APPENDIX T

AREA E ORC-A REAGENT AND FERTILIZER DOSING BASIS

Table 1 - Data Summary

Area C Northern Plume - C2 - Groundwater (ug/L, unless otherwise noted)

Location ID	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	COD (mg/L)	Location
PDI-C17	220	90				62.8	1 to 10 ppm
PDI-C23	2300	1500	29	420	150		1 to 10 ppm
PDI-C26	1600	9.4	30	29	7.9		1 to 10 ppm
PDI-C25	130000	42000	460	7700	10000	436	>10 ppm
PDI-C30	8100	3100	2000	1000	3200	44.8	>10 ppm
MW-C02	75000	24000	190	4900	5600		>10 ppm
MW-C03	94000	26000	240	5100	2700		>10 ppm

Area C Southern Plume - C1 - Groundwater (ug/L, unless otherwise noted)

Location ID	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	COD (mg/L)	Location
PDI-C01	970	160	290	530	190	47.8	1 to 10 ppm
PDI-C06	280	2300	1000	820	12000		>10 ppm
RFI-31	830	8.6	1600	110	1200		>10 ppm

Area E Plume (E1 and E2) - Groundwater (ug/L, unless otherwise noted)

Location ID	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	COD (mg/L)	Location
PDI-E05	2700						1 to 10 ppm
PDI-E06	4800	9		43			1 to 10 ppm
PDI-E07	3.9	5.9					1 to 10 ppm
PDI-E08	4.1						1 to 10 ppm
PDI-E09	4700	8.8	2.5	75			1 to 10 ppm
PDI-E11	1700	3.8				144	1 to 10 ppm
PDI-E12	330	15		2.4			1 to 10 ppm
PDI-E19	5600	59	130	34	3		1 to 10 ppm
PDI-E02	390000						>10 ppm
PDI-E03	190000						>10 ppm
PDI-E04	20000						>10 ppm
PDI-E10	31000					39.3	>10 ppm
PDI-E14	15000	7800	80	1300		130	>10 ppm
PDI-E15	97000	8900	59	1600			>10 ppm
RFI-32	28000			49			>10 ppm
MW-E01	130000						>10 ppm

Notes:
Units in parts per billion (micrograms per liter) unless otherwise noted.
COD - chemical oxidant demand

Prepared by/Date: RTB 9-1-2010 (Rev 1)
Checked by/Date: BPN 9-1-2010

Table 2 - Area C Northern Plume Contaminant Mass Calculations

lbs/gal	8.34
gal/cf	7.48
liters/gal	3.785
lb/kg	2.2

1 ppm contour

area	12864	sf		
thickness	8	ft		
porosity	0.3			
total volume	102914	cf	3812	cy
pore volume	30874	cf	1143	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene
GW Conc. (mg/L)	1.37	0.53	0.03	0.22	0.08
Koc (L/Kg)	224	379	379	616	1659
Soil Conc. (mg/kg)	1.54	1.01	0.06	0.69	0.65
Diss. Mass (lbs)	2.65	1.03	0.06	0.43	0.15
Sorbed Mass (lbs)	17.41	11.44	0.63	7.83	7.41

Note: 1,3-Dichlorobenzene Koc based upon value for 1,2-Dichlorobenzene

10 ppm contour

area	5818	sf		
thickness	8	ft		
porosity	0.3			
total volume	46542	cf	1724	cy
pore volume	13962	cf	517	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	Total	
GW Conc. (mg/L)	76.78	23.78	0.72	4.68	5.38	111.32	
Koc (L/Kg)	224	379	379	616	1659		Weighted Koc
Soil Conc. (mg/kg)	85.99	45.05	1.37	14.40	44.59	191.40	344
Diss. Mass (lbs)	67	21	1	4	5		
Sorbed Mass (lbs)	440.22	230.66	7.01	73.72	228.26		

Est. Contaminant Mass (lbs) 1 ppm Contour	49
Est. Contaminant Mass (lbs) 10 ppm Contour	1077

Prepared by/Date: BPN 5-6-2010
Checked by/Date: RTB 5-7-2010

Table 3 - Area C Southern Plume Contaminant Mass Calculations

lbs/gal	8.34
gal/cf	7.48
liters/gal	3.785
lb/kg	2.2

1 ppm contour

area	4828	sf		
thickness	8	ft		
porosity	0.3			
total volume	38625	cf	1431	cy
pore volume	11587	cf	429	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene
GW Conc. (mg/L)	0.97	0.16	0.29	0.53	0.19
Koc (L/Kg)	224	379	379	616	1659
Soil Conc. (mg/kg)	1.09	0.30	0.55	1.63	1.58
Diss. Mass (lbs)	0.70	0.12	0.21	0.38	0.14
Sorbed Mass (lbs)	1.27	1.29	2.33	6.94	6.70

Note: 1,3-Dichlorobenzene Koc based upon value for 1,2-Dichlorobenzene

10 ppm contour

area	1332	sf		
thickness	8	ft		
porosity	0.3			
total volume	10655	cf	395	cy
pore volume	3197	cf	118	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	Total	
GW Conc. (mg/L)	0.56	1.15	1.30	0.47	6.60	10.07	
Koc (L/Kg)	224	379	379	616	1659		Weighted Koc
Soil Conc. (mg/kg)	0.62	2.19	2.46	1.43	54.75	61.45	1220
Diss. Mass (lbs)	0	0	0	0	1		
Sorbed Mass (lbs)	0.73	2.56	2.89	1.68	64.17		

Est. Contaminant Mass (lbs) 1 ppm Contour	20
Est. Contaminant Mass (lbs) 10 ppm Contour	74

Prepared by/Date: BPN 5-6-2010
Checked by/Date: RTB 5-7-2010

Table 4 - Area E Plume Contaminant Mass Calculations

lbs/gal	8.34
gal/cf	7.48
liters/gal	3.785
lb/kg	2.2

1 ppm contour

area	43834	sf		
thickness	8	ft		
porosity	0.3			
total volume	350673	cf	12988	cy
pore volume	105202	cf	3896	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene
GW Conc. (mg/L)	2.48	0.02	0.07	0.04	0.00
Koc (L/Kg)	224	379	379	616	1659
Soil Conc. (mg/kg)	2.78	0.03	0.13	0.12	0.02
Diss. Mass (lbs)	16.29	0.11	0.44	0.25	0.02
Sorbed Mass (lbs)	107.13	1.24	4.84	4.59	0.96

Note: 1,3-Dichlorobenzene Koc based upon value for 1,2-Dichlorobenzene

10 ppm contour

area	10010	sf		
thickness	8	ft		
porosity	0.3			
total volume	80084	cf	2966	cy
pore volume	24025	cf	890	cy
bulk density	110	lb/cf		
fraction of carbon	0.005			

	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	Total	
GW Conc. (mg/L)	112.63	8.35	0.07	0.98	0.00	122.03	
Koc (L/Kg)	224	379	379	616	1659		Weighted Koc
Soil Conc. (mg/kg)	126.14	15.82	0.13	3.03	0.00	145.12	238
Diss. Mass (lbs)	169	13	0	1	0		
Sorbed Mass (lbs)	1111.19	139.39	1.16	26.67	0.00		

Est. Contaminant Mass (lbs) 1 ppm Contour	136
Est. Contaminant Mass (lbs) 10 ppm Contour	1461

Prepared by/Date: BPN 5-6-2010
Checked by/Date: RTB 5-7-2010

Table 5 -Groundwater Data Statistical Evaluation

Area C Northern Plume: 1 to 10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	2300	1500	30	420	150	4400	63
Mean	1373	533	30	225	79	2239	63
Geometric Mean	932	108	29	110	34	1215	63

Area C Northern Plume: >10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	130000	42000	2000	7700	10000	191700	436
Mean	76775	23775	723	4675	5375	111323	240
Geometric Mean	52198	16883	453	3724	4690	77948	140

Area C Southern Plume: 1 to 10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	970	160	290	530	190	2140	48
Mean	970	160	290	530	190	2140	48
Geometric Mean	970	160	290	530	190	2140	48

Area C Southern Plume: >10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	830	2300	1600	820	12000	17550	
Mean	555	1154	1300	465	6600	10074	
Geometric Mean	482	141	1265	300	3795	5983	

Area E1/E2 Plume: 1 to 10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	5600	59	130	75	3	5867	144
Mean	2480	17	66	39	3	2605	144
Geometric Mean	485	11	18	23	3	539	144

Area E1/E2 Plume: >10 ppm

Statistic/Contaminant	chlorobenzene	1,2-dichlorobenzene	1,3-dichlorobenzene	1,4-dichlorobenzene	1,2,4-trichlorobenzene	total chlorobenzenes	COD (mg/L)
Maximum	390000	8900	80	1600		400580	130
Mean	112625	8350	70	983		122028	85
Geometric Mean	62845	8332	69	467		71713	71

Notes:
Units in parts per billion (micrograms per liter) unless otherwise noted.

Prepared by/Date: RTB 9-1-2010 (Rev 1)
Checked by/Date: BPN 9-1-2010

Table 6 - Summary of ORC-A Design Parameters and Quantities

Area C North	Area (sf)	Target Zone Thickness (ft)	GW Conc. Input (mg/L) (see Note 1)	Assumed Porosity, n	GW Cont. Mass (lbs)	Koc Input (L/kg) (see Note 2)	Calc. Soil Conc. (mg/kg) (see Note 3)	Soil Cont. Mass (lbs) (see Note 4)	ORC-A (lbs) (see Note 5)	ORC-A Application Rate (lbs/sy/vert ft) (see Note 6)
Excavation Area	18392	9	1.2	0.4	5.0	344	assumed zero	assumed zero	118	
20-ft wide area around Excavation	10600	9	1.2	0.3	2.2	344	2.1	21.9	567	
1-ft Layer below Excavation	18392	1	78	0.4	35.8	344	134	271	7222	
TOTAL					**43.0**			**293**	**7907**	**0.39**

Area C South	Excavation Area (sf)	Target Zone Thickness (ft)	GW Conc. Input (mg/L)	Assumed Porosity, n	GW Cont. Mass (lbs)	Koc Input (L/kg) (see Note 2)	Calc. Soil Conc. (mg/kg) (see Note 3)	Soil Cont. Mass (lbs) (see Note 4)	ORC-A (lbs) (see Note 5)	ORC-A Application Rate (lbs/sy/vert ft) (see Note 6)
Excavation Area	2562	9	2.1	0.4	1.2	1220	assumed zero	assumed zero	29	
20-ft wide area around Excavation	3980	9	2.1	0.3	1.4	1220	13.1	51.4	1244	
1-ft Layer below Excavation	2562	1	6.0	0.4	0.4	1220	36	10	251	
TOTAL					**3.1**			**62**	**1524**	**0.54**

Area E1	Excavation Area (sf)	Target Zone Thickness (ft)	GW Conc. Input (mg/L)	Assumed Porosity, n	GW Cont. Mass (lbs)	Koc Input (L/kg) (see Note 2)	Calc. Soil Conc. (mg/kg) (see Note 3)	Soil Cont. Mass (lbs) (see Note 4)	ORC-A (lbs) (see Note 5)	ORC-A Application Rate (lbs/sy/vert ft) (see Note 6)
Excavation Area	15314	6	0.54	0.4	1.2	238	assumed zero	assumed zero	29	
20-ft wide area around Excavation	11860	6	0.54	0.3	0.7	238	0.6	5.0	135	
1-ft Layer below Excavation	15314	1	72	0.4	27.4	238	85	144	4026	
TOTAL					**29.4**			**149**	**4190**	**0.35**

Area E2	Excavation Area (sf)	Target Zone Thickness (ft)	GW Conc. Input (mg/L)	Assumed Porosity, n	GW Cont. Mass (lbs)	Koc Input (L/kg) (see Note 2)	Calc. Soil Conc. (mg/kg) (see Note 3)	Soil Cont. Mass (lbs) (see Note 4)	ORC-A (lbs) (see Note 5)	ORC-A Application Rate (lbs/sy/vert ft) (see Note 6)
Excavation Area	1421	6	0.54	0.4	0.1	238	assumed zero	assumed zero	3	
20-ft wide area around Excavation	3040	6	0.54	0.3	0.2	238	0.6	1.3	35	
1-ft Layer below Excavation	1421	1	72	0.4	2.5	238	85	13	374	
TOTAL					**2.8**			**15**	**411**	**0.37**

Area E3 (see Note 7)	Excavation Area (sf)	Target Zone Thickness (ft)	Calc. GW Conc. Input (mg/L)	Assumed Porosity, n	GW Cont. Mass (lbs)	Koc Input (L/kg)	Soil Conc. (mg/kg) (see Note 3)	Soil Cont. Mass (lbs) (see Note 4)	ORC-A (lbs) (see Note 5)	ORC-A Application Rate (lbs/sy/vert ft) (see Note 6)
Excavation Area	9946	1	0.54	0.4	0.1	238	assumed zero	assumed zero	3	
20-ft wide area around Excavation	12600	1	0.54	0.3	0.1	238	0.6	0.9	24	
1-ft Layer below Excavation	9946	1	72	0.4	17.8	238	85	93	2615	
TOTAL					**18.1**			**94**	**2642**	**1.20**

subtotal ORC-A	16,673	lbs.
Cntgncy (10%)	1,667	lbs.
Total ORC-A	**18,340**	lbs.

Notes:

1) Groundwater Concentration Input value based upon geometric mean for total chlorobenzenes. Excavation and surrounding 20-ft wide area based upon 1- 10 mg/L plume data; 1-ft layer below excavation based upon >10 mg/L plume data.

2) Koc input value calculated as contaminant concentration-weighted average for the >10 mg/L data.

3) Sorbed (soil) concentrations calculated as product of groundwater concentration, Koc input value, and fraction of organic carbon (design value = 0.005)

4) Sorbed soil mass calculated based upon soil bulk density of 110 lb/ft^3

5) ORC-A quantities calculated based upon the target zone contaminant mass, a stoichiometry of 2.0, a safety/additional demand factor of 2.0, and ORC-A provides 17% oxygen on a per weight basis.

6) Based upon applying two applications to the first (bottom) lift of backfill.

7) Area E3 calculations based upon GW Conc. Input values for Area E1 and E2.

Prepared by/Date: RTB 9-3-2010 (I

Checked by/Date: BPN 9-2-2010

Table 6 - Nutrient Amendment Application Calculations

	No. of Atoms				
	Carbon	Hydrogen	Chlorine	Total Mass	%Carbon wt/wt
Chlorobenzene	6	5	1	112.6	64%
Dichlorobenzene	6	4	2	147.0	49%
Trichlorobenzene	6	3	3	181.4	40%

	Atomic Mass
Carbon	12.01
Hydrogen	1.0079
Chlorine	35.453

	GW Cont. Mass (lbs)	GW Cont. Mass as Carbon (lbs)	Soil Cont. Mass (lbs)	Soil Cont. Mass as Carbon (lbs)	Total Cont. Mass as Carbon (lbs)	Nitrogen, lbs (see Note 2)	Phosphorus, lbs (see Note 2)	Nitrogen, mg/L (see Note 3)	Phosphorus, mg/L (see Note 3)	Nitrogen, lbs/vert ft	Phosphorus lbs/vert ft
Area C North	43.0	21.1	293.0	143.7	164.7	32.9	3.3	7.99	0.80	3.29	0.33
Area C South	3.05	1.5	61.7	30.3	31.8	6.4	0.6	11.05	1.11	0.64	0.06
Area E1	29.4	14.4	148.7	72.9	87.3	17.5	1.7	7.63	0.76	2.49	0.25
Area E2	2.8	1.4	14.6	7.2	8.6	1.7	0.2	8.06	0.81	0.24	0.02
Area E3	18.1	8.9	94.2	46.2	55.0	11.0	1.1	44.42	4.44	5.50	0.55

Notes:

1. Mass as Carbon calculated based upon %Carbon wt/wt for dichlorobenzene
2. Calculated based upon required Carbon:Nitrogen:Phosphorus ratio of 100:10:1 for biological growth with additional demand factor of 2.
3. Based upon pore volume of backfilled excavation area only (worst-case)

Prepared by/Date: RTB 9-3-2010 (Rev 3)
Checked by/Date: BPN 9-2-2010

Oxygen Release Compound – Advanced (ORC *Advanced*™)
MATERIAL SAFETY DATA SHEET (MSDS)

Last Revised: March 13, 2007

Section 1 - Material Identification

Supplier:

REGENESIS
1011 Calle Sombra
San Clemente, CA 92673

Phone:	**949.366.8000**
Fax:	**949.366.8090**
E-mail:	**info@regenesis.com**
Chemical Description:	A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
Chemical Family:	Inorganic Chemical
Trade Name:	Advanced Formula Oxygen Release Compound (ORC *Advanced*™)
Chemical Synonyms	Calcium Hydroxide Oxide; Calcium Oxide Peroxide
Product Use:	Used to remediate contaminated soil and groundwater (environmental applications)

Section 2 – Composition

CAS No.	**Chemical**
682334-66-3	**Calcium Hydroxide Oxide [$CaO(OH)_2$]**
1305-62-0	**Calcium Hydroxide [$Ca(OH)_2$]**
7758-11-4	**Dipotassium Phosphate (HK_2O_4P)**
7778-77-0	**Monopotassium Phosphate (H_2KO_4P)**

Section 3 – Physical Data

Form:	Powder
Color:	White to Pale Yellow
Odor:	Odorless
Melting Point:	527 °F (275 °C) – Decomposes
Boiling Point:	Not Applicable (NA)
Flammability/Flash Point:	NA
Auto- Flammability:	NA
Vapor Pressure:	NA
Self-Ignition Temperature:	NA
Thermal Decomposition:	527 °F (275 °C) – Decomposes
Bulk Density:	0.5 – 0.65 g/ml (Loose Method)
Solubility:	1.65 g/L @ 68° F (20° C) for calcium hydroxide.
Viscosity:	NA
pH:	11-13 (saturated solution)
Explosion Limits % by Volume:	Non-explosive
Hazardous Decomposition Products:	Oxygen, Hydrogen Peroxide, Steam, and Heat
Hazardous Reactions:	None

Section 4 – Reactivity Data

Stability:	Stable under certain conditions (see below).
Conditions to Avoid:	Heat and moisture.
Incompatibility:	Acids, bases, salts of heavy metals, reducing agents, and flammable substances.
Hazardous Polymerization:	Does not occur.

Section 5 – Regulations

TSCA Inventory List:	Listed

CERCLA Hazardous Substance (40 CFR Part 302)

Listed Substance:	No
Unlisted Substance:	Yes
Reportable Quantity (RQ):	100 pounds
Characteristic(s):	Ignitibility
RCRA Waste Number:	D001

SARA, Title III, Sections 302/303 (40 CFR Part 355 – Emergency Planning and Notification)

Extremely Hazardous Substance:	No

SARA, Title III, Sections 311/312 (40 CFR Part 370 – Hazardous Chemical Reporting: Community Right-To-Know

Hazard Category:	Immediate Health Hazard Fire Hazard
Threshold Planning Quantity:	10,000 pounds

Section 5 – Regulations (cont)

SARA, Title III, Section 313 (40 CFR Part 372 – Toxic Chemical Release Reporting: Community Right-To-Know

Extremely Hazardous Substance:	No	
WHMIS Classification:	C	Oxidizing Material Poisonous and Infectious Material
	D	Material Causing Other Toxic Effects – Eye and Skin Irritant
Canadian Domestic Substance List:	Not Listed	

Section 6 – Protective Measures, Storage and Handling

Technical Protective Measures

Storage:	Keep in tightly closed container. Store in dry area, protected from heat sources and direct sunlight.
Handling:	Clean and dry processing pipes and equipment before operation. Never return unused product to the storage container. Keep away from incompatible products. Containers and equipment used to handle this product should be used exclusively for this material. Avoid contact with water or humidity.

Section 6 – Protective Measures, Storage and Handling (cont)

Personal Protective Equipment (PPE)

Engineering Controls:	Calcium Hydroxide ACGIH® TLV® (2000) 5 mg/m^3 TWA OSHA PEL Total dust–15 mg/m^3 TWA Respirable fraction– 5 mg/m^3 TWA NIOSH REL (1994) 5 mg/m^3
Respiratory Protection:	For many conditions, no respiratory protection may be needed; however, in dusty or unknown atmospheres use a NIOSH approved dust respirator.
Hand Protection:	Impervious protective gloves made of nitrile, natural rubbber or neoprene.
Eye Protection:	Use chemical safety goggles (dust proof).
Skin Protection:	For brief contact, few precautions other than clean clothing are needed. Full body clothing impervious to this material should be used during prolonged exposure.
Other:	Safety shower and eyewash stations should be present. Consultation with an industrial hygienist or safety manager for the selection of PPE suitable for working conditions is suggested.
Industrial Hygiene:	Avoid contact with skin and eyes.
Protection Against Fire & Explosion:	NA

Section 7 – Hazards Identification

Emergency Overview:	Oxidizer – Contact with combustibles may cause a fire. This material decomposes and releases oxygen in a fire. The additional oxygen may intensify the fire.
Potential Health Effects:	Irritating to the mucous membrane and eyes. If the product splashes in ones face and eyes, treat the eyes first. Do not dry soiled clothing close to an open flame or heat source. Any

	clothing that has been contaminated with this product should be submerged in water prior to drying.
Inhalation:	High concentrations may cause slight nose and throat irritation with a cough. There is risk of sore throat and nose bleeds if one is exposed to this material for an extended period of time.
Eye Contact:	Severe eye irritation with watering and redness. There is also the risk of serious and/or permanent eye lesions.
Skin Contact:	Irritation may occur if one is exposed to this material for extended periods.
Ingestion:	Irritation of the mouth and throat with nausea and vomiting.

Section 8 – Measures in Case of Accidents and Fire

After Spillage/Leakage/Gas Leakage:	Collect in suitable containers. Wash remainder with copious quantities of water.
Extinguishing Media:	See next.
Suitable:	Large quantities of water or water spray. In case of fire in close proximity, all means of extinguishing are acceptable.
Further Information:	Self contained breathing apparatus or approved gas mask should be worn due to small particle size. Use extinguishing media appropriate for surrounding fire. Apply cooling water to sides of transport or storage vessels that are exposed to flames until the fire is extinguished. Do not approach hot vessels that contain this product.
First Aid:	After contact with skin, wash immediately with plenty of water and soap. In case of contact with eyes, rinse immediately with plenty of water and seek medical attention. Consult an opthalmologist in all cases.

Section 8 – Measures in Case of Accidents and Fire

Eye Contact:	Flush eyes with running water for 15 minutes, while keeping the eyelids wide open. Consult with an ophthalmologist in all cases.
Inhalation:	Remove subject from dusty environment. Consult with a physician in case of respiratory symptoms.

Ingestion: If the victim is conscious, rinse mouth and admnister fresh water. DO NOT induce vomiting. Consult a physician in all cases.

Skin Contact: Wash affected skin with running water. Remove and clean clothing. Consult with a physician in case of persistent pain or redness.

Special Precautions: Evacuate all non-essential personnel. Intervention should only be done by capable personnel that are trained and aware of the hazards associated with this product. When it is safe, unaffected product should be moved to safe area.

Specific Hazards: Oxidizing substance. Oxygen released on exothermic decomposition may support combustion. Confined spaces and/or containers may be subject to increased pressure. If product comes into contact with flammables, fire or explosion may occur.

Section 9 – Accidental Release Measures

Precautions: Observe the protection methods cited in Section 3. Avoid materials and products that are incompatible with product. Immediately notify the appropriate authorities in case of reportable discharge (> 100 lbs).

Cleanup Methods: Collect the product with a suitable means of avoiding dust formation. All receiving equipment should be clean, vented, dry, labeled and made of material that this product is compatible with. Because of the contamination risk, the collected material should be kept in a safe isolated place. Use large quantities of water to clean the impacted area. See Section 12 for disposal methods.

Section 10 – Information on Toxicology

Toxicity Data

Acute Toxicity:

Oral Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%)

Dermal Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%)

Inhalation, LD_{50}, rat, > 5,000 mg/m^3 (powder 35%)

Irritation: Rabbit (eyes), severe irritant

Sensitization:	No data
Chronic Toxicity:	In vitro, no mutagenic effect (Powder 50%)
Target Organ Effects:	Eyes and respiratory passages.

Section 11 – Information on Ecology

Ecology Data

	10 mg $Ca(OH)_2$/L: pH = 9.0
	100 mg $Ca(OH)_2$/L: pH = 10.6
Acute Exotoxicity:	Fishes, Cyprinus carpio, LC_{50}, 48 hrs, 160 mg/L
	Crustaceans, Daphnia sp., EC_{50}, 24 hours, 25.6 mg/L
	(Powder 16%)
Mobility:	Low Solubility and Mobility
Abiotic Degradation:	Water – Slow Hydrolysis. Degradation Products: Calcium Hydroxide Water/soil – complexation/precipitation. Carbonates/sulfates present at environmental concentrations. Degradation products: carbonates/sulfates sparingly soluble
Biotic Degradation:	NA (inorganic compound)
Potential for Bioaccumulation:	NA (ionizable inorganic compound)

Section 11 – Information on Ecology (cont)

Comments:	Observed effects are related to alkaline properties of the product. Hazard for the environment is limited due to the product properties of: • No bioaccumulation • Weak solubility and precipatation as carbonate or sulfate in an aquatic environment. Diluted product is rapidly neutralized at environmental pH.
Further Information:	NA

APPENDIX U

REHABILITATION OF STORM SEWERS SCOPE OF WORK

March 2011

To: QUALIFIED CONTRACTOR

RE: REQUEST FOR PROPOSAL
Rehabilitation of Storm Sewers in Area E
Former Buffalo Color Corporation Site
Buffalo, New York

On behalf of the Owner (South Buffalo Development LLC), please accept this Request for Proposal (RFP) for rehabilitating selected storm sewer lines at Area E of the former Buffalo Color Corporation site. This RFP includes the attached Scope of Work and Instructions to Bidders, Figure, Table, and Bid Form. A CD with Closed-Circuit Television (CCTV) Inspection Reports and Videos will be provided to bidders separately upon confirmation of their intent to attend the mandatory pre-bid meeting.

Please note the following:

- As described in the Scope of Work and Instructions to Bidders, a mandatory pre-bid meeting and site walk will be held at 1:00 P.M. Eastern Time on Monday, March 14, 2011. Please notify John Yensan of South Buffalo Development via email or telephone (contact information provided below) of your intent to attend the pre-bid meeting at least two business days prior to the meeting.

- Questions must be submitted in writing (letter, email or fax) to both Mr. John Yensan (Owner) and Mr. John Scrabis (Engineer) no later than 5:00 P.M. Eastern Time on Wednesday, March 16, 2011. All Bidders will be copied on responses to questions.

- Proposals must be submitted by 5:00 P.M. Eastern Time on Monday, March 21, 2011 to:

    Mr. John Yensan for
    South Buffalo Development LLC
    333 Ganson Street
    Buffalo, NY 14203
    Email: jyensan@oscinc.com
    Telephone: (716) 856-3333 ext. 302

    *Bids may be submitted electronically (via email) provided that they are received by the bid due date and a hard copy is delivered to the Mr. Yensan at the above address by C.O.B the following day (March 22, 2011).

Sincerely,

South Buffalo Development LLC

SCOPE OF WORK &

INSTRUCTIONS TO BIDDERS

Rehabilitation of Storm Sewers in Area E

Former Buffalo Color Corporation Site

Buffalo, New York

1.0 TERMS AND CONDITIONS

The terms and conditions of the Contract between South Buffalo Development (SBD) (OWNER) and the successful bidder (CONTRACTOR) shall govern the performance of the services described in this Scope of Work (SOW).

2.0 PROJECT DESCRIPTION

The Work involves rehabilitating storm sewers in Area E (refer to attached Figure) by:

- Closed-circuit television (CCTV) inspection.
- Pipe cleaning, including removing encrustations at leaking joints along the main line and primary laterals.
- Sealing leaking joints along the main line and primary laterals as described herein.
- Abandoning leaking secondary laterals by permanently plugging or sealing the secondary lateral from within the primary laterals.

Refer to Section 5.0 – Scope of Services for further detail.

3.0 SITE DESCRIPTION

The former Buffalo Color Corporation (BCC) property is located on the south side of the City of Buffalo, Erie County, New York, in an area of heavy industrial development that dates to the mid-1800s. The BCC property occupies approximately 47 acres near and adjacent to the Buffalo River and is described by four distinct areas: Areas A, B, C, and E. The property housed a dye plant that produced dyes and organic chemicals from the late 1800s until 2005. SBD has teamed with Honeywell to facilitate the demolition and remediation of the former dye plant and remediate the property.

The Work for this project will occur in Area E, which covers approximately 16 acres (see attached figure). Previous environmental investigations identified the presence of volatile organic compounds (VOCs), including chlorobenzene, dichlorobenzene, trichlorobenzene, and benzene, in the Area E groundwater and soils on the western side of Area E at concentrations that exceeded applicable New York cleanup standards. In addition, semi-volatile organic compounds (SVOCs), including aniline, were identified above the NY standards in site soil and groundwater. Limited amounts of free-phase solvent materials (containing the VOCs and SVOCs listed above) were also found in the subsurface. Lesser levels of other substances, including metals, were identified in the soil and groundwater in excess of state criteria.

The previous investigations found evidence that the contaminated groundwater on Area E can infiltrate the existing Area E storm sewer system and negatively affect the quality of the effluent.

In 2010, SBD completed the demolition of all above-grade structures on Area E and placed a 12-inch thick layer of clean soil cover over much of the eastern half of the property. The structural slabs and foundations for several large buildings on the western half of Area E have been left in place for future reuse. From October 2010 through January 2011, SBD excavated VOC/SVOC-impacted soils from the western side of Area E as part of a NYSDEC-approved remediation plan. This work resulted in the removal of the most highly-contaminated materials (i.e., source areas) known to exist on Area E. The excavated areas were backfilled to grade with clean material. In early 2011, SBD intends to place the remainder of the 12-inch clean cover over non-paved portions on the western half of the site. The site is presently vacant.

The existing storm sewer infrastructure on Area E consists of catch basins and underground piping that convey the effluent to a single outfall located at the Buffalo River (see attached Figure). As part of the remediation program, the storm sewer system must be rehabilitated to eliminate the infiltration of groundwater. During 2010, an OSC subcontractor (National Vacuum) completed a series of closed-caption television (CCTV) surveys of the Area E storm sewers. Electronic copies of the CCTV surveys and written reports will be provided to bidders on CDs submitted under separate cover. All bidders must acknowledge that they have received and reviewed the CCTV videos and reports with submittal of their proposal (bids from any firm that has not reviewed the videos will not be accepted).

4.0 HEALTH AND SAFETY

As noted above, volatile and semi-volatile organic compounds and metals are present in groundwater and soil at the site. These substances are also know to have affected storm water via infiltration of contaminated groundwater and may be encountered during the Area E storm sewer work described herein. Figures and tables that summarize pre-remedial chemical concentration data will be provided under separate cover to potential bidders.

The site is controlled by SBD's General Contractor (Ontario Specialty Contracting, Inc [OSC]). General site safety requirements are enforced by OSC and are documented in OSC's site-specific Health and Safety Plan, a copy of which will be provided to the CONTRACTOR. The CONTRACTOR will be required to comply with all OSC health and safety requirements, or the CONTRACTOR's own requirements, whichever are more stringent. The CONTRACTOR will be required to attend the daily project safety meeting held each morning by OSC in the field office at 100 Lee Street. OSC will have the right to remove any personnel from the job site, at any time, who violate site safety requirements.

Notwithstanding OSC's project health and safety requirements, it is the responsibility of the CONTRACTOR to determine the necessary personal protective equipment to be donned by its employees (or any of its subcontractors) and the health and safety precautions necessary for performing the Work, in accordance with all applicable laws and regulations, including those enforced by the U.S. Occupational Safety and Health Administration (OSHA). It is anticipated that the CONTRACTOR will don dermal protection against liquids consisting of poly-coated Tyvek, chemical resistant gloves and boots, and respiratory protection (when necessary) when performing any Work that may result in contact with site contaminants or as determined necessary by the CONTRACTOR's Health and Safety Department. Hard hats, steel toe boots, reflective "traffic" vests, and safety glasses will be required at a minimum.

All storm sewer pipes and catch basins are considered confined spaces, and as such can only be entered in accordance with OSHA confined space entry requirements. If the CONTRACTOR determines that personnel must enter any storm sewer pipes or catch basins to complete the Work, the CONTRACTOR must submit a written confined space entry procedure to OSC. All personnel involved in the confined space entry work must be properly trained, in accordance with applicable OSHA requirements. The CONTRACTOR will be responsible for providing all necessary equipment and personnel, including air monitoring equipment, emergency extraction equipment, and standby personnel needed to safely complete any confined space entry.

5.0 SCOPE OF SERVICES

Storm sewer lines to be rehabilitated are identified on the attached Figure. An itemization of the storm sewers is provided in Table 1 and the Bid Form, which are attached. The Work encompasses the following components:

5.1 General

5.1.1 The intent of the Work is to mitigate groundwater infiltration into the storm sewers. Groundwater is primarily infiltrating through joints and secondary laterals.

5.1.2 The CONTRACTOR shall supply all labor and furnish all materials, supplies, tools, equipment, and consumable items, and perform all operations required to rehabilitate designated storm sewer lines of various dimensions (18" – 42") (approximately 2,757 feet total).

5.1.3 Storm sewers shall remain in service during the Work.

5.1.4 The CONTRACTOR shall prepare and submit a Work Plan to document the means and methods for performing the Work. Items to be included in the Work Plan are summarized in Section 6.1. Note: Work shall not commence until the Work Plan has been reviewed and accepted by the OWNER.

5.1.5 The CONTRACTOR shall select means and methods for performing the Work that are protective of the environment and human health and safety.

5.1.6 The CONTRACTOR shall comply with all applicable Federal, State, and local requirements.

5.1.7 Confined space entry and excavation shall be avoided whenever feasible.

5.1.8 The CONTRACTOR shall be responsible for the proper disposal of all construction-related solid waste.

5.1.9 The CONTRACTOR shall take all necessary precautions to protect the storm sewer as well as private and public property from damage that could be caused by the Work. It shall be the sole responsibility of the CONTRACTOR to repair damage directly or indirectly resulting from the Work.

5.1.10 Work in excess of 15% of the bid quantity (as stated on the Bid Form) requires written pre-approval from the OWNER.

5.1.11 All existing manholes, including the manhole anticipated for use as the storm water effluent monitoring point under any future storm water discharge permit (manhole DMH-E31), shall be protected and remain accessible upon completion of the Work.

5.2 Cleaning

5.2.1 The CONTRACTOR shall clean designated main line and primary laterals to remove sediment, debris, roots, and encrustations from the storm sewers in preparation for the rehabilitation work.

5.2.2 There are instances of protruding break-in pipe connections where secondary laterals come into the primary laterals. The ends of the secondary laterals may need to be trimmed/cut flush to the primary lateral pipe to facilitate (1) equipment accessibility or (2) plugging of the laterals. It will be the responsibility of the CONTRACTOR to trim/cut the protruding pipe ends as necessary to accomplish the Work.

5.2.3 Cleaning methods that may cause damage to the storm sewers shall not be used.

5.2.4 If necessary, CONTRACTOR will be permitted to use potable City water (obtained from a nearby fire hydrant) to aid in removal of debris and sediment. It will be the CONTRACTOR'S responsibility to make any necessary arrangements with the property owner and/or the City of Buffalo for this purpose.

5.2.5 The CONTRACTOR shall be responsible for ensuring that the waste stream resulting from cleaning is captured and does not enter the Buffalo River.

5.2.6 The CONTRACTOR will discharge the waste stream resulting from cleaning to a Baker tank or other type of containment provided on-site by the OWNER. The OWNER shall be responsible for the legal disposal of the sediment and wastewater generated by the CONTRACTOR's sediment/debris removal work. The CONTRACTOR shall be responsible for rinsing or cleaning the vacuum truck and other equipment provided by the CONTRACTOR to remove or handle the sediment/debris.

5.2.7 Joint sealing and lateral plugging shall be performed immediately following cleaning.

5.3 Joint Sealing and Testing

5.3.1 Joints exhibiting infiltration (i.e., encrustation or active leak observed during review of previously performed CCTV inspection or at the time of this Work) shall be rehabilitated via joint sealing. The CONTRACTOR shall be responsible for identifying joints meeting these criteria.

5.3.2 Joint sealing shall be accomplished via a method identified by the CONTRACTOR and approved by SBD. The method (or methods) proposed must be specified in the proposal. The joint sealing may be accomplished by forcing chemical grout into or through infiltration points using sealing packers and related appurtenances, by installation of CIPP patches, or by other suitable methods. Jetting or driving pipes from the surface will not be allowed. Excavation for the purpose of joint sealing will not be allowed. If grout sealing is proposed, it will be the responsibility of the CONTRACTOR to verify and ensure that use of packers will not cause or exacerbate cracking, fractures, or other damage to existing piping. CCTV inspection will be used to verify that the CONTRACTOR's joint sealing activities have not caused damage to existing pipe, and it will be the CONTRACTOR's responsibility to repair any such damage to the satisfaction of SBD at no additional cost to SBD.

5.3.3 The CONTRACTOR shall provide equipment consisting of a CCTV system, chemical grout containers/tanks, pumps, regulators, valves, hoses, etc., and joint sealing packers for the various sizes of pipes designated to receive chemical grout. The packers shall be cylindrical and have a diameter less than that of the pipes receiving chemical grout. The packers shall have cables attached at each end to pull it through the pipes. The packer shall be constructed in a manner to allow a restricted amount of stormwater to flow. The same equipment shall be used for both testing and sealing joints.

5.3.4 The CONTRACTOR shall be responsible for calibrating and operating equipment in accordance with manufacturer's recommendations and standard industry practices in order to ensure the performance of the Work.

5.3.5 The CONTRACTOR shall add a root inhibitor to the chemical grout mixture that will remain active within the grout for a minimum of one year.

5.3.6 The chemical grout shall be specifically designed and manufactured for the purpose of joint sealing and have a documented history of successful performance in such usage.

5.3.7 The chemical grout (or other sealant if alternate method is used), including root inhibitor, shall be compatible with the pipe materials of construction and the primary Site contaminants, including aniline, chlorobenzene, and related compounds.

5.3.8 All materials shall be delivered to the Site in original, labeled, unopened containers.

5.3.9 Follow the manufacturer's recommendations for mixing, storing, handling, dispensing, and disposing of chemical grout and root inhibitor.

5.3.10 Joint sealing shall not occur if:

- The depth of flow is greater than 25% of the pipe diameter, for pipe diameters ≤ 24".
- The depth of flow is greater than 30% of the pipe diameter, for pipe diameters > 24".

If these parameters are exceeded, refer to Section 5.5 – Bypass Pumping.

5.3.11 When joint sealing is complete, the grout should be essentially flush with the existing pipe surface. Excess grout that extends into the pipe, reduces the pipe diameter, or restricts flow shall be removed from the joint and properly disposed of by the CONTRACTOR.

5.3.12 When joint sealing is complete, the joint shall be tested to verify the effectiveness of the seal. Joint testing shall be accomplished by applying a positive air pressure to the joint and monitoring the pressure in the void. Joints testing criteria shall be proposed in the CONTRACTOR'S Work Plan for approval. Joints that fail the initial test shall be resealed and retested at the CONTRACTOR'S expense until the test criteria are satisfied. Payment will not be provided for joints that do not pass testing.

5.3.13 Records shall be kept to document joint sealing and testing. The data to be recorded shall be defined in the Work Plan.

5.3.14 The CONTRACTOR shall warranty the sealed pipe joints for one year from the completion of Work. The CONTRACTOR shall disclose the terms and conditions of the warranty in the Work Plan.

5.4 Cured-in-Place Pipe (CIPP) Patches and Segments

5.4.1 Secondary laterals exhibiting infiltration (i.e., encrustation or active leak observed during review of previously performed CCTV inspection or at the time of this Work) shall be abandoned by installing CIPP patches in the primary laterals. CIPP patches may also be used to seal pipe joints in lieu of chemical grouting, if specified by the CONTRACTOR and approved by the OWNER. Most secondary laterals are less than or equal to 12" in diameter. The CONTRACTOR shall be responsible for identifying secondary laterals meeting these criteria.

5.4.2 Each CIPP patch shall extend six inches (minimum) in either direction beyond the secondary lateral opening (or joint if the CIPP patch is used to seal selected joints).

5.4.3 As an option to sealing and plugging of individual joints and laterals, the CONTRACTOR may propose to reline entire reaches of pipe (manhole to manhole) with CIPP. An optional pricing section is provided for this work on the attached Bid Form.

5.4.4 CIPP lining shall create an effective, watertight patch. Products shall be compatible with the pipe materials of construction and the primary Site contaminants, including aniline, chlorobenzene, and related compounds.

5.4.5 If launching and receiving pits are necessary, the CONTRACTOR shall contact Dig Safely New York (811 or 800-962-7962) prior to excavating. Excavation should be avoided whenever possible. If excavation is required, the extent shall be identified in the Work Plan. All proposed excavations shall be pre-approved by the OWNER.

5.4.6 CIPP patches and segments shall be manufactured and installed in accordance with ASTM standards and manufacturer's recommendations.

5.4.7 The CONTRACTOR shall be licensed by the liner process manufacturer.

5.4.8 The CONTRACTOR shall be responsible for calibrating and operating equipment in accordance with manufacturer's recommendations and standard industry practices in order to ensure the performance of the Work.

5.4.9 Records shall be kept to document CIPP installation and curing. The data to be recorded shall be defined in the Work Plan.

5.4.10 The finished product shall be a smooth surface free of cracks and crazing. Minor defects (e.g., air bubbles, dimples, waviness) shall be tolerated if, in the opinion of the OWNER, it does not appreciably decrease the flow characteristics or cause blockage of the pipe. Defective work shall be repaired at the CONTRACTOR'S expense.

5.4.11 The CONTRACTOR shall collect sample coupons for testing of the resin, catalyst, and felt. Coupons shall be collected and tested in accordance with ASTM standards. The sampling program shall be defined in the Work Plan (e.g., frequency, testing methodologies, and performance criteria).

5.5 Other Methods

5.5.1 The CONTRACTOR may propose to use methods other than chemical grouting and CIPP to seal joints and laterals and prevent groundwater infiltration. Such methods must be specified and described in the CONTRACTOR's proposal and Work Plan and approved by the OWNER.

5.6 Bypass Pumping

5.6.1 Small (< 5%) flow volumes have typically been observed in Site storm sewers during non-storm periods.

5.6.2 When necessary, the CONTRACTOR shall provide bypass pumping to facilitate completion of the Work. Bypass pumping equipment shall be readily available so that implementation causes minimal interruption to the Work.

5.6.3 The CONTRACTOR shall include a Bypass Pumping Plan as part of the Work Plan.

5.6.4 The bypass pumping system shall be 100% watertight.

5.7 Closed Circuit Television (CCTV) Inspection

5.7.1 Three rounds of CCTV inspection shall be performed:

- Pre-installation (i.e., after cleaning the storm sewer, but before joint sealing or CIPP installation).
- Post-installation (i.e., after joint sealing and CIPP installation).
- At the end of the 1-year warranty period.

5.7.2 Inspect each storm sewer reach (i.e., pipe segment adjoining two structures) in a single, continuous run. Progress through the entire project in a uniform direction, keeping record of each storm sewer reach via identification of upstream and downstream structures.

5.7.3 Produce a color video using a pan-and-tilt, radial viewing, pipe inspection camera. The television camera used for the inspection shall be color format and specifically designed and constructed for sewer inspection. The camera shall be operative in 100% humidity conditions.

5.7.4 Lighting and camera quality shall be suitable to produce a clear, in-focus picture of the entire periphery of the pipe.

5.7.5 Inspect each sealed joint, CIPP patch, and CIPP section utilizing the pan and tilt capabilities of the camera.

5.7.6 Center the camera lens in the pipe being inspected.

5.7.7 The camera shall be moved through the each pipe run at a uniform rate, stopping as necessary to document the condition of the seals and patches. Do not exceed 30 feet of inspection per minute.

5.7.8 The equipment shall have an accurate footage counter, which shall display on the monitor the exact distance of the camera (to the nearest tenth of a foot) from the centerline of the starting structure. Footage measurements shall typically begin at the centerline of the upstream structure and proceed downstream.

5.7.9 At a minimum, the date, identification of storm sewer reach(es) by upstream and downstream structures, and ongoing footage counter shall be displayed on the video data view at all times.

5.7.10 The CONTRACTOR shall keep a data log for each storm sewer reach inspected that identifies (at a minimum) the CONTRACTOR's name, Site name, date televised, line size and material, direction of viewing, and upstream and downstream structures. Identify the joint seals, CIPP patches, and CIPP sections as they are encountered; the seal and CIPP patch/segment identifiers shall coordinate with the field records kept during the work.

5.7.11 Depth of flow shall not exceed twenty percent (20%) of the inside pipe diameter as measured in the structure when performing CCTV inspection. In the event that the depth of flow of the reach being televised exceeds twenty percent (20%) of the inside pipe diameter, the CONTRACTOR shall provide the necessary flow control.

5.7.12 Video

- Provide recordings of sufficient quality for the OWNER to evaluate the condition of the storm sewers and locate lateral connections and defects. If, in the OWNER's opinion, the quality is not sufficient, the CONTRACTOR shall re-tape the storm sewer reaches and provide a new recording and updated written report at no additional cost to the OWNER. Poor quality includes: camera distortion, inadequate lighting, dirty lens, and blurred or hazy pictures. No payment will be made for recordings that do not meet the requirements of this SOW.
- At a minimum, the date, identification of storm sewer reach(es) by upstream and downstream structures, and ongoing footage counter shall be displayed on the video data view at all times.

5.7.13 Written Report

- Provide a written report of the inspection, documenting the condition of joint seals and CIPP patches/sections. Reference the date, storm sewer reach, and footage count for each item documented in the report.
- The data log, as described in Paragraph 5.6.10, shall be typed and included as an attachment to the written report.

6.0 SUBMITTALS

The CONTRACTOR shall submit one electronic copy and one hard copy of each of the following items to the OWNER and OWNER's ENGINEER:

6.1 Work Plan: The CONTRACTOR shall prepare a Work Plan describing the means and methods to be used to accomplish the Work described in Section 5.0 – Scope of Services. At a minimum, the Work Plan shall encompass:

- General: schedule, permits, coordination, and Site access requirements.
- Cleaning: proposed equipment/techniques (e.g., jetting, pigging, rodding) and management of waste stream resulting from cleaning.
- Joint Sealing and Testing: manufacturer's specifications for the chemical grout and root inhibitor intended for use as well as a statement from the manufacturer(s) confirming chemical compatibility with Site conditions (or similar information if a method other than chemical grouting is proposed), detailed description of joint sealing and testing procedures, joint testing criteria, field data to be recorded, and terms and conditions of the warranty.
- CIPP Patches and Sections: recommended liner thickness, setup locations for lining installation, horizontal and vertical extents of launching/receiving pit excavations (if necessary), detailed description of lining process, detailed description of testing program, certificate of licensure, and manufacturer's specifications for proposed products as well as a statement from the manufacturer confirming chemical compatibility with Site conditions. If liner methods other than CIPP are proposed and approved, provide a detailed description of lining process, detailed description of testing program, certificate of licensure, and any manufacturer and/or installation specifications for proposed products.
- Bypass Pumping: number, size, and capacity of pumps; size of generator; size and length of suction and discharge pipes/hoses; pipe/hose restraining methods; plugging methods; discharge methods; and protection of equipment against construction vehicles.
- CCTV Inspection: description of means and methods to be used for inspection and a description of the deliverables.

6.2 Copies of permits.

6.3 Field records for joint sealing and testing.

6.4 Field records for CIPP installation and testing.

6.5 Field records for any other storm sewer rehabilitation methods.

6.6 CCTV inspection videos (CD/DVD) and reports.

6.7 Signed warranty.

7.0 SCHEDULE

A mandatory pre-bid meeting and site walk is scheduled for 1:00 PM Eastern Time on March 14, 2011. Bids are due by 5:00 PM Eastern on March 21, 2011. Written Notice to Proceed (NTP) will be provided upon review of submitted proposals. The CONTRACTOR's Work Plan is due within ten business days following NTP. The Work described herein shall commence within five business days of Work Plan acceptance by the OWNER. Final deliverables shall be submitted to the OWNER no later than ten business days following completion of the Work.

8.0 MEASUREMENT FOR PAYMENT

The CONTRACTOR shall provide the OWNER with a price to perform the Work described in this Scope of Work, including submittals and deliverables. The CONTRACTOR shall provide the OWNER with a schedule of values as described above and itemized on the provided Bid Form.

9.0 PROPOSAL SUBMITTAL REQUIREMENTS

In addition to the Bid Form, the following documentation shall also be submitted as part of the bid for consideration by the OWNER:

- A statement of the CONTRACTOR's qualifications.
- Written acknowledgement that the CONTRACTOR has reviewed all records provided by the OWNER (including the CCTV videos) and inspected the site prior to preparation of the proposal.
- The CONTRACTOR's acknowledgment of the Scope of Work and a description of the specific methods that will be used by the CONTRACTOR to complete the work.
- A detailed project schedule broken down by task and deliverable.
- The CONTRACTOR's insurance coverage and associated limits.
- A summary of the CONTRACTOR's safety record and incident rate for the last three years, along with a description of any OSHA citations, fines or enforcement actions taken against the CONTRACTOR over that time period.
- A preliminary description of the warranty for the Work.

Bids are due to the OWNER by 5:00 pm Eastern Time on March 21, 2011. Incomplete bids will be disregarded. Bids will not be accepted from any firm that did not attend the pre-bid meeting and site walk. The OWNER reserves the right to reject any bid for any reason.

TABLE 1: PIPE REHABILITATION SUMMARY
Rehabilitation of Storm Sewers in Area E
Former Buffalo Color Corporation Site, Buffalo, New York

Reach	Upstream Manhole [2, 3]	Downstream Manhole [2, 3]	Pipe Material of Construction [1]	Approximate Length (feet)	Diameter (inches)	Rehabilitation Method	Estimated No. Joints to be Repaired	Estimated No. Secondary Laterals to be Abandoned
R-E1	DMH-E4	DMH-E5	VT	145	18	Plug laterals only	0	7
R-E2	DMH-E5	DMH-E6	VT	221	18	Plug laterals only	0	11
R-E3	DMH-E6	DMH-E7	VT	210	18	Plug laterals only	0	4
R-E4	DMH-E7	DMH-E15	VT	145	21	Seal joints and plug laterals	15	0
R-E5	DMH-E13	DMH-E14	VT	199	21	Seal joints and plug laterals	7	2
R-E6	DMH-E14	DMH-E15	VT	232	21	Seal joints and plug laterals	10	9
R-E7	DMH-E15	DMH-E18	VT	154	27	Seal joints and plug laterals	7	2
R-E10	DMH-E17	DMH-E18	VT	232	21	Seal joints and plug laterals	8	11
R-E12	DMH-E18	DMH-E21	VT	162	30	Seal joints and plug laterals	10	3
R-E14	DMH-E21	DMH-E20	VT	127	30	Seal joints and plug laterals	8	3
R-E16	DMH-E19	DMH-E20	VT	279	30	Seal joints and plug laterals	18	7
R-E17	DMH-E20	DMH-E23	VT	149	36	Seal joints	41	0
R-E18	DMH-E23	DMH-E26	VT	139	36	Seal joints	22	0
R-E19	DMH-E26	DMH-E30	VT	118	36	Seal joints	4	0
R-E20	DMH-E30	DMH-E31	VT	125	36	Seal joints	0	0
R-E21	DMH-E31	N/A (property line)	VT	120	42	Seal joints	8	0
Total				**2,757**			**158**	**59**

Notes:
1. VT = Vitrified Tile (clay) and RCP = Reinforced Concrete Pipe
2. Drainage Manholes are constructed of brick.
3. Drainage manholes along the main line (refer to Figure 1) are 6 feet or greater in diameter.

BID FORM
Rehabilitation of Storm Sewers in Area E
Former Buffalo Color Corporation Site, Buffalo, New York

	Bid Item	Quantity	Unit of Measure	Unit Cost	Total Cost
5.1	**General**				
	Mob/Demob	1	LS	$	$
	Work Plan/H&S	1	LS	$	$
	Subtotal				**$**
5.2	**Cleaning**				
	18" Pipe	576	LF	$	$
	21" Pipe	808	LF	$	$
	27" Pipe	154	LF	$	$
	30" Pipe	568	LF	$	$
	36" Pipe	531	LF	$	$
	42" Pipe	120	LF	$	$
	Subtotal	**2,757**			**$**
5.3	**Joint Sealing and Testing via Chemical Grouting (or alternate approved by Owner)**				
	21" Pipe - Joints	40	EA	$	$
	27" Pipe - Joints	7	EA	$	$
	30" Pipe - Joints	36	EA	$	$
	36" Pipe - Joints	67	EA	$	$
	42" Pipe - Joints	8	EA	$	$
	Subtotal	**158**			**$**
5.4	**Plug Laterals - CIPP Patches (or alternate approved by Owner)**				
	18" Pipe	22	EA	$	$
	21" Pipe	22	EA	$	$
	27" Pipe	2	EA	$	$
	30" Pipe	13	EA	$	$
	Subtotal	**59**			**$**
5.5	**Bypass Pumping**				
	Bypass Pumping	1	LS	$	$
	Subtotal				**$**

BID FORM
Rehabilitation of Storm Sewers in Area E
Former Buffalo Color Corporation Site, Buffalo, New York

Bid Item	Quantity	Unit of Measure	Unit Cost	Total Cost
5.6 CCTV Inspection				
18" Pipe	576	LF	$	$
21" Pipe	808	LF	$	$
27" Pipe	154	LF	$	$
30" Pipe	568	LF	$	$
36" Pipe	531	LF	$	$
42" Pipe	120	LF	$	$
Subtotal	**2,757**			$
CCTV Inspection Subtotal x 3 rounds				**$**
TOTAL *				**$**

Bid Option 1: CIPP Lining of Complete Pipe Sections in lieu of Bid Items 5.3 and 5.4)				
Additional Mob/Demob	1	LS	$	$
18" Pipe	576	LF	$	$
21" Pipe	808	LF	$	$
27" Pipe	154	LF	$	$
30" Pipe	568	LF	$	$
36" Pipe	531	LF	$	$
42" Pipe	120	LF	$	$
TOTAL *	**2,757**			**$**

* Note: The total bid value shall be inclusive of all Work required to rehabilitate the designated storm sewers as described in the Scope of Work, including, but not limited to: labor, materials, supplies, tools, equipment, consumable items, plans, permits, field documentation, reports, and disposal of construction-related solid waste.

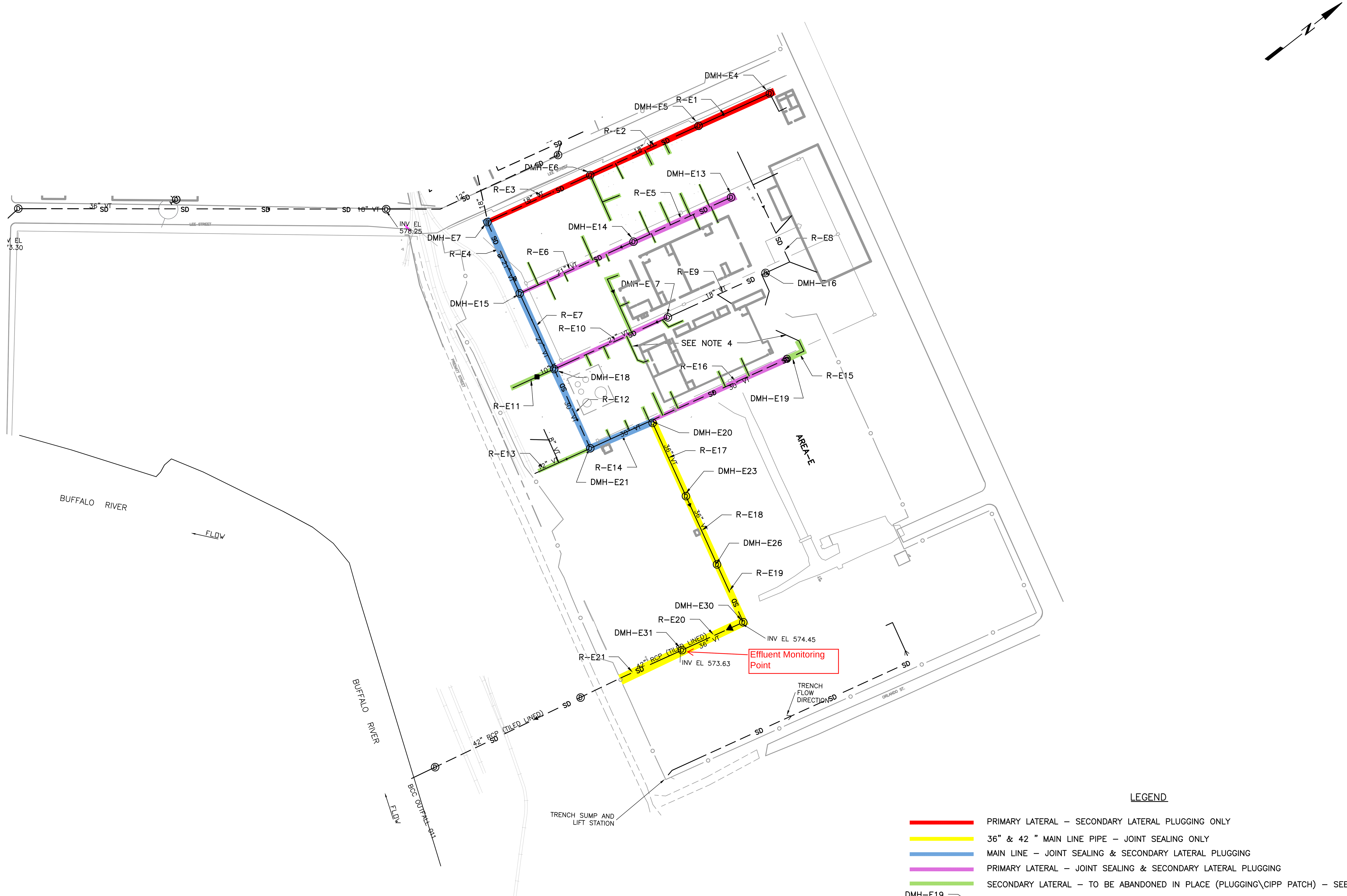
Exemptions or Qualifications to Bid: ☐None ☐Yes (provide detail below)

Company Name

Date

Signature

Title



LEGEND

- PRIMARY LATERAL – SECONDARY LATERAL PLUGGING ONLY
- 36" & 42 " MAIN LINE PIPE – JOINT SEALING ONLY
- MAIN LINE – JOINT SEALING & SECONDARY LATERAL PLUGGING
- PRIMARY LATERAL – JOINT SEALING & SECONDARY LATERAL PLUGGING
- SECONDARY LATERAL – TO BE ABANDONED IN PLACE (PLUGGING\CIPP PATCH) – SEE NOTE 4
- DMH-E19 DRAINAGE STRUCTURE
- R-E16 SD PIPE REACH IDENTIFIER

SOURCES AND NOTES:

1. TOPOGRAPHIC FIELD SURVEY OF AREAS A, B, C, AND E COMPLETED MARCH 2010 BY NIAGARA BOUNDARY & MAPPING SERVICES, 2475 MILITARY ROAD, NIAGARA FALLS, NY 14304.
2. LIMITED LOCATION AND TOPOGRAPHIC FIELD SURVEY OF AREA A AND AREA E COMPLETED BY LU ENGINEERS IN JULY 2005.
3. KNOWN UNDERGROUND UTILITIES AND STRUCTURES ARE SHOWN ON THE DRAWINGS. THE LOCATION OF THESE EXISTING UNDERGROUND UTILITIES AND STRUCTURES SHOULD BE CONSIDERED APPROXIMATE.
4. NOT ALL SECONDARY LATERALS ARE SHOWN.

0 50 100 200
SCALE IN FEET

Prepared/Date: JVM 10/04/10
Checked/Date: KLS 10/04/10
Revised: 2/28/11

STORM SEWER REHABILITATION FORMER BUFFALO COLOR CORP SITE BUFFALO, NEW YORK	MACTEC	REHABILITATION OF STORM SEWERS IN AREA E Project 3410-09-0701 Figure 1

M:\Projects\HONEYWELL\BUFFALO COLOR\SSD AREA C & E FIGURES\AREA E Storm sewer rehab.dwg Mon, 28 Feb 2011 - 2:32pm mopeters

LANZO
Lining Services, Inc.

ENGINEERING DESIGN GUIDE FOR REHABILITATION WITH CURED-IN-PLACE PIPE

Second Edition

LANZO COMPANY HISTORY

Lanzo has been a leading competitor in the construction industry for over 45 years. Lanzo was founded in Roseville, Michigan with offices presently in Detroit, Michigan, Atlanta, Georgia and Deerfield Beach, Florida. Lanzo employs a highly diversified staff of over 400 people providing a full range of construction services with contracting capabilities including:

Professional Services
- Construction Management
- Engineering Design/Build

Trenchless Technologies
- Cured-in-Place Pipe Lining
- "Over the hole" Application
- Noncircular, Box Culvert and Large Bore CIPP
- NSF61 Certified Waterline Rehabilitation
- Air Duct/Plenum Reconstruction
- Lateral Rehabilitation
- Interface seal technology

Heavy Construction
- Road & Highway Construction
- Site Work/Civil Construction
- Water Transmission
- Wastewater Collection Systems
- Water/Wastewater Treatment Facilities
- Marine Construction
- Demolition

Land Development
- Acquisitions
- Design Build

At Lanzo, we value our employees and the residents of the communities within which we serve. Our mission at Lanzo is to provide safe, high quality, cost-effective and on-time construction. Lanzo is an equal opportunity employer meeting all Federal, State and Municipal health & safety regulations. We hold the highest level of ethics and are committed to ensuring the safety of our employees along with both the convenience and safety of the residents of the communities we service.

Trenchless renovation in storm drain application

Environmentally friendly "Green Resin Formulations"

FORWARD

At the time of this publication, Lanzo Lining Services marks seventeen years serving the municipal, industrial, and public works rehabilitation marketplaces with a quality cured-in-place pipe (CIPP) liner. Having installed over 6,000,000 linear feet of sanitary sewer, force main, storm drain, NSF 61 potable water transmission, large diameter, and non-circular CIPP, we offer this newly revised second edition of the Lanzo Lining Services Design Guide as continued confirmation of our experience with design and application.

With millions of feet of CIPP in service throughout the world, it is not necessary to state the applicability or validity of CIPP as a proven rehabilitation technology. Over the years the industry has witnessed the introduction of many new products competing for a portion of the pipeline rehabilitation market. Several seemingly logical technologies have dissipated due to a number of reasons that include short term failure, lack of marketplace support, poor installation practices, and inexperienced contractors. Some products have failed in aggressive environments unanticipated by the designer or installer.

Lanzo Lining Services success can be attributed to five primary directives:

1. An emphasis on safety
2. Consideration of the community.
3. Quality installation by experienced crews.
4. A conservative design approach and superior resins.
5. Third party testing of each liner run.

DAILY THIRD PARTY TESTING vs. CATEGORIC LONG-TERM TESTING

The mere use of long-term testing for product selection is inadequate. The participation in a long-term testing program, while notable, does not insulate the customer from workmanship flaws, inferior resin or batch irregularities, or day-to-day jobsite fluctuations. There is no better way to prove quality and product reliability than to take a test specimen from the actual installation being lined and have it tested by a third party laboratory. For instance, the ability to retrieve samples from CIPP installations with properties in excess of 350,000 psi flexural modulus demonstrates that the submitted design basis has been validated. This additionally proves out the quality of the liner wet out, the adherence by the installer to ASTM installation practices, and the quality of the resin actually used on the day of the installation. The existence of over six million feet of Lanzo installed CIPP in service throughout the United States and Canada may serve to qualify our technology as viable, conservative, and safe.

INNOVATION

Our service is the daily solution of problems and pursuit of a quality installation. This is not simply the installation of a product, but rather the accomplishment of a complete sequence of events ranging from resin preparation and wet out to installation, utility reinstatement and jobsite cleanup with minimal disruption to the surrounding community. In the evolution of our company, many new product developments, installation tools, and refined practices have combined to make the use of our service a practical occurrence. Our conservative use of the highest design standards and field proven methods have been applied to diameters as large as 120", circular and non-circular storm drain applications, pressure rated force main and NSF 61 certified water main "stand alone" pipe liner installations.

CONTENTS

INTRODUCTION

OBJECTIVE OF THE MANUAL

This manual is intended to serve both as a general reference as well as an educational tool for the owner or project engineer designing infrastructure rehabilitation projects. The technology presented includes cured-in-place pipe, NSF61 certified water main transmission and potable water distribution pipeline rehabilitation, lateral lining, large diameter circular and non circular structural pipeline repair as installed by Lanzo Lining Services.

Cured-in-place pipe is prepared and installed by first saturating a specially fabricated tube with a thermosetting resin. The flexible, resin-saturated tube is installed by pulling it in place or inverting the liner into itself directly through the host pipe using either an existing or constructed access point. With the use of a static head of water, steam pressure, or pressurized air; the resin-saturated tube is pressed tightly against the existing "host" pipe. The water or steam is then continuously circulated through a heater in order to quickly polymerize the thermoset resin which forms a new pipe within the existing "host" pipe. Lateral connections are easily identified where the liner dimples and may quickly be reinstated robotically. All of these steps are typically accomplished without the need to excavate demonstrating truly trenchless technology.

Members of both the public and private sectors are finding the benefits of cured-in-place pipelining immeasurable. This trenchless rehabilitation technology allows placement of pipe within a pipe with "stand alone" structural characteristics while eliminating infiltration and exfiltration at a lower cost, in less time, and with fewer inconveniences to the owners and the communities served.

LANZO LINING SERVICES CONSTRUCTION EXPERIENCE

Lanzo Lining Services is among a handful of companies proven competent in the use of a wide array of cured in place pipelining technologies to rehabilitate deteriorated water, sewer, and drainage pipelines.

Lanzo Lining has successfully installed over six million (6,000,000) linear feet of cured-in-place pipe throughout the United States and Canada, in pipe sizes ranging from 6" to 144". Our specialties include large diameter, non-circular, pressure, high temperature, and corrosive environments in collection, transmission, treatment plant, industrial, NSF 61 potable water main, environmentally sensitive," green" and storm drain applications. [1,2].

Lanzo Lining Services has installed over 1,000,000 feet of large bore CIPP, of which over 250,000 feet has been placed using "over the hole" wet out/installation technology; where factory liner preparation or transport to the remote jobsite location was not possible. We have installed non-styrenated polyester, non-styrenated vinyl ester, and epoxy resin impregnated tubes where environmentally sensitive, potable water transmission or air plenum ventilation application prohibits the use of styrene or other VOC's.



"Over the hole" wet out and installation of large bore circular, non-circular, and box culvert applications

THE CORROSIVE PIPELINE ENVIRONMENT

Accelerated aging caused by hydrogen sulfide-related corrosion has generally caused premature failure of our nation's sanitary sewer infrastructure. Awareness of the existence of corrosion and concern about its effect on the sewer system has been an issue since concrete and ductile iron first started displacing clay and brick as the primary materials in sanitary sewer construction. Even though it was known that some corrosion would take place, precautions taken in the sewer design and pipe thickness were intended to produce the 100+ year life expectancy of the sewer system [3]. However, within the last 25 years, hydrogen sulfide-related corrosion has accelerated at an alarming rate throughout the U.S. and has been documented by the Environmental Protection Agency (EPA) in a number of studies [3,4,5,6]. The primary cause of the accelerated corrosion has been attributed to the proliferation of several strains of Desulfiobrio bacteria in response to the reduction of cyanide and other heavy metal pollutants regulated by the EPA [3,4]. An anaerobic bacteria living in the slime layer on the lower hemisphere of the pipe reduces sulfur-containing compounds to hydrogen sulfide (H2S). An aerobic strain living in the slime on the crown of the pipe oxidizes hydrogen sulfide to sulfuric acid (H2SO4). Routine wastewater pH measurements often indicate the effluent to remain in a range of pH 5-8, which would not ordinarily be of concern. However, the area of most concern with materials having low acid resistance is in the slime layer itself where the aerobic bacteria live. The aerobic bacteria have been observed to produce sulfuric acid up to 5% by weight (i.e., pH ~ 0.28) and remains viable in concentrations as high as 7% (i.e., pH < 0.15) [4,7]. At these acid concentrations unprotected concrete or ferrous metals are readily decomposed, producing holes in the top of the pipe commonly found during inspection.

ADMINISTRATIVE ORDER/CONSENT DECREE

Sewage overflow restrictions, overflow monitoring, and stiff penalties for non-compliance imposed by the EPA and state water agencies have motivated municipal sanitation departments to develop aggressive programs to maintain and/or rehabilitate their systems [4]. These programs have fostered the growth and acceptance of number of trenchless pipe rehabilitation techniques, as well as creative maintenance solutions [4,6,8]. The most popular current ongoing maintenance program utilized by many sanitation districts is the development of chemical treatment protocols and inventive application techniques to control hydrogen sulfide corrosion [4,6,8]. Depending on the program objectives, regular addition of one or more chemicals can reduce existing hydrogen sulfide, neutralize the acids, temporarily shock the bacteria, or accomplish all three. Chemicals commonly used for this purpose includes strong oxidizing agents (i.e., hydrogen peroxide, sodium hypochlorite (active ingredient in bleach), chlorine, potassium permanganate), weak oxidizing agents (i.e., oxygen and air injection), acid neutralizing bases (i.e., sodium hydroxide), and iron salts [4,6]. Use of magnesium hydroxide has been utilized as a thick alkaline chemical coating on the crown of cementitious pipe in order to neutralize the acid gases and kill the acid forming bacteria.

In general, this nation's sanitation system has changed dramatically within the last several decades and will continue to evolve. Studies demonstrate that decreased flows related to water conservation efforts increase the corrosive environment in sewer systems [9]. It is suggested that municipal efforts to reduce inflow and infiltration (I/I) through rehabilitation will also increase hydrogen sulfide-related corrosion and concentrate all other chemical agents present [10]. These and other unpredictable changes may necessitate lining to fortify existing pipelines against an increasingly aggressive corrosion environment [11].

Finally as the nation's infrastructure becomes tighter and additionally rehabilitated; the concentration of the many chemicals contributing to system deterioration will naturally increase. This will further emphasize the need to completely renovate our systems and finish the job started.

ALLOWABLE LEAKAGE BY SPECIFICATION

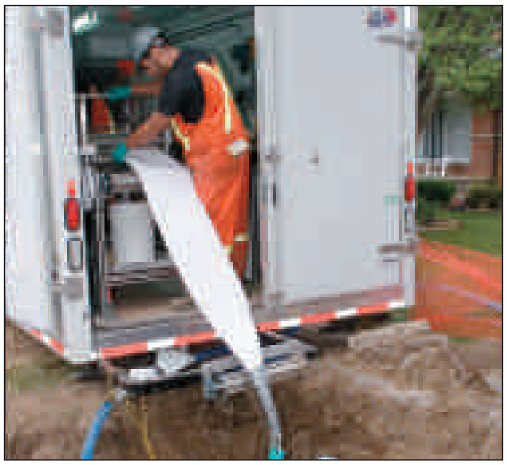
Infiltration & inflow reduction

Maximum flow capacity

As a continuous and joint free pipe material, CIPP has been part of a "Green Revolution" even before the environmental community first coined this phrase. The evolution of specified materials has allowed the Engineering Community to reduce the allowable passage of effluent through the joints of newly installed or rehabilitated pipelines, thus improving the overall environment. As late as the 1980's a leakage level of 200 gallons per inch-mile-day was commonly found in new vitrified clay pipe installations and this has now been reduced to a level of 50 gallons per inch-mile-day available with Unibell installations of PVC pipe today. The impact of a zero leakage system such as CIPP should prove instrumental as efforts to move towards a "greener" society remain emphasized. CIPP offers the luxury of a "pressure rated" sewer pipe where leakage either in or out of the system was previously commonplace in new installations.

CIPP BACKGROUND AND APPLICATION

NSF 61 Certified water main rehabilitation



ASTM F1743 Pull & invert technology

The full technology development of cured-in-place pipe as an industry is attributed to Insituform Technologies back in the early 70's in the United Kingdom. As the technology grew, installation techniques, materials advancements and product marketing were all combined to spawn the international multibillion-dollar business it is today. Recent estimates place the total number of cured in place pipe feet installed at over 100 million feet worldwide. At the present time the North American market has become the largest in the world for CIPP as for many other trenchless technologies.

Cured-in-place pipe has achieved wide popularity and acceptance because it is one of the most versatile methods of trenchless pipeline renewal that exists today. Many of the key features of CIPP are summarized as follows:

1. CIPP is able to span a diameter range of 4 inches to over 120 inches.
2. CIPP has been used to rehabilitate sections of pipe over 3000 feet in length.
3. CIPP can rehabilitate non circular pipe configurations such as ovals, boxes, bends and transitional diameters without digging.
4. Used to rehabilitate partially, as well as, fully deteriorated pipe.
5. Used for gravity, internal pressure and vacuum applications.
6. CIPP is used in extremes of temperature and pH.
7. Specialized products meet NSF61 certification for potable water pipe distribution, green resin applications in sensitive environmental areas, and ventilation applications where styrene use is prohibited
8. CIPP eliminates inflow and infiltration, as well as exfiltration.
9. The smooth inner surface of CIPP increases the flow capacity of the existing pipe.
10. CIPP has ASTM F1216 [12] and ASTM F1743 [13] installation specifications.
11. CIPP tube and resin materials are specified by ASTM D5813 [14].

CIPP INSTALLATION DETAILS

In this section of the manual a general description of the various installation techniques will be described for both the direct inversion and pulled-in-place installation techniques. The descriptions and figures detailed are not intended to encompass all aspects of any given installation. Variable job site, underground piping, and climatic conditions may necessitate a variety of modifications to these descriptions that are intended to produce the same installed product. The basic categories involved with CIPP installation involve the following steps:

1. Inspection
2. Pipe and job site preparation
3. Tube preparation
4. Tube installation
5. Tube curing and cool down
6. Lateral reinstatement and finishing steps

Inspection - Initially before any lining tubes are prepared the existing pipe must be CCTV inspected for debris, roots, damage, offset joints or any other anomaly that does not allow for proper CIPP installation. Inspection also involves measurement of the pipe diameter, pipe length, manhole depths and records of pipe location and other job site conditions (i.e. overhead power lines, or railway, backyard easement, excessive sewerage flows, etc.) that can be properly planned for to help the project proceed efficiently. CIPP can easily be installed over dirt and debris, through severely offset joints or around protruding laterals, and in multiple bends as severe as 90'. CIPP will not eliminate existing pipe defects, but rather will contour the configuration of the host pipe being lined. It must be determined that later inspection with CCTV or water jet cleaning may occur and that bumps or fins in the liner will not disallow equipment from passing through the rehabilitated pipeline.

Pipe Preparation - Preparation for lining may involve internal mechanical cleaning and grinding to remove roots, protruding laterals, or other obstructions in the pipe. Collapsed pipe or severely offset joints (i.e. 40% of the diameter) typically require point excavations at those locations. Loose dirt, debris, or tuberculation may require high pressure water or mechanical cleaning with a final pre-lining inspection showing the full circumference of the pipe.

Tube Preparation - After the engineered tube of proper diameter and thickness for the pipe being rehabilitated has been matched to the host pipe length; it is ready for resin-impregnation. Most liner preparation and resin saturation takes place in the controlled environment of a workshop where the resin and tube temperatures are controlled to desired conditions. The resin and resin-saturated tube may be refrigerated to slow the chemical reaction and provide an additional factor of safety during the transportation and installation of the liner. The tube is prepared by first evacuating the air from it to create a condition for vacuum impregnation. Secondly, the catalyzed resin is introduced into the tube under vacuum so that air is completely displaced with resin while saturating the fabric. The tube is moved through pinch rollers calibrated to the proper thickness so that a controlled amount of resin is introduced into the tube. The tube is then loaded into a refrigerated truck for transportation to the job site. For projects where either the diameter is large and/or the length of the liner is long, this process will take place at the construction site and the liner will go from wet out directly into the pipe being rehabilitated. When properly handled and stored, resin-saturated tubes can be stable for up to a week or more.

Tube Installation - The following installation descriptions are intended to be a generalized overview of common direct inversion and pulled-in-place installations. Since there are so many variables associated with each project and the job site conditions on projects, an overview is provided here to familiarize the reader with general knowledge of this technology. While direct inversion and pulled-in-place installations are performed in a different manner and require different equipment, the decision to choose one installation method over another is related to the project, job site and piping conditions. On a single project it may be advantageous to use both techniques, as well as variations of each to maximize quality and efficiency of the installed product. Both techniques have been used successfully for pipe diameters from 4 inch to greater than 120 inch. The installation techniques described below use water as the installation and curing media since it is by far the most common and reliable method of installing CIPP. However, steam and air pressure may also be used as job conditions dictate. Each technique can be considered a tool in the toolbox of a CIPP installer. As such, each one has its place at the appropriate time to successfully complete a project safely, on time and within budget.

Direct inversion of CIPP is installed to meet or exceed the requirements of specification ASTM F1216 . Initially the tube is attached to a top ring or pulled through a column and turned inside out and attached to an elbow. In both cases, the tube is turned inside out with the use of a hydrostatic head of water as shown in Figure 1. As the water is carefully introduced into a column, the resin-saturated tube is allowed to invert upon itself and progress longitudinally through the pipe in a continuous and controlled manner.

figure1: Direct inversion installation per ASTM F1216

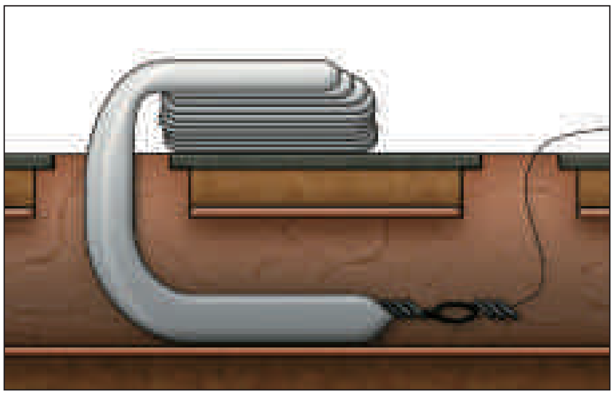


figure 2: Liner pulled-in-place per ASTM F1743

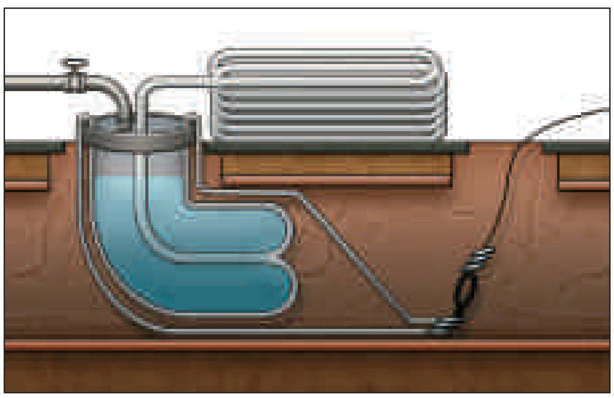


figure 3: Calibration hose or pre liner utilization

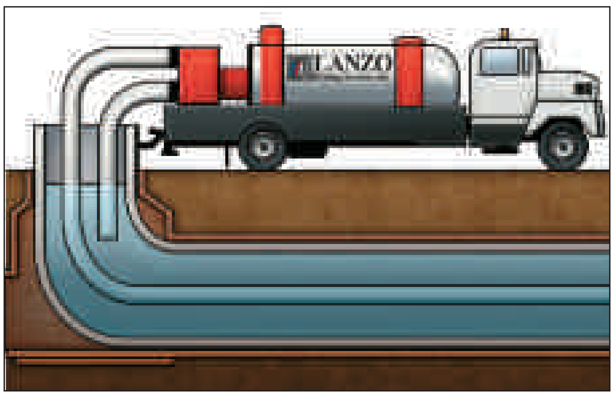


figure 4: Curing liner with hot water or steam

The direct inversion method is the most popular method, available in virtually all sizes, and especially suited to the "over the hole" technique.

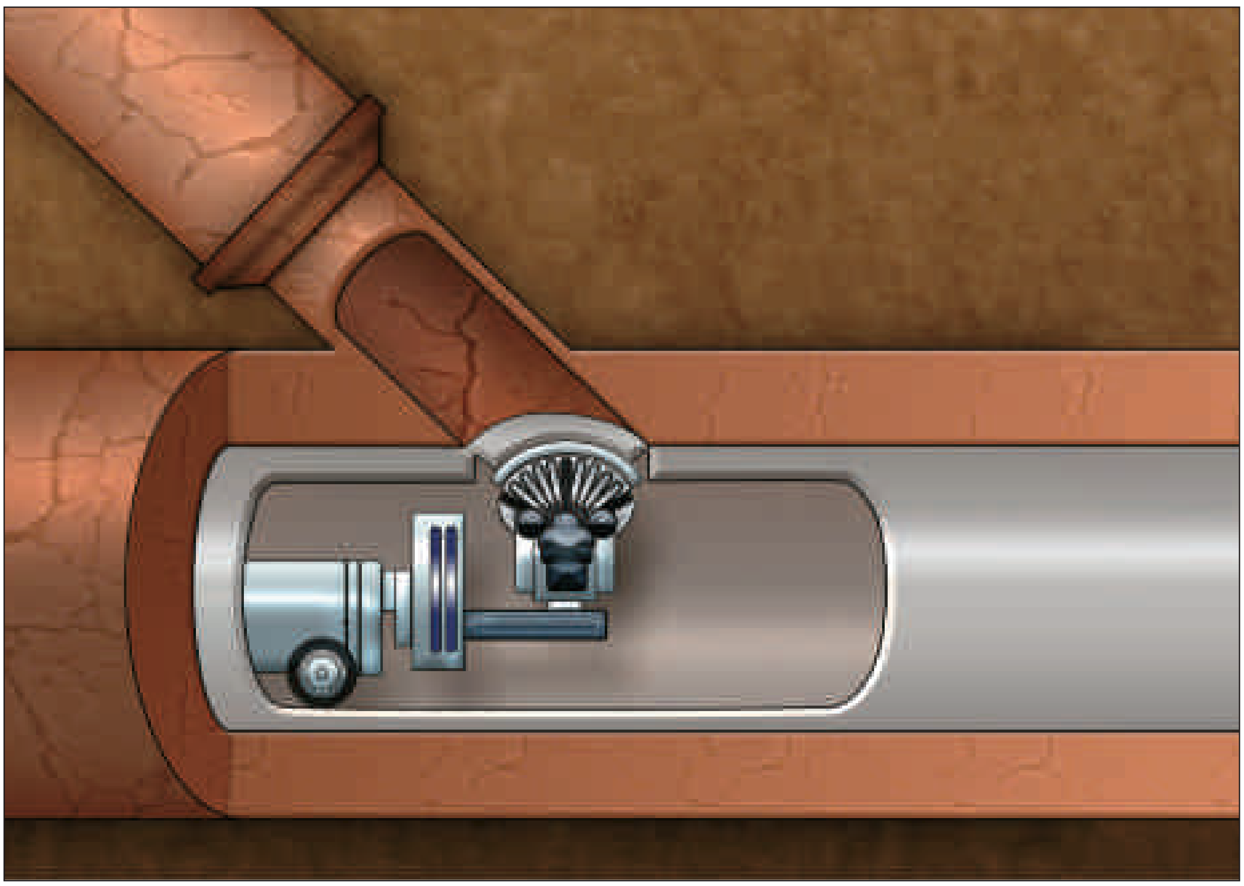
Pulled-in-place CIPP installation is installed to meet or exceed the requirements of specification ASTM F 1743. For this technique a cable is strung through the existing pipe and attached to the tube. Once attached, the tube is carefully pulled into position as shown in Figure 2. In order to reduce potential friction between the pipe and the liner, hydrant water may be introduced into the pipe through the manhole, allowing the tube to easily slide down the pipe. Through the choice of tube materials and careful pulling techniques, pulling forces rarely exceed 10-20% of the maximum tensile properties of the fabric tube. Tube stretch is less than the maximum 5% specified in ASTM F1743, but is usually less than half that value. For a more detailed estimation of maximum tensile strength of a tube and estimated pulling forces, contact Lanzo Lining Services.

Pull in place employs a second installation step. A calibration or retractable hose is inverted into the center of the resin-saturated tube by a hydrostatic head of water. This hose sequentially inflates the resin-saturated tube from one access point to another and holds it tight against the existing pipe as shown in Figure 3. Any residual water trapped in the pipe is directed downstream as the calibration hose inflates and longitudinally progresses within the tube sequentially from one end of the pipe to the other.

Pull in place is extremely instrumental in the many special applications such as Pressure pipe, transitional sizes, NSF 61 water main, ventilation plenum rehabilitation, and large diameter applications where particular placement challenges exist.

CIPP Curing and Cool Down - Once installed by direct inversion or pulled-in-place the tube is cured through the use of circulating heated water, introduction of steam, or the use of an ultraviolet (UV) light.

When water is used, it is taken into the water heater from the column and discharged out into the center of the installed tube at the downstream end. The heated water circulates back to the column at the upstream end where the cycle in



Robotic reinstatement of house connection or "lateral" sewer continued throughout the curing process as shown in Figure 4.

When steam is used as a heat source, the steam is typically introduced at one end and flows through the length of the liner and out the downstream end through a specialized manifold that helps control temperature and internal pressure. New innovations in steam generation technology allow for dryer steam and can also allow the installer to cure at much higher temperatures than circulating hot water.

UV light is a third method of curing CIPP and requires specialized resins and photo sensitive initiators. UV light curing technology is relatively new in North America, but has been used for many years overseas and is proving to have advantages for many different applications. Liners can be stored and transported without refrigeration and still be viable months. When the lights are turned on, curing takes place within minutes.

Whether cured with water or steam, the process must be carried out in a controlled manner with the temperature monitored at both ends of the tube with thermocouples placed between the liner and the host pipe. In addition, the water/steam temperature is monitored at the heater and may also be monitored at the downstream end of the liner. Where intermediate access points exist, the curing process of the tube may also be monitored at those locations also.

Most often the tube is cured in a two-staged heating process and cooled down in a controlled manner to a temperature below 100F. The times and temperatures of these different stages are highly variable based on tube diameter, length, thickness, resin type, catalyst formulation, size of the water heater, environmental and job site conditions. In general, thick tubes require extended curing and cooling times, while thinner tubes may be cured more rapidly. The variable cure times and tube thickness relate to the slow heat transfer into and out of the tube, as well as the requirement to control the exothermic (i.e. heat producing) reaction that occurs when the thermoset resin in the tube polymerizes.

Lateral Reinstatement and Finishing Steps - Once installed, cured and cooled down the CIPP is fully opened on both ends while any lateral connections leading to the pipe are then reinstated. When the pipe is too small for a man entry, CCTV is used to re-locate lateral connections and remotely operated cutting machines are used to re-open the lateral connection. At the manhole connections an end sealing procedure may be utilized which helps eliminate infiltrating water from tracking down or around the host pipe and/or CIPP and re-entering the collection system at the manhole. Where there is heavy groundwater some type of lateral sealing technology is recommended where the lateral connects to the main line. Top hats or interface seals may be applied remotely from inside the liner using a robot without the need to introduce a cleanout or other above ground access. Other trenchless sealing techniques include chemical grouting, lateral lining at the connection and/or up the entire lateral, or robotic placement of polymer putty. Alternatively, laterals may be opened and sealed by making a point excavation to place a new saddle connection at each lateral.

Final Inspection - As with any project, final CCTV inspection provides the documentation for the project engineer that the CIPP was properly installed. Ideally CIPP is smooth and wrinkle free throughout the length of the installation. However, CIPP cannot eliminate piping irregularities and will mirror pre-existing problems in a defective pipe being lined to eliminate I/I, exfiltration, or improve structural integrity. In addition, fins in the CIPP can occur when the pipe diameter decreases to less than the nominal diameter of the existing pipe. During the engineering and design phase of a contract, tubes are commonly specified with an undersized diameter (i.e. 4-8% undersized) to anticipate host pipe diameter changes and moderate bends. When encountering crushed pipe, PVC pipe used for point repairs, and clay pipe the host pipe diameter can decrease to the point where these measures cannot prevent fins. Fins are also unavoidable in sharp bends where the inner radius bunches going around the bend. Wrinkles such as these are cosmetic defects in an otherwise defective host pipe and prevalent in all CIPP construction. Since most all fins run along the length of the pipe they typically increase the physical properties like that of a built-in I-beam and do not affect flow. Typically fins in the CIPP are of little concern to the overall performance objectives of the rehabilitation project.

CIPP PROJECT SPECIFICATION

To insure the desired results from a CIPP rehabilitation project, proper specifications must clearly outline the objectives. With any rehabilitation project it is recommended that the collection system be evaluated as a whole and pipeline sections be segregated for repair using the appropriate rehabilitation technology(s) most suited for the stated project objectives. A project may be put out to bid with multiple technologies (i.e. CIPP, sliplining, open cut replacement, lateral lining) to achieve the desired end result. Exclusive rehabilitation with CIPP is recommended in areas where any or a combination of the following conditions may exist:

1. Suspect structural characteristics in the host pipe are manifested in the form of radial or longitudinal cracks, offset and/or displaced joints.
2. Ovality sufficient to preclude sliplining or folded and re-formed products from reaching a full round configuration consistent with ring compression support theory (see Design Section).
3. Pipes where sections are completely missing.
4. Pipe subject to highway loading in shallow or live loads.
5. Deeply buried pipe where high external hydrostatic pressure may exist.
6. Pipe with line and/or grade differentials (i.e. existing bellies in the pipe run) that may produce friction for sliplining and/or not allow folded products to reach their fully rounded state after installation.

Once it has been determined that CIPP is the proper choice for pipeline rehabilitation there are many aspects of specification that will determine the success and quality of the completed project. Prequalification factors such as threshold contractor experience, minimum installed footage, same liner size or larger, key employee resumes and local wet out facility are significant items that may be taken into account prior to bid. Contact Lanzo Lining Services for a sample specification that can be used as a template for your specific CIPP project.

ASTM SPECIFICATION

ASTM standardization is extremely important to insure consistency in materials and installation practices, while minimizing owner liability in ongoing construction work. It may take as long as five (5) years to obtain a ratified specification. After initial publication ASTM standards are kept current through a mandatory review process that is required every seven years. If there is no interest to review a standard it is dropped from publication. Standards exist for virtually every pipe rehabilitation product, including CIPP. ASTM does not purport to cover all the details of every project or installation, but does provide a valuable framework and set of guidelines that are absolutely necessary for the underground rehabilitation industry in general.

ASTM D5813 "Specification for Cured-In-Place Thermosetting Resin Sewer Pipe" covers material requirements for the resins and fabric tube materials used for CIPP. ASTM D5813 also outlines test methods for evaluating installed CIPP.

ASTM F1216 "Practice for the Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube" provides guidelines for the installation of CIPP with the direct inversion method.

ASTM F1743 "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)" is an installation standard practice for the pulled-in-place method of installation. ASTM F1743 references both ASTM F1216 and ASTM D5813 for designing and specifying CIPP.

As with any technology there are critics within and outside the CIPP industry regarding the validity of the aforementioned standard practices. Two areas that have come under extreme scrutiny are the design criteria and pre-qualifying materials for chemical resistance testing. CIPP gravity sewer design is divided into "Partially and Fully" deteriorated existing piping criteria. Based on the pipe classification, the CIPP is designed to either withstand hydrostatic loading only, or all possible external loads that the CIPP may be exposed to. In addition, some municipalities have developed their own chemical resistance and design criteria, which is much more severe than that specified in ASTM (i.e. The California Green Book [15]). Proponents and supporters of these specifications argue that CIPP has performed admirably in the U.S. for over 40 years and has not failed as a technology because the approach taken has been conservative and aimed at long term performance for the product(s).

Lanzo Lining Services supports the more conservative approach to specification selection. With over six million (6,000,000) feet of failure free installation, primarily in fully deteriorated design basis, serves as testimony to the confidence attainable in a conservative approach.

CIPP APPLICATION GUIDELINES

Since the publication of our premier Design Guide ten (10) years ago there has been an absolute transformation within the CIPP marketplace with respect to comfort with this technology and a relative boom in the range of application for composite felt/resin liner systems.

Lanzo has remained an innovator and pioneer installer of CIPP in many cutting edge applications such as:

- I/I reduction in sanitary collection systems
- Large Diameter and Non Circular sewers, storm drains, and box culverts
- "Over the Hole" wetout and installation
- High temperature chemical concentrations and industrial sewers
- Pressure rated force main sanitary sewer transmission
- NSF 61 certified water main rehabilitation
- Green resin utilization in wetland or environmentally sensitive areas
- Air duct ventilation repair and vacuum pressure line
- Contaminated soil remediation prevention
- Flood control structure rehab
- Submerged or canal enclosure pipeline rehabilitation

CIPP has been installed by Lanzo in diameters ranging from 6" through 144".

The utilization of direct inversion, pull in place, and hand lay-up methods are application dependant but generic in terms of the design parameters presented in this guide. Additionally, both gravity and pressure rated design is presented herein, while an abundance of information has been accumulated on each of these methods available for informational or specification writing purposes by contacting Lanzo.

COMPETING TRENCHLESS PIPELINE REHABILITATION TECHNOLOGIES

In general, trenchless pipeline rehabilitation technologies have proliferated and gained extraordinary acceptance because of the changing chemical environment previously described, enforcement of the clean water regulations, inadequacies of traditional piping materials, and the rising social costs of traditional dig and replace methods. Social costs include the direct and indirect costs that will impact the community surrounding the project. These costs might include destruction of old trees, disturbance of a wetland habitat, disruption to businesses, and impact of traffic congestion on side streets as people are forced to take alternative routes. A number of experts and engineering firms have studied this more closely to develop generalized costs [16]. Pipe repair alternatives include chemical grouting, point repairs/excavation, internal robotic repairs, sectional liners, sliplining, CIPP liners, fold and form liners, and pipe bursting. Acceptance of new technologies has increased competition and pushed the cost down to the point where the cost of a trenchless repair is generally less costly than trenching, even without taking social costs into consideration.

Table 1. Generic costs of Pipeline Construction and Repair Methods [16].

Method	Cost/Inch Diameter/Foot	Type of Installation
Sliplining	$4-$6	Rehab
Grouting	$4-$6	Rehab
Cured-In-Place Pipe	$4-$8	Rehab
Pipe Bursting	$8-$10	Rehab
Over the Hole large diameter CIPP	$10-$28	Rehab
Trenching	$15-$30	Rehab or New
NSF 61 Water main CIPP rehab	$20-$30	Rehab
Sectional CIPP Liner	$50-$85	Rehab

Each method of repair has a niche where it is most applicable. These technologies are briefly reviewed with the understanding that the included summary cannot encompass the full scope of each technology.

Chemical Grouting - Chemical grouting is a technique primarily used to seal leaks in pipes or lateral connections in pipe diameters typically in the range of 6 inch to 24 inch. It has been used for years and includes material selection options such as acrylamide gel, acrylic additives, urethane gels or foam. These products are typically injected under pressure with a specialized packer that forces the liquid grout through the hole in the pipe into the surrounding soil envelope. There it polymerizes to form a solid or semi-solid gel that pervades the soil envelope serving to non-structurally seal the pipe. Grouting is economical and effective but temporary in sealing leaks and not a structural repair to a damaged pipe. The estimated effective lifetime of various grouts is an ongoing point of debate which points to a range from 3 to 7 years.

Sectional or Part Liner – Developed as a repair technique for CIPP defects, this method has seen expanded application and is perhaps "over used" to repair damaged pipe. It can be designed as a structural repair to a fully deteriorated host pipe. This method is essentially a short CIPP repair that may be furnished in lengths ranging from 3 feet to as long as necessary, depending on diameter and location of the repair. The primary issue in electing to utilize this technology is the selection of an adequate repair length. Pre video inspection reports revealing target defects do not offer insight into the underlying cause of the failure or extent of soil envelope deterioration. Consequently, a seemingly adequate repair may not prevent crack propagation outside of the limits of the sectional repair after a relatively short time. It is judicious to select a sectional repair length which takes this phenomenon into account by extending the repair to several joints in either direction beyond the target defect. Additionally, a maintenance program should exist to monitor these repairs over time as post cure shrinkage as well as other effects may cause movement of the short liner.

This method is most typically used for pipes 8 inch to 24 inch in diameter, but is available in diameters as large as 120". Fabric tubes constructed of woven and/or non-woven materials (i.e. polyester felt and/or fiberglass) are manufactured for the project and saturated with a variety of resins which have been modified for a reactive cure with low heat or UV light. The sectional liner is typically pulled into position on a carrier or packer which is then pressurized causing the short CIPP segment to expand tightly against the host pipe then allowed to cure in place.

A practical alternative to this method is an installation technique called a "blind shot" or a sectional CIPP liner section which only requires access to the pipe at one end for a starting point. Although Part Liners typically do not run manhole to manhole, this variety of sectional pipe repair offers the additional benefits of:

-
- a solid connection to a manhole-pipe interface
- a repair which is readily visible from the manhole
- the ability to line past the defect by several joints thus clearing the suspect soil envelope by a more conservative distance

Service Connection Reinstatement, Repair, Interface Seal and Lateral Lining Lanzo has become proficient in providing several technologies to repair lateral connections and lateral pipes both remotely from within the mainline, as well as, from a cleanout located at the property line. These repair technologies require specialized liner materials and equipment, but can successfully seal the lateral-mainline connection and rehabilitate the smaller lateral pipe up to the house or business. These methods require experienced field technicians with an understanding of varying host pipe materials, resin cure, remote camera and robotic equipment operation, variable temperature, flow and piping conditions to complete a successful time sensitive repair.

Different technologies exist in the marketplace which utilizes either water or air as placement media with either water, steam, or UV light for curing the resin systems. There exist several proprietary technological approaches while the end user should be cautious to insulate themselves from sole source specification which may drive cost unduly higher as they become embroiled in trade issues such as full wrap vs. lateral region adhesion, or minimum length of interface seal dimension.

An interface seal is intended to eliminate annular space or shear condition, while lateral lining serves to seal and structurally repair the lead to a determined length within the service. Although certain lateral lining technologies may be remotely launched from within the main, a cleanout is routinely necessary to insure the removal of root manifestation and mineral deposits while visually inspecting defects within the lateral to be rehabilitated. The notion that a lateral may be routinely lined without a cleanout is therefore flawed.

Robotic Repairs - This is a highly specialized technology that can also be used as a trenchless point repair method to seal cracks and leaking lateral connections. Through the use of grinding tools and epoxy resins or chemical grouts a wide variety of pipe defects can be repaired. Widespread use of this method has been hampered by the initial purchase and maintenance expense of the robotic equipment employed which also requires highly trained personnel for a small portion of the repairs typically being addressed in a comprehensive system rehabilitation project.

Repairs consist of employing a remote cutter head to ream, gouge, or machine a channel into an existing defect which then is more receptive to an epoxy which may be robotically troweled or pumped into place. Typical repairs apply to pipes in the 8-inch to 24 inch robotic equipment are repaired with these techniques.

Point Excavation for Repair - When a pipe is severely damaged or crushed it may be most cost effective to dig at that location to repair the section of pipe. This method is often used in conjunction with trenchless lining techniques to replace collapsed sections so the existing pipe may then be inspected, cleaned and subsequently lined from manhole to manhole. All sizes, shapes, and varieties of pipe have been repaired with this method to effect a conventional open cut repair.

Sliplining and Segmental Sliplining - These methods can be used to either pull or push new plastic or composite system into the existing host pipe. Traditional or "discrete" sliplining typically either pulls a high-density polyethylene (HDPE) pipe or pushes a reinforced thermoset resin (RTR) or reinforced plastic mortar (RPM) through one access pit to another. Depending on site conditions, sections of pipe of 1000 feet or more may be pulled or pushed at one time. The pull method of pipe repair is most typically used on pipe 8 inch to 24 inch in diameter, but larger sizes have been installed. In 48 inch and larger applications, segmental sliplining with thermoplastic or composite pipe can become more cost effective depending on site conditions at the entry and receiving pit along with the costs associated with bypass pumping.

Segmental sliplining is performed by lowering individual sections of pipe into an access pit and hydraulically jacking each into the host pipe towards a receiving pit while maintaining pipe flow.

Hard pipe material slipline methods are limited by the frictional forces of the slipline material against the host pipe, which will determine the shot length or allowable distance between pits.

Sliplining reduces the overall hydraulic radius significantly and may reduce the capacity of the pipe rehabilitated. Factors such as pipe joint articulation , mineral deposits, bends and line obstructions must be thoroughly investigated prior to method selection. Reinstatement of lateral connections requires external point excavations.

Pipe Bursting - Pipe bursting is a technology where the existing pipe is sheared or cracked while a new pipe is pulled behind (sliplining) a specialized bursting tool. Many types of tools have been developed with hydraulic or pneumatic bursting capability and include pulling only, pulling and pushing, and so on. This method enables the owner to actually increase the size of the existing pipe by one or more diameters and actually increase the hydraulic radius. Pipe bursting has been used to up-size 8 inch to 10 inch or 12 inch and has been used to increase pipe up to 36 inch or larger, from smaller diameters. The technique works most efficiently on brittle host pipe materials, such as clay, concrete, asbestos cement and "pit" cast iron. HDPE is most often used as the replacement pipe, but PVC, composite pipe, and even clay have been used. The limitations to this technology involve use of the bursting tools when the pipe is close to structures such as foundations or utilities that cross the line being burst. Where these structures can be point excavated, bursting can proceed without incident. Reinstatement of lateral connections requires external point excavations.

Fold and Form Lining - This process uses plastic pipe that has been folded into a "U" shape allowing it to be steam softened then pulled into the existing pipe. Using steam heat and internal pressure the liner is reshaped to meet the existing pipe. Fold and form has been attempted in diameters ranging from 6 inch to 24 inch, but is most applicable in the range of 8 inch to12 inch. HDPE and modified PVC are the piping products used for fold and form. This method is a low cost rehabilitation technology that is used where the existing pipe can provide structural support to the liner for gravity flow applications. Potential problems exist where the liner does not fully unfold, making it susceptible to collapse under external groundwater pressure. For some products the modified PVC materials are often experimental in nature without extensive long-term property research behind them. Therefore, prior to use the owner should review all products carefully. In most cases lateral connections can be reinstated by remote cutting tools, but may require point excavation and typically require grouting to guard against flow tracking through an annular space. There is no reliable "adhesion" or "mechanical bond" between a thermoplastic material and a host pipe.

Pipe Preparation - Most of the technologies listed have the common need for pre-installation inspection, cleaning, and other forms of preliminary pipe preparation. For most applications by pass pumping is of minor concern in diameters up to 15 inch. In the range of 18 inch and above by pass pumping can become a significant portion of project planning and cost. Depending on site conditions pipes greater than 48 inches may be rehabilitated during flow diversions and using techniques that minimize the reliance on by pass pumping.

Lanzo Lining Services brings experience with dig and replace, new pipe construction and multiple rehabilitation technologies while adding value to the project. The Lanzo Companies can combine construction capabilities to optimize the allocation of municipal dollars while streamlining coordination efforts on any given project.

CIPP ENGINEERING AND COMPOSITE MATERIAL PROPERTIES

Since 1993, Lanzo Lining Services representatives have actively participated in national organizations such as ASTM, NASTT, AWWA, APWA and NASSCO in an effort to assist owners, municipal and plant engineers maintain the most current material specifications. Lanzo Lining Services' objective is to provide a competitive CIPP product that will meet or exceed the EPA mandated fifty-year design life. To satisfy ASTM and municipal/industrial specifications it is critical to select tubes, resin, and catalyst products from qualified suppliers providing the highest quality materials and services. Lanzo Lining Services only uses the finest quality manufactured products and supplies from ISO 9000 certified sources. In the following sections, minimum and typical property values for the fabric and resin products are provided. In order to remain competitive while providing the highest quality CIPP; Lanzo Lining has continued to review and update the following published criteria, as the industry and job conditions necessitate.

FABRIC TUBE MATERIALS

The flexible fabric tube is one of several key elements of the CIPP process. The materials used to construct tubes must possess chemical resistance, flexibility, an ability to stretch and conform to irregular piping, and be durable to withstand the rigors of underground construction. Currently, the most commonly used fabric tube material in North America is composed of thermoplastic polyester fibers needled into a dense felt. However fabric tubes made of combinations of needled polyester and polypropylene fibers and needled polyester with various fiber reinforcements are also available. Depending on fiber orientation, liners constructed of fiberglass tubes can easily produce a flexural modulus that would exceed 1,000,000psi and flexural strength values over 15,000psi. At the time this criteria was placed in the referenced ASTM specifications the targeted material(s) were needled polyester felt and coated polyester felt. Many coatings may actually enhance the properties of a tube. Table 2 includes typical values for plain polyester felt and coated polyester felt.

Table 2. Typical tensile properties for polyester felt and plastic coated felt.

Material	% Elongation at Failure	Ultimate Tensile Strength
Felt	85-95	800-1000 psi
Plastic coated felt	70-75	1200-1500 psi

THERMOSET RESINS

Resins Overview and Properties

The thermosetting resins used for CIPP are the most important component to the short- and long-term performance of the product. First, there is a distinction between initial or short-term properties and the long-term performance that dictates the life span of a product. Short-term properties include parameters such as flexural, tensile, and compressive properties. Long-term properties include parameters such as chemical resistance, creep, and strain corrosion. Most all these parameters are important for the qualification, design, and performance of CIPP.

There are three main groups of thermoset resins used for CIPP and they consist of polyester, vinyl ester and epoxy resins. Within each of these three categories exist hundreds of combinations of products with their own characteristics that distinguish their performance. A number of papers have been published that generally review the short- and long-term performance of these three classifications of thermoset resins. In general epoxy and vinyl ester resins are higher performance products compared to polyester resins. They have higher strength, elongation, elevated thermal and chemical resistance compared to polyesters. However, not all pipe rehabilitation applications require the elevated performance of a vinyl ester or epoxy resin. The vast majority of standard gravity flow sewer pipe rehabilitated has been accomplished with polyester resins. However, since there are so many types of products within each category typical properties provided are given as a range of values that could be expected. Table 3 provides some typical properties of neat resins formulated for CIPP that have 'not' been combined with any fabrics or specialty fillers.

Frontal view of 60 inch diameter direct inversion

Finished outfall product at the headwall

Table 3. Typical neat physical properties.

Test Property	Epoxy Resin	Epoxy Vinyl Ester	Isophthalic Polyester
Flexural Modulus[1], psi	500,000-550,000	500,000-570,000	500,000-570,000
Flexural Strength, psi	15,000-25,000	15,000-25,000	10,000-18,000
Maximum Strain, %	4-7%	4-7%	3-5%
Tensile Modulus[2], psi	490,000-540,000	490,000-560,000	490,000-560,000
Tensile Strength, psi	8,000-10,000	8,000-10,000	5,000-8,000
Tensile Elongation, %	4-7%	4-7%	2-5%

1 Flexural properties determined by ASTM D790

2 Tensile properties determined by ASTM D638

Resin/Felt and Resin/Fiber Composite Properties

When the aforementioned thermoset resins are combined with the flexible fabric of a tube, material properties can be dramatically changed, as previously overviewed in the FABRIC TUBE MATERIALS section. The following discussion will focus primarily on the effects of needled polyester felt tubes on the material properties of a thermoset composite. There are several reasons for the observed effect on physical properties. First, the randomly oriented needled fibers of a felt tube are not oriented in a manner that can become load bearing. Therefore, modulus or stiffness and strength values are often reduced 30-50% compared to the neat resin properties. However, it is not as simple as it appears, since fiber types, sizes, orientation, and felt density can also affect material properties. In addition, felts made of combinations of polyester, polypropylene, and/or polyethylene fibers have varying performance due to the level of resin adhesion to the fiber(s). Polyester fibers tend to slightly solvate when exposed to styrene based resins (i.e. polyester and vinyl ester) and bond extremely well. Tubes made with a combination of polyester felt and fiberglass fibers or entirely with fiberglass can produce extremely high physical properties. By so doing, the designer can produce CIPP with a reduced wall thickness, but still perform extremely well for either external hydrostatic pressure or internal pressure applications.

The resin component of the resin/felt or resin/fiberglass composite can also be modified with fillers to effect the processing parameters and the mechanical properties of the composite. The viscosity of thermoset resins developed for CIPP are modified with specialty fillers called thixotropes. Thixotropic fillers are added at small levels (i.e. 1-3%) to increase the viscosity of the resins so that they stay in the tube fabric during processing and installation and do not drain out of the tube and into the host pipe, ground, lateral connections, etc. Thixotropes typically do not effect physical properties since they are added at such low quantities.

Other mineral fillers such as aluminum trihydrate (ATH) are also added to resin to enhance the overall material properties. Newer formulations with calcium carbonate and calcium carbonate/ATH combinations have been developed and have recently been introduced to the market. ATH and other fillers are added to significantly increase the modulus (i.e. stiffness) of the overall composite without diminishing the resins' processability, or decreasing the strength or the chemical resistance of the CIPP. Increasing the modulus of the composite can provide some cost advantages when designing CIPP and this is reviewed in the ENGINEERING DESIGN section of the manual. In addition to design advantages, resins with fillers have an increased thermal conductivity and therefore heat up more uniformly through the entire thickness of the tube which is especially helpful when working in cold climates. Fillers reduce resin and tube shrinkage during curing and cool down, which provides a tighter fit to the host pipe after the CIPP is installed. To illustrate the effects of resin/felt composite properties in Table 4 is provided with typical properties. As consistent with Table 3, these properties are generated from experimental panels made in laboratory conditions and should not be misconstrued to be typical of all installed CIPP.

Table 4. Typical property ranges for resin/felt composites consistent with CIPP construction.

Test Property	Epoxy Resin Data	Epoxy Vinyl Ester Data	Isophthalic Polyester Data	Filled Isophthalic Polyester Data
Flexural Modulus, psi	480,000-550,000	480,000-570,000	480,000-570,000	550,000-750,000
Flexural Strength, psi	10,000-12,000	10,000-12,000	7,000-9,000	7,000-8,500
Maximum Strain, %	3-5%	3-5%	2-4%	2-4%
Tensile Modulus, psi	490,000-540,000	490,000-560,000	490,000-560,000	550,000-750,000
Tensile Strength, psi	7,000-10,000	7,000-10,000	6,000-9,000	5,000-8,000
Tensile Elongation, %	2-4%	2-4%	1-3%	1-3%

Minimum Recommended Design Properties

Typical properties of neat and resin/felt composites produced in the laboratory are not typical of the product produced in the field. When all the parameters of the preparation, installation, curing, and sampling are carefully monitored and controlled the properties of installed CIPP fall within the median range of data provided in Table 4. However, there are many uncontrollable variables of an underground construction project that can negatively affect the end product. The net overall result is that variability is increased and the variability in the test data also increases. Therefore, minimum property values have been established within the industry to provide a conservative minimum value for flexural and tensile properties of installed CIPP. Table 5 provides recommended minimum design values for standard CIPP. The values in Table 5 are relatively low compared to the values of Table 4, but the median value of installed CIPP is typically 15-25% higher than minimums. However, cold weather, high groundwater, poor water or steam circulation and/or equipment failure can produce reduced properties just above the minimum standards. In effect, the majority of all CIPP installed essentially has an additional factor of safety due to the conservative design practices that have been adopted in ASTM standards. Minimum properties are given for both flexural and tensile properties, but it should be pointed out that tensile properties are only used in the design of fully deteriorated (stand-alone) internal pressure pipe.

Although not emphasized in this design guide, minimum properties using fiberglass reinforced liners might be specified with a flexural modulus that would exceed 1,000,000psi and strengths that would exceed 10,000psi for gravity flow applications. With proper fiber orientation, tensile properties can also be greatly enhanced for internal pressure applications like NSF 61 potable water pipe rehabilitation and/or sewer force mains.

Table 5. Minimum recommended design properties for CIPP.

Test Property	Epoxy Resin Data	Epoxy Vinyl Ester Data	Isophthalic Polyester Data	Filled Isophthalic Polyester Data
Flexural Modulus, psi	250,000-300,000	350,000-450,000	250,000-350,000	400,000
Flexural Strength, psi	5,500	5,500	5,500	5,500
Tensile Strength, psi	3,000-5,000	3,000-5,000	3,000-5,000	3,000-5,000

Creep Properties of Thermosetting Resins

Engineering materials of all kinds deform when placed under a load and this is a basis for careful engineering and design for any structural application. When materials such as thermoset and thermoplastic resins are subjected to low loads relative to their ultimate breaking point they will experience incremental deformation occurring over a period of time. These deformations occurring over the design life of a product is referred to as creep. Creep is affected by many factors that include the type of material being analyzed, the degree of cure (for thermoset resins), environmental conditions (temperature, chemical agents), and the amount of load applied. For the thermoset resins used for CIPP creep is an important design parameter that must be taken into account to provide an adequate factor of safety over the design life of the pipe. Loading on CIPP occurs when it is installed under the water table and uniform hydrostatic pressure pushes uniformly around the circumference of the CIPP. Additional forces can occur where CIPP is installed in unstable soil conditions and/or live loads act on the pipe. In these cases the loads may not be uniform, but would push down on the upper half of the CIPP creating a combination of complex loading conditions.

In order to understand long-term creep performance of common resin/felt composites mechanical tests have been developed to characterize the performance of CIPP. The typical expected design life of CIPP is fifty (50) years so testing is performed in a way to estimate long-term performance and produce a safety factor that can be applied to the design of CIPP. Tests include hydrostatic buckling and three point bend tests performed under constant loading conditions. Tests are typically performed over a time period of 10,000 hours. The data is statistically fit to a line and extrapolated out to fifty (50) years for the design life of the CIPP. The reduction of stiffness due to creep is applied to the short-term flexural modulus (as given in Table 5) to estimate a long-term modulus (EL). Many confidential research projects have been conducted without publication until Louisiana Tech University carried out a research program to evaluate the long-term performance of a number of pipe lining products [17]. The results of this study have been highly controversial due to criticism over uncontrolled variables and statistical data treatment. However, this research created a basis for additional analysis and comparison between hydrostatic testing and three-point bend testing as specified in ASTM D2990 [18].

Published results of the aforementioned testing indicate factors like degree of cure, loading level, thermal and chemical environment, and type of resin and/or reinforcement will affect the amount of creep that may be experienced over the life of installed CIPP. Therefore, test results have been analyzed to develop a conservative recommendation for creep. When all conditions are set equal it is generally understood that there are differences between resin types. Therefore, the minimum recommendations in Table 6 given for the different resin categories used for CIPP are multiplied times the short-term modulus or strength to obtain the estimated EL (long-term modulus), sL (long-term flexural strength), or stL (long-term tensile strength) used for long-term CIPP design. For special applications such as pressure pipe, industrial chemical exposure, and/or elevated temperature consult Lanzo Lining for creep recommendations.

Table 6. Recommended minimum factors for creep

	Epoxy* Resin	Epoxy Vinyl Ester	Isophthalic Polyester	Filled Isophthalic Polyester
Creep Factor	0.25 - 0.6	0.5 - 0.6	0.4 - 0.5	0.4 - 0.5

*The creep factor of epoxy resins is quite variable depending on the curing agent chosen. Consult Lanzo Lining technical services for proper recommendations.

Thermal Properties of Thermoset Resins

The thermal properties of thermoset resins are measured by the heat distortion temperature (HDT). The HDT is not the only method of determining the performance of resins at elevated temperature, but is a commonly used indicator. Thermoset resins have what is called a glass transition temperature (Tg) where their properties changing from a glassy or rigid state to a softer or rubbery state. When the temperature reaches and goes beyond the Tg of a particular resin its physical properties diminish significantly. However, as temperatures approach the HDT physical properties remain fairly constant. The Tg and HDT of resins are determined by the inherent chemistry of the resin and the degree of cure. Typical HDT values are provided for the different categories of thermoset resins in Table 7. When pipe rehabilitation products will be required to perform continuously at elevated temperatures alternative resins and/or additional factors of safety may be required to compensate for the resulting reduction of stiffness and/or strength.

Table 7. Typical heat distortion temperatures (HDT) for thermoset resins used for CIPP.

	Epoxy Resin	Epoxy Vinyl Ester	Isophthalic Polyester	Filled Isophthalic Polyester
HDT	150-225F	200-245F	190-225F	190-225F

Chemical Resistance Properties of Thermosetting Resins

By the nature of the application, most CIPP will be exposed to some type of chemical environment. Since most applications involve a combination of chemicals at varying concentrations it is difficult to evaluate all the possibilities that may be necessary to define the exact performance. To simplify this analysis standard chemicals are chosen at higher than normal concentrations. Testing can also be done at elevated temperatures to accelerate the effects of these chemicals on the resin/felt composites. To date there is no defined test method for specifically evaluating CIPP composites. The standard practice currently used is to adopt a modified version of ASTM C581, which was developed for fiberglass/resin composites. By so doing, four resin/felt coupons are submerged into the chemical of interest. At intervals of 30, 90, 180 and 360 days a coupon is removed from the chemical, weighed, measured, and tested for flexural properties. At the end of one year these separate evaluations are compared to a control coupon that was not exposed to the chemical. The one aspect of this test method that can create anomalies arises when the test coupons are not uniform. In other words, all five coupons should initially have identical physical properties before the testing starts. If one or several coupons had significantly higher or lower physical properties initially, this may adversely effect of the outcome of the protocol with an anomalous data point(s). For such cases it is common to eliminate that data point from the data set and use the remaining data as an indication of the overall performance.

Table 8 provides a set of chemical resistance performance for the different types of thermoset resins used for CIPP in a number of different chemicals. This set of chemical data was performed at an elevated temperature of 120F. The one-year data was statistically fit and extrapolated out to obtain a prediction of performance at 25 years. From the data it is clear that different resin categories perform differently in groups of chemicals. Isophthalic polyester resins generally perform extremely well in acidic chemicals (i.e. sulfuric, nitric, hydrochloric acids), but perform moderately in oxidizing agents (i.e. sodium hypochlorite, potassium permanganate, hydrogen peroxide), and poorly in basic chemicals (i.e. ammonium hydroxide, sodium hydroxide). Epoxy resins generally perform extremely well in basic chemicals, but also can withstand acidic and oxidizing chemicals. Epoxy vinyl ester resins have excellent overall chemical resistance to all three categories of chemicals.

Table 9 provides and estimate of the retention of physical properties of resin/felt composites using the chemical agents specified in ASTM F1216. The data obtained in Table 9 was run at room temperature and evaluated for a period of one (1) year. Several different resin types were tested and the 1, 3, 6 and 12 month data was averaged to obtain an overall estimate of the one-year retention of physical properties. This set of tests indicates a high level of chemical resistance to all the chemicals when evaluated at the aforementioned conditions. There also appears to be no significant difference between the standard polyester and the filled polyester resins.

When specifying a resin for CIPP it is obvious one must consider the chemical environment of the application. Since most sewerage applications are acidic in nature, isophthalic polyester resins typically are adequate and work well in this environment. However, it is often difficult to predict what may be introduced into a municipal sewer or industrial piping system. For example, odor-reducing chemicals commonly used in municipal sewers could be potentially damaging to polyester resins, while not effecting epoxy or epoxy vinyl ester resins. As the environment and managing personnel change over years, common practices also change, thereby changing the requirements of the CIPP.

Large bore trenchless renovation in "tight quarters"

Table 8. Chemical Resistance of Thermoset Resins Used for CIPP. Estimated Percent Retention of Flexural Properties.

		Percent Retention of Flexural Properties					
		Epoxy Vinyl Ester		Epoxy		Isophthalic Polyester	
Chemical Tested	Flexural Property	1 Year Actual	25 Years Estimated	1 Year Actual	25 Years Estimated	1 Year Actual	25 Years Estimated
2.5% Sodium	Modulus	100	99	30	42	0	0
Hypochlorite	Strength	100+	100+	42	45	0	0
5%Hydrogen	Modulus	96	94	76	84	75	65
Peroxide	Strength	100	100	66	84	83	76
5% Potassium	Modulus	100+	100+	90	83	84	77
Permanganate	Strength	98	97	83	60	62	49
5% Sodium	Modulus	74	65	78	88	0	0
Hydroxide	Strength	79	71	75	72	0	0
5% Ammonium	Modulus	76	65	66	65	35	22
Hydroxide	Strength	72	61	64	54	38	25
25% Sulfuric	Modulus	100+	100+	93	93	92	89
Acid	Strength	97	95	90	100+	93	91
20% Hydrochloric	Modulus	100+	100+	93	89	84	78
Acid	Strength	100+	100+	99	95	79	70
5% Nitric	Modulus	100+	100+	91	85	86	79
Acid	Strength	100+	100+	100+	82	82	75

Note: 100+ indicates the curve fit would predict physical property retention greater than 100%.

Table 9. Average Chemical Resistance of Typical Thermoset Resins Evaluated for One Year Using Chemicals Specified in ASTM F1216.

		Percent Retention of Flexural Properties		
Chemical Tested	Physical Property	Epoxy Vinyl Ester	Isophthalic polyester	Filled Isophthalic Polyester
10% Sulfuric	Modulus	92	98	90
Acid	Strength	90	87	94
5% Nitric	Modulus	98	95	86
Acid	Strength	93	87	99
10% Phosphoric	Modulus	87	94	87
Acid	Strength	89	90	99
100% Gasoline	Modulus	101	98	90
	Strength	94	94	95
100% Vegetable	Modulus	102	99	95
Oil	Strength	100	94	100
Tap Water	Modulus	92	95	85
	Strength	90	85	99
0.1% Detergent	Modulus	110	94	90
	Strength	108	90	94
0.1% Soap	Modulus	99	93	85
	Strength	95	89	98

CIPP installation at Joe Louis Arena – Home of the Detroit Red Wings

Rehabilitation of 900 feet of 72-inch sanitary trunk sewer at "The Joe"

STRUCTURAL DESIGN OF CIPP

In the previous sections of this Engineering Design Manual ASTM specifications F1216 and F1743 have been reviewed and the design equations utilized in this manual will conform to the requirements of these specifications. Alternative designs for CIPP have merits and potentially offer more accurate predictions of performance. However, it is not the purpose of this Design Manual to advocate or implement the use of these alternative design equations until they have been accepted and adopted by specifying organizations such as ASTM. In order to provide a basis for theses design models a review of the development of the design theory used in the ASTM standards will be discussed. To put these theories into perspective an overview of some recently introduced modeling alternatives will also be discussed in this manual.

DESIGN BACKGROUND

The objective of buried pipe design evolves around the ability to develop a set of equations that can take forces of ground water, soil loading and other pressures such as live loads into consideration. Through practical experience and scientific study it was determined that cylindrical structures such as tubes or pipe failed by buckling when exposed to an external load. Some of the earliest proven buckling theories published were carried out by Timoshenko and others in the early 1900's [19]. This work focused on buckling behavior of thin wall tubes. These equations were subsequently modified to take into account long tubes having a practical thickness consistent with the building materials available at the time. One of the first practical applications of this work was the successful development of the first submarines. The unrestrained buckling equation that was developed for long thin tubes is given as follows:

$$Pw = \frac{2\,E\,t^3}{(1 - v^2)\,D_m^3} \qquad (1)$$

where,	Pw	=	Hydrostatic water pressure
	E	=	Modulus of elasticity of the pipe
	t	=	Pipe wall thickness
	v	=	Poisson's ratio, typically = 0.3
	D_m	=	Mean pipe diameter (Do - t)
	Do	=	Mean outer CIPP diameter

In the 1940's Spangler published work that was conducted on flexible piping systems[20]. This work was the basis by which pipe stiffness of flexible pipes was derived. The measurement of pipe stiffness has been standardized with ASTM D2412[21] and is determined at a pipe deflection of 5%. This is a relatively simple test and is performed on free standing, unsupported pipe placed between two parallel plates that are pressed towards each other at a controlled rate. Spangler's also developed a model for the deflection of buried flexible pipe that took into account factors such as dead load forces, pipe bedding, and soil modulus[20].

Work by these early pioneering engineers was extremely important in laying the foundation that is the basis of the design equations used for CIPP. However, it is important to understand that there is very little similarity between the loading experienced by installed CIPP and that of buried rigid or flexible pipe. CIPP is installed into existing pipe that has typically been buried for many years. As such, the soil has long since consolidated and the soil pipe system is typically very stable. Therefore, installed CIPP is supported by the soil pipe system and subsequent pipe deflections can be expected to be minimal. When CIPP is installed into an existing pipe the surrounding pipe provides constrained ring support to the CIPP under the influence of uniform hydrostatic water pressure. When CIPP is exposed to this type of loading the CIPP is under compression. If the load increases to a critical level the CIPP will eventually deform and fail by buckling. Hydrostatic buckling experiments carried out by Aggerwal and Cooper[22], Lo and Zhang[23], and Kleweno[24] have clearly demonstrated practical ranges of the enhancement that can be obtained by the support provided by the host pipe. These studies demonstrated that supported CIPP can buckle at pressures that are seven to fifteen times greater than that of unrestrained CIPP. In order to account for this support in the development of buckling equations used in the design of CIPP this phenomenon was characterized as an enhancement factor and assigned the variable "K". The enhancement factor is the ratio between the restrained buckling pressure and the unrestrained buckling pressure. By applying a statistical treatment of the data generated by Aggerwal and Cooper the value of K was assigned a value of seven (7). In other words, there is high statistical confidence that the restrained buckling pressure will be at least seven times greater than the unrestrained buckling pressure. By applying the enhancement factor and appropriate safety factors to the buckling equation attributed to Timeshenko, CIPP can be designed to easily withstand the hydrostatic forces that are prevalent around the pipe. In most practical applications, CIPP is installed in conditions where the hydrostatic pressure is significantly less than the critical buckling pressure. As such CIPP failure may still occur, but would occur over a very long period of time. This type of long-term buckling failure occurs as a result of plastic creep deformation. Materials such as thermoset and thermoplastic resins will undergo slight deformations over time when exposed to a constant load, such as hydrostatic water pressure. Given enough pressure and a long enough period of time, the CIPP can deform to the extent that it will produce catastrophic failure by buckling. In order to take the long term effects of creep into account the modulus of elasticity in the buckling equation attributed to Timeshenko was modified to a long-term modulus. In addition, a safety factor and correction for pipe ovality was also added to obtain the restrained buckling equation. By substituting the dimension ratio (DR) for the mean diameter and rearranging, the equation reduces as given below:

$$Pw = \frac{2KE_L}{(1 - v^2)} \frac{1}{(DR - 1)^3} \frac{C}{N} \qquad (2)$$

where, E_L = Long-term modulus of elasticity of the pipe material
K = Enhancement factor, typically K = 7
DR = Do/t, Do = mean outside diameter of the CIPP
N = Safety factor
C = Ovality correction factor (See Appendix Table 12)

$$C = [Domin/(Domax)^2]^3 = [(1 - q/100) / (1 + q/100)^2]^3 = (r/re)^3 \qquad (3)$$

$$q = 100 \times \frac{(D - Dmin)}{D}, \text{ or } 100 \times \frac{(Dmax - D)}{D} \qquad (4)$$

where, C = Ovality reduction factor
q = Percentage of ovality of the original pipe
D = Inside diameter of the original pipe
Dmin = Minimum inside diameter of the original pipe
Dmax = Maximum inside diameter of the original pipe

The effects of long-term hydrostatic buckling of installed CIPP was studied by the Trenchless Technology Center (TTC) at Louisiana Tech University by Guice in 1994[17]. The study carried out by the TTC was an investigation into the long-term structural performance comparing the critical buckling behavior of several pipe rehabilitation systems (i.e. five cured-in-place pipe (CIPP) and one PVC fold and form (FNF)) from a number of commercial product manufacturers. These pipe rehabilitation products were installed in sections of round steel pipe that were sealed with gaskets on the ends.. The annular space between the steel pipe and the liner were pressurized with water at a number of different pressures and monitored over time as the products creeped, deformed, and eventually failed by buckling. Although the report was extensive the data produced had significant scatter and has been the subject of many subsequent papers that questioned the inability to control experimental variables. Subsequent reports and presentations (McAlpine, 1996[25], 1996[26]) have pointed out the flaws of the testing program. These flaws include: 1) testing carried out in perfectly round steel pipe, 2) the CIPP was manufactured above ground under highly controlled conditions, 3) tested under controlled temperature and humidity conditions, 4) no influence of chemicals typically found in sanitary sewer conditions, and 5) lack of detailed statistical analysis. In recent years long-term tests have been extensively analyzed in an attempt to develop experimental protocols that can carefully control variables for long- and short-term hydrostatic buckling. In addition, there has been considerable research to define the relationship between EL and K, and/or to develop alternative buckling models that correlate more closely with data. The model developed by Glock[27] has gained considerable support (Guice & Li, [28], Schrock & Gumbel, [29]) as a more accurately representing existing data. New models being proposed are refinements that can represent pipe imperfections (Moore[30]) and ovality (Omara[31])) more accurately. With all the potential problems pointed out by a number of authors regarding the modified buckling equation that is currently used in ASTM F1216 and ASTM F1743, this equation appears to be providing a conservative design basis for pipe lining systems as evidenced by the lack of failures over the 30+ years of its use.

Since there is currently no single design equation that can be used for all the different conditions that must be taken into account for the proper design of CIPP it is necessary to divide these conditions into different groups. For both gravity flow and internal pressure design equations have been divided into categories of "partially deteriorated" and "fully deteriorated" conditions of the existing pipe to be rehabilitated. These piping conditions are defined as follows:

Partially Deteriorated Piping Condition

A partially deteriorated gravity flow pipe is one in which the existing pipe may have displaced joints, cracks or corrosion, but is structurally able to support all soil and surface loads. In this case the existing pipe is intended to provide structural support over the full circumference of the CIPP. When assuming a pipe is partially deteriorated, the CIPP will be designed to withstand uniform hydrostatic pressure over the full circumference of the CIPP. In addition, as a conservative approach, this design does not assume that the CIPP is attached to the existing pipe in any way.

A partially deteriorated pressure pipe is one in which the existing pipe may also have minor corrosion, leaking joints, and/or small holes, and should be free of any longitudinal cracks. In this case the existing pipe is assumed to be able to withstand the specified internal design pressure over the expected lifetime of the pipe. When assuming a pressure pipe is partially deteriorated, it is assumed that the CIPP will conform tightly against the host pipe everywhere (i.e. in bends or diameter changes, etc.) and uses the strength of the existing pipe to support the stresses. The thickness of the CIPP can be compensated to span small holes or leaking joints, but will not be of sufficient thickness to withstand design pressures. In addition, if the partially deteriorated pressure pipe is assumed to be leaking the designer must also be aware of external hydrostatic pressure to insure that the minimum CIPP thickness is sufficient to withstand these forces over the design life of the product.

Fully Deteriorated Piping Condition

A fully deteriorated gravity flow pipe is one in which the existing pipe has insufficient strength to support all soil and surface loads. A fully deteriorated pipe is characterized by severe corrosion, missing pipe, crushed pipe, longitudinal cracks, and severely deformed pipe. When assuming a pipe is fully deteriorated, the CIPP is designed as a pipe able to withstand all hydrostatic, soil, and live loads that may exist in the CIPP-soil system with adequate soil support.

An alternative strategy for fully deteriorated gravity flow pipes is available to the designer in areas where there are isolated sections of missing or severely offset pipe that would otherwise cause it to be classified as fully deteriorated. In these areas it may be possible to carry out point repairs, and rehabilitate the pipe as a partially deteriorated classification. However, each situation must be considered separately.

A fully deteriorated pressure pipe is one in which the existing pipe has failed and/or has insufficient strength to operate at specified design pressures. A pipe may also be classified as fully deteriorated if it is determined that it will not be able to withstand design pressures at some point during the expected lifetime. A fully deteriorated pressure pipe is characterized by significant loss of wall thickness due to severe corrosion, large holes, missing sections of pipe, and leaking longitudinal cracks. When assuming a pipe is fully deteriorated, the CIPP is designed as a stand alone pipe able to withstand all internal pressure. In addition, the designer must also be aware that fully deteriorated CIPP pressure pipe must be capable of withstanding external hydrostatic pressure.

PARTIALLY DETERIORATED GRAVITY FLOW CIPP DESIGN

When rehabilitating existing pipe that has been classified as partially deteriorated in a gravity flow condition the restrained buckling condition applies. In this case the classical buckling equation that has been described previously is re-arranged to solve for CIPP thickness as follows:

$$t = \frac{Do}{\left(\frac{2KE_LC}{PwN(1 - v^2)}\right)^{1/3} + 1} \qquad (5)$$

where,

Do	=	Mean outer CIPP diameter, inches
K	=	Enhancement factor, typically K = 7
E_L	=	Long-term modulus of elasticity of the pipe material
C	=	Ovality correction factor (See Appendix Table 12)
Pw	=	External water pressure measured above the pipe invert (See Appendix Table 13)
N	=	Safety factor, typically N = 1.5 - 2.0
v	=	Poisson's ratio, typically v = 0.3

For partially deteriorated design conditions where the groundwater is below the invert of the pipe the hydrostatic pressure is equal to zero and the restrained buckling equation cannot be used to calculate CIPP thickness. For this special design case the calculated thickness of the CIPP must be equal to or greater than that which will produce a maximum dimension ratio of DR = 100. When this special design condition exists, CIPP thickness is determined by the following equation:

$$t = Do/100 \qquad (6)$$

When designing for circular partially deteriorated pipe the CIPP is under constant compressive hoop stresses. If the existing pipe is out of round or has localized ovalization, bending moment forces may predominate on the CIPP. For this special case the CIPP must be checked to insure that the bending forces do not exceed the long-term flexural strength of the CIPP. To make this determination the bending stresses on the CIPP are determined by the following equation:

$$\frac{S}{PwN} = [1.5q/100\ (1 + q/100)DR^2] - [0.5(1 + q/100)DR] \qquad (7)$$

where q is defined by Equation 4 and the other parameters have been defined previously.

Partially Deteriorated Design Example

Determine the minimum wall thickness required of the following piping condition:

1) Existing pipe classification = Partially deteriorated

2) Mean outer CIPP diameter (Do) = 24 inches

3) Minimum pipe diameter (Dmin) = 23.1 inches
4) External water above invert = 8 feet
5) Minimum CIPP modulus (E) = 350,000 psi
6) Minimum CIPP strength (s) = 5,500 psi
7) Long-term modulus (E_L) = 175,000 psi
8) Long-term strength (s_L) = 2750 psi

A. Determine hydrostatic pressure acting on CIPP

P = 8 ft x 0.433 psi/ft water = 3.46 psi

B. Calculate the pipe ovality

Determine q using Equation 4.

q = 100(24 - 23.1)/24 = 3.75%

Determine ovality reduction factor using Equation 3

$C = [(1 - 3.75/100)/(1 + 3.75/100)^2]^3 = 0.715$

C. Determine minimum CIPP design thickness using buckling Equation 5

$$t = \frac{24}{\left(\frac{2(7)175{,}000(.715)}{(3.46)2(1 - .32)}\right)^{1/3} + 1} = 0.36 \text{ inches}$$

D. Because the pipe is out of round, bending stresses must be calculated to insure they do not exceed the long-term flexural strength of the CIPP

Determine S using Equation 7

DR = Do/t = 24/0.36 = 66.6

$S/(3.46)2 = [1.5(3.75/100)(1 + 3.75/100)66.6^2] – [0.5(1 + 3.75/100)66.6]$

S = 1552.2 psi

E. The minimum CIPP design thickness is 0.36 inches because the bending stresses are less than the long-term CIPP flexural strength. However, if the bending stresses had exceeded the long-term flexural strength then this equation would control the design. In this case solving for the proper thickness can be accomplished by trial and error. Start by choosing dimension ratios (DR) that are smaller than previously used until the bending stress is less than the long-term flexural strength of the CIPP.

FULLY DETERIORATED GRAVITY FLOW CIPP DESIGN

When rehabilitating existing pipe that has been classified as fully deteriorated in a gravity flow condition ASTM F1216 and ASTM F1743 specifies the use of a design equation from AWWA C950 that has been modified by adding the ovality reduction factor, and the consideration of long-term effects due to creep. In this case the modified AWWA C950 equation from ASTM F1216 has been re-arranged to solve for CIPP thickness as follows:

$$t = .721\, Do \left(\frac{(NP_t)^2}{CE_L Rw B' E'}\right)^{1/3} \qquad (8)$$

where, P_t = Total pressure due to water, soil and live load acting on pipe, psi

Rw = Buoyancy factor, dimensionless

B' = Empirical coefficient of elastic support, dimensionless

E' = Modulus of elasticity of adjacent soils or soil reaction, psi

The CIPP designed by the modified AWWA C950 formula is required to have a minimum stiffness (EI/Do3) which is 50% of the specification. The AWWA C950 specification calls for EI/Do3 to be equal to 0.186 and 50% of this value is 0.093. In the following equation this means that pipe designed with a flexural modulus of elasticity E = 350,000 psi would have a dimension ratio equal to 67 for fully deteriorated pipe. If the CIPP stiffness is too low, the wall thickness must be increased accordingly to insure that the following design condition is met:

$$EI/Do^3 = E/12(DR)^3 \geq 0.093 \quad (9)$$

where, E = Flexural modulus of elasticity of the CIPP, psi

I = Moment of inertia, in^4, in = $t^3/12$

When designing fully deteriorated CIPP where the existing pipe is out of round or the CIPP may have localized ovalization, bending moment forces may predominate on the CIPP. For this special case of the fully deteriorated design the CIPP must be checked to insure that the bending forces do not exceed the long-term flexural strength of the CIPP. To make this determination the bending stresses on the CIPP are determined by modifying Equation 7 and substituting total pressure (Pt) to produce the following equation:

$$\frac{S_L}{P_t N} = [1.5q/100\ (1 + q/100)DR^2] - [0.5(1 + q/100)DR] \quad (10)$$

where q is defined by Equation 4 and the other parameters have been defined previously.

Total External Pressure on CIPP

Several new parameters are introduced for the design of fully deteriorated gravity flow pipe. This manual is intended to provide simplistic explanations of these design parameters that have not been provided in ASTM F1216 or other design guides currently available. When determining fully deteriorated designs all loads acting on the CIPP must be estimated to determine the total pressure (Pt). This is accomplished by estimating the contribution of each individual load and adding them together. The total load is typically made up of hydrostatic water pressure (Pw'), buoyancy corrected soil load (Ps), superimposed or live loads (PL), and other loads such a vacuum (Pv). Loading due to vacuum is a special case and will not be handled here. Consult Lanzo Lining Services for recommendations related to vacuum loading. The total pressure acting on the pipe can be represented as follows:

$$P = Pw' + Ps + P_L + Pv \quad (11)$$

Hydrostatic Water and Soil Loads

Initially, groundwater and soil heights must be determined or estimated to begin the design process. For the fully deteriorated design condition be careful to note that groundwater and soil heights are determined from the top of the pipe and not the invert. The hydrostatic pressure is determined as follows:

$$Pw' = Hw\ (.433psi/ft\ water) \quad (12)$$

where, Hw = Water height above the top of the pipe, ft

The contribution related to soil loading involves many different parameters. The soil prism loading pressure is determined as follows:

$$Ps = wHsRw/144in^2/ft^2 \quad (13)$$

where, w = Soil density, lb/ft^3 (See Table 14 for soil types and densities)

Hs = Soil height above top of pipe, ft.

Rw = Water buoyancy factor, dimensionless

$$Rw = 1 - 0.33(Hw/Hs) \geq 0.67 \quad (14)$$

Other related design parameters are the modulus of soil reaction or elastic support (E') and the coefficient of elastic support (B'). The modulus of soil reaction values used for CIPP design should typically represent stable undisturbed soils that would have E' values in the range of 700 to 3000 psi. Most typically a value of 700 psi is recommended for unknown soil conditions. Where the pipe is buried deep and the soil condition is stable values of 1000 to 1500 psi may be applicable. In areas known to have weak and unstable native soils a value of 200 psi may be appropriate. The coefficient of elastic support (B') is determined with the following relationship:

$$B' = 1/(1 + 4e^{-0.065Hs}) \quad (15)$$

Superimposed or Live Loads

For the fully deteriorated design condition dynamic live load pressures occur frequently and are a standard design condition for the parameter PL. Live loads may be classified as either concentrated or distributed, depending on the soil pipe conditions and the depth the pipe is buried. In some cases the live load may be characterized by impact factors. Impact loading is generally only applicable for pipes that are relatively shallow (i.e. 2-5 ft). A number of maximum live load conditions have bee studied and recommended for pipe buried beneath highways, railways, and airport runways. The generally accepted guidelines for determining these live loading conditions are provided by the ASSHTO Standard Specifications for Highway Bridges[32], HS-20-44 highway loading, American Railway Engineers Association (AREA) Cooper E-80 loading, and the Federal Aviation Agency criteria. The most frequently encountered design condition is that for pipes buried under active roads or highways. For highway HS-20 loading the live load becomes insignificant beyond seven feet of soil height cover over the top of the pipe. Live load pressures (PL) associated with the aforementioned piping conditions are given in Table 18.

Fully Deteriorated Design Example

Determine the minimum wall thickness required of the following piping condition:

1) Existing pipe classification	=	Fully deteriorated
2) Mean outer CIPP diameter (Do)	=	48 inches
3) Minimum pipe diameter (Dmin)	=	47.04 inches
4) External water above pipe (Hw)	=	8 feet
5) Depth of soil cover above pipe (Hs)	=	15 feet
6) Type of soil	=	Ordinary Clay (120lb/ft^3)
7) Soil Modulus (E's)	=	700 psi
8) Live load	=	Live load HS-20
9) Minimum CIPP flexural modulus (E)	=	350,000 psi
10) Minimum CIPP flexural strength (s)	=	5,500 psi
11) Long-term modulus (E_L)	=	175,000 psi
12) Long-term strength (S_L)	=	2750 psi

A. Determine the total load

Hydrostatic water pressure

$Pw = 0.433(Hw) = .433psi/ft(8ft) = 3.46$ psi

Soil load

$Ps = wHsRw/144in^2/ft^2$

$Rw = 1 - 0.33(Hw/Hs) \geq 0.67 = 1 - 0.33(8ft/15ft) = 0.824$ which is > 0.67

Ordinary clay soil density = $120lb/ft^3$

$Ps = 120lb/ft^3(15ft)0.824/144in^2/ft^2 = 10.3$ psi

The soil pressure can also be determined by multiplying the Buoyancy Correction Factor (Rw) times the Soil Prism Pressure give in Table 17.

$Ps = 0.824(12.5) = 10.3$ psi

Live load (P_L) (Table 18) ~ 0 psi

Total pressure load applied to the CIPP

$P_t = 3.46$ psi + 10.3 psi = 13.76

B. Calculate coefficient of elastic support

$B' = 1/(1 + 4e^{-0.065Hs})$

$B' = 1/(1 + 4e^{-0.065}(15ft)) = 0.40$ (Table 16)

C. Calculate pipe ovality using Equation 4

$q = 100(48 – 47.04)/48 = 2.0\%$

Determine ovality reduction factor using Equation 3

$C = [(1 - 2.29/100)/(1 + 2.29/100)^2]^3 = 0.84$ (Table 12)

D. Determine the minimum CIPP thickness for buckling

$$t = .721\,Do\left(\frac{(NP_t)^2}{CE_L RwB'E'}\right)^{1/3} = .721(48)\left(\frac{(2.0(13.76))^2}{(.84)(175{,}000)(.824)(.4)(700)}\right)^{1/3}$$

t = 0.975 inch

E. Check for minimum pipe stiffness

$DR = 48/0.975 = 49.2$

$350{,}000/12(49.2)^3 = .26 \geq 0.093$

F. Check for pressure limited due to bending stresses (Equation 10)

$S_L = 13.76(2)[1.5(2)/100(1 + 2.0/100)48^2] – [0.5(1 + 2/100)48]]$

$S_L = 1920$ psi

G. The calculated bending stress (i.e. 1,920psi) is less than the estimated long-term bending strength of the resin (i.e. 2,750psi) so bending stress does not control the design thickness for this example.

Therefore, the final design thickness for the CIPP is:

t = .975 inch

PARTIALLY DETERIORATED INTERNAL PRESSURE PIPE

When designing for internal pressure, it is critical to obtain a proper evaluation of the condition of the pipe being evaluated. Secondary to this is the requirement to understand the proper operating pressure. The third consideration for the design of pressure pipe is an understanding of test pressures, surge pressures and/or water hammer that may significantly exceed the standard operating or test pressures of the pipe. In addition, the project engineer and contractor must be aware that pipe requiring heavy cleaning may change the condition of the pipe from a partially to a fully deteriorated condition. After cleaning it is recommended that pipe classified as partially deteriorated be tested for the operating or test pressure to verify the condition of the pipe prior to lining. If the pipe is able to maintain the specified pressure then it can be classified as partially deteriorated without question. However, this may not always be possible due to the presence of small holes in the pipe that will not allow it to maintain pressure. When the condition of the pipe and/or the operating parameter is not well defined, it is recommended that the pipe be classified as fully deteriorated. Pressure pipe presents a higher risk application of CIPP and it is recommended that the contractor have experience in this area of technology to insure success[33].

The partially deteriorated design equation for internal pressure pipe given in ASTM F1216 was derived with the assumption that the CIPP acts like a uniformly pressurized round flat plate with fixed edges covering an existing hole in the pipe. The CIPP is designed with the assumption that the aforementioned condition prevails and that bending stresses at and around the hole (if one exists) control the design thickness. This design assumption is more conservative than that of a square or rectangular plate.

The equation given in ASTM F1216 has been incorrectly derived with the term DR-1 in the derivation instead of the correct term DR. Although it may be argued that the difference is negligible to the outcome of the calculated thickness, the technically correct derivation will be advocated for use in this engineering design guide. The technically correct derivation for pressure acting on a flat circular plate covering a hole is given below. This equation has been rearranged to solve for CIPP thickness:

$$t = \frac{Do}{[5.33/Pi\ (Do/Dh)^2(S_L/N)]^{0.5} + 1} \qquad (16)$$

where, Do = Mean outer CIPP diameter, inches

Pi = Internal pipe pressure, psi

Dh = Hole diameter in the pipe, inches

S_L = Long-term flexural bending strength for the CIPP, psi

N = Safety factor, N = 2 minimum

In order for the circular flat plate design condition to be valid the following criteria must be met. If this condition is not met then the CIPP cannot be considered a circular flat plate and ring tension or hoop stress will dominate. For this condition the internal pressure condition is designed as a fully deteriorated internal pressure pipe.

$$Dh/Do \leq 1.83(t/Do)^{0.5} \qquad (17)$$

The variables used in Equation 17 have been previously defined.

Once the CIPP thickness has been calculated this value must be compared with the thickness calculated from Equation 5 to confirm that external hydrostatic water pressure does not dominate the design condition. The larger thickness is then selected for the design. Since design Equation 17 is conservative it may at times lead to a greater CIPP thickness than if the CIPP is evaluated in ring tension as an unrestrained, stand-alone pipe. Any internal pressure pipe application is higher risk so it is recommended that a Lanzo Lining Services representative be contacted for assistance in pressure pipe design assistance.

Partially Deteriorated Internal Pressure Pipe Design Example

1) Determine the CIPP thickness for the following piping conditions:

2) Existing pipe classification	=	Partially deteriorated
3) Existing pipe inner diameter (D)	=	15 inches
4) Existing pipe maximum diameter (Dmax)	=	15.2 inches
5) Internal pressure (Pi)	=	80 psi
6) External water (Hw)	=	5 ft above top of pipe
7) Maximum pipe hole diameter (Dh)	=	1 inch
8) Minimum CIPP flexural modulus (E)	=	350,000 psi
9) Minimum CIPP flexural strength (s)	=	5,500 psi
10) Minimum long-term modulus (E_L)	=	175,000 psi
11) Minimum long-term strength (S_L)	=	2,750 psi
12) Minimum long-term tensile strength (S_{tL})	=	1,750 psi

A. Determine the pressure pipe thickness using Equation 16.

$$Do = \frac{D + Dmax}{2} = \frac{15.0 + 15.2}{2}$$

Do = 15.1 inches

$$t = \frac{15.1}{[5.33/80(15.1/1.0)^2(2,750/2.0)]^{1/2} + 1}$$

t = 0.10 inches

B. Check thickness with Equation 17.

$1/15.1 \leq 1.83(0.1/15.1)^{1/2}$

$0.066 \leq 0.149$

The condition of Equation 17 is met

C. Check the thickness for external pressure using Equation 5.

q = 100(15.2 – 15.0)/15.0 = 1.33%

$C = [(1 - 1.33/100)/(1 + 1.33/100)^2]^3 = 0.89$

Pw = 5(.433) = 2.2psi

t = 0.18 inches

The thickness for external pressure is greater than that required for internal pressure and the DR = 84, which is less than 100, as specified in Equation 6.

D. Since the pipe is slightly out of round, the bending stresses must be checked using Equation 7.

$S_L = 2.2(2.0)[[1.5(.0133)(1 + .0133)84^2] - [0.5(1 + .0133)84]]$

S_L = 440, which is less than the long-term flexural strength of the CIPP. Therefore, the final CIPP thickness is t = 0.18 inches.

FULLY DETERIORATED INTERNAL PRESSURE PIPE

As discussed previously, it is critical to understand the physical conditions of the pipe and the operating parameters of the system when designing for the fully deteriorated pressure condition. This pipe classification assumes the existing pipe has no capability to hold any of the pressure and the CIPP must be designed of a proper thickness to hold all internal and external pressure.

For the design of pressure pipes it may assumed that pipes are either thick or thin walled cylinders with uniform pipe wall thickness. Internal pressure produces an internal ring tension loading condition and tensile strength of the resin/fabric matrix used to construct the CIPP is important to the design. As reviewed in the Materials section of the Engineering Design Guide, high performance resins such as vinyl esters and epoxy resins are recommended for pressure applications due to their high tensile strength and elongation properties. Contact Lanzo Lining technical services for recommendations concerning the design and materials selection for pressure pipe.

The design equation for fully deteriorated pressure pipe given in ASTM F1216 assumes pressure pipe is a thick walled cylinder as given below:

$$Pi = \frac{2s_{tL}}{(DR - 2)\ N} \tag{18}$$

The equation for a thin walled cylinder is given as follows:

$$Pi = \frac{2s_{tL}}{(DR - 1)\ N} \tag{19}$$

When rearranged to solve for thickness Equation 19 becomes:

$$t = \frac{Do}{[(2s_{tL}/PiN) + 1]} \tag{20}$$

The variables used in Equation 20 have previously been defined.

Although the differences are relatively small, the solution for a thin walled cylinder is a more conservative approach than ASTM F1216. Therefore, design Equation 20 for a thin walled pressure cylinder will be used for fully deteriorated pressure pipe. When the pressure pipe is underground the CIPP thickness for internal pressure should be checked against Equations 8 and 9 for fully deteriorated gravity flow pipe. The greatest thickness is chosen for the pressure pipe.

Fully Deteriorated Internal Pressure Pipe Design Example

Determine the CIPP thickness for the following pipe design conditions:

1) Existing pipe classification	=	Fully deteriorated
2) Existing pipe inner diameter (D)	=	15 inches
3) Existing pipe maximum diameter (Dmax)	=	15.2 inches
4) Internal pressure (Pi)	=	80 psi
5) External water (Hw)	=	8 ft above top of pipe
6) Soil height (Hs)	=	15 ft above top of pipe
7) Soil type	=	Ordinary Clay (120lb/ft3)
8) Soil modulus (E′)	=	700 psi
9) Minimum CIPP flexural modulus (E)	=	350,000 psi
10) Minimum CIPP flexural strength (s)	=	5,500 psi
11) Minimum long-term modulus (EL)	=	175,000 psi
12) Minimum long-term strength (sL)	=	2,750 psi
13) Minimum long-term tensile strength (stL)	=	1,750 psi

A. Determine the CIPP thickness using Equation 20.

Do = 15.1 (From previous example)

t = 15.1/[(2(1750)/80(2)) + 1] = 0.66 inches

B. Check the CIPP thickness against the fully deteriorated gravity flow design condition for external buckling (Equation 8).

Determine the total pressure

Pt = Pw + Ps + PL = 3.46 + 10.3 + 0 (see previous Fully Deteriorated example)

Pt = 13.76

Determine pipe ovality (see previous example)

q = 1.33% (Equation 4)

C = 0.89 (Equation 3, Table 12)

Determine CIPP thickness using Equation 8.

Rw = 0.824 (Table 15, see previous example)

B′ = 0.40 (Table 16)

$$t = .721Do\left(\frac{[(NP_t)^2]}{CE_L RwB'E'}\right)^{1/3} = .721(15.1)\left(\frac{((2.0)(13.76))^2}{(.89)(175{,}000)(.824)(.4)(700)}\right)^{1/3}$$

t = 0.30 inch

Since 0.30 in ≤ 0.66 inch internal pressure dominates the design.

C. Check the CIPP thickness for minimum pipe stiffness using Equation 9.

DR = 15.1/0.66 = 22.9

$350{,}000/12(22.9)^3 \geq 0.093$

$2.43 \geq 0.093$

D. Since the pipe is slightly out of round, the bending stresses must be checked using Equation 10.

$S_L = 13.76(2.0)[[1.5(1.33)/100(1+1.33/100)22.9^2] + [0.5(1+1.33/100)22.9]]$

S_L = 612 psi, which is less than 2750psi

E. All checks indicate that internal pressure dominates the design of this fully deteriorated pressure pipe and the specified thickness is t = 0.66 inches.

HYDRAULIC DESIGN OF CIPP

GRAVITY FLOW

The installation of CIPP typically improves the flow characteristics of the pipe being rehabilitated. Flow is improved because the inner surface of CIPP is extremely smooth and continuous, without any joints or discontinuities that create friction to flow. Typically the Manning equation is used to predict flow in gravity or open channel piping conditions as follows:

$$Q = VA = \frac{1.486\ AR^{2/3}\ S^{1/2}}{n} \qquad (21)$$

where,	Q	=	Flow rate, cfs
	V	=	Velocity, fps
	A	=	Flow Area
	n	=	Manning coefficient of roughness (see Table 10)
	R	=	Hydraulic radius, ft = A/P
	P	=	Wetted perimeter of flow, ft
	S	=	Slope of grade line, ft(slope)/ft(pipe)

When the pipe is circular and the flow is full as in a surcharged situation the Manning equation may be modified to the following form:

$$Q = \frac{0.463\ D^{8/3}\ S^{1/2}}{n} \qquad (22)$$

where, D = pipe internal diameter, ft.

For circular pipe flowing full the Manning equation can be abbreviated to produce an easy comparison of flow capacity between CIPP and different piping materials as given below:

$$\%\ \text{Flow Capacity} = \frac{Q_{CIPP} \times 100}{Q_{exist}} = \frac{n_{exist}}{n_{CIPP}} \left(\frac{D_{CIPP}}{D_{exist}}\right)^{8/3} \times 100 \qquad (23)$$

Manning coefficients provide a relative comparison of the resistance to flow for different types of pipe and coefficients for several piping materials have been provided in Table 10. There is a large variation in the coefficients for different materials and even variation for the same piping product because these coefficients are dependent on the condition of the pipe evaluated. A conservative average Manning coefficient for CIPP in relatively smooth concrete, clay, or steel pipe is an 'n' of 0.010. However, this coefficient might be subject to change over time as slime and/or debris build up in uncleaned pipe over time.

Gravity Flow Design Example

Problem: Determine the change in flow capacity when a circular 24 inch concrete pipe is flowing full and is lined with a 12 mm thick CIPP.

1. Select Manning coefficients for the piping materials (Table 10).
   a) n' for CIPP = 0.010
   b) 'n' for concrete = 0.015
2. Determine inside pipe diameters.
   a) Existing concrete pipe D = 24 inches
   b) New CIPP D = 24 - 2(12/25.4) = 23.1 inches
3. Determine increased flow capacity using Equation 23.

$$\% \text{ Flow Capacity} = \frac{0.015}{0.10}\left(\frac{23.1}{24.0}\right)^{8/3} \text{x } 100 = 135\%$$

Therefore, it was determined that the CIPP increased the flow of the pipe approximately 135% compared to the existing concrete pipe. This increase in flow was realized even though the inside diameter of the CIPP was slightly smaller than the existing concrete pipe.

PRESSURE FLOW

For pressure flow the Hazen-Williams equation is commonly utilized for determining the flow rate of the pipe. For pressure flow CIPP also increases the flow capacity of a pipe because of the inherent smoothness of the inner surface. The Hazen-Williams equation is given as follows:

$$Q = 1.318\, C\, R^{0.63}\, S^{0.54}\, A \qquad (24)$$

where,	Q	=	Flow rate, cfs
	C	=	Hazen-Williams coefficient (see Table 11)
	R	=	Hydraulic radius, ft = A/P
	A	=	Flow area, ft^2
	P	=	Wetted perimeter of flow, ft
	S	=	Slope of grade line, ft(slope)/ft(pipe)

As shown previously, the Hazen-Williams equation can be simplified to provide a comparison of flow capacity between CIPP and the existing pipe as follows:

$$\% \text{ Flow Capacity} = \frac{Q_{CIPP} \text{ x } 100}{Q_{exist}} = \frac{C_{CIPP}}{C_{exist}}\left(\frac{D_{CIPP}}{D_{exist}}\right)^{8/3} \text{x } 100 \qquad (25)$$

The Hazen-Williams coefficients for different piping materials, or age of materials are provided in Table 11. Determination of flow capacities of CIPP in a pressure application relative to other existing piping materials is calculated in the same manner as given in the gravity flow design example.

APPENDIX

Table 10. Manning Coefficients for Typical Piping Materials.

Pipe Material	Manning 'n' Coefficient	Recommended Manning 'n'
Cured-In-Place Pipe	0.009 - 0.012	0.010
Vitrified Clay	0.013 - 0.017	0.013
Concrete	0.013 - 0.017	0.015
Corrugated Metal	0.019 - 0.030	0.025
Brick	0.015 - 0.017	0.016

Table 11. Hazen-Williams Coefficients for Typical Piping Materials.

Pipe Material/Condition	Recommended Hazen-Williams 'C' Coefficient
Cured-In-Place Pipe	140
New steel or ductile iron (less than 1 year old)	120
Cement lined new steel or ductile iron	140
Steel (2 years old)	120
Steel (10 years old)	100
Cast Iron (5 years old)	120
Cast Iron (18 years old)	100
Tuberculated Steel or Cast Iron	80

Table 12. Ovality reduction factor, C.

$C = [Domin/(Domax)^2]^3$

Percent Ovality	1	2	3	4	5	6	7	8	9	10
Reduction Factor, C	0.91	0.84	0.76	0.70	0.64	0.59	0.54	0.49	0.45	0.41

Easement installation of subdivision sewer rehab

Subaqueous installation of CIPP into storm drain

Table 13. Partially Deteriorated Gravity Flow CIPP Design Thickness.

CIPP Thickness (mm) for each Pipe Diameter (Inches) at the given Depth (feet)																		
Water Depth	**Water Pressure**	**6**	**8**	**10**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**
1	**0.44**	1.1	1.5	1.8	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2
2	**0.87**	1.4	1.8	2.3	2.8	3.5	4.2	4.8	5.5	6.2	6.9	8.3	9.7	11.1	12.5	13.8	15.2	16.6
3	**1.30**	1.6	2.1	2.6	3.2	3.9	4.7	5.5	6.3	7.1	7.9	9.5	11.1	12.6	14.2	15.8	17.4	19.0
4	**1.73**	1.7	2.3	2.9	3.5	4.3	5.2	6.1	6.9	7.8	8.7	10.4	12.2	13.9	15.6	17.4	19.1	20.8
5	**2.17**	1.9	2.5	3.1	3.7	4.7	5.6	6.5	7.5	8.4	9.4	11.2	13.1	15.0	16.8	18.7	20.6	22.4
6	**2.60**	2.0	2.6	3.3	4.0	5.0	6.0	6.9	7.9	8.9	9.9	11.9	13.9	15.9	17.9	19.9	21.8	23.8
7	**3.03**	2.1	2.8	3.5	4.2	5.2	6.3	7.3	8.4	9.4	10.4	12.5	14.6	16.7	18.8	20.9	23.0	25.1
8	**3.46**	2.2	2.9	3.6	4.4	5.5	6.5	7.6	8.7	9.8	10.9	13.1	15.3	17.4	19.6	21.8	24.0	26.2
9	**3.90**	2.3	3.0	3.8	4.5	5.7	6.8	7.9	9.1	10.2	11.3	13.6	15.9	18.1	20.4	22.7	25.0	27.2
10	**4.33**	2.3	3.1	3.9	4.7	5.9	7.0	8.2	9.4	10.6	11.7	14.1	16.4	18.8	21.1	23.5	25.8	28.2
11	**4.76**	2.4	3.2	4.0	4.8	6.1	7.3	8.5	9.7	10.9	12.1	14.5	17.0	19.4	21.8	24.2	26.6	29.1
12	**5.20**	2.5	3.3	4.2	5.0	6.2	7.5	8.7	10.0	11.2	12.5	15.0	17.5	19.9	22.4	24.9	27.4	29.9
13	**5.63**	2.6	3.4	4.3	5.1	6.4	7.7	9.0	10.2	11.5	12.8	15.4	17.9	20.5	23.0	25.6	28.1	30.7
14	**6.06**	2.6	3.5	4.4	5.2	6.6	7.9	9.2	10.5	11.8	13.1	15.7	18.3	21.0	23.6	26.2	28.8	31.5
15	**6.50**	2.7	3.6	4.5	5.4	6.7	8.0	9.4	10.7	12.1	13.4	16.1	18.8	21.5	24.1	26.8	29.5	32.2
16	**6.93**	2.7	3.7	4.6	5.5	6.8	8.2	9.6	11.0	12.3	13.7	16.4	19.2	21.9	24.6	27.4	30.1	32.9
17	**7.36**	2.8	3.7	4.7	5.6	7.0	8.4	9.8	11.2	12.6	14.0	16.8	19.6	22.3	25.1	27.9	30.7	33.5
18	**7.79**	2.8	3.8	4.7	5.7	7.1	8.5	10.0	11.4	12.8	14.2	17.1	19.9	22.8	25.6	28.5	31.3	34.1
19	**8.23**	2.9	3.9	4.8	5.8	7.2	8.7	10.1	11.6	13.0	14.5	17.4	20.3	23.2	26.1	29.0	31.9	34.8
20	**8.66**	2.9	3.9	4.9	5.9	7.4	8.8	10.3	11.8	13.3	14.7	17.7	20.6	23.6	26.5	29.5	32.4	35.4
Minimum Practical Thickness		4.5	6.0	6.0	7.5	9.0	10.5	10.5	12.0	12.0	13.5	15.0	16.5	18.0	21.0	24.0	27.0	28.5

For determining the CIPP thickness in Table 13 the following variables were utilized in the calculations: E_L = 175,000 psi, S_L = 2750 psi, 2% Ovality, Safety Factor = 2.0, Enhancement Factor K = 7.0, Poisson's Ratio = 0.3

Table 14. Soil Types and Densities.

Soil Type	Density, w (lb/ft3)
Sand & Gravel	110
Saturated Topsoil	115
Ordinary Clay	120
Saturated Clay	130

Table 15. Water Buoyancy Factor, Rw.

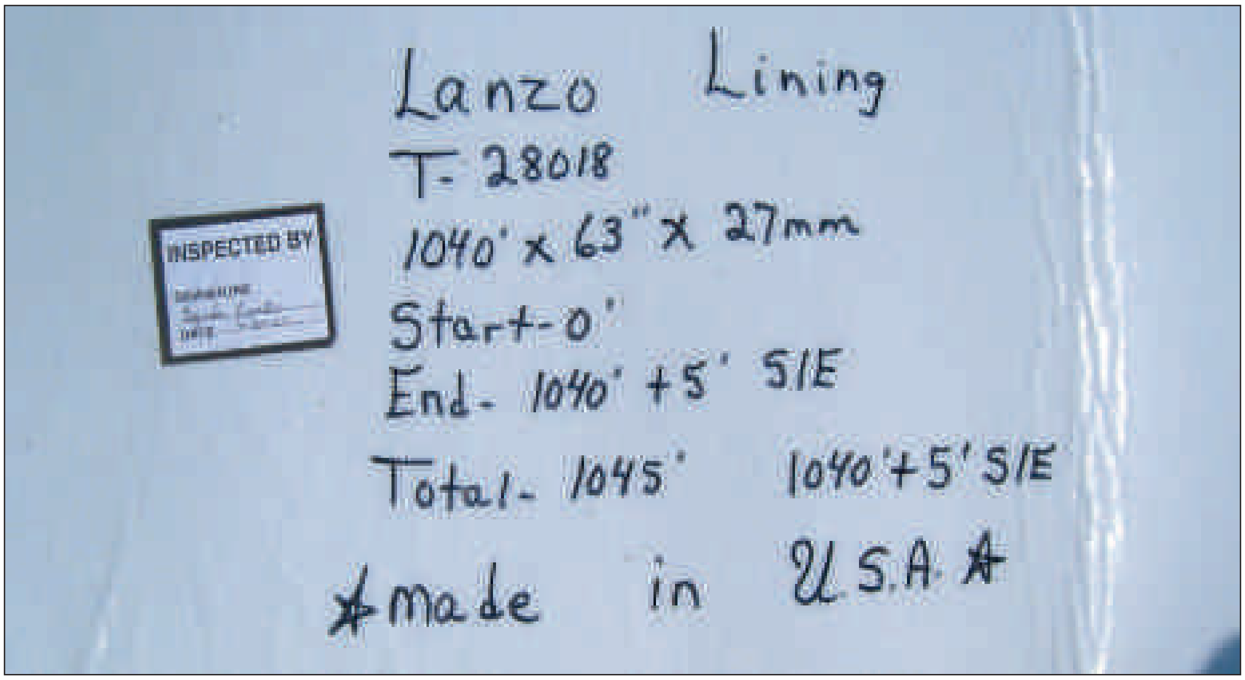
$Rw = 1 - 0.33(Hw/Hs) \geq 0.67$

Ratio Hw/Hs	Factor Rw
0	1.00
0.05	0.98
0.1	0.97
0.15	0.95
0.20	0.93
0.25	0.92
0.30	0.90
0.35	0.88
0.40	0.87
0.45	0.85
0.50	0.84
0.55	0.82
0.60	0.80
0.65	0.79
0.70	0.77
0.75	0.75
0.80	0.74
0.85	0.72
0.90	0.70
0.95	0.69
1.00	0.67

Table 16. Coefficient of Elastic Support, B'

$B' = 1/(1 + 4e^{-0.065Hs})$

Soil Height Hs, ft	Elastic Support B'
0	0.2
1	0.21
2	0.22
3	0.23
4	0.24
5	0.26
6	0.27
7	0.28
8	0.30
9	0.31
10	0.32
11	0.34
12	0.35
13	0.37
14	0.38
15	0.40
16	0.41
17	0.43
18	0.45
19	0.46
20	0.48
22	0.51
24	0.54
26	0.58
28	0.61
30	0.64



All materials are rigorously inspected for quality while Lanzo Lining Services emphasizes materials "Made in America"

APPENDIX

Table 17. Soil Prism Pressure as a Function of Water or Soil Height and Soil Density.

		Soil Prism Pressure, psi Soil Density, w, lbs/ft³				
Height of Water, Hw or Soil, Hs, ft	Hydrostatic Pressure Pw', psi	100 lbs/ft³	110 lbs/ft³	115 lbs/ft³	120 lbs/ft³	130 lbs/ft³
1	0.43	0.7	0.8	0.8	0.8	0.9
2	0.87	1.4	1.5	1.6	1.7	1.8
3	1.30	2.1	2.3	2.4	2.5	2.7
4	1.73	2.8	3.1	3.2	3.3	3.6
5	2.17	3.5	3.8	4.0	4.2	4.5
6	2.60	4.2	4.6	4.8	5.0	5.4
7	3.03	4.9	5.3	5.4	5.8	6.3
8	3.46	5.6	6.1	6.4	6.7	7.2
9	3.90	6.3	6.9	7.2	7.5	8.1
10	4.33	6.9	7.6	8.0	8.3	9.0
11	4.76	7.6	8.4	8.8	9.2	9.9
12	5.20	8.3	9.2	9.6	10.0	10.8
13	5.63	9.0	9.9	10.4	10.8	11.7
14	6.06	9.7	10.7	11.2	11.7	12.6
15	6.50	10.4	11.5	12.0	12.5	13.5
16	6.93	11.1	12.2	12.7	13.3	14.4
17	7.37	11.8	13.0	13.6	14.2	15.3
18	7.79	12.5	13.8	14.4	15.0	16.3
19	8.23	13.2	14.5	15.1	15.8	17.2
20	8.66	13.9	15.3	16.0	16.7	18.1
22	9.53	15.3	16.8	17.5	18.3	19.9
24	10.4	16.7	18.3	19.2	20.0	21.7
26	11.3	18.1	19.9	20.8	21.7	23.5
28	12.1	19.4	21.4	22.3	23.3	25.3
30	13.0	20.8	22.9	24.0	25.0	27.1

Trenchless CIPP rehabilitation of a pipe running under a busy highway during rush hour traffic

Table 18. Live load Pressure and Impact Factors for Surface Load Impact.

Soil Height	Highway HS-20		Railway E-80		Airport	
Hs	**Load, psi**	**Impact**	**Load, psi**	**Impact**	**Load, psi**	**Impact**
0-1	>15.1	0.3	N/A	0.4	N/A	0.5
1	15.1	0.3	N/A	0.4	N/A	0.5
2	10.9	0.2	26.4	0.36	13.2	**
3	5.3	0	23.6	0.28	12.3	**
4	2.2	0	18.4	0.24	11.3	**
5	1.7	0	16.7	0.2	10.1	**
6	1.3	0	15.6	0.16	8.8	**
7	1.1	0	12.2	0.12	7.9	**
8	1.0	0	11.1	0.08	6.9	**
9	*	0	9.4	0.04	6.5	**
10	*	0	7.6	0	6.1	**
12	*	0	5.6	0	4.7	
15	*	0	4.2	0	2.5	

*Insignificant, less that 1.0psi

**Consult FAA requirements for ground conditions

Table 19. Fully Deteriorated Gravity Flow Condition for High Groundwater at Grade.

CIPP Thickness (mm) for each Pipe Diameter (Inches) at the given Depth (feet)																		
Soil Depth	**Water Depth**	**6**	**8**	**10**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**
6	**6**	2.5	3.0	3.7	4.5	5.6	6.7	7.9	9.0	10.1	11.2	13.5	15.7	17.9	20.2	22.4	24.7	26.9
8	**8**	2.5	3.2	4.0	4.7	5.9	7.0	8.1	9.2	10.2	11.3	13.5	15.7	17.9	20.2	22.4	24.7	26.9
10	**10**	2.5	3.3	4.1	5.0	6.1	7.7	8.8	10.0	11.3	12.4	14.6	16.9	19.0	21.2	23.5	25.9	28.2
12	**12**	2.8	3.7	4.6	5.5	7.1	8.4	9.7	11.0	12.3	13.7	16.1	18.5	21.1	23.4	25.8	28.0	30.2
16	**16**	3.2	4.2	5.3	6.3	8.0	9.6	11.1	12.6	14.1	15.6	18.5	21.4	24.3	27.1	29.9	32.6	35.2
20	**20**	3.5	4.7	5.8	7.0	8.9	10.6	12.3	14.0	15.6	17.3	20.6	23.8	27.0	30.3	33.4	36.5	39.5
25	**25**	3.9	5.2	6.4	7.7	9.8	11.7	13.6	15.4	17.3	19.1	22.8	26.5	30.1	33.6	37.2	40.7	44.2
30	**30**	4.2	5.6	7.0	8.4	10.6	12.6	14.7	16.7	18.7	20.8	24.8	28.8	32.7	36.6	40.5	44.3	48.2
Minimum Practical Thickness		4.5	6.0	6.0	7.5	9.0	10.5	10.5	12.0	12.0	13.5	15.0	16.5	18.0	21.0	24.0	27.0	28.5

For determining the thickness of the CIPP in Table 19 the following variables were used: E_L = 175,000 psi, S_L = 2750 psi, 2% Ovality, Safety Factor = 2.0, Soil Density = 120 lb/ft^3, Soil Modulus = 1000 psi, HS-20 Highway Loading at shallow depths

Table 20. Fully Deteriorated Gravity Flow Condition for Groundwater at 50% of Soil Depth.

CIPP Thickness (mm) for each Pipe Diameter (Inches) at the given Depth (feet)																		
Soil Depth	Water Depth	6	8	10	12	15	18	21	24	27	30	36	42	48	54	60	66	72
6	3	2.5	3.0	3.7	4.5	5.6	6.7	7.9	9.0	10.1	11.2	13.5	15.7	17.9	20.2	22.4	24.7	26.9
8	4	2.5	3.1	3.7	4.5	5.6	6.7	7.9	9.0	10.1	11.2	13.5	15.7	17.9	20.2	22.4	24.7	26.9
10	5	2.5	3.3	4.0	4.7	5.7	6.8	7.9	9.0	10.1	11.2	13.5	15.7	17.9	20.2	22.4	24.7	26.9
12	6	2.7	3.5	4.3	5.1	6.3	7.4	8.6	9.7	10.8	12.1	14.3	16.4	18.7	20.7	22.9	24.9	26.9
16	8	3.0	3.9	4.8	5.7	7.1	8.4	9.8	11.1	12.4	13.7	16.3	19.0	21.5	23.9	26.4	28.8	31.2
20	10	3.3	4.3	5.3	6.3	7.8	9.3	10.8	12.3	13.8	15.3	18.2	21.1	23.9	26.8	29.5	32.3	35.0
25	12.5	3.6	4.7	5.8	6.9	8.6	10.3	11.9	13.6	15.2	16.9	20.1	23.3	26.5	29.7	32.8	36.0	39.0
30	15	3.8	5.0	6.3	7.5	9.3	11.1	12.9	14.7	16.5	18.3	21.8	25.4	28.9	32.3	35.7	39.1	42.5
Minimum Practical Thickness		4.5	6.0	6.0	7.5	9.0	10.5	10.5	12.0	12.0	13.5	15.0	16.5	18.0	21.0	24.0	27.0	28.5

For determining the thickness of the CIPP in Table 19 the following variables were used: E_L = 175,000 psi, S_L = 2750 psi, 2% Ovality, Safety Factor = 2.0, Soil Density = 120 lb/ft^3, Soil Modulus = 1000 psi, HS-20 Highway Loading at shallow depths

Lanzo Lining Services crew preparing liner for direct inversion installation of CIPP

REFERENCES

[1] Tingberg Jr., Fred, "Large Bore Rectangular Box Culvert and Non Circular Rehabilitation with CIPP", North American NO-DIG '07 Conference Proceedings, NASTT, San Diego, CA., 2007.

[2] Tingberg Jr., Fred and Janicki, Michael, "Trenchless Cured In Place Watermain Rehabilitation Meeting NSF 61", North American NO-DIG '08 Conference Proceedings, NASTT, Dallas, TX., 2008.

[3] "Hydrogen Sulfide Corrosion in Wastewater Collection and Treatment Systems," Report PB92-117985, Report to Congress, Sept. 1991.

[4] "Process Design Manual for Sulfide Control in Sanitary Sewerage Systems," Report EPA 625/1-74-005, U.S. EPA Technology Transfer, Oct. 1974.

[5] "Sewer System Infrastructure Analysis and Rehabilitation Handbook," Report CERI-91-42, U.S. EPA Office for Environmental Research Information, July 1991.

[6] "Technology Transfer Seminars: Sewer System Infrastructure Analysis and Rehabilitation," Report CERI-91-51, U.S. EPA Office for Environmental Research Information, July 1991.

[7] Parker, C.D., "Species of Bacteria Associated with the Corrosion of Concrete," Nature, Vol. 159, 1947, pp 439-40.

[8] Badia, Jaime, et. al., "Caustic Spray for Sewer Crown Corrosion Control",
Proceedings of the ASCE International Conference on Pipeline Infrastructure, Aug. 1993.

[9] Marshall, G., Batis, G., "Preparing Collection Systems for Water Conservation", Water Environment & Technology, Vol. 5, No. 8, 1993, pp 52-57.

[10] Jeyapalan, J.K., "Prediction and Control of Sulfide Corrosion in Concrete Sewer Infrastructure and Rehabilitation", Corrosion Forms and Control for Infrastructure, STP 1137, Victor Chaker, Ed., American Society for Testing and Materials, Philadelphia, 1992, pp 273-283.

[11] Kleweno, D.G., "Physical Properties and Chemical Resistance of Selected Resins for Cured-in-Place Pipe Rehabilitation," Buried Plastic Pipe Technology: 2nd Volume, ASTM STP 1222, Dave Eckstein, Ed., American Society for Testing and Materials, West Conshohocken, PA, 1994.

[12] F 1216 – 07b, "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube", Volume 08.04 Plastic Pipe and Building Products, American Society for Testing and Materials, West Conshohocken, PA, 1994.

[13] F1743 - 08, "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)", Volume 08.04 Plastic Pipe and Building Products, American Society for Testing and Materials, Conshohocken, PA, 1996.

[14] D5813 - 04, "Standard Specification for Cured-In-Place Thermosetting Resin Sewer Pipe", Volume 08.04 Plastic Pipe and Building Products, American Society for Testing and Materials, West Conshohocken, PA, 1995.

[15] Standard Specification for Public Works Construction (Green Book), BNi Building News, Los Angeles, 1994.

[16] Boyce, G.M. and Bried, E., "Social Cost Accounting for Trenchless Projects", North American No-Dig Conference Proceedings, Albuquerque, NM, 1998, pp 2-12.

[17] Guice, L.K., Straughan, T., Norris, C.R., Bennet, D.R. (1994). "Long Term Structural Behavior of Pipeline Rehabilitation Systems", Trenchless Technology Center, Louisiana Tech University, Ruston, LA, August 15, 1994.

[18] D2990-01 "Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics", Volume 0 Plastic , American Society for Testing and Materials, West Conshohocken, PA, 1993.

[19] Timeshenko, S.P. and Gere, J.M., "Theory of Elastic Stability," McGraw-Hill Publishing Co. Second Ed., New York, NY, 1988.

[20] Spangler, M.G., "The Structural Design of Flexible Pipe Culverts," Bulletin 153, Iowa State College of Engineering Experiment Station, Ames, IA 1941.

[21] ASTM 2412 "Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading," American Society for Testing and Materials, Conshohocken, PA 1992.

[22] Aggerwal, S.C. and M.J. Cooper, "External Pressure Testing of Insituform Lining", Internal Report, Coventry Polytechnic. 1984.

[23] Lo, K.H. and Zhang, J.Q., "Collapse Resistance Modeling of Encased Pipes", Buried Plastic Pipe Technology; 2nd Volume, ASTM STP 1222, Dave Eckstein, Ed., American Society for Testing and Materials, Philadelphia, 1994.

[24] Kleweno, D.G., "Critical Buckling Behavior and Life Cycle Predictions of CIPP", North American NO-DIG '97 Conference Proceedings, NASTT, Seattle, WA., 1997.

[25] McAlpine, G.A. (1996). "Statistical Analysis and Implications of Test Data from Long-term Structural Behavior of Pipeline Rehabilitation Systems", Proceedings of the Water Environment Federation 69th Annual Conf. & Expo., Dallas, TX, 1996.

[26] McAlpine, G.A. (1996). "TTC Report on Long-Term Structural Behavior of Pipeline Rehabilitation Systems", NO-DIG ENGINEERING, May/June, 1996.

[27] Glock, D., "Uberkritisches Verhalten eines starr ummautelten Kreisrohres bei Wasserdruck von auBen und Temperaturdehnung; Der Stahblau, 7, 1977.

[28] Guice, L.K. and Li, J.Y. (1994). "Buckling Models and Influencing Factors for Pipe Rehabilitation Design", Design Theory Workshop, North American NO-DIG '94 Conference Proceedings, NASTT, Dallas, TX, 1994.

[29] Schrock, J.B. and Gumbel, J. (1997). "Pipeline Renewal - 1997", North American NO-DIG '97 Conference Proceedings, NASTT, Seattle, WA, 1997.

[30] Moore, I.D., "Tests for Pipe Liner Stability: What We Can and Cannot Learn" North American NO-DIG '98 Conference Proceedings, NASTT, Albuquerque, NM. 1998.

[31] Omara, A. "Analysis of Cured-in-Place Pipe (CIPP) Installed in Circular and Oval Deteriorated Host Pipes" PhD Thesis, Louisiana Tech University College of Engineering, 1998.

[32] Standard Specifications for Highway Bridges, 14th edition, American Association of State Highway and Transportation Officials, Washington DC, 1989.

[33] Tingberg Jr., Fred and Cavalier, William, "Sewage Force Main Rehabilitation using Cured-in-Place Pipe Technology" North American NO-DIG '99 Conference Proceedings, NASTT, Orlando, FL. 1999.

Clarifier pressure pipe rehabilitation at WWTP

Quality controlled tube impregnation at one of Lanzo Lining Services' state of the art wet out facilities

The Lanzo Companies bring forty-five years of heavy construction experience in addition to over 6,000,000 feet of installed cured-in-place pipe lining experience. Our goal at Lanzo is to provide safe, cost-effective, on-time, and high quality construction services. We hold the highest level of ethics and are committed to ensuring the safety of our employees and the convenience of the people within the communities we service.

LANZO
Lining Services, Inc.

Our mission is to deliver safe, environmentally friendly and low impact trenchless construction services on time at or below budget.

LANZO LINING SERVICES

Deerfield Beach, Florida office

125 SE 5th Court
Deerfield Beach, FL 33441
Phone: (954) 973-9700
Fax: (954) 974-3894

Roseville, Michigan office

28135 Groesbeck Highway
Roseville, Michigan 48066
Phone: (586) 775-5819
Fax: (586) 775-2328

Website: www.lanzo.net

Please direct all technical questions to Fred Tingberg, Jr. (fredt@lanzo.org)

SprayMaster™

QUADEX

Eco Friendly Utility Infrastructure Restoration Solution

The Quadex SprayMaster™ is a completely self-contained cementitious manhole liner installation system. The SprayMaster™ system comes fully rigged with all of the components needed to facilitate low-velocity spray application of the cementitious manhole liner materials.

Water Meter
A Fill-Rite water metering system to insure precise water cement ratio's during the mixing of the materials.

Mortar Mixing System
A 45-gallon capacity, vertical shaft, horizontal blade mixer for high shearing and expedient mixing of the cementitious materials.

Diesel Engine
A 24 H.P. electric start diesel engine power plant that hydraulically drives all components on the trailer.

Air Compressor
A 20 CFM / 90 PSI air compressor anc reservoir to provide compressed air fo spray atomization of the cementitious materials.

Water Transfer Pump
A 40 PSI hydraulically powered water transfer pump to provide continuous delivery of water to all components.

Operator Control Center
An ergonomically positioned operator control center with simple lever type variable speed forward and reverse controls for all mixing and pumping components.

Material Pump
A three stage, progressive cavity, material pump and material holding hopper for use in pumping of the materials to the spray nozzle.

Spray Nozzle/Material Hose
A compact design low-velocity cementitious wet spray nozzle that atomizes the mortar material into a spray pattern for application to the manhole walls. Comes complete with a 25-foot section of 1-inch rout hose with accompanying 3/8-inch airline for use in material delivery to the nozzle.

Pressure Washer
An optional 3500-PSI portable pressure washer for use in manhole surface preparation and equipment clean-up.

Trailer
A heavy-duty dual axle trailer with twin 7,50 lb. rated axles. A 250-gallon poly-lined wate tank engineered within the framework of the trailer to provide a low center of gravity for handling safety.

QUADEX
SEWER REHABILITATION PRODUCTS

4801 Crystal Hill Rd.
North Little Rock, AR 72118
(501) 758-8628
(888) 831-1650
(501) 758-3814 FAX
www.QUADEXonline.com

The Quadex SpinMaster™ System
The use of the SprayMaster unit can be complimented with the addition of the robotic SpinMaster centrifugal manhole lining system. The robotic apparatus allows for centrifugal spin application of the cementitious manhole liner material without man-entry into the manhole during the material application phase. The SpinMaster System is highly effective in deep ranging manholes.

see more at
QUADEXonline.com

QUADEX
SEWER REHABILITATION PRODUCTS

	DESCRIPTION	RECOMMENDED FOR	FEATURES & BENEFITS	PERFORMANCE DATA
QUADEX STRUCTURE GUARD EPOXY Corrosion Resistant Protective Coating	Quadex Structure Guard is a 100% solids high build epoxy coating system. Quadex Structure Guard is specifically engineered to provide long term protection for manholes, pump stations, treatment plants, or any wastewater infrastructure components that is subjected to extremely high levels of hydrogen sulfide induced corrosion. Quadex Structure Guard can also be used as an interior or exterior pipe lining or coating.	• Sewer Pipes and Manholes • Concrete Tanks • Elevator Pits • Cisterns • Basements • Concrete & Masonry Walls	• 100% Solids, No VOC's • Can be sprayed applied at 125 mils in a single pass • Excellent immersion resistance	• Compressive Strength ASTM D638 - >15,000 psi • Flexural Strength ASTM D790 - >11,000 psi • Tensile Strength ASTM D638 - > 5,600 psi • Bond Strength (Pull-Off Adhesion): ASTM D 4541 - > 2700 psi • Elongation – 4.8% • Color: Light Green
QUADEX ALLUMINALINER A Calcium Aluminate Sewer Rehabilitation Mortar	Quadex Aluminaliner is a factory blended, one component, fiber reinforced, fused calcium aluminate cement mortar, enhanced with a monocrystalline quartz aggregate. This mortar is specifically designed to provide ultimate protection against hydrogen sulfide gas induced corrosion, add structural integrity and stop the infiltration of groundwater in sewer structures. This unique formulation allows for a monolithic one-pass application up to three inches in thickness by low pressure spraying.	Vertical and overhead repairs to concrete or masonry sewer structures such as manholes, wetwells, pipe and treatment plant structures where corrosion is a problem.	• Quality controlled one-component blend for uniform results. • High early and ultimate compressive, flexural and bond strengths. • Resistant to sulfide attack. • Excellent freeze-thaw and abrasion resistance. • Extremely low permeability.	Compressive Strength PSI (ASTM C109) 28 day >9000 psi Flexural Strength PSI (ASC293) 28 day >1100 psi
QUADEX DYNASTONE An Acid Resistant Sewer Rehabilitation Mortar	Quadex Dynastone is a factory blended, one component, fiber reinforced, cement and pozzalan mortar, enhanced with a monocrystalline quartz aggregate. Dynastone is specifically designed to provide corrosion resistant protection in a sulfuric acid environment, add structural integrity and stop the infiltration of groundwater in sewer structures. This unique formulation allows for a monolithic one-pass application up to three inches in thickness by low pressure spraying or centrifugally spinning.	Vertical and overhead repairs to concrete and masonry sewer structures such as manholes, wet wells, pipe and treatment plant structures where acid induced corrosion is a problem.	• Quality controlled one-component blend for uniform results • High early and ultimate compressive, flexural and bond strengths • Resistant to acid attack in sulfuric pH of one solution • Extremely low permeability	Compressive Strength PSI (ASTM C109) 28 day >7000 psi Flexural Strength PSI (ASTM C580) 28 day >900 psi
QUADEX QM-1s RESTORE Factory Blended, One Component, High Strength Cement Based Mortar	Quadex QM-1s Restore is a factory blended, on component , high strength cement based, polypropylene fiber reinforced, shrinkage compensated mortar enhanced with a mono crystalline quartz aggregate. It is specifically designed for placement by low pressure spraying of mortar for the repair of concrete and masonry structures. This unique formulation allows for a monolithic one-pass application up to three inches in thickness by low pressure spraying.	Vertical and overhead repairs to concrete or masonry sewer manholes, pipe, water treatment facilities, tunnels, navigation locks, and dams.	• Quality controlled one-component blend for uniform results • High early and ultimate compressive, flexural and bond strengths • Resistant to sulfate attack • Extremely low permeability • Sprayable • Enhanced with finely graded NSG aggregate	Compressive Strength PSI (ASTM C109) 28 day >9000 psi Flexural Strength PSI (ASTM C293) 28 day >1400 psi
QUADEX HYPERFORM Rapid Setting High Early Strength Patching Material	Quadex Hyperform is a one component, rapid-setting, high early strength patching material designed for repairing vertical and horizontal concrete and masonry structures.	• Filling large voids in manhole walls. • Reconstructing inverts. • Catch basin and concrete. • Pipe Repair	• Rapid-setting • High Early and ultimate strengths • Non-shrinking • No calcium chloride • Ready to use - just add water • Excellent resistance to freeze-thaw	Compressive Strength PSI (ASTM C109) 1 hour >4100 psi 28 day >7000 psi Flexural Strength PSI 28 day >1100 psi
QUADEX QUAD-PLUG Fast Setting Cementitious Waterstop	Quadex Quad-Plug is a blend of special cements and admixtures which are designed to instantly stop running water or seepage in all types of concrete and masonry structures	• Sewer Pipes and Manholes • Concrete Tanks • Elevator Pits • Cisterns • Basements • Concrete & Masonry Walls	• Stops running water immediately • Non-Shrink, expands as it sets • Contains no calcium chloride • Non-Metallic • Sulfate resistant • Easily applied • No Mixing	Compressive Strength PSI (ASTM C109) 30 min >1800 psi 28 day >5800 psi Bond Strength (ASTM C 321) 30 min >50 psi 28 day >85 psi

Founded in 1991, QUADEX, INC. manufactures a complete line of cementitious products to restore the structural integrity of manholes, wetwells, pumping stations and other related wastewater structures.

QUADEX lining products provide a permanent seal against corrosion, infiltration and exfiltration, and have an installation life of 10 to 50 years in wastewater applications. Formulated and designed by QUADEX, INC. with the most advanced technology available, our products surpass all other products offered to the industry with regard to structural and flexural strength, permeability, application thickness and workability.

To ensure the performance of each product, QUADEX, INC. verifies the results of all in-house studies through extensive independent laboratory ASTM procedures.

QUADEX, INC. has established itself as a leader in this specialized field, unequaled in the Wastewater Rehabilitation Industry.

QUADEX
SEWER REHABILITATION PRODUCTS

4801 Crystal Hill Rd.
North Little Rock, AR 72118

(501) 758-8628 | (888) 831-1650
(501) 758-3814 FAX
www.QUADEXonline.com

QUADEX SEWER STRUCTURE RESTORATION MATERIALS INSTALLATION SPECIFICATION

For Restoration Using Quadex Rehabilitation Materials

1.0 GENERAL

1.1 These specifications are intended to set a standard of quality and design for the application of cementitious and/or epoxy materials used in the rehabilitation of sanitary sewer structures.

2.0 DEFINITIONS

2.1 The term "approved" shall mean that the proposed material shall meet or exceed each of the performance criteria set forth in this specification. Manufacturers and vendors of various name brand materials must submit proof that any proposed material will meet the guidelines and requirements of this specification. Material approvals shall be made by the engineer no less than two weeks prior to bid date.

3.0 APPROVED MATERIALS

3.1 Infiltration Control

All fast setting materials furnished shall be designed to be applied in dry powder form, with no prior mixing of water, directly to active leaks under hydrostatic pressure in manholes or related structures. Materials shall consist of rapid setting cements, siliceous aggregates, and various accelerating agents. Material shall not contain chlorides, gypsum, or metallic particles. Approved infiltration control material shall be Quadex Quad-Plug as manufactured by Quadex, Inc.

A. Specifications: Infiltration Control Materials

a. Compressive Strength (ASTM C109)

30 mins:	1850 psi
3 days:	4000 psi
7 days:	5000 psi
28 days:	5890 psi

b. Bond Strength (ASTM C321)

30 min:	50 psi
1 day:	85 psi

c. Set Time 30 seconds

3.2 Invert Repair and Patching

All material furnished shall be designed to fill large voids in structure walls and to repair or reconstruct inverts where no hydrostatic pressure exists. Material shall consist of rapid setting cements, NSG aggregates, and various accelerating agents. Material shall not contain chlorides, gypsum, or metallic particles. Approved invert repair and patching material shall be Quadex Hyperform as manufactured by Quadex, Inc.

Approved material shall exhibit the following minimum physical properties:

a. Compressive Strength (ASTM C109)

1 hour:	4170 psi
2 hours:	5840 psi
24 hours:	7660 psi

b. Flexural Strength (ASTM C293)

1 hour:	450 psi
3 hours:	625 psi
24 hours:	820 psi

c. Freeze-Thaw (ASTM C666)

300 cycles with no damage

d. Setting Time (Gilmore ASTM C266)

Initial:	5-8 minutes
Final:	10-15 minutes

3.3 Cementitious Lining Materials

All cementitious lining materials shall be specifically designed for the rehabilitation of manholes and other related wastewater structures. Liner materials shall be cement based, poly-fiber reinforced, shrinkage compensated, and enhanced with chemical admixtures and siliceous aggregates. Liner materials shall be mixed with water per manufacturer's written specifications and applied using equipment specifically designed for either low-pressure spray or centrifugal spin casting application of cement mortars. All cement liner materials must be capable of a placement thickness of ½" to 4" in a one pass monolithic application.

A. Portland cement

Portland cement materials shall be manufactured from Type II Portland cement and enhanced with silica fume and high-density chemically stable aggregates. Materials must resist corrosion when placed in an environment capable of producing a maximum substrate pH level of 3.0. Approved material shall be Quadex QM-1s Restore as manufactured by Quadex, Inc., or "pre-approved" equal.

Approved material shall exhibit the following 28-day minimum physical properties:

a. Compressive Strength (ASTM C109)
   >8,000 psi

b. Flexural Strength (ASTM C293)
   1,400 psi

c. Bond Strength (ASTM C882)
   3,100 psi

d. Permeability (AASHTO T-277)
   Not to exceed 350 coulombs

e. Freeze-Thaw (ASTM C666)
   No damage in minimum 300 cycles

f. Material Wet Density
   Minimum 142 +/-5 PCF

B. Calcium Aluminate

Calcium Aluminate materials shall be manufactured from 100% pure calcium-aluminate cement and enhanced with silica fume and high-density chemically stable aggregates. Materials must resist corrosion when placed in an environment capable of producing a maximum substrate pH level of 2.0. Approved material shall be Quadex Aluminaliner as manufactured by Quadex, Inc., or "pre-approved" equal.

Approved material shall exhibit the following 28-day minimum physical properties:

a. Compressive Strength (ASTM C109)
>9,000 psi

b. Flexural Strength (ASTM C293)
1,100 psi

c. Bond Strength (ASTM C882)
3,100 psi

d. Permeability (AASHTO T-277)
Not to exceed 350 coulombs

e. Freeze-Thaw (ASTM C666)
No damage in minimum 300 cycles

f. Material Wet Density
Minimum 142 +/-5 PC

C. Specialty cementitious lining materials

Specialty cementitious lining materials shall be manufactured from Type II Portland cement with chemically activated fly ash, and enhanced with silica fume and high-density chemically stable aggregates. Materials must resist corrosion when placed in an environment capable of producing a substrate pH level of less than 2.0. Approved cementitious material shall be Quadex Dynastone as manufactured by Quadex, Inc., or "pre-approved" equal.

Approved material shall exhibit the 28-day minimum physical properties:

a. Compressive Strength (ASTM C109)
>8,000 psi

b. Flexural Strength (ASTM C293)
900 psi

c. Bond Strength (ASTM C882)
2,100

d. Permeability (AASHTO T-277)
Not to exceed 300 coulombs

e. Freeze-Thaw (ASTM C666)
No damage in minimum 300 cycles

f. Material Wet Density
Minimum 142 +/-5 PCF

3.4 Epoxy Materials

All epoxy lining materials shall be specifically designed for protecting manholes and other related wastewater structures from severe hydrogen sulfide environments. Liner materials shall be 100% solids epoxy containing no VOC's and capable of building a minimum thickness of 150 mils in a single application. All epoxy lining materials shall be applied only by heated plural component equipment as approved by the manufacturer.

Epoxy materials shall meet the following minimum physical properties:

a. Tensile Strength ASTM D638
5,600 psi

b. Flexural Strength ASTM D790
11,000 psi

c. Compressive Strength ASTM D695
15,000 psi

d. Shore D Hardness ASTM D2240
83

e. Elongation
4.8%

f. Taber Abrasion ASTM4060
1000 gm load @ 1000 cycles
< 100mg loss

4.0 MATERIAL(S) SELECTION / DESIGN CRITERIA

4.1 Condition A: Low to mild hydrogen sulfide environments (pH > 3.0). Substrate shall receive a minimum of ½" cementitious lining material manufactured from Type II Portland cement, and enhanced with silica fume. Materials shall contain poly-fiber reinforcement, chemical admixtures, and siliceous aggregates. Approved material shall be Quadex QM-1s Restore as manufactured by Quadex, Inc.

4.2 Condition B: High hydrogen sulfide environments (pH > 2.0). Substrate shall receive a minimum of ½" cementitious lining material manufactured from 100% pure calcium aluminate cement and enhanced with high-density chemically stable aggregates. Materials shall contain poly fiber reinforcement and chemical admixtures. Approved material shall be Quadex Aluminaliner as manufactured by Quadex, Inc.

4.3 Condition C: New construction with anticipated harsh hydrogen sulfide environments (pH < 2.0) or substrate corrosion < 0.125 inch and harsh hydrogen sulfide environments (pH < 2.0). Substrate shall receive a minimum of 125 mils of 100% solids epoxy lining material containing no VOC's. Approved epoxy material shall be Quadex Structure Guard.

4.4 Condition D: Severe hydrogen sulfide environments (pH < 2.0) and substrate corrosion > 0.125 inch. Substrate shall receive a composite system consisting of a minimum ½" cementitious lining material manufactured from 100% pure calcium aluminate cement and a 125 mil topcoat of 100% solids epoxy lining material containing no VOC's. Approved cementitious material shall be Quadex Aluminaliner and approved epoxy material shall be Quadex Structure Guard.

5.0 CEMENTITIOUS REHABILITATION

5.1 Structure Cleaning and Preparation

The floor and interior walls of the structure shall be thoroughly cleaned and made free of all foreign materials including dirt, grit, roots, grease, sludge and all debris or material that may be attached to the wall or bottom of the manhole.

a. High pressure water blasting with a minimum of 3500psi shall be used to clean free all foreign material within the structure.

b. When grease and oil are present within the structure, an approved detergent or muriatic acid shall be used integrally with the high pressure cleaning water.

c. All materials resulting from the cleaning of the structure shall be removed prior to application of the cement based coating.

d. All loose or defective brick, grout, ledges, steps and protruding ledges shall be removed to provide an even surface prior to application of cement based coating.

5.2 Sealing Active Leaks

The work consists of hand applying a dry quick-setting cementitious mix designed to instantly stop running water or seepage in all types of concrete and masonry structures. The applicator shall apply material in accordance with manufacturer's recommendations and following specifications.

a. The area to be repaired must be clean and free of all debris per the guidelines set forth in 5.1.

b. Once cleaned, prepare crack or hole by chipping out loose material to a minimum depth and width of ¾ inch.

c. With gloved hand, place a generous amount of the dry quick-setting cementitious material to the active leak, with a smooth fast motion, maintaining external pressure for 30 seconds, repeat until leak is stopped.

d. Proper application should not require any special mixing of product or special curing requirements after application.

5.3 Invert Repair and Patching

The work consists of hand mixing and applying a rapid setting, high early strength, non-shrink patching material to fill all large voids and repair inverts prior to spray lining of the structure. For manhole invert repairs, flow must be temporarily restricted by inflatable or mechanical plugs prior to cleaning.

a. The area to be repaired must be cleaned and free of all debris per the guidelines set forth in Section 5.1.

b. Mix water shall be clean potable water and require no additives or admixtures for use with cementitious patching materials.

c. Cementitious material shall be mixed in a mortar tub or 5-gallon pail with water per manufacturer's specifications. Material should be mixed in small quantities, to avoid setting prior to placement in voids or inverts.

d. Once mixed to proper consistency, the materials shall be applied to the invert or void areas by hand or trowel. In invert applications, care should be taken to not apply excessive material in the channel, which could restrict flow. Once applied, materials should be smoothed either by hand or trowel in order to facilitate flow.

e. Flows in inverts can be reestablished within 30 minutes of material placement.

5.4 Application of Cementitious Liner

The work consists of spray applying and/or centrifugally spin-casting a cementitious based liner to the inside of the existing structure. The necessary equipment and application methods to apply the cementitious based liner materials shall be only as approved by the material manufacturer.

a. Material shall be mixed with water in accordance with manufacturer's specifications. Once mixed to proper consistency, the materials shall be pumped via a rotor-stator style progressive cavity pump through a material plaster hose for delivery to the appropriate and / or selected application device.

b. Spray application of the cementitious material.

    a. Material hose shall be coupled to a low-velocity spray application nozzle. Pumping of the material shall commence and the mortar shall be atomized by the introduction of air at the nozzle, creating a low-velocity spray pattern for material application.
    b. Spraying shall be performed by starting at the bottom of the structure and progressing up the wall to the corbel and chimney areas.
    c. Material shall be applied to a specified uniform minimum thickness no less than ½-inch. Material shall be applied to the bench area in such a manner as to provide for proper drainage without ponding.

c. Centrifugal application of the cementitious material.

Spin-cast unit shall be approved by the material manufacturer and be driven only by a direct current (DC) motor with a minimum speed of 2,500 rpm. Motor torque shall be sufficient to apply lining materials evenly within a minimum 8 foot diameter structure.

a. Material hose shall be coupled to the spin-cast unit. The spin-cast unit shall then be positioned within the center of the manhole at either the top of the manhole chimney or the lowest point corresponding to the junction of the manhole bench and walls.

b. The spin-cast unit shall then be initialized, and pumping of the material shall commence. As the mortar begins to be centrifugally cast evenly around the interior of the structure, the rotating applicator head shall be raised and/or lowered at a controlled retrieval speed conducive to providing a uniform material thickness on the structure walls.

c. Controlled multiple passes are then made until the specified minimum finished thickness is attained. If the procedure is interrupted for any reason, simply arrest the retrieval of the applicator head until flows are recommenced.

d. Material thickness may be verified at any point with a depth gauge and shall be no less than a uniform ½-inch. If additional material is required at any level, the spin-cast unit shall be placed at that level and application shall recommence until that area is thickened.

d. Material shall be applied only when the structure is in a damp state, with no visible water dripping or running over the walls.

e. The low-velocity spray nozzle may be used in conjunction with the spin-cast unit to facilitate uniform application of the mortar material to irregularities in the contour of the structure walls and bench areas.

f. When applying materials to open air structures, special precautions shall be taken to ensure proper curing. When recommended by the manufacturer, the contractor shall perform the following:

a. Prior to applying materials contractor shall subject the structure to a water spray for a minimum of 24 hours to ensure substrate is fully saturated.
b. Contractor shall avoid spraying portions of the structure that are subjected to direct sunlight.
c. When directed by the manufacturer, contractor shall apply Quadex Quad Cure curing agent to the surface of all applied and finished materials.
d. Contractor shall cover applied materials with plastic sheeting as soon as feasible to prevent moisture loss.

g. Troweling of materials shall begin immediately following the spray application. Initial troweling shall be in an upward motion, to compress the material into any voids within the structure walls. Precautions should be taken not to overtrowel.

h. Curing will take place once the structure cover has been replaced. It is important that the structure lid/ cover is replaced no more than 10 minutes after troweling is complete to avoid moisture loss in the material due to sunlight and winds. When low flow conditions exist within the structure additional measures may be required such as placing plastic sheeting underneath the lid/cover.

i. Material shall not be applied during freezing weather conditions. Material shall not be placed when the ambient temperature is 37 degrees Fahrenheit and falling or when the temperature is anticipated to fall below 32 degrees Fahrenheit within 24 hours.

6.0 EPOXY REHABILITATION

6.1 Certifications

To ensure contractor proficiency in appling specified epoxy products, the contractor and his equipment shall be certified by the manufacturer. Furthermore, certification of contractor and equipment must be by a NACE Certified Inspector, holding valid and current NACE certification at time of inspection. Written documentation shall be provided to contractor and Project Engineer/ owner before any work commences.

6.2 Coating Application Equipment

a. Manufacturer approved heated plural component spray equipment.

b. Hard to reach areas, primer application, and touch-up may be performed using hand tools.

6.3 Pre-Application Inspections

a. Unless prior approval has been received from the manufacturer new Portland cement concrete structures shall have a minimum cure of 28 days. Should earlier coating be required, coating product manufacturer shall recommend specifications including appropriate cure assessment testing and use of speciality primers and sealers.

b. All active flows shall be plugged or diverted away from all surfaces to be coated.

c. Temperature of the surface to be coated should be maintained between 40 and 120 deg F.

d. Specified surfaces should be shielded to avoid exposure of direct sunlight or other intense heat source. Where varying surface temperatures do exist, coating installation should be scheduled when the temperature is falling versus rising.

e. Prior to commencing surface preparation, Contractor shall inspect all surfaces specified to receive the coating and notify Owner, in writing, of any noticeable disparity in the site, structure or surfaces which may interfere with the work, use of materials or procedures as specified herin.

6.4 Surface Preparation

a. Concrete and/or mortar damaged by corrosion, chemical attack or other means of degradation shall be removed so that only sound substrate remains.

b. Oils, grease, incompatible existing coatings, waxes, form release, curing compounds, efflorescence, sealers, salts, or other contaminants which may affect the performance and adhesion of the coating to the substrate shall be removed.

c. Choice of surface preparation method(s) should be based upon the condition of the structure and concrete or masonry surface, potential contaminants present, access to perform work, and required cleanliness and profile of the prepared surface to receive the coating product(s).

d. Suface preparation method, or combination of methods, that may be used include high pressure water cleaning, water jetting, abrasive blasting, shotblasting, grinding, scarifying, detergent water cleaning, hot water blasting and others as referenced in NACE No. 6/SSPC SP-13 Surface Preparation of Concrete. Whichever method(s) are used, the work shall be performed in a manner that provides a uniform, sound clean neutralized surface suitable for the specified coating product(s).

e. Resulting surface profile shall be at least a CSP 4 in accordance with ICRI Technical Guideline No. 03732.

f. Prior to the application of the coating prodcut, all infiltration shall be eliminated by use of appropriate repair material(s), such as hydraulic cements and/or repair mortars per Section 5.2. Consult with manufacturer when compatiblity issues arise.

6.5 Application of Repair and Resurfacing Products

a. Areas where rebar has been exposed shall be repaired by an abrasive blast according to SSPC-SP10 prior to applying specified primer, as recommended by the manufacturer or in accordance with the Project Engineer’s recommendations.

b. Repair products may be used to fill voids, bugholes, and other surface defects which may affect the performance or adhesion of the coating product(s).

c. Resurfacing products shall be used to repair, smooth or rebuild surfaces with rough profiles to provide a concrete or masonry substrate suitable for the coating product(s) to be applied. These products shall be installed to minimum thickness as recommended within manufacturers published guidelines. Should structural rebuild be necessary, these products shall be installed to a thickness as specified by the Project Engineer.

d. Repair and resurfacing products shall be handled, mixed, installed and cured in accordance with manufacturer guidelines setforth in Section 5.3.

e. All repaired or resurfaced surfaces shall be inspected for cleanliness and suitability to receive the coating product(s).

6.6 Application of Epoxy Coating Product(s)

A. Application procedures shall conform to the recommendations of the coating product(s) manufacturer, including environmental controls, product handling, mixing, application equipment and methods.

B. Spray equipment shall be specifically designed to accurately ratio and apply the coating product(s) and shall be in proper working order.

C. Contractors qualified in accordance per Section 5.1 of these specifications shall perform all aspects of coating product(s) installation.

D. Prepared surfaces shall be coated via spray application of the coating product(s) described herein unless otherwise recommended by the coating product manufacturer.

E. Coating thickness shall be in relation to the profile of the surface to be coated as recommended by the coating product manufacturer.

F. In all cases the coating product(s) shall be applied to a minimum dry film thickness of 80 mils to surface profiles of CSP-4 to CSP-6 or 125 mils minimum DFT to surface profiles of CSP-7 or greater.

G. Subsequent topcoating or additional coats of the coating product(s) shall occur within the product’s recoat window or 24 hours which ever is less. Additional surface preparation procedures will be required if this recoat window is exceeded.

H. Coating product(s) shall interface with adjoining construction materials/components throughout the structure to effectively seal and protect substrates from attack by corrosive elements and to ensure the effective elimination of inflitration into the sewer system.

I. Procedures and materials necessary to effect the interface between dissimilar materials and the coating product shall be as recommended by the coating product(s) manufacturer.

J. Sewage flow shall be stopped, bypassed or diverted as necessary for application of the coating product(s) to the invert/flowline.

7.0 QUALITY CONTROL – CEMENT

The quality and performance of the material and the workmanship of the applicator shall be maintained by one or more of the following measures to be determined and specified by the engineer or owner.

7.1 Visual Inspection

All structures will be visually inspected for cracks, bug holes, and unfinished surfaces.

7.2 Performance Testing

A. Vacuum Testing

All pipes entering the manhole should be plugged, taking care to securely place the plug from being drawn into the manhole. A vacuum pump apparatus shall be placed onto the manhole ring and sealed to the structure in accordance with the pump manufacturers' recommendations. A vacuum pump of ten (10) inches of mercury shall be drawn and the vacuum pump shut off. With the pressure relief valves closed, the time shall be measured for the vacuum to drop to (9) inches. The following are minimum allowable test times for manhole acceptance at the specified vacuum drop.

Manhole Depth	Time (Seconds)		
(Feet)	48" Diameter	60" Diameter	72" Diameter
4	10	13	16
8	20	26	32
12	30	39	48
16	40	52	64
20	50	65	80
24	60	78	96
For each additional 2 ft. depth add:	5	6.5	8

B. Exfiltration Testing

First, incoming and outgoing sewer and service lines shall be plugged. An optional soaking period of up to one (1) hour will be allowed if bypassing of the sewage is not required or has been provided for. At the end of this optional soaking period, the manhole shall be completely filled with water to the manhole cover frame and the test initiated. For manholes that are 0-6 feet in depth, if water loss is less than one (1) inch or less in five (5) minutes, the manhole reconstruction shall be deemed acceptable. For manholes that are over six (6) feet in depth, if water loss is one (1) inch plus 1/8-inch for each additional foot of depth or less in five (5) minutes, the manhole reconstruction shall be deemed acceptable. Should the drop in the water level exceed the previously stated test standard, the manhole shall be deemed a failed installation.

C. Material Testing

One 2 x 2 inch sample cube shall be taken for every 56 bags of material used. Samples shall be sprayed from nozzle, identified, and sent to an independent test laboratory for compression strength testing as described in ASTM C-109 and shall have a minimum average of the strengths set forth in Section 3.3.

8.0 QUALTIY CONTROL – EPOXY

A. During application, a wet film thickness gauge, meeting ASTM D4414 – Standard Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages, shall be used. Measurements shall be taken, documented and attested to by Contractor for submission to Owner.

B. High voltage holiday detection for coating systems installed in corrosive environments, when it can be safely and effectively employed, shall be performed to ensure monolithic protection of the substrate. After the coating product(s) have cured in accordance with manufacturer recommendations, all surfaces shall be inspected for holidays in accordance with NACE RPO 188-99 Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates or ASTM D4787 Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates. All detected holidays shall be marked and repaired according to the coating product(s) manufacturer's recommendations.

a. Test voltage shall be a minimum of 100 volts per mil of coating system thickness.
b. Detection of a known or induced holiday in the coating product shall be confirmed to ensure proper operation of the test unit.
c. All areas repaired shall be retested following cure of the repair material(s).
d. In instances where high voltage holiday detection is not feasible a close visual inspection shall be conducted and all possible holidays shall be marked and repaired as described above.

e. Documentation of areas tested, equipment employed, results and repairs made shall be submitted to the Owner/Engineer by Contractor.

C. Adhesion of the coating system to the substrate shall be confirmed in a minimum of 10% of the manholes coated, or for large structures once every 1000 square feet of coated area. Testing shall be conducted in accordance with ASTM D7234 Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers. Owner's representative shall select the manholes or areas to be tested.

a. For each test manhole a minimum of three 20 mm dollies shall be affixed to the coated surface; one at the cone area, one at the mid section and one near the bottom of the structure.
b. For larger structures a minimum of three 20 mm doliies shall be affixed to the coated surface at random locations within each 1000 square foot area or as otherwise agreeded upon.
c. The adhesive used to attach the dollies to the coating shall be rapid setting with tensile strengths in excess of at least twice the anticipated failure point (generally at least 1000 psi) and permitted to cure in accordance with manufacturer recommendations. The coating and dollies shall be adequately cleaned and prepared to receive the adhesive. Failure of the dolly adhesive shall be deemed a non-test and require retesting.
d. Prior to performing the pull test, the coating shall be scored to the substrate, or within 10 mils of the substrate surface, by mechanical means without disturbing the dolly or coating system bond within the test area.
e. Two of the three adhesion pulls in each test area shall exceed 200 psi and shall include substrate adhered to the back of the dolly or no visual signs of the coating product in the test hole. Pulls tests with results between 150 and 200 psi may be acceptable if more than 50 percent of the substrate in the test area is adhered to the dolly.
f. Should a structure, or area, fail to achieve two successful pulls as described above, additional testing shall be performed at the discretion of the Owner or Project Engineer. Any areas detected to have inadequate bond strength shall be evaluated by the Project Engineer. Further bond tests may be performed in that area to determine the extent of potentially deficient bonded area and repairs shall be made by Contractor
g. All adhesion testing shall be performed by qualifed personnel using calibrated equipment as specified by the applicable ASTM standard(s).
h. All adhesion testing shall be documented and submitted in a consistent format detailing location, test values, description of the failure point/mode, scoring method employed, adhesive used, cure time of coating and adhesive and other data as deemed necessary by the owner/engineer.
i. All a adhesion test locations shall be repaired by the Contractor at no cost to the Owner.

D. Visual inspection shall be made by the Project Engineer and/or Inspector. Any deficiencies in the finished coating effecting the perfomance of the coating system or the operational functionality of the structure shall be marked and repaired according to the recommendations of the coating product(s) manufacturer.

E. The municipal sewer system may be returned to full operational service as soon as the final inspection has taken place and all coating materials have been adequately cured according to the coating product(s) manufacturer’s recommendations.

9.0 WARRANTY

9.1 Product manufacturers shall warrant all materials to be free of defects, product design, and workmanship for a period of one year from date of purchase. Manufacturer will provide replacement materials for any product proven to be defective when applied in accordance with manufacturer’s recommendations. Manufacturer’s obligation shall be limited solely to product replacement.

QUADEX
SEWER REHABILITATION PRODUCTS

QUADEX ALUMINALINER

A CALCIUM ALUMINATE SEWER REHABILITATION MORTAR

DESCRIPTION:

Quadex Aluminaliner is a factory blended, one component fiber reinforced, fused calcium aluminate cement mortar, enhanced with a monocrystalline quartz aggregate (Granusil®). This mortar is specifically designed to provide ultimate protection against hydrogen sulfide gas induced corrosion, add structural integrity and stop the infiltration of groundwater in sewer structures. This unique formulation allows for a monolithic one-pass application up to three inches in thickness by low pressure spraying.

RECOMMENDED FOR:

Vertical and overhead repairs to concrete or masonry sewer structures such as manholes, wetwells, pipe and treatment plant structures where corrosion is a problem.

FEATURES AND BENEFITS:

Quality controlled one-component blend for uniform results.
High early and ultimate compressive, flexural and bond strengths.
Resistant to sulfide attack.
Extremely low permeability.

TYPICAL PERFORMANCE DATA:

Compressive Strength PSI (ASTM C109)
28-day
>9000
Flexural Strength PSI (ASC293)
28-day
>1100
Bond Strength PSI (ASTM C321)
Brick failed before bond
Freeze-Thaw Durability (ASTM C666)
No visible damage after 300 cycles
Permeability (AASHTO T-277)
350 Coulombs
Shrinkage at 95% Humidity (ASTM C596)
28-day
0%
Sulfide Resistance (ASTM C267)
No attack
Density 127 +/- 5 PCF

PACKAGING:

Quadex Aluminaliner is supplied in 60 lb. (27 kg.) poly-lined bags.

YIELD:

One 60-lb. bag of **Quadex Aluminaliner** will yield approximately .54 cu. ft. and will cover 12.5 sq. ft. at a 1 / 2 inch thickness.

PROCEDURE:

Prepare surface to be patched by removing unsound concrete, dirt, dust, oil and other debris using high pressure (3500 PSI) water blasting. Air blast excess water with an oil free air compressor. This will provide a clean, damp surface to allow for a good bond.

Use approximately 0.9 to 1.1 gallons of potable water per 60 lb. bag of **Quadex Aluminaliner**. First add water to mixer, start mixer to mixing and add Quadex Aluminaliner until mortar is completely mixed.

Apply **Quadex Aluminaliner** by low pressure spraying on vertical or overhead surfaces to a monolithic thickness of 1 / 2 to 3 inches in one pass, trowel to smooth surface.

CURING:

Cure in accordance with current ACI recommendations. Use a two coat application of a manufacturer approved water based curing compound.

WARRANTY:

Quadex warrants its products to be free of defects in material and workmanship. **Quadex** will replace any product proved to be defective when applied in accordance with manufacturer's instructions. **Quadex's** obligation shall be limited solely to such replacement. There are no other warranties by **Quadex** expressed or implied.

PRECAUTIONS:

Avoid eye contact or prolonged contact with skin. Wash thoroughly after use. Persons using **Quadex Aluminaliner** should wear necessary eye protection, dusk mask and rubber gloves. Read all product labels and technical literature

4801 Crystal Hill Road □ North Little Rock, AR 72118 □ Phone: (501) 758-8628 □ Toll Free: (888) 831-1650 □ FAX: (501) 803-9444

QUADEX
4801 Crystal Hill Road
North Little Rock, AR 72118
Phone: (501) 758-8628
Fax: (501) 758-3814

ALUMINALINER

MATERIAL SAFETY DATA SHEET

PRODUCT: QUADEX ALUMINALINER **Issue Date: April 9, 1996**

HAZARDOUS INGREDIENTS/ IDENTITY INFORMATION		PHYSICAL / CHEMICAL CHARACTERISTICS	
COMMON NAMES	**ACGIH TLV**	**Boiling Point:** NA	**Specific Gravity:** 3.15
Calcium Aluminate Cement	10 mg/M^3	**Vapor Pressure:** NA	**Melting Point:** NA
Admixtures	10 mg/M^3	**Vapor Density:** NA	**Evaporation Rate:** NA
Monocrystalline Quartz	10 mg/M^3	**Solubility in Water:** Slight (0.01 – 1.0%)	
Polypropylene	10 mg/M^3	**Appearance and Odor:** Grey and Odorless	

FIRE AND EXPLOSION HAZARD DATA	REACTIVITY DATA
Flash Point: NA	**Stability:** Stable
Special Fire Fighting Procedures: Non-Combustible Material	**Conditions to Avoid:** Although no hazardous reaction will occur: product should be kept dry.
Extinguishing Media: NA	**Hazardous Decomposition or Byproducts:** None.
Usual Fire and Explosion Hazards: None.	**Hazardous Polymerization:** Will not occur.

HEALTH HAZARD DATA			
Routes of Entry:	Inhalation: Yes	Skin: Yes	Ingestion: Yes
Carcinogenicity:	NTP: No	IARC Monographs: No	OSHA Regulated: No
Signs and Symptoms of Exposure: May cause skin irritation, eye irritation and respiratory irritation.			
Medical Conditions Generally Aggravated by Exposure: May aggravate existing eye, lung, and skin conditions.			
Emergency and First Aid Procedures: Rinse eyes with clean water and wash affected skin with soap and water.			

PRECAUTIONS FOR SAFE HANDLING AND USE
Steps to Be Taken in Case Material is Released or Spilled: Shovel into labeled waste container for reuse or disposal. Wear adequate protective clothing and equipment. Area may be washed down with water.
Waste Disposal Method: Dispose in sanitary landfill in accordance with federal, state, and local regulations.
Precautions to be Taken in Handling and Storing: Store in dry place and keep sealed until ready to use.
Other Precautions: None

CONTROL MEASURES	
Respiratory Protection: Use NIOSH / MESHA approved respirator.	
Ventilation: Local exhaust recommended if necessary. Mechanical exhaust recommended if necessary.	
Protective Gloves: Rubber	**Eye Protection:** Goggles
Other Protective Clothing or Equipment: Standard work clothing and shoes.	
Work / Hygienic Practices: NA	

LANZO

Lining Services, Inc.

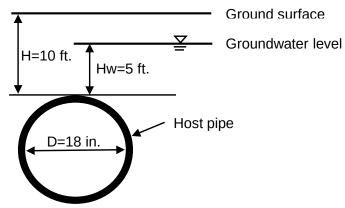
Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 18"

Design Assumptions:

			Shaded cells are user-defined
Condition of host pipe		FD	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	$D =$	18	
Ovality of host pipe (%)	$q =$	2.0	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	$S =$	0.003	
Host pipe Manning's roughness (dimensionless)	$n_i =$	0.015	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	$n_f =$	0.010	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	$M_{sn} =$	1,000	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*						
Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	Description	tons/sf	kPa		psi	kPa
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0

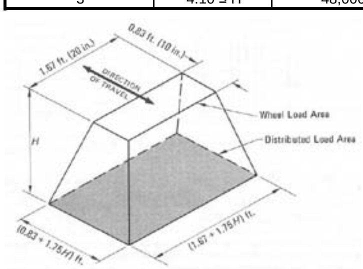


Flexural modulus of Elasticity of CIPP, initial (psi)	$E =$	350,000	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		50%	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	$E_L =$	175,000	Determined from long-term retention %
Design safety factor	$N =$	2	Default value is 2.0
Unit weight of soil (pcf)	$\delta_s =$	120	Applies to fully deteriorated designs only
Unit weight of water (pcf)	$\delta_w =$	62.4	
Depth of cover (ft)	$H =$	10.0	Measured from ground surface to top of pipe
Height of groundwater (ft)	$H_w =$	5.0	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	$P_v =$	0.0	Default value is 0
Internal pressure (psi)	$P =$	0.0	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	$d =$	0.0	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	$n =$	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	$s_i =$	5,500	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	$s_L =$	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	$s_T =$	4,000	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	$s_{TL} =$	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	$K =$	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		H20	H20, E80 or airport

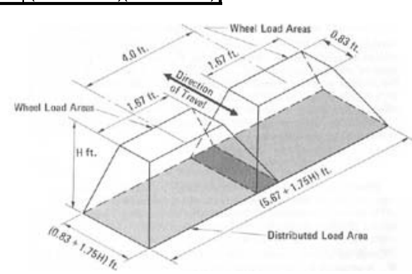
H20 Calculations (Highway Loads)

Impact factor for traffic load (dimensionless)	$I_f =$	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	$A_{LL} =$	517.4	See table and figures below
Total applied surface wheel load (lb)	$P_{LW} =$	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	$w_{LH} =$	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

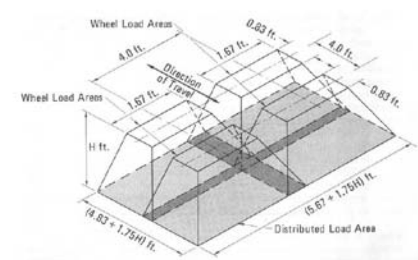
Critical Loading Configurations for H20 loads (per AASHTO)			
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



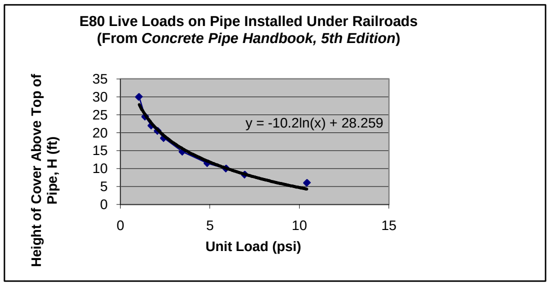
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi)	w_{LR} =	0.00	from graph below



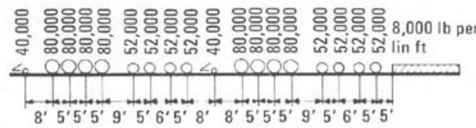
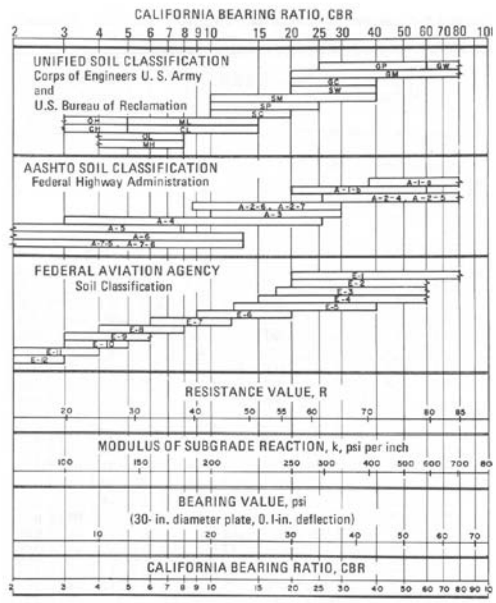


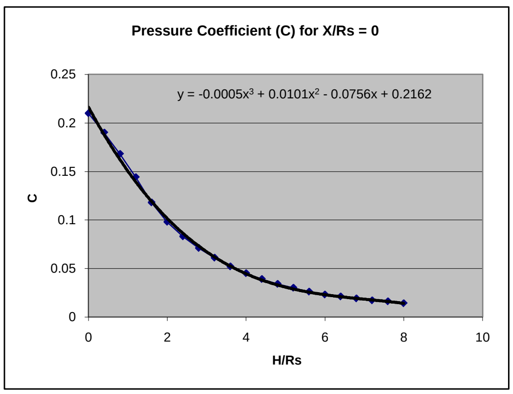
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

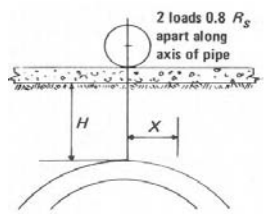
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in^3)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced 0.8R_s apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s =	2.756	
C =	0.074	

Airport live load transferred to pipe at depth H (psi)	w_{LA} =	0.00	$w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless)	C =	0.84		$C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$
External hydrostatic pressure from groundwater (psi)	P_w =	2.82		$P_w = \gamma_w(H_w + D/12)/144$
Minimum thickness required, hydrostatic buckling	t_1 =	0.24	in	$t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_v)}\right]^{1/3}\right)+1}$ ASTM F1216, Equation X1.1
	=	6.12	mm	
Minimum thickness required, ovality check	t_2 =	0.14	in	$1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2
	=	3.60	mm	
	SDR_2 =	127		If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2	a =	0.0306
used to solve for SDR_2 and t_2:	b =	-0.510
	c =	-488.1657

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64	From live load calculations		
Water buoyancy factor (dimensionless)	R_w =	0.84		$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67)	**Note: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	10.42		$q_t = 0.433H_w + \delta_s H R_w/144 + W_s$	**Note: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304		$B' = 1/(1+4e^{-0.065H})$	

Minimum thickness required, Luscher's buckling equation	t_3 =	0.29	in	$t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3
	=	7.48	mm	
Minimum thickness required, pipe stiffness	t_4 =	0.26	in	
	=	6.73	mm	$t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	d/D =	0.00		If $d/D \le 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

<u>CIPP Wall Thickness Design Summary</u>

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**18**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.29	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity
	=	7.48	mm	flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
Minimum CIPP thickness recommended	t_{min} =	0.29	in	Based on a maximum SDR = 100
	=	7.48	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**7.5**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	61		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

<u>Hydraulic Calculations</u>

CIPP inside diameter (in)	D_f =	17.4	
Flow area of host pipe (ft^2)	A_i =	1.77	
Flow area of CIPP (ft^2)	A_f =	1.65	
Capacity of host pipe (cfs)	Q_i =	4.99	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	6.84	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**37%**	

LANZO

Lining Services, Inc.

Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

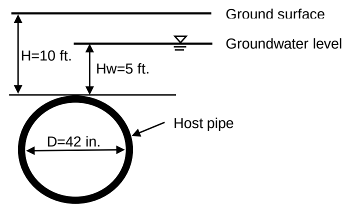
Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 42"

Design Assumptions:

			Shaded cells are user-defined
Condition of host pipe		**FD**	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	$D =$	**42**	
Ovality of host pipe (%)	$q =$	**2.0**	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	$S =$	**0.003**	
Host pipe Manning's roughness (dimensionless)	$n_i =$	**0.015**	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	$n_f =$	**0.010**	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	$M_{sn} =$	**1,000**	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*

Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	Description	tons/sf	kPa		psi	kPa
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0



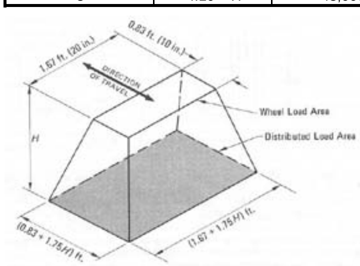
Flexural modulus of Elasticity of CIPP, initial (psi)	$E =$	**350,000**	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		**50%**	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	$E_L =$	175,000	Determined from long-term retention %
Design safety factor	$N =$	**2**	Default value is 2.0
Unit weight of soil (pcf)	$\delta_s =$	**120**	Applies to fully deteriorated designs only
Unit weight of water (pcf)	$\delta_w =$	62.4	
Depth of cover (ft)	$H =$	**10.0**	Measured from ground surface to top of pipe
Height of groundwater (ft)	$H_w =$	**5.0**	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	$P_v =$	**0.0**	Default value is 0
Internal pressure (psi)	$P =$	**0.0**	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	$d =$	**0.0**	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	$n =$	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	$s_i =$	**5,500**	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	$s_L =$	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	$s_T =$	**4,000**	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	$s_{TL} =$	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	$K =$	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		**H20**	H20, E80 or airport

H20 Calculations (Highway Loads)

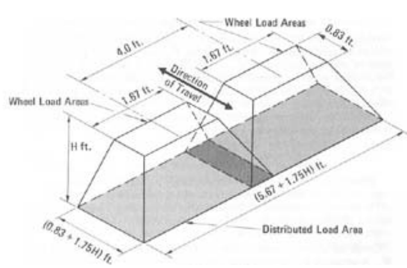
Impact factor for traffic load (dimensionless)	$I_f =$	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	$A_{LL} =$	517.4	See table and figures below
Total applied surface wheel load (lb)	$P_{LW} =$	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	$w_{LH} =$	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

Critical Loading Configurations for H20 loads (per AASHTO)

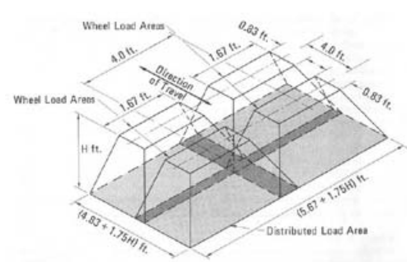
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



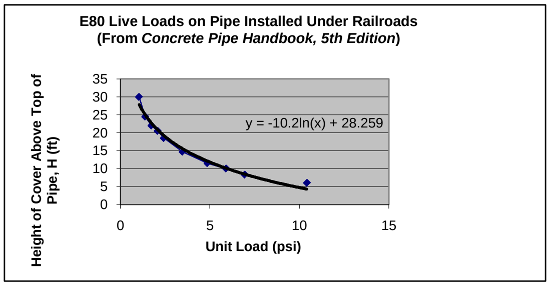
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi)	w_{LR} =	0.00	from graph below



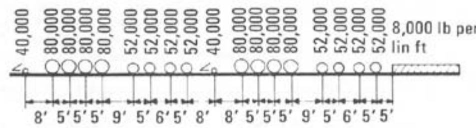
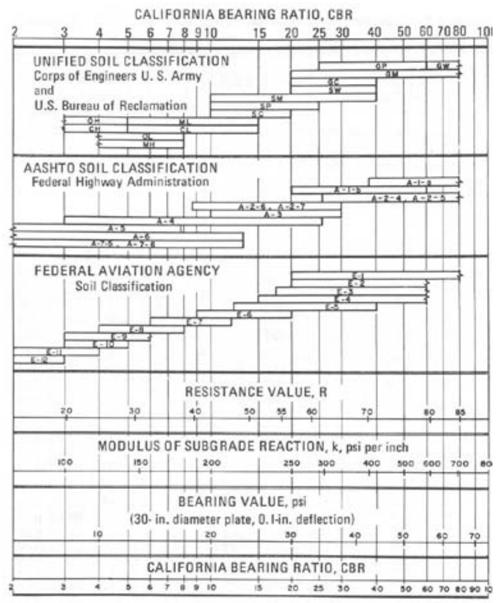


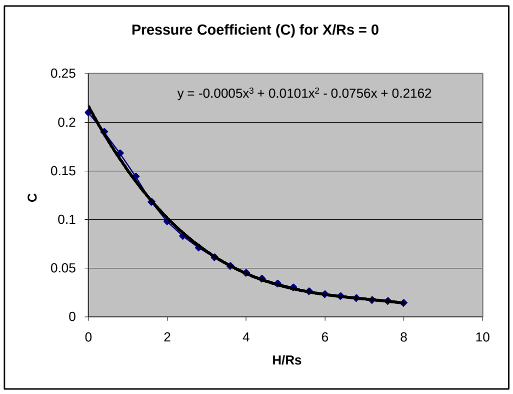
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

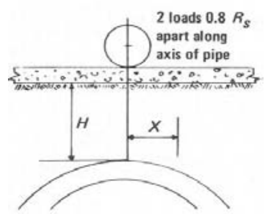
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in³)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced $0.8R_s$ apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s =	2.756	
C =	0.074	

Airport live load transferred to pipe at depth H (psi)	w_{LA} =	0.00	$w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless)	C =	0.84		$C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$
External hydrostatic pressure from groundwater (psi)	P_w =	3.68		$P_w = \gamma_w(H_w + D/12)/144$
Minimum thickness required, hydrostatic buckling	t_1 =	0.61	in	$t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_V)}\right]^{1/3}+1\right)}$ ASTM F1216, Equation X1.1
	=	15.61	mm	
Minimum thickness required, ovality check	t_2 =	0.38	in	$1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2
	=	9.59	mm	
	SDR_2 =	111		If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2 used to solve for SDR_2 and t_2:

a =	0.0306
b =	-0.510
c =	-373.3032

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64	From live load calculations	
Water buoyancy factor (dimensionless)	R_w =	0.84	$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67)	**Note: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	11.29	$q_t = 0.433H_w + \delta_s HR_w/144 + W_s$	**Note: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304	$B' = 1/(1+4e^{-0.065H})$	

Minimum thickness required, Luscher's buckling equation	t_3 =	0.72	in	$t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3
	=	18.41	mm	
Minimum thickness required, pipe stiffness	t_4 =	0.62	in	
	=	15.70	mm	$t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	**d/D =**	0.00		If $d/D \le 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

<u>CIPP Wall Thickness Design Summary</u>

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**42**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.72	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
	=	18.41	mm	
Minimum CIPP thickness recommended	t_{min} =	0.72	in	Based on a maximum SDR = 100
	=	18.41	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**19.5**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	55		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

<u>Hydraulic Calculations</u>

CIPP inside diameter (in)	D_f =	40.5	
Flow area of host pipe (ft^2)	A_i =	9.62	
Flow area of CIPP (ft^2)	A_f =	8.93	
Capacity of host pipe (cfs)	Q_i =	47.76	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	64.87	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**36%**	

LANZO
Lining Services, Inc.

Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

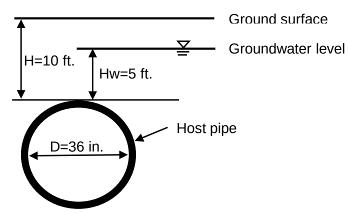
Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 36"

Design Assumptions: Shaded cells are user-defined

Condition of host pipe		FD	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	D =	36	
Ovality of host pipe (%)	q =	2.0	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	S =	0.003	
Host pipe Manning's roughness (dimensionless)	n_i =	0.015	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	n_f =	0.010	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	M_{sn} =	1,000	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*

Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	Description	tons/sf	kPa		psi	kPa
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0



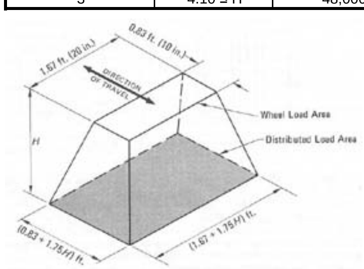
Flexural modulus of Elasticity of CIPP, initial (psi)	E =	350,000	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		50%	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	E_L=	175,000	Determined from long-term retention %
Design safety factor	N =	2	Default value is 2.0
Unit weight of soil (pcf)	δ_s =	120	Applies to fully deteriorated designs only
Unit weight of water (pcf)	δ_w =	62.4	
Depth of cover (ft)	H =	10.0	Measured from ground surface to top of pipe
Height of groundwater (ft)	H_w =	5.0	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	P_v =	0.0	Default value is 0
Internal pressure (psi)	P =	0.0	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	d =	0.0	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	n =	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	s_i =	5,500	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	s_L =	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	s_T =	4,000	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	s_{TL} =	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	K =	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		H20	H20, E80 or airport

H20 Calculations (Highway Loads)

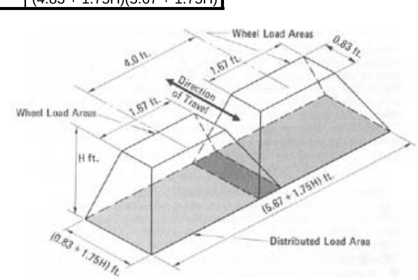
Impact factor for traffic load (dimensionless)	I_f =	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	A_{LL} =	517.4	See table and figures below
Total applied surface wheel load (lb)	P_{LW} =	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	w_{LH} =	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

Critical Loading Configurations for H20 loads (per AASHTO)

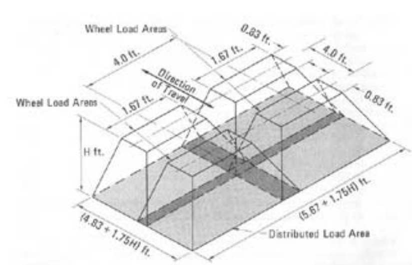
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



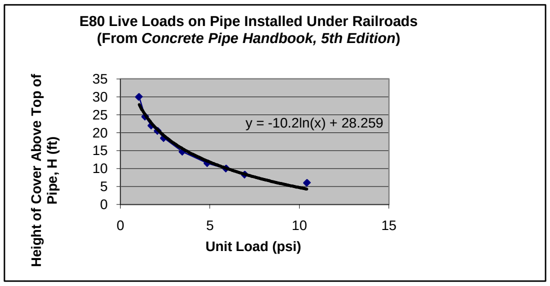
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi)	w_{LR} =	0.00	from graph below



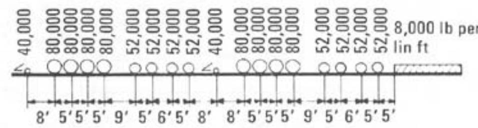
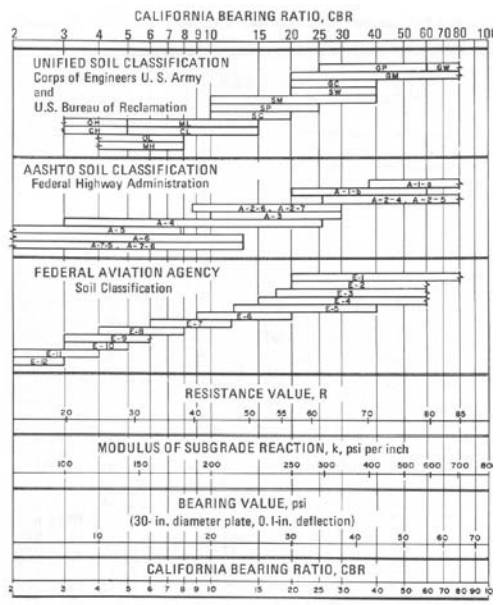


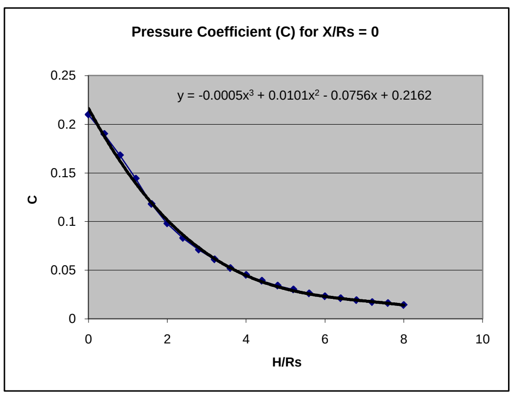
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

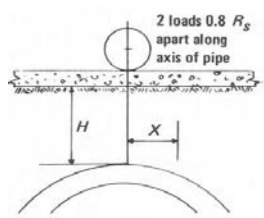
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in^3)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced 0.8R_s apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s =	2.756	
C =	0.074	

Airport live load transferred to pipe at depth H (psi)	w_{LA} =	0.00	$w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless)	C =	0.84		$C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$
External hydrostatic pressure from groundwater (psi)	P_w =	3.47		$P_w = \gamma_w(H_w + D/12)/144$
Minimum thickness required, hydrostatic buckling	t_1 =	0.52	in	$t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_V)}\right]^{1/3}\right)+1}$ ASTM F1216, Equation X1.1
	=	13.12	mm	
Minimum thickness required, ovality check	t_2 =	0.31	in	$1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2
	=	7.97	mm	
	SDR_2 =	115		If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2 a = 0.0306
used to solve for SDR_2 and t_2: b = -0.510
c = -396.6346

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64		From live load calculations
Water buoyancy factor (dimensionless)	R_w =	0.84		$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67) **<u>Note</u>: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	11.07		$q_t = 0.433H_w + \delta_s HR_w/144 + W_s$ **<u>Note</u>: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304		$B' = 1/(1+4e^{-0.065H})$
Minimum thickness required, Luscher's buckling equation	t_3 =	0.61	in	$t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3
	=	15.58	mm	
Minimum thickness required, pipe stiffness	t_4 =	0.53	in	
	=	13.46	mm	$t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	d/D =	0.00		If $d/D \leq 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

CIPP Wall Thickness Design Summary

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**36**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.61	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
	=	15.58	mm	
Minimum CIPP thickness recommended	t_{min} =	0.61	in	Based on a maximum SDR = 100
	=	15.58	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**16.5**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	55		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

Hydraulic Calculations

CIPP inside diameter (in)	D_f =	34.7	
Flow area of host pipe (ft^2)	A_i =	7.07	
Flow area of CIPP (ft^2)	A_f =	6.57	
Capacity of host pipe (cfs)	Q_i =	31.66	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	43.06	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**36%**	

LANZO
Lining Services, Inc.

Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

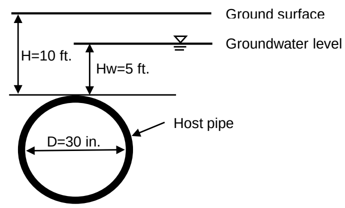
Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 30"

Design Assumptions:

			Shaded cells are user-defined
Condition of host pipe		**FD**	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	**D =**	**30**	
Ovality of host pipe (%)	**q =**	**2.0**	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	**S =**	**0.003**	
Host pipe Manning's roughness (dimensionless)	n_i =	**0.015**	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	n_f =	**0.010**	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	M_{sn} =	**1,000**	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*

Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	**Description**	**tons/sf**	**kPa**		**psi**	**kPa**
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0



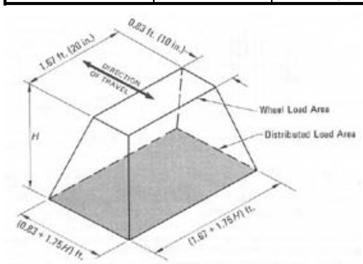
Flexural modulus of Elasticity of CIPP, initial (psi)	**E =**	**350,000**	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		**50%**	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	E_L=	175,000	Determined from long-term retention %
Design safety factor	**N =**	**2**	Default value is 2.0
Unit weight of soil (pcf)	δ_s =	**120**	Applies to fully deteriorated designs only
Unit weight of water (pcf)	δ_w =	62.4	
Depth of cover (ft)	**H =**	**10.0**	Measured from ground surface to top of pipe
Height of groundwater (ft)	H_w =	**5.0**	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	P_v =	**0.0**	Default value is 0
Internal pressure (psi)	**P =**	**0.0**	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	**d =**	**0.0**	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	**n =**	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	s_i=	**5,500**	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	s_L =	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	s_T=	**4,000**	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	s_{TL} =	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	**K =**	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		**H20**	H20, E80 or airport

H20 Calculations (Highway Loads)

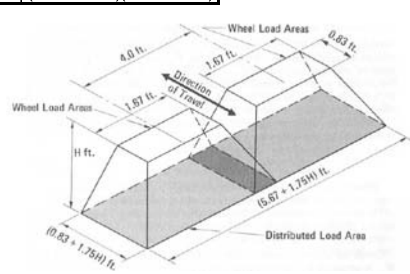
Impact factor for traffic load (dimensionless)	I_f=	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	A_{LL} =	517.4	See table and figures below
Total applied surface wheel load (lb)	P_{LW} =	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	w_{LH} =	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

Critical Loading Configurations for H20 loads (per AASHTO)

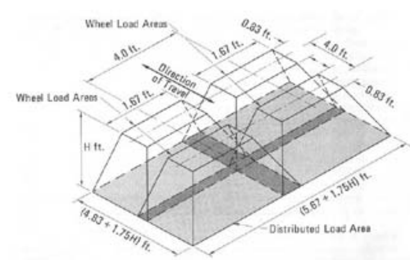
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



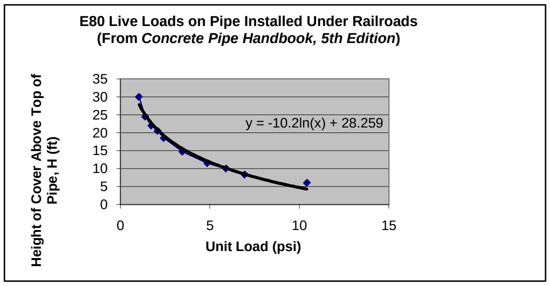
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi) w_{LR} = 0.00 from graph below



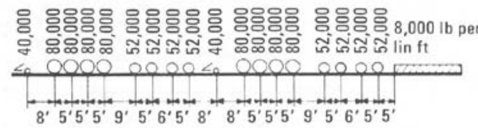
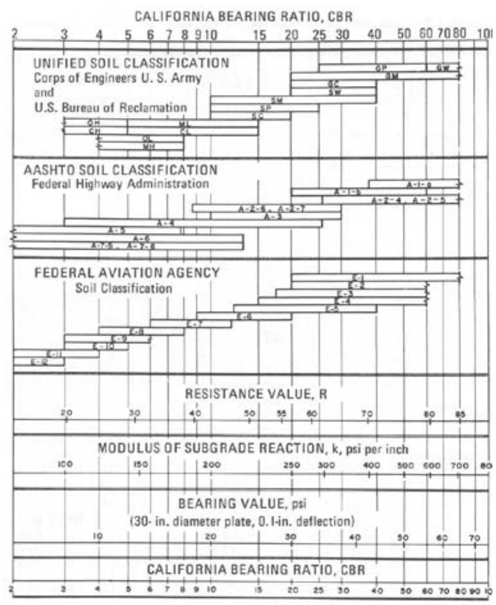


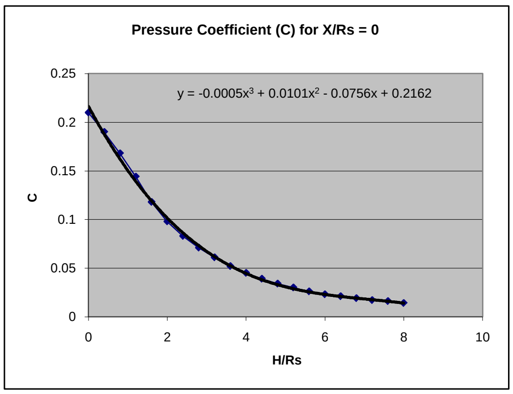
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

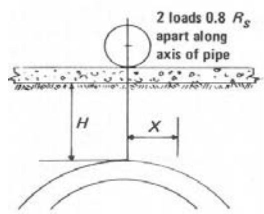
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in^3)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced 0.8R_s apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s = 2.756
C = 0.074

Airport live load transferred to pipe at depth H (psi) w_{LA} = 0.00 $w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless) C = 0.84 $C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$

External hydrostatic pressure from groundwater (psi) P_w = 3.25 $P_w = \gamma_w(H_w + D/12)/144$

Minimum thickness required, hydrostatic buckling t_1 = 0.42 in = 10.70 mm $t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_V)}\right]^{1/3}\right)+1}$ ASTM F1216, Equation X1.1

Minimum thickness required, ovality check t_2 = 0.25 in = 6.44 mm SDR_2 = 118 $1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2

If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2 a = 0.0306
used to solve for SDR_2 and t_2: b = -0.510
c = -423.0769

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64	From live load calculations	
Water buoyancy factor (dimensionless)	R_w =	0.84	$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67)	**Note: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	10.85	$q_t = 0.433H_w + \delta_s HR_w/144 + W_s$	**Note: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304	$B' = 1/(1+4e^{-0.065H})$	

Minimum thickness required, Luscher's buckling equation t_3 = 0.50 in = 12.81 mm $t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3

Minimum thickness required, pipe stiffness t_4 = 0.44 in = 11.22 mm $t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	d/D =	0.00		If $d/D \leq 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

CIPP Wall Thickness Design Summary

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**30**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.50	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity
	=	12.81	mm	flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
Minimum CIPP thickness recommended	t_{min} =	0.50	in	Based on a maximum SDR = 100
	=	12.81	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**13.5**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	56		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

Hydraulic Calculations

CIPP inside diameter (in)	D_f =	28.9	
Flow area of host pipe (ft^2)	A_i =	4.91	
Flow area of CIPP (ft^2)	A_f =	4.57	
Capacity of host pipe (cfs)	Q_i =	19.47	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	26.53	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**36%**	

LANZO
Lining Services, Inc.

Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

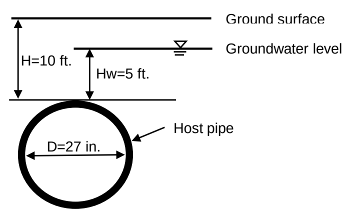
Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 27"

Design Assumptions:

			Shaded cells are user-defined
Condition of host pipe		FD	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	D =	27	
Ovality of host pipe (%)	q =	2.0	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	S =	0.003	
Host pipe Manning's roughness (dimensionless)	n_i =	0.015	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	n_f =	0.010	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	M_{sn} =	1,000	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*

Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	Description	tons/sf	kPa		psi	kPa
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0



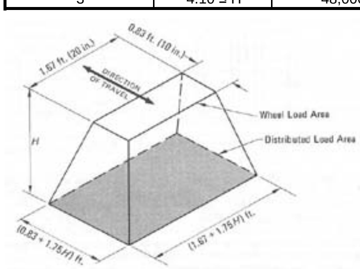
Flexural modulus of Elasticity of CIPP, initial (psi)	E =	350,000	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		50%	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	E_L=	175,000	Determined from long-term retention %
Design safety factor	N =	2	Default value is 2.0
Unit weight of soil (pcf)	δ_s =	120	Applies to fully deteriorated designs only
Unit weight of water (pcf)	δ_w =	62.4	
Depth of cover (ft)	H =	10.0	Measured from ground surface to top of pipe
Height of groundwater (ft)	H_w =	5.0	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	P_v =	0.0	Default value is 0
Internal pressure (psi)	P =	0.0	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	d =	0.0	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	n =	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	s_i =	5,500	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	s_L =	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	s_T =	4,000	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	s_{TL} =	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	K =	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		H20	H20, E80 or airport

H20 Calculations (Highway Loads)

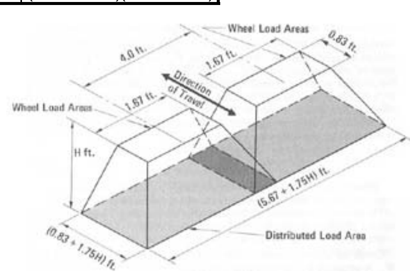
Impact factor for traffic load (dimensionless)	I_f =	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	A_{LL} =	517.4	See table and figures below
Total applied surface wheel load (lb)	P_{LW} =	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	w_{LH} =	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

Critical Loading Configurations for H20 loads (per AASHTO)

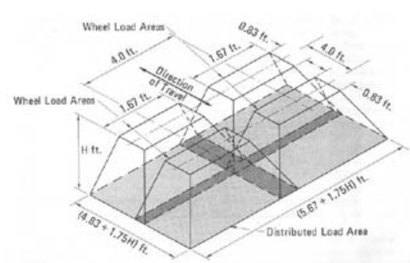
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



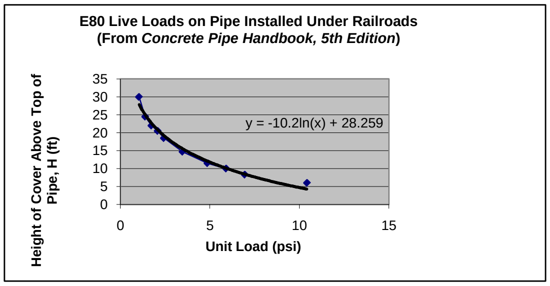
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi)	w_{LR} =	0.00	from graph below



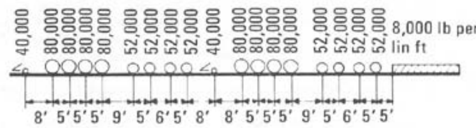
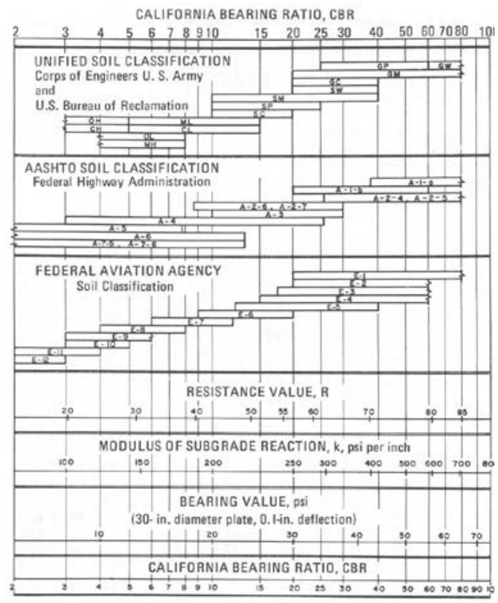


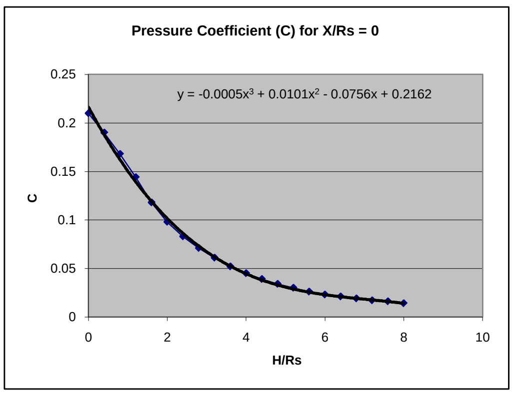
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

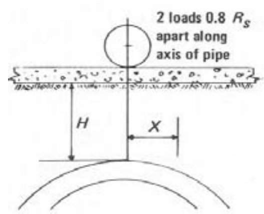
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in^3)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced 0.8R_s apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s = 2.756
C = 0.074

Airport live load transferred to pipe at depth H (psi)	w_{LA} =	0.00	$w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless)	C =	0.84		$C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$
External hydrostatic pressure from groundwater (psi)	P_w =	3.14		$P_w = \gamma_w(H_w + D/12)/144$
Minimum thickness required, hydrostatic buckling	t_1 =	0.37	in	$t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_V)}\right]^{1/3}\right)+1}$ ASTM F1216, Equation X1.1
	=	9.52	mm	
Minimum thickness required, ovality check	t_2 =	0.22	in	$1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2
	=	5.70	mm	
	SDR_2 =	120		If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2 used to solve for SDR_2 and t_2:
a = 0.0306
b = -0.510
c = -437.6658

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64	From live load calculations	
Water buoyancy factor (dimensionless)	R_w =	0.84	$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67)	**Note: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	10.74	$q_t = 0.433H_w + \delta_s HR_w/144 + W_s$	**Note: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304	$B' = 1/(1+4e^{-0.065H})$	

Minimum thickness required, Luscher's buckling equation	t_3 =	0.45	in	$t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3
	=	11.45	mm	
Minimum thickness required, pipe stiffness	t_4 =	0.40	in	
	=	10.09	mm	$t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	d/D =	0.00		If $d/D \le 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

CIPP Wall Thickness Design Summary

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**27**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.45	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
	=	11.45	mm	
Minimum CIPP thickness recommended	t_{min} =	0.45	in	Based on a maximum SDR = 100
	=	11.45	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**12.0**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	57		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

Hydraulic Calculations

CIPP inside diameter (in)	D_f =	26.1	
Flow area of host pipe (ft^2)	A_i =	3.98	
Flow area of CIPP (ft^2)	A_f =	3.70	
Capacity of host pipe (cfs)	Q_i =	14.70	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	20.05	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**36%**	

LANZO
Lining Services, Inc.

Cured-In-Place Pipe (CIPP) Wall Thickness Design and Hydraulic Capacity Calculations

Project: Buffalo Color
Location: Various site Storm Locations
Owner: EQ for Honeywell
Line Segment(s): 21"

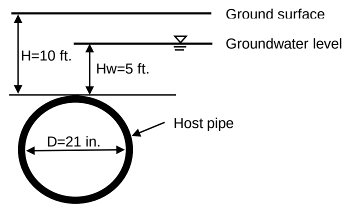
Design Assumptions:

Shaded cells are user-defined

Condition of host pipe		**FD**	PD = partially deteriorated, FD = fully deteriorated
Inside diameter of host pipe (in)	**D =**	**21**	
Ovality of host pipe (%)	**q =**	**2.0**	Default value is 2%; range = 0%-10%
Slope of host pipe (ft/ft)	**S =**	**0.003**	
Host pipe Manning's roughness (dimensionless)	**n_i =**	**0.015**	varies from 0.013-0.030 (dependent on existing pipe material, geometry, diameter and condition)
CIPP Manning's roughness (dimensionless)	**n_f =**	**0.010**	varies from 0.009-0.013
Constrained soil modulus of native soil in the pipe zone (psi)	**M_{sn} =**	**1,000**	See table below for recommended values

From Table 5.6 of *AWWA Manual of Water Practices M45, Second Edition*

Granular Native Soils		Cohesive Native Soils			M_{sn}	
		Unconfined compressive strength (q_u)		Description		
Blows/ft (per ASTM D1586)	Description	tons/sf	kPa		psi	kPa
> 0 - 1	very, very loose	> 0 - 0.125	0 - 13	very, very soft	50	0.3
1 - 2	very loose	0.125 - 0.25	13 - 25	very soft	200	1.4
2 - 4		0.25 - 0.50	25 - 50	soft	700	4.8
4 - 8	loose	0.50 - 1.0	50 - 100	medium	1,500	10.3
8 - 15	slightly compact	1.0 - 2.0	100 - 200	stiff	3,000	20.7
15 - 30	compact	2.0 - 4.0	200 - 400	very stiff	5,000	34.5
30 - 50	dense	4.0 - 6.0	400 - 600	hard	10,000	69.0
> 50	very dense	> 6.0	> 600	very hard	20,000	138.0



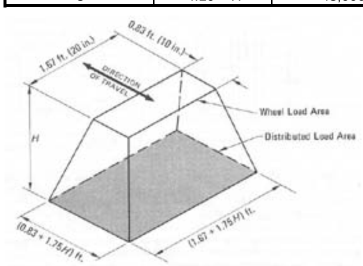
Flexural modulus of Elasticity of CIPP, initial (psi)	**E =**	**350,000**	Minimum value is 250,000 psi per ASTM F1216
Long-term retention of mechanical properties (%)		**50%**	Default value is 50%
Flexural modulus of elasticity of CIPP, long-term (psi)	**E_L=**	175,000	Determined from long-term retention %
Design safety factor	**N =**	**2**	Default value is 2.0
Unit weight of soil (pcf)	**δ_s =**	**120**	Applies to fully deteriorated designs only
Unit weight of water (pcf)	**δ_w =**	62.4	
Depth of cover (ft)	**H =**	**10.0**	Measured from ground surface to top of pipe
Height of groundwater (ft)	**H_w =**	**5.0**	Measured from top of pipe; **Note: If water table is below top of pipe, input a negative number!**
Internal vacuum pressure (psi)	**P_v =**	**0.0**	Default value is 0
Internal pressure (psi)	**P =**	**0.0**	Pressure pipe applications only! If no pressure, input 0
Diameter of hole or opening in original pipe wall (in)	**d =**	**0.0**	Pressure pipe applications only! If no pressure, input 0
Poisson's ratio of CIPP	**n =**	0.30	Average value for CIPP per ASTM F1216
Flexural strength of CIPP, initial (psi)	**s_i =**	**5,500**	Minimum value is 4,500 psi per ASTM F1216
Flexural strength of CIPP, long-term (psi)	**s_L =**	2,750	Determined from long-term retention %
Tensile strength of CIPP, initial (psi)	**s_T =**	**4,000**	Pressure pipe applications only!
Tensile strength of CIPP, long-term (psi)	**s_{TL} =**	2,000	Determined from long-term retention %
Enhancement factor (dimensionless)	**K =**	7.0	Minimum value recommended per ASTM F1216
Surface live loading condition		**H20**	H20, E80 or airport

H20 Calculations (Highway Loads)

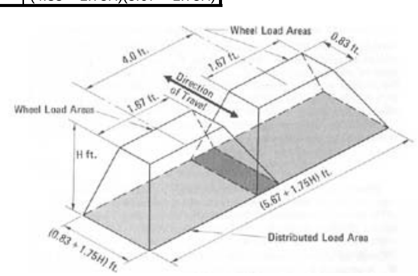
Impact factor for traffic load (dimensionless)	**I_f =**	1.0	From *AASHTO Standard Specifications for Highway Bridges, 12th Edition*
Distributed load area over pipe at depth H (ft^2)	**A_{LL} =**	517.4	See table and figures below
Total applied surface wheel load (lb)	**P_{LW} =**	48,000	Based on critical loading configuration (see table below)
H20 live load transferred to pipe at depth H (psi)	**w_{LH} =**	0.6	$w_L = (P \cdot I_f)/(144 \cdot A_{LL})$

Critical Loading Configurations for H20 loads (per AASHTO)

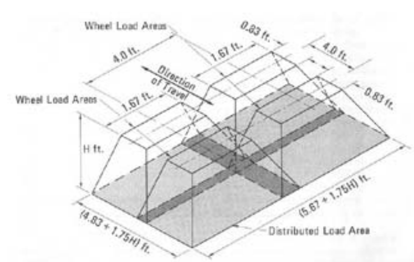
Condition	H, ft	P, lbs	A_{LL}, ft^2
1	H < 1.33	16,000	(0.83 + 1.75H)(1.67 + 1.75H)
2	1.33 ≤ H < 4.10	32,000	(0.83 + 1.75)(5.67 + 1.75H)
3	4.10 ≤ H	48,000	(4.83 + 1.75H)(5.67 + 1.75H)



Condition 1. Distributed Load Area - Single Dual Wheel



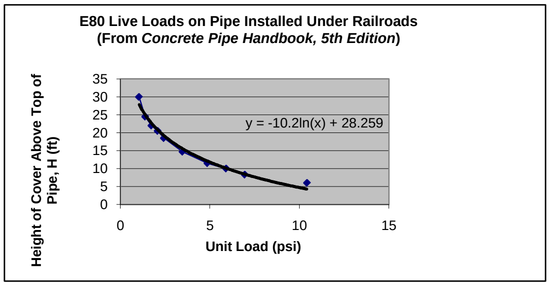
Condition 2. Distributed Load Area - Two H20 Trucks Passing



Condition 3. Distributed Load Area - Alternate Loads in Passing Mode

E80 Calculations (Railway Loads)

E80 live load transferred to pipe at depth H (psi)	w_{LR} =	0.00	from graph below



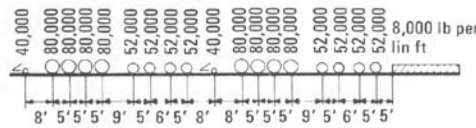
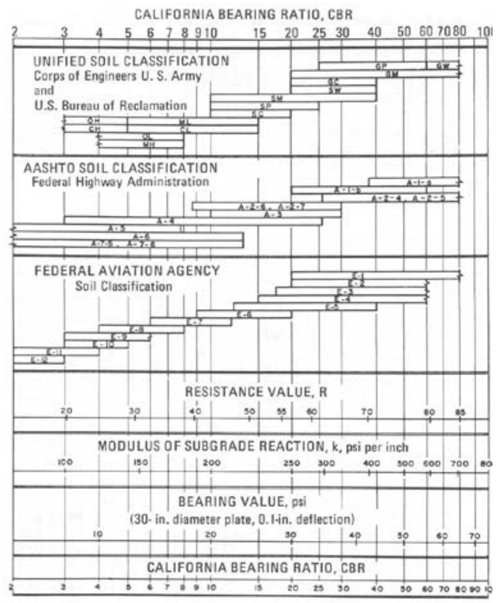


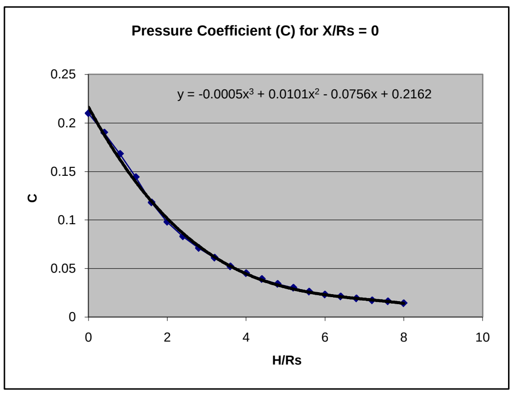
Figure 4.30. Spacing of Wheel Loads Per Axle for a Cooper E 80 Design Loading.

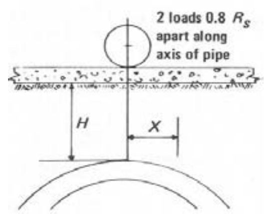
Airport Loads

Modulus of elasticity of concrete (psi)	E_c =	4,000,000	default value is 4,000,000
Poisson's ratio of concrete (dimensionless)	μ =	0.15	default value is 0.15
Modulus of subgrade reaction (lb/in^3)	k =	250	see adjacent figure
Thickness of concrete pavement (in)	h =	12	
Depth of cover, top of pipe to bottom of slab (ft)	H =	9.0	
Horizontal distance from pipe centerline (ft)	X =	0	assumed = 0 (worst case)
Radius of stiffness of the rigid pavement (ft)	R_s =	3.27	$R_s = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$
Wheel load (lbs)	P_{LA} =	90,000	



Worst-case loading scenario is for 2 loads spaced $0.8R_s$ apart and is calculated below.
For alternate loading conditions, see *Concrete Pipe Handbook, 5th Edition*





H/R_s =	2.756	
C =	0.074	

Airport live load transferred to pipe at depth H (psi)	w_{LA} =	0.00	$w_{LA} = CP/R_s^2$

Wall Thickness Design

Partially Deteriorated Gravity Pipe Condition

Ovality reduction factor (dimensionless)	C =	0.84		$C = \left(\frac{1-q/100}{[1+q/100]^2}\right)^3$
External hydrostatic pressure from groundwater (psi)	P_w =	2.93		$P_w = \gamma_w(H_w + D/12)/144$
Minimum thickness required, hydrostatic buckling	t_1 =	0.28	in	$t_1 = \frac{D}{\left(\left[\frac{2\cdot K\cdot E_L\cdot C}{(1-\upsilon^2)\cdot N\cdot(P_w+P_V)}\right]^{1/3}\right)+1}$ ASTM F1216, Equation X1.1
	=	7.24	mm	
Minimum thickness required, ovality check	t_2 =	0.17	in	$1.5\cdot\frac{q}{100}\cdot\left(1+\frac{q}{100}\right)\cdot SDR^2 - 0.5\cdot\left(1+\frac{q}{100}\right)\cdot SDR - \frac{\sigma_L}{P\cdot N} = 0$ ASTM F1216, Equation X1.2
	=	4.28	mm	
	SDR_2 =	125		If P_w = 0, default SDR = 100

Quadratic factors for Eq. X1.2 a = 0.0306
used to solve for SDR_2 and t_2: b = -0.510
c = -470.0855

Fully Deteriorated Gravity Pipe Condition

Total live load transferred to pipe at depth H (psi) =	W_s =	0.64	From live load calculations	
Water buoyancy factor (dimensionless)	R_w =	0.84	$R_w = 1 - 0.33(H_w/H)$ (min. value = 0.67)	**Note: If H_w<0, use H_w = 0 in this calculation**
Total external pressure on pipe (psi)	q_t =	10.53	$q_t = 0.433H_w + \delta_s HR_w/144 + W_s$	**Note: If H_w<0, use H_w = 0 in this calculation**
Coefficient of elastic support (in-lb)	B' =	0.304	$B' = 1/(1+4e^{-0.065H})$	

Minimum thickness required, Luscher's buckling equation	t_3 =	0.35	in	$t = \left[\frac{(q_t\cdot N)^2\cdot D^3\cdot 12}{32\cdot R_w\cdot B'\cdot M_{sn}\cdot E_L\cdot C}\right]^{1/3}$ ASTM F1216, Equation X1.3
	=	8.79	mm	
Minimum thickness required, pipe stiffness	t_4 =	0.31	in	
	=	7.85	mm	$t = D/(E/0.093\cdot 12)^{1/3}$ ASTM F1216, Equation X1.4

Partially Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand internal pressure	t_{pr} =	0.00	in	$t_{pr} = D/([(D/d)^2 \cdot (5.33 \cdot \sigma_L/PN)]^{1/2}+1)$ ASTM F1216, Equation X1.6
in spanning across any holes in the original pipe wall	d/D =	0.00		If $d/D \le 1.83 \cdot (t_{pr}/D)^{1/2}$, liner is in ring tension or hoop stress
	$1.83(t_{pr}/D)^{1/2}$ =	0.00		and fully deteriorated pressure pipe condition applies (ASTM F1216, Equation X1.5)
Minimum thickness required by design check	t_{pr1} =	0.00	in	
	=	0.00	mm	

Fully Deteriorated Pressure Pipe Condition

Minimum thickness required to withstand all external	t_{pr2} =	0.00	in	$t_{pr2} = D/((2 \cdot \sigma_{TL}/PN) + 2)$ ASTM F1216, Equation X1.7
loads and the full internal pressure	=	0.00	mm	

CIPP Wall Thickness Design Summary

Host pipe condition		Fully Deteriorated		
CIPP end use application		Gravity Flow		
CIPP outside diameter (host pipe inside diameter)	**D =**	**21**	**in**	
Minimum CIPP thickness calculated	t_{calc} =	0.35	in	Greatest value calculated from ASTM F1216 Equations X1.1, X1.2, X1.3 and X1.4 (gravity
	=	8.79	mm	flow) or greatest of X1.1, X1.2, X1.3, X1.4 and X1.7 (pressure pipe)
Minimum CIPP thickness recommended	t_{min} =	0.35	in	Based on a maximum SDR = 100
	=	8.79	mm	
Nominal CIPP thickness to be supplied	t_{CIPP} =	**9.0**	**mm**	Rounded up to the nearest 1.5 mm to reflect standard CIPP thicknesses supplied
	SDR_{CIPP} =	59		SDR = D/t Maximum recommended SDR for CIPP is 100 per ASTM F1216

Hydraulic Calculations

CIPP inside diameter (in)	D_f =	20.3	
Flow area of host pipe (ft^2)	A_i =	2.41	
Flow area of CIPP (ft^2)	A_f =	2.25	
Capacity of host pipe (cfs)	Q_i =	7.52	$Q = 1.486/n \cdot A \cdot R_H \cdot S^{1/2}$ (Manning's Equation)
Capacity of CIPP (cfs)	Q_f =	10.30	where R_H = hydraulic radius = D/4 for pipe flowing full
% increase/decrease in Flow Capacity	**ΔQ =**	**37%**	

Section 12 – Disposal Considerations

Waste Disposal Method:	Consult current federal, state and local regulations regarding the proper disposal of this material and its emptied containers.

Section 13 – Shipping/Transport Information

D.O.T Shipping Name:	Oxidizing Solid, N.O.S [A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
UN Number:	1479
Hazard Class:	5.1
Label(s):	5.1 (Oxidizer)
Packaging Group:	II
STCC Number:	4918717

Section 14 – Other Information

HMIS® Rating	Health – 2 Flammability – 0	Reactivity – 1 PPE - Required

HMIS® is a registered trademark of the National Painting and Coating Association.

NFPA® Rating	Health – 2 Flammability – 0	Reactivity – 1 OX

NFPA® is a registered trademark of the National Fire Protection Association.

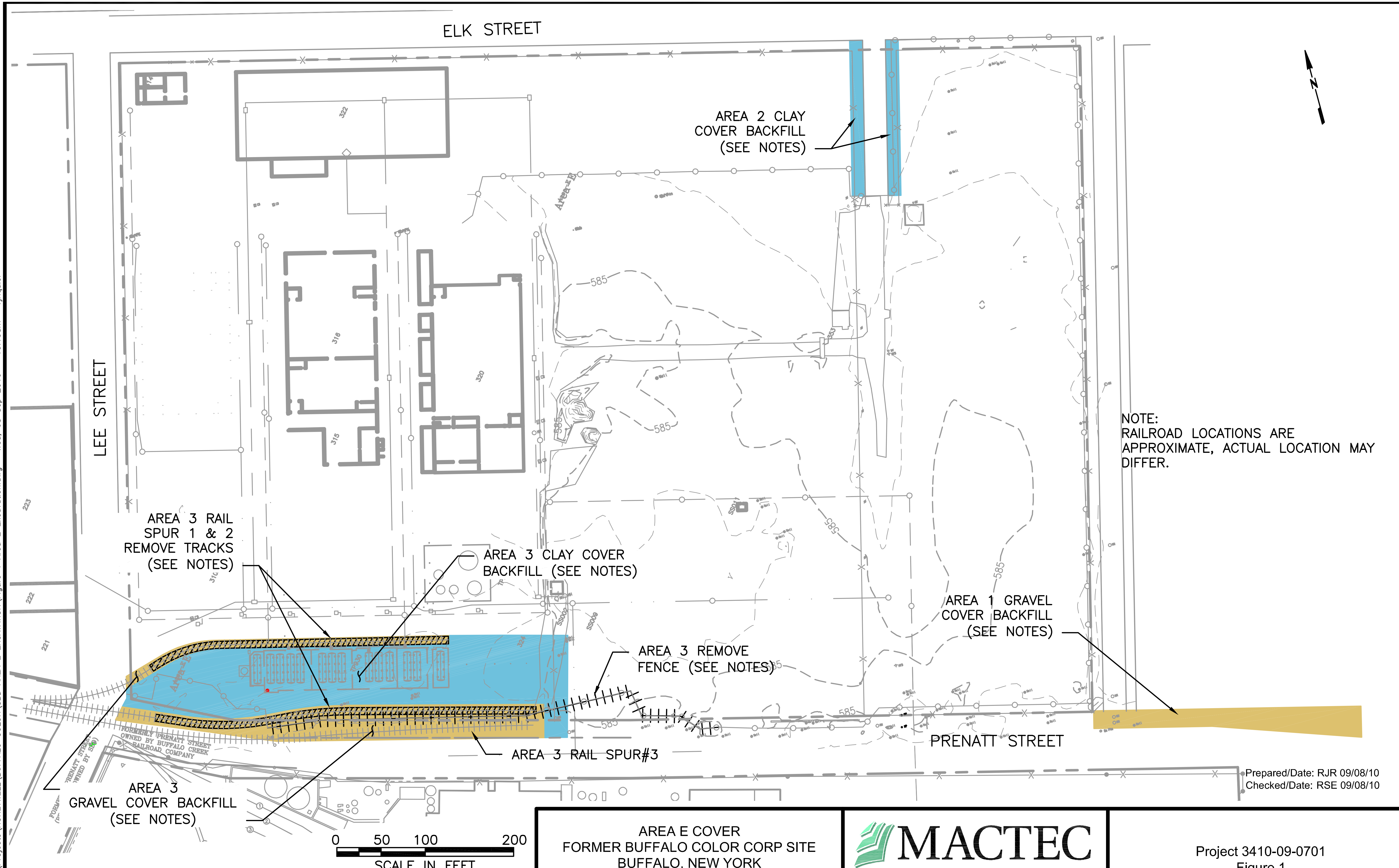
Reason for Issue: Update toxicological and ecological data

Section 15 – Further Information

The information contained in this document is the best available to the supplier at the time of writing, but is provided without warranty of any kind. Some possible hazards have been determined by analogy to similar classes of material. The items in this document are subject to change and clarification as more information become available.

APPENDIX V

QUALITY ASSURANCE/QUALITY CONTROL PLAN, DRAWINGS, AND DETAILS FOR SOIL COVER PLACEMENT



M:\Projects\HONEYWELL\BUFFALO COLOR\SBD AREA E EXCAVATION\Figure 1 Area E Excavation.dwg Wed, 08 Sep 2010 – 10:13am rjriquier

Prepared/Date: RJR 09/08/10
Checked/Date: RSE 09/08/10

AREA E COVER
FORMER BUFFALO COLOR CORP SITE
BUFFALO, NEW YORK

MACTEC

Project 3410-09-0701
Figure 1

Plan Notes

Area 1

1) All soils inside of property boundary shall be excavated to a depth of one (1) foot below existing grade.

2) Existing chain link fence within excavation area shall be removed as necessary to accomplish work. removed sections of fence shall be reinstalled at conclusion of work.

3) Backfill shall be placed and compacted to meet existing grade.

Area 2

1) Soils between curb and existing fence on either side of Maurice Street shall be excavated to a depth of one (1) foot below existing grade.

2) Backfill shall be placed and compacted to meet existing grade.

Area 3

1) Railroad (RR) tracks and ties for Spurs 1 and 2 shall be removed. Spur 3 shall not be disturbed.

2) Soils beneath spurs 1 and 2 shall be excavated to a depth of one (1) foot below existing grade. The lateral extents of the excavation shall extend laterally four (4) feet from ends of rail tie.

3) Limits of excavation shall be pre–marked prior to excavating soils or removing rail spurs.

4) In areas where RR tracks are to remain in place (western portions of Spurs 1 and 2 and all of Spur 3) the excavation shall extend from edge of rail tie to a horizontal distance of four (4) feet outside of rail tie or to the property boundary, whichever is closest.

5) All soils between Spurs 1 and 2 shall be removed to one (1) foot below existing grade. The existing chain link fence shall be removed as shown on drawings.

6) Chain link fence between Spurs 2 and 3 shall be reinstalled along the centerline between the spurs to a distance of ten (10) feet east of the Spur 3 termination. The fence line shall then extend to the property boundary along the southern border of the site. The fence line shall be extended along the southern property boundary until it intersects the existing fence.

7) Caution shall be used while excavating around Buffalo Sewer Authority (BSA) manholes and former utilities lines.

Detail Notes

Area 1

1) A woven geotextile demarcation layer shall be placed within the excavation envelope, along excavation bottom and sidewalls.

2) Gravel backfill shall be placed within the excavation envelope above the demarcation layer.

3) Gravel backfill shall be compacted by a minimum of three passes of a vibratory roller.

4) A post compacted backfill thickness of one (1) foot shall be achieved.

Area 2

1) A woven geotextile demarcation layer shall be placed within the excavation envelope, along excavation bottom and sidewalls.

2) Clay borrow shall be placed within the excavation envelope above the demarcation layer.

3) Clay backfill shall be compacted by a minimum of three passes of the tracks/tires of a bulldozer or frontend loader.

4) A post compacted thickness of clay backfill of ten (10) inches shall be achieved.

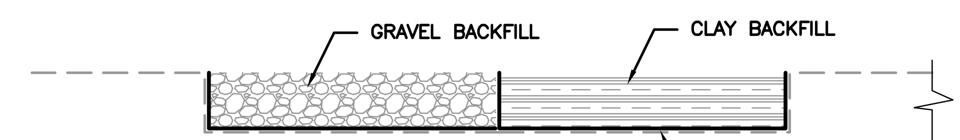
5) A minimum of two (2) inches of topsoil shall be placed and compacted by a minimum of one pass of a bulldozer or frontend loader over the clay backfill.

Area 3

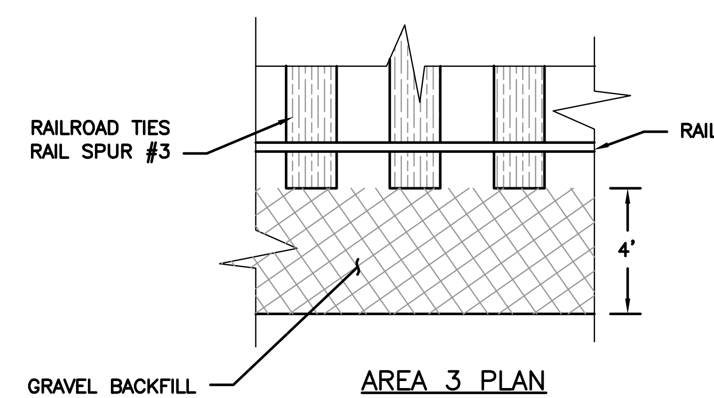
1) A woven geotextile demarcation layer shall be placed within the excavation envelope, along excavation bottom and sidewalls. At the interface between the clay and gravel backfills the demarcation layer installed beneath the clay shall be rolled up to provide filtration between the clay and gravel backfills.

2) For gravel backfill areas, gravel shall be placed within the excavation envelope above the demarcation layer and compacted by a minimum of three passes of a vibratory roller.

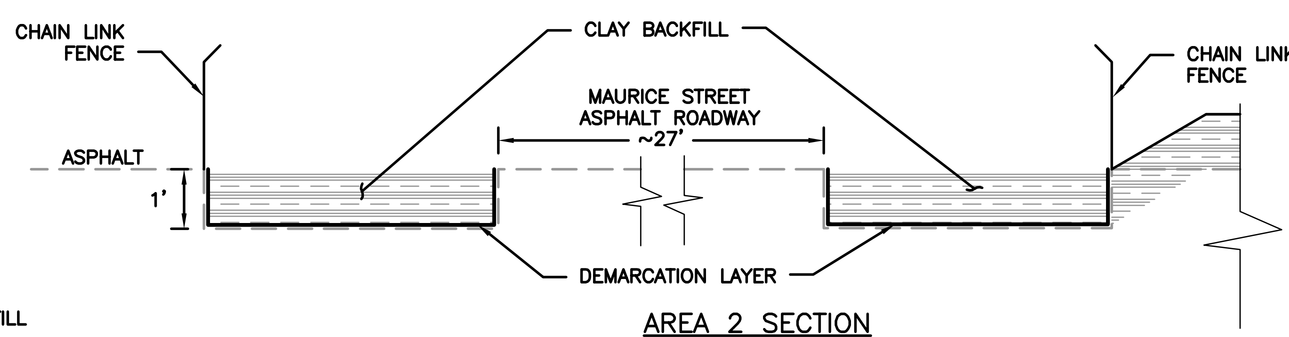
3) For clay borrow backfill areas clay borrow shall be placed within the excavation envelope above the demarcation layer and compacted a minimum of three passes of tracks/tires of a bulldozer or frontend loader.



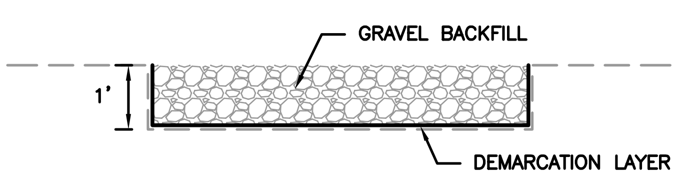
AREA 3 SECTION
NTS



AREA 3 PLAN
NTS



AREA 2 SECTION
NTS



AREA 1 SECTION
NTS

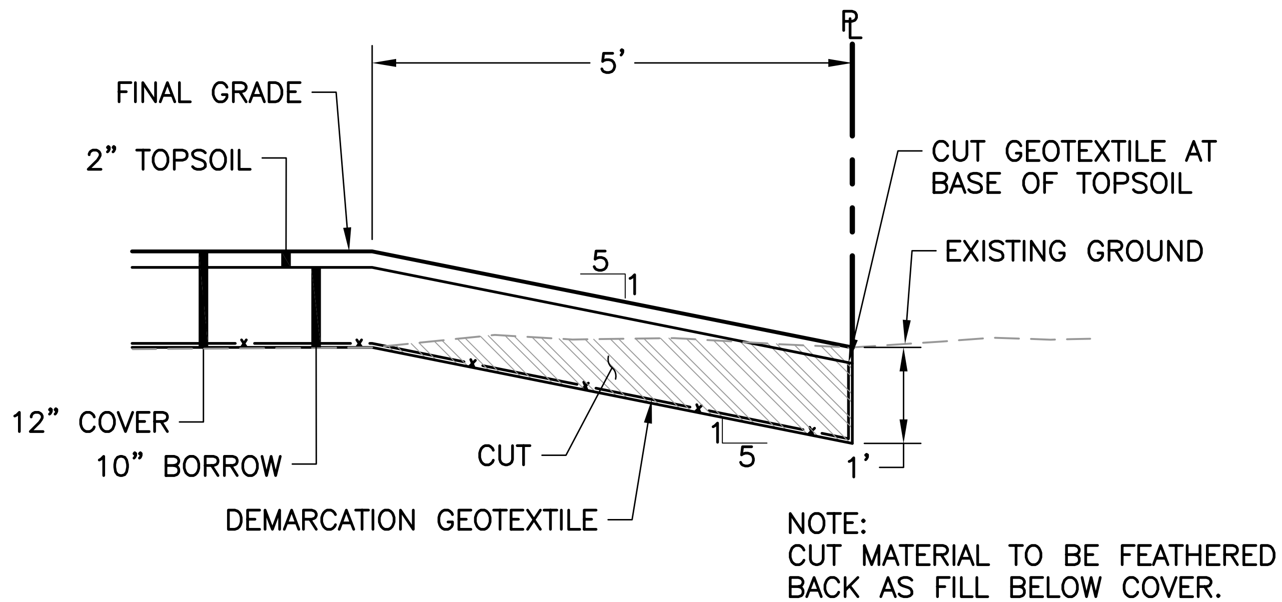
Prepared/Date: RJR 09/07/10
Checked/Date: RSE 09/07/10

AREA E COVER
FORMER BUFFALO COLOR CORP SITE
BUFFALO, NEW YORK

MACTEC

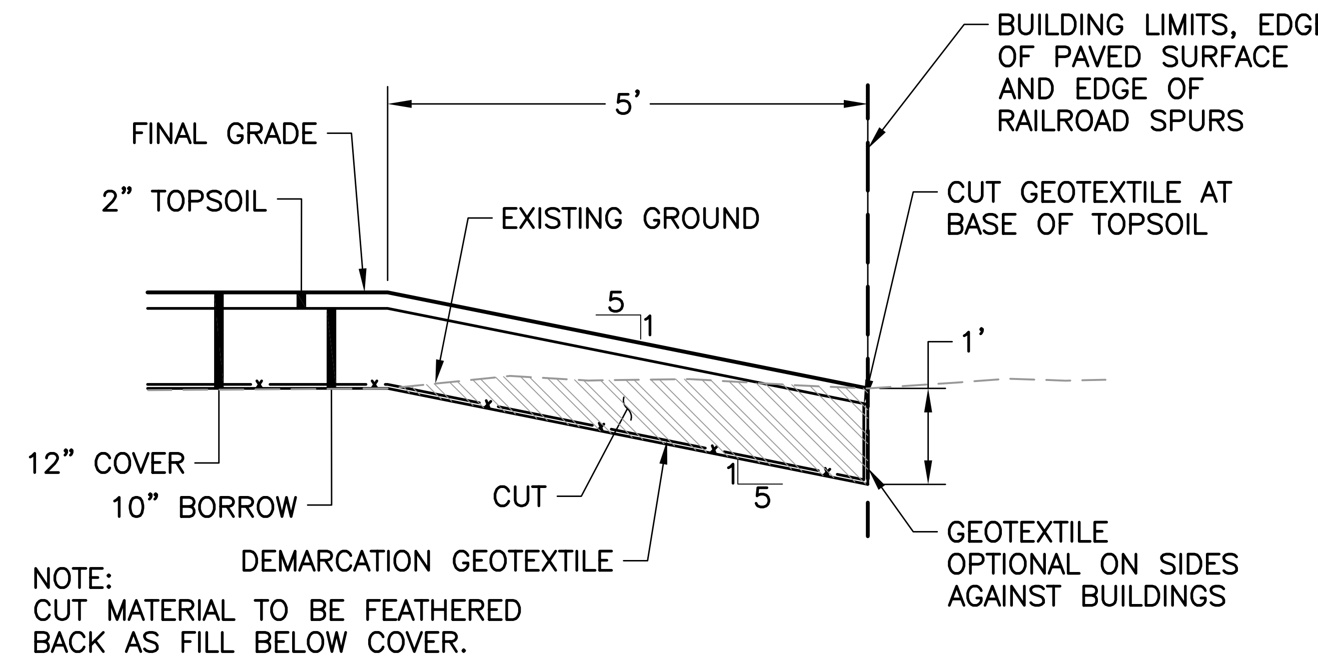
Project 3410-09-0701
Figure 2

M:\Projects\HONEYWELL\BUFFALO COLOR\SBD AREA E EXCAVATION\Figure 1 Area E Excavation.dwg Tue, 07 Sep 2010 - 2:22pm rjriquier



COVER DETAIL @ SITE/PROPERTY LIMITS

SCALE: 1" = 2'



COVER DETAIL @ BUILDING, PAVEMENT, AND RAILROAD LIMITS

SCALE: 1" = 2'

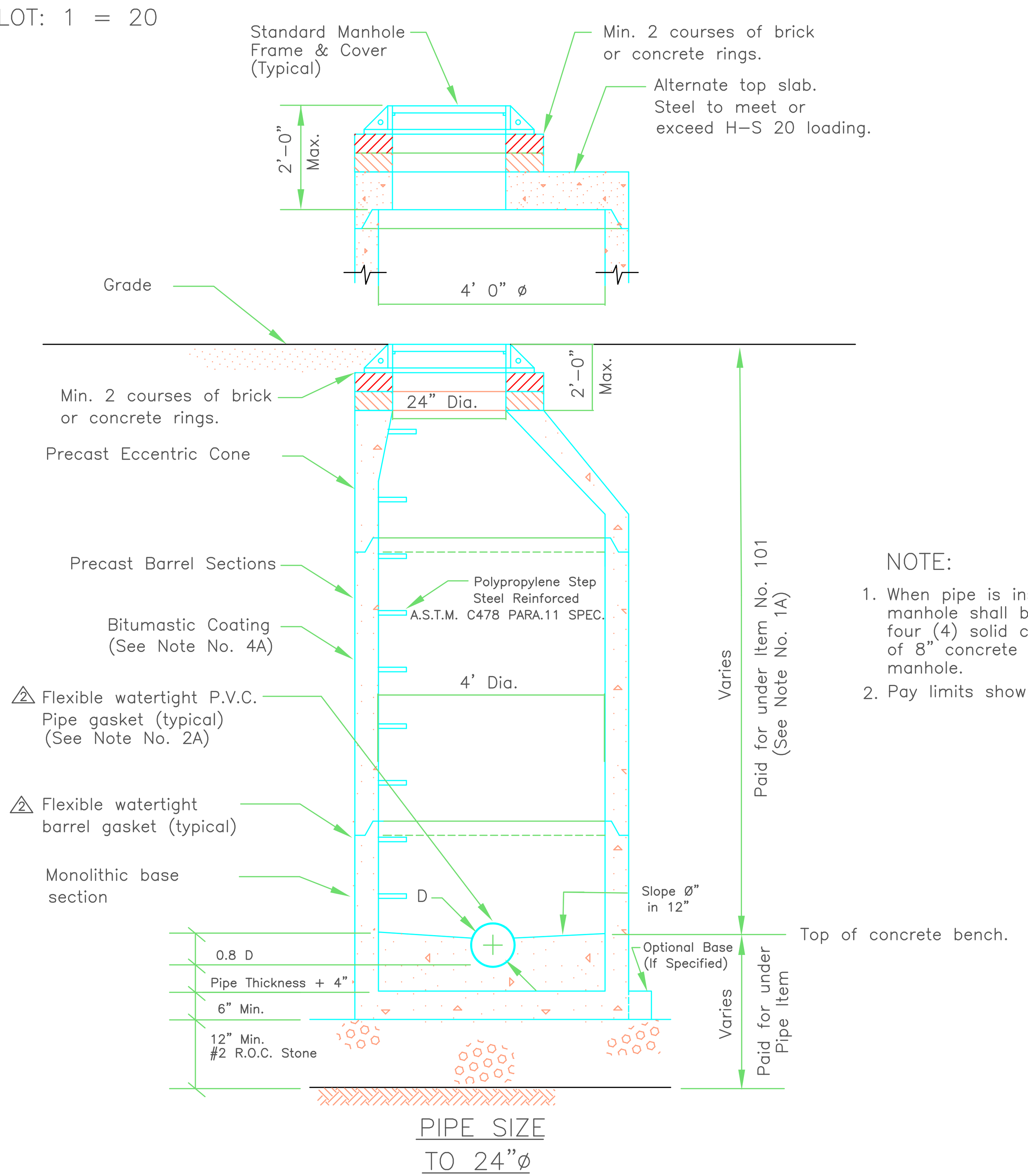
Prepared/Date: MRS 04/06/10
Checked/Date: LNT 04/06/10

AREA ABCE CAP FORMER BUFFALO COLOR CORP SITE BUFFALO, NEW YORK	MACTEC	COVER DETAILS Project 3410-09-0701 Figure 1

P:\Projects\CADD-PORT\Projects\HONEYWELL\BUFFALO COLOR\AREA ABCE 2010\DETAILS.dwg Wed, 07 Apr 2010 - 11:19am mrstacey

G:STDPCMH.DWG

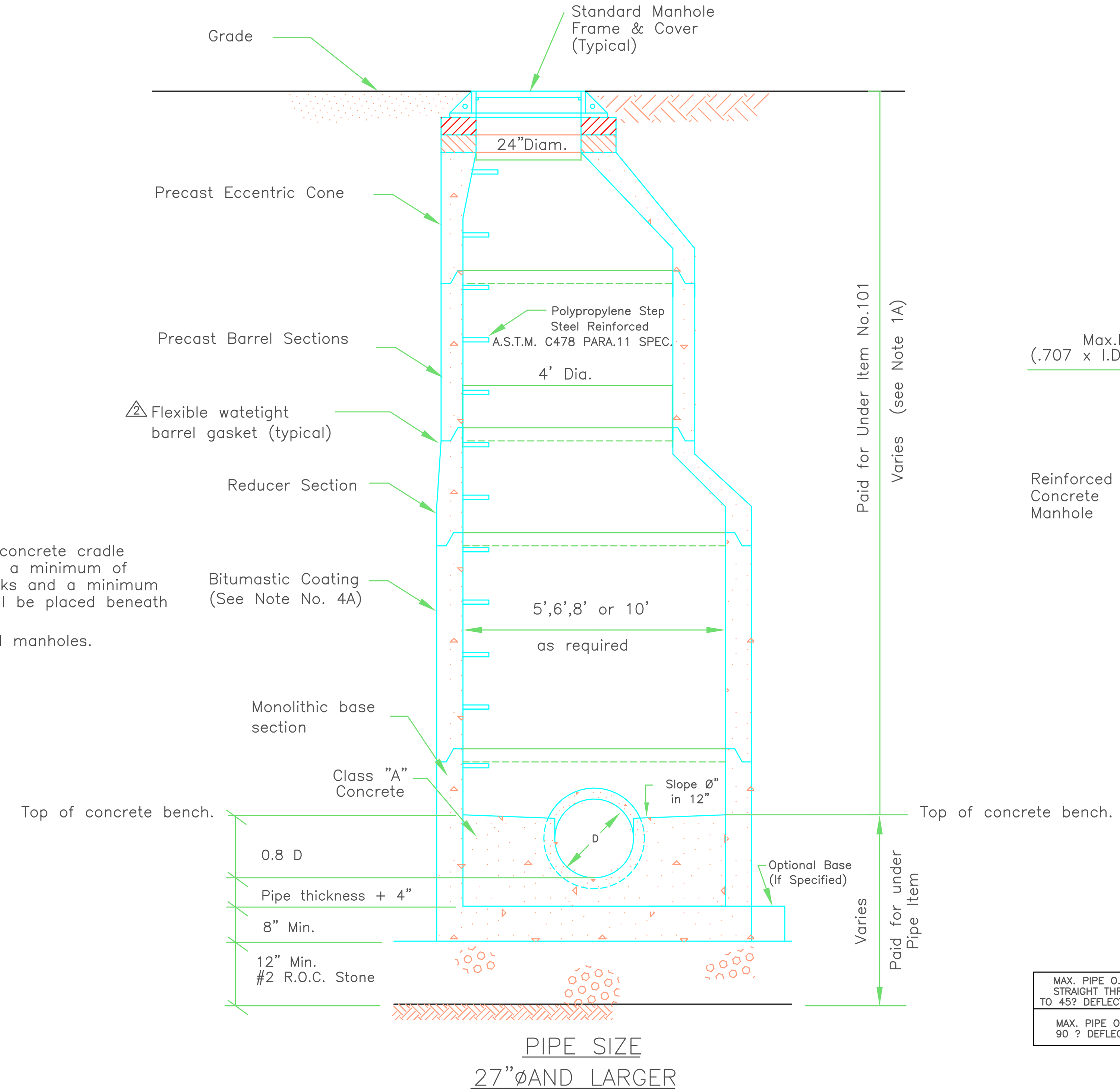
PLOT: 1 = 20



PIPE SIZE TO 24"ø

NOTE:

1. When pipe is installed with concrete cradle manhole shall be placed on a minimum of four (4) solid concrete blocks and a minimum of 8" concrete bedding shall be placed beneath manhole.
2. Pay limits shown are for all manholes.

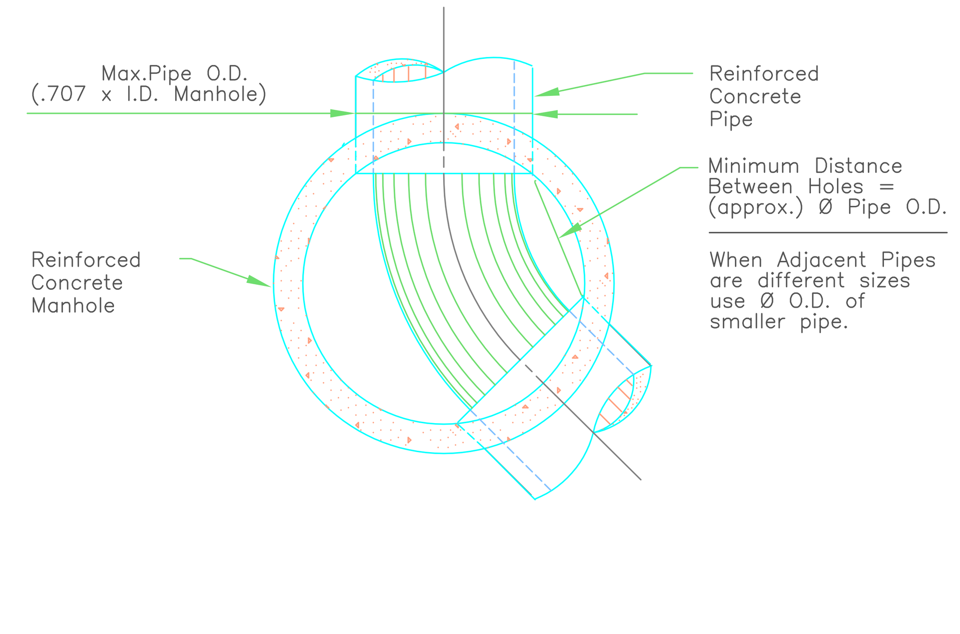


PIPE SIZE 27"øAND LARGER

STANDARD PRECAST MANHOLE

SCALE: Ø" = 1' – 0"

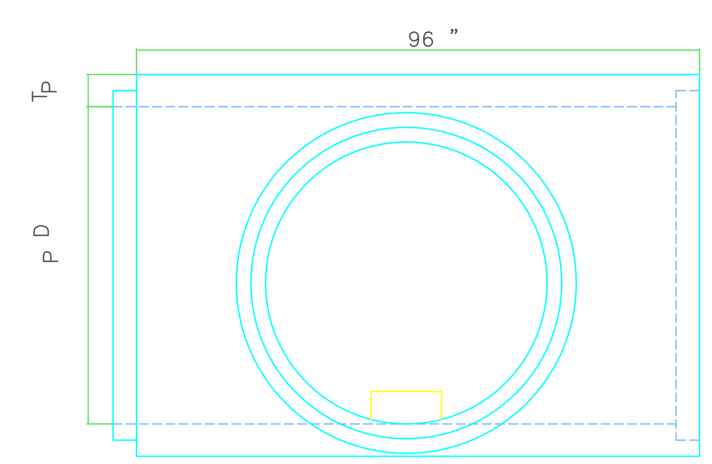
(Paid for under Item No. 101) (See Note No. 1A)



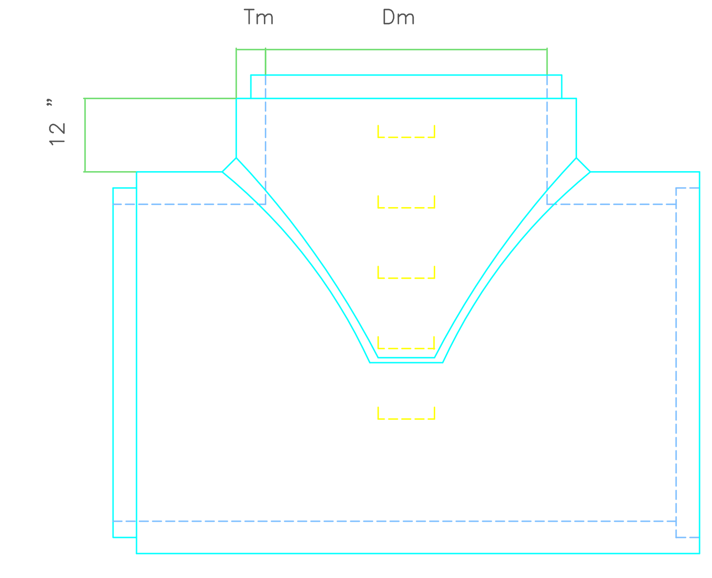
PLAN VIEW OF MANHOLE SHOWING 45° DEFLECTION

SCALE: Ø" = 1'–0"

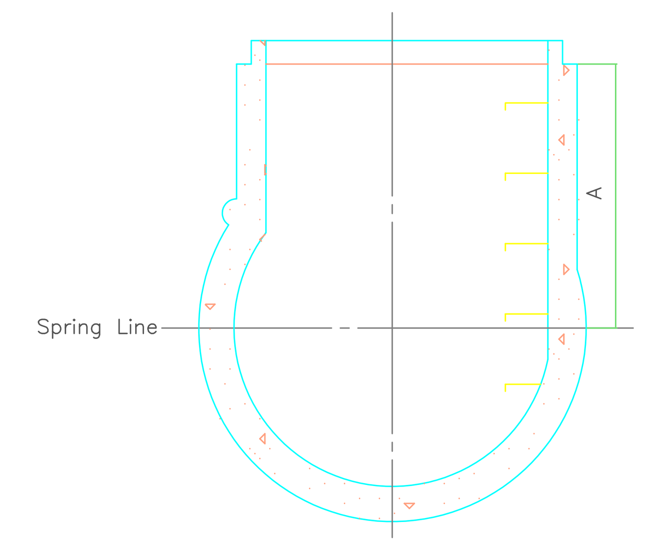
	4 FOOT MANHOLE 5" WALL	5 FOOT MANHOLE 6" WALL	6 FOOT MANHOLE 7" WALL	8 FOOT MANHOLE 9" WALL	10 FOOT MANHOLE 11" WALL
MAX. PIPE O.D. STRAIGHT THRU TO 45? DEFLECTION	30" O.D. 24" R.C. PIPE	44" O.D. 36" R.C. PIPE	51" O.D. 42" R.C. PIPE	72" O.D. 60" R.C. PIPE	86" O.D. 72" R.C. PIPE
MAX. PIPE O.D. 90 ? DEFLECTION	23" O.D. 18" R.C. PIPE	33.5" O.D. 27" R.C. PIPE	37" O.D. 30" R.C. PIPE	51" O.D. 42" R.C. PIPE	72" O.D. 60 " R.C. PIPE



TOP VIEW



SIDE VIEW



SECTIONAL END VIEW

CLASS IV REINFORCED CONCRETE PRECAST MANHOLE TEE

SCALE: Ø" = 1'–0"

(Paid for under Item No. 101 as per Standard Precast Manhole)

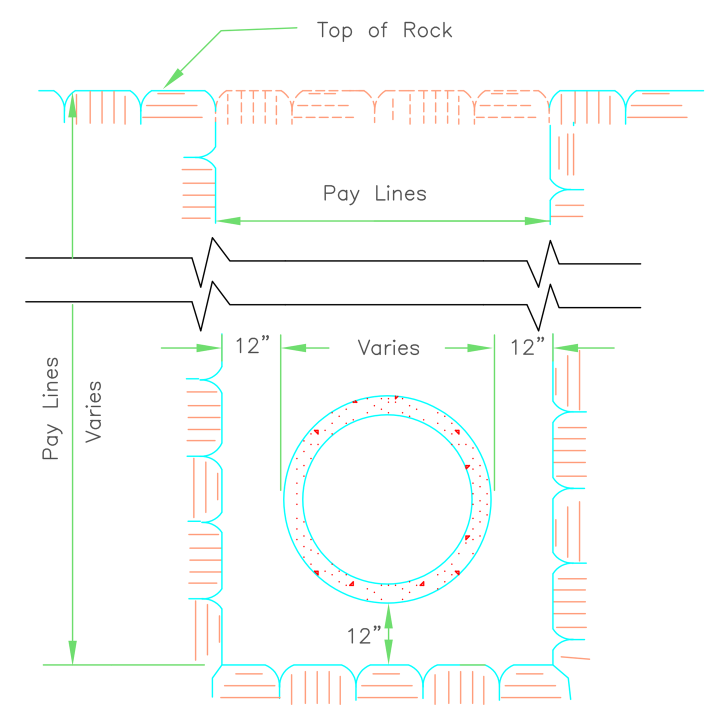
Notes:

1) Reinforced concrete pipe manufactured to A.S.T.M. C 478 specification.
2) Precast manhole riser manufactured to A.S.T.M. C 478 specification.
3) Precast manhole riser will be spigot end up. (Spigot end up illustrated.)
4) Manhole riser section reinforcing welded to pipe reinforcing. Additional reinforcing used in joint. Joint grouted with non-shrink mortar.
5) Rungs may be installed on left or right hand side looking at spigot end of pipe. (Right hand installation illustrated.)
6) Polypropylene Step Steel Reinforced A.S.T.M. C478 installed on 12" centers to spring line.
7) All M.H. tees to be eccentric as shown so that M.H. steps may be extended downward to the spring line of the pipe.

Precast Manhole Tee Dimensions

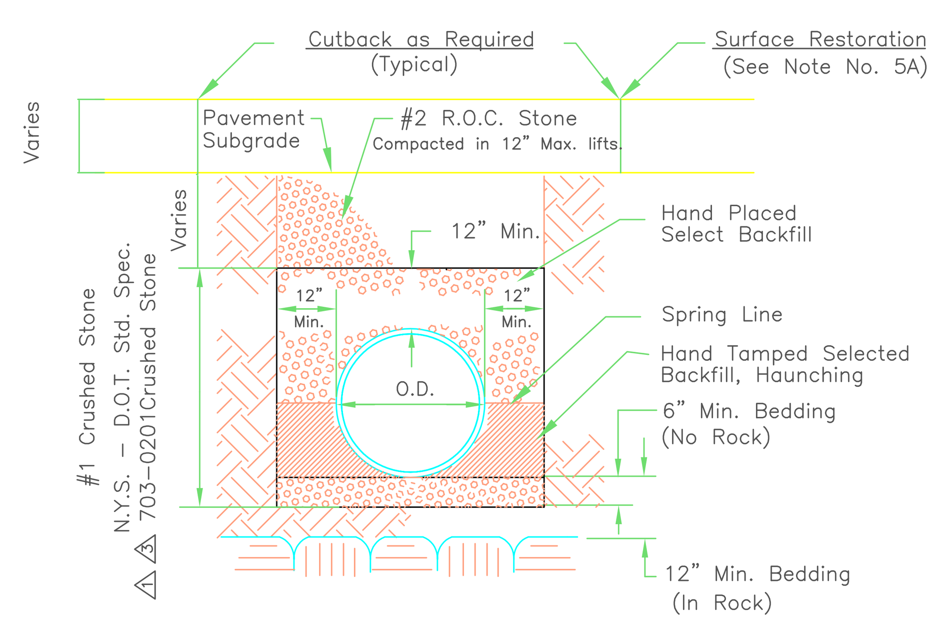
(inches)

I.D. PIPE Dp	I.D. M.H. Dm	WALL PIPE Tp	WALL M.H. Tm	A
48	48	5	5	41
54	48	5Ø	5	45
60	48	6	5	48
66	48	6Ø	5	52
72	48	7	5	55
78	48	7Ø	5	59
84	48	8	5	62
90	48	8Ø	5	66
96	48	9	5	69
102	48	9Ø	5	73
108	48	10	5	76
120	48	11	5	83



PAY LINES FOR ROCK EXCAVATION FOR PIPE TRENCH

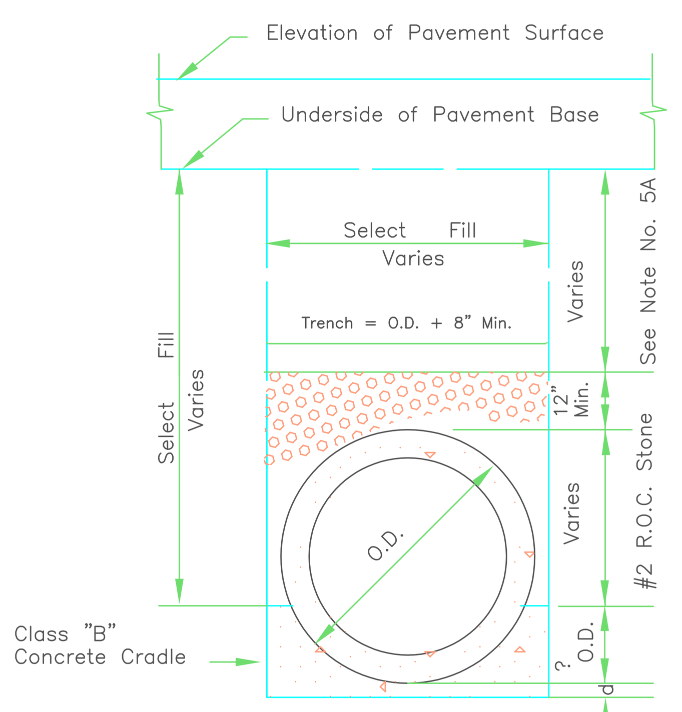
(Paid under item 105 unless otherwise specified)



P.V.C. PIPE TRENCH DETAIL IN R.O.W.

N.T.S.

(Paid for under appropriate pipe item unless otherwise specified.)

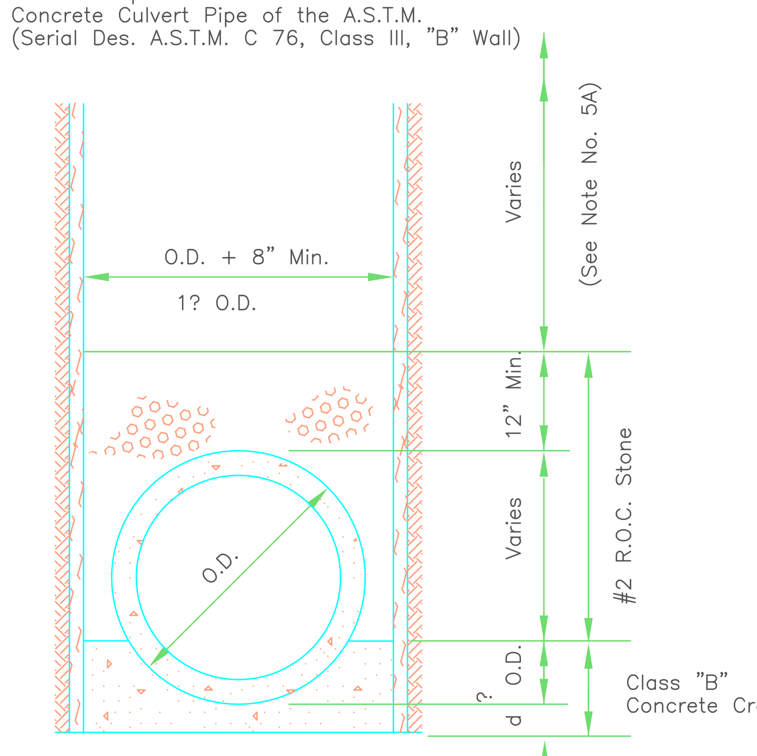


TRENCH DETAIL FOR CLASS III CONCRETE PIPE OR EXTRA STRENGTH VITRIFIED TILE PIPE

N.T.S.

(Paid for under appropriate pipe item unless otherwise specified.)

NOTE:
Pipe to comply with table 1 of the Standard specifications of Reinforced Concrete Culvert Pipe of the A.S.T.M. (Serial Des. A.S.T.M. C 76, Class III, "B" Wall)



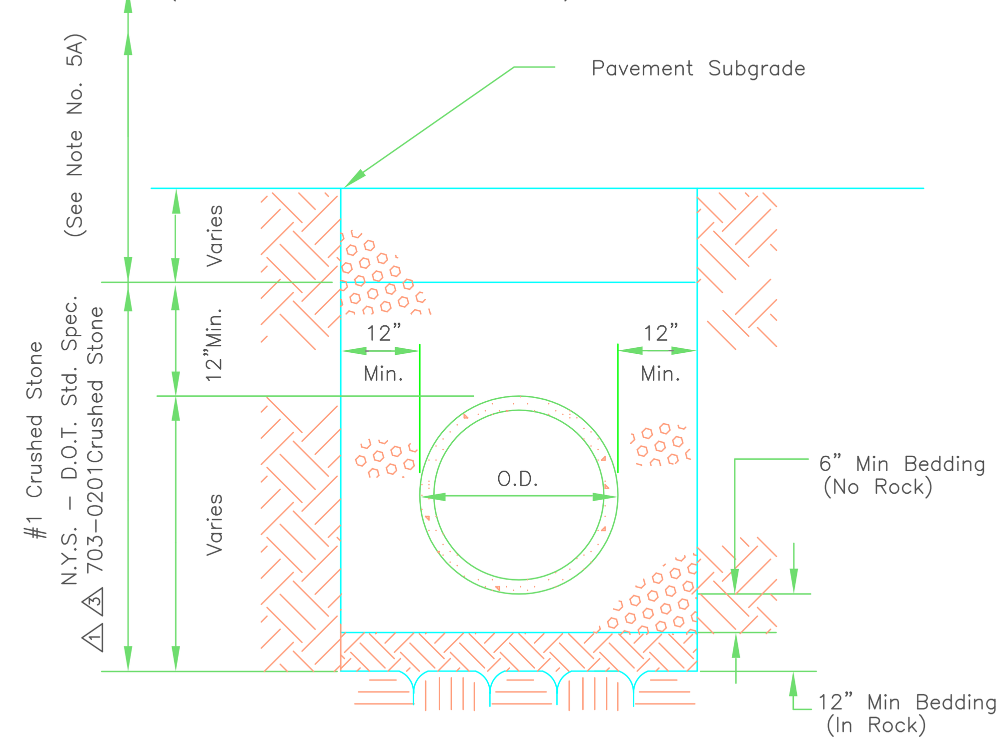
CONCRETE CRADLE FOR CLASS III R.C.P. OR EXTRA STRENGTH VITRIFIED TILE PIPE IN OPEN CUT

N.T.S.

Legend:
O.D.= Outside diameter
d = Depth of bedding material below pipe
D = Inside diameter
T = Wall thickness of pipe
R.O.C.= Run of Crusher

DEPTH OF CONCRETE BELOW PIPE	
D	d Min.
27 " & SMALLER	3 "
30 " TO 60 "	4 "
66 " & LARGER	6 "

NOTE:
Pipe to comply with table 1 of the Standard specifications of Reinforced Concrete Culvert Pipe of the A.S.T.M. (Serial Des. A.S.T.M. C 76, Class IV)



CLASS IV R.C.P. TRENCH DETAIL IN STREET R.O.W.

N.T.S.

(Paid for under appropriate pipe item unless otherwise specified.)

Notes:

1A. To be paid for under Item No. 101, unless otherwise noted in Lump Sum Contracts.

2A. When P.V.C. pipe is used, the manhole will be supplied with a watertight boot seal(s) . Materials must meet or exceed A.S.T.M. C–923.

3A. This drawing represents, in general, a standard manhole in which the inlet/outlet connection is shown in a position to fit the particular condition. This drawing will accompany the location plan for each manhole and must be adjusted to fit that location. The general idea as to sizes, construction and minor details remains the same.

4A. All sanitary and combined sewer manholes to be coated on the outside with a bitumastic coating.

5A. Trench backfill and surface restoration shall conform to the City of Buffalo Dept. of Public Works latest specifications with regard to pavement subgrade, pavement, curbs, sidewalks, driveways and lawn areas except where otherwise noted.

STANDARD PRECAST CONCRETE MANHOLES

AND

VARIOUS STANDARD DETAILS

ENGINEERING DIVISION

BUFFALO SEWER AUTHORITY

JULY 1990 BUFFALO N.Y.

SCALE AS NOTED

SHEET OF SHEETS

REVISED ⚠ 3-00			
REVISED ⚠ 7-92		REVISED ⚠ 3-95	
DESIGNED BY:		TRACED BY:	CADD
DRAWN BY:	R.V.V.	CHECKED BY:	R.G.B.

20092 C

Quality Assurance/Quality Control Plan for Soil Cover Placement

SOUTH BUFFALO DEVELOPMENT AREAS A, B, C & E

BUFFALO, NEW YORK

Prepared for:
SOUTH BUFFALO DEVELOPMENT LLC
Buffalo, NY

Prepared by:

MACTEC Engineering and Consulting, Inc.
800 North Bell Avenue, Suite 200
Pittsburgh, PA

March 2010

Project 3410-09-0701

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
MACTEC	MACTEC Engineering and Consulting, Inc.
NYSDEC	New York State Department of Environmental Conservation
QA/QC	Quality Assurance/Quality Control
Site	Buffalo Color Site Areas A, B, C and E
SWPPP	Storm Water Pollution Prevention Plan

1.0 INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) has prepared this Quality Assurance/Quality Control (QA/QC) Plan for the placement of cover soils at the locations shown on Figure 1, at the Buffalo Color Site Areas A, B, C and E (Site). The intent of this plan is to summarize QA/QC procedures that will be utilized by the project team to ensure that a Site-wide cover system will be placed to meet the design requirements as detailed in the Alternatives Analysis Report (MACTEC, February 2009). The final remedy specified in the AAR requires that Site be provided with a cover system that consists of a combination of 12 inches of clean soil (with underlying demarcation layer), pavement, concrete slabs from former structures and new or existing buildings. This cover system, once installed, will be maintained for the life of the property in accordance with the final Site Management Plan to be prepared for the site as required under the Brownfield Cleanup Agreements between SBD and the New York State Department of Environmental Conservation (NYSDEC).

The project team consists of the following:

OWNER: South Buffalo Development LLC (SBD)

CONTRACTOR: Ontario Specialty Contracting, Inc. (OSC)

ENGINEER: MACTEC Engineering and Consulting, Inc. (MACTEC)

REMEDIATION PARTNER: Honeywell

2.0 SPECIFICATIONS AND CONSTRUCTION METHODS

The following subsections provide descriptions of the soil cover systems and placement methods.

2.1 SOIL COVER SYSTEM MATERIALS

Locations of the soil cover systems are detailed on the attached Figure ("Proposed Final Cover"). The intent of the soil cover system is to provide a minimum of a 1-foot thick barrier between potential receptors and the existing site soils.

For areas that will not be covered by pavement, concrete or buildings, the cover system will consist of not less than 12-inches of clean soil. The Owner intends to meet this requirement by placing not less than 10-inches of clean borrow material and not less than 2-inches of topsoil. The borrow material is from a local source identified and tested by the owner and approved by the New York State Department of Environmental Conservation (NYSDEC). Copies of the gradation and chemical test results for the borrow material are provided in Appendix A.

The overall thickness of the cover system will not be less than 12-inches, although may be greater than 12-inches in some areas to achieve final grades. The cover system will be underlain by a demarcation layer. The intent of the demarcation layer is to create a visible separation between the cap materials and the existing site soils. The demarcation layer will consist of a woven geotextile that was selected by the Owner and has been approved by the Engineer and NYSDEC. The specification sheet for the selected material is in Appendix A.

2.2 PLACEMENT OF SOIL COVER SYSTEM MATERIALS

The Contractor will clear the existing surface of snow, ice and deleterious materials prior to the placement of the cover system. Rough grading of the existing ground surface will be conducted to minimize high and low points such that a more uniform cover system thickness may be placed. The demarcation layer will be placed by hand directly on top of the rough graded surface. The demarcation fabric will be overlapped by 1-foot at the joints and staples placed at a minimum of every 20 feet along the outer edges and at overlaps/joints. Prior to placement of cover soils, the demarcation layer will be visually inspected by the Contractor for tears. All tears, holes or damaged geotextile will be repaired by placing a patch with a minimum of 1-foot overlap or by replacing the entire panel if damage is excessive.

Clean borrow material will be placed over the demarcation layer by bulldozer or front end loader. Care will be taken such that the equipment will not tear or otherwise damage the demarcation layer during installation of cover soils. If the demarcation layer is damaged it will be repaired as described above. Clean borrow will be placed to a post-compaction thickness of at least 10-inches. Compaction will be achieved via 2 to 3 passes made by a 12,000-lb. vibratory roller, with additional compaction achieved via passes by the dozer/front end loader. No quantitative compaction requirements (i.e. moisture-density tests) are required for the cover system soils. The final thickness of the topsoil layer will be at least 2-inches. Additional topsoil may be required in some areas to reach design grades for surficial drainage. Compaction of the topsoil layer will be achieved via the use of the 12,000-lb. vibratory roller, with additional compaction achieved via passes from the dozer/front end loader. After placement of the topsoil layer the cover system will be seeded in accordance with the Stormwater Pollution Prevention Plans (SWPPP) issued for Areas ABC and Area E.

Existing manholes and storm sewer structures within the soil cover areas will be raised by 12-inches to accommodate the cover system. Edges of the cover system will transition to meet existing pavement, buildings or property boundaries. Construction and post-construction soil erosion and sedimentation control measures will be implemented as described in the SWPPPs.

3.0 QA/QC METHODS

The primary components of the QA/QC Plan are described in the following subsections.

3.1 TOPOGRAPHIC SURVEYS

Prior to placement of cover soils a pre-construction topographic survey of the existing ground surface will be conducted. The survey will be conducted by recording elevations on a 50-foot on center grid. Elevations will also be recorded at defining features such as the top of ridges and the bottom of swales. Locations of pavement edges, fence lines, structures, manholes, and other features will also be surveyed. This existing conditions topographic survey will create a baseline survey for the cover system. A post-construction topographic survey of the cover system will be conducted on the same 50-foot on-center grid. The survey will be used to establish the horizontal limits of areas with soil cover, as well as the as-built cover thickness by comparison of elevations of the pre-construction and post-construction surveys. Both surveys will be conducted by a New York State licensed surveyor retained by the Contractor.

3.2 CONSTRUCTION MONITORING

During construction the contractor will place construction grade stakes on a 50-foot on center grid. Grade stakes will be marked showing the required top of the clean borrow layer and top of topsoil layer. Spot thicknesses will be checked at locations between grade stakes by the Contractor by hand digging or auguring to the demarcation layer and measuring thickness of cover system; the locations and results of the spot thickness checks will be documented in the Contractor’s field notes. Spot thickness checks will be conducted at a rate of one test per 20,000 square feet and will be conducted by, or in the presence of, a representative of the Engineer or Honeywell. More frequent spot checks may be conducted at selected locations at the discretion of the Engineer.

Visual monitoring of the cover system installation will be conducted by a MACTEC site representative a minimum of twice daily. Visual monitoring will include photographs of work activities, and development of a daily log describing the location and progress of work activities including the extents of cover soils placed.

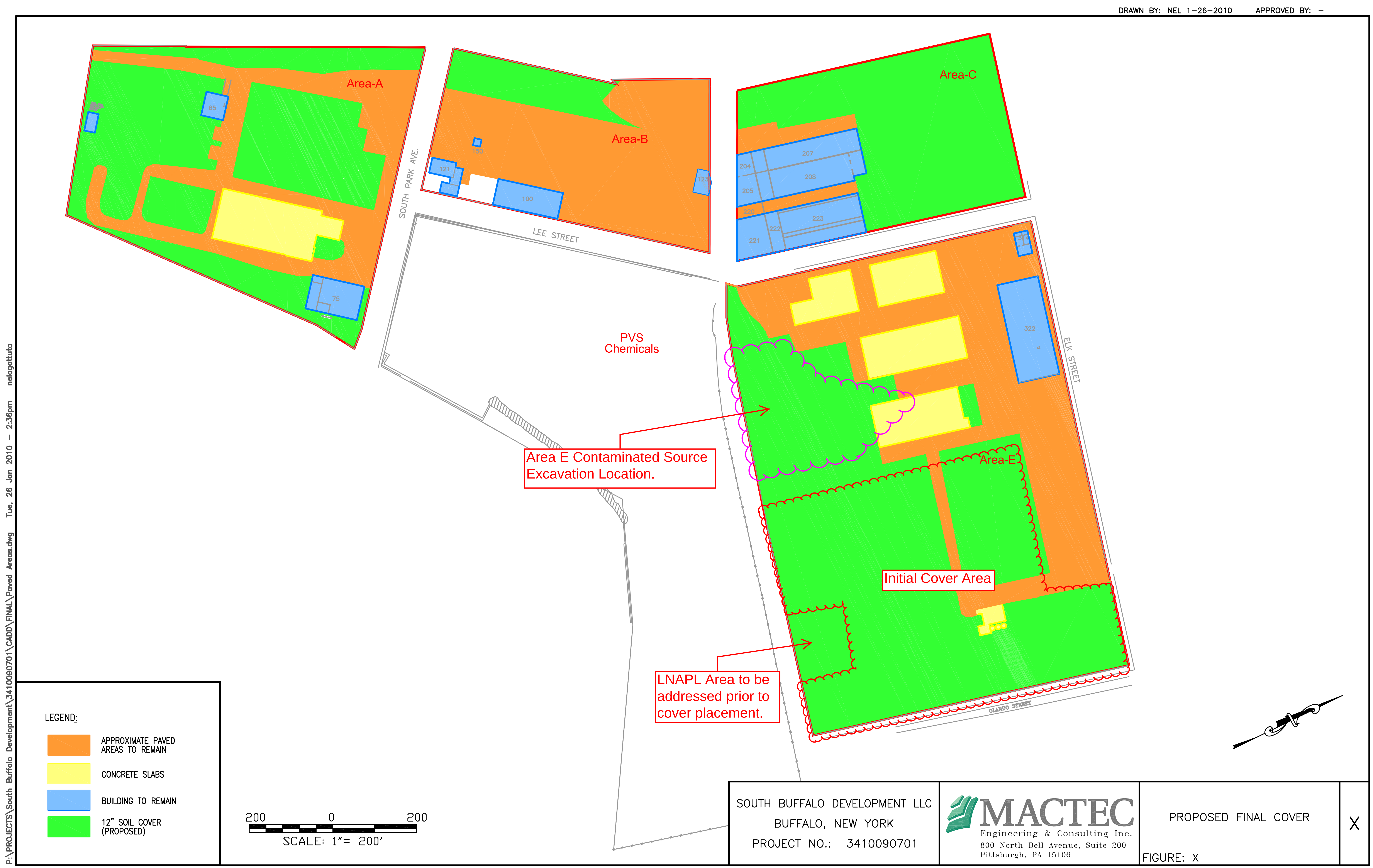
Additional monitoring of the cover system will include monthly monitoring of the system installation by an experienced MACTEC engineer, as well as, routine monitoring of the work by a Honeywell site representative. Discussions of the cover system installation will be added to the agenda of the weekly jobsite meetings attended by NYSDEC.

4.0 FINAL ENGINEERING REPORT/RECORD DRAWINGS

MACTEC will prepare Final Engineering Reports and record drawings to document the completion of the final remedy. This will include documentation for the installation of the soil cover system. Reports will be stamped by a New York State licensed professional engineer and will include the following:

- descriptions of the work, and record drawings showing the extent of cover system;
- pre/post-construction topographic survey data with contours;
- Operation, maintenance, and monitoring requirements;
- cover soils load receipts;
- copies of Contractor’s and Engineer’s field logs and photographs; and
- specifications for cover soil, topsoil, and seed mix

FIGURES



DRAWN BY: NEL 1-26-2010
APPROVED BY: -
Area-A
Area-B
Area-C
Area-E
SOUTH PARK AVE.
LEE STREET
ELK STREET
OLANDO STREET
PVS Chemicals
Area E Contaminated Source Excavation Location.
Initial Cover Area
LNAPL Area to be addressed prior to cover placement.
LEGEND:
APPROXIMATE PAVED AREAS TO REMAIN
CONCRETE SLABS
BUILDING TO REMAIN
12" SOIL COVER (PROPOSED)
200 0 200
SCALE: 1"= 200'
SOUTH BUFFALO DEVELOPMENT LLC
BUFFALO, NEW YORK
PROJECT NO.: 3410090701
MACTEC
Engineering & Consulting Inc.
800 North Bell Avenue, Suite 200
Pittsburgh, PA 15106
PROPOSED FINAL COVER
FIGURE: X
X
P:\PROJECTS\South Buffalo Development\3410090701\CADD\FINAL\Paved Areas.dwg Tue, 26 Jan 2010 - 2:36pm nelagattuta

APPENDIX A

BORROW SOIL GRADATION AND CHEMICAL ANALYSIS

CME Associates, Inc.

LABORATORY TEST REPORT

Client:	Ontario Specialty Contracting	**Page**	1 of 2	**Date:**	09/30/09
Project:	HKJJ, LLC Pond Excavation – Grand Island, NY			**Report No.:**	16113S-03-0909

On September 25, 2009 your representative delivered an on-site excavated Clay for laboratory testing.

Sample Identification as follows:

Sample No.:	Location:
BL2184	On-site, Excavated Pond Material – Grand Island, NY

MECHANICAL ANALYSIS (ASTM C-136, C-117)

Sieve Size	Percent Passing by Weight Sample BL 2184
1"	100
¾"	100
½"	100
¼"	98
No. 4	97
No. 10	96
No. 40	92
No. 200 (wash)	87.8

ATTERBURG LIMITS (ASTM D-4318)

Liquid Limit:	**36**
Plastic Limit:	**19**
Plasticity Index:	**17**

BURMISTER CLASSIFICATION & UNIFIED DESIGNATION

Classification: BROWN RED CLAY trace cmf SAND trace mf GRAVEL – (CL)

LABORATORY MOISTURE-DENSITY RELATIONSHIP ASTM D-1557

100% Maximum Dry Density	=	121.6	**pcf**
Optimum Moisture Content	=	12.8	**%**

The Laboratory Moisture Density Curve is attached.

Feel free to contact this office should you have any questions.

Respectfully Submitted,

CME ASSOCIATES, INC.

Ernest W. Kihl, Sr., CET
Laboratory Supervisor

Reviewed By:

CME ASSOCIATES, INC.

Norman Jurek, EIT
Staff Engineer

EWK/kak

CME Associates, Inc.

MATERIALS TESTING DIVISION

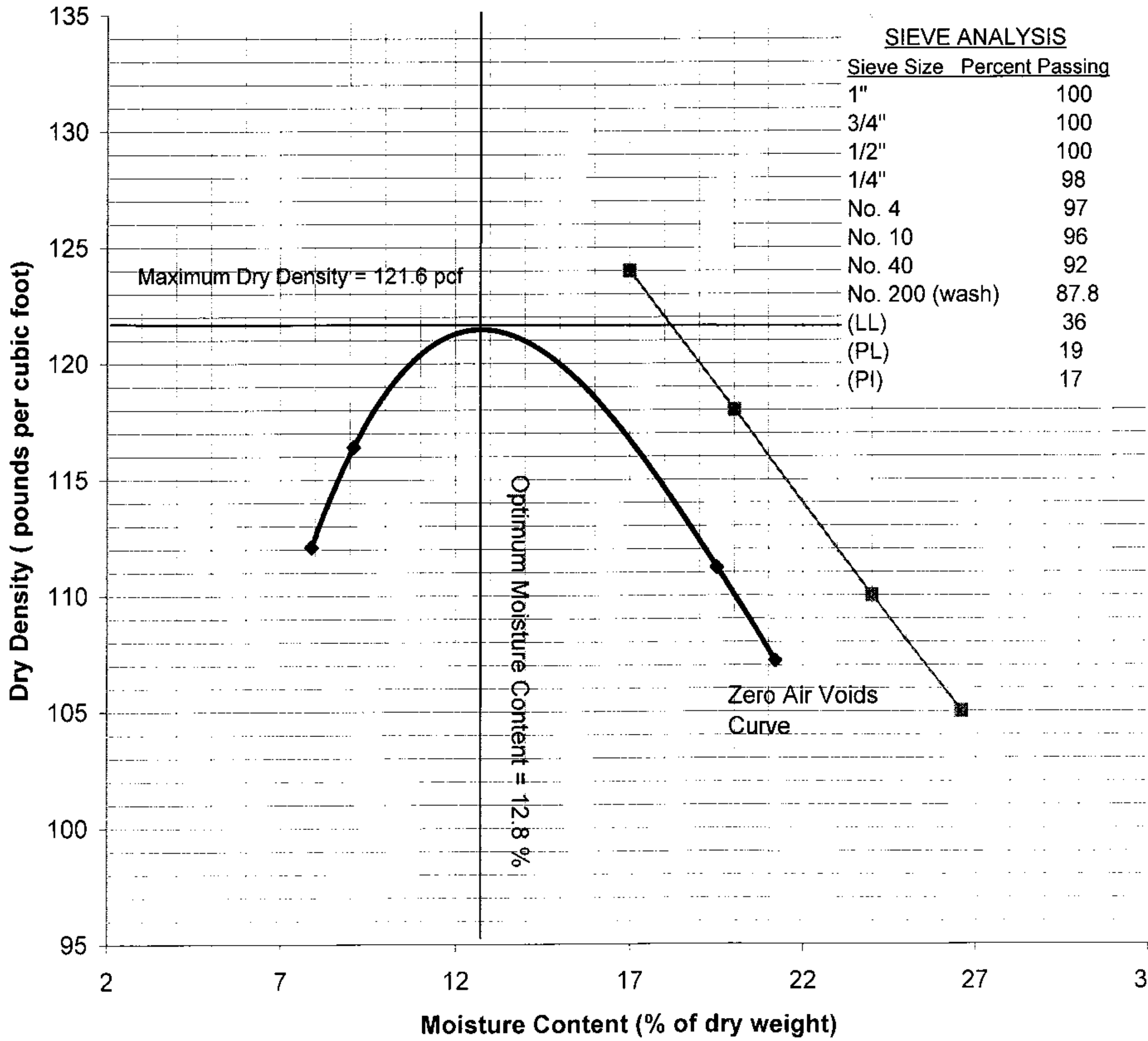
CLIENT: Ontario Specialty Contracting PROJECT: HKJJ, LLC Pond Excavation

REPORT NO: 16113S-03-0909 SAMPLE NO: BL 2184 DATE DELIVERED: 9/25/2009

SAMPLE LOCATION: On-Site Excavated Pond Material - Grand Island, NY

SOIL CLASSIFICATION: BROWN RED CLAY trace cmf SAND trace mf GRAVEL - (CL)

MOISTURE DENSITY RELATIONSHIP CURVE



SIEVE ANALYSIS

Sieve Size	Percent Passing
1"	100
3/4"	100
1/2"	100
1/4"	98
No. 4	97
No. 10	96
No. 40	92
No. 200 (wash)	87.8
(LL)	36
(PL)	19
(PI)	17

MAXIMUM DRY DENSITY 121.6 pcf **OPTIMUM MOISTURE CONTENT** 12.8 %

TESTED IN ACCORDANCE WITH ASTM **D1557** **X** D698 MIL STD 621 CE

Analytical Report Cover Page

Ontario Specialty Contracting, Inc.

For Lab Project # 09-3508
Issued October 2, 2009
This report contains a total of 24 pages

The reported results relate only to the samples as they have been received by the laboratory.

Any noncompliant QC parameters having impact on the data are flagged or documented on the final report.

All soil/sludge samples have been reported on a dry weight basis, unless qualified "reported as received". Other solids are reported as received.

Each page of this document is part of a multipage report. This document may not be reproduced except in its entirety, without the prior consent of Paradigm Environmental Services, Inc.

The Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt. Sample condition requirements are defined under the 2003 NELAC Standard, sections 5.5.8.3.1 and 5.5.8.3.2.

NYSDOH ELAP does not certify for all parameters. Paradigm Environmental Services or the indicated subcontracted laboratory does hold certification for all analytes where certification is offered by ELAP unless otherwise specified.

Data qualifiers are used, when necessary, to provide additional information about the data. This information may be communicated as a flag or as text at the bottom of the report. Please refer to the following list of frequently used data flags and their meaning:

"ND" = analyzed for but not detected.
"E" = Result has been estimated, calibration limit exceeded.
"D" = Duplicate results outside QC limits. May indicate a non-homogenous matrix.
"M" = Matrix spike recoveries outside QC limits. Matrix bias indicated.
"B" = Method blank contained trace levels of analyte. Refer to included method blank report.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

pH Analysis Report

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island	**Lab Project Number:**	09-3508
Client Job Number:	N/A	**Date Sampled:**	9/25/2009
		Time Sampled:	N/A
		Date Received:	9/25/2009
Sample Type:	Soil	**Time Received:**	4:25 PM
Location:	Laboratory	**Date Analyzed:**	9/28/2009
		Time Analyzed:	1:20 PM

Lab Sample Number	Field Number	Field Location	Result (pH)
10808	N/A	TP-1	8.08
10809	N/A	TP-2	8.25
10810	N/A	TP-3	7.91
10811	N/A	TP-4	7.94

ELAP Number 10958

Method: EPA 9045C

Comments:

Signature:

Bruce Hoogesteger: Technical Director

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647-2530 FAX (585) 647-3311

Client:	Ontario Specialty Contracting, Inc.	**Lab Project No.:**	09-3508
Client Job Site:	HKJJ Clay Source Grand Island, NY	**Sample Type:**	Soil
Client Job No.:	N/A	**Date Sampled:**	9/25/2009
		Date Received:	9/25/2009
Analytical Method:	SW 9012	**Date Analyzed:**	10/1/2009

Laboratory Report for Total Cyanide

Lab Sample ID	Sample Location/Field ID	TCN (ug/g)
10808	TP-1	ND<0.57
10809	TP-2	ND<0.59
10810	TP-3	ND<0.59
10811	TP-4	ND<0.60

ELAP ID.No.: 10709

Comments: ND denotes Non Detect.

Approved By Technical Director: ______________________
Bruce Hoogesteger

This report is part of a multipage document and should only be evaluated in its entirety. The Chain of Custody provides additional sample information, including compliance with the sample condition requirements upon receipt

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue, Rochester, NY 14608 (585) 647-2530 FAX (585) 647-3311

Client:	Ontario Specialty Contracting, Inc.	**Lab Project No.:**	09-3508
		Lab Sample No.:	10808
Client Job Site:	HKJJ Clay Source Grand Island, NY	**Sample Type:**	Soil
Client Job No.:	N/A		
		Date Sampled:	09/25/2009
Field Location:	TP-1	**Date Received:**	09/25/2009
Field ID No.:	N/A		

Laboratory Report for TAL Metals Analysis in Solid

Parameter	Date Analyzed	Analytical Method	Result (mg/kg)
Aluminum	10/02/2009	SW846 6010	16300
Antimony	10/02/2009	SW846 6010	<4.38
Arsenic	10/02/2009	SW846 6010	2.92
Barium	10/02/2009	SW846 6010	55.4
Beryllium	10/02/2009	SW846 6010	0.810
Cadmium	10/02/2009	SW846 6010	0.377
Calcium	10/02/2009	SW846 6010	61900
Chromium	10/02/2009	SW846 6010	22.1
Cobalt	10/02/2009	SW846 6010	10.6
Copper	10/02/2009	SW846 6010	22.1
Iron	10/02/2009	SW846 6010	23900
Lead	10/02/2009	SW846 6010	9.79
Magnesium	10/02/2009	SW846 6010	14000
Manganese	10/02/2009	SW846 6010	587
Mercury	09/28/2009	SW846 7471	0.0068
Nickel	10/02/2009	SW846 6010	23.9
Potassium	01/00/1900	SW846 6010	4600
Selenium	10/02/2009	SW846 6010	<0.364
Silver	10/02/2009	SW846 6010	<0.730
Sodium	10/02/2009	SW846 6010	258
Thallium	10/02/2009	SW846 6010	<0.438
Vanadium	10/02/2009	SW846 6010	31.6
Zinc	10/02/2009	SW846 6010	69.9

ELAP ID No.:10958

Comments:

Approved By: ______________________
Bruce Hoogesteger, Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional sample information, including compliance with sample condition requirements upon receipt.

File ID:093508.xls

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue, Rochester, NY 14608 (585) 647-2530 FAX (585) 647-3311

Client: Ontario Specialty Contracting, Inc.

Client Job Site: HKJJ Clay Source
Grand Island, NY

Client Job No.: N/A

Field Location: TP-2
Field ID No.: N/A

Lab Project No.: 09-3508
Lab Sample No.: 10809

Sample Type: Soil

Date Sampled: 09/25/2009
Date Received: 09/25/2009

Laboratory Report for TAL Metals Analysis in Solid

Parameter	Date Analyzed	Analytical Method	Result (mg/kg)
Aluminum	10/02/2009	SW846 6010	19100
Antimony	10/02/2009	SW846 6010	<4.75
Arsenic	10/02/2009	SW846 6010	3.51
Barium	10/02/2009	SW846 6010	127
Beryllium	10/02/2009	SW846 6010	0.936
Cadmium	10/02/2009	SW846 6010	<0.396
Calcium	10/02/2009	SW846 6010	57000
Chromium	10/02/2009	SW846 6010	25.4
Cobalt	10/02/2009	SW846 6010	13.0
Copper	10/02/2009	SW846 6010	23.5
Iron	10/02/2009	SW846 6010	27300
Lead	10/02/2009	SW846 6010	10.9
Magnesium	10/02/2009	SW846 6010	14900
Manganese	10/02/2009	SW846 6010	526
Mercury	09/28/2009	SW846 7471	0.0139
Nickel	10/02/2009	SW846 6010	26.8
Potassium	01/00/1900	SW846 6010	5170
Selenium	10/02/2009	SW846 6010	<0.396
Silver	10/02/2009	SW846 6010	<0.791
Sodium	10/02/2009	SW846 6010	299
Thallium	10/02/2009	SW846 6010	<0.475
Vanadium	10/02/2009	SW846 6010	37.2
Zinc	10/02/2009	SW846 6010	73.2

ELAP ID No.:10958

Comments:

Approved By: ______________________
Bruce Hoogesteger, Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional sample information, including compliance with sample condition requirements upon receipt.

File ID:093508.xls

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue, Rochester, NY 14608 (585) 647-2530 FAX (585) 647-3311

Client: Ontario Specialty Contracting, Inc.

Client Job Site: HKJJ Clay Source
Grand Island, NY

Client Job No.: N/A

Field Location: TP-3
Field ID No.: N/A

Lab Project No.: 09-3508
Lab Sample No.: 10810

Sample Type: Soil

Date Sampled: 09/25/2009
Date Received: 09/25/2009

Laboratory Report for TAL Metals Analysis in Solid

Parameter	Date Analyzed	Analytical Method	Result (mg/kg)
Aluminum	10/02/2009	SW846 6010	16000
Antimony	10/02/2009	SW846 6010	<5.50
Arsenic	10/02/2009	SW846 6010	3.28
Barium	10/02/2009	SW846 6010	133
Beryllium	10/02/2009	SW846 6010	0.809
Cadmium	10/02/2009	SW846 6010	<0.459
Calcium	10/02/2009	SW846 6010	67900
Chromium	10/02/2009	SW846 6010	21.3
Cobalt	10/02/2009	SW846 6010	12.1
Copper	10/02/2009	SW846 6010	21.7
Iron	10/02/2009	SW846 6010	24400
Lead	10/02/2009	SW846 6010	10.1
Magnesium	10/02/2009	SW846 6010	15400
Manganese	10/02/2009	SW846 6010	592
Mercury	09/28/2009	SW846 7471	0.0273
Nickel	10/02/2009	SW846 6010	23.5
Potassium	01/00/1900	SW846 6010	4270
Selenium	10/02/2009	SW846 6010	<0.459
Silver	10/02/2009	SW846 6010	<0.917
Sodium	10/02/2009	SW846 6010	241
Thallium	10/02/2009	SW846 6010	<0.550
Vanadium	10/02/2009	SW846 6010	32.5
Zinc	10/02/2009	SW846 6010	62.9

ELAP ID No.:10958

Comments:

Approved By: ______________________
Bruce Hoogesteger, Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional sample information, including compliance with sample condition requirements upon receipt.

File ID:093508.xls

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue, Rochester, NY 14608 (585) 647-2530 FAX (585) 647-3311

Client: Ontario Specialty Contracting, Inc.

Client Job Site: HKJJ Clay Source
Grand Island, NY

Client Job No.: N/A

Field Location: TP-4
Field ID No.: N/A

Lab Project No.: 09-3508
Lab Sample No.: 10811

Sample Type: Soil

Date Sampled: 09/25/2009
Date Received: 09/25/2009

Laboratory Report for TAL Metals Analysis in Solid

Parameter	Date Analyzed	Analytical Method	Result (mg/kg)
Aluminum	10/02/2009	SW846 6010	18100
Antimony	10/02/2009	SW846 6010	<5.31
Arsenic	10/02/2009	SW846 6010	3.60
Barium	10/02/2009	SW846 6010	90.9
Beryllium	10/02/2009	SW846 6010	0.890
Cadmium	10/02/2009	SW846 6010	<0.443
Calcium	10/02/2009	SW846 6010	57800
Chromium	10/02/2009	SW846 6010	25.5
Cobalt	10/02/2009	SW846 6010	15.0
Copper	10/02/2009	SW846 6010	23.7
Iron	10/02/2009	SW846 6010	28200
Lead	10/02/2009	SW846 6010	10.1
Magnesium	10/02/2009	SW846 6010	13500
Manganese	10/02/2009	SW846 6010	623
Mercury	09/28/2009	SW846 7471	0.0143 D
Nickel	10/02/2009	SW846 6010	30.5
Potassium	01/00/1900	SW846 6010	4250
Selenium	10/02/2009	SW846 6010	<0.442
Silver	10/02/2009	SW846 6010	<0.885
Sodium	10/02/2009	SW846 6010	267
Thallium	10/02/2009	SW846 6010	<0.531
Vanadium	10/02/2009	SW846 6010	36.0
Zinc	10/02/2009	SW846 6010	69.5

ELAP ID No.:10958

Comments:

Approved By: ____________________
Bruce Hoogesteger, Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional sample information, including compliance with sample condition requirements upon receipt.

File ID:093508.xls

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

PCB Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10808
Client Job Number:	N/A		
Field Location:	TP-1	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/28/2009

PCB Identification	Results in mg / Kg
Aroclor 1016	ND< 0.339
Aroclor 1221	ND< 0.339
Aroclor 1232	ND< 0.339
Aroclor 1242	ND< 0.339
Aroclor 1248	ND< 0.339
Aroclor 1254	ND< 0.339
Aroclor 1260	ND< 0.339

ELAP Number 10958 Method: EPA 8082

Comments: ND denotes Non Detect
mg / Kg = milligram per Kilogram

Signature:
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

093508P1.XLS

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

PCB Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10809
Client Job Number:	N/A		
Field Location:	TP-2	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/28/2009

PCB Identification	Results in mg / Kg
Aroclor 1016	ND< 0.346
Aroclor 1221	ND< 0.346
Aroclor 1232	ND< 0.346
Aroclor 1242	ND< 0.346
Aroclor 1248	ND< 0.346
Aroclor 1254	ND< 0.346
Aroclor 1260	ND< 0.346

ELAP Number 10958 Method: EPA 8082

Comments: ND denotes Non Detect
mg / Kg = milligram per Kilogram

Signature: [signature]
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

PCB Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:** **Lab Sample Number:**	09-3508 10810
Client Job Number:	N/A		
Field Location:	TP-3	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/28/2009

PCB Identification	Results in mg / Kg
Aroclor 1016	ND< 0.355
Aroclor 1221	ND< 0.355
Aroclor 1232	ND< 0.355
Aroclor 1242	ND< 0.355
Aroclor 1248	ND< 0.355
Aroclor 1254	ND< 0.355
Aroclor 1260	ND< 0.355

ELAP Number 10958 Method: EPA 8082

Comments: ND denotes Non Detect
mg / Kg = milligram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

PCB Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10811
Client Job Number:	N/A		
Field Location:	TP-4	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/28/2009

PCB Identification	Results in mg / Kg
Aroclor 1016	ND< 0.353
Aroclor 1221	ND< 0.353
Aroclor 1232	ND< 0.353
Aroclor 1242	ND< 0.353
Aroclor 1248	ND< 0.353
Aroclor 1254	ND< 0.353
Aroclor 1260	ND< 0.353

ELAP Number 10958 Method: EPA 8082

Comments: ND denotes Non Detect
mg / Kg = milligram per Kilogram

Signature:
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Pesticide Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:** **Lab Sample Number:**	09-3508 10808
Client Job Number:	N/A		
Field Location:	TP-1	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Pesticide Identification	Results in ug / Kg
Aldrin	ND< 4.00
alpha-BHC	ND< 4.00
beta-BHC	ND< 4.00
delta-BHC	ND< 4.00
gamma-BHC	ND< 4.00
alpha-Chlordane	ND< 4.00
gamma-Chlordane	ND< 4.00
4,4'-DDD	ND< 4.00
4,4'-DDE	ND< 4.00
4,4'-DDT	ND< 4.00
Dieldrin	ND< 4.00
Endosulfan I	ND< 4.00
Endosulfan II	ND< 4.00
Endosulfan Sulfate	ND< 4.00
Endrin	ND< 4.00
Endrin Aldehyde	ND< 4.00
Heptachlor	ND< 4.00
Heptachlor Epoxide	ND< 4.00
Methoxychlor	ND< 4.00
Toxaphene	ND< 200

ELAP Number 10709 Method: EPA 8081

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature:

Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Pesticide Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10809
Client Job Number:	N/A		
Field Location:	TP-2	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Pesticide Identification	Results in ug / Kg
Aldrin	ND< 4.00
alpha-BHC	ND< 4.00
beta-BHC	ND< 4.00
delta-BHC	ND< 4.00
gamma-BHC	ND< 4.00
alpha-Chlordane	ND< 4.00
gamma-Chlordane	ND< 4.00
4,4'-DDD	ND< 4.00
4,4'-DDE	ND< 4.00
4,4'-DDT	ND< 4.00
Dieldrin	ND< 4.00
Endosulfan I	ND< 4.00
Endosulfan II	ND< 4.00
Endosulfan Sulfate	ND< 4.00
Endrin	ND< 4.00
Endrin Aldehyde	ND< 4.00
Heptachlor	ND< 4.00
Heptachlor Epoxide	ND< 4.00
Methoxychlor	ND< 4.00
Toxaphene	ND< 200

ELAP Number 10709 Method: EPA 8081

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Pesticide Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:** **Lab Sample Number:**	09-3508 10810
Client Job Number:	N/A		
Field Location:	TP-3	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Pesticide Identification	Results in ug / Kg
Aldrin	ND< 4.00
alpha-BHC	ND< 4.00
beta-BHC	ND< 4.00
delta-BHC	ND< 4.00
gamma-BHC	ND< 4.00
alpha-Chlordane	ND< 4.00
gamma-Chlordane	ND< 4.00
4,4'-DDD	ND< 4.00
4,4'-DDE	ND< 4.00
4,4'-DDT	ND< 4.00
Dieldrin	ND< 4.00
Endosulfan I	ND< 4.00
Endosulfan II	ND< 4.00
Endosulfan Sulfate	ND< 4.00
Endrin	ND< 4.00
Endrin Aldehyde	ND< 4.00
Heptachlor	ND< 4.00
Heptachlor Epoxide	ND< 4.00
Methoxychlor	ND< 4.00
Toxaphene	ND< 200

ELAP Number 10709 Method: EPA 8081

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature:

Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC.
179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Pesticide Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10811
Client Job Number:	N/A		
Field Location:	TP-4	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Pesticide Identification	Results in ug / Kg
Aldrin	ND< 4.00
alpha-BHC	ND< 4.00
beta-BHC	ND< 4.00
delta-BHC	ND< 4.00
gamma-BHC	ND< 4.00
alpha-Chlordane	ND< 4.00
gamma-Chlordane	ND< 4.00
4,4'-DDD	ND< 4.00
4,4'-DDE	ND< 4.00
4,4'-DDT	ND< 4.00
Dieldrin	ND< 4.00
Endosulfan I	ND< 4.00
Endosulfan II	ND< 4.00
Endosulfan Sulfate	ND< 4.00
Endrin	ND< 4.00
Endrin Aldehyde	ND< 4.00
Heptachlor	ND< 4.00
Heptachlor Epoxide	ND< 4.00
Methoxychlor	ND< 4.00
Toxaphene	ND< 200

ELAP Number 10709 Method: EPA 8081

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Semi-Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10808
Client Job Number:	N/A		
Field Location:	TP-1	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Base / Neutrals	Results in ug / Kg	Base / Neutrals	Results in ug / Kg
Acenaphthene	ND< 330	Dibenz (a,h) anthracene	ND< 330
Anthracene	ND< 330	Fluoranthene	ND< 330
Benzo (a) anthracene	ND< 330	Fluorene	ND< 330
Benzo (a) pyrene	ND< 330	Indeno (1,2,3-cd) pyrene	ND< 330
Benzo (b) fluoranthene	ND< 330	Naphthalene	ND< 330
Benzo (g,h,i) perylene	ND< 330	Phenanthrene	ND< 330
Benzo (k) fluoranthene	ND< 330	Pyrene	ND< 330
Chrysene	ND< 330	Acenaphthylene	ND< 330
Diethyl phthalate	ND< 330	1,2-Dichlorobenzene	ND< 330
Dimethyl phthalate	ND< 824	1,3-Dichlorobenzene	ND< 330
Butylbenzylphthalate	ND< 330	1,4-Dichlorobenzene	ND< 330
Di-n-butyl phthalate	ND< 330	1,2,4-Trichlorobenzene	ND< 330
Di-n-octylphthalate	ND< 330	Nitrobenzene	ND< 330
Bis (2-ethylhexyl) phthalate	ND< 330	2,4-Dinitrotoluene	ND< 330
2-Chloronaphthalene	ND< 330	2,6-Dinitrotoluene	ND< 330
Hexachlorobenzene	ND< 330	Bis (2-chloroethyl) ether	ND< 330
Hexachloroethane	ND< 330	Bis (2-chloroisopropyl) ether	ND< 330
Hexachlorocyclopentadiene	ND< 330	Bis (2-chloroethoxy) methan	ND< 330
Hexachlorobutadiene	ND< 330	4-Bromophenyl phenyl ether	ND< 330
N-Nitroso-di-n-propylamine	ND< 330	4-Chlorophenyl phenyl ether	ND< 330
N-Nitrosodiphenylamine	ND< 330	Benzidine	ND< 824
N-Nitrosodimethylamine	ND< 330	3,3'-Dichlorobenzidine	ND< 330
Isophorone	ND< 330	4-Chloroaniline	ND< 330
Benzyl alcohol	ND< 824	2-Nitroaniline	ND< 824
Dibenzofuran	ND< 330	3-Nitroaniline	ND< 824
2-Methylnapthalene	ND< 330	4-Nitroaniline	ND< 824

Acids	Results in ug / Kg	Acids	Results in ug / Kg
Phenol	ND< 330	2-Methylphenol	ND< 330
2-Chlorophenol	ND< 330	3&4-Methylphenol	ND< 330
2,4-Dichlorophenol	ND< 330	2,4-Dimethylphenol	ND< 330
2,6-Dichlorophenol	ND< 330	2-Nitrophenol	ND< 330
2,4,5-Trichlorophenol	ND< 824	4-Nitrophenol	ND< 824
2,4,6-Trichlorophenol	ND< 330	2,4-Dinitrophenol	ND< 824
Pentachlorophenol	ND< 824	4,6-Dinitro-2-methylphenol	ND< 824
4-Chloro-3-methylphenol	ND< 330	Benzoic acid	ND< 824

ELAP Number 10958 Method: EPA 8270C Data File: S47069.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Semi-Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10809
Client Job Number:	N/A		
Field Location:	TP-2	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Base / Neutrals	Results in ug / Kg	Base / Neutrals	Results in ug / Kg
Acenaphthene	ND< 333	Dibenz (a,h) anthracene	ND< 333
Anthracene	ND< 333	Fluoranthene	ND< 333
Benzo (a) anthracene	ND< 333	Fluorene	ND< 333
Benzo (a) pyrene	ND< 333	Indeno (1,2,3-cd) pyrene	ND< 333
Benzo (b) fluoranthene	ND< 333	Naphthalene	ND< 333
Benzo (g,h,i) perylene	ND< 333	Phenanthrene	ND< 333
Benzo (k) fluoranthene	ND< 333	Pyrene	ND< 333
Chrysene	ND< 333	Acenaphthylene	ND< 333
Diethyl phthalate	ND< 333	1,2-Dichlorobenzene	ND< 333
Dimethyl phthalate	ND< 833	1,3-Dichlorobenzene	ND< 333
Butylbenzylphthalate	ND< 333	1,4-Dichlorobenzene	ND< 333
Di-n-butyl phthalate	ND< 333	1,2,4-Trichlorobenzene	ND< 333
Di-n-octylphthalate	ND< 333	Nitrobenzene	ND< 333
Bis (2-ethylhexyl) phthalate	ND< 333	2,4-Dinitrotoluene	ND< 333
2-Chloronaphthalene	ND< 333	2,6-Dinitrotoluene	ND< 333
Hexachlorobenzene	ND< 333	Bis (2-chloroethyl) ether	ND< 333
Hexachloroethane	ND< 333	Bis (2-chloroisopropyl) ether	ND< 333
Hexachlorocyclopentadiene	ND< 333	Bis (2-chloroethoxy) methan	ND< 333
Hexachlorobutadiene	ND< 333	4-Bromophenyl phenyl ether	ND< 333
N-Nitroso-di-n-propylamine	ND< 333	4-Chlorophenyl phenyl ether	ND< 333
N-Nitrosodiphenylamine	ND< 333	Benzidine	ND< 833
N-Nitrosodimethylamine	ND< 333	3,3'-Dichlorobenzidine	ND< 333
Isophorone	ND< 333	4-Chloroaniline	ND< 333
Benzyl alcohol	ND< 833	2-Nitroaniline	ND< 833
Dibenzofuran	ND< 333	3-Nitroaniline	ND< 833
2-Methylnapthalene	ND< 333	4-Nitroaniline	ND< 833

Acids	Results in ug / Kg	Acids	Results in ug / Kg
Phenol	ND< 333	2-Methylphenol	ND< 333
2-Chlorophenol	ND< 333	3&4-Methylphenol	ND< 333
2,4-Dichlorophenol	ND< 333	2,4-Dimethylphenol	ND< 333
2,6-Dichlorophenol	ND< 333	2-Nitrophenol	ND< 333
2,4,5-Trichlorophenol	ND< 833	4-Nitrophenol	ND< 833
2,4,6-Trichlorophenol	ND< 333	2,4-Dinitrophenol	ND< 833
Pentachlorophenol	ND< 833	4,6-Dinitro-2-methylphenol	ND< 833
4-Chloro-3-methylphenol	ND< 333	Benzoic acid	ND< 833

ELAP Number 10958 Method: EPA 8270C Data File: S47070.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

093508S2.XLS

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Semi-Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10810
Client Job Number:	N/A		
Field Location:	TP-3	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Base / Neutrals	Results in ug / Kg	Base / Neutrals	Results in ug / Kg
Acenaphthene	ND< 339	Dibenz (a,h) anthracene	ND< 339
Anthracene	ND< 339	Fluoranthene	ND< 339
Benzo (a) anthracene	ND< 339	Fluorene	ND< 339
Benzo (a) pyrene	ND< 339	Indeno (1,2,3-cd) pyrene	ND< 339
Benzo (b) fluoranthene	ND< 339	Naphthalene	ND< 339
Benzo (g,h,i) perylene	ND< 339	Phenanthrene	ND< 339
Benzo (k) fluoranthene	ND< 339	Pyrene	ND< 339
Chrysene	ND< 339	Acenaphthylene	ND< 339
Diethyl phthalate	ND< 339	1,2-Dichlorobenzene	ND< 339
Dimethyl phthalate	ND< 846	1,3-Dichlorobenzene	ND< 339
Butylbenzylphthalate	ND< 339	1,4-Dichlorobenzene	ND< 339
Di-n-butyl phthalate	ND< 339	1,2,4-Trichlorobenzene	ND< 339
Di-n-octylphthalate	ND< 339	Nitrobenzene	ND< 339
Bis (2-ethylhexyl) phthalate	ND< 339	2,4-Dinitrotoluene	ND< 339
2-Chloronaphthalene	ND< 339	2,6-Dinitrotoluene	ND< 339
Hexachlorobenzene	ND< 339	Bis (2-chloroethyl) ether	ND< 339
Hexachloroethane	ND< 339	Bis (2-chloroisopropyl) ether	ND< 339
Hexachlorocyclopentadiene	ND< 339	Bis (2-chloroethoxy) methan	ND< 339
Hexachlorobutadiene	ND< 339	4-Bromophenyl phenyl ether	ND< 339
N-Nitroso-di-n-propylamine	ND< 339	4-Chlorophenyl phenyl ether	ND< 339
N-Nitrosodiphenylamine	ND< 339	Benzidine	ND< 846
N-Nitrosodimethylamine	ND< 339	3,3'-Dichlorobenzidine	ND< 339
Isophorone	ND< 339	4-Chloroaniline	ND< 339
Benzyl alcohol	ND< 846	2-Nitroaniline	ND< 846
Dibenzofuran	ND< 339	3-Nitroaniline	ND< 846
2-Methylnapthalene	ND< 339	4-Nitroaniline	ND< 846

Acids	Results in ug / Kg	Acids	Results in ug / Kg
Phenol	ND< 339	2-Methylphenol	ND< 339
2-Chlorophenol	ND< 339	3&4-Methylphenol	ND< 339
2,4-Dichlorophenol	ND< 339	2,4-Dimethylphenol	ND< 339
2,6-Dichlorophenol	ND< 339	2-Nitrophenol	ND< 339
2,4,5-Trichlorophenol	ND< 846	4-Nitrophenol	ND< 846
2,4,6-Trichlorophenol	ND< 339	2,4-Dinitrophenol	ND< 846
Pentachlorophenol	ND< 846	4,6-Dinitro-2-methylphenol	ND< 846
4-Chloro-3-methylphenol	ND< 339	Benzoic acid	ND< 846

ELAP Number 10958 Method: EPA 8270C Data File: S47071.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Semi-Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting

Client Job Site:	HKJJ Clay Source Grand Island, NY	**Lab Project Number:**	09-3508
		Lab Sample Number:	10811
Client Job Number:	N/A		
Field Location:	TP-4	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/29/2009

Base / Neutrals	Results in ug / Kg	Base / Neutrals	Results in ug / Kg
Acenaphthene	ND< 337	Dibenz (a,h) anthracene	ND< 337
Anthracene	ND< 337	Fluoranthene	ND< 337
Benzo (a) anthracene	ND< 337	Fluorene	ND< 337
Benzo (a) pyrene	ND< 337	Indeno (1,2,3-cd) pyrene	ND< 337
Benzo (b) fluoranthene	ND< 337	Naphthalene	ND< 337
Benzo (g,h,i) perylene	ND< 337	Phenanthrene	ND< 337
Benzo (k) fluoranthene	ND< 337	Pyrene	ND< 337
Chrysene	ND< 337	Acenaphthylene	ND< 337
Diethyl phthalate	ND< 337	1,2-Dichlorobenzene	ND< 337
Dimethyl phthalate	ND< 843	1,3-Dichlorobenzene	ND< 337
Butylbenzylphthalate	ND< 337	1,4-Dichlorobenzene	ND< 337
Di-n-butyl phthalate	ND< 337	1,2,4-Trichlorobenzene	ND< 337
Di-n-octylphthalate	ND< 337	Nitrobenzene	ND< 337
Bis (2-ethylhexyl) phthalate	ND< 337	2,4-Dinitrotoluene	ND< 337
2-Chloronaphthalene	ND< 337	2,6-Dinitrotoluene	ND< 337
Hexachlorobenzene	ND< 337	Bis (2-chloroethyl) ether	ND< 337
Hexachloroethane	ND< 337	Bis (2-chloroisopropyl) ether	ND< 337
Hexachlorocyclopentadiene	ND< 337	Bis (2-chloroethoxy) methan	ND< 337
Hexachlorobutadiene	ND< 337	4-Bromophenyl phenyl ether	ND< 337
N-Nitroso-di-n-propylamine	ND< 337	4-Chlorophenyl phenyl ether	ND< 337
N-Nitrosodiphenylamine	ND< 337	Benzidine	ND< 843
N-Nitrosodimethylamine	ND< 337	3,3'-Dichlorobenzidine	ND< 337
Isophorone	ND< 337	4-Chloroaniline	ND< 337
Benzyl alcohol	ND< 843	2-Nitroaniline	ND< 843
Dibenzofuran	ND< 337	3-Nitroaniline	ND< 843
2-Methylnapthalene	ND< 337	4-Nitroaniline	ND< 843

Acids	Results in ug / Kg	Acids	Results in ug / Kg
Phenol	ND< 337	2-Methylphenol	ND< 337
2-Chlorophenol	ND< 337	3&4-Methylphenol	ND< 337
2,4-Dichlorophenol	ND< 337	2,4-Dimethylphenol	ND< 337
2,6-Dichlorophenol	ND< 337	2-Nitrophenol	ND< 337
2,4,5-Trichlorophenol	ND< 843	4-Nitrophenol	ND< 843
2,4,6-Trichlorophenol	ND< 337	2,4-Dinitrophenol	ND< 843
Pentachlorophenol	ND< 843	4,6-Dinitro-2-methylphenol	ND< 843
4-Chloro-3-methylphenol	ND< 337	Benzoic acid	ND< 843

ELAP Number 10958 Method: EPA 8270C Data File: S47072.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature:
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island	**Lab Project Number:**	09-3508
		Lab Sample Number:	10808
Client Job Number:	N/A		
Field Location:	TP-1	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/30/2009

Halocarbons	Results in ug / Kg
Bromodichloromethane	ND< 9.30
Bromomethane	ND< 9.30
Bromoform	ND< 23.3
Carbon Tetrachloride	ND< 23.3
Chloroethane	ND< 9.30
Chloromethane	ND< 9.30
2-Chloroethyl vinyl Ether	ND< 46.5
Chloroform	ND< 9.30
Dibromochloromethane	ND< 9.30
1,1-Dichloroethane	ND< 9.30
1,2-Dichloroethane	ND< 9.30
1,1-Dichloroethene	ND< 9.30
cis-1,2-Dichloroethene	ND< 9.30
trans-1,2-Dichloroethene	ND< 9.30
1,2-Dichloropropane	ND< 9.30
cis-1,3-Dichloropropene	ND< 9.30
trans-1,3-Dichloropropene	ND< 9.30
Methylene chloride	ND< 23.3
1,1,2,2-Tetrachloroethane	ND< 9.30
Tetrachloroethene	ND< 9.30
1,1,1-Trichloroethane	ND< 9.30
1,1,2-Trichloroethane	ND< 9.30
Trichloroethene	ND< 9.30
Trichlorofluoromethane	ND< 9.30
Vinyl chloride	ND< 9.30

Aromatics	Results in ug / Kg
Benzene	ND< 9.30
Chlorobenzene	ND< 9.30
Ethylbenzene	ND< 9.30
Toluene	ND< 9.30
m,p-Xylene	11.3
o-Xylene	ND< 9.30
Styrene	ND< 23.3
1,2-Dichlorobenzene	ND< 23.3
1,3-Dichlorobenzene	ND< 23.3
1,4-Dichlorobenzene	ND< 9.30

Ketones	Results in ug / Kg
Acetone	ND< 46.5
2-Butanone	ND< 46.5
2-Hexanone	ND< 23.3
4-Methyl-2-pentanone	ND< 23.3

Miscellaneous	Results in ug / Kg
Carbon disulfide	ND< 9.30
Vinyl acetate	ND< 23.3

ELAP Number 10958 Method: EPA 8260B Data File: V68992.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram
Surrogate outliers indicate probable matrix interference

Signature: ______________________
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island	**Lab Project Number:**	09-3508
		Lab Sample Number:	10809
Client Job Number:	N/A		
Field Location:	TP-2	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/30/2009

Halocarbons	Results in ug / Kg
Bromodichloromethane	ND< 7.73
Bromomethane	ND< 7.73
Bromoform	ND< 19.3
Carbon Tetrachloride	ND< 19.3
Chloroethane	ND< 7.73
Chloromethane	ND< 7.73
2-Chloroethyl vinyl Ether	ND< 38.6
Chloroform	ND< 7.73
Dibromochloromethane	ND< 7.73
1,1-Dichloroethane	ND< 7.73
1,2-Dichloroethane	ND< 7.73
1,1-Dichloroethene	ND< 7.73
cis-1,2-Dichloroethene	ND< 7.73
trans-1,2-Dichloroethene	ND< 7.73
1,2-Dichloropropane	ND< 7.73
cis-1,3-Dichloropropene	ND< 7.73
trans-1,3-Dichloropropene	ND< 7.73
Methylene chloride	ND< 19.3
1,1,2,2-Tetrachloroethane	ND< 7.73
Tetrachloroethene	ND< 7.73
1,1,1-Trichloroethane	ND< 7.73
1,1,2-Trichloroethane	ND< 7.73
Trichloroethene	ND< 7.73
Trichlorofluoromethane	ND< 7.73
Vinyl chloride	ND< 7.73

Aromatics	Results in ug / Kg
Benzene	ND< 7.73
Chlorobenzene	ND< 7.73
Ethylbenzene	ND< 7.73
Toluene	ND< 7.73
m,p-Xylene	ND< 7.73
o-Xylene	ND< 7.73
Styrene	ND< 19.3
1,2-Dichlorobenzene	ND< 19.3
1,3-Dichlorobenzene	ND< 19.3
1,4-Dichlorobenzene	ND< 7.73

Ketones	Results in ug / Kg
Acetone	ND< 38.6
2-Butanone	ND< 38.6
2-Hexanone	ND< 19.3
4-Methyl-2-pentanone	ND< 19.3

Miscellaneous	Results in ug / Kg
Carbon disulfide	ND< 7.73
Vinyl acetate	ND< 19.3

ELAP Number 10958 Method: EPA 8260B Data File: V68993.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ____________________
Bruce Hoogesteger: Technical Director

This report is part of a multipage document and should only be evaluated in its entirety. Chain of Custody provides additional information, including compliance with sample condition requirements upon receipt.

093508V2.XLS

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island	**Lab Project Number:** **Lab Sample Number:**	09-3508 10810
Client Job Number:	N/A		
Field Location:	TP-3	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/30/2009

Halocarbons	Results in ug / Kg
Bromodichloromethane	ND< 6.73
Bromomethane	ND< 6.73
Bromoform	ND< 16.8
Carbon Tetrachloride	ND< 16.8
Chloroethane	ND< 6.73
Chloromethane	ND< 6.73
2-Chloroethyl vinyl Ether	ND< 33.7
Chloroform	ND< 6.73
Dibromochloromethane	ND< 6.73
1,1-Dichloroethane	ND< 6.73
1,2-Dichloroethane	ND< 6.73
1,1-Dichloroethene	ND< 6.73
cis-1,2-Dichloroethene	ND< 6.73
trans-1,2-Dichloroethene	ND< 6.73
1,2-Dichloropropane	ND< 6.73
cis-1,3-Dichloropropene	ND< 6.73
trans-1,3-Dichloropropene	ND< 6.73
Methylene chloride	ND< 16.8
1,1,2,2-Tetrachloroethane	ND< 6.73
Tetrachloroethene	ND< 6.73
1,1,1-Trichloroethane	ND< 6.73
1,1,2-Trichloroethane	ND< 6.73
Trichloroethene	ND< 6.73
Trichlorofluoromethane	ND< 6.73
Vinyl chloride	ND< 6.73

Aromatics	Results in ug / Kg
Benzene	ND< 6.73
Chlorobenzene	ND< 6.73
Ethylbenzene	ND< 6.73
Toluene	ND< 6.73
m,p-Xylene	ND< 6.73
o-Xylene	ND< 6.73
Styrene	ND< 16.8
1,2-Dichlorobenzene	ND< 16.8
1,3-Dichlorobenzene	ND< 16.8
1,4-Dichlorobenzene	ND< 6.73

Ketones	Results in ug / Kg
Acetone	ND< 33.7
2-Butanone	ND< 33.7
2-Hexanone	ND< 16.8
4-Methyl-2-pentanone	ND< 16.8

Miscellaneous	Results in ug / Kg
Carbon disulfide	ND< 6.73
Vinyl acetate	ND< 16.8

ELAP Number 10958   Method: EPA 8260B   Data File: V68994.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram

Signature: ______________________
Bruce Hoogesteger: Technical Director

PARADIGM
ENVIRONMENTAL SERVICES, INC. 179 Lake Avenue Rochester, New York 14608 (585) 647 - 2530 FAX (585) 647 - 3311

Volatile Analysis Report for Soils/Solids/Sludges

Client: Ontario Specialty Contracting, Inc

Client Job Site:	HKJJ Clay Source Grand Island	**Lab Project Number:**	09-3508
		Lab Sample Number:	10811
Client Job Number:	N/A		
Field Location:	TP-4	**Date Sampled:**	09/25/2009
Field ID Number:	N/A	**Date Received:**	09/25/2009
Sample Type:	Soil	**Date Analyzed:**	09/30/2009

Halocarbons	Results in ug / Kg
Bromodichloromethane	ND< 8.94
Bromomethane	ND< 8.94
Bromoform	ND< 22.4
Carbon Tetrachloride	ND< 22.4
Chloroethane	ND< 8.94
Chloromethane	ND< 8.94
2-Chloroethyl vinyl Ether	ND< 44.7
Chloroform	ND< 8.94
Dibromochloromethane	ND< 8.94
1,1-Dichloroethane	ND< 8.94
1,2-Dichloroethane	ND< 8.94
1,1-Dichloroethene	ND< 8.94
cis-1,2-Dichloroethene	ND< 8.94
trans-1,2-Dichloroethene	ND< 8.94
1,2-Dichloropropane	ND< 8.94
cis-1,3-Dichloropropene	ND< 8.94
trans-1,3-Dichloropropene	ND< 8.94
Methylene chloride	ND< 22.4
1,1,2,2-Tetrachloroethane	ND< 8.94
Tetrachloroethene	ND< 8.94
1,1,1-Trichloroethane	ND< 8.94
1,1,2-Trichloroethane	ND< 8.94
Trichloroethene	ND< 8.94
Trichlorofluoromethane	ND< 8.94
Vinyl chloride	ND< 8.94

Aromatics	Results in ug / Kg
Benzene	ND< 8.94
Chlorobenzene	ND< 8.94
Ethylbenzene	ND< 8.94
Toluene	ND< 8.94
m,p-Xylene	ND< 8.94
o-Xylene	ND< 8.94
Styrene	ND< 22.4
1,2-Dichlorobenzene	ND< 22.4
1,3-Dichlorobenzene	ND< 22.4
1,4-Dichlorobenzene	ND< 8.94

Ketones	Results in ug / Kg
Acetone	ND< 44.7
2-Butanone	ND< 44.7
2-Hexanone	ND< 22.4
4-Methyl-2-pentanone	ND< 22.4

Miscellaneous	Results in ug / Kg
Carbon disulfide	ND< 8.94
Vinyl acetate	ND< 22.4

ELAP Number 10958 Method: EPA 8260B Data File: V68997.D

Comments: ND denotes Non Detect
ug / Kg = microgram per Kilogram
Surrogate outliers indicate probable matrix interference

Signature:

Bruce Hoogesteger: Technical Director

PARADIGM ENVIRONMENTAL SERVICES, INC.

179 Lake Avenue
Rochester, NY 14608
(716) 647-2530 * (800) 724-1997

CHAIN OF CUSTODY

REPORT TO:		INVOICE TO:	
COMPANY:	Ontario Specialty Contracting, Inc.	COMPANY:	Same
ADDRESS:	333 Ganson Street	ADDRESS:	
CITY:	Buffalo STATE: NY ZIP: 14203	CITY: STATE: ZIP:	
PHONE:	716-856-3333 FAX: 716-842-1630	PHONE: FAX:	
ATTN:	John Yensan	ATTN:	
COMMENTS:	PO # 28043 Please e-mail results to jyensan@ontariospecialty.com		

PROJECT NAME/SITE NAME: HKJJ Clay Source Grand Island, NY

LAB PROJECT #: 09-3508

CLIENT PROJECT #:

TURNAROUND TIME: (WORKING DAYS) ☐ 1 ☐ 2 ☐ 3 STD ☒ 5 OTHER ☐

REQUESTED ANALYSIS

	DATE	TIME	COMPOSITE	GRAB	SAMPLE LOCATION/FIELD ID	MATRIX	NUMBER CONTAINERS	TAL Metals	VOC's TCL	SVOC's TCL	PCB's	Pesticides	Cyanide	pH				REMARKS	PARADIGM LAB SAMPLE NUMBER
1	9/25/09		X		TP-1	Soil	3	X	X	X	X	X	X	X					10808
2	9/25/09		X		TP-2	S	3	X	X	X	X	X	X	X					10809
3	9/25/09		X		TP-3	S	3	X	X	X	X	X	X	X					10810
4	9/25/09		X		TP-4	S	3	X	X	X	X	X	X	X					10811
5																		quote	
6																		$825 per	
7																		sample JH	
8																		9-25-09	
9																			
10																			

LAB USE ONLY

SAMPLE CONDITION: Check box if acceptable or note deviation:

CONTAINER TYPE: ☒ PRESERVATIONS: ☐ N/A HOLDING TIME: ☒ TEMPERATURE: ☒ 18°C iced - pres. begun in field

Sampled By: Jason Yensan	Date/Time: 9/25/09 10:45AM	Relinquished By:	Date/Time:
Relinquished By: Jason Yensan	Date/Time: 9/25/09	Received By:	Date/Time:
Received By: [signature]	Date/Time: 9/25/09	Received @ Lab By: Elizabeth A. Honck 9/25/09	Date/Time: 1625

Total Cost:

P.I.F.

APPENDIX B

DEMARCATION LAYER SPECIFICATION SHEET

HANES GEO COMPONENTS
A Leggett & Platt® COMPANY

TerraTex GS

Woven Geotextile

TerraTex GS is a woven geotextile made up of polypropylene filaments. These filaments are woven to form a stable and durable network such that the filaments retain their relative position. It is non-biodegradable and resistant to most soil chemicals, acids, and alkali with a pH range of 3 to 12. TerraTex GS is manufactured to meet or exceed the following minimum average roll values:

Property	Test Method	Minimum Average Roll Value English	Minimum Average Roll Value Metric
Tensile Strength	ASTM D-4632	200 lb	0.8890 kN
Tensile Elongation	ASTM D-4632	15%	15%
Mullen Burst	ASTM D-3786	400 psi	2756 kPa
Puncture Strength	ASTM D-4833	90 lb	0.400 kN
Trapezoid Tear	ASTM D-4533	75 lb	0.333 kN
UV Resistance	ASTM D-4355	70% @ 500 hr	70% @ 500 hr
AOS	ASTM D-4751	50 US Sieve	0.300 mm
Permittivity	ASTM D-4491	0.05 sec-1	0.05 sec-1
Water Flow Rate	ASTM D-4491	5 gal/min/ft^2	203 l/min/m^2

1/2008

815 Buxton Street Winston Salem, NC 27101
888 - 239 - 4539 • Fax: 336 - 747 - 1652
www.hanesgeo.com info@hanesgeo.com

APPENDIX W

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

FOR GENERAL CONSTRUCTION

SECTION 01330

SUBMITTAL PROCEDURES

PART 1 - GENERAL

1.01 DESCRIPTION

A. Required Submittals are identified in each technical specification section of the Contract Documents. A summary of Submittals is provided at the end of this section. Submittals shall be provided to the Engineer, as required, unless otherwise specified. Submittals may include:

1. Data;
2. Drawings;
3. Instructions;
4. Schedules;
5. Statements;
6. Reports;
7. Plans;
8. Certificates;
9. Samples;
10. Records; and
11. Operation and Maintenance Manuals.

B. The Contractor shall make Submittals as required by the Contract and the individual specification sections but not limited to the summarized items in Table 01330-1: Submittal Summary provided at the end of this section.

PART 2 - PRODUCTS

Not Applicable.

PART 3 - EXECUTION

3.01 GENERAL

A. Submittals shall include items such as:

1. Manufacturer's or fabricator's drawings;
2. Descriptive literature including (but not limited to) catalog cuts, diagrams, operating charts or curves;
3. Test reports;
4. Samples;
5. Operation and Maintenance Manuals (including parts list);
6. Certifications;
7. Warranties; and
8. Other pertinent data.

3.02 SUBMITTAL REQUIREMENTS

A. Transmittal Form:

1. A Transmittal form shall accompany all Submittals.
2. The Transmittal form shall be developed and furnished by the Engineer.
3. Transmittals shall include the following information, at a minimum:
    a. Submittal number in sequence, beginning with 1 (subsequent revised Submittals shall be identified with a number and letter);
    b. Date;
    c. Project title and project number;
    d. Contractor's name and address;
    e. Identification of each item submitted under the single Transmittal with a separate sequential number (e.g. 1.1, 1.2, etc.). Group only like items in a single Submittal;
    f. Reference to the specification section and sub-part number and/or Contract Drawing sheet and detail number (if applicable) pertinent to the data submitted.
    g. Notification of any deviations from Contract Documents;
    h. Return date required by Contractor; and
    i. Other pertinent data.

B. Contractor Certification: The Contractor’s Certification that the Submittal meets contract requirements shall contain the following:

1. Contractor firm name;
2. Point of contact name, signature, and title;
3. Date; and
4. Contractor’s corrections as noted on Submittal data and/or attached sheets(s).
5. The certification may be provided as part of the Transmittal, on a separate sheet attached to the Transmittal, or as a stamp on the Submittal itself.

C. Procedures:

1. The Contractor shall schedule submissions at least 14 days before Submittal approvals will be needed, except where different lead time is specified.
2. The Contractor shall deliver to Engineer three copies of all Submittals and Transmittals that are sent in the mail. To expedite the review of smaller Submittals, the Contractor may provide a legible fax, if followed by the required number of original copies.
3. The Contractor may deliver Submittals to the Engineer in electronic form by email. The Contractor-signed Transmittal shall be scanned and attached to the other electronic Submittal documents. The subject line of the email shall clearly note the project name and Submittal number.
4. The Contractor shall maintain one copy of the Submittal and Transmittal on site.
4. At the time of each submission, the Contractor shall call to the Engineer's attention, in writing, any deviations that the Submittal may have from the requirements of the Contract Documents.

D. Submittals shall include:

1. Date and revision dates;
2. Project title and number;
3. The names of:
    a. Engineer;

b. Contractor;
c. Subcontractor;
d. Supplier;
e. Manufacturer; and
f. Separate detailer when pertinent.

4. Identification of product or material;
5. Field dimensions, clearly identified as such;
6. Specification section and sub-part number and/or Drawing sheet and detail number;
7. Applicable standards, such as ASTM or Federal Specification number;
8. For Submittals which include proposed deviations requested by the Contractor, "variation" shall be clearly indicated on the Transmittal. The Contractor shall state the reason for any deviations and annotate such deviations on the Submittal. The Engineer reserves the right to rescind inadvertent acceptance of Submittals containing unnoted deviations.

E. Submittals shall be of standardized sizes.

1. Approved standard sizes shall be:
   a. 24 inches by 36 inches;
   b. 11 inches by 17 inches; and
   c. 11 inches by 8 1/2 inches.
2. Provision shall be made in preparing Submittals to afford a binding margin on left hand side of sheet.
3. Submittals put forward other than as specified herein may be returned for resubmittal without being reviewed.

Table 01330-1: Submittal Summary

No.	Specification Section	Specification Part	Submittal Item	Schedule
1	00001	5b	Preliminary Critical Path Method (CPM) Diagram, Schedule of Values, and supporting narrative	Within 5 days of Apparent Low Bidder notification
2	00001	5c	Interim CPM Diagram, Schedule of Values, Schedule of Shop Drawing Submissions, and supporting narrative	Prior to commencing construction
3	00001	5d	Detailed CPM Diagram, Schedule of Values, Schedule of Shop Drawing Submissions, and supporting narrative	To accompany each request for progress payment
4	00001	5h	As-Built CPM Diagram and Schedule Reconciliation Report	To accompany request for final payment
5	00002	1.2b	Name and location of Precaster; Precaster Product Data/Shop Drawings for Precast Units; Certification of design loading; and Manufacturer's Product Data on manhole frames, covers, and grates	14 days prior to day approval is required
6	00003	1.01B	Health and Safety Plan (HASP)	Within 5 days of Apparent Low Bidder notification
7	01110	1.03C	Construction Work Plan (Plan of Operations)	Within 5 days of Apparent Low Bidder notification
8	01410	1.03A	Copies of approved permits	Prior to commencing construction associated with the permit
9	01450	1.03A	Construction Quality Control Plan (CQCP)	Within 5 days of Apparent Low Bidder notification
10	01450	1.03B	Weekly CQC Reports, Test Reports, Deficiency Reports, and/or Project Summaries	As soon as the report is available
11	01720	1.03A	Qualifications of persons providing field engineering and surveying services	At the request of the Engineer
12	01720	1.03B	Documentation verifying accuracy of survey work or instrumentation	At the request of the Engineer
13	01720	1.03C	Results of the field verification survey and results of the comparison with the Drawings	Prior to commencing excavation
14	01720	1.03D	Survey data in support of quantity measurements	Prior to or along with payment requisitions

Table 01330-1: Submittal Summary

No.	Specification Section	Specification Part	Submittal Item	Schedule
15	01720	1.03E	Survey data and measurements as the Work progresses in support of establishing Record Documents	At the request of the Engineer
16	01770	1.07	Project Record Documents including • As-built survey data • All outstanding submittals (documentation and test data)	At project completion along with request for final payment
17	02105	1.03A	Quality Assurance Project Plan	14 days prior to baseline groundwater sampling
18	02105	1.03B	Preliminary (verbal) laboratory analysis results	Within 15 days of sampling completion for each: • Pre-construction baseline groundwater sampling; • Post-construction groundwater sampling; and • Post-excavation soil sampling
19	02105	1.03C	Sampling and Analysis Reports	Within 30 days of post-excavation sampling completion
20	02110	1.02B	Waste characterization laboratory reports	14 days prior to day approval is required.
21	02120	1.02B	Permit profile of the Treatment Storage and/or Disposal Facility	14 days prior to day approval is required
22	02120	1.02C	Bill of Lading and Manifests for all transported waste loads	As work progresses and as an attachment in support of payment requisitions
23	02120	1.02D	Certified weight slips for each load transported to the disposal facility	As work progresses and as an attachment in support of payment requisitions
24	02221	1.03A	Waste characterization laboratory reports	14 days prior to day approval is required.
25	02240	1.03A	Dewatering methods	14 days prior to day approval is required
26	02250	1.03A	Engineered shoring system design, signed and sealed by a New York licensed professional engineer for informational purposes	10 days prior to commencing excavation
27	02250	1.03B	Vibration monitoring readings for the duration of the work	At the completion of the Work

Table 01330-1: Submittal Summary

No.	Specification Section	Specification Part	Submittal Item	Schedule
28	02300	1.04A	Borrow source information: • Name; and • Location	14 days prior to day approval is required
29	02300	1.04B	Subcontractor's Quality Control Testing Laboratory(ies) information: • Name; and • Qualifications	7 days following Notice to Proceed
30	02300	1.04C	Subgrade Fill Source Test Reports - Geotechnical	14 days prior to day approval is required
31	02300	1.04C	Crushed Stone Source Test Reports - Geotechnical	14 days prior to day approval is required
32	02300	1.04C	Subbase Course Source Test Reports - Geotechnical	14 days prior to day approval is required
33	02300	1.04C	Subgrade Fill Source Test Reports - Analytical	14 days prior to day approval is required
34	02300	1.04C	Subgrade Fill Field Moisture/Density (Compaction) Test Reports	As soon as the report is available
35	02300	1.04C	Subbase Course Field Moisture/Density (Compaction) Test Reports	As soon as the report is available
36	02370	1.05A	Manufacturer's Product Data for catchbasin inlet filters	14 days prior to day approval is required
37	02370	1.05A	Manufacturer's Product Data for filter berm material (if utilized)	14 days prior to day approval is required
38	02370	1.05A	Manufacturer's Product Data for silt fence (if utilized)	14 days prior to day approval is required
39	02522	1.03A	Information, including the following: • Drilling and well installation methodology; • Well development approach; • Water treatment plan and justification; • Recommended material for well housing and justification; • Number of personnel to be deployed during the field program; and • Proposed schedule/logistics for completing the Work.	14 days prior to day approval is required

Table 01330-1: Submittal Summary

No.	Specification Section	Specification Part	Submittal Item	Schedule
40	02522	1.03C	Field Test Reports including: • Written assurance each well meets the requirements specified in the Contract Documents for materials, depths, plumbness, and alignment; • Well development records; and • Drilling records including casings, cement grout, well screens, penetration, and filter sand.	As soon as possible after installation work is complete

END OF SECTION

SECTION 01450

CONTRACTOR QUALITY CONTROL

PART 1 - GENERAL

1.01 DESCRIPTION

This section covers quality control procedures and testing to be completed by the Contractor during the Work. Prior to commencement of the Work, the Contractor shall prepare a Contractor Quality Control (CQC) Plan detailing the procedures to be followed and testing to be completed. Quality control testing shall be executed as required in the Contract Documents.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Section 01330: Submittal Procedures

B. Section 01770: Project Closeout Procedures

1.03 REFERENCES AND STANDARDS

A. Conform to referenced standards with date of issue current on the date of the bid, except where stated otherwise or referenced differently by code.

1.04 SUBMITTALS

A. Pre-Construction Submittals:

1. Contractor Quality Control (CQC) Plan shall identify personnel, procedures, instructions, records, and forms to be used in carrying out the requirements of the Work. The CQC Plan shall provide the Contractor with a means to provide and maintain effective Quality Control for construction, sampling, and testing activities. No work on-site shall be permitted until comments received are adequately addressed by the Contractor and the CQC Plan is approved by the Engineer.

B. Weekly CQC Reports, Test Reports, Deficiency Reports, and Project Summaries

1.05 DEFINITIONS

A. Quality Control: Activities undertaken by the Contractor including observing, measuring, sampling, and testing undertaken by the Contractor to determine that work performed and/or products/materials provided and installed meet the requirements of the Contract Documents and the quality specified therein.

1.06 QUALITY CONTROL SAMPLING AND TESTING

A. The Contractor shall notify the Engineer a minimum of 72 hours prior to any quality control sampling and testing activities. The Engineer and Department reserve the right to collect duplicate quality control samples.

B. All third party quality control test reports shall be reported/sent directly to the Engineer and shall not be routed through the Contractor. The Contractor shall give their subcontracted laboratory permission to send reports directly to the Engineer.

PART 2 - PRODUCTS

Not applicable.

PART 3 - EXECUTION

3.01 GENERAL REQUIREMENTS

A. The quality of all Work shall be the responsibility of the Contractor.

B. Perform sufficient inspections and tests of all items of work, on a continuing basis, including that of subcontractors, to ensure conformance to applicable specifications and drawings with respect to the quality of materials, workmanship, construction, and functional performance.

C. Provide qualified personnel, appropriate facilities, instruments, and testing devices necessary for the performance of the quality control function.

D. Controls shall be adequate to cover all construction operations, shall be keyed to the proposed construction sequence, and shall be coordinated by the Contractor's quality control personnel.

3.02 CONTRACTOR QUALITY CONTROL (CQC) PLAN

A. Prepare and submit a Contractor Quality Control Plan to the Engineer for approval.

B. Comments or approval from the Engineer will be submitted to the Contractor within 14 calendar days following receipt of the plan. The Contractor shall adequately respond to comments to the satisfaction of the Engineer within 14 calendar days following receipt of any comments from the Engineer.

C. No work on site shall be permitted until the comments received are adequately addressed by the Contractor and the CQC Plan is approved by the Engineer.

D. The CQC Plan, at a minimum, shall include the following:

  1. A description of the Quality Control Organization, including charts showing lines of internal Contractor authority, and external Contractor, subcontractor, and Engineer relationships. The Quality Control Organization shall include the names, qualifications, duties, and responsibilities of each person assigned to a quality control function. The Quality Control Organization chart shall identify a Contractor's Quality Control Manager whose responsibilities and qualifications are described in Sub-Part 3.04 - Contractor Quality Control Organization.
  2. Method of performing, documenting, and enforcing quality control operations of both Contractor and subcontract work including inspection and testing.
  3. Inspections as described in the Sub-Part 3.05 – Inspections.
  4. Provide a list of analytical or testing laboratories to be used by the Contractor for testing required by the Specifications with listed test methods to be performed by each laboratory indicated.
  5. Protocol describing corrective actions to be taken by the Contractor with specifically defined feedback systems. The Engineer will then decide what further corrective action, if any, shall be taken by the Contractor. Personnel responsible for initiating and carrying out corrective action shall be indicated in the protocol.

E. Submit Weekly CQC Reports, Test Reports, Deficiency Reports and Project Summaries as required by this Specification.

3.03 NOTIFICATION OF CHANGE

A. After submittal and approval of the CQC Plan, the Engineer shall be notified in writing of any proposed changes to the CQC Plan.

3.04 CONTRACTOR QUALITY CONTROL ORGANIZATION

A. CQC Manager:

1. Identify an individual, within the Contractor's organization at the Site who shall be responsible for overall management of the CQC Plan and have the authority to act in all CQC matters for the Contractor.
2. The CQC Manager for this Contract shall be a qualified construction manager/engineer or comparable individual with a minimum of 2 years of applicable experience, at the Project Manager, Project Engineer, Superintendent, or CQC Manager level, whose responsibility is to ensure compliance with the Construction Documents.. The CQC Manager shall be independent of the Project Superintendent.
3. The CQC Manager shall be on-site whenever work is in progress so that he/she may be in charge of the CQC Plan for the project.
4. All submittals for approval shall be reviewed and modified or corrected as needed by the CQC Manager or authorized assigns prior to forwarding to the Engineer.

3.05 INSPECTIONS

A. The CQC Plan shall include the following inspections and tests:

1. The Contractor shall perform preparatory inspections prior to beginning each feature of work on any on-site construction conducted by the Contractor or a subcontractor. Preparatory inspections for the applicable feature of work shall include:
   a. review of submittal requirements and all other Contract requirements with the performance of the work;
   b. check to assure that provisions have been made to provide required field quality control testing;
   c. examine the work area to ascertain that all preliminary work has been completed;
   d. verify all field dimensions and advise the Engineer of any discrepancies;
   e. perform a physical examination of materials and equipment to assure that they conform to approved shop drawings or submittal data and that all required materials and/or equipment are on hand and comply with the Contract requirements.
2. Perform initial inspection as soon as work begins on a representative portion of the particular feature of work, and include examination of the quality of workmanship as well as review of quality control testing for compliance with the Construction Document requirements.
3. Perform follow-up inspections continuously as any particular feature of work progresses to ensure compliance with Contract requirements, including quality control testing, until completion of that feature of work.

3.06 TESTING

A. The Contractor shall be responsible for all required testing, documentation, and corrective measures. The Contractor shall perform tests specified or required to verify that control measures are adequate to provide a product which conforms to Contract requirements.

3.07 CONSTRUCTION MONITORING

A. Prior to commencing invasive construction activities including but not limited to installing sheeting and shoring or excavating, complete an existing infrastructure assessment to record conditions of building and surrounding infrastructure. Record condition with video or photographs noting existing deficiencies or damage as observed prior to construction. The assessment shall at a minimum include the following components:
   1. Building façade;
   2. Building foundation wall;
   3. Building doors and windows;
   4. Building roof overhang, fascia, or general roofline;
   5. Pavement and concrete surface treatments;
   6. Prominent exterior site features within 50 feet of the limit of work including retaining walls, stairs, bollards, manhole frames and grates, etc.; and
   6. Interior building finishes within 50 feet of the limit of work;

B. Maintain continuous vibration monitoring (seismograph recording) during sheeting and shoring installation, excavation, backfilling and compaction, paving, and all other activities utilizing heavy construction equipment likely to cause strong vibrations.

END OF SECTION

SECTION 01720

FIELD ENGINEERING AND SURVEYING

PART 1 - GENERAL

1.01 DESCRIPTION

A. Established survey control points are available on site for construction purposes. The Contractor shall verify locations of survey control points prior to starting work. The Contractor shall safeguard all survey control points. Should any of these points be damaged or destroyed, the Contractor shall replace the control point at no cost to the Department. The Contractor shall assume the entire expense of rectifying work improperly constructed due to failure to maintain and protect such established survey control points.

B. The Contractor shall be responsible for the layout of the construction and any additional survey control points, grid coordinate locations, lines, grades, and levels necessary for the proper construction and testing of the work required in the Contract Documents. Survey control shall include, but not be limited to, maintaining appropriate slopes and specified thicknesses.

C. The Contractor shall employ a surveyor using standard practices and datum for the State of New York to provide the surveying functions necessary for the proper execution of the work, and to document and record the completed work.

D. The Contractor is responsible for scheduling the surveys to coincide with his construction activities. If the survey documentation shows improper slopes, elevations, locations, or layer thicknesses, the Contractor shall correct the deficiency and re-survey the re-work at no additional cost to the Department. Survey documentation may include, but not be limited to:

1. Initial field verification survey, as described in Sub-part 1.03;
2. Depth and configuration of building footing as determined during the Contractor performed Existing Conditions Assessment;
3. Location and invert elevation of any and all utility penetrations of the building foundation wall as determined during the Contractor performed investigations;
4. Excavation horizontal and vertical extents;
5. Location, rim elevation, and inverts of new catchbasin (CB-1), new stormdrain manholes (SD-1, SD-2, SD-3, and SD-4), new stormdrain piping;
6. Location and elevation of chambers and bottom of stone for the subsurface stormdrain management systems (SSMS-1A, SSMS 1B, and SSMS 2);
7. Location, rim elevation, and inverts of re-installed (or new) sanitary sewer manhole and new sanitary sewer service;
8. Bottom of structure, rim, and invert elevations of existing DW-3
9. Limit of installed pavement;
10. Location, and top and bottom elevation of all sheet piling left in place;
11. Final constructed topography within the limit of disturbance based on a 10’ maximum grid pattern;

12. Location and elevation of Contractor established survey control points and/or benchmarks; and
13. Soil boring and monitoring well locations.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Section 01110: Summary of Work
B. Section 01330: Submittal Procedures
C. Section 01450: Contractor Quality Control
D. Section 01770: Project Closeout Procedures

1.03 SUBMITTALS

A. On request, submit data demonstrating qualifications of persons providing field engineering and survey services.
B. On request, submit documentation verifying accuracy of survey work.
C. The Contractor shall perform a field verification of survey as part of the work prior to the start of construction activities to verify/establish current conditions. The Contractor shall then compare the existing condition information shown on the Construction Drawings to the current conditions determined during the field verification activities. Where discrepancies exist, the Contractor shall submit to the Engineer the results of the field verification survey and results of the comparison with the Construction Drawings. All discrepancies shall be resolved by the Engineer prior to initiation of construction activities affected by discrepancies.
D. Survey data in support of quantity measurements as required in Section 01270 – Measurement and Payment
E. Survey data and measurements as the Work progresses for the project in support of establishing Record Documents as specified in Section 01770 - Project Closeout

1.04 FIELD ENGINEERING AND SURVEY REQUIREMENTS

A. Provide field engineering and survey services using appropriate construction practices. Use skilled persons, trained and experienced in the necessary tasks and techniques for the proper execution of the Work. Locate and layout the Work by survey instrumentation and similar appropriate means.
B. The Contractor shall sufficiently establish the existing ground elevations before earthwork is started.
C. The Contractor shall perform the layout and shall document completed construction on Record Drawings, including the features listed in Sub-part 1.01D.
D. Measure final excavated depth during construction to verify that excavation has occurred to the required limit.
E. The Contractor shall sufficiently survey to verify quantities included in requests for payment as required in Section XII, Measurement for Payment.
F. Vertical and horizontal control shall be sufficient to assure work is constructed within 0.1 foot of proposed fill thickness requirements (or proposed grades as indicated where settlement is not a concern) and location.

G. Verification surveys, surveys for measurement and payment, and Project Record documentation shall be provided in electronic file format compatible with AutoCAD 2006 or later.

1.05 TECHNICAL REQUIREMENTS OF SURVEY

A. Horizontal ground control shall originate and terminate on New York State Plane North American Datum 1983 (NAD 83). Vertical control shall be tied to North American Vertical Datum 1988 (NAVD 88).

B. Map Accuracy - Ninety percent of the elevations determined from the solid-line contours for the topographic maps shall have accuracy with respect to true elevation of 0.5 contour interval (0.5 foot) or better, and the remaining 10 percent of such elevations shall not be in error by more than one contour interval (1 foot).

C. Vertical Control: Establish a permanent project benchmark for vertical control.

D. Horizontal Control: Each horizontal control point shall be plotted on the map within the coordinate grid in which it should lie to an accuracy of one one-hundredth foot (0.01 foot) of its true position as expressed by the plane coordinates computed for this point.

E. Spot Elevations: Survey shall be constructed to provide an accuracy of 0.1 feet vertically. No shots exceeding 500 feet shall be taken. Ninety percent of all spot elevations placed on the maps shall have an accuracy of at least 0.1 foot, and the remaining 10 percent shall not be in error by more than one-half (1/2) of the contour interval (0.5 foot).

F. Accuracies and accuracy tests apply to the stereo compilation scale of the original manuscript (i.e., if the manuscript is compiled at a scale of 1" = 100' and then reduced to 1"=200', then the accuracies will apply to the original 1"=100' scale). This is also true if the manuscript is enlarged to 1"=50' or some larger scale.

1.06 EXISTING CONDITIONS SURVEY

A. The existing conditions depicted on the Drawings are based on a survey prepared by YEC, Inc. (2006, 2007).

PART 2 - PRODUCTS

Not applicable.

PART 3 - EXECUTION

Not applicable.

END OF SECTION

SECTION 02105

CHEMICAL SAMPLING AND ANALYSIS

PART 1 – GENERAL

1.01 DESCRIPTION

A. The Contractor shall provide all necessary personnel, equipment, materials, and subcontracting required to perform the following chemical sampling and analysis associated with the remedial design at the Former Alsy Manufacturing Site (Site) in Hicksville, New York for the purpose of:
   1. Conducting pre-construction (baseline) and post-construction groundwater sampling and analysis of the on-site and off-site monitoring wells identified herein,
   2. Conducting post-excavation soil sampling of the excavation extents prior to backfilling.

B. The sampling and analysis shall be conducted in accordance with USEPA and NYSDEC standards and requirements for environmental sampling and analysis.

1.02 REFERENCES

A. United States Environmental Protection Agency Region 1 - New England Low Stress (low-flow) Purging and Sampling Procedures for the Collection of Ground Water Samples from Monitoring Wells. Revision 2, July 30, 1996.

B. New York State Department of Environmental Conservation "Analytical Services Protocol." June 2000 - revised July 2005.

C. New York State Department of Environmental Conservation "Technical Guidance for Site Investigation and Remediation"; Draft DER-10; December 2002.

D. Guidance for the Development of Data Usability Reports; Division of Environmental Remediation; September 1997.

1.03 SUBMITTALS

A. Quality Assurance Project Plan:
   1. Submit the following two weeks prior to start of the work:
      a. Site-specific Quality Assurance Project Plan (QAPP) prepared in accordance with New York State Department of Environmental Conservation "Technical Guidance for Site Investigation and Remediation"; Draft DER-10; December 2002.
      b. Proposed Project Analytical Laboratory and certifications. Documentation shall be provided that the analytical laboratory is New York State Department of Health certified for solid and hazardous waste analyses.

B. Health and Safety Items:
   1. Submit the following items within one week prior to start of the work:
      a. Site-specific Health and Safety Plan (HASP) along with evidence that all on-site personnel are enrolled in medical monitoring and are current with completed OSHA 40-hour HAZMAT training requirements.

C. Sampling and Analysis Reports:
   1. Submit the following reports:
      a. Field sampling data records including copies of completed field sheets, chain-of-custodies, and field log book entries;

b. Laboratory Data Deliverable;
c. Data Usability Summary Report.

PART 2 - PRODUCTS

NOT USED

PART 3 – EXECUTION

3.01 GROUNDWATER SAMPLE COLLECTION

A. Groundwater samples shall be collected from nine (9) on-site wells including ERM-1, LMS-4, AMS-2, MW-3, LMS-3, LMS-5, AMS-1, LMS-1, LMS-2, and one (1) off-site monitoring well, ERM-3. The monitoring well locations are shown on Drawing C-101.

B. Groundwater sampling shall be conducted in accordance with low-flow purging and sampling procedure as presented in the "USEPA Region 1 - New England Low Stress (low-flow) Purging and Sampling Procedures for the Collection of Ground Water Samples from Monitoring Wells", Revision 2, July 30, 1996 (USEPA, 1996).

C. Field equipment shall include:

1. Peristaltic, bladder or inertial pump capable of a flow rate between 50 and 500 ml/minute and appropriate power supply. The pump type will principally depend on the depth to water and well diameter. Bladder pumps are preferred; peristaltic pumps are acceptable only for wells where the depth to water is less than about 25 ft; Inertail pumps are only recommended for narrow diameter wells that cannot be sampled using a bladder or peristaltic pump.
2. Field probe and flow-through cell (e.g., Horiba) for measuring pH, temperature, conductance (and/or specific conductance), DO and ORP of groundwater, and a turbidity meter.
3. Calibration solutions for the field probes
4. Water level tape
5. Tubing, connections and tools as appropriate
6. Graduated cylinder and stopwatch
7. 5-gallon bucket and funnel for purge water
10. Decontamination supplies (e.g., DI water, Liquinox soap, paper towels)
11. Sample containers and cooler (provided by the laboratory)
12. Ice for sample preservation
13. Clean plastic sheeting, paper towels and miscellaneous supplies

D. Field parameter measurements shall be made using instrumentation and a commercially manufactured flow through cell.

E. Dedicated high density polyethylene (HDPE) tubing shall be used.

F. Sampling will be conducted using the following procedure:

1. Determine target depth for location of the pump intake. Target depth should be the portion of the screened interval that intersects the zone of highest conductivity (K). If the zone of highest K is unknown, or if the screen is placed within homogenous material, then the target depth shall be the midpoint of the saturated screen length. Primary flow zones should be identified in wells with screen lengths longer than 10 ft.

2. Measure and record the depth to water. Care should be taken to minimize disturbance of the water column within the well during pre-sample measurements.

3. Decontaminate pump prior to use (if pumps are dedicated then this applies to the initial effort only). Attach appropriate length of dedicated HDPE tubing or mark the tubing at the appropriate point so that when the pump and tubing are lowered into the well, and the mark is at the top of the well riser, the pump shall be located at the target depth within the screened interval.

4. Carefully lower the pump to the predetermined target depth. Start the pump at a purge rate low enough to achieve 0.3 ft of drawdown or less based on historical data. If sampling the well for the first time, start the pump at the lowest possible setting (or approximately 100-ml per minute) and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no drawdown (less than 0.3 ft) if possible. If stabilized drawdown cannot be achieved, use the no-purge method described later in this section.

5. Monitor and record pumping rate and water levels every 3 to 5 minutes (or as appropriate) during purging. Record any adjustments to pumping rates.

6. During purging, monitor field parameters using a flow through cell (the flow through cell can not be used for turbidity measurements and the sample for turbidity measurement must be collected prior to entering the flow through cell). Purging is considered complete and sampling may begin when the field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at 3 to 5 minute intervals, are within the following limits:

   a. Turbidity (+/- 10% for values >10 NTU)
   b. DO (+/- 10%)
   c. Specific conductivity (+/- 3%)
   d. Temperature (+/- 10%)
   e. pH (± 0.1 unit)
   f. ORP (± 10 millivolts)

7. The final purge volume must be greater than the stabilized drawdown volume plus the tubing extraction volume.

8. During purging and sampling the tubing should remain filled with water.

9. Disconnect the tubing from the flow through cell to collect the analytical samples. Water samples for laboratory analyses must not be collected after water has passed through the flow through assembly. Fill sample containers directly from the tubing without alterations to the pumping rate.

10. The volatile organic compound (VOC) fraction sample shall be collected first. The VOC sample container shall be completely filled without air space within the container.

11. The total and dissolved (field-filtered) metals (Nickel and Zinc) shall then be collected. The dissolved metals sample shall consist of a groundwater sample filtered through a 0.45 micron filter.

12. For subsequent sampling efforts, duplicate the pump intake depth and final purge rate from the initial sampling event (use final pump dial setting information).

13. If using non-dedicated equipment, remove the pump and decontaminate by flushing with the decontamination fluid specified herein, or dispose. Obtain and record a depth to bottom of well measurement before closing the well.

14. Include any observations made during sampling such as color, odor, etc., in the field logbook and field sample data record.

15. Secure the well cap and lock.

3.02 POST-EXCAVATION SOIL SAMPLE COLLECTION

A. Post-excavation soil samples shall be collected from the excavation bottom prior to backfilling.

B. Samples shall be collected from the bottom of the excavation sidewalls at a rate of one per 30 linear feet of excavation sidewall and from the excavation bottom at a rate of one per 900 square feet of excavation bottom.

C. Samples shall be collected by using a hand auger, trowel, or spoon to obtain the necessary volume of soil for each sample.

D. The required volume, containerization methods, and sample preservation methods shall be as directed by the Project Analytical Laboratory.

3.03 LABORATORY ANALYSIS

A. Groundwater samples shall be analyzed by the Project Analytical Laboratory for analyses of total and dissolved (field-filtered) Nickel and Zinc using USEPA 6010 methods and target compound list (TCL) VOCs using USEPA OLM04.2 methods as described in the NYSDEC ASP.

B. Soil samples shall be analyzed by the Project Analytical Laboratory for total nickel and synthetic precipitation leaching procedure (SPLP) nickel using USEPA 6010 methods as described in the NYSDEC ASP.

C. Off-site laboratory analysis shall include Category B deliverables as defined in the NYSDEC ASP.

D. Contractor shall prepare a Data Usability Summary Report (DUSR) in accordance with the "Guidance for the Development of Data Usability Reports" (NYSDEC, 1997).

3.04 DISPOSAL OF INVESTIGATION DERIVED WASTES

A. Groundwater generated during groundwater sampling shall be containerized for characterization. Contractor shall transport the filled drums to a designated storage area at the Site for temporary storage and characterization. Contractor shall arrange for offsite disposal at an appropriate facility based upon the characterization results and at the direction of the Engineer, and as approved by the Department.

B. Store generated groundwater and decontamination fluids in DOT approved containers supplied by the Contractor. All wastewater shall be containerized and stored on the Site until the samples taken by the Contractor have been analyzed.

C. Waste characterization and disposal shall be done as specified in Section 02110 – Waste Removal and Handling and Section 02120 – Off-Site Transportation and Disposal.

3.06 DECONTAMINATION

A. Contaminated sampling equipment will be washed with a Liquinox ®, or equivalent soap and water solution, rinsed with clean potable water, and finally rinsed with deionized water.

3.07 HEALTH AND SAFETY

A. Field personnel will be required to utilize the personnel protection as defined in Specification Section 00003 – Minimum Requirements for Health and Safety.

B. Contractor personnel will be required to review the site or task-specific Health and Safety Plan prepared for this project and acknowledge that they have done so before initiating subsurface work.

END OF SECTION

SECTION 02110

WASTE REMOVAL AND HANDLING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes a description of responsibilities for proper on-site handling and management of materials including, but not limited to, excavated contaminated indigenous and borrow soil, fill, bedding, etc; excavated contaminated concrete/masonry, metal, and all other debris; excavated non-contaminated concrete/masonry, metal, bituminous pavement, and all other debris; liquid waste (contaminated stormwater, decontamination water, construction dewatering, etc.); Site trash; soil boring cuttings; and remediation waste (disposable PPE, plastic sheeting and sampling equipment).

1.02 SUBMITTALS

A. The Contractor shall include as a component of the Work Plan (described in Section 01110 – Summary of Work) a description of planned means and methods for management of all waste materials removed or generated as a component of the Work.

B. Laboratory Reports: Provide laboratory reports of analytical testing performed as required by the waste characterization program.

1.03 WASTE CONTAINERS

A. The Contractor shall provide:

1. Trucks for the direct loading of indigenous contaminated soils, concrete, metal, and other debris for off-site disposal.
2. Appropriate containers and/or trucks for the management and off-site disposal/recycling of non-contaminated material and debris from the excavation areas (e.g., asphalt pavement) and all other non-contaminated debris removed during site preparation.
3. Plastic bags for disposable personnel protection equipment. Plastic bags shall have a minimum thickness of six (6) mils.
4. Portable, temporary storage tanks (FRAC tanks, etc.) for the storage/treatment of collected liquids (i.e. decontamination fluids, construction dewatering, and contaminated stormwater). The Contractor is responsible for the rental of FRAC tanks or similar containers.
5. Containers (e.g., roll-off containers) for non-hazardous municipal trash and debris. Roll-off containers shall be utilized for storage of wastes generated during the site preparation activities, construction activities and waste materials from site cleanup activities.
6. DOT-approved, steel drums (55-gallon capacity) for possible storage of residual contaminated material and/or water including soil boring cuttings extracted from the off-site Work.

1.04 ON-SITE MANAGEMENT AND STORAGE OF MATERIALS

A. The Contractor shall be responsible for proper on-site management of wastes generated in compliance with all Federal, State and local regulations. Management shall include handling, segregating, testing and storing all wastes generated during the Work.

B. The Contractor shall be responsible for movement of the containers, trucks, etc. into positions required for proper loading and management of material.

C. The Contractor shall segregate hazardous from non-hazardous materials as required for proper off-site disposal.

D. The Contractor shall be responsible for loading all waste containers, trucks, etc. with all removed soil, material, and debris.

E. The Contractor shall limit stockpiling of indigenous contaminated soil or contaminated material (concrete/masonry, metal, and all other debris) from the excavation areas.

F. The Contractor shall not load waste containers, trucks, etc. with non-contaminated materials prior to inspection and determination by the Engineer that decontamination of the waste containers has been achieved.

G. The Contractor shall be responsible for coordinating the schedule for delivery and pick-up of supplied waste containers. The Contractor shall also be responsible for movement and storage of containers within the Site to allow the progress of the Work.

H. The Contractor shall cover any stockpiles with plastic sheeting to prevent erosion of the stockpiles or uncontrolled runoff while promoting runoff of precipitation. The plastic sheeting shall be weighted down.

1.05 SAMPLING AND TESTING OF WASTES

A. Testing shall not be required for non-contaminated wastes including:
   1. Removed asphalt pavement within the top one foot of the excavation area.
   2. General trash and rubbish from outside the Work Area (e.g., office waste).

B. The Contractor shall be responsible for the sample collection and laboratory testing of the following wastes:
   1. Collected liquids (i.e. decontamination fluids, construction dewatering, and contaminated stormwater). Collected liquids that require off-site disposal shall be sampled and tested using the required methods and at the required frequency of the designated off-site disposal facility.
   2. Contaminated material (soil, masonry/concrete, metal, and all other debris). Solid wastes shall be sampled and tested using the required methods and at the required frequency of the designated off-site facility.

C. The Contractor shall collect samples and shall coordinate the sampling and testing with the Engineer.

D. Laboratory testing of wastes shall be performed by a certified laboratory as required by the selected disposal facility:
   1. Laboratory reports shall be prepared by the subcontracted laboratory to include all requirements of the State.
   2. All laboratory test methods and frequencies shall be in accordance with NYSDEC requirements.

PART 2 PRODUCTS

Not Applicable

PART 3 EXECUTION

Not Applicable

END OF SECTION

SECTION 02120

OFF-SITE TRANSPORTATION AND DISPOSAL

PART 1 GENERAL

1.01 SUMMARY

A. This section includes a description of responsibilities for proper transportation and disposal of excavated contaminated indigenous and borrow soil, fill, bedding, etc.; excavated contaminated concrete/masonry, metal, and all other debris; excavated non-contaminated concrete/masonry, metal, bituminous pavement, and all other debris; liquid waste (contaminated stormwater, decontamination water, construction dewatering, etc.); Site trash; soil boring cuttings, and remediation waste (disposable PPE, plastic sheeting and sampling equipment).

1.02 SUBMITTALS

A. The Contractor shall include as a component of the Work Plan (described in Section 01110 – Summary of Work) a description of planned means and methods for transporting and disposing of all waste materials removed or generated as a component of the Work.

B. Permit profile of the Treatment Storage and/or Disposal Facility

C. Bill of Lading and Manifests for all transported waste loads.

D. Certified weight slips for each load transported to the disposal facility.

1.03 WASTE CONTAINERS

A. The Contractor shall provide waste containers specific to the individual waste as described in Section 02110 – Waste Excavation, Removal, and Handling.

1.04 TRANSPORTATION OF WASTES

A. The Contractor shall be responsible for the transportation of all solid wastes specified or generated as a result of the Work off-site. This includes materials generated by final Site cleanup activities including the dismantling of the temporary facilities and controls.

B. The Contractor shall be responsible for the transportation of all collected contaminated liquids as specified or generated as a result of the Work.

C. The Contractor shall be responsible for coordinating the number and schedule of vehicles required for off-site transportation of waste materials generated during the execution of the specified work.

D. The Contractor shall be responsible to inspect the transportation vehicles before and after loading to ensure compliance with all local, State, and Federal regulations for the safe transport of wastes from the Site to the receiving facility. The Contractor shall provide the necessary labor and materials to insure all trucks, containers, etc. are lined with plastic prior to filling, foamed or stabilized with an agent, if necessary, and covered prior to departure.

E. The Contractor shall insure that the transporters arriving at the Site for loading do not cause undue congestion to local streets, and shall stage trucks either within the perimeter of the Site or at an off-site staging area approved by the Engineer. Transporters shall not be accepted at the site before 7:00 AM and after 5:00 PM and shall not idle during queuing beneath the covered breezeway along the ingress route.

F. The Contractor's transporters shall proceed directly from the Site to the designated receiving facility. Temporary staging or storage of material at intermediate locations between the Site and the receiving facility is prohibited.

G. The Contractor shall originate, maintain, and provide the Engineer with a copy of each executed Bill of Lading for all loads shipped off-site. In addition, the Contractor shall provide the Engineer, documentation and records verifying receipt of each truck load by the receiving facility. Such documentation shall indicate the actual weight of each load shipped.

H. Transporters shall proceed from the Site along traffic routes established by the Contractor and approved by the local municipality. Transporters shall call back weights after each load and modify loads accordingly. The Contractor shall ensure that trucks leaving the Site are within appropriate weight limitations for the local roads along the designated route.

1.05 DISPOSAL OF WASTES

A. The Contractor shall be responsible for the proper disposal of all solid and liquid wastes that are specified as a component of the Work or that are generated during the execution of the Work in conformance with all Federal, State, and local regulations and requirements. Proper disposal requires that the facility accepting the waste be a state licensed disposal/recycling facility that is approved for acceptance of the waste based on the results of the characterization testing and analysis.

B. The disposal facilities shall be approved by the Engineer/Department prior to the transporting of waste. The Contractor shall not change facilities without prior consent of the Engineer/Department.

PART 2 PRODUCTS

Not Applicable

PART 3 EXECUTION

Not Applicable

END OF SECTION

APPENDIX X

QUALITY ASSURANCE PROJECT PLAN – ENVIRONMENTAL SAMPLING AND LABORATORY ANALYSIS

APPENDIX X – EXAMPLE PLAN - QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) procedures will be utilized throughout the project as described in the following sections. The project QA/QC protocol will be consistent with NYSDEC's Draft Technical Guidance for Site Investigation and Remediation (DER-10, December 2002).

1. LABORATORY ANALYSES

The primary goal of this section is to provide a description of the laboratory analytical program and the analytical methods used to analyze soil and water samples collected during field investigation activities. The majority of the analytical data will be generated using USEPA analytical procedures. Analyses will be completed using USEPA SW-846 methods (USEPA, 1996). Samples will be analyzed by a subcontract laboratory with NYSDOH ELAP Certification.

At this time, the analytical laboratory has not been selected for the RI/FS. Laboratory information and contacts will be included provided to NYSDEC when a laboratory is selected.

Analytical methods and parameters for are described in Sections 5.1 and 5.2 and are summarized below:

- Volatile Organic Compounds (VOCs) by Method 8260B
- Semivolatile Organic Compounds (SVOCs) by Method 8270C
- Polychlorinated biphenyls (PCBs) by Method 8082
- Metals by Methods 6000/7000 including mercury by Methods 7470A and 7471A
- Cyanide by Method 9012A
- Alcohols by Method 8015
- Hydrocarbons (diesel fuel compounds) by methods specified in the STARS #1 Memo
- Other inorganics in groundwater by various EPA Methods
- VOCs by EPA Method TO-15 (soil gas/air samples only)

The laboratory testing will be performed in accordance with procedures specified in the NYSDEC Analytical Services Protocol (ASP) [NYSDEC, 2000] and the published EPA SW-846 methods.

2. RECORDKEEPING

Notes regarding field activities, observations, and measurements will be documented in ink in a bound project logbook. Information to be recorded will include the following:

- The names of personnel on site and their organizations
- A time log that records the events that occur during each day on site
- A list of equipment used
- A description of sampling methods and procedures
- Sample types, locations, collection times and required laboratory analyses
- Weather conditions
- Instrument calibration results
- Water levels
- Well purging data
- Other information as necessary

3. EQUIPMENT DECONTAMINATION

In order to minimize the potential for cross contamination during sampling, disposable sampling equipment will be used when possible. Decontamination of non-disposable equipment will be performed prior to use at a new location or for sample collection. Decontamination of non-disposable sampling equipment will include a soap/water wash, potable water rinse, distilled water rinse, and wipe-drying with a clean cloth or air drying. During groundwater sampling, new pump tubing will be used at each well location. The submersible pump, if used, will be cleaned with a soap/water wash and distilled water rinse prior to purging/sampling each well.

4. QUALITY CONTROL SAMPLES

Quality control samples will be collected and analyzed as follows:

- An aqueous trip blank prepared by the laboratory will accompany each sample shipment. The trip blanks will be analyzed for the same VOC parameters as the soil and groundwater samples.

- Aqueous field blank samples will be collected during the soil and groundwater sampling events. One aqueous field blank will be collected during the RI/FS soil sampling and one aqueous field blank will be collected for each groundwater monitoring event. The field blanks will be collected by pouring analyte-free water (provided by the laboratory) over the sampling equipment and containerizing the rinsate in the appropriate laboratory bottles. The field blanks will be analyzed for the same parameters as the soil and groundwater samples.

- One duplicate groundwater sample will be collected from a specific monitoring well during each groundwater sampling event. The duplicate will be collected at the same time, using the same procedures, and analyzed for the same parameters as the original groundwater sample.

- A matrix spike/matrix spike duplicate (MS/MSD) sample will be collected from a specific well during each groundwater monitoring event. MS/MSDs are known amounts of specific chemical constituents added by the laboratory to selected samples to evaluate the effect of the sample matrix on the preparation and analytical procedures. Matrix spikes are performed in duplicate and are referred to as MS/MSDs.

- One blank sample will be collected for analysis by EPA Method TO-15 during each sub-slab vapor and indoor/outdoor air sampling event completed at the Area B office building.

5. DATA REVIEW AND VALIDATION

Category B deliverables as defined in the NYSDEC ASP will be reported for all samples collected during remedial investigation activities. Analytical data will be validated by a MACTEC project chemist in accordance with NYSDEC Data Usability Summary Report (DUSR) guidelines (NYSDEC, 2002) and Honeywell Remediation program data validation procedures. Validation will be completed prior to use as final data in investigation reports. Three levels of validation are established for Honeywell projects. A data validation scope will be selected for each sample set based on the data quality goals and needs of that task.

5.1 Project Accuracy and Precision Goals

Accuracy and precision limits have been identified for the analytical quality control measurements that will be performed in association with the collection and analysis of field samples. A summary of project limits are summarized in Table 8-1. These limits were determined based on USEPA Region 2 data validation guidelines and the professional judgment of the project QAO. They represent QA/QC goals for the project to ensure that data meet a minimum quality standard for evaluation of site contamination and data use in remedial investigation reports. These limits will be used to review and evaluate data quality and data usability during data validation.

5.2 Data Validation Levels

Data validation will be completed for all remedial investigation samples and the data validation observations and actions will be summarized in a DUSR. Three general levels of data validation are described for data collected under the Honeywell Remediation Program. Validation Levels II, III, and IV have been established to provide standards for analytical data review and to allow projects to determine validation procedures that are appropriate for the data quality goals for each investigation task. Level II validation includes a review of basic QA/QC procedures and measurements that are associated with environmental laboratory analyses, and it represents a generic minimum review of data quality. Level II and Level IV are completed for investigation data that need more intensive validation to support additional data quality objectives or regulatory guidelines and to provide calculation and transcription. Remedial investigation samples will have Level II validation with 10 percent Level IV.

Level II includes the following data checks and evaluations:

- A review of the data set narrative to identify and issues that the lab reported in the data deliverable;
- A check of sample integrity (sample collection, preservation, and holding times);
- An evaluation of basic QC measurements used to assess the accuracy and precision of data including QC blanks, laboratory control samples (LCS), matrix spikes/matrix spike duplicates (MS/MSD), surrogate recovery when applicable, and field or lab duplicate results; and,
- A review of sample results, target compounds, and detection limits to verify that project analytical requirements are met.

Level III would include all of Level II plus some additional method-specific QC checks including instrument calibration, internal standard response for gas chromatography/mass spectrometry (GC/MS), and interference checks and serial dilutions data for inorganics.

Level IV would include all Level II and Level III checks with additional calculation and raw data checks to verify that no reporting errors have occurred. Data validation actions will be based on general USEPA National guidance documents (USEPA; 1999; USEPA, 2004) and the professional judgment of the project chemist and QAO.

MACTEC may use the EIM system to complete a computerized Level II validation of each data package to check that the project quality control requirements specified in subsections 4.2 and subsection 8.1. Data qualifiers will be applied to results that do not meet project goals. EIM will produce a summary of data validation actions for each sample set. The summaries will be reviewed and approved by the project chemist prior to finalization of the validated data. The data will be evaluated/qualified based on the following parameters (if available/applicable) and specified criteria:

A DUSR will be prepared for data sets reported from each distinct sample collection effort. The validation report will include a summary of analytical methods performed, listings of samples included in the review, and summaries of data validation actions or observations.