Orogeny in the Taconic Area," Studies in Appalachian Geology, Interscience Publishers.

2035 109

Zen, E., 1968, "Stratigraphic-Structural Contrasts in Thrust Slices of the Taconic Allochthon," Abstracts for 1967, Geological Society of American Special Paper 115, p 304-305.

Zen, E., 1969, "Stratigraphy, Structure and Metamorphism of the Taconic Allochthon and Surrounding Autochthon in the Bashbish Falls and Egremont Quadrangles and Adjacent Areas," New England Intercollegiate Conference Guidebook.

Zen, E., 1972, "A Lithlogic Map of the New England States and Eastern New York," U.S. Geological Survey Open File Report 458, 18 sheets, Scale 1:250,000.

Zen, E., 1972, "Some Revisions in the Interpretation of the Taconic Allochthon in West-Central Vermont," Geological Society of America Bulletin, Vol. 83, p 2573-2588.

Zen, E., 1972, "The Taconic Zone and the Taconic Orogeny in the Western Part of the Northern Appalachian Orogen," Geological Society of America Special Paper No. 135, 72 p.

Zen, E., 1974, "Prehnite- and Pumpellyite-Bearing Mineral Assemblages, West Side of the Appalachian Metamorphic Belt, Pennsylvania to Newfoundland," Journal of Petrology, Vol. 15, No. 2, p 197-242.

Zen, E. and J.H. Hartsworth, 1966, "Geology of the Bashbish Falls Quadrangle Massachusetts, Connecticut, New York," U.S. Geological Survey, GQ 507

Zen, E. and N.M. Ratcliffe, 1966, "A Possible Breccia in Southern, Massachusetts, and Adjoining Areas, and its Bearing on the Existence of the Taconic Allochthon," United States Geological Society Professional Paper 550-C, p D39-D46.

Zen, E. and N.M. Ratcliffe, 1971, "Bedrock Geologic Map of the Egremont Quadrangle and adjoining areas, Berkshire County, Mass., and Columbia County, NY," U.S. Geological Survey Miscellaneous Geological Investigation Map I-628.

Zenger, D.H., 1965, "Calcite-Dolomite Ratios Versus Insoluble Content in the Lockport Formation (Niagaran) in New York State," Journal of Sedimentary Petrology, Vol. 35, p 262-264.

Zenger, D.H., 1965, "Stratigraphy of the Lockport Formation (Middle Silurian) in New York State," New York State Museum and Science Service Bulletin No. 404, 210 p.

Zenger, D.H., October 1966, "Redefinition of the Herkimer Sandstone (Middle Silurian) New York," Geological Society of America Abstracts, Vol. 77, p 1159-1166.

2035 110

Zenger, D.H., 1969, "Stratigraphy of the Little Falls Formation (Upper Cambrian) in the Type Locality Area, East-Central New York," Geological Society of America Abstracts, Vol. 1, p 67-68.

Zenger, D.H., 1971, "Age and Stratigraphic Relations of the Ritchie Limestone New York," Geological Society of America Abstracts, Vol. 3, No. 1, p 65.

Zenger, D.H., 1976, "Definition of Type Little Falls Dolostone (Late Cambrian), East-Central New York," American Association of Petroleum Geologist's Bulletin, Vol. 60, p 1570-1575.

Zietz, I., et al, 1966, "Crustal Study of a Continental Strip from the Atlantic Ocean to the Rocky Mountains," Geological Society of America Bulletin, Vol. 77, p 1427-1488.

Zietz, I., F. Gilbert, and J.R. Kirby, 1972, Northeastern United States Regional Aeromagnetic Maps U.S. Geological Survey Open File Report No. 459.

2035 111

TABLE 2.5-14

SUMMARY OF GEOTECHNICAL SURFACE AND SUBSURFACE INSTRUMENTATION

	Type of Instrumentation	Approximate Number	Locations	Installation Schedule	Monitoring Frequency	Anticipated Duration
1.	Primary Survey Monuments	4-6	Outside plant area	2 years before site excavation	As needed to account for drift	Permanent
2.	Secondary Survey Monuments	10-20	Adjacent to annulus building and standby cooling tower excavations	Before rock excavation and as required	As needed to account for drift	3-5 years/ permanent, if needed
3.	Heave Monuments	5-10	Within annulus building and standby cooling tower excavations	Before start of excavation	Before excavation, after stripping, and after all excavation	2-3 years
4.	Settlement Monuments	10-20	Within major plant structure mats and walls	Before and during concrete mat pours	Weekly during concrete pours/ monthly thereafter	Duration of major structural loading
5.	Observation Wells/ Piezometers	10-20	Onsite as needed to monitor groundwater within 1,000 ft of major site excavations	Some installed at present/others added before start of excavation	Monthly during deep excavation dewatering/bimonthly thereafter	2-5 years/ permanent, if needed
6.	Inclinometers	No estimate	Adjacent to walls of annulus building and standby cooling tower excavations	Before or during site excavation	Weekly throughout excavation/as needed thereafter	2 years/ permanent, if needed
7.	MPBX Extensometers	No estimate	Horizontal holes within annulus building and standby cooling tower excavations	During or after excavation	Weekly throughout excavation/as needed thereafter	1-2 years

2035 112

DOCUMENT/ PAGE PULLED

ANO. 7908310504

NO. OF PAGES 1

REASON:

☐ PAGE ILLEGIBLE:

☐ HARD COPY FILED AT: PDR CF
OTHER BFT

☐ BETTER COPY REQUESTED ON ___/___/___

☒ PAGE TOO LARGE TO FILM:

☐ HARD COPY FILED AT: PDR CF
OTHER BFT

☐ FILMED ON APERTURE CARD NO. 7908310504

2035 113

DOCUMENT/ PAGE PULLED

ANO. 7908310504

NO. OF PAGES 1

REASON:

☐ PAGE ILLEGIBLE:

☐ HARD COPY FILED AT: PDR CF
OTHER BFT

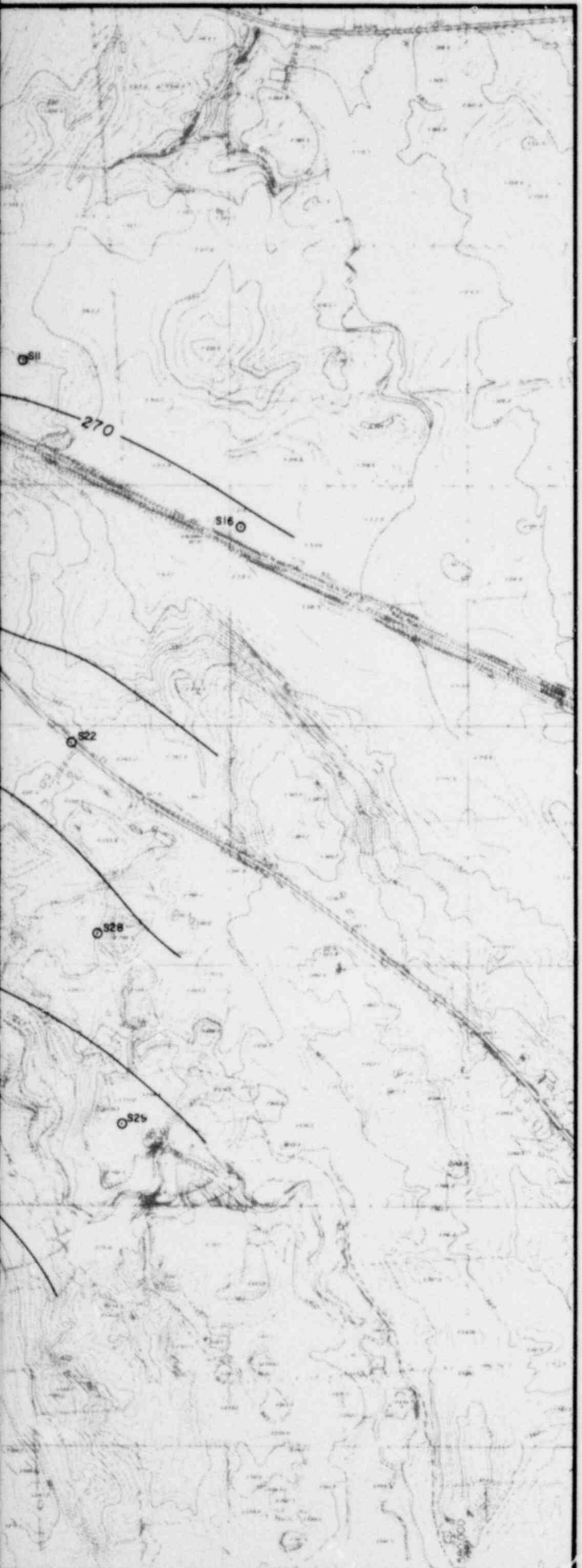
☐ BETTER COPY REQUESTED ON ___/___/___

☒ PAGE TOO LARGE TO FILM:

☐ HARD COPY FILED AT: PDR CF
OTHER BFT

☐ FILMED ON APERTURE CARD NO. 7908310504-1

2035 114



EXPLANATION

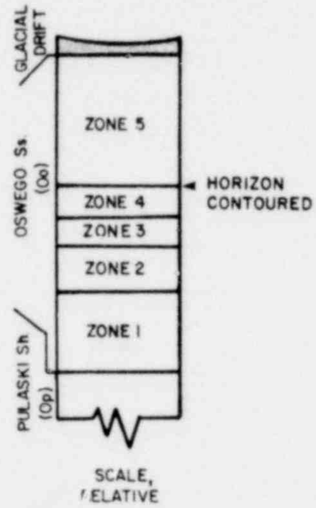
⊙B BORINGS, 1976

⊙S BORINGS, 1977

⊙G BORINGS, 1977

CONTOUR LINE

STRATIGRAPHIC DIAGRAM
SITE / AREA



C. NTOUR INTERVAL :5 FT.

BA... 2 FT. CONTOUR TOPOGRAPHY

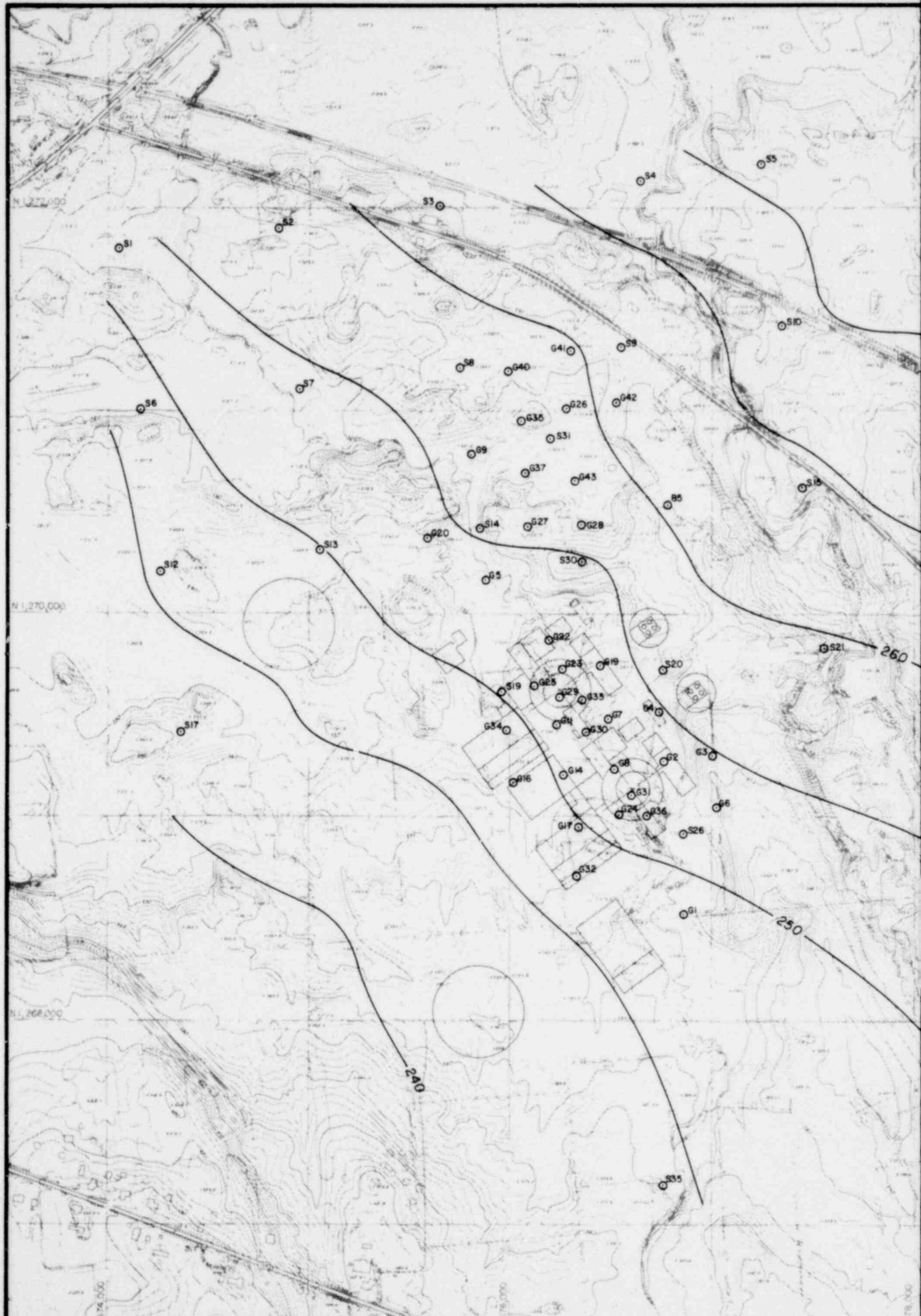
0 1000 FT.

2035 115

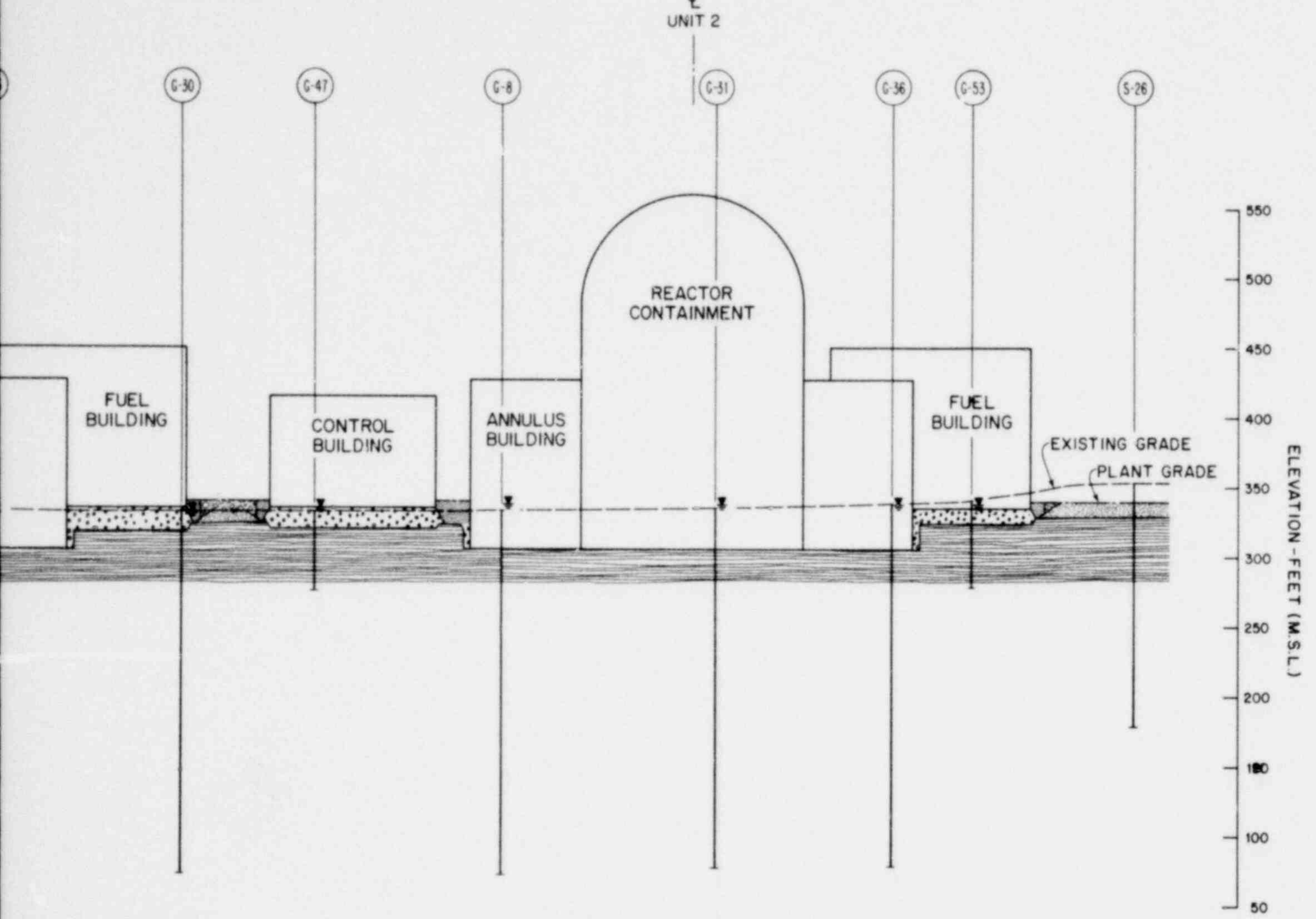
FIGURE 2.5-17 NEW HAVEN SITE

STRUCTURE CONTOUR MAP TOP OF OSWEGO SANDSTONE ZONE 4 SITE

NEW YORK STATE ELECTRIC & GAS CORPORATION


N 1,272,000
N 1,270,000
N 1,268,000
E 574,000
E 576,000
E 578,000
240
250
260
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S12
S13
S14
S15
S17
S19
S20
S21
S26
S30
S31
S35
G1
G2
G3
G4
G5
G6
G7
G8
G9
G14
G17
G19
G20
G22
G23
G24
G25
G26
G27
G28
G29
G30
G31
G32
G33
G34
G35
G36
G37
G40
G41
G42
G43
B5
B16

2035 116



NOTES:

1. SOIL EXCAVATION SLOPES TYPIC... 1.5 HORIZONTAL: 1 VERTICAL IN T... AND 2 HORIZONTAL: 1 VERTICAL IN... GLACIAL LAKE DEPOSITS.
2. SEE FIGURE 2.5-47 FOR LOCATION PROFILE.

50 100 150
SCALE-FEET

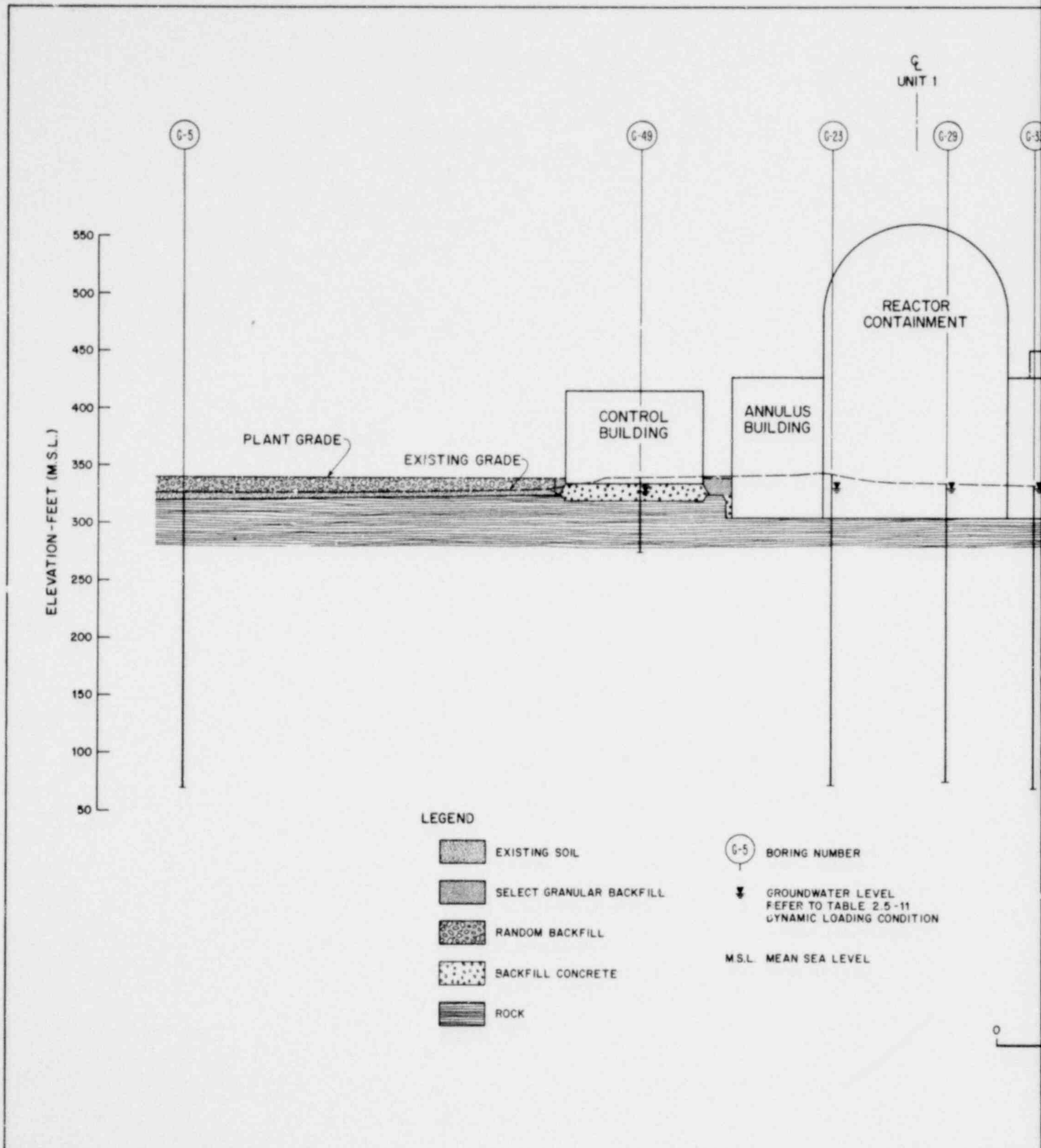
FIGURE 2.5-42 NEW HAVEN SITE

EXCAVATION PROFILE A-A

NEW YORK STATE ELECTRIC & GAS CORPORATION

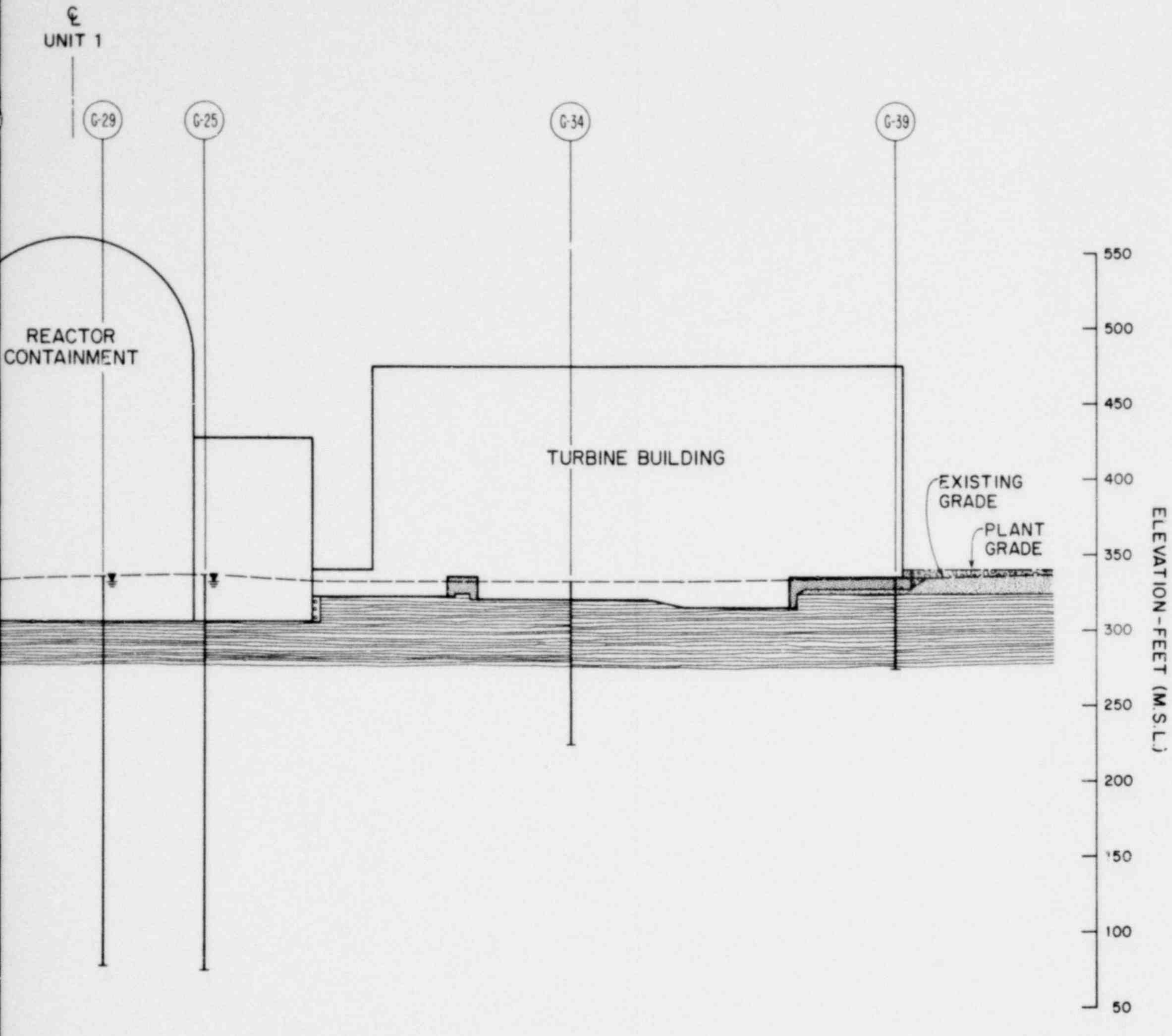
AMENDMENT 5

2035 117



℄
UNIT 1
G-5
G-49
G-23
G-29
550
500
450
400
350
300
250
200
150
100
50
ELEVATION-FEET (M.S.L.)
REACTOR
CONTAINMENT
CONTROL
BUILDING
ANNULUS
BUILDING
PLANT GRADE
EXISTING GRADE
LEGEND
EXISTING SOIL
SELECT GRANULAR BACKFILL
RANDOM BACKFILL
BACKFILL CONCRETE
ROCK
G-5 BORING NUMBER
GROUNDWATER LEVEL
REFER TO TABLE 2.5-11
DYNAMIC LOADING CONDITION
M.S.L. MEAN SEA LEVEL
0

2035 118



NOTES:

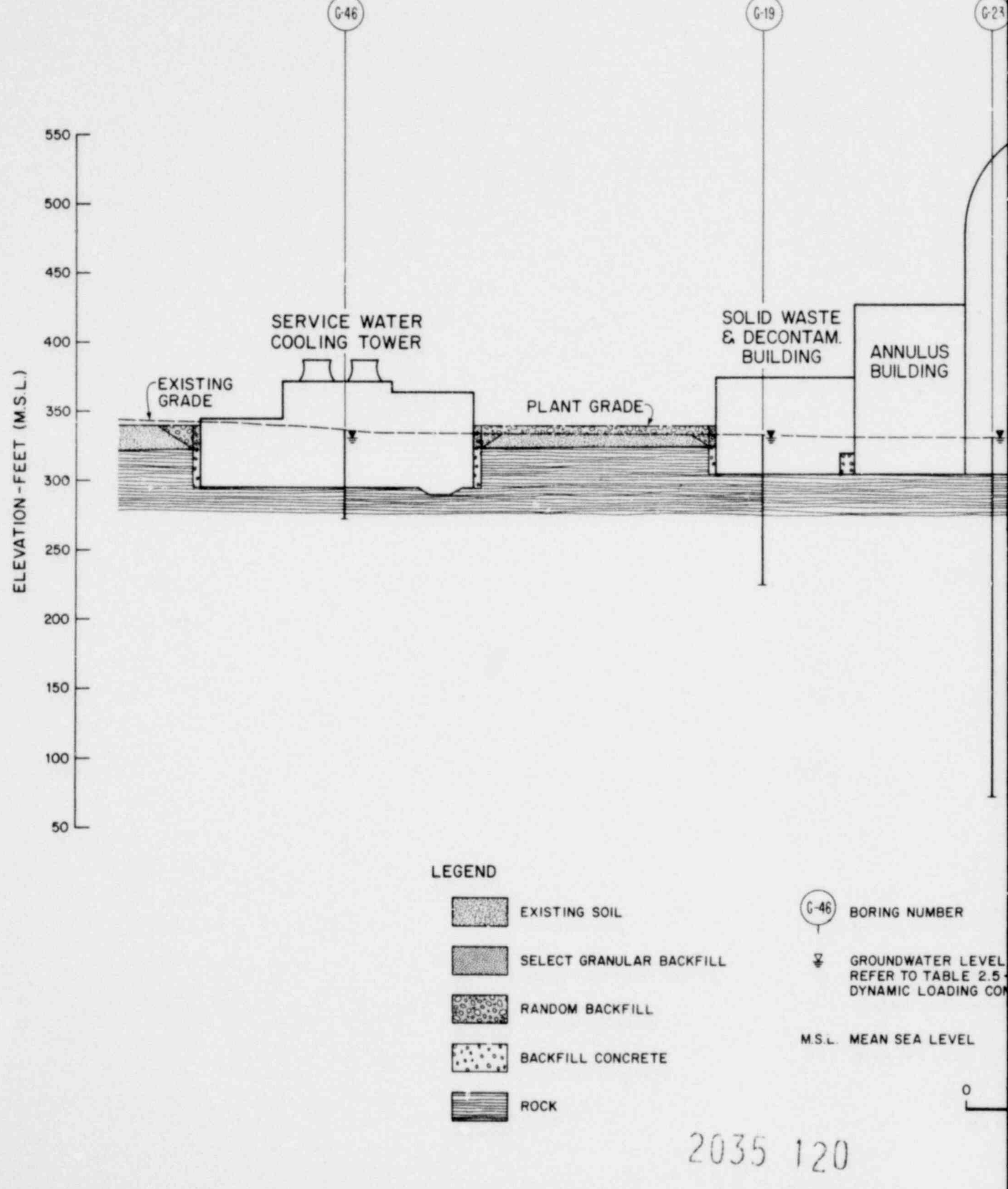
1. SOIL EXCAVATION SLOPES TYPICALLY 1.5 HORIZONTAL: 1 VERTICAL IN TILL AND 2 HORIZONTAL: 1 VERTICAL IN GLACIAL LAKE DEPOSITS.
2. SEE FIGURE 2.5-47 FOR LOCATION PROFILE.

2035 119

FIGURE 2.5-45 NEW HAVEN SITE

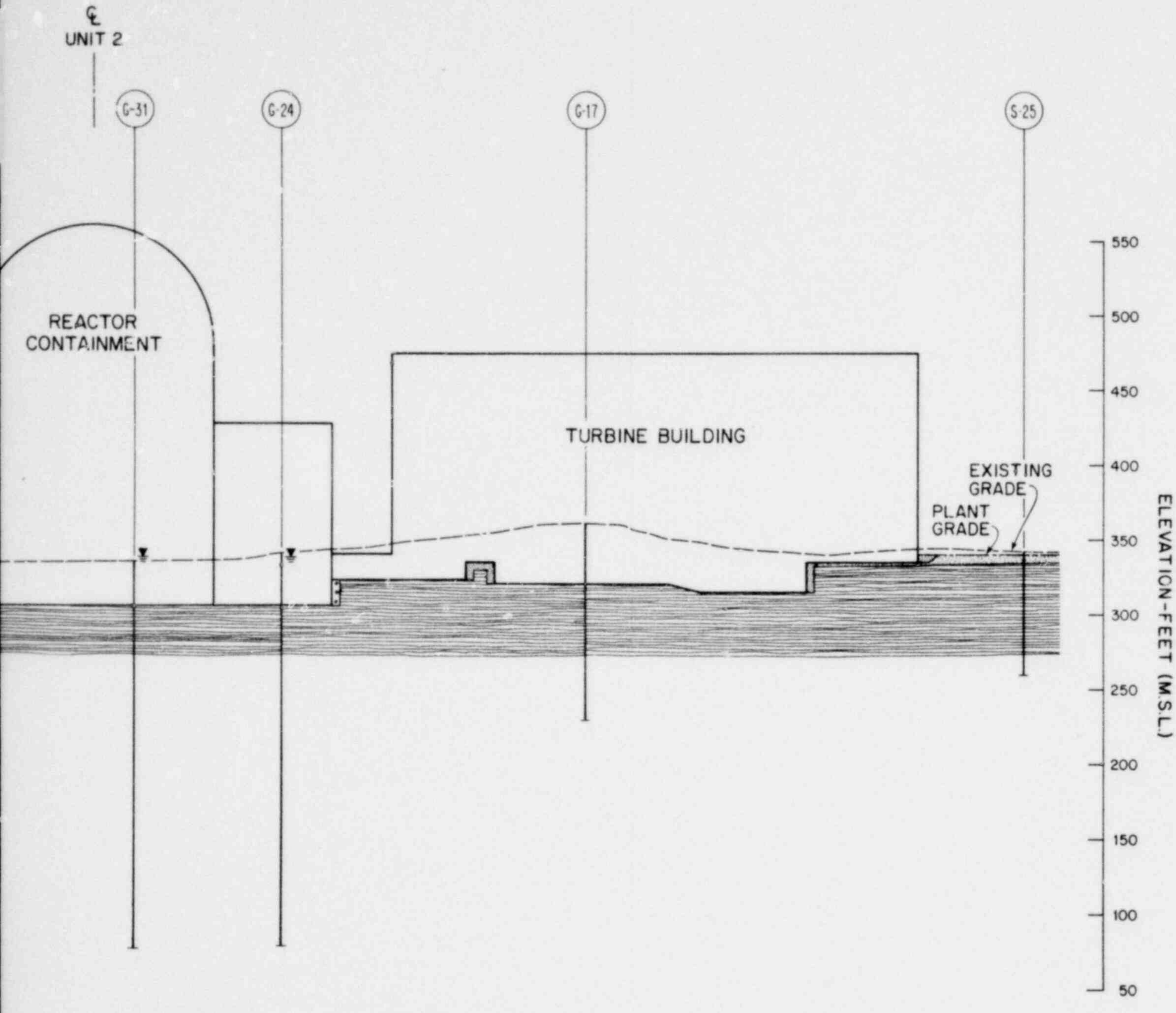
EXCAVATION PROFILE D-D

NEW YORK STATE ELECTRIC & GAS CORPORATION



G-46
G-19
550
500
450
400
350
300
250
200
150
100
50
ELEVATION-FEET (M.S.L.)
SERVICE WATER COOLING TOWER
EXISTING GRADE
PLANT GRADE
SOLID WASTE & DECONTAM. BUILDING
ANNULUS BUILDING
LEGEND
EXISTING SOIL
SELECT GRANULAR BACKFILL
RANDOM BACKFILL
BACKFILL CONCRETE
ROCK
G-46 BORING NUMBER
GROUNDWATER LEVEL
M.S.L. MEAN SEA LEVEL

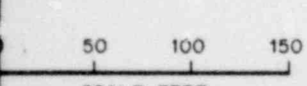
2035 120



EL
5-11
CONDITION

NOTES:

1. SOIL EXCAVATION SLOPES TYPICALLY 1.5 HORIZONTAL: 1 VERTICAL IN TILL AND 2 HORIZONTAL: 1 VERTICAL IN GLACIAL LAKE DEPOSITS.
2. SEE FIGURE 2.5-47 FOR LOCATION PROFILE.

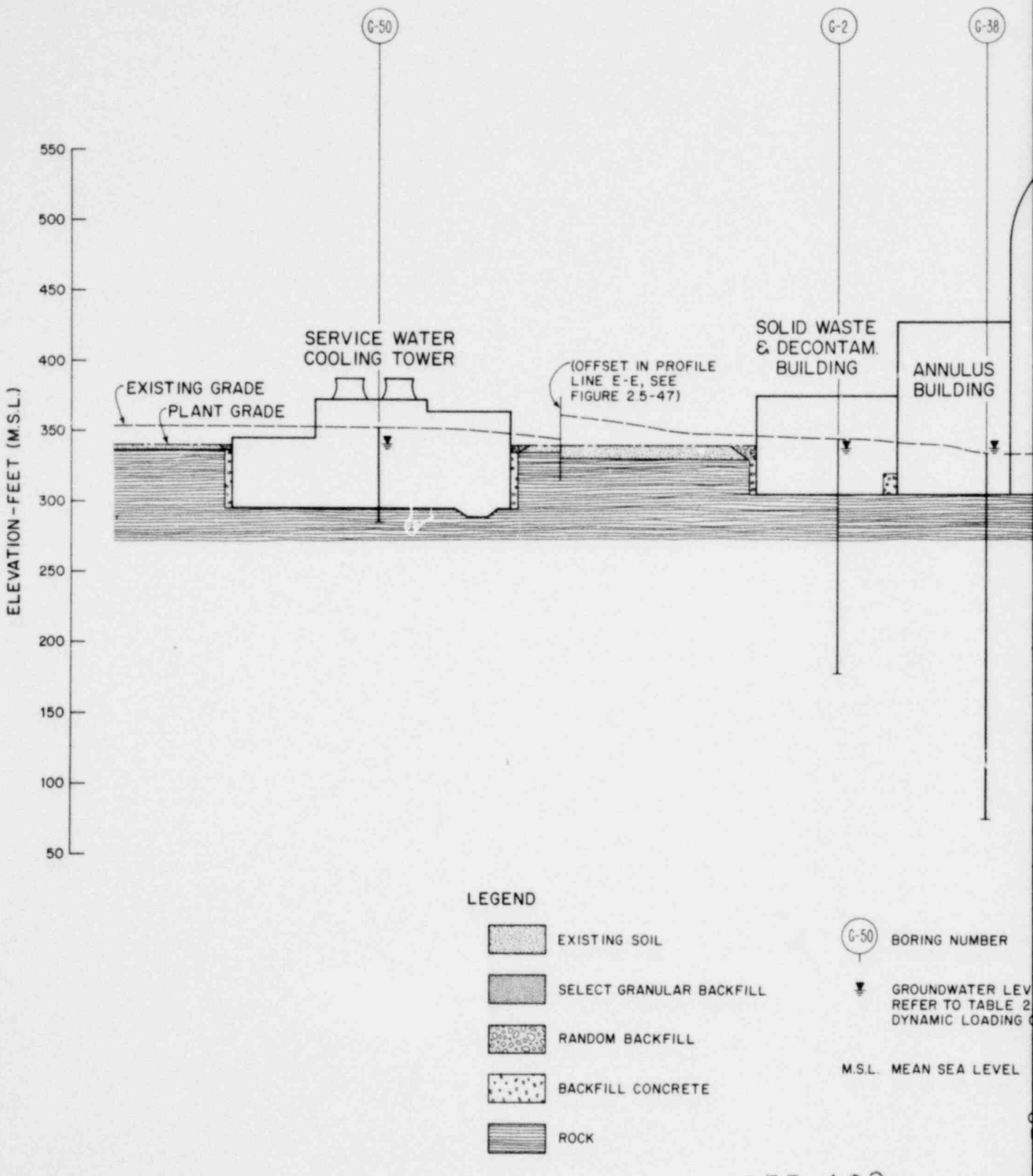


2035 121

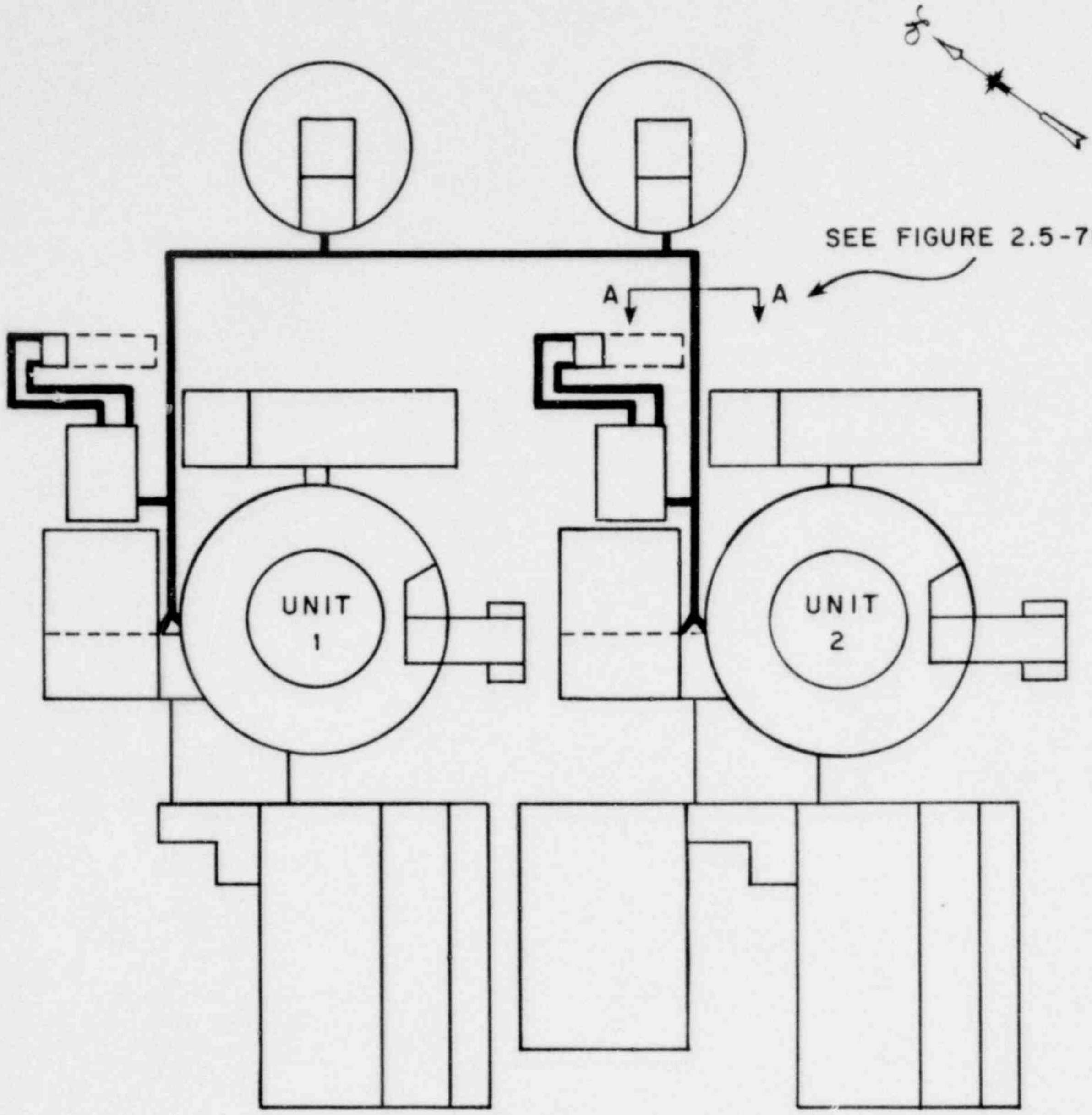
FIGURE 2.5-46 NEW HAVEN SITE

EXCAVATION PROFILE E-E

NEW YORK STATE ELECTRIC & GAS CORPORATION


G-50
G-2
G-38
ELEVATION-FEET (M.S.L.)
550
500
450
400
350
300
250
200
150
100
50
SERVICE WATER
COOLING TOWER
EXISTING GRADE
PLANT GRADE
(OFFSET IN PROFILE
LINE E-E, SEE
FIGURE 2.5-47)
SOLID WASTE
& DECONTAM.
BUILDING
ANNULUS
BUILDING
LEGEND
EXISTING SOIL
SELECT GRANULAR BACKFILL
RANDOM BACKFILL
BACKFILL CONCRETE
ROCK
G-50
BORING NUMBER
GROUNDWATER LEV
REFER TO TABLE 2
DYNAMIC LOADING
M.S.L. MEAN SEA LEVEL

2035 122



NOTE:

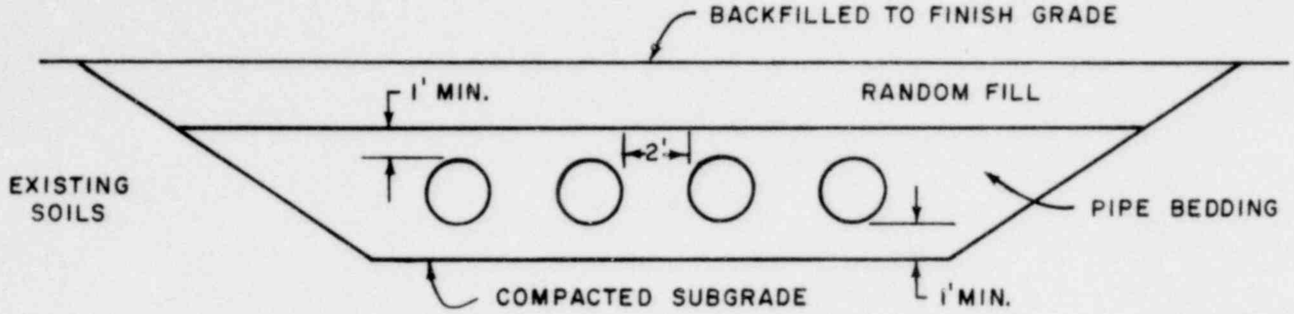
1. THE CROSSOVER SECTION BETWEEN UNITS I AND II PIPES IS NOT SHOWN.
2. SEE FIGURE 2.5-34 FOR BUILDING IDENTIFICATION.

2035 123

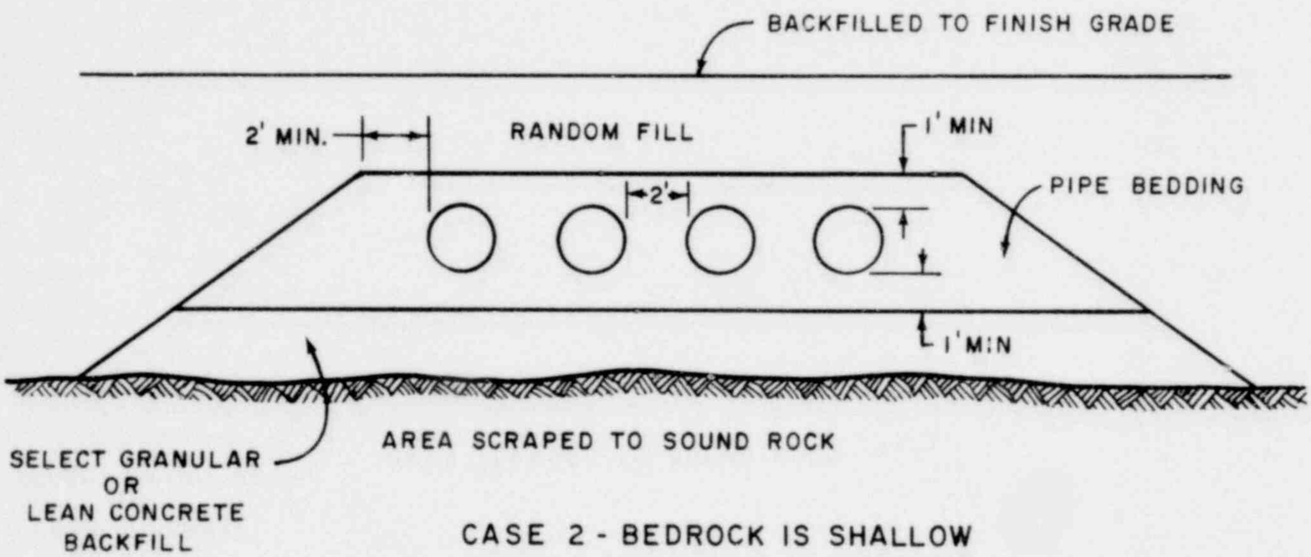
FIGURE 2.5-70 NEW HAVEN SITE

EXTERIOR CATEGORY I PIPELINES AND DUCTLINES - LOCATION PLAN

NEW YORK STATE ELECTRIC & GAS CORPORATION
PRELIMINARY SAFETY ANALYSIS REPORT



CASE 1 - BEDROCK IS DEEP



CASE 2 - BEDROCK IS SHALLOW

NOTE:
1. EXTERIOR CATEGORY I DUCTLINES WILL ALSO BE SUPPORTED AS SHOWN

2035 124

FIGURE 2.5-71 NEW HAVEN SITE
TYPICAL PIPE BEDDING DETAILS-
EXTERIOR CATEGORY I PIPELINES-
SECTION A-A (FIGURE 2.5-70)
NEW YORK STATE ELECTRIC & GAS CORPORATION
PRELIMINARY SAFETY ANALYSIS REPORT

LIST OF EFFECTIVE PAGES
(Amendment 5, August 1979)

2035 125

Page, Table (T), or Figure (F)	Amendment Number
T3.6-5(1 of 2 thru 2 of 2)	5
T3.6-6(1 of 1)	3
F3.6-1 thru 3.6-2	0
F3.6-3	3
F3.6-4	0
F3.6-5	3
3.7-1	0
3.7-2	3
T3.7-1(1 of 1)	3
T3.7-2(1 of 2 thru 2 of 2)	3
T3.7-3	3
F3.7-1	0
3.8-1	0
3.9-1 thru 3.9-37	0
T3.9-1(1 of 1)	0
T3.9-2(1 of 1)	0
T3.9-3(1 of 3 thru 3 of 3)	0
T3.9-4(1 of 1)	0
T3.9-5(1 of 4 thru 4 of 4)	0
T3.9-6(1 of 2 thru 2 of 2)	0
T3.9-7(1 of 2 thru 2 of 2)	0
T3.9-8(1 of 8 thru 8 of 8)	1
T3.9-9(1 of 2 and 2 of 2)	0
T3.9-10(1 of 1)	0
T3.9-11(1 of 1)	0
F3.9-1 thru 3.9-72	0

2035 126

TABLE OF CONTENTS

CHAPTER 3

THE STATION

2035 127

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

2035 129

LIST OF TABLES

2035 130

LIST OF TABLES (Cont'd)

2035 131

LIST OF TABLES (Cont'd)

2035 132

3.6.7 Discharges to Water

3.6.7.1 Cooling Tower Blowdown

The evaporation of water is the main heat transfer mechanism and results in an increase of the dissolved solids concentration in the circulating water. To control the dissolved solids level in the circulating water, a portion of the circulating water is withdrawn as blowdown. The cooling tower blowdown rate varies, such that under normal operating conditions, the makeup to blowdown flow ratio results in an average concentration factor of dissolved solids of approximately 3.0. As the cooling tower evaporation varies during the year, the resulting concentration factor varies from a maximum of 6.0 to a minimum of 2.45. It is estimated that the maximum instantaneous concentration factor (as measured by mass balance of makeup flow and evaporative losses determined from hourly meteorological observations) during the data period will be equalled or exceeded for 3 hr in 10 years, based on 10 years of meteorological data from Syracuse Hancock International Airport (National Weather Service). Table 3.6-1 lists the estimated average and maximum chemical concentrations in the cooling tower blowdown. The average concentration is based on the average concentration factor and average ambient concentration of each parameter. The annual average and maximum ambient water quality is summarized in Table 3.6-6.

The maximum composition represents the estimated worst possible conditions for that particular parameter while the average composition represents the expected normal operating condition.

Both the average and the maximum concentrations for iron, chromium, and nickel include the increase in the concentrations of these metals due to corrosion in the circulating water system and the turbine plant and reactor plant service water systems.

Cooling tower blowdown complies with 40CFR423.

3.6.7.2 Neutralized Demineralizer Wastes

Neutralization is performed on a batch basis. The neutralized wastes are released at a rate of approximately 100 gpm to the cooling tower blowdown system.

Table 3.6-2 lists the expected mean and maximum chemical concentrations in the neutralized waste resulting from:

1. Carbon filter backwash and rinse
2. A cation and anion regeneration cycle
3. A cation, anion, and mixed bed regeneration cycle

The mean concentration is based on the design regeneration cycle and the maximum concentration of each parameter, except for the trace elements which are based on average ambient concentrations. The maximum concentration is based on the design regeneration cycle and the maximum concentration of all parameters, including the trace elements. It is assumed that the effect of

2035 133

carbon filter waste on the total neutralized waste is an increase of suspended solids only.

The neutralized waste complies with 40CFR423.

3.6.7.3 Chemical Additions to Plant Water

Table 3.6-3 lists all chemicals and corrosion products added to the station water. A brief description of the reasons for their use is included in the table. The table gives estimates of monthly station use, station discharge, and the frequency of use.

Table 3.6-4 shows the chemicals used for initial plant startup. The quantities of sulfuric acid and sodium hydroxide indicated in Table 3.6-4 represent the total requirement for chemically regenerating the ion exchange demineralizers for the makeup demineralizer and the condensate polishing demineralizer systems during initial startup. Of these total quantities, 15 percent are discharged from the neutralized makeup demineralizer regeneration waste. The composition of the neutralized waste is indicated in Table 3.6-2. The remaining acid and caustic quantities, as well as all other chemicals indicated in Table 3.6-4, are not discharged, but are either used in closed systems or evaporated as described in Section 3.5-2. Preoperational cleaning is described in Section 4.1.1.11.

3.6.7.4 Combined Waste Discharge

Cooling tower blowdown is released continuously to Lake Ontario during station operation and serves as dilution water for the release of other treated liquid wastes. The estimated average and maximum chemical concentrations of the combined waste discharge is shown in Table 3.6-5. The expected plant discharge was computed by performing a mass balance based on the flow rate and chemical composition of the blowdown and other plant liquid wastes. Corrosion products were added directly to the cooling tower blowdown.

Neutralized makeup demineralizer wastes and low level radioactive wastes were added to the cooling tower blowdown using the following relationship.

$$C = \frac{C_1Q_1 + C_2Q_2 + C_3Q_3}{Q_1 + Q_2 + Q_3} \quad (3.6\text{-}1)$$

where:

C = concentration in plant discharge

C_1Q_1 = concentration and flow, respectively, cooling tower blowdown

2035 134

C_2Q_2 = concentration and flow, respectively, makeup demineralizer regeneration waste

TABLE 3.6-1

ESTIMATED CHEMICAL COMPOSITION OF COOLING TOWER BLOWDOWN

Constituent	Average	Maximum*
Alkalinity, total (mg/l) as $CaCO_3$	84	86
Chlorides (mg/l)	95.5	240
Sulfate (mg/l)	254	691
Phenols(ug/l)	5.2	24
Ammonia (total) (mg/l) as N	0.06	0.24
Nitrite (mg/l) as N	0.01	0.04
Nitrate (mg/l) as N	0.55	1.96
Nitrogen (organic) (mg/l)	0.76	1.92
Orthophosphate (mg/l) as P (total)	0.013	0.078
Phosphorus (mg/l) as P (total)	0.04	0.16
Total dissolved solids (TDS) (mg/l)	607	1,360
Total suspended solids (TSS) (mg/l)	7.3	30
Silica (mg/l)	0.76	3.72
Aluminum (mg/l)	0.251	1.53
Calcium (mg/l)	114.5	258.3
Cadmium (ug/l)	0.47	3.7
Chromium (ug/l)	14.6	37.0
Copper (ug/l)	6.72	26.4
Iron (mg/l)	0.40	1.24
Lead (ug/l)	<2.9	7.8
Magnesium (mg/l)	24.2	51.6
Manganese (mg/l)	0.02	0.10
Mercury (ug/l)	<0.61	3.1
Nickel (ug/l)	<15	63
Potassium (mg/l)	4.09	9.60
Sodium (mg/l)	43.8	102
Zinc (ug/l)	89.1	324
pH	7.8	6.0 to 9.0
Organic carbon (total)(mg/l)	9.1	24
Fluoride (mg/l)	0.38	0.90
Cyanide (total) as $Fe(CN)_6$ (mg/l)	<0.01	<0.03
Beryllium (ug/l)	<3.2	9.0
Boron (ug/l)	102	270
Cobalt (ug/l)	<4.67	27.0
Molybdenum (ug/l)	<149	330.0
Selenium (ug/l)	<4.97	24.0
Vanadium (ug/l)	<353	1,320.0
Arsenic (ug/l)	<5.55	18.2
Iodine (mg/l)	<0.82	<5.45
Free available chlorine (mg/l)	0.2**	0.5**
Oxygen, dissolved (mg/l)	9.1	7.3 (minimum)

2035 135

TABLE 3.6-1 (Cont'd)

NOTES:

* Maximum concentrations are based on maximum concentration factor and the maximum concentrations of each chemical observed in the ambient (makeup) water. Accordingly, the simultaneous occurrence of all maximum concentrations is extremely unlikely.

** Free available chlorine concentrations refer to the daily, 2-hour period (see 40CFR423). At all other times, there is no measurable discharge of chlorine.

2035 136

TABLE 3.6-3

CHEMICAL ADDITIONS TO WATER USED FOR STATION OPERATION, BOTH UNITS

Chemical Used and System Involved	Reason for Use, or Source of Chemical	Estimated Monthly Quantities (lb/mo)* Addition to System Average	Addition to System Maximum	Station Discharge Average	Station Discharge Maximum	Frequency of Chemical Addition
Sodium hypochlorite (as Cl_2)						
Circulating water system	Biofouling control	38,900	46,700	73	13 lb/day	Twice/day each unit
Reactor plant service water system	Biofouling control	3,400	4,100	2.4	0.4 lb/day	Twice/day each unit
Turbine plant service	Biofouling control	1,400	1,600	None	None	Twice/day each unit
Sanitary treatment facilities	Disinfection of sewage treatment plant effluent	15	38	0.04	0.1 lb/day	Continuous
Potable water system	Disinfection of potable water	2	5	None	None	Continuous
Sulfuric acid (as 100% H_2SO_4)						
Makeup water treatment system	Scaling control of circulating water system makeup water	710,700	994,000	696,200 as SO_4	973,700 as SO_4	Continuous
Demineralized water makeup treatment system	Regeneration of ion exchanges	6,000	66,000	5,900 as SO_4	64,700 as SO_4	Once every 5 days (avg) Twice per day (max)
Condensate polisher system	Regeneration of ion exchange resins	13,200	17,100	None	None	Once every 3 days
Sodium hydroxide (as 100% NaOH)						
Demineralized water makeup treatment system	Regeneration of ion exchange resins	5,000	55,000	2,900 as Na	31,600 as Na	Once every 5 days (avg) Twice per day (max)
Condensate polisher system	Regeneration of ion exchange resin	10,800	141,000	None	None	Once every 3 days

2035 137

TABLE 3.6-3 (Cont'd)

Chemical Used and System Involved	Reason for Use, or Source of Chemical	Estimated Monthly Quantities (lb/mo)* Addition to System Average	Addition to System Maximum	Station Discharge Average	Station Discharge Maximum	Frequency of Chemical Addition
Boron (as B)						
Reactor coolant system	Soluble neutron absorber	20,000 lb/yr	N/A	0.86	0.17 lb/day	N/A
Chromates (as K_2CrO_4)						
Reactor plant component cooling water system	Corrosion control	80 lb/yr	N/A	None	None	N/A
Turbine plant component cooling water system	Corrosion control	365 lb/yr	N/A	None	None	N/A
Ammonia (as NH_3) (28%)						
Steam and power conversion system	Steam generator corrosion control	12,400	27,000	None	None	Continuous
Hydrazine (as N_2H_4) (35%)						
Steam and power conversion system	Feedwater train corrosion control	800	4,500	None	None	Continuous
Iron, Nickel, Chromium Oxides as Indicated						
Main cooling water system	Corrosion products from main condenser	N/A**	N/A	Cr: 44 Fe: 166 Ni: 22	N/A	N/A
Reactor plant service water service	Corrosion products from heat exchangers and service water piping	N/A	N/A	Cr: 6.6 Fe: 830 Ni: 3.4	N/A	N/A
Turbine plant service water system	Corrosion products from service water piping	N/A	N/A	Cr: 1.7 Fe: 127 Ni: 0.84	N/A	N/A

NOTES:

* Based on 100-percent capacity

** Not applicable

2035 138

TABLE 3.6-4

CHEMICALS USED FOR INITIAL STARTUP (PER UNIT BASIS)

Chemical	System and Purpose	Quantity (lb)
Sulfuric Acid (as 93% H_2SO_4)	Regeneration of cation resins	14,471
Sodium Hydroxide (as 100% NaOH)	Regeneration of anion resins	10,978
Ammonia (as NH_3) (28%)	Wet layup of steam generators	24
Hydrazine (as N_2H_4) (35%)	Wet layup of steam generators	165
Chromates (as K_2CrO_4)	Corrosion inhibitor for the reactor plant component cooling water system	1,600*
	Corrosion inhibitor for the turbine plant component cooling water system	100*

NOTE:

* The quantity shown is that required to charge the system during the initial fill. There is no discharge from this system.

2035 139

TABLE 3 6-5

ESTIMATED COMBINED DISCHARGE CHEMICAL CHARACTERISTICS

Constituent (mg/l except where noted)	Concentration (mg/l unless noted) Average*	Maximum*	Monthly Quantities Added (lb/mo.) Average	Maximum
Alkalinity, total as $CaCO_3$	84	86		
Chlorides	95.5	243		
Sulfate	255	357	765,500	1,104,200
Phenols (ug/l)	3.2	24		
Ammonia N (total)	0.06	0.24		
Nitrite N as N	0.01	0.04		
Nitrate N as N	0.55	1.96		
Nitrogen (organic) as N	0.76	1.94		
Orthophosphate as P (total)	0.01	0.08		
Phosphorus as P (total)	0.04	0.16		
TDS	609	1,490	769,000	1,135,300
TSS	7.3	31.1		
Silica	0.76	3.8		
Aluminum	0.251	1.54		
Calcium	114	261		
Cadmium (ug/l)	0.47	3.7		
Chromium (ug/l)	14.6	37.0	52.3	NA
Copper (ug/l)	6.72	26.4		
Iron	0.40	1.24	1,123	NA
Lead (ug/l)	<2.92	7.88		
Magnesium	24.2	52.2		
Manganese	0.02	0.10		
Mercury (ug/l)	<0.62	3.93		
Nickel (ug/l)	<15	63	26.2	NA
Potassium	4.09	9.77		
Sodium	44.5	137	2,900	31,100
Zinc (ug/l)	89.1	327		
pH	7.83	6.0 to 9.0		
Organic carbon (total)	9.1	24		
Fluoride	0.38	0.91		
Cyanide (total) $Fe(CN)_6$	<0.01	<0.03		
Beryllium (ug/l)	<3.21	9.09		
Boron (ug/l)	102	273	0.15	3.06
Cobalt (ug/l)	<4.67	27.3		
Molybdenum (ug/l)	<149	330		
Selenium (ug/l)	<4.97	24.2		
Vanadium (ug/l)	<353	1,330		
Iodine	<0.82	<5.45		
Arsenic (ug/l)	<5.55	18.2		
Oxygen, dissolved	9.1	7.3 (min)		
Chlorine, free available	0.2*	0.5*		

NOTE:
* Free available chlorine concentrations refer to the daily, 2-hr period (40 CFR423. At all other times, there is no measureable discharge of chlorine.

2035 140

LIST OF EFFECTIVE PAGES
(Amendment 5, August 1979)

Page, Table (T), or Figure (F)	Amendment Number
4-i thru 4-iv	4
4-v thru 4-vi	3
4-vii	3
4.1-1	0
4.1-2	[illegible]
4.1-2a	1
4.1-3 thru 4.1-6d	3
4.1-7 thru 4.1-10	1
4.1-11 thru 4.1-12	2
4.1-12a	1
4.1-13	0
4.1-17 thru 4.1-18a	4
4.1-19	1
4.1-20 thru 4.1-30	0
4.1-31	3
4.1-32	0
4.1-33 thru 4.1-35	1
4.1-36 thru 4.1-38d	3
4.1-39 thru 4.1-61	0
4.1-62 thru 4.1-69	3
T4.1-1(1 of 1)	3
T4.1-2(1 of 1)	3
T4.1-3(1 of 1)	0
T4.1-4(1 of 2 thru 2 of 2)	0
T4.1-5(1 of 1)	0
T4.1-6(1 of 1)	0
T4.1-7(1 of 2 thru 2 of 2)	0
T4.1-8(1 of 2 thru 2 of 2)	0
T4.1-9(1 of 1)	0
T4.1-10(1 of 1)	1
T4.1-11(1 of 2 thru 2 of 2)	1
T4.1-12(1 of 1)	0
T4.1-13(1 of 2 thru 2 of 2)	0
T4.1-14(1 of 3 thru 3 of 3)	0
T4.1-15(1 of 1)	1
T4.1-16(1 of 1)	5
F4.1-1 thru F4.1-2	0
F4.1-3	1
F4.1-4 thru F4.1-10	0
F4.1-11 thru F.1-12	1
F4.1-13	5
4.2-1 thru 4.2-30	0
T4.2-1(1 of 2 thru 2 of 2)	0
T4.2-2(1 of 3 thru 3 of 3)	0
T4.2-3(1 of 1)	0
F4.2-1 thru F4.2-5	0
4.3-1	0
4.3-2	1
4.3-3	0
4.4-1 thru 4.4-2	0
T4.4-1(1 of 1)	0
T4.4-2(1 of 1)	0
4.5-1 thru 4.5-4a	3
4.5-5 thru 4.5-9	1
T4.5-1(1 of 1)	1

2035 141

Page, Table (T), or Figure (F)	Amendment Number
T4.5-2(1 of 2)	0
T4.5-2(2 of 2)	1
T4.5-3(1 of 1)	0
4.6-1	0
F4.6-1	0

2035 142

TABLE 4.1-15

EFFECT OF SWITCHYARD EXCAVATION ON PRIVATE WELL SYSTEMS

Well* No.	Surface** Elev. (ft)	Distance to*** Excavation (ft)	Well Elev. (ft)	Depth** (ft)	Existing**** Water Level Elev. (ft)	Calculated Drawdown (ft)	Effect on Well/Comments
89	410	540	398	12	410	8	New well to be installed
90	414	610	394	20	410	5	New well to be installed
91	418	570	398	20	410	7	New well to be installed
92	420	500	330	90	410	9	Minor-deep drilled well
93	420	475	unknown		410	10	Assume shallow dug well; new well to be installed
94	420	430	382	38	410	11	New well to be installed
95	424	440	364	60	410	10	Minor-deep drilled well
97	434	380	339	95	410	13	Minor-deep drilled well
99	435	470	355	80	410	10	Minor-deep drilled well

NOTES:

* See Figure 2.1-18 and 4.1-11 for location of wells.
** From Table 2.1-46
*** Scaled distance (Fig. 4.1-11) from excavation slope
**** Water level used in computer model

2035 143

TABLE 4.1-16

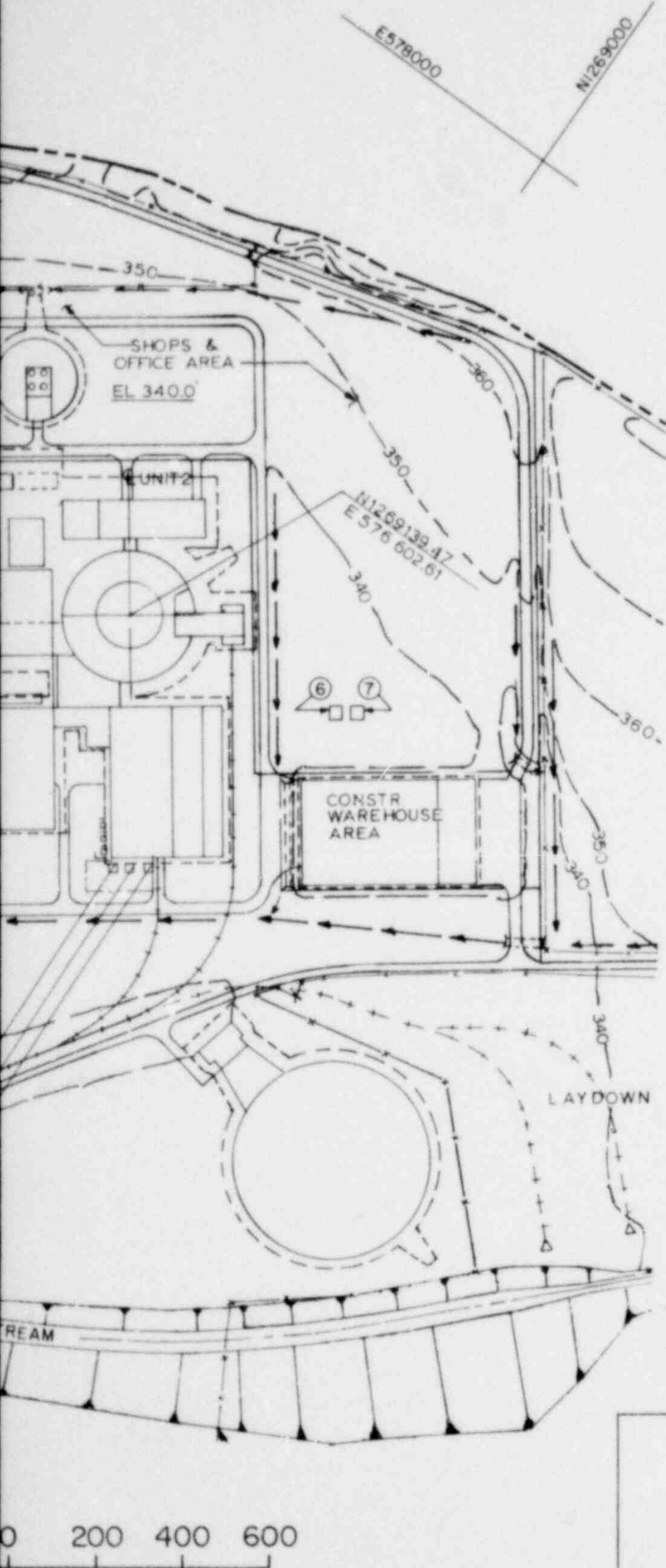
EXPECTED STORAGE OF CONSTRUCTION OILS, LUBRICANTS, AND CHEMICALS*

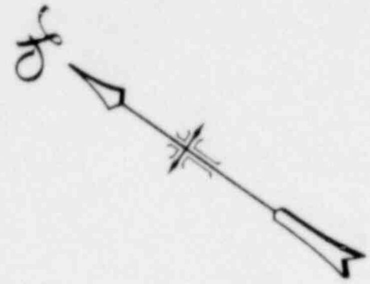
Material	Container	Total Storage (gal)	Expected Containment
Fuel oil (batch plant boiler)	Tank	5,000	Below ground
Diesel fuel oil	Tank	20,000	Below ground
Leaded and unleaded gasoline	Tanks	20,000	Below ground
Kerosene	Tank	15,000	Below ground
Lubrication oil (all types and grades)	55 gal drums	10,000	Curbed area within enclosed facility
Cleaning solvents	55 gal drums or	1,400	Enclosed trailer
Paint, thinner, and solvents	Small containers	1,000	Enclosed trailer
Sulfuric acid (93%)	Tank	500	Curbed area within potable water treatment building
Sodium hydroxide (50%)	Tank	500	Curbed area within potable water treatment building
Sodium hypochlorite (15%)	Tank	200	Curbed area within sanitary waste treatment building

NOTE:

* Refer to Figure 4.1-13 for storage locations of above items

2035 144





KEY

① BATCH PLANT BOILER FUEL OIL TANK
② DIESEL FUEL OIL TANK
③ UNLEADED AND LEADED FUEL TANKS
④ KEROSENE STORAGE TANK
⑤ LUBRICATION OIL (ALL GRADES & TYPES) IN 55 GALLON DRUMS
⑥ CLEANING SOLVENTS
⑦ PAINT, THINNER AND SOLVENTS
⑧ SULFURIC ACID AND SODIUM HYDROXIDE
⑨ SODIUM HYPOCHLORITE

ITEMS ① THROUGH ④ WILL BE BELOW GROUND STORAGE. ALL OTHER ITEMS WILL BE STORED WITHIN AN ENCLOSED FACILITY. TABLE 4.1-16 LISTS ESTIMATED QUANTITIES FOR ABOVE ITEMS.

LEGEND

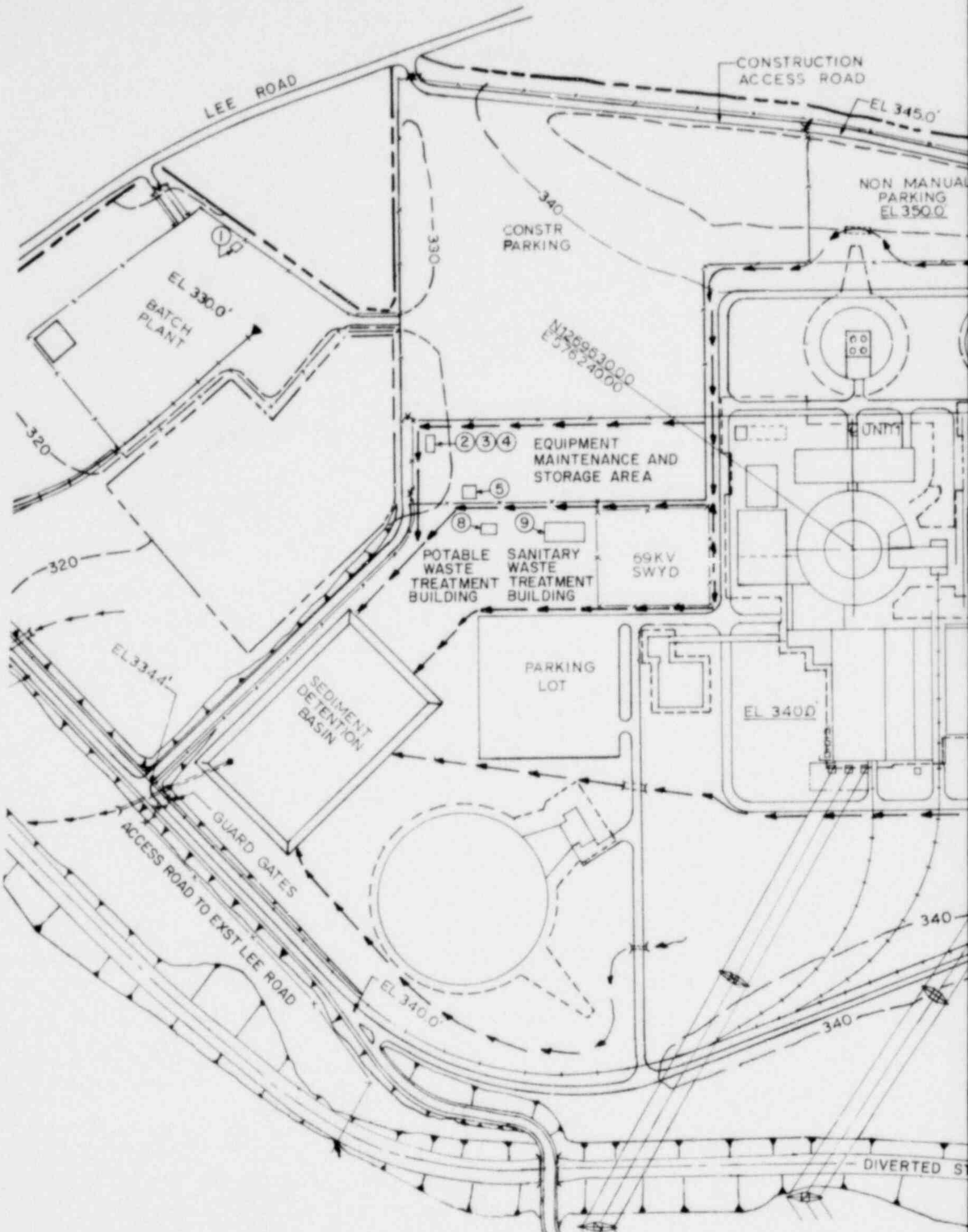
MAJOR EXCAVATION
LIMIT OF CONSTRUCTION
DRAINAGE DITCHES
CULVERT
CONSTRUCTION FENCE
---360--- PROPOSED CONTOURS

FIGURE 4.1-13 NEW HAVEN SITE

LOCATION OF STORAGE FACILITIES FOR CONSTRUCTION LUBRICANTS, OILS, AND CHEMICALS

NEW YORK STATE ELECTRIC & GAS CORPORATION
ENVIRONMENTAL REPORT

2035 145



NOTES:

1. SCALE: AS SHOWN
2. REF DWG: FIGURE 3.1-15

200

2035 146

LIST OF EFFECTIVE PAGES
(Amendment 5, August 1979)

Page, Table (T), or Figure (F)	Amendment Number
10-i thru 10-ii	0
10-iii	0
10-v	0
10.1-1 thru 10.1-6	0
10.1-7 thru 10.1-11	1
T10.1-1(1 of 1)	0
T10.1-2(1 of 1)	0
T10.1-3(1 of 1)	0
T10.1-4(1 of 1)	0
T10.1-5(1 of 2 thru 2 of 2)	0
T10.1-6(1 of 1)	0
T10.1-7(1 of 2 thru 2 of 2)	0
T10.1-8	0
F10.1-1 thru 10.1-12	0
10.2-1	5
10.2-2 thru 10.2-3	0
10.3-1	0
10.4-1	0
10.5-1	0
10.6-1	0
10.7-1	0
10.8-1	0
10.9-1 thru 10.9-8	0
T10.9-1(1 of 1)	0
T10.9-2(1 of 1)	0
T10.9-3(1 of 1)	0
T10.9-4(1 of 1)	0
T10.9-5(1 of 1)	0
F10.9-1 thru 10.9-5	0
10.10-1	0
F10.10-1	0

2035 147

10.2 INTAKE SYSTEM

The makeup water intake system diverts water from Lake Ontario to replace water lost due to evaporation, blowdown, and drift in the circulating water system cooling tower and ultimate heat sink, and plant consumptive use.

Proposed Intake System

The proposed intake system consists of an offshore submerged velocity cap inlet structure, an onshore pumphouse, and the connecting conduits between the inlet structure and the pumphouse, and between the pumphouse and the turbine building. The inlet structure is located in Lake Ontario as shown in Figure 3.4-4. Section 3.4.3 describes the system.

The proposed makeup water intake system is designed to minimize the potential for fish entrapment within the system and impingement of fish on the traveling screens. It is also designed to reduce the potential for entrainment of bed load silt and benthic organisms. To achieve this, the following features have been incorporated into the offshore inlet design:

1. Low uniform approach velocities at the inlet face (less than 0.5 fps) by utilizing a velocity cap

2. Submerged inlet located 6 ft above lake bottom

3. Inlet located in an area and at a depth based on biological field studies

4. The inlet base is constructed of solid concrete with the inlet face flush with the sill. This feature and the absence of riprap ensures that the inlet structure will not create a new habitat

Information pursuant to approval of the intake system in accordance with Section 316(b) of PL92-500 is provided in the Applicant's 316(b) Demonstration, New Haven Site, issued January 1979. Consistent with the Development Document for 316(b) published by the EPA[1], the proposed intake system employs the best technology available commercially at an economically practicable cost for minimizing adverse environmental impact, including that due to fish entrapment and impingement.

Alternative intake systems considered are Ranney radial collector wells, shoreline intake structure, and an offshore stationary screen intake. These alternative systems represent typical variations of available generic engineering designs. They were considered promising in terms of environmental protection or economics.

Ranney Radial Collector Well System

The Ranney radial collector well system consists of large diameter caissons or wet wells excavated into the ground near the Lake Ontario shoreline. The

collector system for each well would be comprised of a number of smaller diameter slotted well screen pipes extending radially outward from the caisson. During system operation, ground water would flow through the slotted well screen pipes into the central caisson. Vertical wet pit pumps would withdraw the water and discharge it into the pipeline leading to the station site.

Investigations conducted to date near the shoreline area indicate that the low permeability rock is very shallow, typically less than 20 ft below grade. Under such circumstances, the aquifer (which would be recharged by the lake) required to supply the makeup water requirements would not be available. This information indicates that this alternative is not feasible at this site.

Shoreline Intake Structure

A shoreline intake structure, located on the south shore of Lake Ontario, was considered. The structure would include trash racks, traveling screens, and six 50-percent capacity makeup water pumps. The face of the traveling screens would be directly aligned with the shoreline. The trash racks and remainder of the structure would protrude into the lake. Concrete curtain walls would be provided to prevent surface ice and large debris from entering the structure and damaging operating equipment. An approach channel would be excavated to ensure water availability in the event of the formation of pack ice windrows. A deicing system would also be necessary to insure availability of the makeup water system.

The southern shoreline of Lake Ontario is subject to extensive surface water freezing and pack ice problems. Ice loadings on shoreline structures can become severe enough to cause structural failure. A deicing system would not be adequate to ensure system availability during these times, nor protect the intake structure against wind-blown pack ice. There is no assurance that an approach channel, regardless of depth, would remain unblocked by pack ice. For these reasons, the system is not feasible at this site.

Offshore Stationary Screen Intake

An offshore stationary screen intake, employing Johnson wedge wire screens, would consist of three sets of screens. Each set would consist of two 4-ft diameter by 6-ft long screens attached to a center tee. The slot width would be 10 mm. Based on a total makeup flow of 36,372 gpm, the through-the-slot velocity would be 0.3 fps. Each screening unit (located 3,000 ft offshore) would convey the water through individual pipelines which would be located inside a tunnel (similar to the proposed intake system). The onshore pumphouse would not require trash racks or traveling screens, since the offshore screens would prevent debris from entering the system. The onshore pumphouse would, therefore, be much smaller than the proposed pumphouse.

The offshore screens are much more susceptible to blockage by frazil ice (initial stage of ice crystalization) and anchor ice and by biological growth than is the proposed offshore inlet structure. In Lake Ontario, the potential exists for floating mats of Cladophora, an aquatic vegetation, to become

2035 149

LIST OF EFFECTIVE PAGES
(Amendment 2, April 1979)

2035 150

Page, Table (T), or Figure (F)	Amendment Number
(2.5I)A3 Chem Anal 1 thru 3(Att 3)	1
(2.5I)A4 Cover(Att 4)	1
(2.5I)A4 Ltr R-204-1 thru R-204-7	1
(2.5I)A5 Cover(Att 5)	1
(2.5I)A5 Chem Anal 1 thru 7(Att 5)	1

2035 151

Stratigraphic offset between Borings R-29 and R-27 is approximately 6 ft (Figure 2.5I-8). The true sense of this offset is not determinable due to the intervening folding. However, based on subsurface data (Figure 2.5I-8), the offset appears to be of a reverse sense. Offset across the main fault zone exposed in the trench floor is approximately 12 to 15 ft of normal movement. Offsets along the R-5/P-2 boring alignment (Figure 2.5I-10) indicate the same type of structural features and styles of displacement. However, lack of bedrock control limits the subsurface interpretation.

Delineation of the structural zone on the R-5/P-2 boring alignment (Figure 2.5I-10) was provided mainly by Boring R-14, which crosscuts the fault zone from 202 ft to 246 ft downhole. Also, Boring R-13 was collared in intensely brecciated and gouged strata but entered unbroken rock at a depth of 84.3 ft downhole. Data from these two borings indicate that the fault zone dips approximately 73° northwestward. Additional subsurface control was provided by Borings R-5, R-17, and P-2.

The boring data indicate an elevation differential of 94 ft on the Oswego/Pulaski boundary between Borings P-2 and R-5; most of this elevation differential occurs northwest of the fault zone. This major offset is due to broad folding with the Oswego/Pulaski boundary higher to the northwest as on the R-9/R-11 boring alignment (Figure 2.5I-8). Stratigraphic offset between Borings R-14 and R-13 shows approximately 19 ft of reverse displacement. An exact amount of offset at the fault plane is somewhat uncertain due to complex folding in the fault zone, as determined from the dip analysis (Figure 2.5I-17). The offset, however, appears to be approximately 10 ft with the northwest side down.

Detailed mapping indicates the bedrock structures exposed in Trench II can be subdivided into three small-scale structural domains for description and analysis. These domains are delineated on the basis of deformation style and structural elements. The southeast domain, Stations 9+48 to 10+40, is characterized by steeply southeast-dipping, Zone 2 strata grading to gentle, southeast-dipping, Zone 3 strata. No faults or folds are observed in the southeast domain. Joints and minor bedding plane slips are the only structural elements recognized, besides the partial limb of the main fold. The joint pattern consisting of five joint sets is plotted on Pi-diagrams shown on Figure 2.5I-21.

The central domain bounded at Stations 9+48 and 8+78 by faults with normal movement consists of intensely-fractured, faulted, and folded strata (Zone 1 and two minor amounts of Zone 2). This domain shows the greatest amount of deformation exposed in the trench and characteristically, exhibits bedding plane gouge, flexural slip, folding, and faulting.

The northwest domain, Stations 8+78 to 8+00, consists of gentle, southeast-dipping, Zone 1 strata. Small-scale reverse faulting and joints are the predominant structural elements. The joint pattern in this domain is shown on Figure 2.5I-6. Bedding dips recorded in all three structural domains reflect the areal southwest-plunging fold, and appear in cored boring data to continue northwestward to about Boring R-2.

2.5I.3.4.2 Southeast Structural Domain

The southeast structural domain extends from Stations 9+48 to 10+40 and exhibits deformation resulting from folding and reverse faulting in the central structural domain. However, no faults or folds occur within this domain.

Geological details of the trench floor are shown on Figure 2.5I-6. Mapping shows that from Stations 10+40 to 10+20, Zone 3 strata are lying sandstones and shales which exhibit an areal structural dip of 2°-6°SE. Section 2.5I.2.4 gives a detailed description of Zone 3 strata. Joints are well developed, mineralized with calcite, and stained with iron oxides that impart a distinct coloration to the bedrock. Joints are invariably parallel to the main N45°E fault structure and the areal folding trend (Figure 2.5I-21). Between Stations 10+20 and 9+98, Zone 3 strata increase in dip to 6°-15°SE. Steepening in the areal structural dip from the observed 2°-6°SE is related to folding and subsequent reverse faulting (Figure 2.5I-5). At Station 9+98, Zone 3 strata change to shales and fossiliferous sandstones of Zone 2. The lithologic aspects of Zone 2 and details of the sedimentological criteria for this stratigraphic division are discussed in Section 2.5I.2.2 Zone 2 strata exposed between Stations 9+98 and 9+51 increase in dip from 15°-30°SE. Both jointing and the amount of calcite mineralization increase in frequency. Shales and siltstones in this area are intensely jointed and disintegrate rapidly when exposed. Fractures and joints primarily develop along bedding planes with cross joints subordinate (Figure 2.5I-6). Calcite and associated minor sulfides (pyrite, marcasite, sphalerite, chalco pyrite, and galena) are preferentially developed in sandstones and to a lessor extent in siltstones; shales are invariably barren of calcite. Details of sulfide textures, paragenesis, and occurrence are described in Section 2.5I.4.4.

The Zone 1/Zone 2 contact at Station 9+51 is marked by the occurrence of marker Bed B, a thick bedded sandstone finely laminated at the top. This bed dips 35°SE. Subsurface data from Borings R-27 and R-12 combined with the Trench II exposure indicate that the underlying strata strike uniformly N45°E. Between Stations 10+40 and 9+48, structure contours (Figure 2.5I-5) show a similar strike on an areal scale. This bedding strike and dip are at variance with the reported regional dip for this part of New York State (Broughten et al, 1966; Patchen, 1968; and McCann et al, 1968). Deviation in trend and dip are due to the low amplitude, southwest-plunging folds outlined by the structure contours on Figures 2.5-14 and 2.5-15.

2.5I.3.4.3 Central Structural Domain

The geology and structure of the central structural domain (Stations 9+48 to 8+78) are shown on Figures 2.5I-6 and 2.5I-13. This domain exhibits two phases of faulting, with one phase post-folding of Demster Beach anticline. The principal feature of this domain consists of the main fault zone, between Stations 9+48 and 9+45, that exhibits the maximum amount of movement. Boring R-12 intersects this fault zone at a depth of 173 ft downhole which results in a strike of N45°E, and dip of 70°NW.

Potassium-Argon age determinations were made on clay minerals from the gouge and rock samples. The clay minerals were removed from samples by Dr. R. T. Martin, and these concentrates were checked for purity by x-ray diffraction. Results of the K-Ar dating are listed in Attachment 5. Figure 2.5I-23 shows the time relations of the samples.

The siltstone sample has an inferred age of 488±14 m.y.a., which is slightly older than the acknowledged depositional age of the rock. An age older than the depositional age of the rock indicates that the clay minerals analyzed were not heated in past geologic history to a sufficient temperature that would allow the complete escape of radiogenic argon from the clay minerals. Only when radiogenic argon is completely lost from a sample during an event can that event be dated with certainty. Consequently, the incomplete loss of argon will yield an inferred age that is significantly older than the age of the actual event. The excess age is proportional to the excess pre-event argon that did not escape and can represent an error of tens of millions of years.

Since the age of the siltstone sample is older than the age of diagenesis, it can be concluded that the heat produced during diagenesis was not sufficiently high to completely remove the excess argon produced in the clays prior to deposition. The six gouge samples give ages from 392 m.y.a. to about 430 m.y.a. The sample with the youngest age is from the largest area of gouge and area of greatest movement. This would indicate that at least some resetting and possibly a complete resetting of the clay through argon release may have occurred. The difference of almost 100 m.y. between the control sample (siltstone) and the gouge sample (T-II-26-NH, Figure 2.5I-23) indicates that a significant amount of resetting did take place. Whether enough heat was generated to completely reset the clays of the gouge samples is unknown.

2.5I.4.5 Conclusions

An exact age of faulting and last movement cannot be assigned based on the mineralogical studies; yet, the various lines of evidence provide several conclusions. Fluid inclusion studies indicate that the calcite formed at depth, possibly with an overlying rock column of 2 km or more. Sulfur isotope data indicate very high $\delta 34S$ values, and most of the sulfide was produced by bacterial reduction of limited sulfate. Sulfur isotope data eliminate the possibility of a hypothetical igneous mass as the source of the mineralizing fluid for the sulfides and calcite. Since only nonmagnetic sulfides are present in the veins, any explanation of the fluid inclusion temperatures involving unknown magnetic activity must be precluded. Detailed petrographic studies of the vein minerals agree with this hypothesis.

All deformational features in the calcite are minor. Deformation occurs in the middle of the one-time mineralized sequence. Furthermore, deformation was not sufficiently pervasive to open new fractures in the preexisting mineralized areas. End stages of the mineral sequence are not deformed. Detritus (see Attachment 1) deposited during this sequence may be related to the stress relaxation interval of the fold/fault structures.

Potassium-Argon age determinations yield an age of around 400 m.y. for samples of clays. However, the similarities in the clay mineralogy of the gouge samples and control samples and the probability of partial resetting of Argon in the clays analyzed prevent a conclusive determination of the age of minerals and time of last movement of the Demster Structural Zone.

2.5I.5 Field Geophysical Surveys

2.5I.5.1 Introduction

Land seismic refraction and magnetometer surveys and an offshore seismic survey were conducted in the vicinity of the Demster Structural Zone.

Seismic refraction measurements across the Demster Structural Zone showed that the zone of intense deformation is evidenced by a seismic velocity anomaly. Subsequently, seismic coverage was extended to the southwest to investigate the trend of the structural zone and to the west to determine whether a suspected, mirror-image, structural zone exists. The results of the seismic investigation showed no evidence of such a structural zone (Section 2.5I.5.2.4).

An offshore seismic survey, including seismic refraction and reflection measurements, was conducted in the Mexico Bay area of Lake Ontario to determine whether the Demster Structural Zone could be traced and/or detected along its northeast projection. The results of the offshore seismic survey did not show any evidence of faulting in the study area (Section 2.5I.5.3.4).

A reconnaissance land magnetometer survey was undertaken across the Demster Structural Zone and its northeastern and southwestern projections to determine if magnetic signature could be used to identify near-surface faulting. The land magnetometer survey was not able to accurately locate the intense deformation of the Demster Structural Zone (Section 2.5I.5.4).

2.5I.5.2 Land Seismic Refraction Survey

2.5I.5.2.1 Introduction and Purpose

A seismic refraction survey was conducted in the vicinity of the Demster Structural Zone. The seismic work was completed in stages, starting in September of 1977 and ending in July 1978. A total of 23,170 ft of seismic refraction profiling was accomplished (Figure 2.5I-1).

The overall objective of the seismic refraction survey was to determine depths to bedrock, as well as seismic (compressional) velocities of the bedrock in an attempt to delineate the known structural zone.

The study began with a broad reconnaissance survey at a few selected locations in the vicinity of Boreholes R-1, R-2, R-5 and in the vicinity of the quarry (Boring R-15) during the fall of 1977. The purpose of these seismic lines was to investigate possible anomalous geologic conditions in bedrock and outline the fault zone.

2.5I.6.3 Possible Causes Folding/Faulting Eastern Stable Platform

The origin and possible causes of folding/faulting throughout the Eastern Stable Platform sector of central New York are much less clearly understood than structures in the Appalachian Plateau sector to the south. They may be related in origin, yet, there are limitations to many of the possible correlations involving geologic events, structures, and hypotheses of origin between the provinces.

The shorter-length anticlinal and synclinal structures of the Eastern Stable Platform sector (Figure 2.5-5A) exhibit some of the characteristics of the Appalachian Plateau-type folds and may have originated due to the causes discussed in Section 2.5I.6.2. However, the folds of the Platform differ in certain critical aspects, such as:

1. folds occur in Ordovician-Cambrian rocks within 1,000 to 2,000 ft of Precambrian basement throughout the Platform. Apparently, these early formations are not always folded in the Appalachian Plateau sector where they occur at depth below the many regional folds (Figure 2.5-5A);

2. thick salt beds are not a part of the rock column as they are to the south where folds are extensive in Appalachian Plateau sector. However, thick shales do occur beneath the Ordovician/Oswego Sandstone (Pulaski and Utica Shales) and could act in a similar manner to salt to enhance thin-skin deformation;

3. the trend of folds is about S50°W (Auburn, New Haven and Pulaski sector and beyond) while the main Appalachian Plateau trend is about east-west in New York. However, the Appalachian trend does bend and approach a southwest direction west of Seneca Lake (Figure 2.5-5A) and particularly southward into Pennsylvania. This sector of southward-trending folds does project northeastward through Auburn, the site area, and the Pulaski folds and beyond (Figure 2.5-5A);

4. axial planes of folds in Oswego/Mexico sector dip steeply northwestward.

A number of investigators have advanced hypotheses to account for the folding and faulting of the Eastern Stable Platform sector of central New York. Tensional deformation is recognized in the Mohawk Valley of eastern New York as the Chamhawkian Taphrogeny (Hypothesis No. 2, Section 2.5I.7.1) by Fisher (1977). This post-Taconic (post-Utica Shale) deformation is expressed principally as normal faults with a maximum displacement of 1,500 ft (Kay, 1942). The deformation is considered mid-Silurian of 430-420 m.y.a. The exact age relationships of this deformation is clouded; mapping does not show any strata younger than mid-Silurian deformed (Fisher et al, 1970). In central New York, structural contour data on the Lockport formation (mid-Silurian) delineate apparent northeast-trending fold structures near Auburn (Figure 2.5-5A). Available evidence suggests that tensional forces were

2035 156

greatest in eastern New York (i.e., asymmetric) and resulted in northeast-trending normal faults around the Adirondack uplift and eastern edge of Tug Hill plateau such as near Utica, at Lowville and Carthage. Broad, low-amplitude folds and minor faults are recognized by Johnson (1971) in the Ordovician Black River and Trenton carbonates, some 50 mi northeast of the site. In central New York, mid-Silurian deformation has not been documented to date, but might conceivably be expressed by the southwest-plunging folds (Demster Beach, New Haven, and Mexico) and associated faulting of the site area including the Demster Structural Zone.

Another possible mechanism responsible for the deformation might be asymmetric basin subsidence (related to Hypothesis No. 3, Section 2.5I.7.1); the deformation style would be a function of the existing stratigraphic thickness. For example, one could speculate that, in eastern New York, the folds associated with this deformation have been eroded away while those in Oswego County of central New York are preserved. By early Devonian, deformation ceased and, if so, would account for the absence of northeast-trending deformation in strata younger than the Silurian. However, this trend occurs southwestward in the Appalachian Plateau.

Subsidence of the sedimentary basin on an areal scale might conceivably be associated with at least the northern part of the Appalachian basin (Hypothesis No. 3, Section 2.5I.7.1). Local folding and faulting would be attributed to forces acting from a variation in sediment thickness and differential loading. Local and areal downwarping was originally suggested by Hartnagel and Russel (1929) as a possible mechanism for the widespread folding of Paleozoic beds throughout central-southern New York. Price (1966) demonstrates that basin subsidence, due to tensional tectonics, can result in structures that are similar to ones caused by compression.

Cambrio-Ordovician strata, some 75 miles northeast of the site area, are folded into broad, small-scale, northeast-trending folds (Barber and Bursnall, 1978). At localities 20 mi further to the northeast, near Ogdensburg, in the St. Lawrence lowlands, similar northeast-trending folds have been described by Chadwick (1915) as post-Ordovician. Movements in the basement rocks may have occurred due to strain concentrations caused by abrupt changes in basement relief (Barber and Bursnall, 1978).

Uplift of the northern part of the Appalachian basin, due to Canadian shield and/or Adirondack uplift, is described in Section 2.5.1.1.4.3 as a possible origin for regional dip. If such an uplift acted differentially on the basement and overlying Paleozoic rocks, conceivably the northeast trending folding/faulting could occur as a result (Hypothesis No. 4, Section 2.5I.7.1).

2035 157

REFERENCES

Barber, B. G. and J. T. Bursnall, 1978, "Deformation Structures in Lower Paleozoic Rocks Northwestern New York", 50th Annual Meeting Guidebook New York State Geological Association, D. F. Merriam (ed.), pp. 48-57.

Barnes, H. L., 1977, "Fluid Inclusion Analyses for Dames & Moore, Inc.", in Nine-Mile Point Nuclear Station, Geologic Investigation, Vol. I (1978).

Broughton, J.G., D. W. Fisher, Y. W. Isachsen, and L. V. Rickard, 1966, "Geology of New York, A Short Account", New York State Museum and Science Service, Educational Leaflet No. 20, 45 p.

Chadwick, G. H., 1915, "Post-Ordovician Deformation in the Saint Lawrence Valley, New York", Geological Society of America Bulletin 26, pp. 287-294.

Chute, N. E., 1969, "Structural Features in the Syracuse Area", New York State Geological Association 36th Annual Meeting Guidebook to Field Trips, Prucha, JJ (ed.), pp 74-127.

Coates, D. R., S. O. Landry, and W. D. Lipe, 1971, "Mastodon Bone Age And Geomorphic Relations in the Susquehanna Valley", Geological Society of America Bulletin, Vol. 82, pp. 2005-2010.

Dames and Moore, 1978, "Nine-Mile Point, Nuclear Station, Geologic Investigation, Three Volumes, Niagara Mohawk Power Corporation, Syracuse, New York.

Engelder, T. and R. Engelder, 1977, "Fossil Distortion and Décollement Tectonics of the Appalachian Plateau", Geology, Vol. 5, pp. 457-460.

Epstein, A. G., J. B. Epstein, and L. D. Harris, 1977, "Conodont Color Alteration - An Index to Organic Metamorphism", United States Geological Survey Professional Paper 995, 27 p.

Eysinga, F. W. B, 1975, "Geological Time Scale", Elsevier, New York, 3rd edition.

Faure, G., 1977, Principles of Isotope Geology, John Wiley & Sons, New York, 464 p.

Fettke, C. R., 1933, "Subsurface Devonian and Silurian Sections Across Northern Pennsylvania and Southern New York", Geological Society of America Bulletin, 44, pp. 601-660.

Fettke, C. R., 1938, "The Bradford Oil Field (McKean County) Pennsylvania and New York", Pennsylvania Geological Survey, 4th Series, M21, 454 p.

2035 158

Fisher, D. W., Y. W. Isachsen, and L. V. Rickard, 1970, "Geologic Map of New York", New York State Museum and Science Service Map and Chart Series 15, 5 sheets.

Fisher, D. W., 1977, "Correlation of the Hadrynian, Cambrian, and Ordovician Rocks in New York State", New York State Museum Map and Chart Series No. 25, 75 pp.

Fullerton, D., 1971, "The Indian Castle Glacial Readvance in the Mohawk Lowland and Its Regional Implications - Parts I and II", Princeton University, unpublished Ph.D.

Frye, J. C., H. B. Willman, M. Rubin, and R. F. Black, 1968, "Definition of Wisconsinian Stage", United States Geological Survey Bulletin, 1274-E.

Hartnagel, C. A. and W. L. Russell, 1929, "New York Oil Fields", Structure of Typical American Oil Fields, Vol. 2, pp. 269-289.

Johnson, J. H., 1971, "Limestones (Middle Ordovician) of Jefferson County, New York", New York State Museum and Science Service Map and Chart Series 13, 88 p.

Karrow, P. F., J. R. Clark, and J. Terasmae, 1961, "The Age of Lake Iroquois and Lake Ontario", Journal of Geology, Vol. 69, pp. 659-667.

Kay, M., 1942, "Ottawa-Bonnechere Graben and Lake Ontario Homocline", Geological Society of America Bulletin, 53, pp. 585-646.

Kindle, E. M., 1904, "A Series of Gentle Folds on the Border of the Appalachian System", Journal of Geology, 12, pp. 281-289.

Kindle, E. M., 1909, "Geologic Structure in Devonian Rocks", in "Description of the Watkins Glenn-Catatonk District", United States Geological Survey Folio, No. 169, pp. 13-15.

Kinsland, G. L., 1977, "Formation Temperature of Flourite in the Lockport Dolomite in Upper New York State as Indicated by Fluid Inclusion Studies - With a Discussion of Heat Sources", Economic Geology, Vol. 72, pp. 849-854.

Kreidler, W. L., A. M. Van Tyne, K. M. Jorgensen, 1972, "Deep Wells in New York State", New York State Museum and Science Service, Bulletin Bulletin 418A, 335 pp.

McCann, T. P., N. C. Privrasky, F. L. Stead, and J. E. Wilson, 1968, "Possibilities for Disposal of Industrial Wastes in Subsurface Rocks on the North Flank of the Appalachian Basin in New York", Subsurface Disposal in Geologic Basins-A Study of Reservoir Strata, J. F. Galley (ed.), American Association of Petroleum Geologists, Memoir 10, pp. 43-92.

Muller, E. H., 1965, "Quaternary Geology of New York", Quaternary of the United States, H. E. Wright and D. G. Frey (eds.), Princeton University Press, Princeton, New Jersey, pp. 99-112.

2035 159