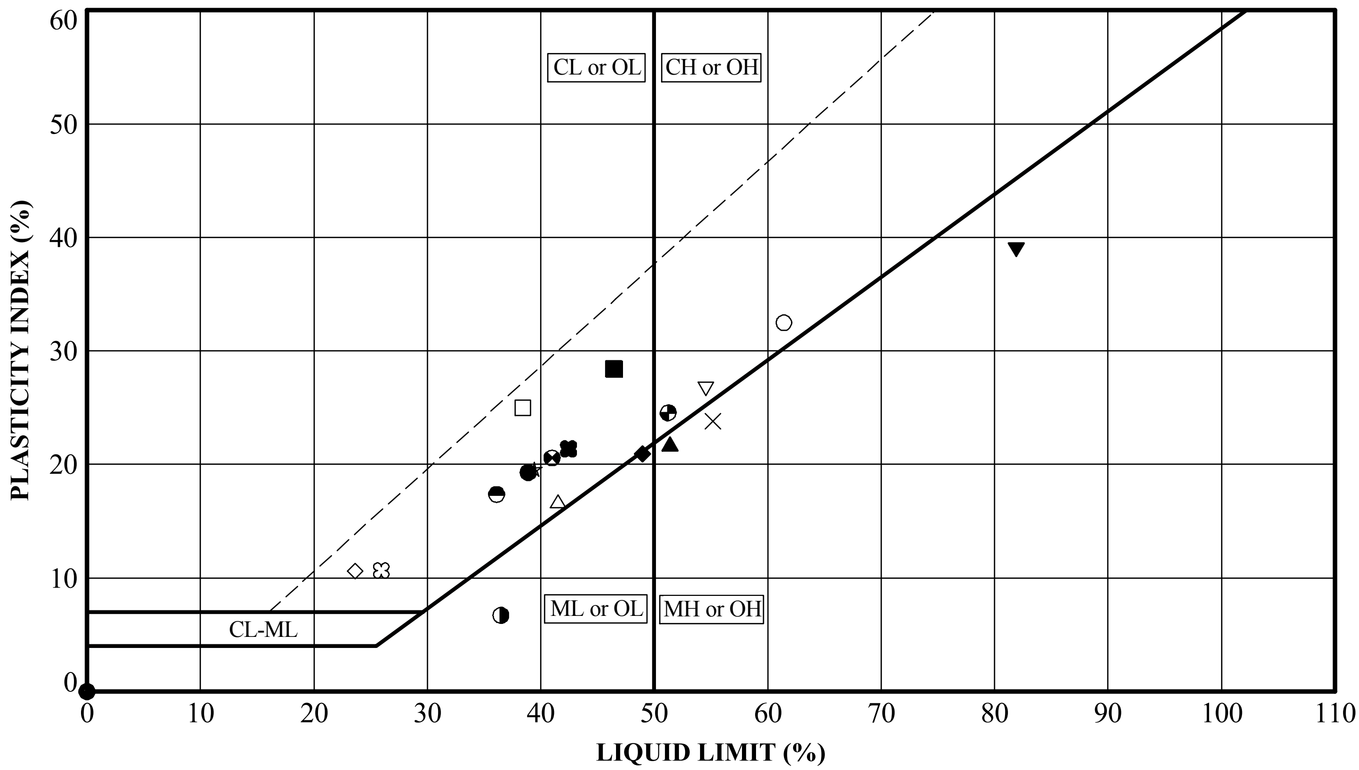

SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-164	54.5	61	29	32	FAT CLAY (CH)
●	G-165	25.5	39	20	19	CLAYEY SAND (SC)
△	G-165	67.5	42	25	17	LEAN CLAY with SAND (CL)
▲	G-165	120.5	51	30	21	ELASTIC SILT (MH)
□	G-166A/B	31.5	38	13	25	SANDY LEAN CLAY (CL)
■	G-166A/B	52.5	46	18	28	LEAN CLAY (CL)
▽	G-166A/B	62.5	55	28	27	FAT CLAY with SAND (CH)
▼	G-166A/B	68.5	82	43	39	ELASTIC SILT (MH)
⊙	G-166A/B	105.5	NP	NP	NP	SILTY SAND (SM)
◇	G-166A/B	115.5	24	13	11	CLAYEY SAND (SC)
◆	G-168	17.5	49	28	21	LEAN CLAY (CL)
⊗	G-168	26.5	41	20	21	LEAN CLAY (CL)
⊕	G-168	97.5	51	27	24	FAT CLAY with SAND (CH)
☆	G-169	14.5	39	20	19	LEAN CLAY (CL)
⌘	G-169	29.5	26	15	11	CLAYEY SAND (SC)
◓	G-169	95.5	36	19	17	SANDY LEAN CLAY (CL)
⊖	G-171	80.5	NP	NP	NP	SILT with SAND (ML)
◑	G-173	80.5	36	30	6	SILT (ML)
×	G-173	100.5	55	31	24	ELASTIC SILT with SAND (MH)
✖	G-174A	60.5	42	21	21	LEAN CLAY (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: JF 6/14/2011
Checked/Date: JAG 6/27/2011

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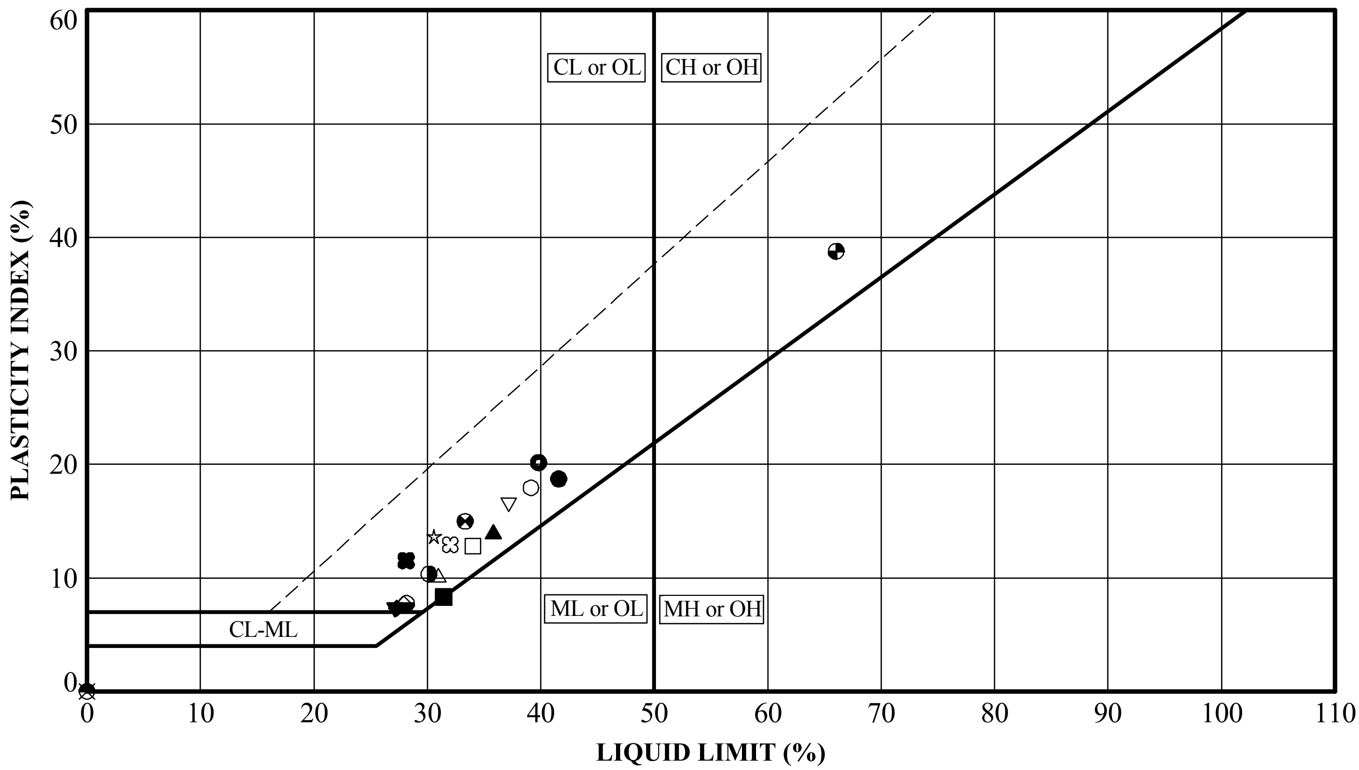
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.14



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-174A	80.5	39	21	18	LEAN CLAY with SAND (CL)
●	G-174A	100.5	42	23	19	LEAN CLAY (CL)
△	G-175	110.0	31	21	10	LEAN CLAY with SAND (CL)
▲	G-175	117.5	36	22	14	SANDY LEAN CLAY (CL)
□	G-175	120.5	34	21	13	SANDY LEAN CLAY (CL)
■	G-175	140.5	31	23	8	LEAN CLAY (CL)
▽	G-176	79.5	37	21	16	SANDY LEAN CLAY (CL)
▼	G-176	90.5	27	20	7	SANDY SILTY CLAY (CL-ML)
◉	G-176	95.5	40	20	20	SANDY LEAN CLAY (CL)
◇	G-176	102.5	28	20	8	CLAYEY SAND (SC)
◆	G-176	120.5	27	20	7	SILTY, CLAYEY SAND (SC-SM)
⊗	G-177	65.5	33	18	15	CLAYEY SAND (SC)
⊕	G-177	75.5	66	27	39	FAT CLAY (CH)
☆	G-177	95.5	31	17	14	CLAYEY SAND (SC)
☒	G-177	105.5	32	19	13	LEAN CLAY with SAND (CL)
◓	G-177	115.5	NP	NP	NP	SILTY SAND (SM)
◒	G-178	20.5	28	20	8	LEAN CLAY (CL)
◑	G-178	40.5	30	20	10	LEAN CLAY (CL)
×	G-178	60.5	NP	NP	NP	SILTY SAND (SM)
✖	G-178	63.0	28	17	11	CLAYEY SAND (SC)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: JF 6/14/2011
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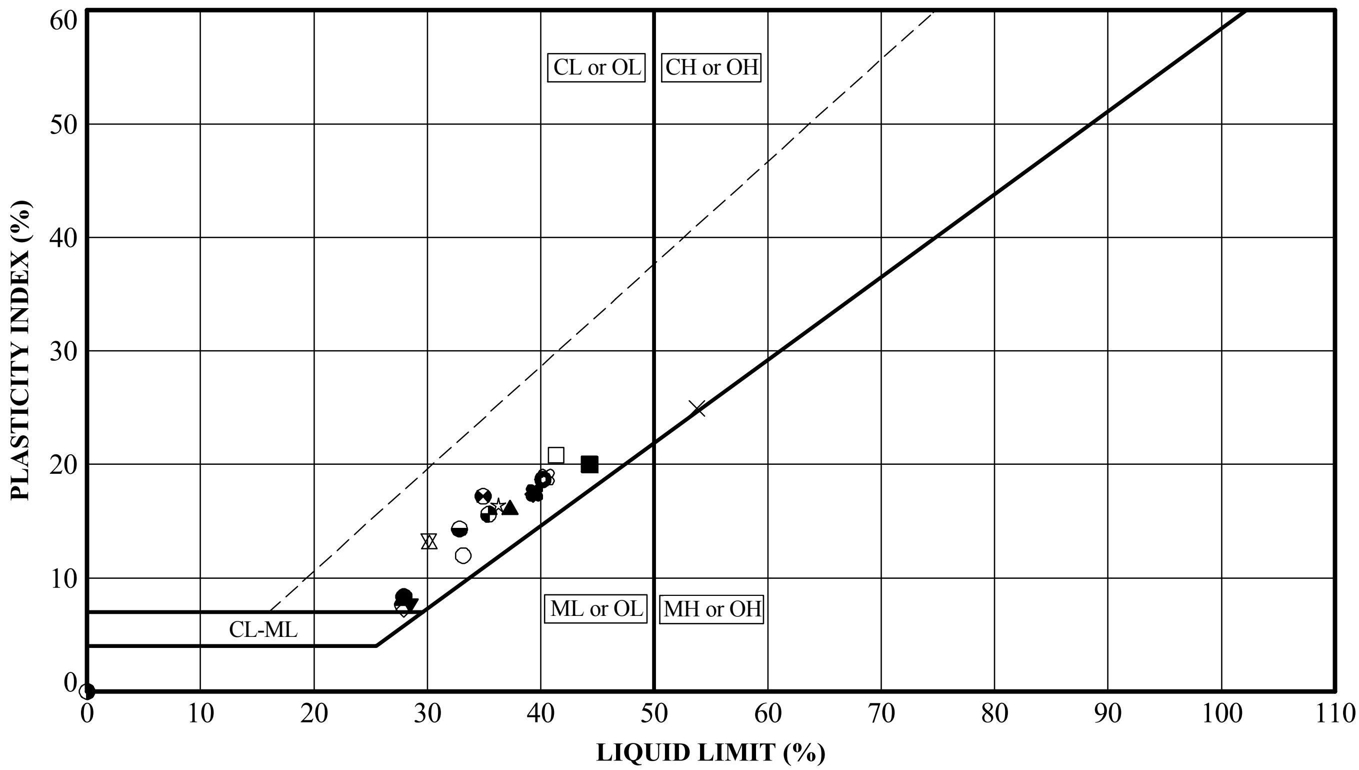
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.15



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-178	68.0	33	21	12	SANDY LEAN CLAY (CL)
●	G-178	70.5	28	20	8	CLAYEY SAND (SC)
△	G-178	78.0	30	17	13	CLAYEY SAND (SC)
▲	G-178	93.5	37	21	16	LEAN CLAY (CL)
□	G-179	45.5	41	21	20	LEAN CLAY (CL)
■	G-179	60.5	44	24	20	CLAYEY SAND with GRAVEL (SC)
▽	G-179	77.5	30	17	13	CLAYEY SAND (SC)
▼	G-179	95.5	29	21	8	SANDY LEAN CLAY (CL)
⊙	G-179	120.5	40	22	18	LEAN CLAY (CL)
◇	G-180	35.5	28	21	7	CLAYEY SAND (SC)
◆	G-180	50.5	39	22	17	LEAN CLAY (CL)
⊗	G-180	70.5	35	18	17	LEAN CLAY (CL)
⊕	G-180	80.5	35	20	15	SANDY LEAN CLAY (CL)
☆	G-180	93.5	36	20	16	LEAN CLAY (CL)
⌘	G-180	98.5	40	22	18	LEAN CLAY (CL)
◓	G-180	105.5	28	20	8	CLAYEY SAND (SC)
◒	G-181	80.5	33	19	14	LEAN CLAY with SAND (CL)
◑	G-181	85.5	NP	NP	NP	SILTY SAND with GRAVEL (SM)
×	G-181	95.5	54	29	25	FAT CLAY (CH)
✖	G-181	105.5	39	22	17	SILT (ML)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: JF 6/14/2011
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ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.16

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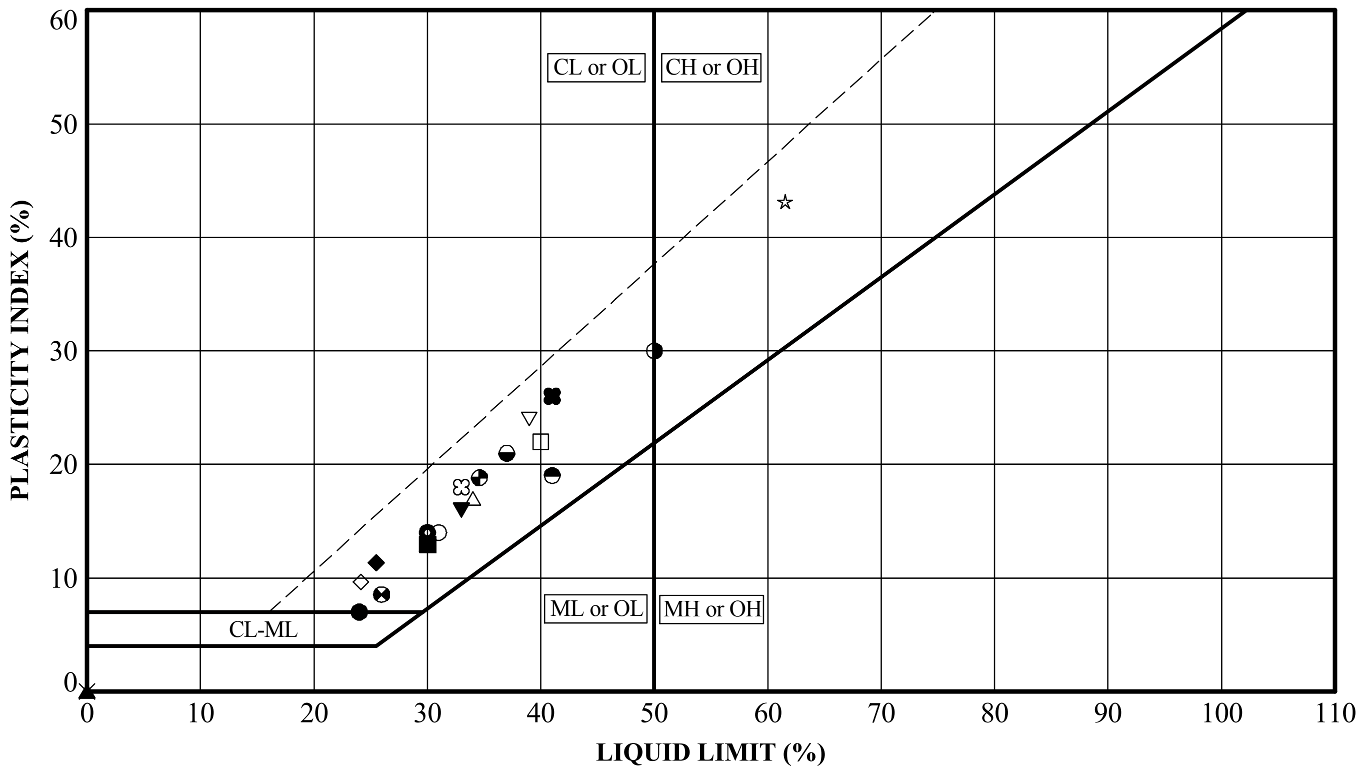

SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-186	5.5	31	17	14	CLAYEY SAND with GRAVEL (SC)
●	G-186	15.5	24	17	7	SILTY, CLAYEY SAND (SC-SM)
△	G-186	25.5	34	17	17	LEAN CLAY with SAND (CL)
▲	G-186	35.5	NP	NP	NP	SILTY SAND (SM)
□	G-186	60.5	40	18	22	LEAN CLAY (CL)
■	G-186	65.5	30	17	13	SANDY LEAN CLAY (CL)
▽	G-186	75.5	39	15	24	LEAN CLAY with SAND (CL)
▼	G-186	80.5	33	17	16	LEAN CLAY with SAND (CL)
⊙	G-186	90.5	30	16	14	CLAYEY SAND (SC)
◇	G-187	10.5	24	15	9	SANDY LEAN CLAY (CL)
◆	G-187	60.5	25	14	11	CLAYEY SAND with GRAVEL (SC)
⊗	G-187	65.5	26	17	9	CLAYEY SAND (SC)
⊕	G-187	75.5	35	16	19	LEAN CLAY with SAND (CL)
☆	G-187	85.5	62	18	44	FAT CLAY (CH)
⌘	G-188	45.5	33	15	18	SANDY LEAN CLAY (CL)
◓	G-188	70.5	41	22	19	SANDY LEAN CLAY (CL)
◒	G-188	75.5	37	16	21	LEAN CLAY with SAND (CL)
◑	G-189	5.5	50	20	30	FAT CLAY with SAND (CH)
×	G-189	15.5	NP	NP	NP	SILTY SAND with GRAVEL (SM)
✖	G-189	33.5	41	15	26	LEAN CLAY (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: YN 9/13/2011
Checked/Date: HP 9/13/2011

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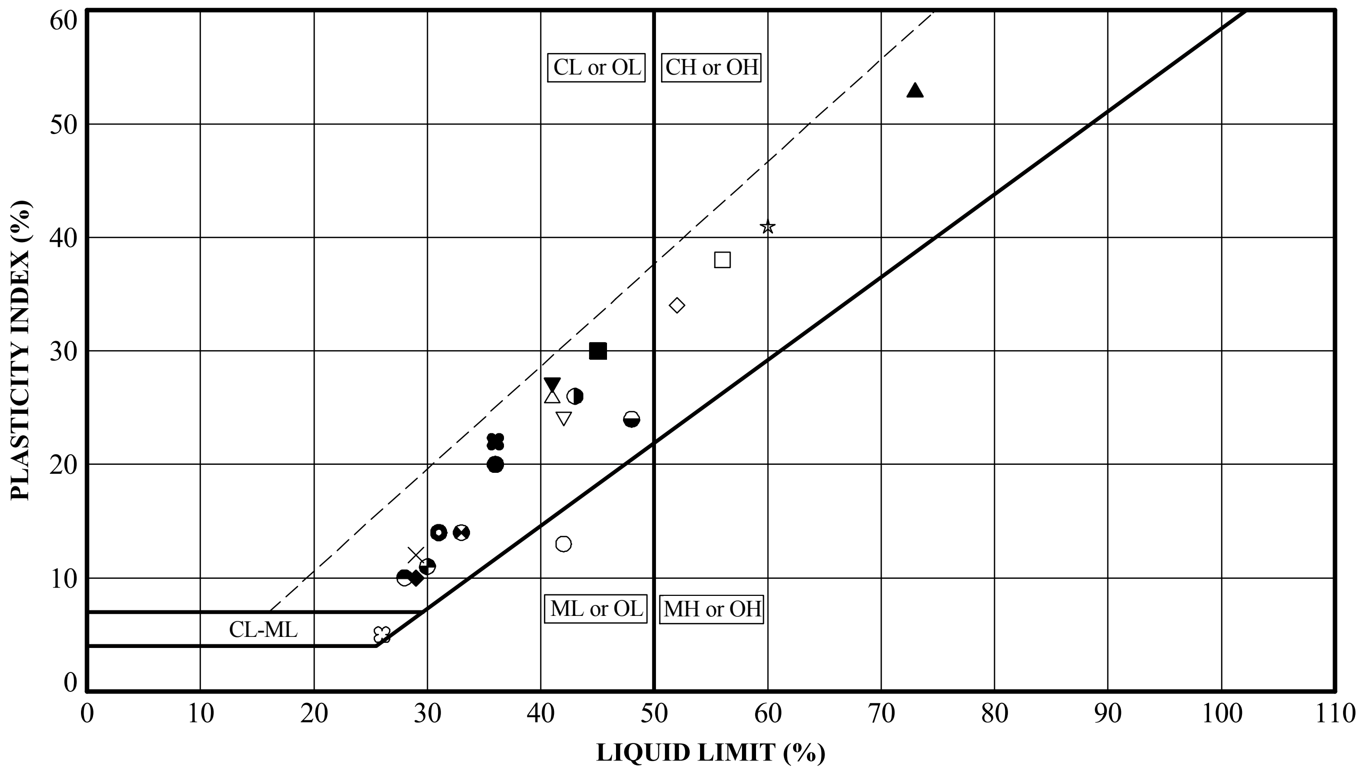
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.17



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-189	55.5	42	29	13	SANDY SILT (ML)
●	G-189	65.5	36	16	20	LEAN CLAY with SAND (CL)
△	G-189	80.5	41	15	26	LEAN CLAY with SAND (CL)
▲	G-189	85.5	73	20	53	FAT CLAY (CH)
□	G-189	95.5	56	18	38	FAT CLAY (CH)
■	G-189	110.5	45	15	30	LEAN CLAY with SAND (CL)
▽	G-190	10.5	42	18	24	CLAYEY SAND (SC)
▼	G-190	30.5	41	14	27	LEAN CLAY (CL)
◉	G-190	35.5	31	17	14	CLAYEY SAND (SC)
◇	G-190	55.5	52	18	34	FAT CLAY (CH)
◆	G-190	65.5	29	19	10	SANDY LEAN CLAY (CL)
⊗	G-190	66.0	33	19	14	
◕	G-190	75.5	30	19	11	SANDY LEAN CLAY (CL)
☆	G-190	95.5	60	19	41	FAT CLAY (CH)
⌘	G-191	25.5	26	21	5	SILTY, CLAYEY SAND with GRAVEL (SC-SM)
◓	G-191	55.5	28	18	10	CLAYEY SAND (SC)
⊖	G-191	65.5	48	24	24	LEAN CLAY with SAND (CL)
◑	G-191	75.5	43	17	26	LEAN CLAY (CL)
×	G-191	80.5	29	17	12	LEAN CLAY (CL)
✖	G-191	100.5	36	14	22	LEAN CLAY with SAND (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: YN 9/7/2011
Checked/Date: HP 9/13/2011

MTA Westside Subway Extension Los Angeles, California	amec	ATTERBERG LIMITS TEST RESULTS Project No.: 4953-10-1561 Figure: F-7.2.18

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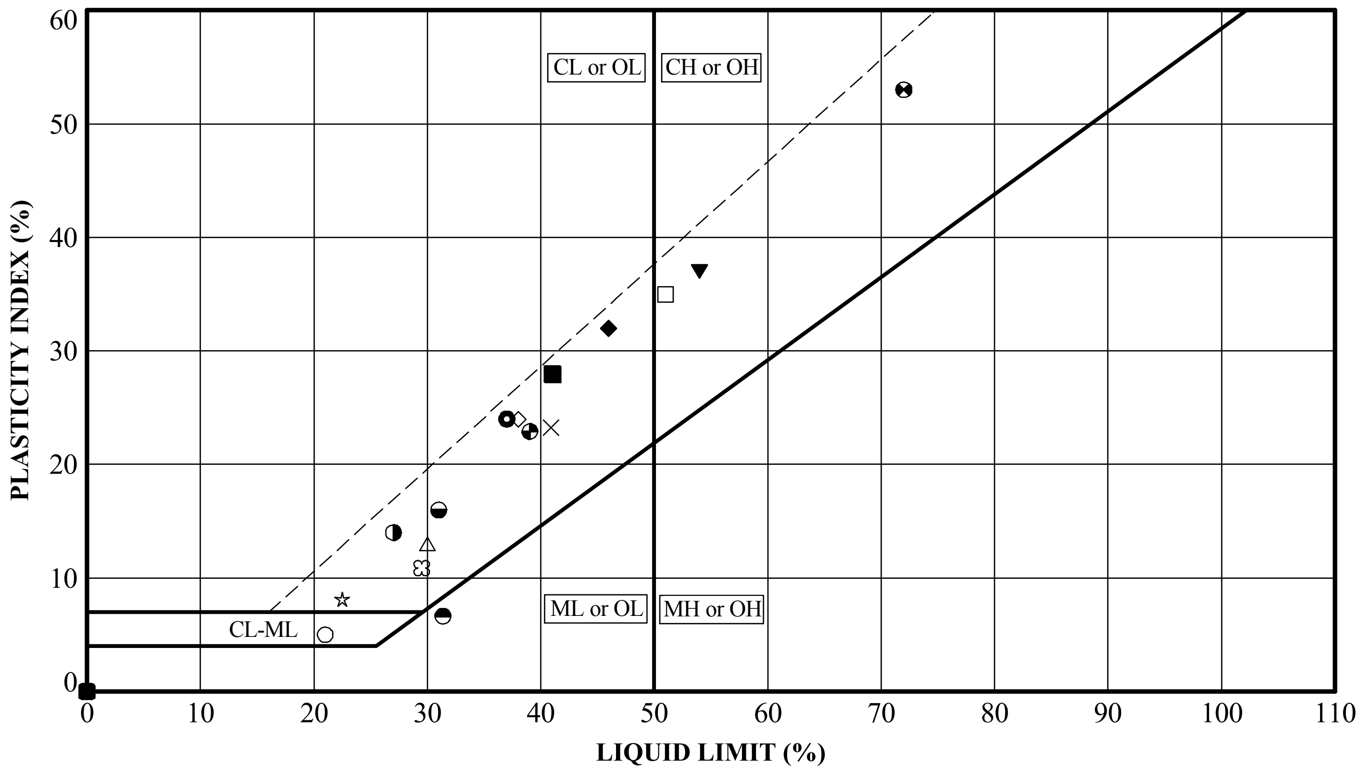
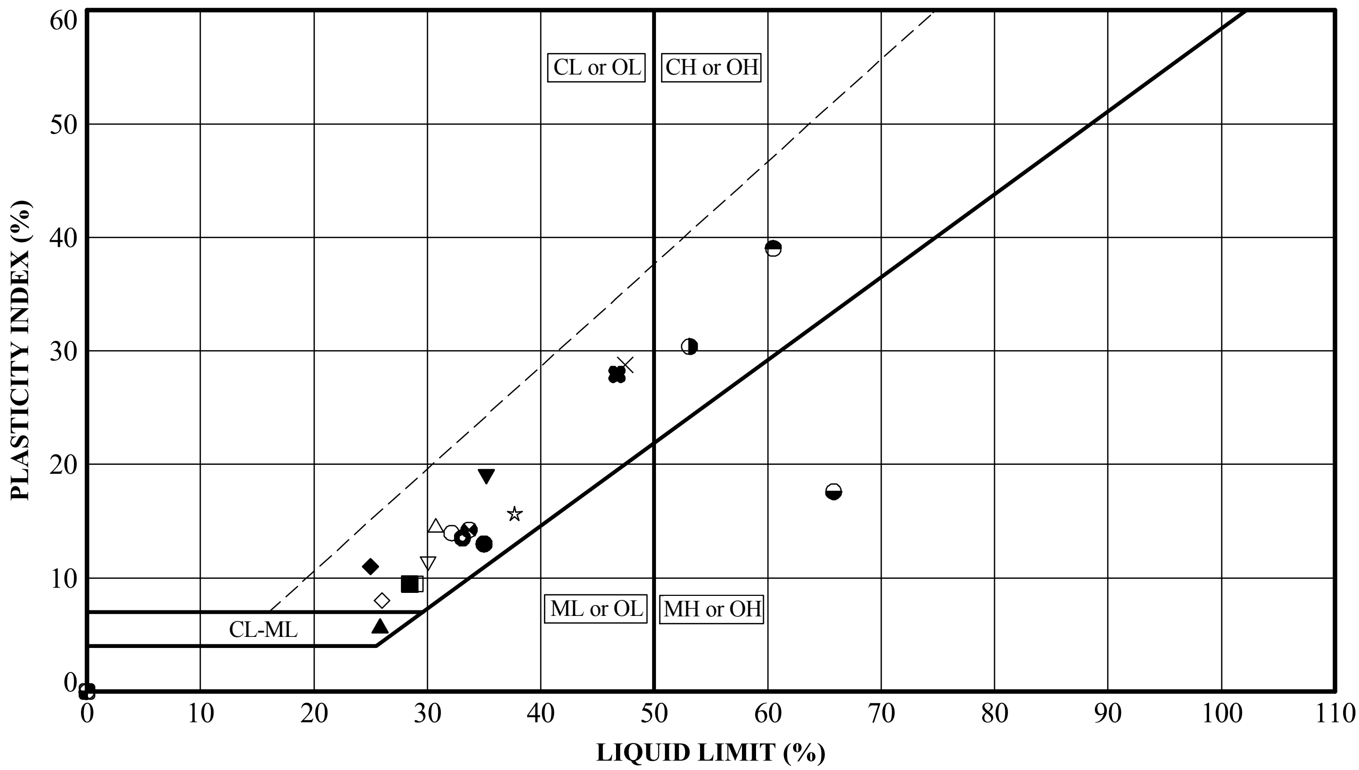


SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-199	40.5	21	16	5	SILTY, CLAYEY SAND with GRAVEL (SC-SM)
●	G-199	60.5	NP	NP	NP	SILTY SAND with GRAVEL (SM)
△	G-199	67.5	30	17	13	SANDY LEAN CLAY (CL)
▲	G-199	75.5	NP	NP	NP	SILTY SAND (SM)
□	G-199	95.5	51	16	35	FAT CLAY with SAND (CH)
■	G-200Alt	10.5	41	13	28	SANDY LEAN CLAY (CL)
▽	G-200Alt	25.5	NP	NP	NP	SILTY SAND (SM)
▼	G-200Alt	50.5	54	17	37	FAT CLAY (CH)
⊙	G-200Alt	65.5	37	13	24	CLAYEY SAND (SC)
◇	G-200Alt	85.5	38	14	24	SANDY LEAN CLAY (CL)
◆	G-200Alt	95.5	46	14	32	SANDY LEAN CLAY (CL)
⊗	G-200Alt	105.5	72	19	53	FAT CLAY (CH)
◕	G-203	5.5	39	16	23	LEAN CLAY (CL)
☆	G-203	10.5	22	14	8	CLAYEY SAND (SC)
⌘	G-203	15.5	30	19	11	LEAN CLAY with SAND (CL)
◒	G-203	25.5	31	25	6	SANDY SILT (ML)
◓	G-203	35.5	31	15	16	SANDY LEAN CLAY (CL)
◑	G-203	50.5	27	13	14	LEAN CLAY with SAND (CL)
×	G-203	65.5	41	18	23	LEAN CLAY with SAND (CL)
✖	G-203	90.5	NP	NP	NP	SILTY SAND (SM)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: YN 9/9/2011
Checked/Date: HP 9/13/2011

MTA Westside Subway Extension Los Angeles, California	amec	ATTERBERG LIMITS TEST RESULTS Project No.: 4953-10-1561 Figure: F-7.2.19



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-203	95.5	32	18	14	LEAN CLAY (CL)
●	G-204	5.5	35	22	13	LEAN CLAY (CL)
△	G-204	35.5	31	16	15	SANDY LEAN CLAY (CL)
▲	G-204	70.5	26	20	6	SILTY, CLAYEY SAND with GRAVEL (SC-SM)
□	G-204	85.5	29	19	10	LEAN CLAY with SAND (CL)
■	G-204	90.5	28	19	9	LEAN CLAY with SAND (CL)
▽	G-204	100.5	30	19	11	SANDY LEAN CLAY (CL)
▼	G-205	5.5	35	16	19	LEAN CLAY (CL)
⊙	G-205	10.5	33	20	13	SANDY LEAN CLAY (CL)
◇	G-205	15.5	26	18	8	SANDY LEAN CLAY (CL)
◆	G-205	25.5	25	14	11	SANDY LEAN CLAY (CL)
⊗	G-205	35.5	34	19	15	LEAN CLAY with SAND (CL)
◕	G-205	45.5	NP	NP	NP	SILTY SAND (SM)
☆	G-205	100.5	38	22	16	LEAN CLAY (CL)
⌘	G-206	40.5	NP	NP	NP	SANDY SILT (ML)
◓	G-206	45.5	60	21	39	FAT CLAY with SAND (CH)
⊖	G-206	80.5	66	48	18	SILTSTONE
◑	G-207	30.5	53	23	30	FAT CLAY (CH)
×	G-207	35.5	47	19	28	SANDY LEAN CLAY (CL)
✖	G-207	51.5	47	19	28	LEAN CLAY with SAND (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: YN 8/16/2011
Checked/Date: LT 8/22/2011

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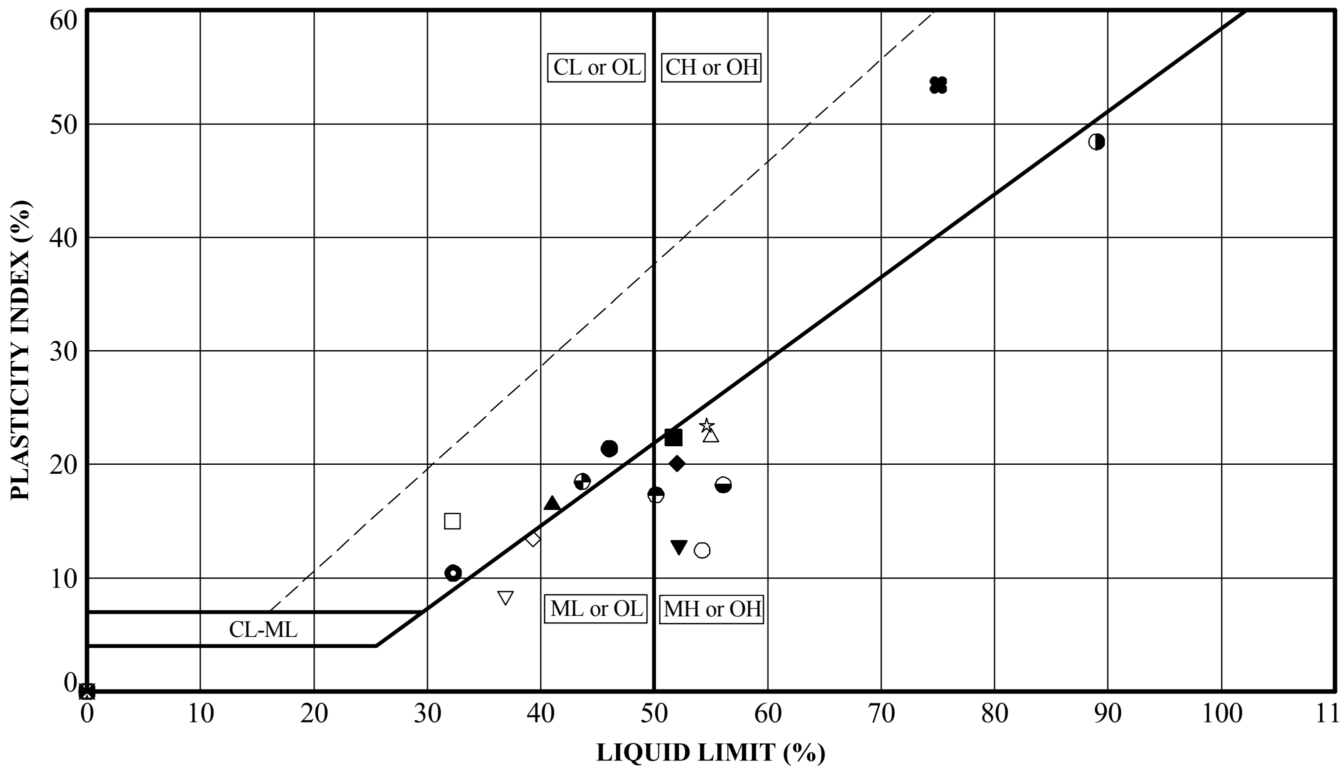
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.20



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	G-207	80.5	54	42	12	SANDY SILTSTONE
●	S-101	19-20	46	25	21	SANDY LEAN CLAY (CL)
△	S-101	23-24	55	32	23	ELASTIC SILT with SAND (MH)
▲	S-101	33.1-33.9	41	24	17	SANDY LEAN CLAY (CL)
□	S-101	39-40	32	17	15	CLAYEY SAND (SC)
■	S-101	44.4-45.4	52	29	23	ELASTIC SILT (MH)
▽	S-101	71-72	37	29	8	SILTSTONE
▼	S-101	82-83	52	39	13	SILTSTONE
⊙	S-102	27-28	32	22	10	SANDY LEAN CLAY (CL)
◇	S-102	31.2-32	39	26	13	SANDY SILT (ML)
◆	S-102	38.5-39.5	52	32	20	ELASTIC SILT (MH)
⊗	S-102	42.7-43.7	NP	NP	NP	SANDY SILT (ML)
◕	S-102	48.5-49.5	44	25	19	CLAYEY SAND (SC)
☆	S-102	56.1-57.1	55	31	24	ELASTIC SILT (MH)
⌘	S-102	72.5-73	NP	NP	NP	POORLY GRADED SAND with SILT and GRAVEL (SP-SM)
◓	S-102	79-80	50	33	17	SILTSTONE
◒	S-102	87-88	56	38	18	SILTSTONE
◑	S-103A	14-15	89	41	48	ELASTIC SILT with SAND (MH)
×	S-103A	26-27	NP	NP	NP	SILTY SAND (SM)
✖	S-103A	32-33	75	22	53	FAT CLAY (CH)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: YN 9/19/2011
Checked/Date: LT/HP 9/19/2011

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ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.21

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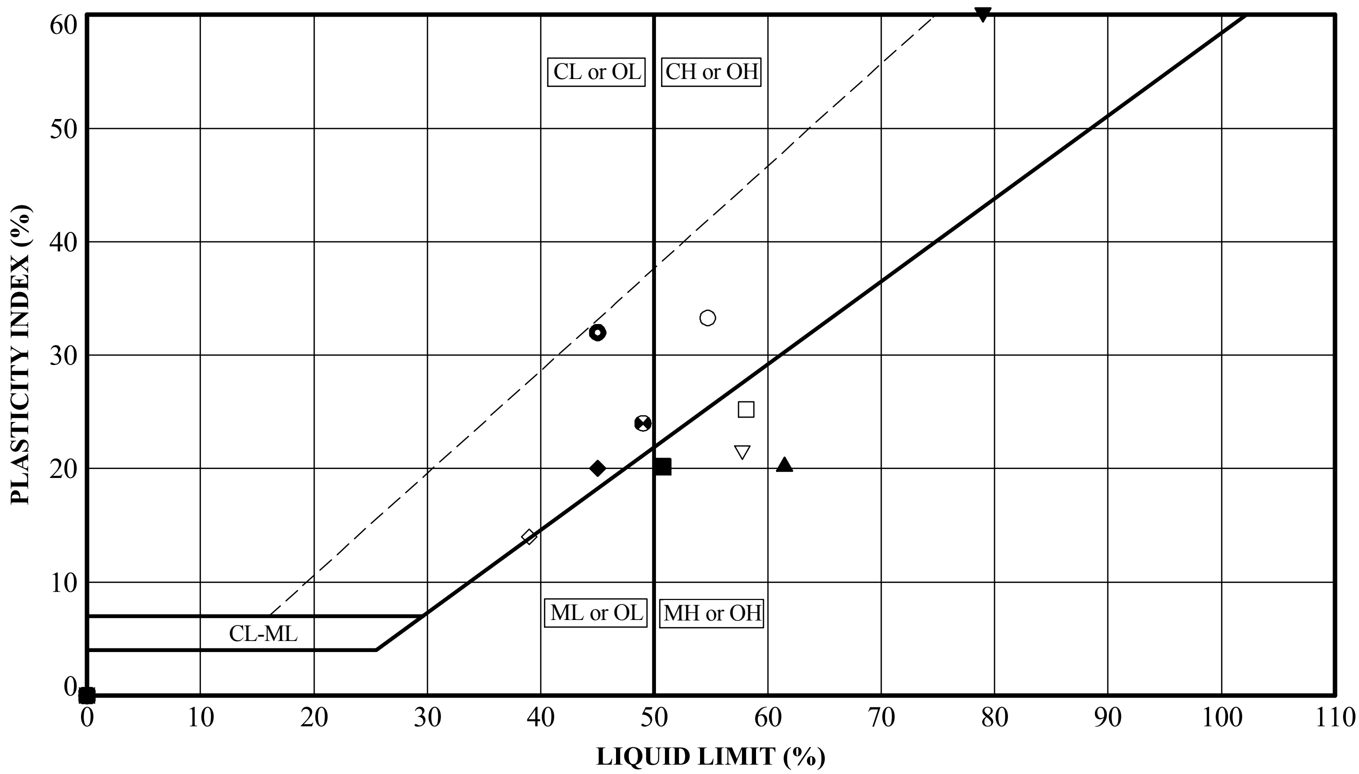

SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	S-103A	46-47	55	21	34	FAT CLAY (CH)
●	S-103A	59-60	NP	NP	NP	POORLY GRADED SAND (SP)
△	S-103A	68-69	NP	NP	NP	SILTY SAND (SM)
▲	S-103A	81-82	61	41	20	SILTSTONE
□	S-103A	96-97	58	33	25	SILTSTONE
■	S-103A	106-107	51	31	20	SILTSTONE
▽	S-103A	121-122	58	36	22	SILTSTONE
▼	S-104	17-18	79	19	60	FAT CLAY (CH)
⊙	S-104	35-36	45	13	32	CLAYEY SAND with GRAVEL (SC)
◇	S-104	86-87	39	25	14	CLAYEY SILTSTONE
◆	S-104	92-93	45	25	20	CLAYEY SILTSTONE
⊗	S-104	101.2-102.2	49	25	24	CLAYEY SILTSTONE
◕	S-105	26-27	NP	NP	NP	SILTY SAND (SM)
☆	S-105	72-73	NP	NP	NP	SANDY SILTSTONE
⌘	S-105	82-83	NP	NP	NP	SANDY SILTSTONE
◓	S-105	96-97	NP	NP	NP	SANDY SILTSTONE
◒	S-106	18-19	NP	NP	NP	SILTY SAND (SM)
◑	S-106	21-22	NP	NP	NP	SILTY SAND (SM)
×	S-106	26-27	NP	NP	NP	SILTY SAND (SM)
✖	S-106	36-37	NP	NP	NP	SILTY SAND (SM)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: WL 9/14/2011
Checked/Date: LT 9/23/2011

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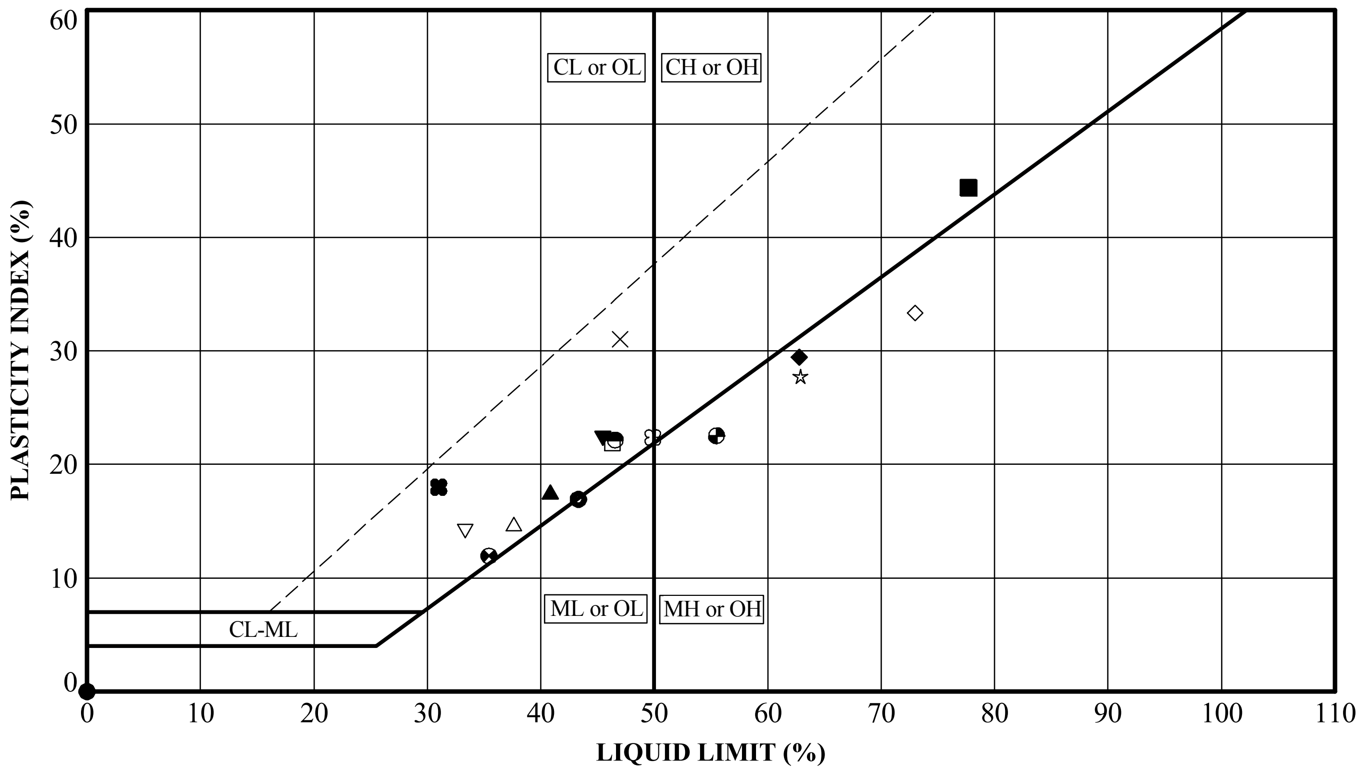
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.22



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	S-106	106-107	NP	NP	NP	POORLY GRADED SAND with SILT (SP-SM)
●	S-106	117-118	NP	NP	NP	SILTSTONE
△	S-107	18.5-19.5	38	23	15	LEAN CLAY (CL)
▲	S-107	28-29	41	23	18	LEAN CLAY (CL)
□	S-107	33.5-34.5	46	24	22	CLAYEY SAND (SC)
■	S-107	37-38	78	33	45	FAT CLAY (CH)
▽	S-107	42-43	33	19	14	SANDY LEAN CLAY (CL)
▼	S-107	48-49	45	23	22	CLAYEY SAND (SC)
⊙	S-107	59-60	43	26	17	SANDY LEAN CLAY (CL)
◇	S-107	67-68	73	40	33	ELASTIC SILT with SAND (MH)
◆	S-107	72-73	63	33	30	ELASTIC SILT with SAND (MH)
⊗	S-107	85-86	35	23	12	SANDY LEAN CLAY (CL)
◕	S-108	63-64	55	33	22	ELASTIC SILT (MH)
☆	S-108	72.5-73.5	63	35	28	ELASTIC SILT with SAND (MH)
⌘	S-108	78-79	50	27	23	FAT CLAY with SAND (CH)
◓	S-108	82-83	47	24	23	SANDY LEAN CLAY (CL)
◒	S-108	91-92	NP	NP	NP	SILTY SAND with GRAVEL (SM)
◑	S-108	97-98	NP	NP	NP	SANDY SILT (ML)
×	S-109	10-11	47	16	31	LEAN CLAY (CL)
✖	S-109	22-23	31	13	18	SANDY LEAN CLAY (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: WL 9/20/2011
Checked/Date: LT 9/27/2011

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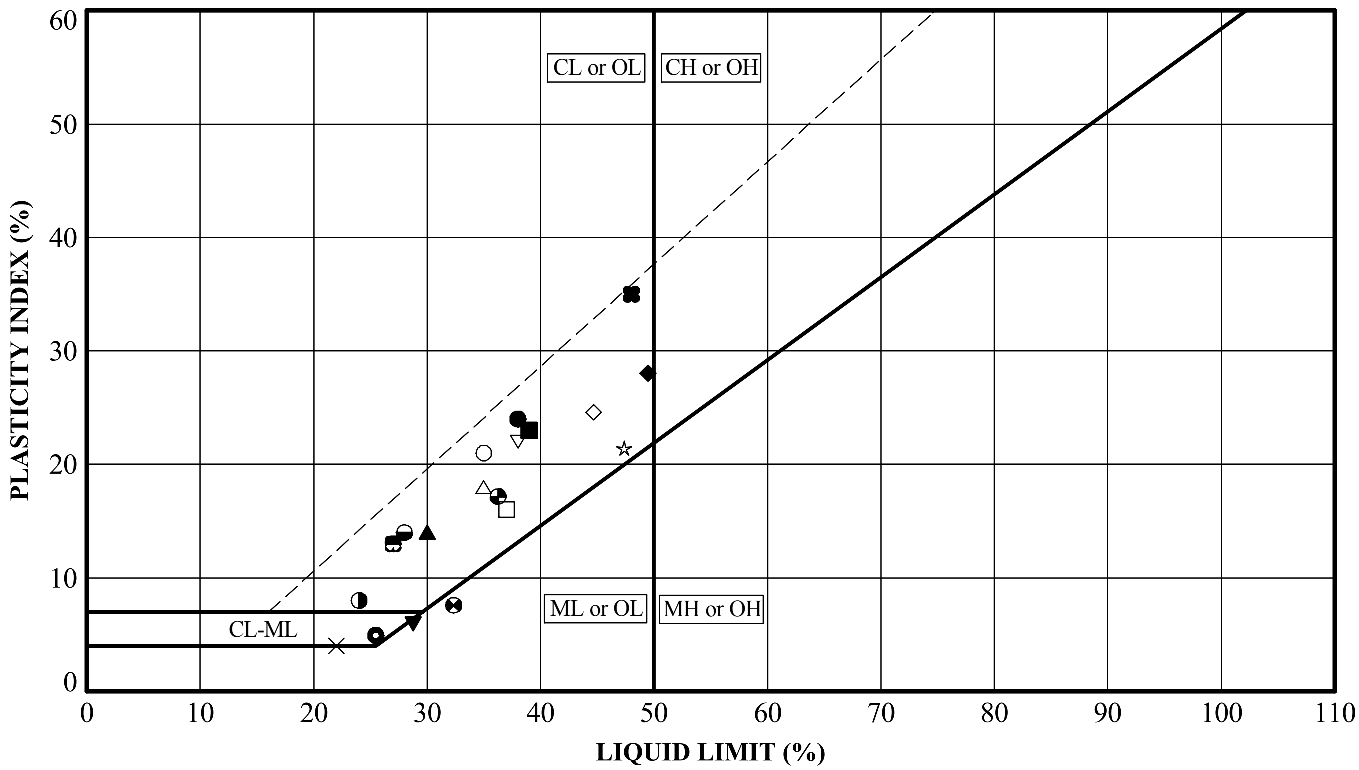
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.23

MACTEC LA ATTERBERG LIMITS S:\70131 GEOTECH\GINTW\LIBRARY MACTEC JUNE2011.GLB
G:\PROJECT DIRECTORIES\4953\2010\101561 METRO WESTSIDE EXTENSION\6.2.3.1 GEOTECHNICAL DESIGN\3.2 ALL FIELD NOTES\GINT LOG\4953-10-1561 MTA WESTSIDE SUBWAY EXTENSION.GPJ 12/4/11



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	S-109	51-52	35	14	21	LEAN CLAY with SAND (CL)
●	S-109	56-57	38	14	24	SANDY LEAN CLAY (CL)
△	S-109	62-63	35	17	18	SANDY LEAN CLAY (CL)
▲	S-109	77-78	30	16	14	CLAYEY SAND (SC)
□	S-109	88.5-89.5	37	21	16	LEAN CLAY with SAND (CL)
■	S-109	101-102	39	16	23	LEAN CLAY (CL)
▽	S-109	112-113	38	16	22	LEAN CLAY (CL)
▼	S-110	33-34	29	23	6	SANDY SILT (ML)
◉	S-110	40.5-41.5	25	21	4	SILTY, CLAYEY GRAVEL with SAND (GC-GM)
◇	S-110	44-45	45	20	25	LEAN CLAY (CL)
◆	S-110	54-55	49	21	28	LEAN CLAY (CL)
⊗	S-110	66.6-67	32	25	7	SILTY SAND with GRAVEL (SM)
◕	S-111	45-46	36	19	17	POORLY GRADED GRAVEL with CLAY and SAND (GP-GC)
☆	S-111	52-53	47	26	21	LEAN CLAY (CL)
⌘	S-113	67-68	27	14	13	CLAYEY SAND (SC)
◒	S-113	83-84	27	14	13	CLAYEY SAND (SC)
◒	S-113	98.5-99.5	28	14	14	CLAYEY SAND (SC)
◑	S-113	106-107	24	16	8	CLAYEY SAND (SC)
×	S-113	110.3-111.3	22	18	4	SILTY, CLAYEY SAND (SC-SM)
✖	S-113	117-118	48	13	35	LEAN CLAY with SAND (CL)

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

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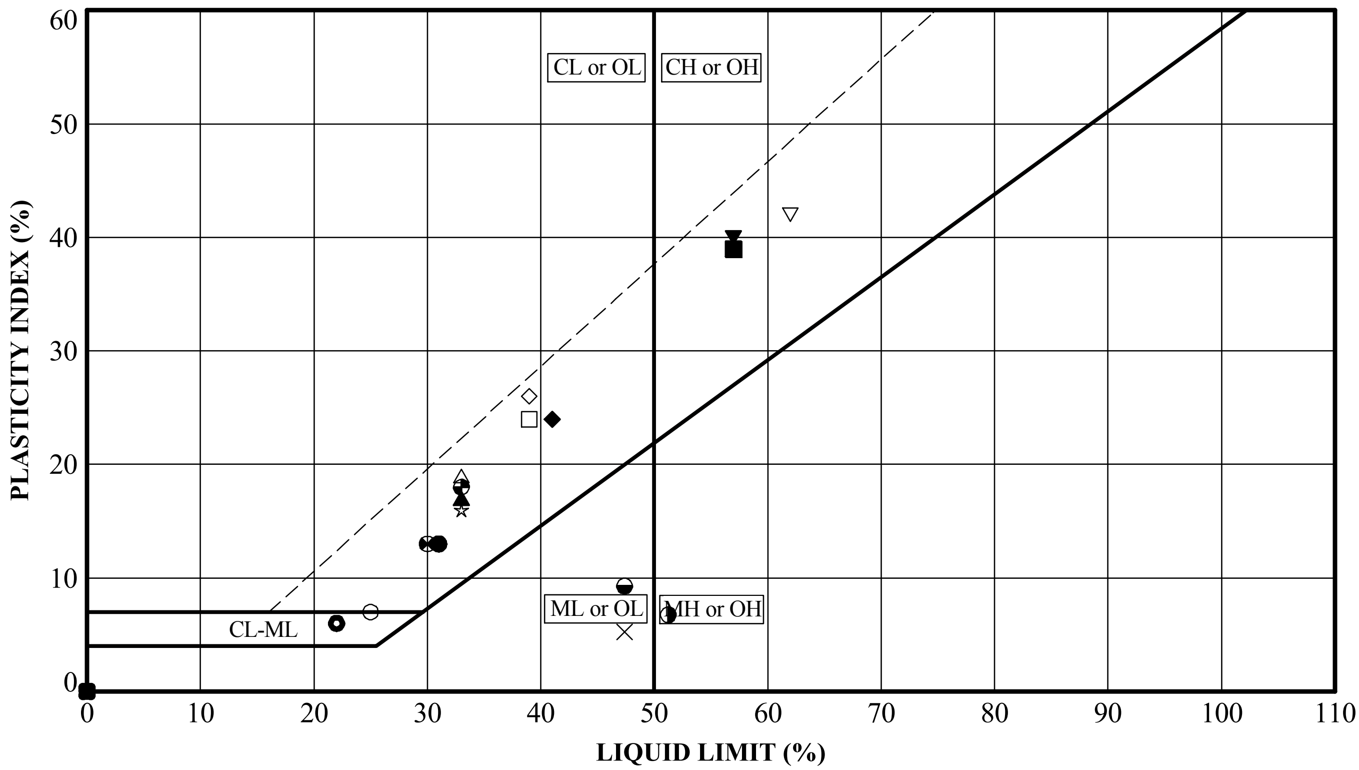
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.24



SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	S-114	21-22	25	18	7	SILTY, CLAYEY SAND (SC-SM)
●	S-114	47-48	31	18	13	SANDY LEAN CLAY (CL)
△	S-114	59-60	33	14	19	SANDY LEAN CLAY (CL)
▲	S-114	68-69	33	16	17	LEAN CLAY with SAND (CL)
□	S-114	77-78	39	15	24	LEAN CLAY with SAND (CL)
■	S-114	87-88	57	18	39	FAT CLAY (CH)
▽	S-114	93-94	62	20	42	FAT CLAY (CH)
▼	S-114	105-106	57	17	40	FAT CLAY (CH)
⊙	S-115	16-17	22	16	6	SANDY SILTY CLAY (CL-ML)
◇	S-115	30-31	39	13	26	LEAN CLAY with SAND (CL)
◆	S-115	71-72	41	17	24	LEAN CLAY (CL)
⊗	S-115	78-79	30	17	13	SANDY LEAN CLAY (CL)
◕	S-115	86-87	33	15	18	SANDY LEAN CLAY (CL)
☆	S-115	102-103	33	17	16	SANDY LEAN CLAY (CL)
⌘	S-116	18-19	NP	NP	NP	POORLY GRADED SAND with SILT (SP-SM)
◓	S-116	62-63	NP	NP	NP	SANDY SILT (ML)
◒	S-116	76-77	47	38	9	SILTSTONE
◑	S-116	81-82	51	44	7	SILTSTONE
×	S-116	101-102	47	42	5	SILTSTONE
✖	S-117	11-12	NP	NP	NP	

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

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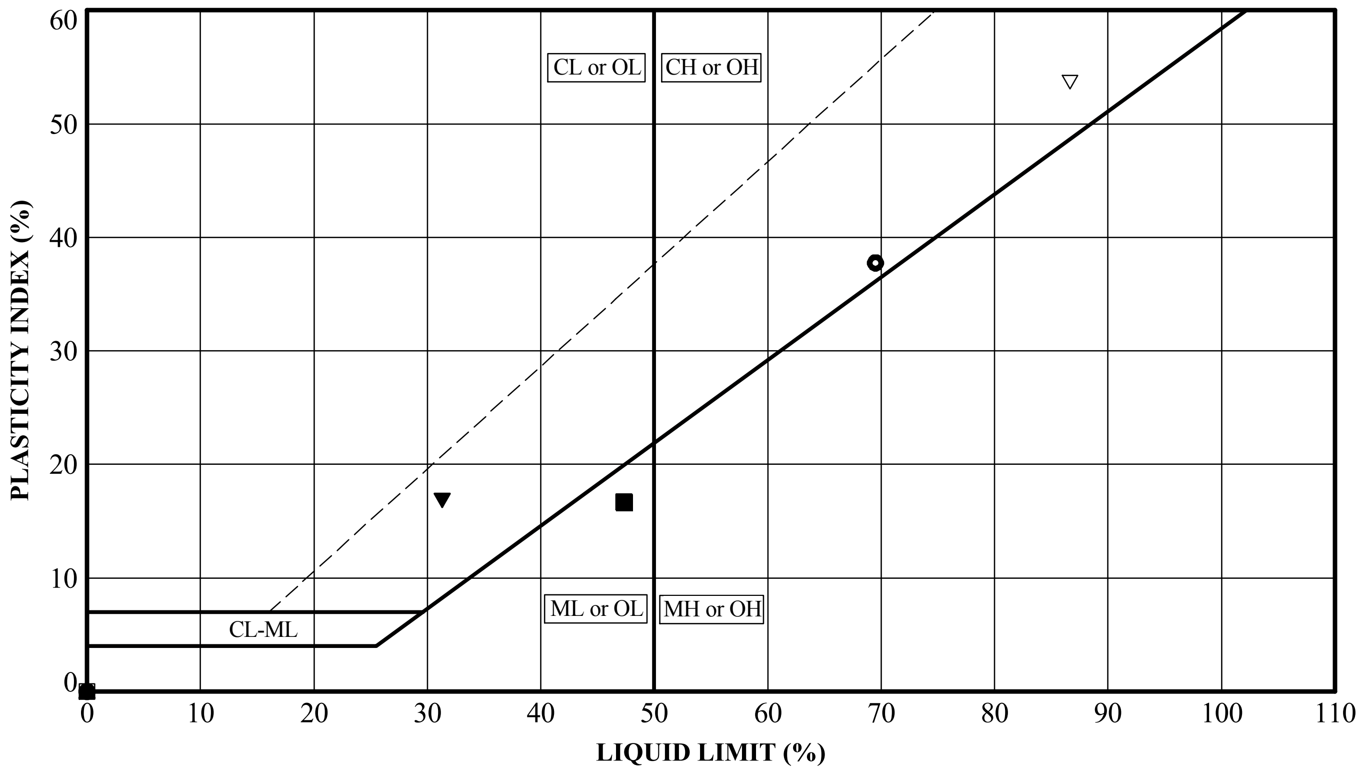

SYMBOL	BORING	DEPTH (ft)	LL (%)	PL (%)	PI (%)	CLASSIFICATION
○	S-117	24-25	NP	NP	NP	SILTY SAND (SM)
●	S-117	39-40	NP	NP	NP	SILTY SAND (SM)
△	S-117	62-63	NP	NP	NP	SILTY SAND (SM)
▲	S-117	67-68	NP	NP	NP	SILTSTONE
□	S-117	92-93	NP	NP	NP	SILTSTONE
■	S-118	7-8	47	31	16	SANDY SILT (ML)
▽	S-118	16-17	87	33	54	FAT CLAY (CH)
▼	S-118	27-28	31	14	17	SANDY LEAN CLAY (CL)
⊙	S-118	34-35	69	32	37	FAT CLAY (CH)
◇	S-118	84-85	NP	NP	NP	SILTSTONE

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: WL 9/11/2011
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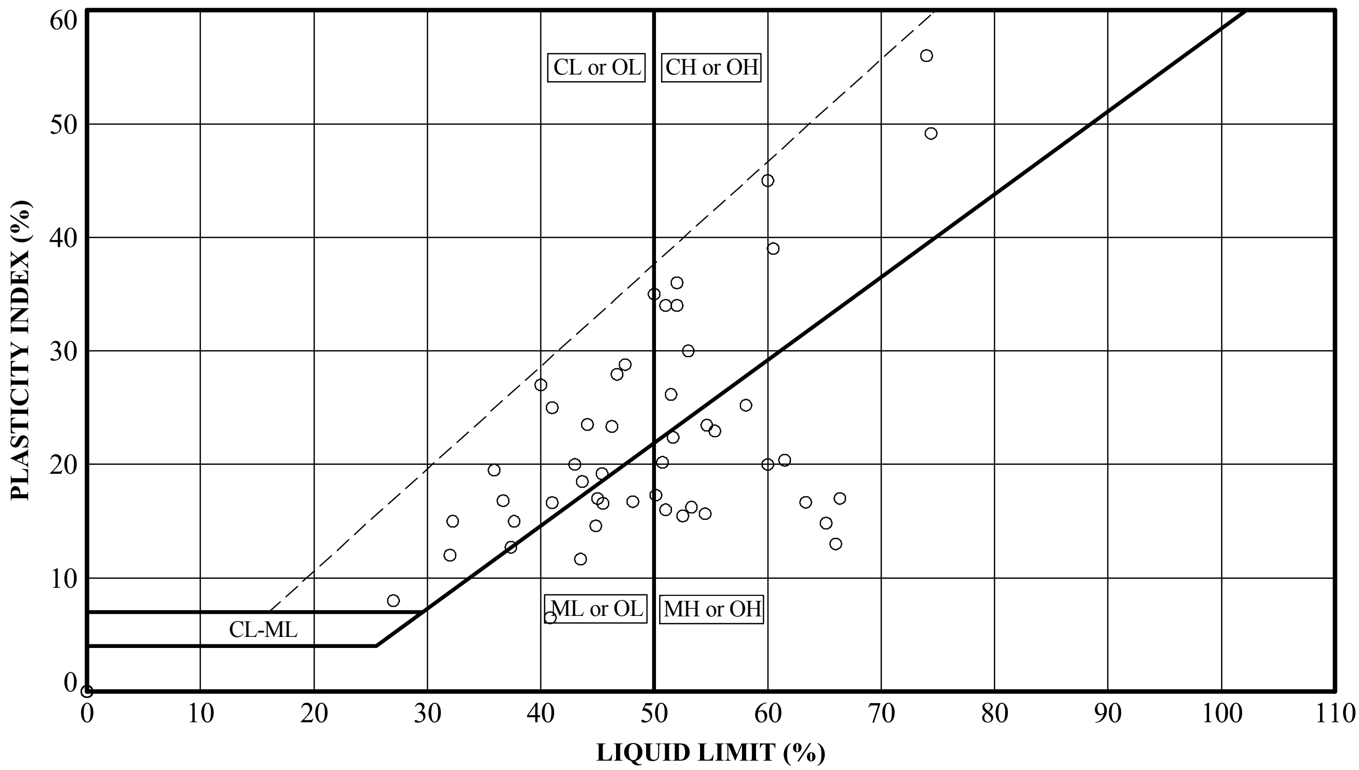
ATTERBERG LIMITS TEST RESULTS
Project No.: 4953-10-1561
Figure: F-7.2.26



WESTERN-COCHRAN REACH

Laboratory Test Method: ASTM D 4318

"NP" indicates Non-Plastic

Prepared/Date: JF 7/28/2011
Checked/Date: LT 7/28/2011

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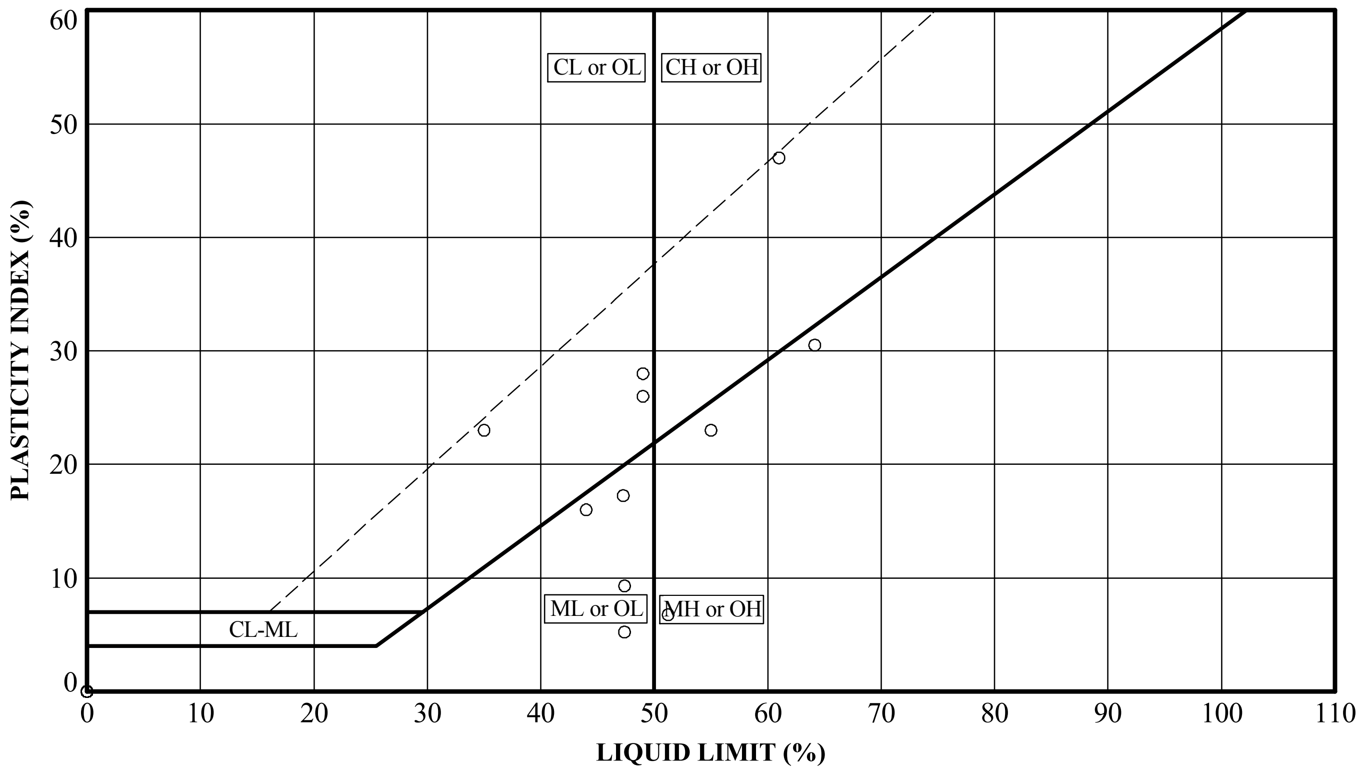
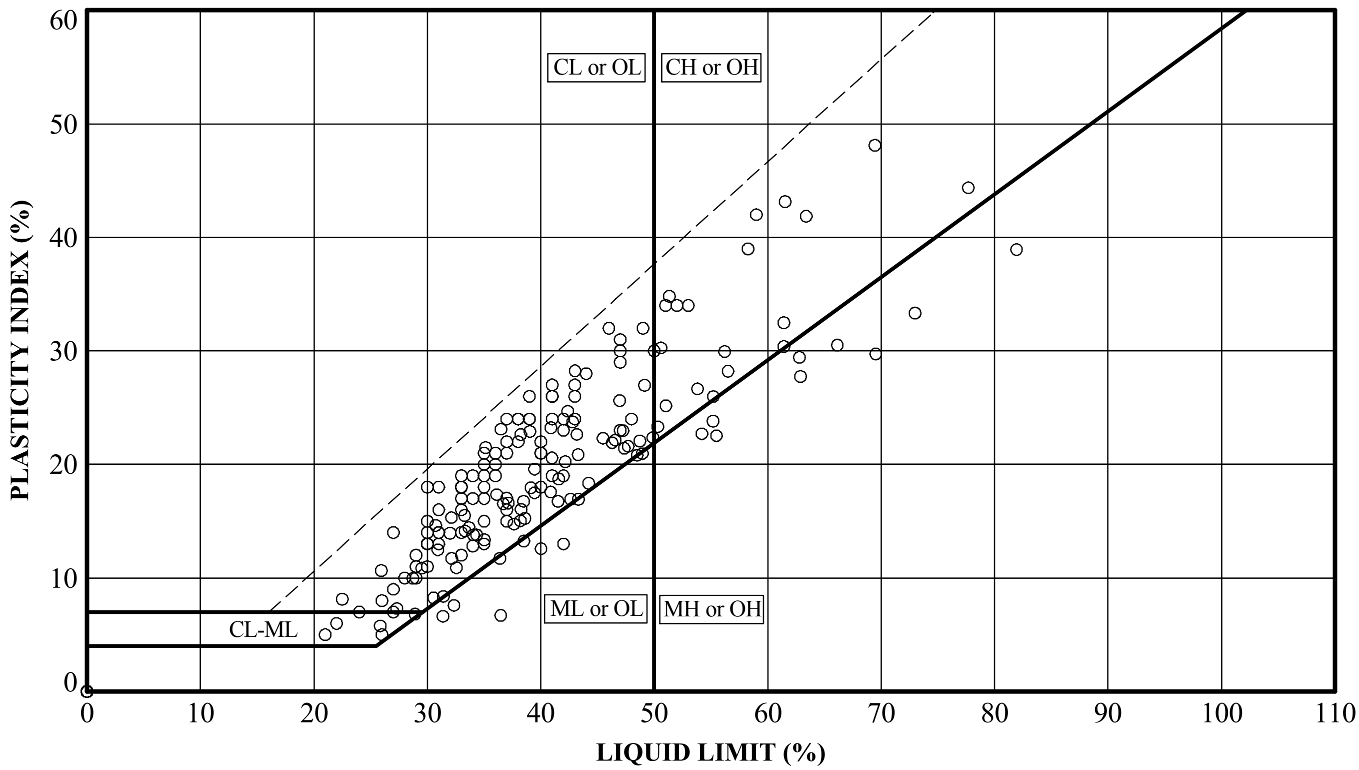


COCHRAN-LA JOLLA REACH

Laboratory Test Method: ASTM D 4318 "NP" indicates Non-Plastic

Prepared/Date: JF 9/9/2011
Checked/Date: LT 9/13/2011

MTA Westside Subway Extension Los Angeles, California	amec	ATTERBERG LIMITS TEST RESULTS Project No.: 4953-10-1561 Figure: F-7.2.28



LA JOLLA-VA REACH

Laboratory Test Method: ASTM D 4318

"NP" indicates Non-Plastic

Prepared/Date: JF 6/29/2011
Checked/Date: HP 12/2/2011

MTA Westside Subway Extension Los Angeles, California	amec	ATTERBERG LIMITS TEST RESULTS Project No.: 4953-10-1561 Figure: F-7.2.29

FIGURES F-8.1 THROUGH F-8.26
HYDROCONSOLIDATION TEST DATA (PE PHASE)

BORING NUMBER AND SAMPLE DEPTH:	G-101 at 59'	G-101 at 69'
SOIL TYPE:	POORLY GRADED SAND with SILT	WELL GRADED SAND with SILT and GRAVEL
SURCHARGE PRESSURE: (lbs./sq.ft.)	2000	2000
PERCENT HYDROCONSOLIDATION: (%)	0.11	0.09

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Checked/Date: LT 10/2/11

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.1

BORING NUMBER AND SAMPLE DEPTH:	G-102 at 40½'	G-103 at 28½'	G-103 at 34½'	G-103 at 58½'
SOIL TYPE:	SANDY LEAN CLAY	SILT	SILTY SAND	POORLY GRADED SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.21	0.05	0.06	0.07

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HYDROCONSOLIDATION TEST DATA
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Figure F-8.2

BORING NUMBER AND SAMPLE DEPTH:	G-104 at 55½'	G-106 at 25½'	G-106 at 61½'	G-106 at 67½'
SOIL TYPE:	SANDY LEAN CLAY	POORLY GRADED SAND with SILT	POORLY GRADED SAND	POORLY GRADED SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.01	0.07	0.04	0.10

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HYDROCONSOLIDATION TEST DATA
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Figure F-.8.3

BORING NUMBER AND SAMPLE DEPTH:	G-108 at 60½'	G-108 at 110½'	G-109 at 60½'	G-109 at 130½'
SOIL TYPE:	POORLY GRADED SAND with SILT	SILTSTONE	SILTY SAND	SILTSTONE
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.4	-0.16	0.03	-0.04

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.4

BORING NUMBER AND SAMPLE DEPTH:	G-111 at 55½'	G-112 at 15½'	G-114 at 45	G-116 at 60
SOIL TYPE:	POORLY GRADED SAND with SILT	SILTY SAND	SANDY FAT CLAY	POORLY GRADED SAND with SILT
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	2000	1800
PERCENT HYDROCONSOLIDATION: (%)	0.00	0.00	-0.05	0.01

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.5

BORING NUMBER AND SAMPLE DEPTH:	G-118 at 34½'	G-118 at 46½'	G-118 at 58½'	G-119 at 65½'
SOIL TYPE:	SILTY SAND with TAR	SANDY SILT with TAR	POORLY GRADED SAND with SILT with TAR	POORLY GRADED SAND with SILT and GRAVEL and TAR
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	2000
PERCENT HYDROCONSOLIDATION: (%)	0.07	0.06	0.21	0.35

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Checked/Date: LT 10/2/11

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.6

BORING NUMBER AND SAMPLE DEPTH:	G-126 at 55½'	G-126 at 95½'	G-127 at 80½'	G-130B at 30½'
SOIL TYPE:	SILTY SAND	SILTY SAND	POORLY GRADED SAND	LEAN CLAY
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.07	0.03	0.23	0.06

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.7

BORING NUMBER AND SAMPLE DEPTH:	G-131 at 55½'	G-131 at 85½'	G-132 at 75½'	G-133 at 41½'
SOIL TYPE:	SILTY SAND	SILTY SAND	POORLY GRADED SAND	LEAN CLAY
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.02	0.00	0.11	0.03

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.8

BORING NUMBER AND SAMPLE DEPTH:	G-133 at 89½'	G-134 at 35½'	G-134 at 45½'	G-134 at 55½'
SOIL TYPE:	SILTY SAND	SANDY SILT	SILT with SAND	SILT with SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.09	0.06	0.05	0.02

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.9

BORING NUMBER AND SAMPLE DEPTH:	G-134 at 95½'	G-135 at 101½'	G-139 at 45½'	G-139 at 95½'
SOIL TYPE:	SILTY SAND	SILTY SAND	WELL GRADED SAND with SILT and GRAVEL	SILTY SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	2000	2000
PERCENT HYDROCONSOLIDATION: (%)	0.03	0.02	0.06	0.17

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.10

BORING NUMBER AND SAMPLE DEPTH:	G-140 at 56½'	G-140 at 74½'	G-140 at 86½'	G-140 at 98½'
SOIL TYPE:	SANDY SILT	CLAYEY SAND	POORLY GRADED SAND with GRAVEL	SILTY SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.11	0.08	0.01	-0.09

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.11

BORING NUMBER AND SAMPLE DEPTH:	G-141 at 50½'	G-142 at 35½'	G-147 at 85½'	G-148 at 85½'
SOIL TYPE:	SANDY SILT	POORLY GRADED SAND	SILTY SAND	SILTY SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	2000
PERCENT HYDROCONSOLIDATION: (%)	0.05	Canceled	0.11	0.12

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.12

BORING NUMBER AND SAMPLE DEPTH:	G-148 at 105½'	G-149 at 63½'	G-149 at 73½'	G-149 at 83½'
SOIL TYPE:	SANDY LEAN CLAY	SILTY SAND	SILTY SAND	SANDY LEAN CLAY
SURCHARGE PRESSURE: (lbs./sq.ft.)	2000	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.11	0.06	0.03	0.02

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.13

BORING NUMBER AND SAMPLE DEPTH:	G-150 at 70½'	G-150 at 100½'	G-152 at 48½'	G-152 at 68½'
SOIL TYPE:	SILTY SAND	SILTY SAND with GRAVEL	WELL GRADED SAND with GRAVEL	SANDY LEAN CLAY
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.04	0.05	0.35	0.01

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BORING NUMBER AND SAMPLE DEPTH:	G-152 at 83½'	G-154 at 33½'	G-154 at 48½'	G-154 at 58½'
SOIL TYPE:	SILTY SAND	LEAN CLAY with SAND	SILTY SAND with GRAVEL	SILTY SAND with GRAVEL
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.08	0.27	0.75	0.15

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.15

BORING NUMBER AND SAMPLE DEPTH:	G-156 at 23'	G-156 at 68'	G-159 at 45½'	G-159 at 65½'
SOIL TYPE:	SILTY SAND	WELL GRADED GRAVEL	SANDY LEAN CLAY	SILTY SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	-0.01	0.07	-0.16	-0.02

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.16

BORING NUMBER AND SAMPLE DEPTH:	G-161 at 55½'	G-161 at 85½'	G-162 at 20½'	G-164 at 39½'
SOIL TYPE:	POORLY GRADED SAND	SANDY LEAN CLAY	SANDY LEAN CLAY	SILTY SAND with GRAVEL
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.20	-0.03	0.07	0.02

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.17

BORING NUMBER AND SAMPLE DEPTH:	G-164 at 48½'	G-164 at 60½'	G-164 at 72½'	G-168 at 77½'
SOIL TYPE:	POORLY GRADED GRAVEL with SILT and SAND	SILTY SAND	POORLY GRADED SAND	POORLY GRADED SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	2000
PERCENT HYDROCONSOLIDATION: (%)	0.07	0.14	0.06	0.14

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.18

BORING NUMBER AND SAMPLE DEPTH:	G-169 at 67½'	G-171 at 58½'	G-171 at 68'	G-171 at 83'
SOIL TYPE:	SILTY SAND	SILTY SAND	SILTY SAND with GRAVEL	POORLY GRADED SAND with SILT
SURCHARGE PRESSURE: (lbs./sq.ft.)	2000	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.05	0.00	0.05	1.03

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.19

BORING NUMBER AND SAMPLE DEPTH:	G-173 at 60½'	G-174A at 45½'	G-175 at 95½'	G-175 at 145½'
SOIL TYPE:	SILTY SAND	CLAYEY SAND	POORLY GRADED SAND with SILT	LEAN to FAT CLAY
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	2000	2000
PERCENT HYDROCONSOLIDATION: (%)	-0.17	0.03	0.02	-0.62

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.20

BORING NUMBER AND SAMPLE DEPTH:	G-176 at 84½'	G-176 at 120½'	G-177 at 83'	G-177 at 108'
SOIL TYPE:	SILTY SAND	SILTY, CLAYEY SAND	SANDY LEAN CLAY	POORLY GRADED SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	2000	2000	7200	8100
PERCENT HYDROCONSOLIDATION: (%)	0.07	-0.01	-0.01	0.02

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.21

BORING NUMBER AND SAMPLE DEPTH:	G-177 at 117½'	G-178 at 63'	G-178 at 88'	G-179 at 65½'
SOIL TYPE:	SILTY SAND	CLAYEY SAND	SILTY SAND with GRAVEL	POORLY GRADED SAND with GRAVEL
SURCHARGE PRESSURE: (lbs./sq.ft.)	9000	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.00	0.02	0.07	0.48

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.22

BORING NUMBER AND SAMPLE DEPTH:	G-179 at 115½'	G-180 at 75½'	G-180 at 88'	G-180 at 103'
SOIL TYPE:	SILTY SAND	LEAN CLAY	CLAYEY SAND	SILT with SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.01	0.01	0.07	0.09

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.23

BORING NUMBER AND SAMPLE DEPTH:	G-180 at 113'	G-181 at 55½'	G-181 at 105½'	G-181 at 125½'
SOIL TYPE:	SILTY SAND	POORLY GRADED SAND	SILT	SILTY SAND
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	0.07	0.44	-0.07	0.06

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

MTA Westside Subway Extension
Los Angeles, California

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.24

BORING NUMBER AND SAMPLE DEPTH:	G-187 at 25½'	G-188 at 80½'	G-191 at 90½'	G-206 at 50'
SOIL TYPE:	SILTY SAND	SILT with SAND	SILTY SAND	SILTY SAND with GRAVEL
SURCHARGE PRESSURE: (lbs./sq.ft.)	3000	2000	8000	1800
PERCENT HYDROCONSOLIDATION: (%)	0.22	0.05	0.24	0.11

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

MTA Westside Subway Extension
Los Angeles, California

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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.25

BORING NUMBER AND SAMPLE DEPTH:	G-207 at 40'	G-207 at 55'
SOIL TYPE:	SILTY SAND	POORLY GRADED SAND with SILT
SURCHARGE PRESSURE: (lbs./sq.ft.)	1800	1800
PERCENT HYDROCONSOLIDATION: (%)	1.01	0.06

Prepared/Date: LH 09/29/11
Checked/Date: LT 10/2/11

MTA Westside Subway Extension
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HYDROCONSOLIDATION TEST DATA
Project No.: 4953-10-1561
Figure F-8.26

FIGURES F-9.1 THROUGH F-9.15
CORROSION TEST DATA (ACE PHASE)

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-1 @ 40'	G-1 @ 60'	G-2 @ 35'	G-3 @ 40'	G-4 @ 20'
Resistivity		**Units**					
as-received		ohm-cm	1,760	800	1,280	6,000	3,800
saturated		ohm-cm	660	780	1,200	900	600
pH			8.1	7.7	8.2	8.4	8.1
Electrical Conductivity		mS/cm	0.31	0.46	0.22	0.21	0.17
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	111	211	81	102	80
magnesium	Mg^{2+}	mg/kg	34	85	28	26	30
sodium	Na^{1+}	mg/kg	144	113	152	92	80
potassium	K^{1+}	mg/kg	52	56	22	27	20
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	271	43	464	207	336
flouride	F^{1-}	mg/kg	3.7	1.9	7.9	8.3	12
chloride	Cl^{1-}	mg/kg	21	35	20	11	7.9
sulfate	SO_4^{2-}	mg/kg	411	955	115	263	93
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.3	3.9	3.9	0.9	ND
nitrate	NO_3^{1-}	mg/kg	1.0	ND	6.6	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-4 @ 30'	G-5 @ 20'	G-5 @ 30'	G-7 @ 20'	G-7 @ 40'
Resistivity		**Units**					
as-received		ohm-cm	600	5,600	3,680	2,640	1,300
saturated		ohm-cm	580	880	520	760	840
pH			8.1	8.2	6.8	6.7	7.8
Electrical Conductivity		mS/cm	0.44	0.42	0.84	0.10	0.22
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	185	75	180	37	72
magnesium	Mg^{2+}	mg/kg	93	66	186	21	40
sodium	Na^{1+}	mg/kg	136	308	508	96	157
potassium	K^{1+}	mg/kg	28	22	16	6.1	16
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	241	634	235	122	369
flouride	F^{1-}	mg/kg	4.2	3.9	1.9	13	1.9
chloride	Cl^{1-}	mg/kg	15	23	46	15	26
sulfate	SO_4^{2-}	mg/kg	812	362	1,600	74	173
phosphate	PO_4^{3-}	mg/kg	ND	1.0	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	5.9	4.3	5.1	ND	3.5
nitrate	NO_3^{1-}	mg/kg	0.5	1.2	ND	1.5	1.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
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Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-8 @ 20'	G-8 @ 30'	G-9 @ 30'	G-9 @ 60'	G-10 @ 35'
Resistivity		**Units**					
as-received		ohm-cm	1,440	1,840	1,600	1,200	5,680
saturated		ohm-cm	1,000	1,560	1,500	1,200	2,960
pH			7.7	8.0	7.8	8.0	8.1
Electrical Conductivity		mS/cm	0.28	0.25	0.24	0.23	0.08
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	95	78	120	103	43
magnesium	Mg^{2+}	mg/kg	42	31	30	34	13
sodium	Na^{1+}	mg/kg	179	195	140	120	73
potassium	K^{1+}	mg/kg	26	10	19	36	5.8
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	708	515	616	549	76
flouride	F^{1-}	mg/kg	15	18	6.8	4.6	2.8
chloride	Cl^{1-}	mg/kg	16	27	21	34	12
sulfate	SO_4^{2-}	mg/kg	58	93	61	69	97
phosphate	PO_4^{3-}	mg/kg	ND	ND	2.3	1.5	2.6
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	1.0	1.7	ND
nitrate	NO_3^{1-}	mg/kg	ND	1.0	ND	0.5	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-10 @ 65'	G-11 @ 20'	G-11 @ 70'	G-12 @ 50'	G-13 @ 40'
Resistivity		**Units**					
as-received		ohm-cm	5,400	6,800	1,080	3,320	760
saturated		ohm-cm	1,260	1,520	1,020	1,048	760
pH			8.0	7.7	7.8	7.7	7.4
Electrical Conductivity		mS/cm	0.23	0.08	0.12	0.09	0.12
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	100	43	60	50	53
magnesium	Mg^{2+}	mg/kg	30	12	19	16	16
sodium	Na^{1+}	mg/kg	116	79	69	62	92
potassium	K^{1+}	mg/kg	31	8.2	24	17	20
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	555	189	189	159	140
flouride	F^{1-}	mg/kg	6.5	1.9	1.5	1.7	1.5
chloride	Cl^{1-}	mg/kg	6.2	3.4	18	15	33
sulfate	SO_4^{2-}	mg/kg	46	37	79	56	108
phosphate	PO_4^{3-}	mg/kg	3.3	4.7	ND	ND	5.6
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.8	0.8	2.0	0.7	1.0
nitrate	NO_3^{1-}	mg/kg	2.1	1.4	1.6	1.3	5.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
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Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-14 @ 50'	G-16 @ 55'	G-32 @ 30'	G-32 @ 60'
Resistivity		**Units**				
as-received		ohm-cm	920	1,160	3,420	840
saturated		ohm-cm	920	1,140	740	840
pH			7.3	7.7	7.3	7.6
Electrical Conductivity		mS/cm	0.09	0.18	0.09	0.06
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	59	100	47	44
magnesium	Mg^{2+}	mg/kg	17	24	14	13
sodium	Na^{1+}	mg/kg	68	98	87	52
potassium	K^{1+}	mg/kg	17	24	6.4	6.0
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	217	454	159	79
flouride	F^{1-}	mg/kg	2.6	2.0	1.6	10
chloride	Cl^{1-}	mg/kg	10	29	12	10
sulfate	SO_4^{2-}	mg/kg	32	32	64	47
phosphate	PO_4^{3-}	mg/kg	2.6	6.3	5.2	2.8
Other Tests						
ammonium	NH_4^{1+}	mg/kg	0.6	1.3	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	0.7	5.3	5.3
sulfide	S^{2-}	qual	na	na	na	na
Redox		mV	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
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Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			B-3 @ 45.5'	G-12 @ 70'	G-16 @ 70'	G-17 @ 70'	G-17 @ 80'
Resistivity		**Units**					
as-received		ohm-cm	3,040	900	1,640	992	1,000
saturated		ohm-cm	660	900	1,640	992	860
pH			7.9	7.7	7.6	7.8	7.5
Electrical Conductivity		mS/cm	0.74	0.11	0.09	0.23	0.19
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	462	65	50	124	114
magnesium	Mg^{2+}	mg/kg	132	19	13	31	29
sodium	Na^{1+}	mg/kg	118	68	67	117	94
potassium	K^{1+}	mg/kg	62	16	16	30	5.7
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	46	85	85	531	464
flouride	F^{1-}	mg/kg	ND	1.9	1.8	1.7	10
chloride	Cl^{1-}	mg/kg	23	18	21	12	12
sulfate	SO_4^{2-}	mg/kg	1,720	92	68	66	41
phosphate	PO_4^{3-}	mg/kg	ND	0.7	4.0	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	9.8	ND	2.5	2.4	ND
nitrate	NO_3^{1-}	mg/kg	2.3	0.7	2.9	1.5	ND
sulfide	S^{2-}	qual	TRACE	na	na	na	na
Redox		mV	-68	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-25 @ 80'	G-26 @ 50'	G-33 @ 30'	G-33 @ 60'	G-34 @ 35.5'
Resistivity		**Units**					
as-received		ohm-cm	10,640	8,000	19,760	5,400	21,200
saturated		ohm-cm	1,416	2,596	3,144	1,180	2,100
pH			7.4	7.7	7.6	7.2	7.5
Electrical Conductivity		mS/cm	0.11	0.07	0.09	0.10	0.11
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	57	66	48	40	51
magnesium	Mg^{2+}	mg/kg	20	15	14	13	14
sodium	Na^{1+}	mg/kg	55	47	64	97	95
potassium	K^{1+}	mg/kg	17	10	9.1	10	10
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	67	49	104	134	104
flouride	F^{1-}	mg/kg	4.1	4.6	0.5	0.6	ND
chloride	Cl^{1-}	mg/kg	18	11	4.9	2.7	15
sulfate	SO_4^{2-}	mg/kg	129	70	50	47	86
phosphate	PO_4^{3-}	mg/kg	ND	ND	10	10	15
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	3.1	3.3	3.9
nitrate	NO_3^{1-}	mg/kg	4.1	1.8	ND	2.2	1.7
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-34 @ 55.5'	G-36 @ 70'	G-38 @ 20'	G-38 @ 40'	G-38 @ 50'
Resistivity		**Units**					
as-received		ohm-cm	12,800	6,000	1,420	2,760	7,600
saturated		ohm-cm	2,320	2,828	1,420	2,760	5,800
pH			7.8	7.6	7.5	7.8	8.0
Electrical Conductivity		mS/cm	0.09	0.07	0.16	0.08	0.09
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	42	38	95	52	47
magnesium	Mg^{2+}	mg/kg	11	9.1	22	13	12
sodium	Na^{1+}	mg/kg	76	62	82	48	65
potassium	K^{1+}	mg/kg	8.1	8.6	17	17	12
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	85	76	256	95	85
flouride	F^{1-}	mg/kg	0.6	3.4	1.3	1.2	3.4
chloride	Cl^{1-}	mg/kg	13	10	19	8.2	13
sulfate	SO_4^{2-}	mg/kg	69	47	94	54	62
phosphate	PO_4^{3-}	mg/kg	6.5	11	ND	2.4	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	3.0	2.7	3.9	2.7	2.4
nitrate	NO_3^{1-}	mg/kg	3.2	ND	ND	1.0	0.4
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-39 @ 50'	G-39 @ 70'	G-40 @ 30'	G-40 @ 60'	G-41 @ 25.5'
Resistivity		**Units**					
as-received		ohm-cm	716	4,800	1,092	1,040	1,180
saturated		ohm-cm	616	1,640	1,092	1,040	824
pH			7.7	7.9	7.8	7.9	8.2
Electrical Conductivity		mS/cm	1.21	0.21	0.10	0.21	0.69
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	911	120	54	113	495
magnesium	Mg^{2+}	mg/kg	394	37	21	35	127
sodium	Na^{1+}	mg/kg	149	90	72	78	133
potassium	K^{1+}	mg/kg	120	17	7.0	45	34
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	1,617	583	137	482	720
flouride	F^{1-}	mg/kg	4.2	3.3	1.5	5.1	7.5
chloride	Cl^{1-}	mg/kg	18	6.0	28	13	57
sulfate	SO_4^{2-}	mg/kg	1,270	34	46	62	917
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	0.7
Other Tests							
ammonium	NH_4^{1+}	mg/kg	39.5	ND	ND	1.7	16.2
nitrate	NO_3^{1-}	mg/kg	0.6	ND	ND	2.9	0.5
sulfide	S^{2-}	qual	TRACE	na	na	na	TRACE
Redox		mV	-40	na	na	na	-38

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-41 @ 60'	G-42 @ 25.5'	G-42 @ 25.5'	G-42 @ 60'
Resistivity		**Units**				
as-received		ohm-cm	880	2,560	3,512	860
saturated		ohm-cm	740	1,200	1,240	860
pH			8.1	8.1	8.0	8.4
Electrical Conductivity		mS/cm	0.53	0.52	0.29	0.35
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	274	254	142	180
magnesium	Mg^{2+}	mg/kg	110	120	45	61
sodium	Na^{1+}	mg/kg	154	101	101	107
potassium	K^{1+}	mg/kg	37	18	46	47
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	506	67	555	409
flouride	F^{1-}	mg/kg	4.4	ND	2.6	5.9
chloride	Cl^{1-}	mg/kg	11	21	19	12
sulfate	SO_4^{2-}	mg/kg	915	1,150	85	483
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND
Other Tests						
ammonium	NH_4^{1+}	mg/kg	4.0	21.5	3.4	ND
nitrate	NO_3^{1-}	mg/kg	1.6	ND	0.9	ND
sulfide	S^{2-}	qual	TRACE	TRACE	na	POSITIVE
Redox		mV	-47	-54	na	-130

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
MTA Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-6 @ 70' ML	G-18 @ 10' ML/CL	G-18 @ 30' CL	G-18 @ 50' ML/SM	G-19 @ 30' ML
Resistivity		**Units**					
as-received		ohm-cm	18,000	1,400	5,600	1,640	10,000
saturated		ohm-cm	600	1,040	1,120	1,640	2,080
pH			7.3	7.6	7.3	7.3	7.3
Electrical Conductivity		mS/cm	1.16	0.09	0.05	0.06	0.07
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	361	145	29	29	21
magnesium	Mg^{2+}	mg/kg	180	41	10	8.1	8.0
sodium	Na^{1+}	mg/kg	557	122	49	50	65
potassium	K^{1+}	mg/kg	75	4.6	3.8	3.7	1.9
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	217	159	64	40	34
flouride	F^{1-}	mg/kg	1.4	15	7.4	4.0	5.4
chloride	Cl^{1-}	mg/kg	264	29	19	28	46
sulfate	SO_4^{2-}	mg/kg	1,810	40	22	34	21
phosphate	PO_4^{3-}	mg/kg	ND	21	5.9	2.1	9.3
Other Tests							
ammonium	NH_4^{1+}	mg/kg	32	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	0.9	3.7	4.6	1.0
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
MTA Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-20 @ 50' ML	G-23 @ 40' SM/SW	G-24 @ 20' CL w/ Gravel	G-24 @ 40' ML	G-27 @ 40' SC/CL
Resistivity		**Units**					
as-received		ohm-cm	9,200	2,200	14,800	2,120	5,200
saturated		ohm-cm	1,880	1,720	1,920	2,120	3,520
pH			7.3	7.6	7.3	7.6	7.6
Electrical Conductivity		mS/cm	0.05	0.12	0.05	0.05	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	28	67	30	28	19
magnesium	Mg^{2+}	mg/kg	8.3	18	12	10	10
sodium	Na^{1+}	mg/kg	32	47	21	43	53
potassium	K^{1+}	mg/kg	6.0	7.9	2.1	2.3	2.6
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	49	210	76	49	46
flouride	F^{1-}	mg/kg	4.5	1.9	10	3.2	5.9
chloride	Cl^{1-}	mg/kg	12	16	11	9.2	6.7
sulfate	SO_4^{2-}	mg/kg	37	69	23	46	45
phosphate	PO_4^{3-}	mg/kg	2.9	3.2	16	6.6	14
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	8.3	10.5	0.6	1.8	20
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
MTA Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-27 @ 50' ML/SM	G-28 @ 10' ML	G-28 @ 50' SM	G-29 @ 30' ML	G-29 @ 40' SM w/ Gravel
Resistivity		**Units**					
as-received		ohm-cm	1,840	37,200	23,200	41,200	20,000
saturated		ohm-cm	1,840	4,320	4,800	2,560	4,800
pH			7.4	7.5	7.8	7.5	8.1
Electrical Conductivity		mS/cm	0.08	0.04	0.05	0.09	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	35	25	19	36	15
magnesium	Mg^{2+}	mg/kg	21	11	10	24	8.1
sodium	Na^{1+}	mg/kg	74	37	49	97	60
potassium	K^{1+}	mg/kg	3.5	2.0	2.3	3.7	2.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	61	49	61	110	64
flouride	F^{1-}	mg/kg	7.8	3.5	6.9	12	5.9
chloride	Cl^{1-}	mg/kg	10	7.0	8.7	13	8.6
sulfate	SO_4^{2-}	mg/kg	54	23	32	45	48
phosphate	PO_4^{3-}	mg/kg	14	11	12	45	11
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	55	2.8	4.6	2.3	2.2
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
MTA Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-30 @ 20' ML	G-30 @ 30' SM/CL/ML	G-31 @ 10' CL	G-31 @ 20' ML/SM	G-31 @ 50' ML/CL
Resistivity		**Units**					
as-received		ohm-cm	3,000	10,400	17,200	1,320	4,200
saturated		ohm-cm	1,320	1,360	1,280	1,200	1,240
pH			7.6	7.5	7.4	7.4	7.3
Electrical Conductivity		mS/cm	0.11	0.10	0.07	0.06	0.05
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	36	32	20	20	21
magnesium	Mg^{2+}	mg/kg	16	12	7.7	7.6	8.7
sodium	Na^{1+}	mg/kg	73	78	67	54	39
potassium	K^{1+}	mg/kg	2.9	2.5	1.6	4.7	3.4
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	186	73	98	82	61
flouride	F^{1-}	mg/kg	2.0	3.8	7.5	3.2	3.9
chloride	Cl^{1-}	mg/kg	26	33	8.1	12	5.2
sulfate	SO_4^{2-}	mg/kg	51	70	34	52	38
phosphate	PO_4^{3-}	mg/kg	5.6	10	5.7	4.4	3.8
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	4.6	17	8.7	6.3	4.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC
MTA Westside Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-35 @ 20' SM	G-35 @ 60' SM	G-37 @ 40' SM
Resistivity		**Units**			
as-received		ohm-cm	5,200	26,400	6,000
saturated		ohm-cm	3,400	4,800	4,080
pH			8.0	7.8	7.7
Electrical Conductivity		mS/cm	0.11	0.05	0.04
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	40	21	23
magnesium	Mg^{2+}	mg/kg	13	6.7	8.3
sodium	Na^{1+}	mg/kg	76	35	22
potassium	K^{1+}	mg/kg	4.2	4.2	10
Anions					
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	210	40	52
flouride	F^{1-}	mg/kg	1.4	2.6	5.0
chloride	Cl^{1-}	mg/kg	13	8.8	10
sulfate	SO_4^{2-}	mg/kg	65	41	27
phosphate	PO_4^{3-}	mg/kg	4.7	4.2	1.8
Other Tests					
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	5.1	4.9	3.1
sulfide	S^{2-}	qual	na	na	na
Redox		mV	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.1 THROUGH F-10.62
CORROSION TEST DATA (PE PHASE)

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			168 @ 1-5' CL - Fill	168 @ 38.5' CL with Sand	168 @ 72.5' SP	169 @ 26' CL	169 @ 72' SP-SM / SM
Resistivity		**Units**					
as-received		ohm-cm	8,000	2,640	4,000	6,400	1,480
saturated		ohm-cm	1,680	840	3,040	920	960
pH			8.2	7.3	8.2	7.9	7.8
Electrical Conductivity		mS/cm	0.09	0.07	0.13	0.46	0.29
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	21	27	34	73	135
magnesium	Mg^{2+}	mg/kg	10	10	6.6	32	17
sodium	Na^{1+}	mg/kg	115	88	132	377	129
potassium	K^{1+}	mg/kg	3.3	5.6	6.4	11	26
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	45	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	143	98	142	183	259
fluoride	F^{1-}	mg/kg	24	14	1.9	9.0	1.2
chloride	Cl^{1-}	mg/kg	3.9	21	13	99	58
sulfate	SO_4^{2-}	mg/kg	27	25	51	672	358
phosphate	PO_4^{3-}	mg/kg	16	13	ND	1.5	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	3.7
nitrate	NO_3^{1-}	mg/kg	2.8	2.3	4.2	ND	9.0
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			169 @ 100.5' ML	175 @ 110' CH	175 @ 120' Clayey ML	175 @ 135' SP-SM / SM	177 @ 90.5' ML
Resistivity		**Units**					
as-received		ohm-cm	3,920	2,200	10,000	12,000	4,800
saturated		ohm-cm	640	1,560	3,920	6,000	2,600
pH			7.7	7.8	8.0	8.2	7.5
Electrical Conductivity		mS/cm	0.50	0.04	0.03	0.03	0.04
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	289	29	25	23	29
magnesium	Mg^{2+}	mg/kg	55	8.5	6.2	5.1	8.8
sodium	Na^{1+}	mg/kg	84	34	34	29	40
potassium	K^{1+}	mg/kg	76	5.8	4.1	6.3	7.7
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	101	88	61	76	76
fluoride	F^{1-}	mg/kg	0.5	3.2	2.7	1.1	6.0
chloride	Cl^{1-}	mg/kg	45	5.1	10	7.6	12
sulfate	SO_4^{2-}	mg/kg	968	15	10	13	8.5
phosphate	PO_4^{3-}	mg/kg	ND	1.9	ND	2.8	4.8
Other Tests							
ammonium	NH_4^{1+}	mg/kg	14	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	0.8	2.1
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			177 @ 100.5' ML	178 @ 20' ML	178 @ 40' ML	178 @ 68' CL	178 @ 93' SM/CL
Resistivity		**Units**					
as-received		ohm-cm	7,200	4,000	20,000	160,000	4,000
saturated		ohm-cm	2,640	2,400	1,800	1,480	1,280
pH			7.7	7.5	7.4	7.4	7.6
Electrical Conductivity		mS/cm	0.04	0.04	0.04	0.06	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	22	28	26	30	31
magnesium	Mg^{2+}	mg/kg	6.6	9.1	7.6	10	10
sodium	Na^{1+}	mg/kg	41	48	45	51	41
potassium	K^{1+}	mg/kg	6.3	5.5	5.0	7.1	13
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	49	70	58	79	70
fluoride	F^{1-}	mg/kg	3.8	5.3	8.0	5.9	6.8
chloride	Cl^{1-}	mg/kg	16	3.3	5.1	24	26
sulfate	SO_4^{2-}	mg/kg	16	19	23	26	17
phosphate	PO_4^{3-}	mg/kg	1.2	6.7	3.7	3.8	2.3
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	3.1	5.9	5.6	3.5	4.4
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

431 West Baseline Road · Claremont, CA 91711
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Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			179 @ 77' SC / Sandy CL	179 @ 100' SC / Sandy CL
Resistivity		**Units**		
as-received		ohm-cm	2,840	3,120
saturated		ohm-cm	1,840	2,280
pH			7.4	7.6
Electrical Conductivity		mS/cm	0.05	0.05
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	22	19
magnesium	Mg^{2+}	mg/kg	6.6	6.2
sodium	Na^{1+}	mg/kg	39	45
potassium	K^{1+}	mg/kg	7.2	5.2
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	61	52
fluoride	F^{1-}	mg/kg	5.0	5.4
chloride	Cl^{1-}	mg/kg	20	25
sulfate	SO_4^{2-}	mg/kg	10	18
phosphate	PO_4^{3-}	mg/kg	4.5	3.0
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	1.6	1.4
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0229LAB
3-Mar-11

Sample ID			161 @ 70' CL	161 @ 110' CL / CL-CH	162 @ 60' CL with Sand	162 @ 93' CL / CL-CH	164 @ 30' Clayey ML
Resistivity		**Units**					
as-received		ohm-cm	1,600	1,200	2,200	1,400	1,800
saturated		ohm-cm	1,400	1,120	1,000	1,120	1,720
pH			7.8	7.7	7.7	7.6	7.5
Electrical Conductivity		mS/cm	0.08	0.05	0.08	0.06	0.08
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	34	25	46	34	25
magnesium	Mg^{2+}	mg/kg	9.4	8.4	11	9.3	5.6
sodium	Na^{1+}	mg/kg	62	50	50	47	91
potassium	K^{1+}	mg/kg	6.9	3.1	11	5.8	3.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	116	64	110	82	92
fluoride	F^{1-}	mg/kg	6.2	6.2	4.6	5.3	1.8
chloride	Cl^{1-}	mg/kg	9.3	6.3	15	23	29
sulfate	SO_4^{2-}	mg/kg	82	36	79	30	62
phosphate	PO_4^{3-}	mg/kg	6.1	5.2	0.6	2.4	17
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	2.6	1.8	2.8	4.7	0.5
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC
Westside Extension
Your #4953-10-1561, SA #11-0229LAB
3-Mar-11

Sample ID			164 @ 54.5' CL	164 @ 75' SP	181 @ 100' CL	181 @ 110' ML with Sand
Resistivity		**Units**				
as-received		ohm-cm	1,080	4,800	1,400	2,680
saturated		ohm-cm	600	3,200	960	2,280
pH			7.4	7.8	7.6	7.5
Electrical Conductivity		mS/cm	0.17	0.07	0.06	0.04
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	72	21	39	21
magnesium	Mg^{2+}	mg/kg	20	5.1	10	5.5
sodium	Na^{1+}	mg/kg	87	58	53	42
potassium	K^{1+}	mg/kg	16	4.6	7.6	5.5
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	387	64	73	46
fluoride	F^{1-}	mg/kg	4.7	2.6	7.5	6.0
chloride	Cl^{1-}	mg/kg	37	20	22	19
sulfate	SO_4^{2-}	mg/kg	26	61	21	16
phosphate	PO_4^{3-}	mg/kg	ND	4.7	2.0	3.4
Other Tests						
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	4.2	2.8	5.2	5.4
sulfide	S^{2-}	qual	na	na	na	na
Redox		mV	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, SA #11-0291LAB
23-Mar-11

Sample ID			180 @ 80' CL with Sand	180 @ 98' CL / Clayey ML
Resistivity		**Units**		
as-received		ohm-cm	16,000	20,000
saturated		ohm-cm	1,160	1,640
pH			7.6	7.6
Electrical Conductivity		mS/cm	0.05	0.06
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	26	27
magnesium	Mg^{2+}	mg/kg	8.5	8.9
sodium	Na^{1+}	mg/kg	46	44
potassium	K^{1+}	mg/kg	3.8	7.3
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	55	76
fluoride	F^{1-}	mg/kg	7.2	7.8
chloride	Cl^{1-}	mg/kg	20	26
sulfate	SO_4^{2-}	mg/kg	18	18
phosphate	PO_4^{3-}	mg/kg	4.4	2.4
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	3.1	2.9
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

Mactec Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, SA #11-0344LAB
8-Apr-11

Sample ID			149 55' ML/CL	149 75' CL/ML	150 50' CL-CH	150 75.5' CL-CH	154 40' ML/CL
Resistivity		**Units**					
as-received		ohm-cm	3,240	2,720	2,720	3,600	8,400
saturated		ohm-cm	920	880	920	800	1,480
pH			7.7	7.8	7.9	8.0	7.8
Electrical Conductivity		mS/cm	0.08	0.09	0.08	0.08	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	39	48	35	42	20
magnesium	Mg^{2+}	mg/kg	11	12	12	12	6.7
sodium	Na^{1+}	mg/kg	57	67	60	59	59
potassium	K^{1+}	mg/kg	10	11	6.2	10	4.2
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	101	128	76	98	64
fluoride	F^{1-}	mg/kg	4.4	5.1	4.2	5.8	8.2
chloride	Cl^{1-}	mg/kg	14	14	18	15	4.6
sulfate	SO_4^{2-}	mg/kg	78	89	86	64	16
phosphate	PO_4^{3-}	mg/kg	5.1	4.1	0.7	2.5	8.3
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	5.9	4.9	3.3	ND	55
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

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Checked By: JF 5/12/2011

Table 1 - Laboratory Tests on Soil Sample(s)

Mactec Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, SA #11-0344LAB
8-Apr-11

Sample ID			154 60' CLAYEY ML
Resistivity		**Units**	
as-received		ohm-cm	3,640
saturated		ohm-cm	880
pH			7.8
Electrical Conductivity		mS/cm	0.05
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	27
magnesium	Mg^{2+}	mg/kg	8.8
sodium	Na^{1+}	mg/kg	51
potassium	K^{1+}	mg/kg	3.4
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	76
fluoride	F^{1-}	mg/kg	6.3
chloride	Cl^{1-}	mg/kg	14
sulfate	SO_4^{2-}	mg/kg	19
phosphate	PO_4^{3-}	mg/kg	4.1
Other Tests			
ammonium	NH_4^{1+}	mg/kg	ND
nitrate	NO_3^{1-}	mg/kg	12
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Checked By: JF 5/12/2011

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0416LAB
3-May-11

Sample ID			G-103 @ 37' Clayey ML	G-103 @ 49' SM / Sandy ML	G-106 @ 34' ML	G-106 @ 58' ML and SM	G-159 @ 50' CL
Resistivity		**Units**					
as-received		ohm-cm	3,080	1,320	4,000	1,600	22,000
saturated		ohm-cm	600	560	640	1,080	1,200
pH			7.0	7.8	8.1	8.1	7.8
Electrical Conductivity		mS/cm	1.25	0.54	0.26	0.26	0.11
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	690	212	87	103	61
magnesium	Mg^{2+}	mg/kg	315	67	23	33	13
sodium	Na^{1+}	mg/kg	176	204	142	86	50
potassium	K^{1+}	mg/kg	77	57	57	35	12
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	9.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	119	295	137	299
fluoride	F^{1-}	mg/kg	ND	2.0	2.5	1.6	3.0
chloride	Cl^{1-}	mg/kg	20	25	23	18	7.0
sulfate	SO_4^{2-}	mg/kg	2,441	1,044	252	432	18
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	4.7	1.4	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	0.5	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

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Corrosion Control and Condition Assessment (C3A) Department

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0416LAB
3-May-11

Sample ID			G-159 @ 70' Sandy CL	G-173 @ 77' SM	G-173 @ 115' Claystone	S-110 @ 33'-34' ML / CL	S-110 @ 44'-45' CH
Resistivity		**Units**					
as-received		ohm-cm	40,000	22,000	6,400	8,400	28,000
saturated		ohm-cm	1,280	3,360	720	1,480	1,040
pH			7.8	8.2	7.8	7.8	7.5
Electrical Conductivity		mS/cm	0.07	0.11	0.62	0.08	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	33	62	317	33	28
magnesium	Mg^{2+}	mg/kg	6.3	11	114	9.3	8.7
sodium	Na^{1+}	mg/kg	47	65	96	53	43
potassium	K^{1+}	mg/kg	5.4	10	67	2.7	10
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	21	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	73	185	195	61	76
fluoride	F^{1-}	mg/kg	2.8	2.2	1.3	2.3	4.4
chloride	Cl^{1-}	mg/kg	51	19	19	27	12
sulfate	SO_4^{2-}	mg/kg	22	27	1,215	70	43
phosphate	PO_4^{3-}	mg/kg	1.3	ND	ND	3.8	4.2
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	17	ND	ND
nitrate	NO_3^{1-}	mg/kg	2.1	0.7	ND	1.0	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0416LAB
3-May-11

Sample ID			S-110 @ 60'-61' CL w/ Sand and Gravel
Resistivity		**Units**	
as-received		ohm-cm	6,000
saturated		ohm-cm	1,000
pH			7.7
Electrical Conductivity		mS/cm	0.05
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	37
magnesium	Mg^{2+}	mg/kg	10
sodium	Na^{1+}	mg/kg	38
potassium	K^{1+}	mg/kg	5.4
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	82
fluoride	F^{1-}	mg/kg	3.8
chloride	Cl^{1-}	mg/kg	12
sulfate	SO_4^{2-}	mg/kg	39
phosphate	PO_4^{3-}	mg/kg	3.7
Other Tests			
ammonium	NH_4^{1+}	mg/kg	ND
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0457LAB
13-May-11

Sample ID			S-101 @ 33.1-33.9' ML/CL	S-101 @ 44.4-45.4' ML	S-101 @ 71-72' ML	S-102 @ 27-28' ML/CL	S-102 @ 33.6-34.6' CL/ML
Resistivity		**Units**					
as-received		ohm-cm	1,400	880	1,800	2,600	4,400
saturated		ohm-cm	1,000	480	440	1,400	880
pH			8.0	7.6	5.1	6.3	7.5
Electrical Conductivity		mS/cm	0.29	1.17	1.65	0.09	0.17
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	84	523	388	27	85
magnesium	Mg^{2+}	mg/kg	34	267	238	11	16
sodium	Na^{1+}	mg/kg	136	260	887	89	118
potassium	K^{1+}	mg/kg	36	68	145	2.8	20
Anions							
carbonate	CO_3^{2-}	mg/kg	30	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	110	82	ND	98	351
fluoride	F^{1-}	mg/kg	1.4	1.0	2.2	2.9	2.6
chloride	Cl^{1-}	mg/kg	47	50	233	21	23
sulfate	SO_4^{2-}	mg/kg	420	2,120	2,660	87	44
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	1.7	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	0.9	8.4	57	ND	3.6
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	ND	ND
sulfide	S^{2-}	qual	Trace	Trace	na	na	na
Redox		mV	-100	-90	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0457LAB
13-May-11

Sample ID			S-102 @ 53.6-54.6' Sandy ML/CL	S-102 @ 64-65' SP-SM	S-102 @ 84-85' ML/CL	G-118 @ 34.5' Sandy ML-SM with tar	G-118 @ 61' Sandy ML/SM with tar
Resistivity		**Units**					
as-received		ohm-cm	2,000	2,880	2,040	18,400	4,400
saturated		ohm-cm	880	1,960	480	1,760	920
pH			7.3	7.3	7.0	7.5	7.3
Electrical Conductivity		mS/cm	0.57	0.16	1.34	0.28	0.39
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	271	65	289	59	85
magnesium	Mg^{2+}	mg/kg	91	21	200	43	26
sodium	Na^{1+}	mg/kg	132	53	776	189	211
potassium	K^{1+}	mg/kg	51	16	153	26	14
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	262	70	37	314	ND
fluoride	F^{1-}	mg/kg	2.0	0.8	ND	ND	ND
chloride	Cl^{1-}	mg/kg	12	12	208	51	275
sulfate	SO_4^{2-}	mg/kg	1,003	256	2,230	307	303
phosphate	PO_4^{3-}	mg/kg	ND	ND	1.3	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.6	1.2	52	8.3	3.5
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	2.4	0.7
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0457LAB
13-May-11

Sample ID			G-118 @ 67' Sandy ML/SM with tar	G-126 @ 65' SP-SM/SM	G-126 @ 85.5' Sandy CL/SC	G-140 @ 59.5' CL	G-140 @ 71' Sandy CL/SC
Resistivity		**Units**					
as-received		ohm-cm	4,400,000	1,680	2,080	1,560	3,400
saturated		ohm-cm	8,000	1,080	800	1,280	2,360
pH			7.4	7.5	7.6	7.9	8.0
Electrical Conductivity		mS/cm	0.08	0.34	0.48	0.19	0.18
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	70	123	186	92	96
magnesium	Mg^{2+}	mg/kg	4.5	53	76	25	20
sodium	Na^{1+}	mg/kg	32	123	168	93	68
potassium	K^{1+}	mg/kg	3.3	19	29	27	25
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	113	299	424	323
fluoride	F^{1-}	mg/kg	ND	1.3	1.6	3.1	0.6
chloride	Cl^{1-}	mg/kg	22	13	10	26	22
sulfate	SO_4^{2-}	mg/kg	161	594	829	87	130
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.6	2.7	10	2.2	1.9
nitrate	NO_3^{1-}	mg/kg	ND	62	1.1	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	Positive
Redox		mV	na	na	na	na	-206

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0457LAB
13-May-11

Sample ID			G-174A @ 70' Sandy CL	G-174A @ 90' Sandy CL
Resistivity		**Units**		
as-received		ohm-cm	2,400	2,000
saturated		ohm-cm	1,440	1,360
pH			7.8	7.8
Electrical Conductivity		mS/cm	0.07	0.11
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	46	70
magnesium	Mg^{2+}	mg/kg	9.0	13
sodium	Na^{1+}	mg/kg	44	51
potassium	K^{1+}	mg/kg	4.8	10
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	159	265
fluoride	F^{1-}	mg/kg	2.9	3.6
chloride	Cl^{1-}	mg/kg	9.3	15
sulfate	SO_4^{2-}	mg/kg	21	17
phosphate	PO_4^{3-}	mg/kg	1.8	1.5
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	0.8	1.3
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0482LAB
25-May-11

Sample ID			G-133 @ 50' CL	G-133 @ 62' CL	G-133 @ 74' Sandy ML / SM	G-134 @ 60' CL / CL-CH	G-134 @76' CL / CL-CH
Resistivity		**Units**					
as-received		ohm-cm	2,840	2,080	1,280	1,160	4,000
saturated		ohm-cm	960	1,760	1,080	800	1,840
pH			7.7	8.0	8.0	8.0	8.1
Electrical Conductivity		mS/cm	0.22	0.19	0.24	0.24	0.13
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	62	75	103	94	72
magnesium	Mg^{2+}	mg/kg	26	21	24	27	16
sodium	Na^{1+}	mg/kg	127	96	99	111	61
potassium	K^{1+}	mg/kg	27	19	35	41	5.7
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	12
bicarbonate	HCO_3^{1-}	mg/kg	458	360	360	515	183
fluoride	F^{1-}	mg/kg	3.6	2.9	3.8	8.8	5.3
chloride	Cl^{1-}	mg/kg	56	65	37	60	31
sulfate	SO_4^{2-}	mg/kg	48	33	186	53	31
phosphate	PO_4^{3-}	mg/kg	ND	1.0	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.9	2.0	2.2	3.4	ND
nitrate	NO_3^{1-}	mg/kg	1.0	1.7	1.3	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0482LAB
25-May-11

Sample ID			G-165 @ 67' CL	G-165 @ 109' SC	S-108 @ 63-64' ML/CL	S-108 @ 75.5'-76.5' CL/CH	S-108 @ 82-83' ML/CL
Resistivity		**Units**					
as-received		ohm-cm	1,000	810	1,880	4,000	2,320
saturated		ohm-cm	600	680	1,040	1,560	1,560
pH			7.7	7.8	8.2	8.0	8.0
Electrical Conductivity		mS/cm	0.24	0.42	0.18	0.15	0.15
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	106	189	73	74	71
magnesium	Mg^{2+}	mg/kg	13	24	19	17	19
sodium	Na^{1+}	mg/kg	123	172	94	76	76
potassium	K^{1+}	mg/kg	16	18	20	6.8	6.2
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	12	9.0
bicarbonate	HCO_3^{1-}	mg/kg	329	256	381	226	245
fluoride	F^{1-}	mg/kg	3.6	2.7	7.9	5.6	4.3
chloride	Cl^{1-}	mg/kg	172	432	48	43	38
sulfate	SO_4^{2-}	mg/kg	8.8	53	27	24	14
phosphate	PO_4^{3-}	mg/kg	ND	ND	2.0	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	0.8	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	7.4	ND	1.0	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0482LAB
25-May-11

Sample ID			S-108 @ 97-98' CL/SC
Resistivity		**Units**	
as-received		ohm-cm	2,680
saturated		ohm-cm	1,800
pH			8.0
Electrical Conductivity		mS/cm	0.14
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	57
magnesium	Mg^{2+}	mg/kg	18
sodium	Na^{1+}	mg/kg	79
potassium	K^{1+}	mg/kg	7.2
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	311
fluoride	F^{1-}	mg/kg	2.7
chloride	Cl^{1-}	mg/kg	39
sulfate	SO_4^{2-}	mg/kg	11
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	ND
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0498LAB
31-May-11

Sample ID			S-107 @ 28-29' CL	S-107 @ 42-43' ML	S-107 @ 59-60' ML/CL	S-107 @ 72-73' CL	S-107 @ 85-86' CL/ML
Resistivity		**Units**					
as-received		ohm-cm	1,600	1,360	960	800	1,240
saturated		ohm-cm	1,240	960	640	480	760
pH			8.1	7.9	8.1	8.0	7.9
Electrical Conductivity		mS/cm	0.24	0.34	0.45	0.57	0.50
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	52	115	128	247	201
magnesium	Mg^{2+}	mg/kg	21	51	51	95	90
sodium	Na^{1+}	mg/kg	188	124	259	180	137
potassium	K^{1+}	mg/kg	35	51	38	55	71
Anions							
carbonate	CO_3^{2-}	mg/kg	24	ND	9.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	275	305	176	458	354
fluoride	F^{1-}	mg/kg	3.5	2.5	0.6	ND	ND
chloride	Cl^{1-}	mg/kg	47	40	49	97	131
sulfate	SO_4^{2-}	mg/kg	158	427	792	853	696
phosphate	PO_4^{3-}	mg/kg	ND	0.9	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.7	4.6	7.9	10	8.8
nitrate	NO_3^{1-}	mg/kg	1.0	ND	1.1	0.9	0.6
sulfide	S^{2-}	qual	Positive	Positive	Positive	Positive	Positive
Redox		mV	-126	-267	-117	-272	-313

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0498LAB
31-May-11

Sample ID			S-107 @ 102-103' ML	S-107 @ 121-122' ML	S-111 @ 52-53' CL w/sand	S-111 @ 81-82' SM	G-130 @ 45' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	3,480	3,400	1,920	5,200	1,280
saturated		ohm-cm	480	800	760	3,280	880
pH			8.0	8.2	7.6	7.9	8.0
Electrical Conductivity		mS/cm	0.58	0.29	0.12	0.06	0.39
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	244	113	40	19	95
magnesium	Mg^{2+}	mg/kg	102	43	11	5.3	40
sodium	Na^{1+}	mg/kg	124	80	60	52	248
potassium	K^{1+}	mg/kg	68	79	6.3	5.1	44
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	9.0	ND	ND	12
bicarbonate	HCO_3^{1-}	mg/kg	354	245	92	43	231
fluoride	F^{1-}	mg/kg	1.1	2.5	4.6	2.1	2.0
chloride	Cl^{1-}	mg/kg	57	48	45	32	40
sulfate	SO_4^{2-}	mg/kg	921	318	39	50	554
phosphate	PO_4^{3-}	mg/kg	ND	ND	1.3	3.1	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	12	3.3	ND	ND	2.2
nitrate	NO_3^{1-}	mg/kg	1.1	ND	3.4	1.0	ND
sulfide	S^{2-}	qual	na	Trace	na	na	na
Redox		mV	na	-97	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

MACTEC Engineering & Consulting, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0498LAB
31-May-11

Sample ID			G-130 @ 65' CL-ML/CL
Resistivity		**Units**	
as-received		ohm-cm	800
saturated		ohm-cm	560
pH			8.1
Electrical Conductivity		mS/cm	0.46
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	151
magnesium	Mg^{2+}	mg/kg	63
sodium	Na^{1+}	mg/kg	191
potassium	K^{1+}	mg/kg	63
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	296
fluoride	F^{1-}	mg/kg	ND
chloride	Cl^{1-}	mg/kg	81
sulfate	SO_4^{2-}	mg/kg	684
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	5.9
nitrate	NO_3^{1-}	mg/kg	1.0
sulfide	S^{2-}	qual	Positive
Redox		mV	-270

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			G-105 @ 50' ML	G-105 @ 90' Siltstone	G-107 @ 75' CL-ML	G-107 @ 95' Siltstone	G-127 @ 45' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	880	480	720	800	1,120
saturated		ohm-cm	560	228	520	352	800
pH			8.0	4.0	5.2	7.2	7.6
Electrical Conductivity		mS/cm	0.76	2.81	1.23	1.64	0.45
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	417	761	438	228	159
magnesium	Mg^{2+}	mg/kg	133	721	248	115	72
sodium	Na^{1+}	mg/kg	133	1,825	493	1,236	169
potassium	K^{1+}	mg/kg	73	202	85	142	42
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	9.0
bicarbonate	HCO_3^{1-}	mg/kg	241	12	247	372	281
fluoride	F^{1-}	mg/kg	1.0	5.2	0.9	1.0	2.1
chloride	Cl^{1-}	mg/kg	18	921	139	611	11
sulfate	SO_4^{2-}	mg/kg	1,438	7,382	2,137	2,044	702
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.7	85	37	47	1.9
nitrate	NO_3^{1-}	mg/kg	0.6	ND	3.0	5.0	2.5
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			G-127 @ 85' CL	G-131 @ 20' ML	G-131 @ 90' ML	G-132 @ 10' CL	G-156 @ 10' CL
Resistivity		**Units**					
as-received		ohm-cm	1,120	1,080	1,080	1,000	10,400
saturated		ohm-cm	720	1,080	600	1,000	1,480
pH			7.8	8.1	8.1	8.0	7.5
Electrical Conductivity		mS/cm	0.42	0.25	0.54	0.29	0.09
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	139	60	208	62	22
magnesium	Mg^{2+}	mg/kg	66	27	102	35	7.2
sodium	Na^{1+}	mg/kg	163	198	121	185	75
potassium	K^{1+}	mg/kg	47	12	78	7.8	6.2
Anions							
carbonate	CO_3^{2-}	mg/kg	9.0	27	ND	18	ND
bicarbonate	HCO_3^{1-}	mg/kg	224	389	153	387	67
fluoride	F^{1-}	mg/kg	2.7	6.0	1.7	15	1.1
chloride	Cl^{1-}	mg/kg	1.0	15	33	41	22
sulfate	SO_4^{2-}	mg/kg	671	153	1,002	108	86
phosphate	PO_4^{3-}	mg/kg	ND	0.8	ND	0.6	10
Other Tests							
ammonium	NH_4^{1+}	mg/kg	8.0	ND	9.4	ND	ND
nitrate	NO_3^{1-}	mg/kg	14	0.5	0.7	15	1.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			G-156 @ 25' SM	G-156 @ 45' CL	G-156 @ 70' SM/SW	G-156 @ 80' CL	S-104 @ 47-48' ML/CL
Resistivity		**Units**					
as-received		ohm-cm	9,600	1,160	6,000	4,400	1,640
saturated		ohm-cm	1,720	800	2,200	1,200	480
pH			7.1	7.2	7.4	7.3	7.8
Electrical Conductivity		mS/cm	0.08	0.12	0.08	0.06	0.65
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	21	41	21	2.5	339
magnesium	Mg^{2+}	mg/kg	5.6	11	5.3	6.7	106
sodium	Na^{1+}	mg/kg	55	80	62	40	126
potassium	K^{1+}	mg/kg	7.2	6.0	5.3	7.3	92
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	61	73	40	67	305
fluoride	F^{1-}	mg/kg	0.6	1.2	0.7	4.2	2.5
chloride	Cl^{1-}	mg/kg	23	29	23	18	11
sulfate	SO_4^{2-}	mg/kg	70	120	81	33	1,199
phosphate	PO_4^{3-}	mg/kg	3.3	3.6	2.0	0.7	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	4.7
nitrate	NO_3^{1-}	mg/kg	5.2	0.7	2.6	2.5	0.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-104 @ 86-87' ML	S-104 @ 97-98' ML	S-109 @ 30-31' CL	S-109 @ 53-54' CL	S-109 @ 65-66' ML
Resistivity		**Units**					
as-received		ohm-cm	1,520	1,320	1,480	1,440	1,640
saturated		ohm-cm	352	220	1,480	1,200	1,160
pH			3.7	5.1	6.7	7.1	7.0
Electrical Conductivity		mS/cm	2.22	3.21	0.07	0.06	0.10
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	935	843	24	24	37
magnesium	Mg^{2+}	mg/kg	644	848	7.6	7.8	11
sodium	Na^{1+}	mg/kg	585	1,561	64	46	58
potassium	K^{1+}	mg/kg	195	278	2.4	6.7	6.6
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	43	76	73	82
fluoride	F^{1-}	mg/kg	10	ND	4.0	4.3	4.1
chloride	Cl^{1-}	mg/kg	109	634	15	8.8	17
sulfate	SO_4^{2-}	mg/kg	6,721	7,926	53	49	84
phosphate	PO_4^{3-}	mg/kg	ND	ND	2.0	2.7	2.0
Other Tests							
ammonium	NH_4^{1+}	mg/kg	76	98	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	1.6	ND
sulfide	S^{2-}	qual	Trace	Trace	na	na	na
Redox		mV	-37	-46	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-109 @ 77-78' ML	S-109 @ 92-93' ML	S-113 @ 98.5-99.5' CL-ML	S-113 @ 114.3-115.3' CL	S-114 @ 27-28' SM
Resistivity		**Units**					
as-received		ohm-cm	4,200	2,440	2,200	1,840	312,000
saturated		ohm-cm	2,520	2,400	1,480	1,120	22,400
pH			7.2	4.0	6.9	7.3	7.7
Electrical Conductivity		mS/cm	0.06	0.08	0.04	0.06	0.03
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	27	31	21	43	27
magnesium	Mg^{2+}	mg/kg	7.6	9.2	6.4	10	5.6
sodium	Na^{1+}	mg/kg	41	46	34	40	14
potassium	K^{1+}	mg/kg	5.6	5.8	7.9	17	6.9
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	61	70	49	92	52
fluoride	F^{1-}	mg/kg	4.7	2.6	4.4	3.4	0.9
chloride	Cl^{1-}	mg/kg	12	20	13	3.7	3.4
sulfate	SO_4^{2-}	mg/kg	56	79	26	27	20
phosphate	PO_4^{3-}	mg/kg	2.0	1.6	3.1	4.7	2.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	0.8	ND	1.0	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-114 @ 49-50' CL	S-114 @ 61-62' CL/ML	S-114 @ 83-84' ML	S-115 @19-20' ML	S-115 @ 39-40' SM
Resistivity		**Units**					
as-received		ohm-cm	1,680	2,600	1,840	1,880	128,000
saturated		ohm-cm	1,680	1,880	1,160	1,600	5,600
pH			7.3	7.3	7.6	7.1	7.2
Electrical Conductivity		mS/cm	0.09	0.07	0.20	0.06	0.05
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	45	34	92	38	22
magnesium	Mg^{2+}	mg/kg	11	7.4	18	21	6.4
sodium	Na^{1+}	mg/kg	54	43	72	91	64
potassium	K^{1+}	mg/kg	10	11	24	3.4	3.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	9.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	64	49	265	73	64
fluoride	F^{1-}	mg/kg	3.4	4.5	6.3	12	5.7
chloride	Cl^{1-}	mg/kg	22	13	9.2	3.8	3.1
sulfate	SO_4^{2-}	mg/kg	83	72	94	14	19
phosphate	PO_4^{3-}	mg/kg	3.1	2.9	1.4	19	15
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	3.3	2.4	3.9	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-115 @ 68-69' ML	S-115 @ 96-97' ML	S-115 @ 116-117' ML	S-118 @ 75-76' SP/SM with tar	S-118 @ 89-90' ML
Resistivity		**Units**					
as-received		ohm-cm	2,840	3,760	4,400	4,400,000	3,400
saturated		ohm-cm	1,280	1,880	1,760	na*	212
pH			7.3	7.3	7.4	na*	7.1
Electrical						na*	
Conductivity		mS/cm	0.07	0.08	0.07	na*	3.37
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	38	35	35	na*	783
magnesium	Mg^{2+}	mg/kg	11	13	12	na*	343
sodium	Na^{1+}	mg/kg	41	44	35	na*	2,634
potassium	K^{1+}	mg/kg	6.0	11	13	na*	170
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	na*	ND
bicarbonate	HCO_3^{1-}	mg/kg	73	128	64	na*	442
fluoride	F^{1-}	mg/kg	3.5	4.4	4.2	na*	ND
chloride	Cl^{1-}	mg/kg	11	16	8.3	na*	2,958
sulfate	SO_4^{2-}	mg/kg	47	85	68	na*	4,155
phosphate	PO_4^{3-}	mg/kg	2.4	1.8	1.7	na*	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	na*	49
nitrate	NO_3^{1-}	mg/kg	1.4	2.7	1.1	na*	ND
sulfide	S^{2-}	qual	na	na	na	na*	na
Redox		mV	na	na	na	na*	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
na *= Tar sample was hydrophobic. Therefore aqueous extraction of chemical content was incomplete.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-118 @ 99-100' ML
Resistivity		**Units**	
as-received		ohm-cm	3,240
saturated		ohm-cm	192
pH			7.0
Electrical Conductivity		mS/cm	2.24
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	192
magnesium	Mg^{2+}	mg/kg	163
sodium	Na^{1+}	mg/kg	2,151
potassium	K^{1+}	mg/kg	156
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	323
fluoride	F^{1-}	mg/kg	ND
chloride	Cl^{1-}	mg/kg	2,168
sulfate	SO_4^{2-}	mg/kg	2,096
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	47
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-102 @ 25.5' CL	G-104 @ 10.5' CL	G-104 @ 40.5' CL/ML	G-104 @ 86' ML	G-108 @ 65.5' Sandy ML
Resistivity		**Units**					
as-received		ohm-cm	2,000	2,320	9,200	1,160	680
saturated		ohm-cm	1,400	560	1,200	420	480
pH			7.3	7.4	8.0	7.5	4.0
Electrical Conductivity		mS/cm	0.08	0.24	0.23	2.03	2.19
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	23	28	89	1,089	1,353
magnesium	Mg^{2+}	mg/kg	11	14	20	418	547
sodium	Na^{1+}	mg/kg	75	219	117	753	256
potassium	K^{1+}	mg/kg	5.6	2.1	31	147	88
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	9.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	85	125	242	232	ND
fluoride	F^{1-}	mg/kg	3.7	2.7	1.6	1.7	18
chloride	Cl^{1-}	mg/kg	14	217	34	142	64
sulfate	SO_4^{2-}	mg/kg	87	78	208	5,333	6,599
phosphate	PO_4^{3-}	mg/kg	2.5	2.9	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	4.1	46	34
nitrate	NO_3^{1-}	mg/kg	0.5	1.2	0.5	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-109 @ 105.5' ML	G-109 @ 125' Clayey ML	G-111 @ 50' SM/Sandy ML	G-111 @70' SP-SM	G-111 @ 90' Clayey ML
Resistivity		**Units**					
as-received		ohm-cm	560	560	1,640	2,800	1,160
saturated		ohm-cm	208	156	1,480	2,160	280
pH			7.1	4.6	7.7	7.7	3.2
Electrical Conductivity		mS/cm	2.52	3.39	0.18	0.14	2.38
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	341	425	62	55	927
magnesium	Mg^{2+}	mg/kg	149	324	23	18	658
sodium	Na^{1+}	mg/kg	2,281	3,022	89	57	856
potassium	K^{1+}	mg/kg	228	268	20	13	13
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	403	61	299	119	ND
fluoride	F^{1-}	mg/kg	ND	ND	2.6	1.4	20
chloride	Cl^{1-}	mg/kg	1,503	2,384	20	18	241
sulfate	SO_4^{2-}	mg/kg	3,616	5,440	146	167	6,915
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	59	99	5.5	1.6	69
nitrate	NO_3^{1-}	mg/kg	ND	ND	0.5	11	21
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-112 @ 10' SM	G-112 @ 25' CL	G-112 @ 45' Sandy CL	G-112 @ 75' SP-SM/SM	G-112 @ 105' ML
Resistivity		**Units**					
as-received		ohm-cm	2,720	1,280	2,920	3,000	570
saturated		ohm-cm	1,640	1,000	1,520	2,120	244
pH			7.2	7.4	7.8	7.8	7.4
Electrical Conductivity		mS/cm	0.21	0.20	0.16	0.15	3.03
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	51	69	71	77	1,170
magnesium	Mg^{2+}	mg/kg	20	20	20	15	428
sodium	Na^{1+}	mg/kg	157	121	81	62	1,794
potassium	K^{1+}	mg/kg	4.6	7.9	13	14	241
Anions							
carbonate	CO_3^{2-}	mg/kg	21	18	9.0	9.0	ND
bicarbonate	HCO_3^{1-}	mg/kg	169	217	231	119	464
fluoride	F^{1-}	mg/kg	1.8	3.6	1.5	1.2	ND
chloride	Cl^{1-}	mg/kg	69	19	15	11	888
sulfate	SO_4^{2-}	mg/kg	165	161	107	204	6,509
phosphate	PO_4^{3-}	mg/kg	ND	ND	0.7	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	1.3	69
nitrate	NO_3^{1-}	mg/kg	20	5.5	5.6	3.5	13
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-123 @ 41' Tar Sand	G-123 @ 47' Tar Sand	G-123 @ 63' Tar Sand	G-124 @ 35' CL w/Tar	G-124 @ 55' SP w/Tar
Resistivity		**Units**					
as-received		ohm-cm	1,680,000	18,400	3,240,000	10,400	4,400,000
saturated		ohm-cm	13,200	2,680	3,640	1,200	8,000
pH			4.9	5.5	7.0	7.5	3.3
Electrical Conductivity		mS/cm	0.11	0.11	0.43	0.27	0.49
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	45	38	196	67	240
magnesium	Mg^{2+}	mg/kg	33	30	42	59	119
sodium	Na^{1+}	mg/kg	13	34	174	113	55
potassium	K^{1+}	mg/kg	0.9	1.9	6.9	13	7.3
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	12	15	64	ND
fluoride	F^{1-}	mg/kg	ND	ND	ND	0.9	2.8
chloride	Cl^{1-}	mg/kg	1.2	5.2	49	6.5	4.4
sulfate	SO_4^{2-}	mg/kg	244	230	833	544	1,183
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	0.9	0.9	6.8	4.2	4.8
nitrate	NO_3^{1-}	mg/kg	5.0	0.8	ND	6.5	1.4
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-125 @ 56' Clayey ML	G-125 @ 68.5' SM	G-125 @ 86' SP	G-136 @ 65' CL/CL-CH	G-136 @ 105' SM
Resistivity		**Units**					
as-received		ohm-cm	1,640	1,280	1,080	1,640	3,920
saturated		ohm-cm	720	1,120	392	960	3,440
pH			7.6	7.8	2.1	7.4	7.8
Electrical Conductivity		mS/cm	0.38	0.26	2.40	0.25	0.10
Chemical Analyses							
Cations							
calcium	Ca2+	mg/kg	125	52	1,589	83	43
magnesium	Mg2+	mg/kg	30	13	343	29	12
sodium	Na1+	mg/kg	213	183	24	121	52
potassium	K1+	mg/kg	39	15	5.2	28	7.3
Anions							
carbonate	CO32-	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO31	mg/kg	223	317	ND	390	113
fluoride	F1-	mg/kg	2.7	2.5	22	6.8	1.7
chloride	Cl1-	mg/kg	8.8	15	12	27	23
sulfate	SO42-	mg/kg	667	249	8,074	157	82
phosphate	PO43-	mg/kg	ND	0.5	ND	ND	ND
Other Tests							
ammonium	NH41+	mg/kg	7.2	6.5	4.4	1.6	ND
nitrate	NO31-	mg/kg	0.6	4.2	ND	0.6	2.3
sulfide	S2-	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-142 @ 50.5' CL-ML	G-142 @ 70.5' Gravelly CL	G-143 @ 20.5' CL w/Gravel	G-143 @ 40.5' SP/SW	G-143 @ 80.5' Sandy ML
Resistivity		**Units**					
as-received		ohm-cm	1,320	5,200	6,000	144,000	2,480
saturated		ohm-cm	880	1,520	2,600	4,040	1,600
pH			7.6	7.8	7.6	7.8	7.4
Electrical Conductivity		mS/cm	0.24	0.21	0.07	0.08	0.10
Chemical Analyses							
Cations							
calcium	Ca2+	mg/kg	95	102	24	29	43
magnesium	Mg2+	mg/kg	30	25	5.6	9.2	15
sodium	Na1+	mg/kg	91	74	74	53	51
potassium	K1+	mg/kg	39	26	2.6	5.4	6.8
Anions							
carbonate	CO32-	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO31	mg/kg	125	195	67	37	49
fluoride	F1-	mg/kg	1.8	1.5	5.1	2.3	3.3
chloride	Cl1-	mg/kg	15	23	8.4	9.2	21
sulfate	SO42-	mg/kg	405	297	59	104	119
phosphate	PO43-	mg/kg	ND	ND	8.6	1.8	2.6
Other Tests							
ammonium	NH41+	mg/kg	1.8	ND	ND	ND	ND
nitrate	NO31-	mg/kg	2.1	11	41	18	3.3
sulfide	S2-	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-146 @ 66' CL-ML w/Sand	G-146 @ 78.5' Clayey ML	G-166 @ 57' CL/CL-CH	S-103A @ 86-87' ML	S-103A @ 111-112' ML
Resistivity		**Units**					
as-received		ohm-cm	1,280	4,800	1,360	1,360	1,160
saturated		ohm-cm	1,120	1,840	1,040	408	244
pH			7.3	7.0	6.5	6.9	5.0
Electrical Conductivity		mS/cm	0.11	0.09	0.09	1.20	2.39
Chemical Analyses							
Cations							
calcium	Ca2+	mg/kg	45	39	32	164	481
magnesium	Mg2+	mg/kg	13	11	10	106	320
sodium	Na1+	mg/kg	69	51	73	827	1,748
potassium	K1+	mg/kg	7.8	13	10	168	321
Anions							
carbonate	CO32-	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO31	mg/kg	79	79	67	201	ND
fluoride	F1-	mg/kg	3.7	3.1	7.4	ND	ND
chloride	Cl1-	mg/kg	19	11	23	349	599
sulfate	SO42-	mg/kg	134	94	79	1,637	5,384
phosphate	PO43-	mg/kg	2.5	2.1	5.6	ND	ND
Other Tests							
ammonium	NH41+	mg/kg	ND	ND	ND	62	107
nitrate	NO31-	mg/kg	2.8	1.1	6.0	0.7	105
sulfide	S2-	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-101 @ 33.5' CL	G-101 @ 43.5' CL-ML	G-101 @ 63.5' SP-SM	G-114 @ 33.5' CL	G-114 @ 53.5' ML
Resistivity		**Units**					
as-received		ohm-cm	1,280	1,520	1,280	1,520	1,160
saturated		ohm-cm	720	600	920	1,080	1,040
pH			8.2	8.2	7.1	7.8	8.3
Electrical Conductivity		mS/cm	0.22	0.37	0.32	0.17	0.19
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	48	110	73	55	67
magnesium	Mg^{2+}	mg/kg	20	53	29	15	15
sodium	Na^{1+}	mg/kg	136	148	180	103	101
potassium	K^{1+}	mg/kg	20	40	26	7.8	26
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	18	ND
bicarbonate	HCO_3^{1-}	mg/kg	250	143	12	217	271
fluoride	F^{1-}	mg/kg	1.5	1.3	1.1	2.1	1.7
chloride	Cl^{1-}	mg/kg	15	20	71	20	2.4
sulfate	SO_4^{2-}	mg/kg	251	664	557	94	171
phosphate	PO_4^{3-}	mg/kg	0.6	ND	3.4	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.7	4.9	1.7	ND	0.9
nitrate	NO_3^{1-}	mg/kg	0.9	0.6	5.4	3.9	3.5
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-114 @ 77.5' SP-SM	G-114 @ 89' ML	G-114 @ 100.5' CL-ML	G-139 @ 60' CL	G-139 @ 70' CL
Resistivity		**Units**					
as-received		ohm-cm	3,200	1,240	880	1,800	2,600
saturated		ohm-cm	1,760	332	248	1,800	1,880
pH			7.9	5.2	5.9	7.6	7.7
Electrical Conductivity		mS/cm	0.18	2.35	2.40	0.11	0.13
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	59	730	629	60	61
magnesium	Mg^{2+}	mg/kg	14	571	493	13	16
sodium	Na^{1+}	mg/kg	81	935	1,427	65	70
potassium	K^{1+}	mg/kg	21	196	217	6.5	11
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	12	9.0
bicarbonate	HCO_3^{1-}	mg/kg	104	40	58	229	279
fluoride	F^{1-}	mg/kg	1.0	3.9	0.7	3.0	2.5
chloride	Cl^{1-}	mg/kg	13	285	625	5.0	3.4
sulfate	SO_4^{2-}	mg/kg	256	5,751	5,688	17	14
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	1.5	1.7
Other Tests							
ammonium	NH_4^{1+}	mg/kg	1.1	742	74	ND	ND
nitrate	NO_3^{1-}	mg/kg	21	ND	3.5	ND	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-139 @ 80' CL	G-189 @ 10' ML	G-189 @ 40' SW	G-189 @ 70' ML	G-189 @ 100' CL
Resistivity		**Units**					
as-received		ohm-cm	1,920	1,760	28,400	2,280	1,720
saturated		ohm-cm	1,920	1,760	4,800	2,280	1,400
pH			7.9	7.6	7.6	7.3	7.2
Electrical Conductivity		mS/cm	0.14	0.06	0.04	0.04	0.05
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	67	49	20	22	30
magnesium	Mg^{2+}	mg/kg	15	7.8	6.2	5.5	6.8
sodium	Na^{1+}	mg/kg	70	29	33	32	35
potassium	K^{1+}	mg/kg	10	3.5	3.2	46	10
Anions							
carbonate	CO_3^{2-}	mg/kg	12	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	263	143	70	46	67
fluoride	F^{1-}	mg/kg	0.9	2.5	2.8	2.5	3.4
chloride	Cl^{1-}	mg/kg	10	1.7	6.3	11	5.6
sulfate	SO_4^{2-}	mg/kg	36	14	19	33	54
phosphate	PO_4^{3-}	mg/kg	ND	3.6	4.7	2.0	2.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	10	22	2.5	2.7
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-191 @ 15-16.5' SP	G-191 @ 45-46.5' SP-SM	G-191 @ 95-96' CL-ML
Resistivity		**Units**			
as-received		ohm-cm	5,200	13,200	880
saturated		ohm-cm	3,680	5,200	880
pH			7.8	7.7	7.6
Electrical Conductivity		mS/cm	0.10	0.05	0.12
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	69	19	48
magnesium	Mg^{2+}	mg/kg	11	3.7	11
sodium	Na^{1+}	mg/kg	36	45	61
potassium	K^{1+}	mg/kg	12	2.3	11
Anions					
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	229	55	140
fluoride	F^{1-}	mg/kg	2.3	3.5	4.6
chloride	Cl^{1-}	mg/kg	2.2	5.0	11
sulfate	SO_4^{2-}	mg/kg	45	6.1	103
phosphate	PO_4^{3-}	mg/kg	4.1	3.6	3.0
Other Tests					
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	28	22	3.9
sulfide	S^{2-}	qual	na	na	na
Redox		mV	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-113 @ 25.5' CL	G-113 @ 45.5' ML	G-113 @ 75.5' SM	G-113 @ 85.5' CL	G-128 @ 25.5' CL-ML
Resistivity		**Units**					
as-received		ohm-cm	8,800	1,880	2,680	840	1,880
saturated		ohm-cm	1,720	1,200	800	400	1,760
pH			6.9	7.5	4.2	5.5	7.4
Electrical Conductivity		mS/cm	0.04	0.16	1.13	1.85	0.15
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	22	70	774	740	38
magnesium	Mg^{2+}	mg/kg	8.2	17	233	461	17
sodium	Na^{1+}	mg/kg	40	78	83	755	123
potassium	K^{1+}	mg/kg	3.1	25	28	159	7.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	12	ND	ND	23
bicarbonate	HCO_3^{1-}	mg/kg	88	224	ND	ND	192
fluoride	F^{1-}	mg/kg	2.1	1.6	5.1	2.1	2.7
chloride	Cl^{1-}	mg/kg	6.9	23	20	258	20
sulfate	SO_4^{2-}	mg/kg	14	101	2,301	3,147	50
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	5.0	8.0	61	ND
nitrate	NO_3^{1-}	mg/kg	ND	2.5	5.2	0.5	ND
sulfide	S^{2-}	qual	na	na	Trace	na	na
Redox		mV	na	na	10	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-128 @ 50.5' SC	G-128 @ 80.5' CL	G-129 @ 20' CL	G-129 @ 40' ML	G-129 @ 70' ML
Resistivity		**Units**					
as-received		ohm-cm	1,360	680	2,120	3,200	1,520
saturated		ohm-cm	1,240	520	1,160	560	840
pH			7.9	7.6	7.8	7.9	7.8
Electrical Conductivity		mS/cm	0.21	0.58	0.19	0.25	0.25
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	46	212	45	63	70
magnesium	Mg^{2+}	mg/kg	28	111	22	33	39
sodium	Na^{1+}	mg/kg	135	214	130	145	114
potassium	K^{1+}	mg/kg	13	47	8.8	32	22
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	21	9.0	ND
bicarbonate	HCO_3^{1-}	mg/kg	183	262	229	220	159
fluoride	F^{1-}	mg/kg	1.7	2.0	4.3	2.5	0.9
chloride	Cl^{1-}	mg/kg	9.4	11	56	27	67
sulfate	SO_4^{2-}	mg/kg	316	1,120	47	274	329
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.3	6.2	ND	1.2	2.6
nitrate	NO_3^{1-}	mg/kg	4.1	2.0	0.7	0.8	13
sulfide	S^{2-}	qual	Positive	Trace	na	na	na
Redox		mV	-108	-97	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-129 @ 83.5' CL	G-129 @ 100' CL	G-186 @ 30.5' CL	G-186 @ 75.5' CL-ML	G-186 @ 85.5 CL
Resistivity		**Units**					
as-received		ohm-cm	680	1,360	2,920	2,880	1,640
saturated		ohm-cm	560	600	2,480	1,480	1,120
pH			7.8	7.8	7.9	7.7	7.7
Electrical Conductivity		mS/cm	0.50	0.61	0.09	0.13	0.12
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	197	247	64	70	65
magnesium	Mg^{2+}	mg/kg	87	134	11	16	15
sodium	Na^{1+}	mg/kg	144	136	28	51	51
potassium	K^{1+}	mg/kg	47	47	7.1	13	10
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	12	9.0	9.0
bicarbonate	HCO_3^{1-}	mg/kg	259	262	169	215	178
fluoride	F^{1-}	mg/kg	1.8	1.2	1.7	4.6	0.8
chloride	Cl^{1-}	mg/kg	78	50	2.1	3.5	7.0
sulfate	SO_4^{2-}	mg/kg	807	1,104	24	51	62
phosphate	PO_4^{3-}	mg/kg	ND	ND	3.3	2.1	2.0
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.5	10	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	4.5	2.6	0.8	1.9	1.6
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-110 @ 80.5' Clayey Siltstone	G-110 @ 90.5' Clayey Siltstone	G-110 @ 100.5' Clayey Siltstone	G-110 @ 110.5' Clayey Siltstone	G-135 @ 62' CL
Resistivity		**Units**					
as-received		ohm-cm	960	760	600	480	1,120
saturated		ohm-cm	480	368	216	228	1,120
pH			7.7	7.6	3.1	3.9	7.7
Electrical Conductivity		mS/cm	1.33	1.39	2.77	2.52	0.18
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	538	330	628	407	54
magnesium	Mg^{2+}	mg/kg	212	144	629	344	22
sodium	Na^{1+}	mg/kg	664	950	1,844	1,976	97
potassium	K^{1+}	mg/kg	101	147	194	266	18
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	9.0
bicarbonate	HCO_3^{1-}	mg/kg	381	314	ND	15	168
fluoride	F^{1-}	mg/kg	1.6	0.8	14	2.8	8.8
chloride	Cl^{1-}	mg/kg	197	399	724	901	33
sulfate	SO_4^{2-}	mg/kg	2,183	2,055	7,712	5,313	50
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	0.7
Other Tests							
ammonium	NH_4^{1+}	mg/kg	20	41	96	81	1.9
nitrate	NO_3^{1-}	mg/kg	2.9	30	401	ND	1.1
sulfide	S^{2-}	qual	Positive	Positive	Positive	Positive	Negative
Redox		mV	-106	-44	-86	-98	-21

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-135 @ 86' CL	G-135 @ 92' SW	G-144 @ 10.5' CL-ML	G-144 @ 30.5' CL-ML	G-144 @ 50.5' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	6,000	11,600	960	1,560	1,480
saturated		ohm-cm	2,800	4,400	960	1,560	1,360
pH			8.1	7.8	7.6	7.6	7.5
Electrical Conductivity		mS/cm	0.09	0.08	0.13	0.04	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	43	42	79	25	28
magnesium	Mg^{2+}	mg/kg	15	12	17	7.5	8.3
sodium	Na^{1+}	mg/kg	49	43	57	42	48
potassium	K^{1+}	mg/kg	6.3	7.0	7.7	2.4	4.9
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	195	156	345	79	67
fluoride	F^{1-}	mg/kg	3.9	2.1	5.6	5.1	4.0
chloride	Cl^{1-}	mg/kg	13	23	2.0	6.8	13
sulfate	SO_4^{2-}	mg/kg	35	62	33	12	56
phosphate	PO_4^{3-}	mg/kg	3.1	1.7	3.8	6.3	2.5
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	1.1	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	1.0	25	13	0.9
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	22	37	18	63	38

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-144 @ 60.5' Sandy CL	G-144 @ 80.5' CL	G-144 @ 100.5' SC	G-145 @ 31.5' Sandy CL	G-145 @ 61.5' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	1,360	1,720	9,600	1,680	3,040
saturated		ohm-cm	1,360	1,160	2,440	1,680	1,840
pH			7.5	7.5	7.6	7.7	7.8
Electrical Conductivity		mS/cm	0.06	0.06	0.05	0.05	0.09
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	33	30	23	24	36
magnesium	Mg^{2+}	mg/kg	10	9.0	6.8	6.3	0.5
sodium	Na^{1+}	mg/kg	51	44	39	44	67
potassium	K^{1+}	mg/kg	5.5	4.7	6.2	3.8	6.8
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	67	58	43	95	140
fluoride	F^{1-}	mg/kg	4.5	5.3	2.0	2.3	3.1
chloride	Cl^{1-}	mg/kg	15	13	11	8.4	13
sulfate	SO_4^{2-}	mg/kg	62	49	46	12	57
phosphate	PO_4^{3-}	mg/kg	3.1	ND	2.6	6.3	2.8
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	0.5	2.1	1.5	20	3.2
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	60	31	56	80	57

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-145 @ 95.5' SM w/gravel	G-145 @ 115.5' Sandy CL	G-148 @ 80.5' Sandy ML/SW	G-148 @ 90.5' SM	G-148 @ 110.5' CL-ML
Resistivity		**Units**					
as-received		ohm-cm	5,600	1,000	1,680	2,040	1,160
saturated		ohm-cm	2,840	1,000	1,680	1,920	1,160
pH			7.8	8.3	8.0	7.7	7.8
Electrical Conductivity		mS/cm	0.06	0.15	0.07	0.07	0.07
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	22	65	28	29	32
magnesium	Mg^{2+}	mg/kg	6.4	15	8.7	9.1	9.2
sodium	Na^{1+}	mg/kg	42	75	46	44	51
potassium	K^{1+}	mg/kg	3.8	22	3.8	5.0	7.0
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	58	253	67	52	125
fluoride	F^{1-}	mg/kg	3.1	5.1	3.2	3.1	4.9
chloride	Cl^{1-}	mg/kg	15	10	18	17	4.5
sulfate	SO_4^{2-}	mg/kg	50	122	65	68	43
phosphate	PO_4^{3-}	mg/kg	2.9	2.0	2.9	2.8	5.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	1.9	ND	2.9	1.9	0.9
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	66	28	43	99	47

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-148 @ 120.5' SC	G-200 Alt @ 70.5' Sandy CL	G-200 Alt @ 80.5' SC	G-200 Alt @ 90.5' CL/ML	G-200 Alt @ 100.5' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	4,800	2,200	3,880	1,760	1,760
saturated		ohm-cm	1,440	2,200	3,400	1,760	640
pH			7.7	8.1	8.1	8.1	8.5
Electrical Conductivity		mS/cm	0.11	0.09	0.09	0.18	0.31
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	63	67	58	92	156
magnesium	Mg^{2+}	mg/kg	12	11	12	19	37
sodium	Na^{1+}	mg/kg	69	46	43	70	104
potassium	K^{1+}	mg/kg	13	5.6	13	24	52
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	18	18	12	ND
bicarbonate	HCO_3^{1-}	mg/kg	259	160	160	302	290
fluoride	F^{1-}	mg/kg	3.6	4.7	2.7	4.8	3.9
chloride	Cl^{1-}	mg/kg	3.4	6.3	3.8	5.3	4.7
sulfate	SO_4^{2-}	mg/kg	66	26	17	65	504
phosphate	PO_4^{3-}	mg/kg	2.0	ND	1.9	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	0.6
nitrate	NO_3^{1-}	mg/kg	ND	1.8	0.7	0.7	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Positive
Redox		mV	20	28	9	43	-163

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-203 @ 30' ML	G-203 @ 45.5' SM	G-203 @ 80.5' SM	G-204 @ 10' ML	G-204 @ 40' ML
Resistivity		**Units**					
as-received		ohm-cm	4,800	800	5,200	2,600	1,360
saturated		ohm-cm	1,720	760	3,360	2,400	960
pH			8.0	7.5	8.0	7.4	7.1
Electrical Conductivity		mS/cm	0.16	0.27	0.06	0.05	0.22
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	25	41	19	18	44
magnesium	Mg^{2+}	mg/kg	8.7	21	7.2	9.1	26
sodium	Na^{1+}	mg/kg	139	222	44	69	136
potassium	K^{1+}	mg/kg	3.6	7.4	4.8	1.8	9.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	107	52	58	70	40
fluoride	F^{1-}	mg/kg	7.8	3.3	2.7	12	3.7
chloride	Cl^{1-}	mg/kg	43	242	16	2.1	115
sulfate	SO_4^{2-}	mg/kg	150	250	50	7.3	264
phosphate	PO_4^{3-}	mg/kg	6.6	ND	1.6	31	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	0.7	ND	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	35	105	60	131	119

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-204 @ 80' CL	G-204 @ 100' ML/CL	G-205 @ 35.5' ML	G-205 @ 50' ML	G-205 @ 95.5' ML
Resistivity		**Units**					
as-received		ohm-cm	1,400	1,880	840	12,000	1,560
saturated		ohm-cm	1,400	1,880	760	3,560	1,560
pH			7.9	7.0	6.9	7.7	7.5
Electrical Conductivity		mS/cm	0.08	0.09	0.34	0.07	0.07
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	36	33	41	19	30
magnesium	Mg^{2+}	mg/kg	13	14	17	4.6	11
sodium	Na^{1+}	mg/kg	41	46	304	66	39
potassium	K^{1+}	mg/kg	12	14	5.3	3.3	12
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	67	46	49	43	46
fluoride	F^{1-}	mg/kg	5.0	4.9	5.1	3.4	4.8
chloride	Cl^{1-}	mg/kg	16	24	75	43	15
sulfate	SO_4^{2-}	mg/kg	81	103	559	28	73
phosphate	PO_4^{3-}	mg/kg	1.3	1.3	4.0	4.3	2.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	3.3	1.4	ND	ND	1.8
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	92	93	69	74	72

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0750LAB
29-Jul-11

Sample ID			G-116 @ 35' CL-ML	G-137 @ 61' CL	G-137 @ 73' CH	G-137 @ 85' CL	G-137 @ 103' CH
Resistivity		**Units**					
as-received		ohm-cm	960	1,680	1,120	2,560	1,800
saturated		ohm-cm	880	1,680	1,120	1,800	1,440
pH			8.2	8.3	8.5	8.4	8.2
Electrical Conductivity		mS/cm	0.27	0.14	0.15	0.13	0.11
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	91	71	50	49	41
magnesium	Mg^{2+}	mg/kg	40	22	22	26	23
sodium	Na^{1+}	mg/kg	121	71	95	81	72
potassium	K^{1+}	mg/kg	33	10	2.3	7.4	11
Anions							
carbonate	CO_3^{2-}	mg/kg	6.0	9.0	30	18	9.0
bicarbonate	HCO_3^{1-}	mg/kg	208	247	247	249	224
fluoride	F^{1-}	mg/kg	3.5	5.4	7.0	5.3	3.8
chloride	Cl^{1-}	mg/kg	11	20	16	3.4	2.9
sulfate	SO_4^{2-}	mg/kg	377	41	31	22	18
phosphate	PO_4^{3-}	mg/kg	ND	4.0	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	7.8	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	1.0	ND	0.5	ND	ND
sulfide	S^{2-}	qual	Trace	Trace	Trace	Negative	Negative
Redox		mV	-33	35	-71	46	58

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0750LAB
29-Jul-11

Sample ID			G-138 @ 70.5' CL	G-138 @ 80.5' CH
Resistivity		**Units**		
as-received		ohm-cm	11,200	2,040
saturated		ohm-cm	1,560	1,800
pH			8.3	8.2
Electrical Conductivity		mS/cm	0.17	0.13
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	55	56
magnesium	Mg^{2+}	mg/kg	20	21
sodium	Na^{1+}	mg/kg	87	79
potassium	K^{1+}	mg/kg	24	6.3
Anions				
carbonate	CO_3^{2-}	mg/kg	21	15
bicarbonate	HCO_3^{1-}	mg/kg	252	254
fluoride	F^{1-}	mg/kg	6.4	4.8
chloride	Cl^{1-}	mg/kg	3.1	3.0
sulfate	SO_4^{2-}	mg/kg	8.0	18
phosphate	PO_4^{3-}	mg/kg	1.7	2.4
Other Tests				
ammonium	NH_4^{1+}	mg/kg	2.5	ND
nitrate	NO_3^{1-}	mg/kg	0.5	ND
sulfide	S^{2-}	qual	Negative	Trace
Redox		mV	3.6	54

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering, Inc.
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0765LAB
1-Aug-11

Sample ID			G-187 @ 40.5' SM	G-187 @ 60.5' ML	G-187 @ 70.5' ML	G-187 @ 100.5' CL
Resistivity		**Units**				
as-received		ohm-cm	18,800	300	2,560	2,040
saturated		ohm-cm	5,200	2,920	1,720	1,520
pH			7.8	7.3	7.0	6.6
Electrical Conductivity		mS/cm	0.04	0.04	0.05	0.05
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	22	23	23	31
magnesium	Mg^{2+}	mg/kg	6.2	5.1	7.0	10
sodium	Na^{1+}	mg/kg	54	53	48	43
potassium	K^{1+}	mg/kg	1.8	3.4	6.5	9.2
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	52	46	34	55
fluoride	F^{1-}	mg/kg	5.3	3.6	5.4	7.2
chloride	Cl^{1-}	mg/kg	11	14	32	31
sulfate	SO_4^{2-}	mg/kg	20	27	11	10
phosphate	PO_4^{3-}	mg/kg	11	11	6.6	3.0
Other Tests						
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	9.0	4.0	5.4
sulfide	S^{2-}	qual	Positive	Trace	Trace	Trace
Redox		mV	34	104	76	133

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

MACTEC Engineering
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0784LAB
5-Aug-11

Sample ID			G-119 @ 70.5' ML	G-119 @ 90.5' ML/CL	G-119 @ 100.5' ML	G-121 @ 75.5' ML/CL	G-121 @ 85.5' ML
Resistivity		**Units**					
as-received		ohm-cm	4,800	4,400	4,280	6,000	11,600
saturated		ohm-cm	356	4,400	520	2,040	2,240
pH			7.0	6.1	4.3	7.4	3.9
Electrical Conductivity		mS/cm	2.29	2.93	2.69	2.22	1.85
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	253	216	169	609	83
magnesium	Mg^{2+}	mg/kg	203	406	338	133	74
sodium	Na^{1+}	mg/kg	2,125	2,574	2,414	1,867	1,692
potassium	K^{1+}	mg/kg	164	192	188	130	126
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	177	140	49	250	24
fluoride	F^{1-}	mg/kg	ND	ND	ND	ND	3.1
chloride	Cl^{1-}	mg/kg	1,998	2,444	2,198	1,274	942
sulfate	SO_4^{2-}	mg/kg	2,667	3,892	3,508	3,590	2,149
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	3.8
Other Tests							
ammonium	NH_4^{1+}	mg/kg	85	98	100	59	67
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	ND	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Trace	Negative
Redox		mV	-23	1.3	28	-40	64

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E & I
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0793LAB
8-Aug-11

Sample ID			G-190 @ 20-21.5' ML	G-190 @ 50' ML	G-190 @ 70' ML/SM	G-190 @ 80' ML	G-199 @ 31-32.5' SP-SM w/gravel
Resistivity		**Units**					
as-received		ohm-cm	1,560	2,200	1,400	1,360	10,000
saturated		ohm-cm	1,000	2,040	1,400	1,360	6,400
pH			7.9	7.8	8.0	8.0	8.2
Electrical Conductivity		mS/cm	0.17	0.06	0.11	0.13	0.05
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	90	35	65	96	21
magnesium	Mg^{2+}	mg/kg	19	8.7	16	17	4.7
sodium	Na^{1+}	mg/kg	68	45	48	48	49
potassium	K^{1+}	mg/kg	6.3	4.3	8.7	8.9	4.6
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	9.0	18	ND
bicarbonate	HCO_3^{1-}	mg/kg	223	58	156	194	64
fluoride	F^{1-}	mg/kg	4.1	3.6	4.0	6.1	1.8
chloride	Cl^{1-}	mg/kg	3.9	18	11	6.7	3.2
sulfate	SO_4^{2-}	mg/kg	9.2	57	52	80	53
phosphate	PO_4^{3-}	mg/kg	1.8	2.1	1.4	1.7	3.0
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	176	6.7	6.1	5.6	1.7
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	68	47	2	56	50

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E & I
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0793LAB
8-Aug-11

Sample ID			G-199 @ 80-81.5' SM	G-206 @ 35-36.5' SM	G-206 @ 55-56.5' CL Sandy Clay	G-206 @ 75-76.5' CL Sandy Clay	G-206 @ 85-86.5' Sandy Siltstone
Resistivity		**Units**					
as-received		ohm-cm	2,800	1,560	560	1,080	800
saturated		ohm-cm	2,720	1,120	560	440	312
pH			7.8	8.1	8.4	4.3	3.9
Electrical Conductivity		mS/cm	0.03	0.18	0.28	1.73	2.19
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	19	69	97	757	546
magnesium	Mg^{2+}	mg/kg	4.6	25	39	467	621
sodium	Na^{1+}	mg/kg	3.8	119	131	499	927
potassium	K^{1+}	mg/kg	4.5	23	24	86	147
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	21	6.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	37	263	130	ND	ND
fluoride	F^{1-}	mg/kg	1.7	2.1	1.1	4.2	7.3
chloride	Cl^{1-}	mg/kg	7.2	13	21	96	210
sulfate	SO_4^{2-}	mg/kg	22	99	455	3,068	5,799
phosphate	PO_4^{3-}	mg/kg	2.0	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	2.4	44	77
nitrate	NO_3^{1-}	mg/kg	7.5	ND	3.0	ND	32
sulfide	S^{2-}	qual	Negative	Negative	Trace	Positive	Positive
Redox		mV	53	16	-8	-22	134

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E & I
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0793LAB
8-Aug-11

Sample ID			G-207 @ 75-76.5' Sandy Siltstone
Resistivity		**Units**	
as-received		ohm-cm	600
saturated		ohm-cm	312
pH			3.3
Electrical Conductivity		mS/cm	1.98
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	442
magnesium	Mg^{2+}	mg/kg	391
sodium	Na^{1+}	mg/kg	948
potassium	K^{1+}	mg/kg	85
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND
fluoride	F^{1-}	mg/kg	6.8
chloride	Cl^{1-}	mg/kg	222
sulfate	SO_4^{2-}	mg/kg	3,192
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	65
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	Positive
Redox		mV	143

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Extension
Your #4953-10-1561, HDR|Schiff #11-0948LAB
15-Sep-11

Sample ID			G-141 @ 55' CL	G-141 @ 65' CL	G-141 @ 80.5' Sandy CL
Resistivity		**Units**			
as-received		ohm-cm	5,200	1,480	1,760
saturated		ohm-cm	1,280	1,320	1,120
pH			7.4	7.8	8.0
Electrical Conductivity		mS/cm	0.11	0.16	0.15
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	41	83	56
magnesium	Mg^{2+}	mg/kg	13	20	15
sodium	Na^{1+}	mg/kg	66	83	78
potassium	K^{1+}	mg/kg	21	23	29
Anions					
carbonate	CO_3^{2-}	mg/kg	ND	6.0	ND
bicarbonate	HCO_3^{1-}	mg/kg	110	323	183
fluoride	F^{1-}	mg/kg	ND	1.1	2.4
chloride	Cl^{1-}	mg/kg	13	6.0	38
sulfate	SO_4^{2-}	mg/kg	132	48	132
phosphate	PO_4^{3-}	mg/kg	0.5	ND	ND
Other Tests					
ammonium	NH_4^{1+}	mg/kg	4.5	2.9	3.9
nitrate	NO_3^{1-}	mg/kg	0.5	1.8	ND
sulfide	S^{2-}	qual	Positive	Positive	Positive
Redox		mV	-71	-115	-65

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.63.1 THROUGH F-10.63.18
SOIL CORROSIVITY EVALUATION FOR
WILSHIRE/LA BREA STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WILSHIRE/LA BREA STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

PROJECT MANAGER: MR. MARTY HUDSON

prepared by

HDR ENGINEERING, INC.
Consulting Corrosion Engineers
431 West Baseline Road
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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Wilshire/La Brea station is one of the eight stations planned for the project. The station will be approximately 1,000 feet long and about 75 to 80 feet below ground surface.

Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Ten of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride, and aggressive with respect to exposure of concrete to acid attack.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type V cement should be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system. Concrete structures and pipe should be protected from acid attack

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (7/8/11)
Table 1 – Laboratory Tests on Soil Samples (7/14/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Wilshire/La Brea station is one of the eight stations planned for the project. The station will be approximately 1,000 feet long and about 75 to 80 feet below ground surface. Ground water was encountered at depths of about 10 to 30 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Ten of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the ten samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the moderately to severely corrosive categories with as-received moisture. When saturated, the resistivities were in the moderately to severely corrosive categories.

Soil pH values varied from 5.2 to 8.3. This range is strongly acidic to moderately alkaline (Romanoff, 1989). Total acidity is assumed to be high enough to warrant concern of acid attack on concrete. Soil with a pH less than 5.5 is considered aggressive to copper.

The soluble salt content of the samples ranged from low to very high.

The soluble salt content was very high in the samples from borings G-112 @ 105' and G-114 @ 89' and 100.5' and less in the others. Chloride and sulfate salts were the predominant constituents. Chloride is particularly corrosive to ferrous metals, and in the higher concentrations measured in the soil samples, chloride can overcome the corrosion inhibiting effect of concrete on reinforcing steel. High concentrations of sulfate, as was measured in the soil samples, can react with components in concrete to cause degradation and reduced strength in a mechanism known as sulfate attack.

Nitrate was detected in low concentrations. The ammonium concentration was high enough to be deleterious to copper.

Tests were not made for sulfide and negative oxidation-reduction (redox) potential because these samples did not exhibit characteristics typically associated with anaerobic conditions.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride, and aggressive with respect to exposure of concrete to acid attack.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride, and aggressive with respect to exposure of concrete to acid attack.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type V cement should be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system. Concrete structures and pipe should be protected from acid attack.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
   a. Polyurethane per AWWA C222 *or*
   b. Extruded polyethylene per AWWA C215 *or*
   c. A tape coating system per AWWA C214 *or*
   d. Hot applied coal tar enamel per AWWA C203 *or*
   e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with a dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.

5. Provide permanent test facilities and apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

   OPTION 2

   a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If Steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe (Non-Pressurized)

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

    Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

    Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

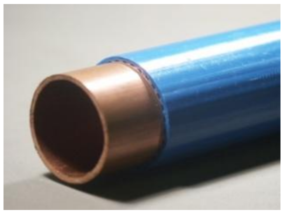
6. Apply a suitable coating intended for underground use such as:
    a. Epoxy coating; *or*
    b. Polyurethane; *or*
    c. Wax tape.

    NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:



1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.

2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolans can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. Protect concrete structures and pipe from sulfate attack in soil with a severe sulfate concentration, between 0.20 and 2.0 percent. Use Type V cement, a maximum water/cement ratio of 0.45, and minimum strength of 4500 psi per applicable code.
2. Chloride levels were measured at levels where additional protective measures may be required for concrete, including increased cover, admixtures, or other modifications of design based on the Metro Rail Design Criteria. Possible measures are presented below.
    a. Protective Concrete - A concrete mix designed to protect embedded steel and iron that should be based on the following parameters: 1) a chloride content of 900 ppm in the soil; 2) the desired service life; and 3) concrete cover. A protective concrete mix may include a corrosion inhibitor admixture and/or silica fume admixture.

b. Waterproof Concrete - Waterproofing for concrete could be a gravel capillary break under the concrete, a waterproof membrane, and/or a liquid applied waterproof barrier coating such as Grace PrePrufe® Products. Visqueen, similar rolled barriers, or bentonite-based membranes are not viable waterproofing systems, from a corrosion standpoint.

c. Coat Embedded Metal - A coating for embedded steel and iron could be an epoxy coating applied to the metal. Purple fusion bonded epoxy (FBE) (ASTM A934) intended for prefabricated reinforcing steel reinforcing steel is suitable. The green flexible FBE (ASTM A775) is not recommended.

d. Cathodic Protection - Cathodic protection is most practical for pipelines and must be designed for each application. The amount of cathodic protection current needed can be minimized by coating the steel or iron.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

4. Concrete structures and pipe should be protected from acid attack because soil with a pH ≤ 5.5 and assumed total acidity ≥ 250 mmol H^{1+}/kg (AWWA 1995) was found on-site. Concrete can be protected by preventing contact with the moisture in acidic soil. Contact can be prevented with an impermeable, waterproof, acid resistant barrier coating such as Grace PrePrufe Products®. ®.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

   a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

   b. All components exposed to the job site should be protected within one working day after their exposure during installation.

   c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

   d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

   e. Inspect the following to ensure the encapsulated system is completely watertight:

      i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

      ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

iii. End caps: Ensure proper installation before patching the pocket former recesses.

iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Wilshire-LaBrea_IB_rev00

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Romanoff, M. (1989). Underground Corrosion, National Bureau of Standards (NBS) Circular 579. Houston, TX, United States of America: Reprinted by NACE.

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Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-3 @ 40'
Resistivity		**Units**	
as-received		ohm-cm	6,000
saturated		ohm-cm	900
pH			8.4
Electrical Conductivity		mS/cm	0.21
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	102
magnesium	Mg^{2+}	mg/kg	26
sodium	Na^{1+}	mg/kg	92
potassium	K^{1+}	mg/kg	27
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	207
flouride	F^{1-}	mg/kg	8.3
chloride	Cl^{1-}	mg/kg	11
sulfate	SO_4^{2-}	mg/kg	263
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	0.9
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-112 @ 10' SM	G-112 @ 25' CL	G-112 @ 45' Sandy CL	G-112 @ 75' SP-SM/SM	G-112 @ 105' ML
Resistivity		**Units**					
as-received		ohm-cm	2,720	1,280	2,920	3,000	570
saturated		ohm-cm	1,640	1,000	1,520	2,120	244
pH			7.2	7.4	7.8	7.8	7.4
Electrical Conductivity		mS/cm	0.21	0.20	0.16	0.15	3.03
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	51	69	71	77	1,170
magnesium	Mg^{2+}	mg/kg	20	20	20	15	428
sodium	Na^{1+}	mg/kg	157	121	81	62	1,794
potassium	K^{1+}	mg/kg	4.6	7.9	13	14	241
Anions							
carbonate	CO_3^{2-}	mg/kg	21	18	9.0	9.0	ND
bicarbonate	HCO_3^{1-}	mg/kg	169	217	231	119	464
fluoride	F^{1-}	mg/kg	1.8	3.6	1.5	1.2	ND
chloride	Cl^{1-}	mg/kg	69	19	15	11	888
sulfate	SO_4^{2-}	mg/kg	165	161	107	204	6,509
phosphate	PO_4^{3-}	mg/kg	ND	ND	0.7	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	1.3	69
nitrate	NO_3^{1-}	mg/kg	20	5.5	5.6	3.5	13
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-114 @ 33.5' CL	G-114 @ 53.5' ML	G-114 @ 77.5' SP-SM	G-114 @ 89' ML	G-114 @ 100.5' CL-ML
Resistivity		**Units**					
as-received		ohm-cm	1,520	1,160	3,200	1,240	880
saturated		ohm-cm	1,080	1,040	1,760	332	248
pH			7.8	8.3	7.9	5.2	5.9
Electrical Conductivity		mS/cm	0.17	0.19	0.18	2.35	2.40
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	55	67	59	730	629
magnesium	Mg^{2+}	mg/kg	15	15	14	571	493
sodium	Na^{1+}	mg/kg	103	101	81	935	1,427
potassium	K^{1+}	mg/kg	7.8	26	21	196.0	217
Anions							
carbonate	CO_3^{2-}	mg/kg	18	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	217	271	104	40	58
fluoride	F^{1-}	mg/kg	2.1	1.7	1.0	3.9	0.7
chloride	Cl^{1-}	mg/kg	20	2.4	13	285	625.0
sulfate	SO_4^{2-}	mg/kg	94	171	256	5,751	5,688
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	0.9	1.1	742	74
nitrate	NO_3^{1-}	mg/kg	3.9	3.5	21	ND	3.5
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.64.1 THROUGH F-10.64.19 SOIL CORROSIVITY EVALUATION FOR WILSHIRE/FAIRFAX STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WILSHIRE/FAIRFAX STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

PROJECT MANAGER: MR. MARTY HUDSON

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Wilshire/Fairfax station is one of the eight stations planned for the project. The station will be approximately 860 feet long and about 60 to 70 feet below ground surface.

Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Thirteen of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria, and aggressive with respect to exposure of concrete to acid attack.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type V cement plus pozzolan should be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design base on the Metro Rail Design Criteria. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system. Concrete structures and pipe should be protected from acid attack.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (12/28/09)
Table 1 – Laboratory Tests on Soil Samples (7/8/11)
Table 1 – Laboratory Tests on Soil Samples (9/12/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Wilshire/Fairfax station is one of the eight stations planned for the project. The station will be approximately 860 feet long and about 60 to 70 feet below ground surface. Ground water was encountered at depths of about 15 to 45 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Thirteen of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the 13 samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the mildly corrosive to corrosive categories with as-received moisture. When saturated, the resistivities were in the mildly to severely corrosive categories. The resistivities dropped considerably with added moisture because the samples were dry as-received. The wide variations in soil resistivity can create concentration type corrosion cells that increase corrosion rates above what would be expected from the chemical characteristics alone.

Soil pH values varied from 2.6 to 7.7. This range is extremely acidic to mildly alkaline (Romanoff, 1989). Total acidity is assumed to be high enough to warrant concern of acid attack on concrete.

The soluble salt content of the samples ranged from low to very high.

The soluble salt content was very high in the samples from borings S-106 @ 23-24’ and G-6 @ 70’ and less in the others. Chloride and sulfate salts were the predominant constituents. Chloride is particularly corrosive to ferrous metals, and in the higher concentrations measured in the soil samples, chloride can overcome the corrosion inhibiting effect of concrete on reinforcing steel. High concentrations of sulfate, as was measured in the soil samples, can react with components in concrete to cause degradation and reduced strength in a mechanism known as sulfate attack.

Nitrate was detected in low concentrations. The ammonium concentration was high enough to be deleterious to copper.

Some of the samples were tested for sulfides as they exhibited characteristics typically associated with anaerobic conditions. Sulfide, which is aggressive to copper and ferrous metals, showed no reaction in a qualitative test. The positive and negative redox potentials measured in the samples from S-106 @ 23-24’, 33-34’, 47-48’, 61-62’, 77-78’, 91-92’ and 108-109’ indicate oxidizing conditions in which anaerobic, sulfide-producing bacteria are inactive.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria, and aggressive with respect to exposure of concrete to acid attack.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, very severe for sulfate attack on concrete, aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria, and aggressive with respect to exposure of concrete to acid attack.

Tar was found within the soil samples used for analysis of the Wilshire/Fairfax station. Chemical constituents were found to be more aggressive at this site in comparison to the other sites.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type V cement plus pozzolan should be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design base on the Metro Rail Design Criteria. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system. Concrete structures and pipe should be protected from acid attack.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

    Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

    Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
    a. Polyurethane per AWWA C222 *or*
    b. Extruded polyethylene per AWWA C215 *or*
    c. A tape coating system per AWWA C214 *or*
    d. Hot applied coal tar enamel per AWWA C203 *or*
    e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5a -#5e5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

   OPTION 2

   a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If Steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe (Non-Pressurized)

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

    Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
   a. Epoxy coating; *or*
   b. Polyurethane; *or*
   c. Wax tape.

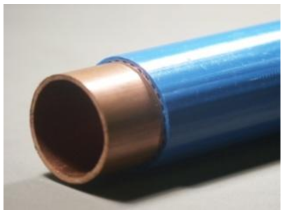
   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:

1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.



2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as

bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolans can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. Protect concrete structures and pipe from sulfate attack in soil with a very severe sulfate concentration, over 2.0 percent. Use Type V cement plus pozzolan, a maximum water/cement ratio of 0.45, and minimum strength of 4500 psi per applicable code.

2. Chloride levels were measured at levels where additional protective measures may be required for concrete, including increased cover, admixtures, or other modifications of design based on the Metro Rail Design Criteria. Possible measures are presented below.

    a. Protective Concrete - A concrete mix designed to protect embedded steel and iron that should be based on the following parameters: 1) a chloride content of 270 ppm in the soil; 2) the desired service life; and 3) concrete cover. A protective concrete mix may include a corrosion inhibitor admixture and/or silica fume admixture.

    b. Waterproof Concrete - Waterproofing for concrete could be a gravel capillary break under the concrete, a waterproof membrane, and/or a liquid applied waterproof barrier coating such as Grace PrePrufe Products®. Visqueen, similar rolled barriers, or bentonite-based membranes are not viable waterproofing systems, from a corrosion standpoint.

    c. Coat Embedded Metal - A coating for embedded steel and iron could be an epoxy coating applied to the metal. Purple fusion bonded epoxy (FBE) (ASTM A934) intended for prefabricated reinforcing steel reinforcing steel is suitable. The green flexible FBE (ASTM A775) is not recommended.

    d. Cathodic Protection - Cathodic protection is most practical for pipelines and must be designed for each application. The amount of cathodic protection current needed can be minimized by coating the steel or iron.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

4. Concrete structures and pipe should be protected from acid attack because soil with a pH $\leq$ 5.5 and assumed total acidity $\geq$ 250 mmol H^{1+}/kg (AWWA 1995) was found on-site. Concrete can be protected by preventing contact with the moisture in acidic soil. Contact can be prevented with an impermeable, waterproof, acid resistant barrier coating such as Grace PrePrufe Products®.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

    b. All components exposed to the job site should be protected within one working day after their exposure during installation.

    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

e. Inspect the following to ensure the encapsulated system is completely watertight:

    i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

    ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

    iii. End caps: Ensure proper installation before patching the pocket former recesses.

    iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

REGISTERED PROFESSIONAL ENGINEER STEVEN R FOX No. CR 1137 Exp. 3-31-13 CORROSION STATE OF CALIFORNIA

Ian Budner
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Steven R. Fox, P.E.
Vice President

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Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-5 @ 20'	G-5 @ 30'	G-6 @ 70' ML	G-7 @ 20'	G-7 @ 40'
Resistivity		**Units**					
as-received		ohm-cm	5,600	3,680	18,000	2,640	1,300
saturated		ohm-cm	880	520	600	760	840
pH			8.2	6.8	7.3	6.7	7.8
Electrical Conductivity		mS/cm	0.42	0.84	1.16	0.10	0.22
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	75	180	361	37	72
magnesium	Mg^{2+}	mg/kg	66	186	180	21	40
sodium	Na^{1+}	mg/kg	308	508	557	96	157
potassium	K^{1+}	mg/kg	22	16	75	6.1	16
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	634	235	217	122	369
flouride	F^{1-}	mg/kg	3.9	1.9	1.4	12.9	1.9
chloride	Cl^{1-}	mg/kg	23	46	264	15	26
sulfate	SO_4^{2-}	mg/kg	362	1,600	1,810	74	173
phosphate	PO_4^{3-}	mg/kg	1.0	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	4.3	5.1	32	ND	3.5
nitrate	NO_3^{1-}	mg/kg	1.2	ND	ND	1.5	1.9
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

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Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0647LAB
8-Jul-11

Sample ID			G-123 @ 41' Tar Sand	G-123 @ 47' Tar Sand	G-123 @ 63' Tar Sand	G-124 @ 35' CL w/Tar	G-124 @ 55' SP w/Tar
Resistivity		**Units**					
as-received		ohm-cm	1,680,000	18,400	3,240,000	10,400	4,400,000
saturated		ohm-cm	13,200	2,680	3,640	1,200	8,000
pH			4.9	5.5	7.0	7.5	3.3
Electrical Conductivity		mS/cm	0.11	0.11	0.43	0.27	0.49
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	45	38	196	67	240
magnesium	Mg^{2+}	mg/kg	33	30	42	59	119
sodium	Na^{1+}	mg/kg	13	34	174	113	55
potassium	K^{1+}	mg/kg	0.9	1.9	6.9	13	7.3
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	12	15	64	ND
fluoride	F^{1-}	mg/kg	ND	ND	ND	0.9	2.8
chloride	Cl^{1-}	mg/kg	1.2	5.2	49	6.5	4.4
sulfate	SO_4^{2-}	mg/kg	244	230	833	544	1,183
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	0.9	0.9	6.8	4.2	4.8
nitrate	NO_3^{1-}	mg/kg	5.0	0.8	ND	6.5	1.4
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0815LAB
12-Aug-11

Sample ID			S-106 @ 23-24' ML w/Tar	S-106 @ 33-34' ML w/Tar	S-106 @ 47-48' SM w/Tar	S-106 @ 61-62' SM w/Tar	S-106 @ 77-78' SM w/Tar
Resistivity		**Units**					
as-received		ohm-cm	3,240	1,520	18,400	392,000	560,000
saturated		ohm-cm	560	920	2,760	26,400	14,400
pH			3.4	7.4	7.7	6.4	3.3
Electrical Conductivity		mS/cm	2.53	0.33	0.05	0.04	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	1,755	56	14	20	22
magnesium	Mg^{2+}	mg/kg	922	60	17	12	6.9
sodium	Na^{1+}	mg/kg	293	165	28	18	29
potassium	K^{1+}	mg/kg	12	18	3.2	2.9	ND
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	162	18	15	ND
fluoride	F^{1-}	mg/kg	ND	ND	ND	ND	ND
chloride	Cl^{1-}	mg/kg	8.1	7.4	3.3	3.0	6.9
sulfate	SO_4^{2-}	mg/kg	8,790	580	81	83	111
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	14	7.0	2.2	1.3	2.7
nitrate	NO_3^{1-}	mg/kg	ND	ND	ND	ND	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	141	-19	-67	-14	43

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0815LAB
12-Aug-11

Sample ID			S-106 @ 91-92' ML w/Tar	S-106 108-109' ML w/Tar
Resistivity		**Units**		
as-received		ohm-cm	4,400,000	31,200
saturated		ohm-cm	20,000	2,560
pH			2.6	3.0
Electrical Conductivity		mS/cm	0.07	0.30
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	25	63
magnesium	Mg^{2+}	mg/kg	7.0	25
sodium	Na^{1+}	mg/kg	19	157
potassium	K^{1+}	mg/kg	ND	ND
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	ND	ND
fluoride	F^{1-}	mg/kg	ND	ND
chloride	Cl^{1-}	mg/kg	6.0	90
sulfate	SO_4^{2-}	mg/kg	142	530
phosphate	PO_4^{3-}	mg/kg	ND	ND
Other Tests				
ammonium	NH_4^{1+}	mg/kg	2.8	4.5
nitrate	NO_3^{1-}	mg/kg	ND	ND
sulfide	S^{2-}	qual	Negative	Negative
Redox		mV	125	-13

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.65.1 THROUGH F-10.65.19
SOIL CORROSIVITY EVALUATION FOR
WILSHIRE/LA CIENEGA STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WILSHIRE/LA CIENEGA STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
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Los Angeles, CA 90040

Project No.: 4953-10-1561

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Wilshire/La Cienega station is one of the eight stations planned for the project. The station will be approximately 1,000 feet long and about 60 to 70 feet below ground surface.

Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. 18 of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals, aggressive to copper, moderate for sulfate attack on concrete, and could subject metal to microbial induced corrosion.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement should be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (5/31/11)
Table 1 – Laboratory Tests on Soil Samples (7/7/11)
Table 1 – Laboratory Tests on Soil Samples (7/14/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Wilshire/La Cienega station is one of the eight stations planned for the project. The station will be approximately 1,000 feet long and about 60 to 70 feet below ground surface. Ground water was encountered at depths of about 20 to 30 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. 18 of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the 18 samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the moderately to severely categories with as-received moisture. When saturated, the resistivities were in the corrosive and severely corrosive categories.

Soil pH values varied from 7.4 to 8.2. This range is mildly to moderately alkaline (Romanoff, 1989). These values do not particularly increase soil corrosivity.

The soluble salt content of the samples ranged from low to high.

The soluble salt content was high in the samples from borings S-107 @ 102-103’, G-131 @ 90’, G-128 @ 80.5, and G-129 @ 83.5’ and less in the others. Sulfate salts were the predominant constituents. High concentrations of sulfate, as was measured in the soil samples, can react with components in concrete to cause degradation and reduced strength in a mechanism known as sulfate attack.

Nitrate was detected in low concentrations. The ammonium concentration was high enough to be deleterious to copper.

Sulfide, which is aggressive to copper and ferrous metals, was found to be present in a qualitative test performed on the samples from borings S-107 @ 121-122’ and G-128 @ 50.5’ and 80.5’. The negative redox potential measured on the sample indicates reducing conditions in which anaerobic, sulfide-producing bacteria are active.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, moderate for sulfate attack on concrete, and could subject metal to microbial induced corrosion.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, moderate for sulfate attack on concrete, and could subject metal to microbial induced corrosion.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement should be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
   a. Polyurethane per AWWA C222 *or*
   b. Extruded polyethylene per AWWA C215 *or*
   c. A tape coating system per AWWA C214 *or*
   d. Hot applied coal tar enamel per AWWA C203 *or*
   e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.

6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

   OPTION 2

   a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:

   a. Pumping plants.

b. Reservoirs.
c. Flow meters.
d. Motorized operated valves.
e. Dissimilar metals.
f. Dissimilarly coated piping (cement-mortar vs. dielectric).
g. Above ground steel pipe.
h. All existing piping.

Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
   a. Epoxy coating; *or*
   b. Polyurethane; *or*
   c. Wax tape.

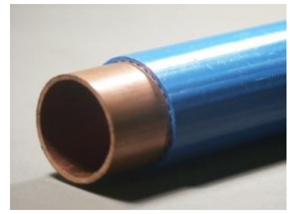
   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:

1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.



2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolans can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement should be used for concrete structures and pipe because the sulfate concentration is moderate, 0.10 to 0.20 percent.

2. Standard concrete cover over reinforcing steel may be used for concrete structures and pipe in contact with these soils due to the low chloride concentration found onsite.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

    b. All components exposed to the job site should be protected within one working day after their exposure during installation.

    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

e. Inspect the following to ensure the encapsulated system is completely watertight:

   i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

   ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

   iii. End caps: Ensure proper installation before patching the pocket former recesses.

   iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

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11-1050SCS-RPT_Wilshire_LaCienega_IB_rev00

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Table 1 - Laboratory Tests on Soil Sample(s)

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0498LAB
31-May-11

Sample ID			S-107 @ 28-29' CL	S-107 @ 42-43' ML	S-107 @ 59-60' ML/CL	S-107 @ 72-73' CL	S-107 @ 85-86' CL/ML
Resistivity		**Units**					
as-received		ohm-cm	1,600	1,360	960	800	1,240
saturated		ohm-cm	1,240	960	640	480	760
pH			8.1	7.9	8.1	8.0	7.9
Electrical Conductivity		mS/cm	0.24	0.34	0.45	0.57	0.50
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	52	115	128	247	201
magnesium	Mg^{2+}	mg/kg	21	51	51	95	90
sodium	Na^{1+}	mg/kg	188	124	259	180	137
potassium	K^{1+}	mg/kg	35	51	38	55	71
Anions							
carbonate	CO_3^{2-}	mg/kg	24	ND	9.0	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	275	305	176	458	354
fluoride	F^{1-}	mg/kg	3.5	2.5	0.6	ND	ND
chloride	Cl^{1-}	mg/kg	47	40	49	97	131
sulfate	SO_4^{2-}	mg/kg	158	427	792	853	696
phosphate	PO_4^{3-}	mg/kg	ND	0.9	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	2.7	4.6	7.9	10	8.8
nitrate	NO_3^{1-}	mg/kg	1.0	ND	1.1	0.9	0.6
sulfide	S^{2-}	qual	Positive	Positive	Positive	Positive	Positive
Redox		mV	-126	-267	-117	-272	-313

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

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Table 1 - Laboratory Tests on Soil Sample(s)

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0498LAB
31-May-11

Sample ID			S-107 @ 102-103' ML	S-107 @ 121-122' ML
Resistivity		**Units**		
as-received		ohm-cm	3,480	3,400
saturated		ohm-cm	480	800
pH			8.0	8.2
Electrical Conductivity		mS/cm	0.58	0.29
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	244	113
magnesium	Mg^{2+}	mg/kg	102	43
sodium	Na^{1+}	mg/kg	124	80
potassium	K^{1+}	mg/kg	68	79
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	9.0
bicarbonate	HCO_3^{1-}	mg/kg	354	245
fluoride	F^{1-}	mg/kg	1.1	2.5
chloride	Cl^{1-}	mg/kg	57	48
sulfate	SO_4^{2-}	mg/kg	921	318
phosphate	PO_4^{3-}	mg/kg	ND	ND
Other Tests				
ammonium	NH_4^{1+}	mg/kg	12	3.3
nitrate	NO_3^{1-}	mg/kg	1.1	ND
sulfide	S^{2-}	qual	na	Trace
Redox		mV	na	-97

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			G-131 @ 20' ML	G-131 @ 90' ML	G-132 @ 10' CL
Resistivity		**Units**			
as-received		ohm-cm	1,080	1,080	1,000
saturated		ohm-cm	1,080	600	1,000
pH			8.1	8.1	8.0
Electrical Conductivity		mS/cm	0.25	0.54	0.29
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	60	208	62
magnesium	Mg^{2+}	mg/kg	27	102	35
sodium	Na^{1+}	mg/kg	198	121	185
potassium	K^{1+}	mg/kg	12	78	7.8
Anions					
carbonate	CO_3^{2-}	mg/kg	27	ND	18
bicarbonate	HCO_3^{1-}	mg/kg	389	153	387
fluoride	F^{1-}	mg/kg	6.0	1.7	15
chloride	Cl^{1-}	mg/kg	15	33	41
sulfate	SO_4^{2-}	mg/kg	153	1,002	108
phosphate	PO_4^{3-}	mg/kg	0.8	ND	0.6
Other Tests					
ammonium	NH_4^{1+}	mg/kg	ND	9.4	ND
nitrate	NO_3^{1-}	mg/kg	0.5	0.7	15
sulfide	S^{2-}	qual	na	na	na
Redox		mV	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-128 @ 25.5' CL-ML	G-128 @ 50.5' SC	G-128 @ 80.5' CL	G-129 @ 20' CL	G-129 @ 40' ML
Resistivity		**Units**					
as-received		ohm-cm	1,880	1,360	680	2,120	3,200
saturated		ohm-cm	1,760	1,240	520	1,160	560
pH			7.4	7.9	7.6	7.8	7.9
Electrical Conductivity		mS/cm	0.15	0.21	0.58	0.19	0.25
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	38	46	212	45	63
magnesium	Mg^{2+}	mg/kg	17	28	111	22	33
sodium	Na^{1+}	mg/kg	123	135	214	130	145
potassium	K^{1+}	mg/kg	7.1	13	47	8.8	31.9
Anions							
carbonate	CO_3^{2-}	mg/kg	23	ND	ND	21	9.0
bicarbonate	HCO_3^{1-}	mg/kg	192	183	262	229	220
fluoride	F^{1-}	mg/kg	2.7	1.7	2.0	4.3	2.5
chloride	Cl^{1-}	mg/kg	20	9.4	11	56	27
sulfate	SO_4^{2-}	mg/kg	50	316	1,120	47	274
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	2.3	6.2	ND	1.2
nitrate	NO_3^{1-}	mg/kg	ND	4.1	2.0	0.7	0.8
sulfide	S^{2-}	qual	na	Positive	Trace	na	na
Redox		mV	na	-108	-97	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-129 @ 70' ML	G-129 @ 83.5' CL	G-129 @ 100' CL
Resistivity		**Units**			
as-received		ohm-cm	1,520	680	1,360
saturated		ohm-cm	840	560	600
pH			7.8	7.8	7.8
Electrical Conductivity		mS/cm	0.25	0.50	0.61
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	70	197	247
magnesium	Mg^{2+}	mg/kg	39	87	134
sodium	Na^{1+}	mg/kg	114	144	136
potassium	K^{1+}	mg/kg	22	47	47.0
Anions					
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	159	259	262
fluoride	F^{1-}	mg/kg	0.9	1.8	1.2
chloride	Cl^{1-}	mg/kg	67	78	50
sulfate	SO_4^{2-}	mg/kg	329	807	1,104
phosphate	PO_4^{3-}	mg/kg	ND	ND	ND
Other Tests					
ammonium	NH_4^{1+}	mg/kg	2.6	2.5	10
nitrate	NO_3^{1-}	mg/kg	13	4.5	2.6
sulfide	S^{2-}	qual	na	na	na
Redox		mV	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.66.1 THROUGH F-10.66.18 SOIL CORROSIVITY EVALUATION FOR WILSHIRE/RODEO STATION

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SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WILSHIRE/RODEO STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

PROJECT MANAGER: MR. MARTY HUDSON

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Wilshire/Rodeo station is one of the eight stations planned for the project. The station will be approximately 1,050 feet long and about 70 to 80 feet below ground surface.

Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. 15 of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals, aggressive to copper, and aggressive with respect to exposure of concrete to acid attack.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement should be used for concrete structures. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system. Concrete structures and pipe should be protected from acid attack.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (7/7/11)
Table 1 – Laboratory Tests on Soil Samples (7/20/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Wilshire/Rodeo station is one of the eight stations planned for the project. The station will be approximately 1,050 feet long and about 70 to 80 feet below ground surface. Ground water was encountered at depths of about 25 to 70 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. 15 of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the 15 samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the moderately to severely categories with as-received moisture. When saturated, the resistivities were in the moderately to severely corrosive categories. Some as-received resistivities were at or near their saturated values. The remaining resistivities dropped considerably with added moisture because the samples were dry as-received.

Soil pH values varied from 4.0 to 8.3. This range is extremely acidic to moderately alkaline (Romanoff, 1989). Total acidity is assumed to be high enough to warrant concern of acid attack on concrete. Soil with a pH less than 5.5 is considered aggressive to copper.

The soluble salt content of the samples was low.

Nitrate was detected in low concentrations.

Some of the samples were tested for sulfides as they exhibited characteristics typically associated with anaerobic conditions. Sulfide, which is aggressive to copper and ferrous metals, showed no reaction in a qualitative test. The positive redox potentials measured in all of the samples from borings G-144 and G-145 indicates oxidizing conditions in which anaerobic, sulfide-producing bacteria are inactive.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, and aggressive with respect to exposure of concrete to acid attack.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals, aggressive to copper, and aggressive with respect to exposure of concrete to acid attack.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
   a. Polyurethane per AWWA C222 *or*
   b. Extruded polyethylene per AWWA C215 *or*
   c. A tape coating system per AWWA C214 *or*

d. Hot applied coal tar enamel per AWWA C203 *or*
e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5a -#5e5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

OPTION 2

a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
   a. Epoxy coating; *or*
   b. Polyurethane; *or*
   c. Wax tape.

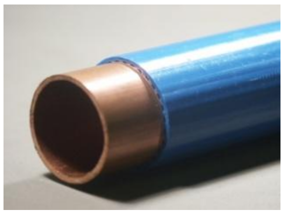
   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:

1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.



2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolans can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid “paste” phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement may be used for concrete structures and pipe because the sulfate concentration is negligible, 0 to 0.1 percent.

2. Standard concrete cover over reinforcing steel may be used for concrete structures and pipe in contact with these soils due to the low chloride concentration found onsite.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

4. Concrete structures and pipe should be protected from acid attack because soil with a pH $\leq$ 5.5 and assumed total acidity $\geq$ 250 mmol H^{1+}/kg (AWWA 1995) was found on-site. Concrete can be protected by preventing contact with the moisture in acidic soil. Contact can be prevented with an impermeable, waterproof, acid resistant barrier coating such as Grace PrePrufe Products®.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)
   a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.
   b. All components exposed to the job site should be protected within one working day after their exposure during installation.
   c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.
   d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.
   e. Inspect the following to ensure the encapsulated system is completely watertight:

i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

iii. End caps: Ensure proper installation before patching the pocket former recesses.

iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Wilshire_Rodeo_IB_rev00

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Post-Tensioning Manual, sixth edition. Post-Tensioning Institute (PTI), Phoenix, AZ, 2006.

Romanoff, M. (1989). Underground Corrosion, National Bureau of Standards (NBS) Circular 579. Houston, TX, United States of America: Reprinted by NACE.

Specification for Unbonded Single Strand Tendons. Post-Tensioning Institute (PTI), Phoenix, AZ, 2000.

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-09-0472, SA #09-0628SCSP
13-Aug-09

Sample ID			G-11 @ 20'	G-11 @ 70'
Resistivity		**Units**		
as-received		ohm-cm	6,800	1,080
saturated		ohm-cm	1,520	1,020
pH			7.7	7.8
Electrical Conductivity		mS/cm	0.08	0.12
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	43	60
magnesium	Mg^{2+}	mg/kg	12	19
sodium	Na^{1+}	mg/kg	79	69
potassium	K^{1+}	mg/kg	8.2	24
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	189	189
flouride	F^{1-}	mg/kg	1.9	1.5
chloride	Cl^{1-}	mg/kg	3.4	18
sulfate	SO_4^{2-}	mg/kg	37	79
phosphate	PO_4^{3-}	mg/kg	4.7	ND
Other Tests				
ammonium	NH_4^{1+}	mg/kg	0.8	2.0
nitrate	NO_3^{1-}	mg/kg	1.4	1.6
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-109 @ 30-31' CL	S-109 @ 53-54' CL	S-109 @ 65-66' ML	S-109 @ 77-78' ML	S-109 @ 92-93' ML
Resistivity		**Units**					
as-received		ohm-cm	1,480	1,440	1,640	4,200	2,440
saturated		ohm-cm	1,480	1,200	1,160	2,520	2,400
pH			6.7	7.1	7.0	7.2	4.0
Electrical Conductivity		mS/cm	0.07	0.06	0.10	0.06	0.08
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	24	24	37	27	30.8
magnesium	Mg^{2+}	mg/kg	7.6	7.8	11	7.6	9.2
sodium	Na^{1+}	mg/kg	64	46	58	41	46
potassium	K^{1+}	mg/kg	2.4	6.7	6.6	5.6	5.8
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	76	73	82	61	70
fluoride	F^{1-}	mg/kg	4.0	4.3	4.1	4.7	2.6
chloride	Cl^{1-}	mg/kg	15	8.8	17	12	20
sulfate	SO_4^{2-}	mg/kg	53	49	84	56	79
phosphate	PO_4^{3-}	mg/kg	2.0	2.7	2.0	2.0	1.6
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	1.6	ND	0.8	ND
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

www.hdrinc.com
Corrosion Control and Condition Assessment (C3A) Department

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-144 @ 10.5' CL-ML	G-144 @ 30.5' CL-ML	G-144 @ 50.5' Sandy CL	G-144 @ 60.5' Sandy CL	G-144 @ 80.5' CL
Resistivity		**Units**					
as-received		ohm-cm	960	1,560	1,480	1,360	1,720
saturated		ohm-cm	960	1,560	1,360	1,360	1,160
pH			7.6	7.6	7.5	7.5	7.5
Electrical Conductivity		mS/cm	0.13	0.04	0.06	0.06	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	79	25	28	33	30
magnesium	Mg^{2+}	mg/kg	17	7.5	8.3	10	9.0
sodium	Na^{1+}	mg/kg	57	42	48	51	44
potassium	K^{1+}	mg/kg	7.7	2.4	4.9	5.5	4.7
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	345	79	67	67	58
fluoride	F^{1-}	mg/kg	5.6	5.1	4.0	4.5	5.3
chloride	Cl^{1-}	mg/kg	2.0	6.8	13	15	13
sulfate	SO_4^{2-}	mg/kg	33	12	56	62	49
phosphate	PO_4^{3-}	mg/kg	3.8	6.3	2.5	3.1	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	25	13	0.9	0.5	2.1
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	18	63	38	60	31

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-144 @ 100.5' SC	G-145 @ 31.5' Sandy CL	G-145 @ 61.5' Sandy CL	G-145 @ 95.5' SM w/gravel	G-145 @ 115.5' Sandy CL
Resistivity		**Units**					
as-received		ohm-cm	9,600	1,680	3,040	5,600	1,000
saturated		ohm-cm	2,440	1,680	1,840	2,840	1,000
pH			7.6	7.7	7.8	7.8	8.3
Electrical Conductivity		mS/cm	0.05	0.05	0.09	0.06	0.15
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	23	24	36	22	65
magnesium	Mg^{2+}	mg/kg	6.8	6.3	0.5	6.4	15
sodium	Na^{1+}	mg/kg	39	44	67	42	75
potassium	K^{1+}	mg/kg	6.2	3.8	6.8	3.8	22
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	43	95	140	58	253
fluoride	F^{1-}	mg/kg	2.0	2.3	3.1	3.1	5.1
chloride	Cl^{1-}	mg/kg	11	8.4	13	15	10
sulfate	SO_4^{2-}	mg/kg	46	12	57	50	122
phosphate	PO_4^{3-}	mg/kg	2.6	6.3	2.8	2.9	2.0
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	1.5	20	3.2	1.9	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	56	80	57	66	28

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.67.1 THROUGH F-10.67.16
SOIL CORROSIVITY EVALUATION FOR
CENTURY CITY CONSTELLATION STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

CENTURY CITY CONSTELLATION STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

PROJECT MANAGER: MR. MARTY HUDSON

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Century City Constellation station is one of the eight stations planned for the project. The station will be approximately 980 feet long and about 85 to 95 feet below ground surface.

Laboratory tests on the soil samples provided by AMEC E&I have been completed. Six of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectric coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23.

A dielectric coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Test on Soil Samples

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Century City Constellation station is one of the eight stations planned for the project. The station will be approximately 980 feet long and about 85 to 95 feet below ground surface. Ground water was encountered at depths of about 35 to 50 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures, and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the soil samples provided by AMEC E&I have been completed. Six of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the six samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the moderately corrosive and corrosive categories with as-received moisture. When saturated, the resistivities were in the moderately to severely corrosive categories. The resistivities dropped considerably with added moisture because the samples were dry as-received.

Soil pH values varied from 7.3 to 8.2. This range is neutral to moderately alkaline (Romanoff, 1989). These values do not particularly increase soil corrosivity.

The soluble salt content of the samples ranged from low to high.

Nitrate was detected in low concentrations. The ammonium concentration was high enough to be deleterious to copper.

Tests were not made for sulfide and negative oxidation-reduction (redox) potential because these samples did not exhibit characteristics typically associated with anaerobic conditions.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
   a. Polyurethane per AWWA C222 *or*
   b. Extruded polyethylene per AWWA C215 *or*
   c. A tape coating system per AWWA C214 *or*

d. Hot applied coal tar enamel per AWWA C203 *or*
e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with a dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Provide permanent test facilities and apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

OPTION 2

a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If Steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

    Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
    a. Polyethylene encasement per AWWA C105; *or*
    b. Epoxy coating; *or*
    c. Polyurethane; *or*
    d. Wax tape.

    NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

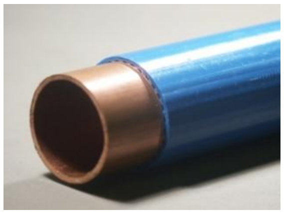
7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Iron Pipe (Non-Pressurized)

1. Encase iron pipe, fittings, and valves in an 8 mil polyethylene wrap per AWWA Standard C105/ANSI 21.5.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:



1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.

2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolons can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement may be used for concrete structures and pipe because the sulfate concentration is negligible, 0 to 0.1 percent.

2. Standard concrete cover over reinforcing steel may be used for concrete structures and pipe in contact with these soils due to the low chloride concentration found onsite.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

    b. All components exposed to the job site should be protected within one working day after their exposure during installation.

    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

    d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

    e. Inspect the following to ensure the encapsulated system is completely watertight:

i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

iii. End caps: Ensure proper installation before patching the pocket former recesses.

iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Century_City-Constellation_IB_rev01_IB

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AWWA. (C105-05). "American National Standard for Polyethylene Encasement for Ductile-Iron Pipe Systems". Denver, CO: www.awwa.org/.

Post-Tensioning Manual, sixth edition. Post-Tensioning Institute (PTI), Phoenix, AZ, 2006.

Romanoff, M. (1989). Underground Corrosion, National Bureau of Standards (NBS) Circular 579. Houston, TX, United States of America: Reprinted by NACE.

Specification for Unbonded Single Strand Tendons. Post-Tensioning Institute (PTI), Phoenix, AZ, 2000.

Table 1 - Laboratory Tests on Soil Sample(s)

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			168 @ 1-5' CL - Fill	168 @ 38.5' CL with Sand	168 @ 72.5' SP	169 @ 26' CL	169 @ 72' SP-SM / SM
Resistivity		**Units**					
as-received		ohm-cm	8,000	2,640	4,000	6,400	1,480
saturated		ohm-cm	1,680	840	3,040	920	960
pH			8.2	7.3	8.2	7.9	7.8
Electrical Conductivity		mS/cm	0.09	0.07	0.13	0.46	0.29
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	21	27	34	73	135
magnesium	Mg^{2+}	mg/kg	10	10	6.6	32	17
sodium	Na^{1+}	mg/kg	115	88	132	377	129
potassium	K^{1+}	mg/kg	3.3	5.6	6.4	11	26
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	45	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	143	98	142	183	259
fluoride	F^{1-}	mg/kg	24	14	1.9	9.0	1.2
chloride	Cl^{1-}	mg/kg	3.9	21	13	99	58
sulfate	SO_4^{2-}	mg/kg	27	25	51	672	358
phosphate	PO_4^{3-}	mg/kg	16	13	ND	1.5	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	3.7
nitrate	NO_3^{1-}	mg/kg	2.8	2.3	4.2	ND	9.0
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Sample(s)

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, SA #11-0184LAB
21-Feb-11

Sample ID			169 @ 100.5' ML
Resistivity		**Units**	
as-received		ohm-cm	3,920
saturated		ohm-cm	640
pH			7.7
Electrical Conductivity		mS/cm	0.50
Chemical Analyses			
Cations			
calcium	Ca^{2+}	mg/kg	289
magnesium	Mg^{2+}	mg/kg	55
sodium	Na^{1+}	mg/kg	84
potassium	K^{1+}	mg/kg	76
Anions			
carbonate	CO_3^{2-}	mg/kg	ND
bicarbonate	HCO_3^{1-}	mg/kg	101
fluoride	F^{1-}	mg/kg	0.5
chloride	Cl^{1-}	mg/kg	45
sulfate	SO_4^{2-}	mg/kg	968
phosphate	PO_4^{3-}	mg/kg	ND
Other Tests			
ammonium	NH_4^{1+}	mg/kg	14
nitrate	NO_3^{1-}	mg/kg	ND
sulfide	S^{2-}	qual	na
Redox		mV	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.68.1 THROUGH F-10.68.19
SOIL CORROSIVITY EVALUATION FOR
WESTWOOD/UCLA STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WESTWOOD/UCLA STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

PROJECT MANAGER: MR. MARTY HUDSON

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Westwood/UCLA station is one of the eight stations planned for the project. The station will be approximately 1,020 feet long and about 70 to 75 feet below ground surface.

Laboratory tests on the soil samples provided by AMEC E&I have been completed. 18 of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (7/7/11)
Table 1 – Laboratory Tests on Soil Samples (7/14/11)
Table 1 – Laboratory Tests on Soil Samples (7/14/11)
Table 1 – Laboratory Tests on Soil Samples (9/8/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Westwood/UCLA station is one of the eight stations planned for the project. The station will be approximately 1,020 feet long and about 70 to 75 feet below ground surface. Ground water was encountered at depths of about 30 to 60 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures, and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. 18 of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the 18 samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the mildly corrosive to severelycorrosive categories with as-received moisture. When saturated, the resistivities were in the mildly to severely corrosive categories. Some as-received resistivities were at or near their saturated values. The remaining resistivities dropped considerably with added moisture because the samples were dry as-received. The wide variations in soil resistivity can create concentration type corrosion cells that increase corrosion rates above what would be expected from the chemical characteristics alone.

Soil pH values varied from 7.2 to 8.0. This range is neutral to moderately alkaline (Romanoff, 1989). These values do not particularly increase soil corrosivity.

The soluble salt content of the samples was low.

The nitrate concentration was high enough to be deleterious to copper.

Some of the samples were tested for sulfides as they exhibited characteristics typically associated with anaerobic conditions. Sulfide, which is aggressive to copper and ferrous metals, showed no reaction in a qualitative test. The positive redox potentials measured in the samples from G-190 @ 20-21.5', 50', 70', and 80' indicates oxidizing conditions in which anaerobic, sulfide-producing bacteria are inactive.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

    Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

    Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
    a. Polyurethane per AWWA C222 *or*
    b. Extruded polyethylene per AWWA C215 *or*
    c. A tape coating system per AWWA C214 *or*

d. Hot applied coal tar enamel per AWWA C203 *or*
e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Provide permanent test facilities and apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

OPTION 2

a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
   a. Polyethylene encasement per AWWA C105; *or*
   b. Epoxy coating; *or*
   c. Polyurethane; *or*
   d. Wax tape.

   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

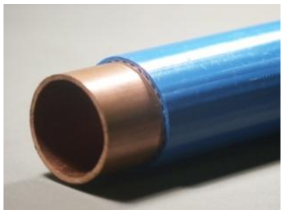
7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Iron Pipe (Non-Pressurized)

1. Encase iron pipe, fittings, and valves in an 8 mil polyethylene wrap per AWWA Standard C105/ANSI 21.5.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:



1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.

2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

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All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolons can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
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Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement may be used for concrete structures and pipe because the sulfate concentration is negligible, 0 to 0.1 percent.

2. Standard concrete cover over reinforcing steel may be used for concrete structures and pipe in contact with these soils due to the low chloride concentration found onsite.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

    b. All components exposed to the job site should be protected within one working day after their exposure during installation.

    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

    d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

    e. Inspect the following to ensure the encapsulated system is completely watertight:

i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.
ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.
iii. End caps: Ensure proper installation before patching the pocket former recesses.
iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Westwood-UCLA_IB_rev00

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Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-114 @ 27-28' SM	S-114 @ 49-50' CL	S-114 @ 61-62' CL/ML	S-114 @ 83-84' ML
Resistivity		**Units**				
as-received		ohm-cm	312,000	1,680	2,600	1,840
saturated		ohm-cm	22,400	1,680	1,880	1,160
pH			7.7	7.3	7.3	7.6
Electrical Conductivity		mS/cm	0.03	0.09	0.07	0.20
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	27	45	34	92
magnesium	Mg^{2+}	mg/kg	5.6	11	7.4	18
sodium	Na^{1+}	mg/kg	14	54	43	72
potassium	K^{1+}	mg/kg	6.9	9.8	11.2	24.3
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	9.0
bicarbonate	HCO_3^{1-}	mg/kg	52	64	49	265
fluoride	F^{1-}	mg/kg	0.9	3.4	4.5	6.3
chloride	Cl^{1-}	mg/kg	3.4	22	13	9.2
sulfate	SO_4^{2-}	mg/kg	20	83	72	94
phosphate	PO_4^{3-}	mg/kg	2.1	3.1	2.9	1.4
Other Tests						
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	3.3	2.4	3.9
sulfide	S^{2-}	qual	na	na	na	na
Redox		mV	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0673LAB
14-Jul-11

Sample ID			G-186 @ 30.5' CL	G-186 @ 75.5' CL-ML	G-186 @ 85.5 CL
Resistivity		**Units**			
as-received		ohm-cm	2,920	2,880	1,640
saturated		ohm-cm	2,480	1,480	1,120
pH			7.9	7.7	7.7
Electrical Conductivity		mS/cm	0.09	0.13	0.12
Chemical Analyses					
Cations					
calcium	Ca^{2+}	mg/kg	64	70	65
magnesium	Mg^{2+}	mg/kg	11.4	16	15
sodium	Na^{1+}	mg/kg	28	51	51
potassium	K^{1+}	mg/kg	7.1	13	10
Anions					
carbonate	CO_3^{2-}	mg/kg	12	9.0	9.0
bicarbonate	HCO_3^{1-}	mg/kg	169	215	178
fluoride	F^{1-}	mg/kg	1.7	4.6	0.8
chloride	Cl^{1-}	mg/kg	2.1	3.5	7.0
sulfate	SO_4^{2-}	mg/kg	24	51	62
phosphate	PO_4^{3-}	mg/kg	3.3	2.1	2.0
Other Tests					
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	0.8	1.9	1.6
sulfide	S^{2-}	qual	na	na	na
Redox		mV	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-189 @ 10' ML	G-189 @ 40' SW	G-189 @ 70' ML	G-189 @ 100' CL	G-191 @ 15-16.5' SP
Resistivity		**Units**					
as-received		ohm-cm	1,760	28,400	2,280	1,720	5,200
saturated		ohm-cm	1,760	4,800	2,280	1,400	3,680
pH			7.6	7.6	7.3	7.2	7.8
Electrical Conductivity		mS/cm	0.06	0.04	0.04	0.05	0.10
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	49	20	22	30	69
magnesium	Mg^{2+}	mg/kg	7.8	6.2	5.5	6.8	11
sodium	Na^{1+}	mg/kg	29	33	32	35	36
potassium	K^{1+}	mg/kg	3.5	3.2	46	9.6	12
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	143	70	46	67	229
fluoride	F^{1-}	mg/kg	2.5	2.8	2.5	3.4	2.3
chloride	Cl^{1-}	mg/kg	1.7	6.3	11	5.6	2.2
sulfate	SO_4^{2-}	mg/kg	14	19	33	54	45
phosphate	PO_4^{3-}	mg/kg	3.6	4.7	2.0	2.1	4.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	10	22	2.5	2.7	28
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0674LAB
14-Jul-11

Sample ID			G-191 @ 45-46.5' SP-SM	G-191 @ 95-96' CL-ML
Resistivity		**Units**		
as-received		ohm-cm	13,200	880
saturated		ohm-cm	5,200	880
pH			7.7	7.6
Electrical Conductivity		mS/cm	0.05	0.12
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	19	48
magnesium	Mg^{2+}	mg/kg	3.7	11
sodium	Na^{1+}	mg/kg	45	61
potassium	K^{1+}	mg/kg	2.3	11
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	55	140
fluoride	F^{1-}	mg/kg	3.5	4.6
chloride	Cl^{1-}	mg/kg	5.0	11
sulfate	SO_4^{2-}	mg/kg	6.1	103
phosphate	PO_4^{3-}	mg/kg	3.6	3.0
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	22	3.9
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0793LAB
8-Aug-11

Sample ID			G-190 @ 20-21.5' ML	G-190 @ 50' ML	G-190 @ 70' ML/SM	G-190 @ 80' ML
Resistivity		**Units**				
as-received		ohm-cm	1,560	2,200	1,400	1,360
saturated		ohm-cm	1,000	2,040	1,400	1,360
pH			7.9	7.8	8.0	8.0
Electrical Conductivity		mS/cm	0.17	0.06	0.11	0.13
Chemical Analyses						
Cations						
calcium	Ca^{2+}	mg/kg	90	35	65	96
magnesium	Mg^{2+}	mg/kg	19	8.7	16	17
sodium	Na^{1+}	mg/kg	68	45	48	48
potassium	K^{1+}	mg/kg	6.3	4.3	8.7	8.9
Anions						
carbonate	CO_3^{2-}	mg/kg	ND	ND	9.0	18
bicarbonate	HCO_3^{1-}	mg/kg	223	58	156	194
fluoride	F^{1-}	mg/kg	4.1	3.6	4.0	6.1
chloride	Cl^{1-}	mg/kg	3.9	18	11	6.7
sulfate	SO_4^{2-}	mg/kg	9.2	57	52	80
phosphate	PO_4^{3-}	mg/kg	1.8	2.1	1.4	1.7
Other Tests						
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	176	6.7	6.1	5.6
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative
Redox		mV	68	47	2	56

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.69.1 THROUGH F-10.69.19
SOIL CORROSIVITY EVALUATION FOR
WESTWOOD/VA HOSPITAL STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

WESTWOOD/VA HOSPITAL STATION

in

LOS ANGELES, CA

prepared for

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Westwood/VA Hospital station is one of the eight stations planned for the project. The station will be approximately 880 feet long and about 70 to 80 feet below ground surface.

Laboratory tests on the soil samples provided by AMEC E&I have been completed. 17 of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals and aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design base on the Metro Rail Design Criteria. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (12/28/09)
Table 1 – Laboratory Tests on Soil Samples (7/7/11)
Table 1 – Laboratory Tests on Soil Samples (7/20/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Westwood/VA Hospital station is one of the eight stations planned for the project. The station will be approximately 880 feet long and about 70 to 80 feet below ground surface. Ground water was encountered at depths of about 40 to 70 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the soil samples provided by AMEC E&I have been completed. 17 of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the 17 samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the mildly corrosive to severely corrosive categories with as-received moisture. When saturated, the resistivities were in the moderately to severely corrosive categories. Some as-received resistivities were at or near their saturated values. The remaining resistivities dropped considerably with added moisture because the samples were dry as-received.

Soil pH values varied from 6.9 to 8.0. This range is neutral to moderately alkaline (Romanoff, 1989). These values do not particularly increase soil corrosivity.

The soluble salt content of the samples ranged from low to moderate.

The soluble salt content was moderate in the sample from boring G-203 @ 45.5’ and less in the others. Chloride salts were the predominant constituents. Chloride is particularly corrosive to ferrous metals, and in the higher concentrations measured in the soil samples, chloride can overcome the corrosion inhibiting effect of concrete on reinforcing steel.

Nitrate was detected in low concentrations.

Some of the samples were tested for sulfides as they exhibited characteristics typically associated with anaerobic conditions. Sulfide, which is aggressive to copper and ferrous metals, showed no reaction in a qualitative test. The positive redox potentials measured in the samples from G-203 @ 30’, 45.5’, and 80.5’, G-204 @ 10’, 40’, 80’, and 100’, and G-205 @ 50’ and 95.5’ indicates oxidizing conditions in which anaerobic, sulfide-producing bacteria are inactive.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals and aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals and aggressive with respect to exposure of reinforcing steel to the migration of chloride based on the Metro Rail Design Criteria.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Chloride levels were measured at levels where additional protective measures are required for concrete, including increased cover, admixtures, or other modifications of design base on the Metro Rail Design Criteria. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
    a. Polyurethane per AWWA C222 *or*
    b. Extruded polyethylene per AWWA C215 *or*
    c. A tape coating system per AWWA C214 *or*
    d. Hot applied coal tar enamel per AWWA C203 *or*
    e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5a -#5e5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.

6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

   OPTION 2

   a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If Steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe (Non-Pressurized)

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:

   a. Pumping plants.

b. Reservoirs.
c. Flow meters.
d. Motorized operated valves.
e. Dissimilar metals.
f. Dissimilarly coated piping (cement-mortar vs. dielectric).
g. Above ground steel pipe.
h. All existing piping.

Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

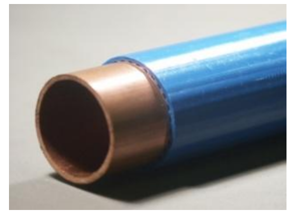
6. Apply a suitable coating intended for underground use such as:
   a. Epoxy coating; *or*
   b. Polyurethane; *or*
   c. Wax tape.

   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:



1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.

2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolons can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement may be used for concrete structures and pipe because the sulfate concentration is negligible, 0 to 0.1 percent.
2. Chloride levels were measured at levels where additional protective measures may be required for concrete, including increased cover, admixtures, or other modifications of design based on the Metro Rail Design Criteria. Possible measures are presented below.
    a. Protective Concrete - A concrete mix designed to protect embedded steel and iron that should be based on the following parameters: 1) a chloride content of 250 ppm in the soil; 2) the desired service life; and 3) concrete cover. A protective concrete mix may include a corrosion inhibitor admixture and/or silica fume admixture.
    b. Waterproof Concrete - Waterproofing for concrete could be a gravel capillary break under the concrete, a waterproof membrane, and/or a liquid applied waterproof barrier coating such as Grace PrePrufe® products. Visqueen, similar rolled barriers, or bentonite-based membranes are not viable waterproofing systems, from a corrosion standpoint.
    c. Coat Embedded Metal - A coating for embedded steel and iron could be an epoxy coating applied to the metal. Purple fusion bonded epoxy (FBE) (ASTM A934) intended for prefabricated reinforcing steel reinforcing steel is suitable. The green flexible FBE (ASTM A775) is not recommended.
    d. Cathodic Protection - Cathodic protection is most practical for pipelines and must be designed for each application. The amount of cathodic protection current needed can be minimized by coating the steel or iron.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)
    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.
    b. All components exposed to the job site should be protected within one working day after their exposure during installation.
    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.
    d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.
    e. Inspect the following to ensure the encapsulated system is completely watertight:
        i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.
        ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.
        iii. End caps: Ensure proper installation before patching the pocket former recesses.
        iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.
    f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.
    g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Westwood-VA_Hospital_IB_rev00

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Post-Tensioning Manual, sixth edition. Post-Tensioning Institute (PTI), Phoenix, AZ, 2006.

Romanoff, M. (1989). Underground Corrosion, National Bureau of Standards (NBS) Circular 579. Houston, TX, United States of America: Reprinted by NACE.

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Table 2 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-09-0472, SA #09-0628SCSP
28-Dec-09

Sample ID			G-24 @ 20' CL w/ Gravel	G-24 @ 40' ML
Resistivity		**Units**		
as-received		ohm-cm	14,800	2,120
saturated		ohm-cm	1,920	2,120
pH			7.3	7.6
Electrical Conductivity		mS/cm	0.05	0.05
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	30	28
magnesium	Mg^{2+}	mg/kg	12	10
sodium	Na^{1+}	mg/kg	21	43
potassium	K^{1+}	mg/kg	2.1	2.3
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	76	49
flouride	F^{1-}	mg/kg	10	3.2
chloride	Cl^{1-}	mg/kg	11	9.2
sulfate	SO_4^{2-}	mg/kg	23	46
phosphate	PO_4^{3-}	mg/kg	16	6.6
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	0.6	1.8
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			S-115 @19-20' ML	S-115 @ 39-40' SM	S-115 @ 68-69' ML	S-115 @ 96-97' ML	S-115 @ 116-117' ML
Resistivity		**Units**					
as-received		ohm-cm	1,880	128,000	2,840	3,760	4,400
saturated		ohm-cm	1,600	5,600	1,280	1,880	1,760
pH			7.1	7.2	7.3	7.3	7.4
Electrical Conductivity		mS/cm	0.06	0.05	0.07	0.08	0.07
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	38	22	38	35	35.1
magnesium	Mg^{2+}	mg/kg	20.9	6.4	11	13.2	12.1
sodium	Na^{1+}	mg/kg	91	64	41	44	35
potassium	K^{1+}	mg/kg	3.4	3.1	6.0	10.6	13.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	73	64	73	128	64
fluoride	F^{1-}	mg/kg	12	5.7	3.5	4.4	4.2
chloride	Cl^{1-}	mg/kg	3.8	3.1	11	16	8.3
sulfate	SO_4^{2-}	mg/kg	14	19	47	85	68
phosphate	PO_4^{3-}	mg/kg	19	14.6	2.4	1.8	1.7
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	1.4	2.7	1.1
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-203 @ 30' ML	G-203 @ 45.5' SM	G-203 @ 80.5' SM	G-204 @ 10' ML	G-204 @ 40' ML
Resistivity		**Units**					
as-received		ohm-cm	4,800	800	5,200	2,600	1,360
saturated		ohm-cm	1,720	760	3,360	2,400	960
pH			8.0	7.5	8.0	7.4	7.1
Electrical Conductivity		mS/cm	0.16	0.27	0.06	0.05	0.22
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	25	41	19	18	44
magnesium	Mg^{2+}	mg/kg	8.7	21	7.2	9.1	26
sodium	Na^{1+}	mg/kg	139	222	44	69	136
potassium	K^{1+}	mg/kg	3.6	7.4	4.8	1.8	9.1
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	107	52	58	70	40
fluoride	F^{1-}	mg/kg	7.8	3.3	2.7	11.8	3.7
chloride	Cl^{1-}	mg/kg	43	242	16	2.1	115
sulfate	SO_4^{2-}	mg/kg	150	250	50	7.3	264
phosphate	PO_4^{3-}	mg/kg	6.6	ND	1.6	31	ND
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	ND	ND	0.7	ND	ND
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	35	105	60	131	119

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0699LAB
20-Jul-11

Sample ID			G-204 @ 80' CL	G-204 @ 100' ML/CL	G-205 @ 35.5' ML	G-205 @ 50' ML	G-205 @ 95.5' ML
Resistivity		**Units**					
as-received		ohm-cm	1,400	1,880	840	12,000	1,560
saturated		ohm-cm	1,400	1,880	760	3,560	1,560
pH			7.9	7.0	6.9	7.7	7.5
Electrical Conductivity		mS/cm	0.08	0.09	0.34	0.07	0.07
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	36	33	41	19	30
magnesium	Mg^{2+}	mg/kg	13	14	17	4.6	10.9
sodium	Na^{1+}	mg/kg	41	46	304	66	39
potassium	K^{1+}	mg/kg	11.8	14.1	5.3	3.3	12.2
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	67	46	49	43	46
fluoride	F^{1-}	mg/kg	5.0	4.9	5.1	3.4	4.8
chloride	Cl^{1-}	mg/kg	16	24	74.7	42.9	15
sulfate	SO_4^{2-}	mg/kg	81	103	559	28	73
phosphate	PO_4^{3-}	mg/kg	1.3	1.3	4.0	4.3	2.1
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	3.3	1.4	ND	ND	1.8
sulfide	S^{2-}	qual	Negative	Negative	Negative	Negative	Negative
Redox		mV	92	93	69	74	72

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

FIGURES F-10.70.1 THROUGH F-10.70.16
SOIL CORROSIVITY EVALUATION FOR
CENTURY CITY SANTA MONICA STATION

SOIL CORROSIVITY EVALUATION

for the

WESTSIDE SUBWAY EXTENSION

CENTURY CITY SANTA MONICA STATION

in

LOS ANGELES, CA

prepared for

AMEC E&I
5628 East Slauson Avenue
Los Angeles, CA 90040

Project No.: 4953-10-1561

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HDR|SCHIFF #172549

October 18, 2011

EXECUTIVE SUMMARY

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. Santa Monica Century City station is one of the eight stations planned for the project. The station will be approximately 1,360 feet long and about 70 to 85 feet below ground surface.

Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Seven of the samples were selected for analysis. This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

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APPENDIX: Table 1 – Laboratory Tests on Soil Samples (4/8/11)
Table 1 – Laboratory Tests on Soil Samples (7/11/11)

INTRODUCTION

The existing subway system is owned and operated by Los Angeles County Metropolitan Transportation Authority (MTA) and provides public transportation throughout the City of Los Angeles, and surrounding areas.

The Westside Subway Extension is a proposed extension of the Metro Purple Line subway westward from the Wilshire/Western Station to the Veterans Administration West Los Angeles Hospital. In the Century City area, two alternative alignments are considered; one with a station along Santa Monica Boulevard, and one with a station along Constellation Boulevard. The proposed subway alignment is about 9 miles long. The depth to tunnel invert varies along the alignment from 40 to 160 feet below grade. The subway will consist of heavy rail transit operated in a twin tunnel configuration with eight new passenger stations, with two options in Century City.

Santa Monica Century City station is one of the eight stations planned for the project. The station will be approximately 1,360 feet long and about 70 to 85 feet below ground surface. Ground water was encountered at depths of about 25 to 50 feet below ground surface. The station will include walls below grade, utility piping, hydraulic elevator systems, concrete structures and post-tensioning systems.

An analysis of soil corrosivity along the route of the Metro rail alignment was requested. Laboratory tests on the provided soil samples provided by AMEC E&I have been completed. Seven of the samples were selected for analysis. HDR Engineering, Inc. (HDR|Schiff) assumes that the samples selected are representative of the most corrosive soils at the site.

The scope of this study is limited to a determination of soil corrosivity and general corrosion control recommendations for materials planned for construction. HDR|Schiff understands shoring piles will be used only temporarily during construction and will not be considered in this study. If steel piles are considered for use as permanent structures in the future, HDR|Schiff will be glad to perform Romanoff similitude analysis for metal loss and determine estimated corrosion rates.

LABORATORY TESTS ON SOIL SAMPLES

The electrical resistivity of each of the seven samples was measured in a soil box per ASTM G187 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured per ASTM G 51. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soil per ASTM D4327, D6919, and D513. Test results are shown in Table 1 in the Appendix to this report.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is (Romanoff, 1989):

Soil Resistivity in ohm-centimeters	Corrosivity Category
Greater than 10,000	Mildly Corrosive
2,001 to 10,000	Moderately Corrosive
1,001 to 2,000	Corrosive
0 to 1,000	Severely Corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in the mildly corrosive to corrosive categories with as-received moisture. When saturated, the resistivities were in the moderately to severely corrosive categories. The resistivities dropped considerably with added moisture because the samples were dry as-received.

Soil pH values varied from 7.1 to 7.8. This range is neutral to mildly alkaline (Romanoff, 1989). These values do not particularly increase soil corrosivity.

The soluble salt content of the samples was low.

The nitrate concentration was high enough to be deleterious to copper.

Tests were not made for sulfide and negative oxidation-reduction (redox) potential because these samples did not exhibit characteristics typically associated with anaerobic conditions.

The variation in soil types can create differential-aeration corrosion cells that would affect all metals.

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

Heavy rail transit systems can present a multitude of DC stray current issues. These issues can affect not only the system of concern, but also other metallic utilities or structures proximal to rails, and DC substations if the proper mitigation practices are not followed. Stray current can increase corrosion rates above what would be expected from the chemical characteristics alone.

CONCLUSIONS

This soil is classified as severely corrosive to ferrous metals and aggressive to copper.

A dielectrically coated steel pipeline for this route should also have bonded joints and test stations. In addition, cathodic protection should be installed and applied concurrently with the pipeline.

Cathodically protect and provide corrosion monitoring for hydraulic elevators and associated components as required for compliance with Title 23 as necessary.

A dielectrically coated ductile iron pipe would also be a suitable choice. In addition, cathodic protection should be installed and applied concurrently with the pipeline. A polyethylene wrap may be used on non-pressurized iron pipe due to corrosive soils along portions of the route.

A polyvinyl chloride (PVC) pipe would also be a suitable choice. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating.

Type II cement may be used for concrete structures. Standard concrete cover over reinforcing steel may be used. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Due to the soils at this site, post-tensioned slabs should be protected in accordance with soil considered aggressive (corrosive).

Due to the nature and magnitude of the project and the long design service life requirements, tolerance for corrosion on all project components is low. Based on the need for high reliability and the corrosivity considerations discussed above, it is clear that corrosion protection must be provided for the components exposed to the environment discussed with consideration given to the level of risk and practicality.

RECOMMENDATIONS

DC Stray Current

A study of the impact of the DC powered heavy rail system was not detailed as part of the scope work in this project. It is recommended that the client pursue such a study in order to take the necessary precautions to avoid the deleterious effects known to result from DC stray current.

Steel Pipe

Implement *all* the following measures.

1. Underground steel pipe with rubber gasketed, mechanical, grooved end, or other nonconductive type joints should be bonded for electrical continuity. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

2. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
    a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
    b. Four-wire test stations at all buried insulating joints.
    c. Four-wire test stations at each end of all casings.
    d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

    Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

3. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried steel pipeline per NACE Standard SP0286 from:
    a. Pumping plants.
    b. Reservoirs.
    c. Flow meters.
    d. Motorized operated valves.
    e. Dissimilar metals.
    f. Dissimilarly coated piping (cement-mortar vs. dielectric).
    g. Above ground steel pipe.
    h. All existing piping.

    Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

4. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

5. Apply a suitable dielectric coating intended for underground use such as:
    a. Polyurethane per AWWA C222 *or*
    b. Extruded polyethylene per AWWA C215 *or*
    c. A tape coating system per AWWA C214 *or*
    d. Hot applied coal tar enamel per AWWA C203 *or*
    e. Fusion bonded epoxy per AWWA C213.

6. Buried steel and iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, should be coated with a material listed above or with coal-tar epoxy, wax tape, moldable sealant, or equivalent. If copper is used, electrically insulate it from the steel with an insulating joint or with a dielectric union.

7. Apply cathodic protection to steel piping as per NACE Standard SP0169.

8. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

9. After the pipeline is backfilled, but before the construction contract is completed, the pipeline should be tested to insure that the joint bonds are intact and test stations properly installed. Also, native pipe-to-soil potentials should be measured and recorded. These data will be useful in determining if pipeline conditions change in the future.

10. Pipe-to-soil potentials should be measured biennially to determine if conditions on the pipeline are changing.

Hydraulic Elevator

Implement *all* the following measures:

1. Coat hydraulic elevator cylinders as described above for steel pipe, item #5a -#5e5 that is resistant to petroleum products (hydraulic fluid).
2. Electrically insulate each cylinder from building metals by installing dielectric material between the piston platen and car, insulating the bolts, and installing an insulated joint in the oil line.
3. Place each cylinder in a non-metallic casing with a plastic watertight seal at the bottom. Fill the annulus with dry sand with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 6.5 and 7.5 and a maximum chloride content of 200 ppm.
4. A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.
5. Apply cathodic protection to hydraulic cylinders as per NACE Standard SP0169.
6. The elevator oil line should be placed above ground if possible but, if underground, should be protected by one of the following corrosion control options:

   OPTION 1

   a. Provide a bonded dielectric coating.
   b. Electrically isolate the pipeline.
   c. Apply cathodic protection to steel piping as per NACE Standard SP0169.

   OPTION 2

   a. Place the oil line in a PVC casing pipe with solvent-welded joints to prevent contact with soil and soil moisture.

7. If Steel underground storage tanks are used, cathodic protection and corrosion control requirements shall comply with Title 23.

Reinforced Concrete Pipe

Implement *all* the following measures.

1. To prevent dissimilar metal corrosion cells electrically isolate the storm drain per NACE Standard SP0286 from all structures and facilities.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Prevent contact between the steel pipe and concrete and/or reinforcing steel, such as at wall penetrations and thrust blocks, with such items as plastic sleeves, rubber seals, or 20 mil plastic tape.

3. Buried steel and iron pipe and fittings in appurtenances should be cement-mortar coated or concrete or cement slurry encased where possible. Otherwise, they should be wrapped with wax tape per AWWA Standard C-217

4. To insure that corrosion control is properly designed, preliminary construction drawings should be reviewed by a qualified corrosion engineer.

5. Apply a suitable dielectric waterproofing coating intended for underground use. This coating is to be compatible with and applied over the concrete/cement-mortar.

Iron Pipe

Implement *all* the following measures:

1. To prevent dissimilar metal corrosion cells and to facilitate the application of cathodic protection, electrically isolate each buried iron pipeline per NACE Standard SP0286 from:
   a. Pumping plants.
   b. Reservoirs.
   c. Flow meters.
   d. Motorized operated valves.
   e. Dissimilar metals.
   f. Dissimilarly coated piping (cement-mortar vs. dielectric).
   g. Above ground steel pipe.
   h. All existing piping.

   Insulated joints should be placed above grade or in vaults where possible. Wrap all buried insulators with wax tape per AWWA C217.

2. Bond all nonconductive type joints for electrical continuity. Electrical continuity is necessary for corrosion monitoring and cathodic protection. For pipe diameters less 18 inches use two joint bonds. For pipe diameters greater than or equal to 18 inches use three joint bonds. Electrical continuity is necessary for corrosion monitoring and cathodic protection.

3. Install corrosion monitoring test stations to facilitate corrosion monitoring and the application of cathodic protection:
   a. Two or four-wire test stations at each end of the pipeline depending on how the pipe terminates.
   b. Four-wire test stations at all buried insulating joints.
   c. Four-wire test stations at each end of all casings.
   d. Two-wire test stations at other locations as necessary so the interval between test stations does not exceed 1,200 feet.

   Where 4-wire test stations are required, use wires of difference size or insulation color for identification. Each wire should be independently welded or pin-brazed to the pipe.

4. Use iron pipe, fittings, and valves in appurtenances to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated with wax tape. If copper is used, electrically isolate it from the iron.

5. Prevent contact between iron and concrete including reinforcing steel, using such items as plastic sleeves, rubber seals, two layers of 8 mil thick polyethylene plastic, or 20 mil plastic tape.

6. Apply a suitable coating intended for underground use such as:
   a. Polyethylene encasement per AWWA C105; *or*
   b. Epoxy coating; *or*
   c. Polyurethane; *or*
   d. Wax tape.

   NOTE: The thin factory-applied asphaltic coating applied to ductile iron pipe for transportation and aesthetic purposes does not constitute a corrosion control coating.

7. Apply cathodic protection to cast and ductile iron piping as per NACE Standard SP0169.

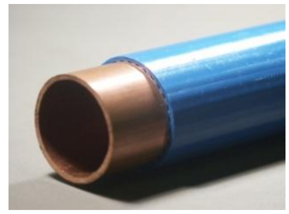
Iron Pipe (Non-Pressurized)

1. Encase iron pipe, fittings, and valves in an 8 mil polyethylene wrap per AWWA Standard C105/ANSI 21.5.

Copper Pipe

Protect buried copper pipe by *one* of the following measures:

1. Installation of a factory-coated copper pipe with a minimum 25-mil thickness such as Kamco's Aqua Shield™, Mueller's Streamline Protec™, or equal. The coating must be continuous with no cuts or defects.



2. Installation of 12-mil polyethylene pipe wrapping tape with butyl rubber mastic over a suitable primer. Protect wrapped copper tubing by applying cathodic protection per NACE Standard SP0169.

Polyvinyl Chloride (PVC) Pipe

1. No special measures are required to protect PVC.

2. Coat any iron parts, such as fittings and valves, with a high quality dielectric coating such as wax tape per AWWA C217, plastic pipe wrapping tape, coal tar epoxy, polyurethane, or equivalent.

3. Install electrically insulated joints in iron riser connections to above grade metallic piping.

4. Use iron pipe, fittings, and valves in appurtenances, such as air valves and blowoffs, to the extent possible to avoid creating dissimilar metal corrosion cells. Steel appurtenances such as bolts should be coated as described above. If copper is used, electrically isolate it from the iron.

All Pipe

1. On all pipes, appurtenances, and fittings not protected by cathodic protection or encased in concrete, coat pipe specials such as valves, bolts, flange joints, joint harnesses, and flexible couplings with wax tape per AWWA C217 after assembly.

2. Where metallic pipelines penetrate concrete structures such as building floors, vault walls, and thrust blocks use plastic sleeves, rubber seals, or other dielectric material to prevent pipe contact with the concrete and reinforcing steel.

Concrete Structures

The concrete mix design should provide the least permeable and mostly crack-free matrix to reduce penetration of aggressive ions and oxygen into the concrete. The concrete mixture should be designed to help protect the steel adequately from corrosion. Factors in concrete mix design that can reduce the permeability of the concrete include lowering the water-to-cement ratio by either increasing the cement content or decreasing water content. Finely divided materials such as fly ash, granulated blast furnace slag, silica fume, and other pozzolons can further reduce permeability of the concrete.

In addition, aggregates having water-soluble chloride ions on their surfaces, or even within their particles, can cause corrosion problems. If enough surface-borne chlorides are present, a portion will not be bound within the solid "paste" phase during hydration of the cement. Most of the chlorides released from the interior of an aggregate particle after the first few hours of hydration will not be bound at all. Unbound chloride ions can cause passivity breakdown of the steel created by the alkaline cement.

The following standards contain important guidelines for the maximum concentration of chloride, sulfate and carbonate ions on the mixing water and admixture:

- Portland Cement Association PCA Publication E B.001, Design and Control of Concrete mixtures
- American Concrete Institute ACI 318, Building Code Requirements for Reinforced Concrete Structures
- American Concrete Institute ACI 222, Corrosion of Metals in Concrete

Nevertheless, there are certain steps that can be taken to enhance the protective properties of the concrete. The most important factor is keeping the cement content high enough to maintain a pH of 12.5 or greater.

1. From a corrosion standpoint, Type II cement may be used for concrete structures and pipe because the sulfate concentration is negligible, 0 to 0.1 percent.

2. Standard concrete cover over reinforcing steel may be used for concrete structures and pipe in contact with these soils due to the low chloride concentration found onsite.

3. Due to the high ground water table encountered at this site, cyclical or continual wetting may be an issue. Any contact between concrete structures and ground water should be prevented. Contact can be prevented with an impermeable waterproofing system.

Post Tensioning Slabs: Unbonded Single-Stranded Tendons and Anchors

1. Soil is considered an aggressive environment for post-tensioning strands and anchors. Therefore, due to the soils found on-site, protect post-tensioning strands and anchors against corrosion in this aggressive (corrosive) environment. Implement *all* the following measures: (ACI 2001)(PTI 2006)(PTI 2000)

    a. Completely encapsulate the tendon and anchor with polyethylene to create a watertight seal.

    b. All components exposed to the job site should be protected within one working day after their exposure during installation.

    c. Ensure the minimum concrete cover over the tendon tail is 1-inch, or greater if required by the applicable building code.

d. Caps and sleeves should be installed within one working day after the cutting of the tendon tails and acceptance of the elongation records by the engineer.

e. Inspect the following to ensure the encapsulated system is completely watertight:

   i. Sheathing: Verify that all damaged areas, including pin-holes, are repaired.

   ii. Stressing tails: After removal, ensure they are cut to a length for proper installation of P/T coating filled end caps.

   iii. End caps: Ensure proper installation before patching the pocket former recesses.

   iv. Patching: Ensure the patch is of an approved material and mix design, and installed void-free.

f. Limit the access of direct runoff onto the anchorage area by designing proper drainage.

g. Provide at least 2 inches of space between finish grade and the anchorage area, or more if required by applicable building codes.

CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
HDR ENGINEERING, INC.

Ian Budner
EIT Corrosion Technician

REGISTERED PROFESSIONAL ENGINEER
STEVEN R FOX
No. CR 1137
Exp. 3-31-13
CORROSION
STATE OF CALIFORNIA

Steven R. Fox, P.E.
Vice President

11-1050SCS-RPT_Santa_Monica-Century_City_IB_rev00

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ACI 423.6-01: Specification for Unbonded Single Strand Tendons. American Concrete Institute (ACI), 2001

AWWA. (C105-05). "American National Standard for Polyethylene Encasement for Ductile-Iron Pipe Systems". Denver, CO: www.awwa.org/.

Post-Tensioning Manual, sixth edition. Post-Tensioning Institute (PTI), Phoenix, AZ, 2006.

Romanoff, M. (1989). Underground Corrosion, National Bureau of Standards (NBS) Circular 579. Houston, TX, United States of America: Reprinted by NACE.

Specification for Unbonded Single Strand Tendons. Post-Tensioning Institute (PTI), Phoenix, AZ, 2000.

Table 1 - Laboratory Tests on Soil Sample(s)

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0344LAB
8-Apr-11

Sample ID			154 40' ML/CL	154 60' CLAYEY ML
Resistivity		**Units**		
as-received		ohm-cm	8,400	3,640
saturated		ohm-cm	1,480	880
pH			7.8	7.8
Electrical Conductivity		mS/cm	0.06	0.05
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	20	27
magnesium	Mg^{2+}	mg/kg	6.7	8.8
sodium	Na^{1+}	mg/kg	59	51
potassium	K^{1+}	mg/kg	4.2	3.4
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	64	76
fluoride	F^{1-}	mg/kg	8.2	6.3
chloride	Cl^{1-}	mg/kg	4.6	14
sulfate	SO_4^{2-}	mg/kg	16	19
phosphate	PO_4^{3-}	mg/kg	8.3	4.1
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	55	12
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

AMEC E&I
Westside Subway Extension
Your #4953-10-1561, HDR|Schiff #11-0633LAB
7-Jul-11

Sample ID			G-156 @ 10' CL	G-156 @ 25' SM	G-156 @ 45' CL	G-156 @ 70' SM/SW	G-156 @ 80' CL
Resistivity		**Units**					
as-received		ohm-cm	10,400	9,600	1,160	6,000	4,400
saturated		ohm-cm	1,480	1,720	800	2,200	1,200
pH			7.5	7.1	7.2	7.4	7.3
Electrical Conductivity		mS/cm	0.09	0.08	0.12	0.08	0.06
Chemical Analyses							
Cations							
calcium	Ca^{2+}	mg/kg	22	21	41	21	2.5
magnesium	Mg^{2+}	mg/kg	7.2	5.6	11	5.3	6.7
sodium	Na^{1+}	mg/kg	75	55	80	62	40
potassium	K^{1+}	mg/kg	6.2	7.2	6.0	5.3	7.3
Anions							
carbonate	CO_3^{2-}	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	67	61	73	40	67
fluoride	F^{1-}	mg/kg	1.1	0.6	1.2	0.7	4.2
chloride	Cl^{1-}	mg/kg	22	23	29	23	18
sulfate	SO_4^{2-}	mg/kg	86	70	120	81	33
phosphate	PO_4^{3-}	mg/kg	10	3.3	3.6	2.0	0.7
Other Tests							
ammonium	NH_4^{1+}	mg/kg	ND	ND	ND	ND	ND
nitrate	NO_3^{1-}	mg/kg	1.9	5.2	0.7	2.6	2.5
sulfide	S^{2-}	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

431 West Baseline Road · Claremont, CA 91711
Phone: 909.626.0967 · Fax: 909.626.3316

FIGURES F-11.1 THROUGH F-11.6
ANALYTICAL TESTING OF BAT SAMPLES (PE PHASE)

AirTECHNOLOGY Laboratories, Inc.

18501 E. Gale Ave., Suite 130
City of Industry, CA 91748
Ph: 626-964-4032
Fx: 626-964-5832

CHAIN OF CUSTODY RECORD

TURNAROUND TIME: Standard ☐ 48 hours ☐ Same Day ☐ 72 hours ☐ 24 hours ☐ 96 hours ☐ Other:

DELIVERABLES: EDD ☐ EDF ☐ Level 3 ☐ Level 4 ☐

PAGE: OF

Condition upon receipt: Sealed Yes ☐ No ☐ Intact Yes ☐ No ☐ Chilled 13° deg C

Project No.: 4953-10-1561
Project Name: METRO WSE
Report To:
Company: MACTEC Engineering
Street: 5628 E Slauson Ave
City/State/Zip: LA, CA
Phone& Fax: 323 889-5300 / Fax: 323-721-6700
e-mail:

BILLING
P.O. No.:
Bill to:

ANALYSIS REQUEST

LAB USE ONLY	SAMPLE IDENTIFICATION	SAMPLE DATE	SAMPLE TIME	CONTAINER QTY/TYPE (ml)	MATRIX	PRESERVATION	Methane RSK 175	Butane Ethane				
↑	CB101 - RUN1 - TUBE1	6/9/11	1430	5ml	Water	None				} Depth - 57'		
C061008 - 01	CB101 - RUN2 - TUBE1	6/10/11	1100	35	"	"	X	X X				
↓	- RUN2 - TUBE2	6/10/11	1100	5	"	"						

AUTHORIZATION TO PERFORM WORK: Rajni Sukhwani	COMPANY: MACTEC	DATE/TIME: 6/10/11	
SAMPLED BY: Rajni Sukhwani	COMPANY: MACTEC	DATE/TIME: 6/10/11	
RELINQUISHED BY: Rajni Sukhwani	DATE/TIME: 6/10/11 1717	RECEIVED BY: [signature]	DATE/TIME: 6/10/11 1717
RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME

COMMENTS
* Smpls provided w/significant headspace.

METHOD OF TRANSPORT (circle one): Walk-in FedEx UPS Courier ATLI Other______

DISTRIBUTION: White & Yellow - Lab Copies / Pink - Customer Copy

Preservation: H=HCl N=None / Container: B=Bag C=Can V=VOA O=Other *Rev. 03 - 5/7/09*

Figure F-11.1

Client:	**MACTEC Engineering**
Attn:	**S. V. (Jag) Jagannath**
Project Name:	**Metro WSE**
Project No.:	**4953-10-1561**
Date Received:	**06/10/11**
Matrix:	**Water**
Reporting Units:	**ug/L**

RSK175

Lab No.:	**C061008-01**							
Client Sample I.D.:	**CB101 - Run2 - Tube 1**							
Date Sampled:	**06/10/11**							
Date Analyzed:	**06/15/11**							
QC Batch No.:	**110614GC11A2**							
Analyst Initials:	**ZK**							
Dilution Factor:	**1.0**							
ANALYTE	**Result ug/L**	**RL ug/L**						
Ethane	**8.4**	0.72						
Methane	**530**	1.2						
Butane	**ND**	0.50						

ND = Not Detected (below RL)
RL = Reporting Limit

Reviewed/Approved By: ______ **Date** 6/23/11

Mark Johnson
Operations Manager

The cover letter is an integral part of this analytical report

AirTECHNOLOGY *Laboratories, Inc.*

18501 E. Gale Avenue, Suite 130 ⬩ City of Industry, CA 91748 ⬩ Ph: (626) 964-4032 ⬩ Fx: (626) 964-5832

Figure F-11.2

QC Batch # 110614GC11A2
Matrix: Water
Units: ug/L

QC for RSK175

Lab No.:	Blank		LCS		LCSD			
Fixed Gas Date Analyzed:	6/15/2011		6/15/2011		6/15/2011			
Hydrocarbon Date Analyzed:	6/14/2011		6/14/2011		6/14/2011			
Analyst Initials:	ZK		ZK		ZK			
Dilution Factor:	1.0		1.0		1.0			
ANALYTE	RL	Results	%R	Criteria	%R	Criteria	RPD	Criteria
Methane	1.0	ND	107	70-130	105	70-130	1.0	<30
Ethane	1.0	ND	92	70-130	92	70-130	0.8	<30
n-Butane	1.0	ND	94	70-130	93	70-130	1.2	<30

ND = Not Detected (Below RL).

RL = PQL X Dilution Factor

Reviewed/Approved By: ______________ Date: 6/23/11

Mark Johnson
Operations Manager

The cover letter is an integral part of this analytical report.

Figure F-11.3