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Appendix I

Estimated Site Life

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Imagine the result

Calculation Sheet

Client: **CWM Chemical Services, LLC**

Project Location: **Model City, New York**

Project: **RMU-2 Design Calculations** **Project No.:** **B0023725.2011**

Subject: **Appendix I: Estimated Site Life**

Prepared By: **BMS** **Date:** **February 2013**

Reviewed By: **BMS** **Date:** **February 2013**

Checked By: **PHB** **Date:** **February 2013**

OBJECTIVE:

Determine the estimated site life for RMU-2.

REFERENCES:

1. RMU-2 Permit Drawing No. 6 entitled "Top of Waste Grades", ARCADIS, February 2013.
2. RMU-2 Permit Drawing No. 5 entitled "Top of Operations Layer Grades", ARCADIS, February 2013.
3. Terramodel v10.52, Trimble Navigation Limited.
4. *RMU-2 Engineering Report*, ARCADIS February 2013.
5. *Engineering Report for Residuals Management Unit 1*, Earth Tech.

ASSUMPTIONS:

1. Average incoming waste to the facility is a maximum of 500,000 tons/year (as specified by CWM).
2. The volume of select fill placed for access roads and around vertical risers throughout the cell areas is estimated to be 96,700 in-place cubic yards (cy). This volume was determined based on information presented in Reference 5 and assuming a similar ratio (0.024) of select fill to total airspace.
3. Approximate RMU-2 total airspace from top of operations layer to bottom of final cover is 4,030,700 cy based on References 1, 2 and 3.
4. Bulking of the placed waste material is expected. A portion of the bulking will be a direct result from the inclusion of stabilizing agents to the fraction of waste requiring use of these items. For the following calculation it has been assumed that approximately 25% of the incoming waste will need stabilization. Stabilized waste is assumed to contain 20%, by volume, stabilizing agents. The total waste bulking percentage is expected to be offset by the total percentage of the compaction of the waste due to construction/operation equipment (Reference 5).
5. Assumed unit weights:
   - Composite in-place waste material (stabilized and non-stabilized) and select fill = 111.1 lb/ft^3

Calculation Sheet

(Reference 5)

- Average in-place soil = 100 lb/ft^3 (Reference 5)
- Stabilized waste material = 115 lb/ft^3 (Reference 5)

CALCULATIONS:

1. Net Volume Available in RMU-2 for Waste Placement (Volumes Rounded to Nearest 100 cy)

Total Airspace (Assumption 3)	= 4,030,700 cy
Volume of Select Fill for Access Roads and Around Vertical Risers (Assumption 2)	= 96,700 cy
Total Net Volume Available for Waste Material (Including Stabilizing Agents)	= 3,934,000 cy
Volume Occupied by Stabilizing Agents (3,934,000 cy x 0.25 x 0.20, Assumption 4)	= 196,700 cy
Net Volume Available for Incoming Waste Materials	**= 3,737,300 cy**

2. Unit Weight of In-Place Waste

With the inclusion of stabilizing agents and select fill material into the landfill volume, the actual unit weight of the material in the landfill is greater than the unit weight of the incoming waste material. Assuming the average unit weight of in-place waste and select fill used for access roads, vertical risers, and daily cover is 111.1 lb/ft^3, the following mass balance may be written:

$$V_{SF}*\gamma_{SF} + V_{AW}*\gamma_{AW} = V*\gamma$$

where,

V_{SF} = volume of select fill within RMU-2 used for access roads and vertical risers, = 96,700 cy
γ_{SF} = in-place unit weight of select fill = 100 lb/ft^3
V_{AW} = total net volume available within RMU-2 for waste material = 3,934,000 cy
γ_{AW} = average in-place unit weight of waste (unknown)
V = total airspace within RMU-2 = 4,030,700 cy
γ = in-place composite unit weight of waste and select fill = 111.1 lb/ft^3

Thus,

$$\gamma_{AW} = [(111.1\ lb/ft^3)(4{,}030{,}700\ cy) – (96{,}700\ cy)(100\ lb/ft^3)]/\ 3{,}934{,}000\ cy$$

Average In-Place Unit Weight of Waste
(Including Stabilizing Agents and Excluding Select Fill) = 111.37 lb/ft^3

Since the average in-place unit weight of waste includes both waste material and stabilizing agents, the following expression may be written to determine the in-place unit weight of the waste material alone:

$$\gamma_{AW} = 0.75\ \gamma_W + 0.25\gamma_{SW}$$

where,

γ_{AW} = average in-place unit weight of stabilized and unstabilized waste (from above) = 111.37 lb/ft^3
γ_W = unit weight of waste material (unknown)

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γ_{SW} = unit weight of stabilized waste material = 115 lb/ft^3

Thus,

γ_W =[111.37 lb/ft^3 - (0.25)(115 lb/ft^3)]/0.75

In-Place Unit Weight of Waste = 110.16 lb/ft^3 = 1.487 tons/cy

3. Estimated RMU-2 Site Life

The site life of RMU-2 is estimated using the total net volume available within RMU-2 for incoming waste material, the above-calculated in-place unit weight of waste, and a maximum annual inflow of waste to the facility of 500,000 tons (Assumption 1):

$L = V_w/Q_w$

where,

L = site life (unknown)

V_w = volume available within RMU-2 for incoming waste material = 3,737,300 cy

Q_w = maximum annual volumetric inflow of waste to RMU-2 = (500,000 tons/yr)/γ_w = 336,247cy/yr

Thus,

L = (3,737,300 cy)/(336,247 cy/yr)

Estimated RMU-2 Site Life = 11.1 years (Minimum)

SUMMARY:

Based on a total airspace of 4,030,700 cy and a maximum annual waste inflow of 500,000 tons/year, the site life of RMU-2 is estimated to be approximately 11.1 years. With annual waste inflow less than the assumed maximum, a longer site life will result.

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Appendix J

Fac Pond Transfer Line Calculations

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Appendix J-1

Fac Pond Transfer Line Pipe Crush Analysis at Road Crossings

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Calculation Sheet

Client: **CWM Chemical Services, LLC**

Project Location: **Model City, New York**

Project: **RMU-2 Design Calculations** **Project No.:** **B0023725.2011**

Subject: **Appendix J-1: Fac Pond Transfer Line Pipe Crush Analysis at Road Crossings**

Prepared By: **BMS** **Date:** **November 2013**

Reviewed By: **PHB** **Date:** **November 2013**

Checked By: **JM** **Date:** **November 2013**

OBJECTIVE:

Determine the minimum required wall thickness for the proposed ductile iron sleeve pipes to be used to protect the high-density polyethylene (HDPE) fac pond transfer line at road crossings.

REFERENCES:

1. Fac Pond 5 Permit Drawings, ARCADIS, February 2013 (revised November 2013).

2. "Truck Loads on Pipe Buried at Shallow Depths," Ductile Iron Pipe Research Association (DIPRA), January 2009 (attached).

3. *National Engineering Handbook*, U.S. Department of Agriculture, Natural Resources Conservation Service, Chapter 52 – Structural Design of Flexible Conduits, pp. 52-8, 52-11, and 52-12 (attached).

4. "Design of Ductile Iron Pipe," DIPRA, October 2006 (attached).

ASSUMPTIONS:

1. The proposed fac pond transfer pipeline consists of two double-contained HDPE pipes in parallel (6-inch-diameter DR 11 carrier pipe inside of 10-inch-diameter DR 11 containment pipe). Where the HDPE pipes cross site roads, they will be sleeved inside of ductile iron pipes. Thus, this analysis focuses on the ability of the ductile iron pipe to withstand the stresses due to truck traffic and burial at road crossings. All other reaches of the pipeline where sleeve pipes are not identified are assumed to not be subject to and will be protected from vehicle loading by surface grading and/or road edge markers.

2. A nominal 12-inch-diameter ductile iron casing pipe will be used to protect the HDPE pipeline from stresses due to truck traffic at all road crossing locations. This allows the pipe to be installed with less cover. The ductile iron pipe has an actual outer diameter of 13.20 inches (Reference 4) and allows the 10-inch-diameter HDPE containment pipe to be installed inside of the casing pipe with some interstitial space between the inner diameter of the ductile iron pipe and the outer diameter of the HDPE pipe. To reduce the height of the road crossing to the extent possible, a minimum of 9 inches of cover is proposed over the top of the ductile iron pipe.

3. References 2 and 4 are used to model the performance of ductile iron pipe at roadway crossings. These references are specific to ductile iron pipe and truck loadings at shallow burial depths. The procedure contained in these references checks both bending stress and ring deflection. Per Reference 4, the maximum design ring bending stress is 48,000 psi and the maximum ring deflection for pipes with flexible linings is 5.0 percent.

Calculation Sheet

4. Vehicle traffic is assumed to consist of a semi-truck with a maximum single axle load of 40,000 pounds (lbs) (based on American Association of State Highway and Transportation Officials HS-25 loading). Thus, each set of dual wheels is assumed to carry a maximum load of 20,000 lbs. The static wheel load of 20,000 lbs is multiplied by an impact factor of 2.0 to account for dynamic effects due to the truck traveling at speed over an uneven road surface. It is noted that Reference 3 suggests a value of 1.3 for pipes with cover thicknesses of 12 inches of less so the 2.0 value is somewhat conservative.

5. The bedding material and remaining backfill are conservatively assumed to have a unit weight of 130 pounds per cubic foot (pcf).

CALCULATIONS:

The design of the ductile iron pipes used to protect the HDPE pipes at road crossings is evaluated using ductile iron-specific methods as published by DIPRA. Reference 4 is a DIPRA guidance document for determining the minimum wall thickness for ductile iron pipes subject to internal pressure, burial, and truck loading. Reference 2 is a DIPRA guidance document that is used to evaluate the effect of truck loading on ductile iron pipes buried at shallow (less than 2.5 feet) depths. The ductile iron sleeve pipes are designed to withstand the applied loading due to burial and assuming the occurrence of surface loads consisting of loaded semi-trucks conforming to the HS-25 configuration.

According to Reference 4, the minimum wall thickness is based on the larger of the two calculated thicknesses for containing internal pressures and for withstanding external loads. In this application, the sleeve pipe is not pressurized so the minimum wall thickness is based on withstanding external loads only. For ductile iron pipes buried at shallow depths and subject to truck loads, Reference 2 is used to calculate the pressure at the top of the pipe due to truck loads at the ground surface as follows:

$$P_t = RF\frac{CP}{bD}$$

where,

P_t = truck load at top of pipe in pounds per square inch (psi)
R = reduction factor due to only part of the pipe being subjected to full intensity of truck load = 1 (Table 2, Reference 4)
F = wheel impact factor = 2.0 (Assumption 4)
C = surface load factor (see equation below for value)
P = wheel load in pounds = ½ of HS-25 axle load = 20,000 lbs
b = effective pipe length = 36 inches (value to assume per Reference 2)
D = outside diameter of ductile iron pipe = 13.20 inches (Table 3, Reference 4)

The surface load factor, C, is based on the integration of the Bousinnesq stress distribution formula and accounts for the vertical distance between the ground surface (point of wheel load application) and the top of the pipe as well as the horizontal distance between the point of wheel load application and the top of the pipe. Because the wheel load is assumed to eventually pass over the top of the pipe, the surface load factor is calculated for the instant in time when the wheel is directly over the top of the pipe. depth of the top of pipe Reference 2 gives the following equation for the calculation of the surface load factor:

$$C = 1 - \frac{2}{\pi}\sin^{-1}\left[H\sqrt{\frac{A^2+H^2+1.5^2}{(A^2+H^2)(1.5^2+H^2)}}\right] + \frac{2}{\pi}\left(\frac{1.5AH}{\sqrt{A^2+H^2+1.5^2}}\right)\left[\frac{1}{A^2+H^2}+\frac{1}{1.5^2+H^2}\right]$$

Calculation Sheet

where,

H = depth of cover over top of pipe (ft) = 0.75 feet (Assumption 2)
A = outside radius of pipe (ft) = 0.55 feet

Using the above formula, the surface load factor, C, is found to be 0.6922. Thus the truck load at the top of the pipe, P_t, equals 58.3 psi. The indicated cover depth of 0.75 feet (minimum) produces an earth load, P_e, of approximately 98 pounds per square feet (0.75 feet x 130 pcf) or approximately 0.7 psi. Thus, the total trench load, P_v, equals 59.0 psi.

By trial and error, a net wall thickness of 0.36 inches is found to be the minimum for the ductile iron casing pipe using the following equation from Reference 4:

$$P_{v(max)} = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]}$$

where,

$P_{v(max)}$ = max trench load based on max design ring bending stress of 48,000 psi
f = design max bending stress = 48,000 psi
D = outside diameter (in) = 13.20 inches
t = net wall thickness (in) = 0.36 inches (found by trial and error)
K_b = bending moment coefficient (Table 1, Reference 4, assuming Type 2 laying condition) = 0.210
K_x = deflection coefficient (Table 1, Reference 4, assuming Type 2 laying condition) = 0.105
E = modulus of elasticity for ductile iron = 24,000,000 psi (Reference 4)
E' = modulus of soil reaction (Table 1, Reference 4, assuming Type 2 laying condition) = 300 psi

Using the above formula, $P_{v(max)}$ is found to equal 60.2 psi, which exceeds the total calculated trench load of 59.0 psi. As recommended in Reference 4, an additional 0.08 inches is added to the net wall thickness to yield a minimum manufacturing thickness of 0.44 inches. This 0.08 inch "service allowance" is intended to provide an additional safety factor for unknowns.

Finally, the minimum manufacturing thickness of 0.44 inches is used to verify that the maximum ring deflection is less than the 5 percent maximum value recommended by DIPRA. Reference 4 gives the following formula for verifying that the maximum ring deflection value is not exceeded:

$$P_{v(5\%\,Defl)} = \frac{0.05}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3} + 0.732E'\right]$$

where,

$P_{v(5\%\,Defl)}$ = max trench load corresponding to 5 percent deflection
D = outside diameter (in) = 13.20 inches
t_1 = min manufacturing thickness (in) = 0.44 inches
K_x = deflection coefficient (Table 1, Reference 4, assuming Type 2 laying condition) = 0.105
E = modulus of elasticity for ductile iron = 24,000,000 psi (Reference 4)

Calculation Sheet

E’ = modulus of soil reaction (Table 1, Reference 4, assuming Type 2 laying condition) = 300 psi

Using the above formula, $P_{v(5\% \text{ Defl})}$ is found to equal 321 psi, which exceeds the total calculated trench load of 59.0 psi. Thus, the pipe is not predicted to experience deflection greater than the maximum recommended value of 5 percent.

SUMMARY:

The ductile iron sleeve pipes used to protect the HDPE pipes at road crossings require a net wall thickness of 0.36 inches. With the inclusion of DIPRA-recommended service allowance and casting tolerance of 0.08 and 0.06 inches, respectively, the minimum wall thickness for the ductile iron pipe is 0.50 inches.

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Attachment 1

References

TRUCK LOADS ON PIPE BURIED AT SHALLOW DEPTHS

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TRUCK LOADS ON PIPE BURIED AT SHALLOW DEPTHS

By
Richard W. Bonds, P.E.
DIPRA Research/Technical Director

Depth of cover less than $2^1/_2$ feet is generally not recommended under roads and highways due to the possibility of high dynamic loading. Such loadings could result in damage to the pavements and/or the pipes. If impact factors higher than 1.5 (which is used in this paper) are anticipated, then such should be employed. For any given project, the ultimate responsibility for the proper use of the equations and other data provided in this paper rests with the design engineer. Call DIPRA with questions before applying this paper.

The procedure for calculating truck loads on buried Ductile Iron pipe is provided in ANSI/AWWA Standard C150/A21.50.[1] This procedure is based on the teachings of Merlin Spangler and others and utilizes the same procedures used in the venerable design standard ANSI A21.1[2] for Cast Iron pipe. The design method is based on two assumptions:

1. A single concentrated wheel load at the surface, and
2. Uniform load distribution over an effective pipe length of 3 feet.

The truck load on pipe buried under flexible pavement is given by Equation 5 in ANSI/AWWA C150/A21.50. It is shown below as Equation 1.

Equation 1

$$P_t = RF\,\frac{CP}{bD}$$

where
P_t = Truck load in pounds per square inch
R = Reduction factor (see Table 4 in C150/A21.50). This factor takes account of the fact that the part of the pipe directly below the wheels receives the truck superload in its full intensity but is aided in carrying the load by adjacent parts of the pipe that receive little or no load from the truck
F = Impact factor of 1.5 (this is consistent with ASCE Manual No. 37)[3]
C = Surface load factor
P = Wheel load in pounds (for design purposes, 16,000 lbs., for a single AASHTO H-20 truck on unpaved road or flexible pavement)
b = Effective pipe length of 36 inches
D = Outside diameter of the pipe in inches

The surface load factor, C, is a measure of how the wheel load at the surface is transmitted and distributed through the soil to the pipe. C is given by Equation 6 in C150/A21.50 and is shown here as Equation 2.

Equation 2

$$C = 1 - \frac{2}{\pi}\,ARCSIN\left[H\sqrt{\frac{A^2 + H^2 + 1.5^2}{(A^2 + H^2)\,(1.5^2 + H^2)}}\right] + \frac{2}{\pi}\left(\frac{1.5\,AH}{\sqrt{A^2 + H^2 + 1.5^2}}\right)\left[\frac{1}{A^2 + H^2} + \frac{1}{1.5^2 + H^2}\right]$$

NOTE: Angles are in radians.

where
H = Depth of cover in feet
A = Outside radius of the pipe in feet

This equation for the surface load factor, C, is derived from Holl's integration of the Boussinesq formula for vertical unit pressure, assuming the load is to be determined on a 3-foot section of pipe directly under the point load.[4]

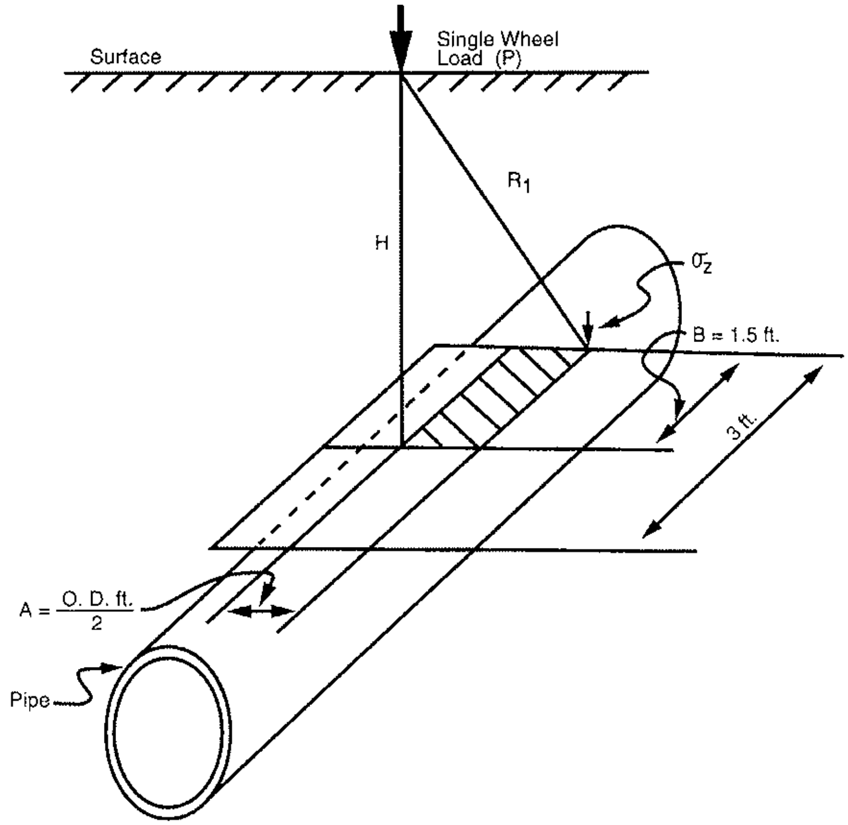
Regarding the point load assumption, the following Boussinesq equation (Equation 3) gives the vertical stress at any point in an elastic medium when a point load is exerted at the surface.

Equation 3

$$\sigma_z = \left(\frac{3P}{2\pi}\right)\left(\frac{H^3}{R_1^5}\right)$$

where
σ_z = Vertical stress in pounds per square inch
P = Point load at surface in pounds
H = Depth in inches
R_1 = Distance from the point load to the point at which the stress is to be determined in inches (See Figure 1)

Figure 1
Single Wheeload



Integration of the Boussinesq equation (Equation 3) over the rectangular area over the pipe (as shown in Figure 1) results in the total load on a 3-foot section of pipe due to the point load, P, at the surface. Equation 2 is a function of this integration. The bD in the denominator of Equation 1 yields the desired units of pounds per square inch in expressing the truck load. The result thus represents an "average" pressure on the 3-foot length of pipe centered under the load.

The factors discussed above as well as other factors such as the assumed flexible pavement, the large wheel load used for design, the safety factors in the thickness design procedure, and the inherent structural strength of Ductile Iron,[5] lead to the conclusion that the above approach to calculating truck loading is adequate at any depth of cover. Quite obviously, the actual distributed load of a truck tire "footprint" will produce less concentrated effects on a pipe than will the assumed "point" load. The typical dual truck tire imprint may have a contact area of approximately 200 square inches.[6] Also, the length of pipe "effective" in carrying the load may be much greater than that assumed, particularly for large-diameter pipe. Further, in shallow cover situations under highways, the road bed stability will necessitate well-compacted fill around the pipe, which will increase its load bearing capacity.

Included herein for convenience is Table 1 (Earth Loads P_e, Truck Loads P_t, and Trench Loads P_v), Table 2 (Surface Load Factors for Single Truck on Unpaved Road), and Table 3 (Thickness for Earth Loads Plus Truck Loads), which can be used in the same manner as Tables 1, 6, and 12 in ANSI/AWWA C150/A21.50, respectively.

References

1 ANSI/AWWA C150/A21.50, Thickness Design of Ductile Iron Pipe.
2 ANSI A21.1, Manual for the Computation of Strength and Thickness of Cast Iron Pipe.
3 ASCE Manual No. 37, Design and Construction of Sanitary and Storm Sewers.
4 Soil Engineering, Merlin G. Spangler, 4th Edition, 1982, Chapter 16.
5 Ductile Iron Pipe Design Criteria, T.F. Stroud, P.E.
6 The Asphalt Handbook, The Asphalt Institute, Manual Series No. 4.

Table 1

Earth Loads P_e, Truck Loads P_t, and Trench Loads P_v, (psi)

Depth of cover (ft.)		3-in. pipe		4-in. pipe		6-in. pipe		8-in. pipe		10-in. pipe		12-in. pipe		14-in. pipe		16-in. pipe		18-in. pipe	
	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
1.0	0.8	33.3	34.1	33.1	33.9	32.2	33.0	31.0	31.8	29.8	30.6	28.4	29.2	24.8	25.6	22.5	23.3	20.6	21.4
1.5	1.3	20.7	22.0	20.6	21.9	20.3	21.6	19.9	21.2	19.5	20.8	19.1	20.4	17.0	18.3	15.8	17.1	14.8	16.1
2.0	1.7	13.9	15.6	13.9	15.6	13.8	15.5	13.6	15.3	13.5	15.2	13.3	15.0	12.0	13.7	11.3	13.0	10.6	12.3

Depth of cover (ft.)		20-in. pipe		24-in. pipe		30-in. pipe		36-in. pipe		42-in. pipe		48-in. pipe		54-in. pipe		60-in. pipe		64-in. pipe	
	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
1.0	0.8	19.0	19.8	16.6	17.4	14.2	15.0	12.1	12.9	10.6	11.4	9.4	10.2	8.4	9.2	7.9	8.7	7.4	8.2
1.5	1.3	13.9	15.2	12.6	13.9	11.3	12.6	10.0	11.3	8.9	10.2	8.0	9.3	7.2	8.5	6.8	8.1	6.4	7.7
2.0	1.7	10.2	11.9	9.4	11.1	8.7	10.4	7.9	9.6	7.2	8.9	6.6	8.3	6.0	7.7	5.7	7.4	5.4	7.1

Table 2

Surface Load Factors for Single Truck on Unpaved Road

Depth of cover (ft.)	3-in. pipe	4-in. pipe	6-in. pipe	8-in. pipe	10-in. pipe	12-in. pipe	14-in. pipe	16-in. pipe	18-in. pipe
1.0	0.1980	0.2380	0.3329	0.4210	0.4956	0.5623	0.6195	0.6680	0.7087
1.5	0.1227	0.1482	0.2102	0.2708	0.3253	0.3773	0.4252	0.4690	0.5086
2.0	0.0828	0.1001	0.1428	0.1853	0.2244	0.2627	0.2993	0.3338	0.3661

Depth of cover (ft.)	20-in. pipe	24-in. pipe	30-in. pipe	36-in. pipe	42-in. pipe	48-in. pipe	54-in. pipe	60-in. pipe	64-in. pipe
1.0	0.7427	0.7944	0.8428	0.8714	0.8881	0.8985	0.9054	0.9082	0.9104
1.5	0.5442	0.6043	0.6700	0.7155	0.7458	0.7667	0.7818	0.7884	0.7936
2.0	0.3964	0.4504	0.5154	0.5656	0.6025	0.6303	0.6520	0.6620	0.6703

Table 3

Thickness for Earth Load Plus Truck Load

		Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
Size (in.)	Depth of Cover (ft.)	Total Calculated Thickness (in.)*	Use Pressure Class	Total Calculated Thickness (in.)*	Use Pressure Class	Total Calculated Thickness (in.)*	Use Pressure Class	Total Calculated Thickness (in.)*	Use Pressure Class	Total Calculated Thickness (in.)*	Use Pressure Class
3	1.0	0.22	350	0.21	350	0.20	350	0.19	350	0.16	350
	1.5	0.20	350	0.19	350	0.18	350	0.17	350	0.15	350
	2.0	0.19	350	0.18	350	0.17	350	0.16	350	0.14	350
4	1.0	0.23	350	0.23	350	0.22	350	0.20	350	0.17	350
	1.5	0.21	350	0.20	350	0.20	350	0.18	350	0.15	350
	2.0	0.20	350	0.19	350	0.18	350	0.16	350	0.15	350
6	1.0	0.28	-	0.27	-	0.25	350	0.23	350	0.18	350
	1.5	0.25	350	0.24	350	0.22	350	0.20	350	0.16	350
	2.0	0.23	350	0.21	350	0.20	350	0.17	350	0.16	350
8	1.0	0.32	-	0.30	-	0.29	-	0.26	-	0.20	350
	1.5	0.28	-	0.27	-	0.25	350	0.21	350	0.17	350
	2.0	0.26	-	0.24	350	0.22	350	0.19	350	0.16	350
10	1.0	0.37	-	0.35	-	0.33	-	0.30	-	0.22	350
	1.5	0.33	-	0.31	-	0.29	-	0.24	350	0.19	350
	2.0	0.30	-	0.27	-	0.25	350	0.21	350	0.18	350
12	1.0	0.41	-	0.38	-	0.36	-	0.32	-	0.24	350
	1.5	0.36	-	0.33	-	0.31	-	0.25	350	0.20	350
	2.0	0.32	-	0.30	-	0.27	350	0.22	350	0.19	350
14	1.0	**	-	0.41	-	0.38	-	0.33	-	0.26	250
	1.5	**	-	0.36	-	0.33	-	0.27	250	0.21	250
	2.0	**	-	0.32	-	0.29	300	0.24	250	0.20	250
16	1.0	**	-	0.43	-	0.40	-	0.33	350	0.27	250
	1.5	**	-	0.38	-	0.34	350	0.27	250	0.22	250
	2.0	**	-	0.33	350	0.30	250	0.24	250	0.21	250
18	1.0	**	-	0.45	-	0.41	-	0.33	300	0.27	250
	1.5	**	-	0.39	-	0.35	350	0.28	250	0.22	250
	2.0	**	-	0.35	350	0.31	250	0.25	250	0.21	250
20	1.0	**	-	0.46	-	0.42	-	0.34	300	0.27	250
	1.5	**	-	0.41	-	0.36	300	0.29	250	0.23	250
	2.0	**	-	0.36	300	0.32	250	0.26	250	0.22	250
24	1.0	**	-	0.49	-	0.44	-	0.37	250	0.26	200
	1.5	**	-	0.44	-	0.38	300	0.31	200	0.24	200
	2.0	**	-	0.39	300	0.34	250	0.27	200	0.23	200
30	1.0	**	-	0.53	-	0.46	350	0.41	250	0.27	150
	1.5	**	-	0.48	350	0.41	250	0.34	150	0.25	150
	2.0	**	-	0.43	300	0.37	200	0.30	150	0.24	150
36	1.0	**	-	0.56	350	0.48	300	0.40	200	0.28	150
	1.5	**	-	0.51	300	0.43	250	0.33	150	0.27	150
	2.0	**	-	0.46	250	0.40	200	0.31	150	0.26	150
42	1.0	**	-	0.58	350	0.50	250	0.39	150	0.29	150
	1.5	**	-	0.54	300	0.45	200	0.35	150	0.28	150
	2.0	**	-	0.49	250	0.42	200	0.33	150	0.27	150
48	1.0	**	-	0.60	300	0.52	200	0.39	150	0.31	150
	1.5	**	-	0.57	250	0.48	200	0.37	150	0.30	150
	2.0	**	-	0.53	250	0.45	150	0.36	150	0.29	150
54	1.0	**	-	0.64	250	0.53	200	0.41	150	0.33	150
	1.5	**	-	0.60	250	0.51	150	0.40	150	0.32	150
	2.0	**	-	0.57	200	0.48	150	0.39	150	0.31	150
60	1.0	**	-	0.65	250	0.54	150	0.42	150	0.33	150
	1.5	**	-	0.61	200	0.52	150	0.41	150	0.33	150
	2.0	**	-	0.58	200	0.50	150	0.40	150	0.32	150
64	1.0	**	-	0.66	250	0.55	150	0.43	150	0.34	150
	1.5	**	-	0.62	200	0.53	150	0.42	150	0.33	150
	2.0	**	-	0.59	200	0.51	150	0.41	150	0.32	150

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.
**For pipe 14-inch and larger, consideration should be given to laying conditions other than Type 1.

DIPRA MEMBER COMPANIES

American Cast Iron Pipe Company
P.O. Box 2727
Birmingham, Alabama 35202-2727

Atlantic States Cast Iron Pipe Company
183 Sitgreaves Street
Phillipsburg, New Jersey 08865-3000

Canada Pipe Company, Ltd.
1757 Burlington Street East
Hamilton, Ontario L8N 3R5 Canada

Clow Water Systems Company
P.O. Box 6001
Coshocton, Ohio 43812-6001

McWane Cast Iron Pipe Company
1201 Vanderbilt Road
Birmingham, Alabama 35234

Pacific States Cast Iron Pipe Company
P.O. Box 1219
Provo, Utah 84603-1219

United States Pipe and Foundry Company
P.O. Box 10406
Birmingham, Alabama 35202-0406

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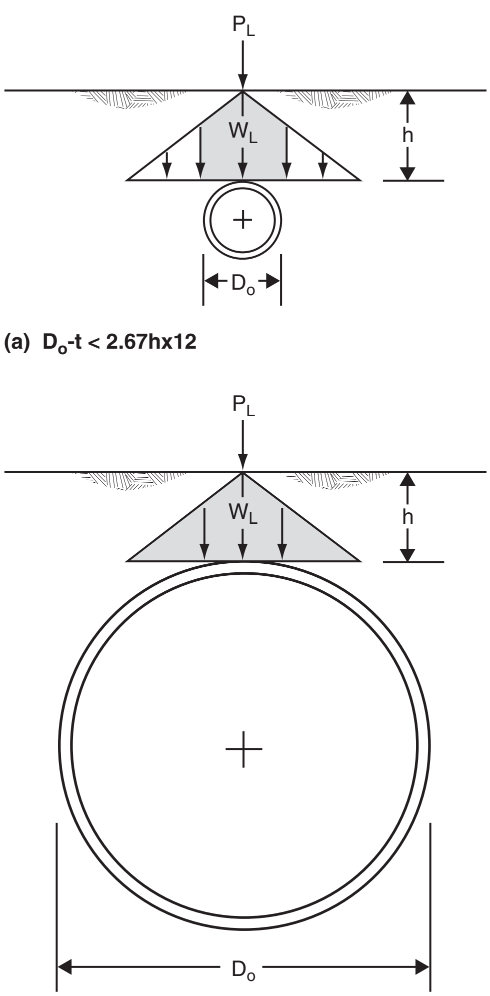
Manufactured from recycled materials.

TL/1-09/2.5M
Published 1-92
Revised 1-09

Depth of cover	Impact factor
< 1'0"	1.3
1'1" – 2'0"	1.2
2'0" – 2'11"	1.1
≥ 3'0"	1.0

Figure 52–9 Load pressure distribution



(a) D_o**-t < 2.67hx12**

(b) D_o**-t ≥ 2.67hx12**

The pressure on the pipe from the wheel load may be determined by:

$$P_W = \frac{W_L}{\left(\frac{D_o}{12}\right)} \tag{52–21}$$

where:
P_w = pressure on pipe from wheel load, lb/ft^2
D_o = outside diameter of pipe, in

When the depth of fill is 2 feet or more, wheel loads may be considered as uniformly distributed over a square with sides equal to 1 3/4 times the depth of fill.

$$P_w = \frac{P_L}{(1.75h)^2} \tag{52–22}$$

(c) Vacuum pressure

Pipe may be subject to an effective external pressure because of an internal vacuum pressure, P_v. Sudden valve closures, shutoff of a pump, or drainage from high points within the system often create a vacuum in pipelines. Siphons will all be subject to negative pressures.

Vacuum pressure should be incorporated into the design of buried and aboveground pipes as described in this chapter. The vacuum pressure may be intermittent (short term), for long durations, or continuously (long term).

The vacuum load per length of pipe may be determined by:

$$W_V = P_V \times \frac{D_i}{12} \tag{52–23}$$

where:
W_v = vacuum load per linear foot of pipe, lb/ft
P_v = internal vacuum pressure, lb/ft^2
D_i = inside pipe diameter, in

DESIGN OF DUCTILE IRON PIPE

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Depth of cover	Impact factor
< 1'0"	1.3
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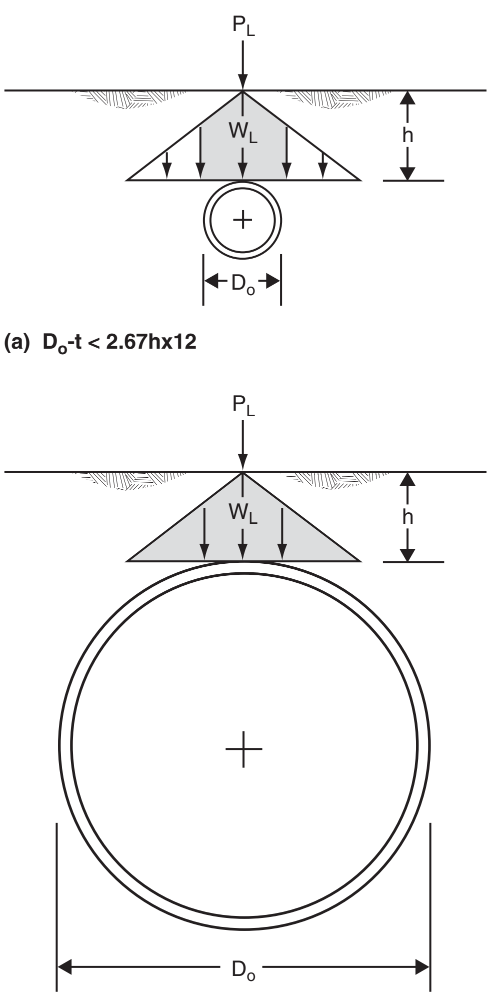
2'0" – 2'11"	1.1
≥ 3'0"	1.0

Figure 52–9 Load pressure distribution



(a) D_o-t < 2.67hx12

(b) D_o-t ≥ 2.67hx12

The pressure on the pipe from the wheel load may be determined by:

$$P_W = \frac{W_L}{\left(\frac{D_o}{12}\right)} \qquad (52\text{–}21)$$

where:
P_w = pressure on pipe from wheel load, lb/ft^2
D_o = outside diameter of pipe, in

When the depth of fill is 2 feet or more, wheel loads may be considered as uniformly distributed over a square with sides equal to 1 3/4 times the depth of fill.

$$P_w = \frac{P_L}{(1.75h)^2} \qquad (52\text{–}22)$$

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where:
W_v = vacuum load per linear foot of pipe, lb/ft
P_v = internal vacuum pressure, lb/ft^2
D_i = inside pipe diameter, in

DESIGN OF DUCTILE IRON PIPE

With more than five decades of outstanding field experience, Ductile Iron pipe is widely recognized as the industry standard for modern water and wastewater systems.

One of the most important reasons for the success of Ductile Iron pipe is that, like Gray Iron pipe before it, it is the subject of the most extensive series of product standards in the pipe industry. Since the 1920s, American National Standards Institute—now the American Water Works Association—Standards Committee A21 has been responsible for this series of standards on Gray and Ductile Iron pipe. Since Ductile Iron pipe was first introduced in 1955, the Standards Committee on Ductile Iron Pipe and Fittings has been provided with extensive data on trench loading tests, strength tests, corrosion resistance, tapping strength, flow characteristics, impact resistance, lining and joint integrity, and virtually all aspects of the material that can affect its performance.

From this data and the dedicated work of the members of AWWA Standards Committee A21, the American National Standard for the Thickness Design of Ductile Iron Pipe (ANSI/AWWA C150/A21.50) has evolved. No more thorough and comprehensive standard design procedure exists for any piping material.

Design Basis

The basis of the design standard for Ductile Iron pipe is the long-established fact that Ductile Iron pipe, subjected to internal pressure and underground loading conditions, behaves as a flexible conduit and rerounds under pressure. Therefore, the pipe is designed separately to withstand external loads and internal pressure. The result is more conservative than designing for the combined loading condition. Thus the separate stress design approach was chosen as the basis of the original ANSI standard in 1965.

Briefly, the design procedure for Ductile Iron pipe includes:
1. Design for internal pressures (static pressure plus surge pressure allowance).
2. Design for bending stress due to external loads (earth load plus truck loads).
3. Select the larger resulting net wall thickness.
4. Add an 0.08-inch service allowance.
5. Check deflection.
6. Add a standard casting tolerance.

This procedure results in the total calculated design thickness, from which the appropriate pressure class is chosen.

Important Criteria

The Standards Committee carefully chose the following criteria in the 1976 standard for use in calculating required thickness of Ductile Iron pipe. These criteria remain unchanged in the current edition of the standard.
1. Earth load is based upon the prism load concept, a very conservative assumption for loads normally experienced by a flexible pipe.
2. Truck loads are based upon a single AASHTO H-20 truck with 16,000 pounds wheel load and an impact factor of 1.5 at all depths.
3. External load design includes calculation of both ring bending stress and deflection. Ring bending stress is limited to 48,000 psi, providing a safety factor of at least 2.0 based upon ultimate bending stress.
4. Deflection of the pipe ring is limited to a maximum of 3 percent for cement-lined pipe. Again, this limit provides a safety factor of at least 2.0 against applicable performance limits of the lining. (Unlined pipe and pipe with flexible linings are capable of withstanding greater deflections.)
5. Five trench types have been defined in the standard (see Figure 1 and Table 1) to give the designer a selection of laying conditions. This ensures a cost-effective trench section design for varying job conditions.
6. Internal pressure design of standard pressure classes is based on rated working pressure plus a surge allowance of 100 psi. A safety factor of 2.0 is applied to this calculation, which is based on a minimum yield strength in tension of 42,000 psi.

Internal Pressure Design

The net thickness required for internal pressure is calculated using the equation for hoop stress:

$$t = \frac{P_i D}{2S}$$

where: t = net pipe wall thickness, in.
P_i = design internal pressure, psi
D = outside diameter of pipe, in.
S = minimum yield strength in tension, psi

The design internal pressure (P_i) is equal to the safety factor of 2.0 times the sum of working pressure (P_w) plus surge allowance (P_s) for water pipe; that is $P_i = 2.0\ (P_w + P_s)$. The standard surge allowance of 100 psi is adequate for most applications; however, if anticipated surge pressures are other than 100 psi, the actual anticipated surge pressure should be used.

External Load Design

The net wall thickness required for external load is based on two design considerations: limitation of ring bending stress and ring deflection. When a trench load of sufficient magnitude is applied, Ductile Iron pipe will deflect amply to develop passive resistance from the sidefill soil, thereby transmitting part of the trench load to the sidefill soil. Thus, the load-carrying capacity of Ductile Iron pipe is a function of soil and ring stiffness. In addition, an upward reaction to the vertical trench load exerted on the pipe develops in the trench embedment below the pipe. This reaction is distributed almost uniformly over the width of bedding of the pipe; the greater the width of bedding, the greater the load-carrying capacity of the pipe. Therefore, certain design criteria dependent on the effective width of bedding and on the available passive resistance of the sidefill soil are essential to calculating ring bending stress and ring deflection of Ductile Iron pipe. These design criteria have been conservatively established from test data for various standard laying conditions discussed later in this article. (See Table 1.) Also, due to its inherent greater ring stiffness, Ductile Iron pipe is less reliant on soil support than other flexible pipe materials.

Bending Stress Design

Design maximum ring bending stress for Ductile Iron pipe is 48,000 psi, which provides safety factors under trench loading of at least 1.5 based on ring yield strength and at least 2.0 based on ultimate ring strength. The following equation is used to calculate the trench load required to develop a bending stress of 48,000 psi at the pipe invert:

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \dfrac{K_x}{\dfrac{8E}{E'\left(\frac{D}{t}-1\right)^3} + 0.732}\right]}$$

where: P_v = trench load, psi = $P_e + P_t$
P_e = earth load, psi
P_t = truck load, psi
f = design maximum bending stress, 48,000 psi
D = outside diameter, in.
t = net thickness, in.
K_b = bending moment coefficient (Table 1)
K_x = deflection coefficient (Table 1)
E = modulus of elasticity (24×10^6 psi)
E' = modulus of soil reaction, psi (Table 1)

Net Thickness and Service Allowance

A net thickness is computed using both the internal pressure and bending stress equations as described above. The larger of the two net thicknesses is then selected as the net thickness required for internal pressure and bending stress design.

A service allowance (0.08-inch for all pipe sizes) is then added to the larger net thickness. This service allowance provides an additional safety factor for unknowns. The resulting thickness is the minimum thickness t_1.

Deflection Check

Maximum allowable ring deflection for cement-mortar-lined Ductile Iron pipe is 3 percent of the outside diameter (5 percent for flexible linings). Tests have shown that 3 percent deflection will provide a safety factor of at least 2.0 with regard to failure of the cement-mortar lining. Much larger deflections can be sustained without damage to the pipe wall. The following equation is used to calculate the trench load required to develop a ring deflection of 3 percent of the outside diameter.

$$P_v = \frac{\Delta x/D}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3} + 0.732E'\right]$$

where: t_1 = minimum thickness, in. (t + 0.08)
Δx = design deflection, in. ($\Delta x/D = 0.03$)
P_v, K_x, E, E', and D are the same as in the equation for bending stress.

The t_1 required for deflection is compared to the t_1 resulting from internal pressure and bending stress design. The greater t_1 is used and is called the minimum manufacturing thickness.

Allowance For Casting Tolerance

Once the minimum manufacturing thickness is determined, an allowance for casting tolerance is added to provide the latitude required by the manufacturing process and to prevent the possibility of significant minus deviation from design thickness. Additionally, required weight tolerances assure that effective wall thickness is always greater than calculated minimum manufacturing thickness. Casting allowance is dependent on the pipe size as shown in the table to the right.

Allowances for Casting Tolerance

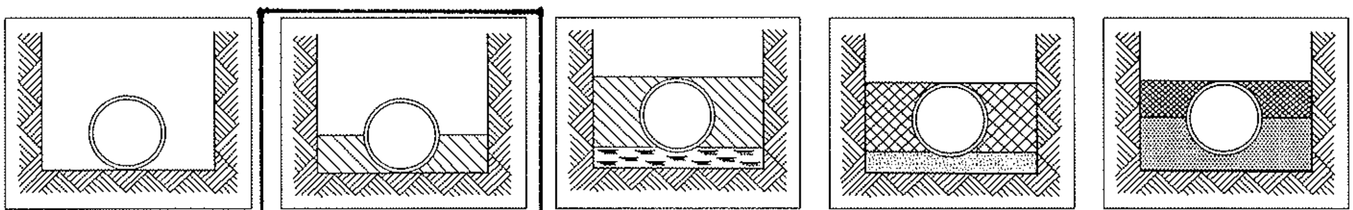
Size – in.	Casting Tolerance – in.
3-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54-64	0.09

Standard Laying Conditions

As indicated previously, certain factors dependent on the specified type of laying condition are essential to the design of Ductile Iron pipe for external loads. Two of these factors, the coefficients for bending (K_b) and deflection (K_x), are dependent on the width of bedding at the pipe bottom. The width of bedding is the contact area on the pipe bottom where bedding support is sufficient to develop an equal reaction to the vertical trench load and is commonly referred to as the bedding angle. The other factor is modulus of soil reaction (E'), which is a measure of the passive resistance that can be developed in the sidefill soil. To facilitate design calculations, these factors have been conservatively established from reliable test data for five standard laying conditions (Table 1), thus giving the design engineer a great deal of flexibility in selecting the most economical combinations of wall thickness and bedding and backfill requirements.

FIGURE 1

Standard Laying Conditions for Ductile Iron Pipe



Type 1* Flat-bottom trench.† Loose backfill.

Type 2 Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.

Type 3 Pipe bedded in 4-inch minimum loose soil.‡ Backfill lightly consolidated to top of pipe.

Type 4 Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99.)§

Type 5 Pipe bedded to its centerline in compacted granular material**, 4-in. minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)§

TABLE 1

Standard Pipe Laying Conditions

Laying Condition†	Description	E' psi	Bedding Angle degrees	K_b	K_x
Type 1*	Flat-bottom trench.† Loose backfill.	150	30	0.235	0.108
Type 2	Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
Type 3	Pipe bedded in 4-in minimum loose soil.‡ Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-in. minimum. Backfill compacted to top of pipe. (Approx. 80 percent Standard Proctor, AASHTO T-99.)§	500	90	0.157	0.096
Type 5	Pipe bedded to its centerline in compacted granular material,** 4-in. minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approx. 90 percent Standard Proctor, AASHTO T-99.)§	700	150	0.128	0.085

Note: Consideration of the pipe-zone embedment condition included in this table may be influenced by factors other than pipe strength. For additional information see ANSI/AWWA C600 "Standard for Installation of Ductile Iron Water Mains and Their Appurtenances."

* For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

**Granular materials are defined per the AASHTO Soil Classification System (ASTM D3282) or the United Soil Classification System (ASTM D2487), with the exception that gravel bedding/backfill adjacent to the pipe is limited to 2" maximum particle size per ANSI/AWWA C600.

† Flat-bottom is defined as "undisturbed earth."

‡ Loose soil or select material is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."

§ AASHTO T-99, "Moisture Density Relations of Soils Using a 5.5 pound Rammer 12-in. Drop."

Trench Load

The trench load (P_v) used in the design of Ductile Iron pipe is expressed as vertical pressure in psi, and is the sum of earth load (P_e) and truck load (P_t). Earth load (P_e) is the weight of the unit prism of soil above the pipe to the ground surface. The unit weight of the backfill soil is assumed to be 120 lbs./cu. ft., which is conservative for most soils. In unusual conditions where heavier backfill material is used, the design earth load should be increased accordingly. The equation used to compute earth load is as follows:

$$P_e = \frac{wH}{144} = \frac{120H}{144} = \frac{H}{1.2}$$

where: P_e = earth load, psi
w = soil weight, 120 lbs./cu. ft.
H = depth of cover, ft.

Truck load (P_t) is based on a single AASHTO H-20 truck on unpaved road or flexible pavement, having a 16,000 pound wheel load and using a 1.5 impact factor at all depths. The equation used to compute truck load is as follows:

$$P_t = RF\frac{CP}{bD}$$

where: P_t = truck load, psi
R = reduction factor which takes into account that the part of the pipe directly below the wheels is aided in carrying the truckload by adjacent parts of the pipe that receive little or no direct load from the wheels (Table 2)
F = impact factor, 1.5
C = surface load factor calculated for a single concentrated wheel load centered over an effective pipe length of 3 ft.
P = wheel load, 16,000 lbs.
b = effective pipe length, 36 in.
D = outside diameter of pipe, in.

The surface load factor, C, is a measure of how the wheel load at the surface is transmitted and distributed through the soil to the pipe. The equation used to calculate the surface load factor is as follows:

$$C = 1 - \frac{2}{\pi}\arcsin\left[H\sqrt{\frac{A^2+H^2+1.5^2}{(A^2+H^2)(1.5^2+H^2)}}\right] + \frac{2}{\pi}\left(\frac{1.5AH}{\sqrt{A^2+H^2+1.5^2}}\right)\left[\frac{1}{A^2+H^2}+\frac{1}{1.5^2+H^2}\right]$$

(Note: angles are in radians.)

where: H = depth of cover, ft.
A = outside radius of pipe, ft.

Earth loads (P_e), truck loads (P_t), trench loads (P_v), and surface load factors (C) computed using the above equations are listed in ANSI/AWWA C150/A21.50 for depths of cover ranging from 2.5 feet to 32 feet.

TABLE 2
Reduction Factors R for Truck Load Calculations

Size In.	Depth of Cover — ft.			
	<4	4-7	7-10	>10
3-12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24-30	0.81	0.85	0.95	1.00
36-64	0.80	0.85	0.90	1.00

Design Tables

Manual use of the equations for bending stress and deflection to determine net thickness is somewhat lengthy and time-consuming. To expedite calculations, design tables giving diameter-thickness ratios for a wide range of trench loads have been developed from these equations for all five standard laying conditions. With these design tables, a designer need only know trench load and desired laying condition to compute net thickness required for bending stress design and deflection design.

Standard Pressure Classes

Ductile Iron pipe is manufactured in standard pressure classes (150-350) which vary in thickness depending on pipe size. (See Table 3.) Pressure classes are defined as the standard rated water working pressure of the pipe in psi. The thickness shown for each pressure class is thus adequate for the rated water working pressure plus a surge allowance of 100 psi. Once the total calculated thickness has been determined for a particular application, the appropriate standard pressure class thickness should be selected for purposes of specifying and ordering. When the calculated thickness is between two standard thicknesses, the larger of the two should be selected.

TABLE 3
Standard Pressure Classes and Nominal Thicknesses of Ductile Iron Pipe

Size in.	Outside Diameter in.	Pressure Class				
		150	200	250	300	350
		Nominal Thickness—in.				
3	3.96	–	–	–	–	0.25*
4	4.80	–	–	–	–	0.25*
6	6.90	–	–	–	–	0.25*
8	9.05	–	–	–	–	0.25*
10	11.10	–	–	–	–	0.26
12	13.20	–	–	–	–	0.28
14	15.30	–	–	0.28	0.30	0.31
16	17.40	–	–	0.30	0.32	0.34
18	19.50	–	–	0.31	0.34	0.36
20	21.60	–	–	0.33	0.36	0.38
24	25.80	–	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

* Calculated thicknesses for these sizes and pressure ratings are less than those shown above. These are the lowest nominal thicknesses currently available in these sizes.

Pressure classes are defined as the rated water working pressure of the pipe in psi. The thicknesses shown are adequate for the rated water working pressure plus a surge allowance of 100 psi. Calculations are based on a minimum yield strength in tension of 42,000 psi and 2.0 safety factor times the sum of working pressure and 100 psi surge allowance.

Thickness can be calculated for rated water working pressure and surges other than the above by use of the design procedure outlined in this article and detailed in ANSI/AWWA C150/A21.50.

Ductile Iron pipe can be utilized for water working pressure greater than 350 psi and is available in thicknesses greater than Pressure Class 350. Contact DIPRA member companies on specific requirements.

Standard Selection Table

Using the design procedure described, a standard selection table (Table 4) was developed that gives maximum depth of cover for each standard pressure class and laying condition. This table was provided so that a designer may simply select, rather than calculate, the appropriate pressure class and laying condition for a given design application. For extraordinary design conditions not shown in the table, such as extremely high internal pressures or extreme depths of cover, it may be advisable to consult DIPRA member companies for recommendations to maximize system design.

Safety Factor

As stated, the safety factor for internal pressure is 2.0 based on minimum yield strength of Ductile Iron in tension. For external loads, two explicit safety factors are specified: at least 1.5 based on ring yield strength and at least 2.0 based on ultimate strength. Also, the design ring deflection check provides a safety factor of at least 2.0 based on test data regarding deflections required to cause failure in cement-mortar lining.

The above explicit safety factors are used to establish a design criteria and should not be confused with the total available safety factor of Ductile Iron pipe, which has been shown to be much greater than the specified safety factors used in design calculations for the following reasons:

1. The stringent design criteria for Ductile Iron pipe are not based on the much greater performance limits associated with failure of the pipe wall.
2. Specified safety factors are used to calculate net wall thickness requirements, after which both service allowance and casting allowance are added. (For example, the nominal wall thickness of 30-inch Class 150 Ductile Iron pipe is approximately 180 percent of the net wall thickness required by design.) Additionally, required weight tolerances ensure that effective wall thicknesses are always greater than calculated net wall thicknesses.
3. The physical properties of Ductile Iron pipe will consistently exceed the minimum values specified for design.
4. Ductile Iron pipe can sustain stresses considerably higher than yield strength determined by standard test methods without damage to the pipe wall.
5. Design considerations dependent on laying conditions were established on a conservative basis.

In the early 1960s, extensive tests were conducted on Ductile Iron pipe to determine average values for tensile strength, ring strength, hardness, and elongation. Test pipes ranged in size from 2 inches to 24 inches and represented five different producers. These test results showed the average bursting tensile strength to be 52,320 psi and the average ring yield strength to be 84,880 psi for all pipes tested. These values remain consistent when compared to test data derived from burst tests and ring crush tests that have been conducted since that time. Using these values, an example of total safety factor with regard to internal pressure design can be made:

To determine the total safety factor of 6-inch Pressure Class 350 Ductile Iron pipe with respect to internal pressure for 350 psi working pressure and a standard surge pressure allowance of 100 psi:

1. Compute the hoop stress developed using the minimum manufacturing thickness: $S = \frac{P_i D}{2t_1}$

   a. Let $P_i = 350 + 100 = 450$ psi since total safety factor is desired. D = 6.90 in.
   b. Nominal thickness of Pressure Class 350 = 0.25 in.
   c. Subtract casting tolerance to obtain minimum thickness manufactured (t_1).* $t_1 = 0.25 - 0.05 = 0.20$ in.
   * Note: This is a conservative basis on which to determine actual safety factor, as weight controls ensure greater effective thickness than t_1 in the pipe.

$$\therefore S = \frac{(450)\ (6.90)}{(2)\ (0.20)} = 7{,}762.5 \text{ psi}$$

2. Compare computed hoop stress to average bursting tensile strength to determine a representative total safety factor:

$$\frac{52{,}320 \text{ psi average}}{7{,}762.5 \text{ psi computed}} = 6.74$$

The total safety factor for internal pressure design will vary with pipe size, pressure class, and design working pressure, but the above example serves to prove that the total available safety factor of Ductile Iron pipe is actually much greater than the explicit design safety factor of 2.0.

With regard to external load design, actual external loading tests were conducted on large-diameter Ductile Iron pipe at Utah State University in the early 1970s to evaluate the C150/A21.50 procedure. From this test data, which was based on rigorous conditions, safety factors were calculated by dividing the loads at cement-mortar lining failure by allowable loads as well as by dividing the loads at pipe failure by the allowable loads. Allowable loads were calculated using the C150/A21.50 design procedure for external loads. This comparison showed that when cement-mortar lining failure was used, the calculated safety factor of the test pipe averaged 2.98; when pipe failure was used, the calculated safety factor averaged 5.46.

Using this data as a basis, it is apparent that the total available safety factor of Ductile Iron pipe with respect to external loads is far greater than explicit design safety factors of 1.5 and 2.0. Further, the above total available safety factors were determined on the basis of a separate stress design; for a combined stress situation (i.e., external load+internal pressure), the total available safety factor would be even greater because internal pressure would tend to reround the pipe, thereby reducing deflection and ring bending stresses created by external load. It is therefore evident that the total safety factor for Ductile Iron pipe is much more than adequate, and it is obvious that a thorough analysis of both the pipe material and the design procedure is necessary to properly determine actual comparative safety factors.

Linings

Unless otherwise specified, all Ductile Iron pipe installed today is normally furnished with a Portland cement-mortar lining that conforms to ANSI/AWWA C104/A21.4. Special linings such as epoxies are also available for applications where standard cement-mortar linings are not applicable.

Polyethylene Encasement

Ductile Iron pipe, which is manufactured with an asphaltic shop coating, needs no external protection in the majority of installations. There are, however, highly aggressive soil conditions and/or stray current conditions where the use of external protection for the pipe is warranted. In these instances, encasing the pipe with polyethylene in accordance with the ANSI/AWWA C105/A21.5 Standard is the generally recommended method of protection.

To date, polyethylene encasement has been used to protect thousands of miles of Gray and Ductile Iron pipe in severely corrosive soils. In addition to the U.S. standard, several other countries have adopted standards for polyethylene encasement and an international standard (ISO 8180) was adopted in 1985.

Summary

In the current edition of ANSI/AWWA C150/A21.50, design criteria are:

- *yield strength in tension, 42,000 psi*
- *ring bending stress, 48,000 psi*
- *ring deflection, 3 percent*
- *AASHTO H-20 truck loading at all depths with 1.5 impact factor*
- *prism earth load for all pipe sizes, and*
- *five types of laying conditions*

Minimum explicit safety factors are set, but actual total field service safety factors far exceed these values. Unparalleled field service history, improvements in manufacturing and quality control, and research results, including load tests and conclusive evidence of high-level corrosion resistance, have led to the establishment of the procedures outlined in this article for the design of Ductile Iron pipe.

Note: DIPRA has developed a computer program to perform these design calculations. For your free copy of this program, contact DIPRA Headquarters in Birmingham, your local DIPRA Regional Engineer, or download it from our website (http://www.dipra.org).

TABLE 4
Rated Working Pressure and Maximum Depth of Cover

Size in.	Pressure† Class psi	Nominal Thickness in.	Laying Condition: Type 1 Trench	Type 2 Trench	Type 3 Trench	Type 4 Trench	Type 5 Trench
			Maximum Depth of Cover—ft‡				
3	350	0.25	78	88	99	100§	100§
4	350	0.25	53	61	69	85	100§
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11*	15	19	28	45
12	350	0.28	10*	15	19	28	44
14	250	0.28	††	11*	15	23	36
	300	0.30	††	13	17	26	42
	350	0.31	††	14	19	27	44
16	250	0.30	††	11*	15	24	34
	300	0.32	††	13	17	26	39
	350	0.34	††	15	20	28	44
18	250	0.31	††	10*	14	22	31
	300	0.34	††	13	17	26	36
	350	0.36	††	15	19	28	41
20	250	0.33	††	10	14	22	30
	300	0.36	††	13	17	26	35
	350	0.38	††	15	19	28	38
24	200	0.33	††	8*	12	17	25
	250	0.37	††	11	15	20	29
	300	0.40	††	13	17	24	32
	350	0.43	††	15	19	28	37
30	150	0.34	††	—	9	14	22
	200	0.38	††	8*	12	16	24
	250	0.42	††	11	15	19	27
	300	0.45	††	12	16	21	29
	350	0.49	††	15	19	25	33
36	150	0.38	††	—	9	14	21
	200	0.42	††	8*	12	15	23
	250	0.47	††	10	14	18	25
	300	0.51	††	12	16	20	28
	350	0.56	††	15	19	24	32
42	150	0.41	††	—	9	13	20
	200	0.47	††	8	12	15	22
	250	0.52	††	10	14	17	25
	300	0.57	††	12	16	20	27
	350	0.63	††	15	19	23	32
48	150	0.46	††	—	9	13	20
	200	0.52	††	8	11	15	22
	250	0.58	††	10	13	17	24
	300	0.64	††	12	15	19	27
	350	0.70	††	15	18	22	30
54	150	0.51	††	—	9	13	20
	200	0.58	††	8	11	14	22
	250	0.65	††	10	13	16	24
	300	0.72	††	13	15	19	27
	350	0.79	††	15	18	22	30
60	150	0.54	††	5*	9	13	20
	200	0.61	††	8	11	14	22
	250	0.68	††	10	13	16	24
	300	0.76	††	13	15	19	26
	350	0.83	††	15	18	22	30
64	150	0.56	††	5*	9	13	20
	200	0.64	††	8	11	14	21
	250	0.72	††	10	13	16	24
	300	0.80	††	12	15	19	26
	350	0.87	††	15	17	21	29

Note: This table is based on a minimum depth of cover of 2.5 feet. For shallower depths of cover please consult the DIPRA brochure *Truck Loads on Pipe Buried at Shallow Depths.*

† Ductile Iron pipe is adequate for the rated working pressure indicated for each nominal size plus a surge allowance of 100 psi. Calculations are based on a 2.0 safety factor times the sum of working pressure and 100 psi surge allowance. Ductile Iron pipe for working pressures higher than 350 psi is available.

‡ An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.

§ Calculated maximum depth of cover exceeds 100 ft.

* Minimum allowable depth of cover is 3 ft.

†† For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

DIPRA MEMBER COMPANIES

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P.O. Box 2727
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Canada Pipe Company, Ltd.
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Clow Water Systems Company
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McWane Cast Iron Pipe Company
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Pacific States Cast Iron Pipe Company
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Provo, Utah 84603-1219

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Revised 10-06

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Appendix J-2

Fac Pond Transfer Line Hydraulic Analysis

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Client: **CWM Chemical Services, LLC**

Project Location: **Model City, New York**

Project: **RMU-2 Design Calculations** **Project No.:** **B0023725.2011**

Subject: **Appendix J-2 : Fac Pond Transfer Line Hydraulic Analysis**

Prepared By: **PTO/NWF/BMS** **Date:** **November 2013**

Checked By: **BMS** **Date:** **November 2013**

Reviewed By: **BMS** **Date:** **November 2013**

TASK:

Model the hydraulics of the proposed high-density polyethylene (HDPE) pipeline between Fac Ponds 1 and 2 and Fac Pond 5. Identify a continuous-duty submersible pump that could potentially be used in the fac ponds and estimate the in-service flowrate that could be achieved when transferring impounded liquid from one pond to the other and when discharging from Fac Pond 5 to the Niagara River outfall.

REFERENCES:

1. "Leachate Level Compliance Plan for Residuals Management Unit 1, Cells 1 through 14 – Final Sequence Phase 3" prepared by ARCADIS, dated August 2011 (Revised November 2011).

2. WaterCAD for Windows, Version 5.0, pressure network analysis software, Haestad Methods, Inc.

3. Fac Pond 5 Permit Drawings, ARCADIS, February 2013 (revised November 2013).

4. Literature from Performance Pipe (attached).

5. Flygt Pumps Literature from Xylem, Inc. (attached).

ASSUMPTIONS:

1. The existing Fac Ponds 1 and 2 will be maintained and a new Fac Pond 5 will be constructed to provide on-site storage and qualification of treated leachate prior to discharge to the Niagara River. A new buried double-contained HDPE transfer pipeline is proposed to allow for the transfer of impounded liquid between the two fac ponds and to allow the discharge of impounded liquid in either fac pond to the Niagara River outfall.

2. Continuous-duty submersible pumps will be installed in each fac pond to dewater the pond (one pump per pond). For maintenance and repair reasons, the same pump model will likely be used in both ponds. The pumps will be mounted on floating platforms so that the pumps can be accessed for repairs regardless of pond liquid levels. Because the pumps will rise and fall with liquid elevations and may move laterally to some extent, 6-inch-diameter flex hose will be used to connect the pumps to the HDPE fac pond transfer pipeline on the fac pond perimeter berms.

3. To discharge impounded water off site to the Niagara River outfall, a connection from the proposed fac pond transfer line to existing subsurface piping will be made immediately north of Fac Ponds 1 and 2 as shown in Reference 3. By aligning the appropriate valves in the proposed valve house, flow can be diverted from the transfer pipeline, through above-grade filters, and into the existing

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Calculation Sheet

subsurface piping that leads to the outfall.

4. The proposed fac pond transfer pipeline consists of 6-inch-diameter DR 11 HDPE pipe. Based on Reference 4, the average inner diameter of this pipe is 5.349 inches. Hazen-Williams coefficients for the flex hose and the HDPE pipe are based on Reference 1. Minor loss coefficients for fittings are based on values embedded in Reference 2. The number and type of fittings are estimated from Reference 3.

5. Rather than attempt to model the existing subsurface off-site discharge piping, ARCADIS utilized pressure and flow observations collected by CWM to back-calculate a “k” value to represent the losses associated with the piping and the above-grade filters. This “k” value is then applied to the downstream end of the hydraulic model for scenarios involving off-site discharge. Based on information provided by CWM, a pressure gauge in the existing piping system immediately upstream of the filters indicated a gauge pressure of approximately 23 pounds per square inch (psi) at a measured flowrate of approximately 600 gallons per minute (gpm).

6. The fac pond transfer pipeline is evaluated based on two scenarios. The first scenario models the transfer of liquid between the two ponds. Because of the pond floor low point and berm crest elevations, the transfer of liquid from Fac Ponds 1 and 2 to Fac Pond 5 is predicted to require the greatest head. Thus, only this flow direction is evaluated herein. The second scenario models the off-site discharge of liquid from the ponds. Discharging from Fac Pond 5 involves pumping through significantly more pipe than discharging from Fac Ponds 1 and 2. Consequently, only this off-site discharge scenario is evaluated herein. For both scenarios, the liquid level in the fac ponds is assumed to be 2 feet above the pond low point. Because of the additional head required to lift the impounded liquid from these relatively low levels, the estimated flowrates represent worst-case conditions.

7. The maximum allowable flowrate for off-site discharge is 1 million gallons per day (equivalent to approximately 694 gpm averaged over a 24-hour period) according to CWM and is established by the SPDES permit limit for the Niagara River outfall.

8. The primary submersible pump is assumed to be a Flygt Model 2670 high head (B 253 HT) pump. The head versus flowrate for this pump is obtained from Reference 5. The performance of this pump when coupled with the fac pond transfer line is simulated using WaterCAD (Reference 2). Other pump models may be used provided the in-service flowrate to the Niagara River outfall does not exceed the 694 gpm maximum value established by the SPDEC permit.

CALCULATIONS:

1. Estimation of “k” Value for Existing Filters and Off-Site Discharge Piping

As discussed in Assumption 5, CWM has noted that a flowrate of approximately 600 gpm corresponds to a gauge pressure of approximately 23 psi at a location immediately upstream of the existing filters. At this point in the piping system, the pressure is based on losses through the filters and the existing piping between the filters and the Niagara River outfall. Because this part of the piping system is expected to remain intact, the losses associated with this part of the system are expected to remain unchanged from current conditions. However, the losses are proportional to the flowrate so the 23 psi observed pressure is specific to only one flowrate. Thus, it is necessary to back-calculate a “k” value (or loss coefficient) to simulate the expected losses at any flowrate due to the filters and downstream piping.

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Applying the energy equation between the point in the existing piping system corresponding to the pressure gauge location (point 1) and the Niagara River water surface at the pipe outfall (point 2) results in the following expression:

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

where,

V_1 = flow velocity at point 1 = 8.6 ft/s (based on assumed 6-inch-diameter pipe)
P_1 = gauge pressure in piping system at point 1 = 23 psi (Assumption 5)
z_1 = elevation of point 1 = 320 ft (approximately)
V_2 = flow velocity at point 2 = 0 ft/s (flow velocity of jet is negligible at river surface)
P_2 = gauge pressure at point 2 = 0 psi (atmospheric pressure at river surface)
z_2 = elevation of point 2 = 245 ft (river surface approximately equal to average Lake Ontario water surface elevation)
h_L = headloss in system between points 1 and 2 = unknown

Substituting the above values and solving for the headloss results in approximately 129 feet of headloss. Note that this value includes not only friction and minor losses in the discharge piping but also the pressure drop caused by the filters.

With the headloss known for the 600 gpm flowrate, a loss coefficient, k, can be calculated to represent the headloss in the existing discharge piping and filters for any flowrate as follows:

$$h_L = k\frac{V^2}{2g}$$

where,

h_L = headloss in system between points 1 and 2 at 600 gpm flow = 129 ft (determined above)
V = flow velocity as used in hydraulic model (based on 6-inch-diameter HDPE pipe) = 8.6 ft/s
k = loss coefficient accounting for energy loss due to pipe friction and minor losses in fittings and filters = unknown

Substituting the above values and solving for the loss coefficient results in a value of 113. Note that because the loss coefficient will be used in the WaterCAD model of the proposed transfer pipeline and because that model includes only the proposed 6-inch-diameter DR 11 HDPE pipe, the loss coefficient must be calculated using a flow velocity that would occur if the discharge piping had an identical pipe diameter (5.349 inches).

2. Fac Pond Transfer Line Hydraulic Model and Estimated Flowrates

WaterCAD is used to model the hydraulics of the proposed fac pond transfer line for both scenarios described in Assumption 6. A summary of the WaterCAD output for flow for each scenario is presented in Table 1 assuming use of a Flygt model 2670 high head pump model (Assumption 8). This pump model was selected to simulate in-service flowrates using a typical submersible pump. Consequently, it is not a requirement to use only this pump model and other manufacturers and models may be substituted provided they meet CWM's operational requirements and do not exceed the maximum off-site discharge limit of 694 gpm.

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Table 1 – Estimated Flows for Fac Pond Transfer Pipeline

Scenario Description	Potential Pump Model	Predicted Flowrate with Identified Pump (gpm)	Pump Head (ft)
Fac Ponds 1 and 2 to Fac Pond 5	Flygt 2670 High Head (B 253 HT)	483	130
Fac Pond 5 to Niagara River Outfall		496	127

Detailed WaterCAD output for both pumping scenarios is provided in Attachment 1. Also included in Attachment 1 are plots of the system and pump curves for each scenario. The point of pump operation for a given scenario is represented by the intersection of the system and pump curves.

SUMMARY:

The hydraulics of the proposed fac pond transfer pipeline were evaluated assuming the use of a Flygt model 2670 high head pump. Other pump manufacturers and models may also be used at CWM's discretion.

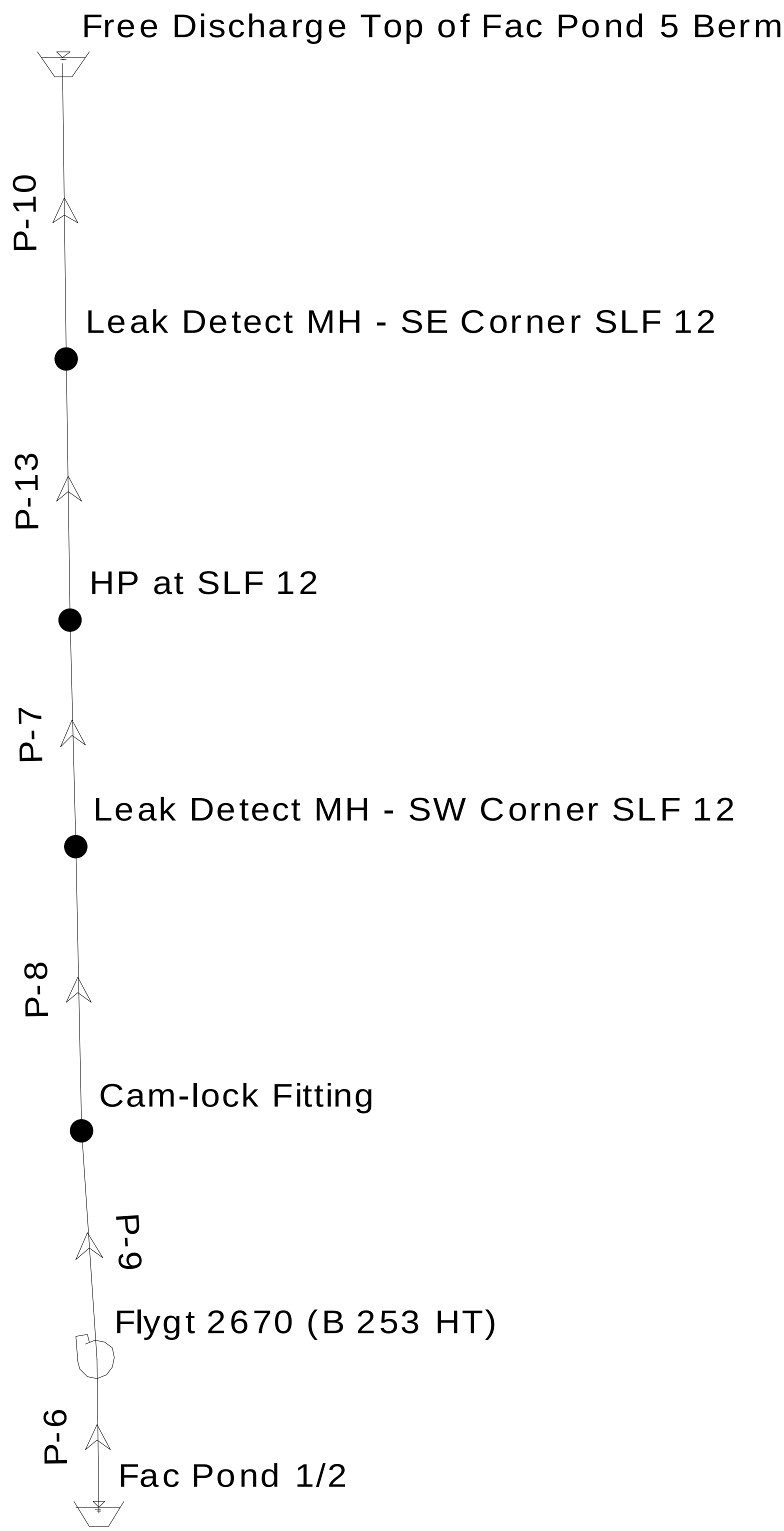
Attachment 1

WaterCAD Output

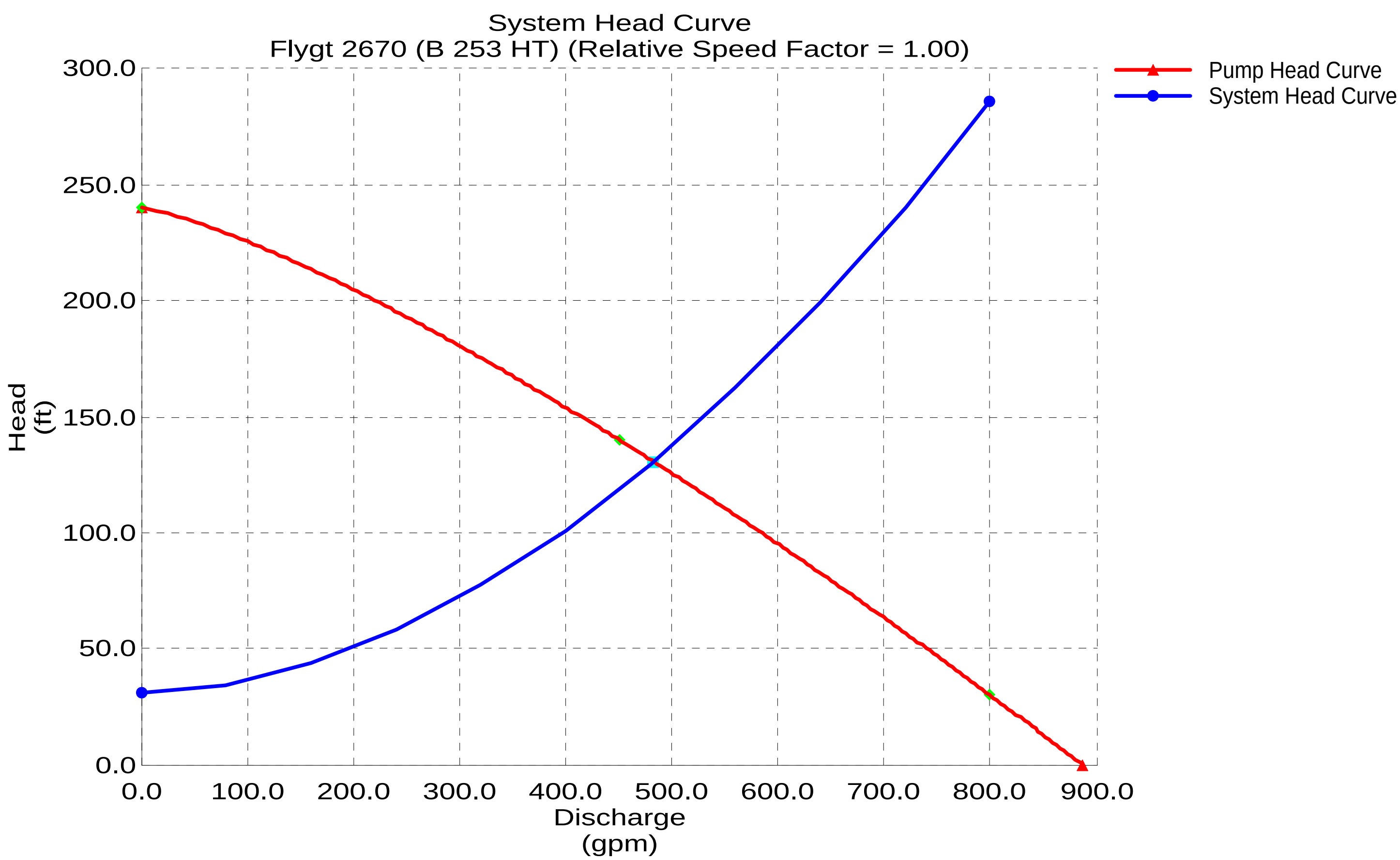
Scenario: Base

FAC POND TRANSFER CALCS

FAC POND 1/2 TO FAC POND 5



Graph


System Head Curve
Flygt 2670 (B 253 HT) (Relative Speed Factor = 1.00)
Head
(ft)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
Discharge
(gpm)
Pump Head Curve
System Head Curve

Project Inventory

Title: Fac Pond Transfer Line
Project Engineer: Blasland Bouck & Lee
Project Date: 08/23/11
Comments:

Scenario Summary

Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternat	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Liquid Characteristics

Liquid	Water at 20C(68F)	Specific Gravity	1.00
Kinematic Viscosity	1.0804e-5 ft²/s		

Network Inventory

Pressure Pipes	6	Number of Tanks	0
Number of Reservoirs	2	- Constant Area:	0
Number of Pressure Junctic	4	- Variable Area:	0
Number of Pumps	1	Number of Valves	0
- Constant Power:	0	- FCV's:	0
- One Point (Design Point):	0	- PBV's:	0
- Standard (3 Point):	1	- PRV's:	0
- Standard Extended:	0	- PSV's:	0
- Custom Extended:	0	- TCV's:	0
- Multiple Point:	0	- GPV's:	0
Number of Spot Elevations	0		

Pressure Pipes Inventory

5.3 in	3,786.00 ft	24.0 in	1.00 ft
6.0 in	100.00 ft		
Total Length	3,887.00 ft		

Detailed Report for Pressure Junction: Cam-lock Fitting

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,769.97 ft	Elevation	322.22 ft
Y	10,228.59 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	432.41	47.68	110.19	0.00

Detailed Report for Reservoir: Fac Pond 1/2

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,772.80 ft	Elevation	304.18 ft
Y	10,167.69 ft	Zone	Zone-1

User Data			
Date Installed		Date Retired	
Inspection Date		Condition	
Clearwell Storage	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Inflow (gpm)	Outflow (gpm)
0.00	304.18	-482.92	482.92

Detailed Report for Pump: Flygt 2670 (B 253 HT)

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary				
X	9,772.44	ft	Upstream Pipe	P-6
Y	10,192.30	ft	Downstream Pipe	P-9
Elevation	304.18	ft		

Pump Definition Summary					
Pump Type	Standard (3 Point)				
Shutoff Head	240.00	ft	Shutoff Discharge	0.00	gpm
Design Head	140.00	ft	Design Discharge	450.00	gpm
Maximum Operating Head	30.00	ft	Maximum Operating Discharge	800.00	gpm

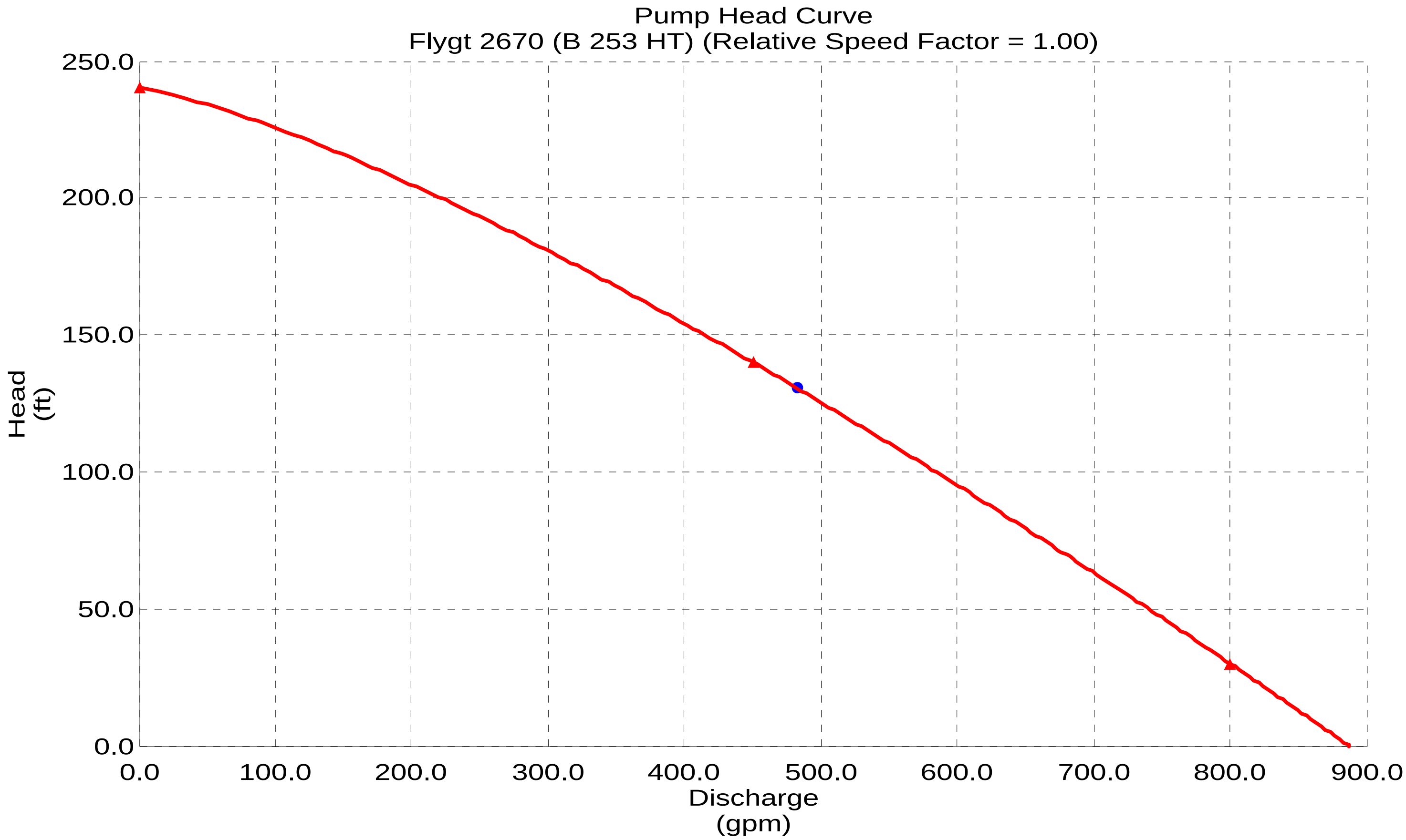
Initial Status			
Initial Pump Status	On	Initial Relative Speed Factor	1.00

User Data				
Date Installed			Date Retired	
Inspection Date			SCADA ID	
Rated Power	0	Hp	Condition	
Manufacturer			Model	
Serial Number			Metered	false
Existing	false			

Calculated Results Summary

Time (hr)	Control Status	Intake Pump Grade (ft)	Discharge Pump Grade (ft)	Discharge (gpm)	Pump Head (ft)	Relative Speed	Calculated Water Power (Hp)
0.00	On	304.18	434.65	482.92	130.47	1.00	15.91

Detailed Report for Pump: Flygt 2670 (B 253 HT)



Detailed Report for Reservoir: Free Discharge Top of Fac Pond 5 Berm

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,767.20 ft	Elevation	335.00 ft
Y	10,398.87 ft	Zone	Zone-1

User Data			
Date Installed		Date Retired	
Inspection Date		Condition	
Clearwell Storage	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Inflow (gpm)	Outflow (gpm)
0.00	335.00	482.92	-482.92

Detailed Report for Pressure Junction: HP at SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,768.24 ft	Elevation	321.80 ft
Y	10,310.17 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	373.04	22.17	51.24	0.00

Detailed Report for Pressure Junction: Leak Detect MH - SE Corner SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,767.80 ft	Elevation	313.40 ft
Y	10,351.83 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	357.73	19.18	44.33	0.00

Detailed Report for Pressure Junction: Leak Detect MH - SW Corner SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,769.09 ft	Elevation	310.20 ft
Y	10,274.02 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	397.95	37.97	87.75	0.00

Detailed Report for Pressure Pipe: P-6

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics					
Material	HDPE		Hazen- Williams C	155.0	
Diameter	24.0	in	Minor Loss Coefficient	0.00	
Check Valve?	false		Length	1.00	ft
From Node	Fac Pond 1/2		To Node	Flygt 2670 (B 253 HT)	

Elevations					
From Elevation	304.18	ft	To Elevation	304.18	ft

Initial Status	
Initial Status	Open

User Data				
Date Installed			Date Retired	
Inspection Date			Lining	
Pipe Class			Exterior Coating	
Nominal Diameter	0.00	in	Condition	
Skeletonized	false		Metered	false
Existing	false			

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	482.92	0.34	304.18	304.18	0.00	0.00	0.00	0.03

Detailed Report for Pressure Pipe: P-7

Scenario Summary

Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary

Demand	<None>	Roughness	<None>

Pipe Characteristics

Material	HDPE		Hazen- Williams C	155.0	
Diameter	5.3	in	Minor Loss Coefficient	0.65	
Check Valve?	false		Length	1,004.00	ft
From Node	Leak Detect MH - SW Corner SLF 12		To Node	HP at SLF 12	

Elevations

From Elevation	310.20	ft	To Elevation	321.80	ft

Initial Status

Initial Status	Open

User Data

Date Installed			Date Retired	
Inspection Date			Lining	
Pipe Class			Exterior Coating	
Nominal Diameter	0.00	in	Condition	
Skeletonized	false		Metered	false
Existing	false			

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	482.92	6.89	397.95	373.04	24.43	0.48	24.91	24.81

Detailed Report for Pressure Pipe: P-8

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	3.07
Check Valve?	false	Length	1,323.00 ft
From Node	Leak Detect MH - SW Corner SLF 12	To Node	Cam-lock Fitting

Elevations			
From Elevation	310.20 ft	To Elevation	322.22 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	-482.92	6.89	397.95	432.41	32.19	2.27	34.46	26.05

Detailed Report for Pressure Pipe: P-9

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics					
Material	flex hose		Hazen- Williams C	120.0	
Diameter	6.0	in	Minor Loss Coefficient	0.00	
Check Valve?	false		Length	100.00	ft
From Node	Flygt 2670 (B 253 HT)		To Node	Cam-lock Fitting	

Elevations					
From Elevation	304.18	ft	To Elevation	322.22	ft

Initial Status	
Initial Status	Open

User Data				
Date Installed			Date Retired	
Inspection Date			Lining	
Pipe Class			Exterior Coating	
Nominal Diameter	0.00	in	Condition	
Skeletonized	false		Metered	false
Existing	false			

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	482.92	5.48	434.65	432.41	2.23	0.00	2.23	22.34

Detailed Report for Pressure Pipe: P-10

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	3.43
Check Valve?	false	Length	830.00 ft
From Node	Leak Detect MH - SE Corner SLF 12	To Node	Free Discharge Top of Fac Pond 5 Berm

Elevations			
From Elevation	313.40 ft	To Elevation	335.00 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	482.92	6.89	357.73	335.00	20.20	2.53	22.73	27.39

Detailed Report for Pressure Pipe: P-13

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics					
Material	HDPE		Hazen- Williams C	155.0	
Diameter	5.3	in	Minor Loss Coefficient	0.00	
Check Valve?	false		Length	629.00	ft
From Node	HP at SLF 12		To Node	Leak Detect MH - SE Corner SLF 12	

Elevations					
From Elevation	321.80	ft	To Elevation	313.40	ft

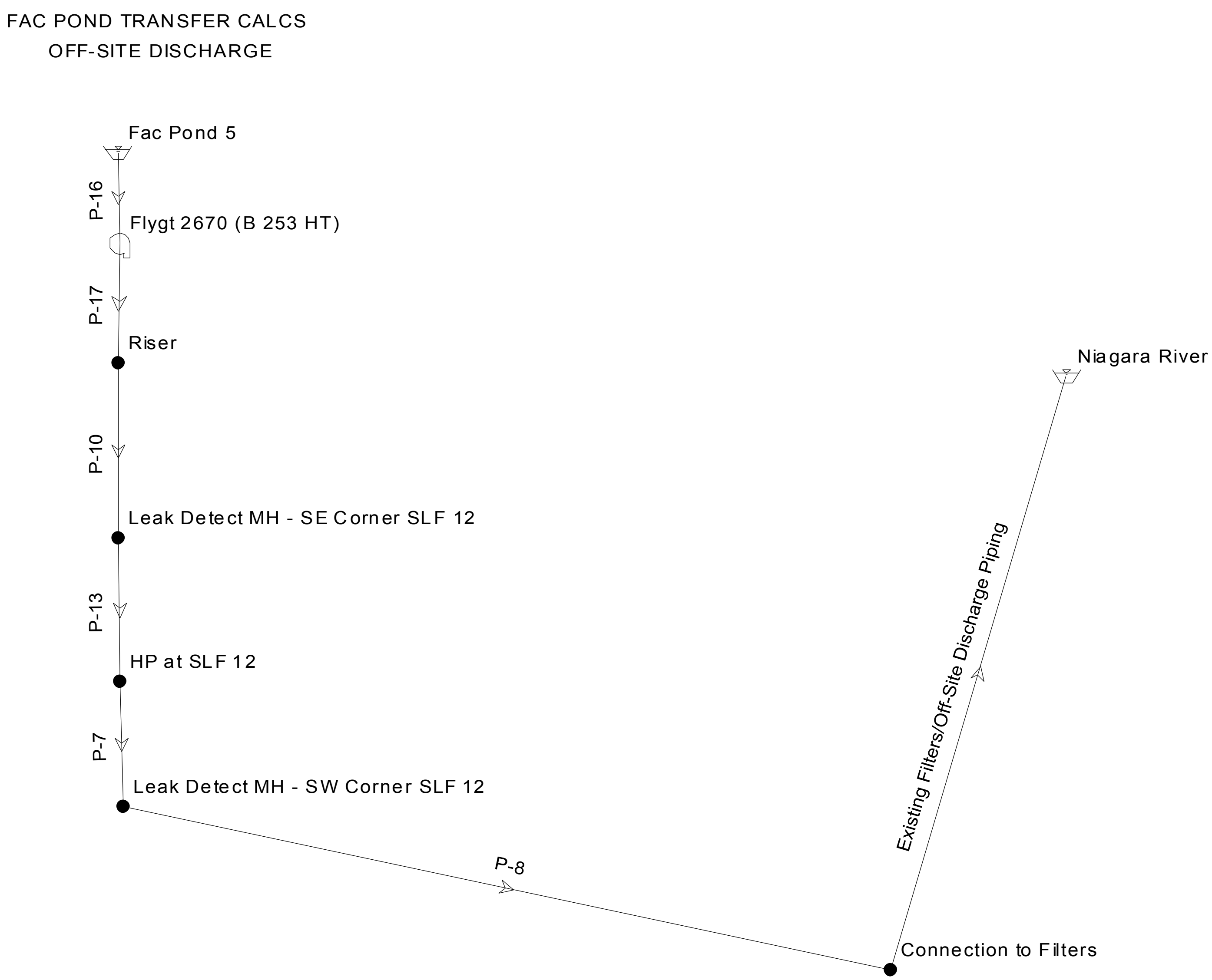
Initial Status	
Initial Status	Open

User Data				
Date Installed			Date Retired	
Inspection Date			Lining	
Pipe Class			Exterior Coating	
Nominal Diameter	0.00	in	Condition	
Skeletonized	false		Metered	false
Existing	false			

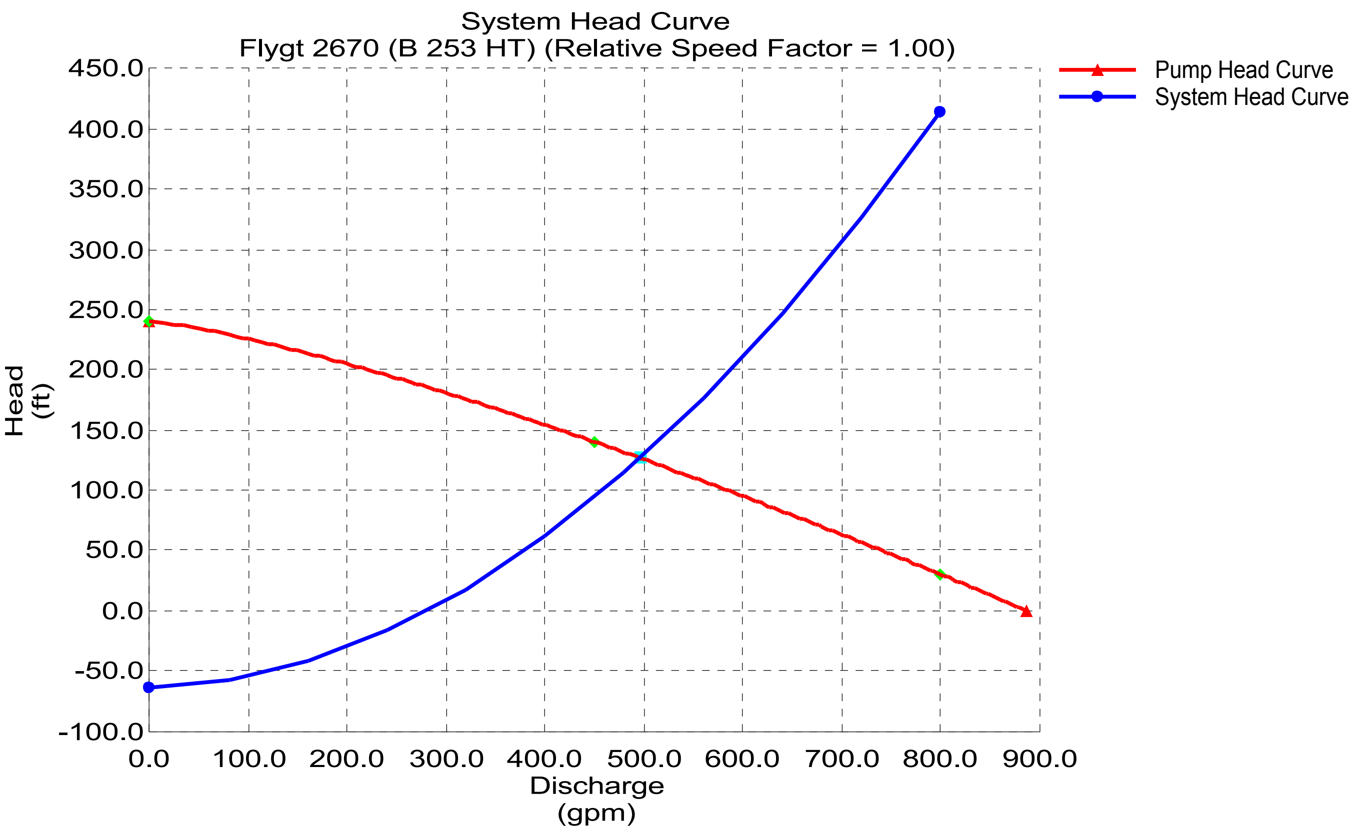
Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	482.92	6.89	373.04	357.73	15.31	0.00	15.31	24.34

Scenario: Base



Graph


System Head Curve
Flygt 2670 (B 253 HT) (Relative Speed Factor = 1.00)
Pump Head Curve
System Head Curve
Head
(ft)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
Discharge
(gpm)

Analysis Results
Scenario: Base
Steady State Analysis

Title: Fac Pond Transfer Line
Project Engineer: Blasland Bouck & Lee
Project Date: 08/23/11
Comments:

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Liquid Characteristics			
Liquid	Water at 20C(68F)	Specific Gravity	1.00
Kinematic Viscosity	1.0804e-5 ft²/s		

Network Inventory			
Pressure Pipes	7	Number of Tanks	0
Number of Reservoirs	2	- Constant Area:	0
Number of Pressure Junctions	5	- Variable Area:	0
Number of Pumps	1	Number of Valves	0
- Constant Power:	0	- FCV's:	0
- One Point (Design Point):	0	- PBV's:	0
- Standard (3 Point):	1	- PRV's:	0
- Standard Extended:	0	- PSV's:	0
- Custom Extended:	0	- TCV's:	0
- Multiple Point:	0	- GPV's:	0
Number of Spot Elevations	0		

Pressure Pipes Inventory			
5.3 in	3,637.00 ft	6.0 in	150.00 ft
Total Length	3,787.00 ft		

Analysis Results
Scenario: Base
Steady State Analysis

Pressure Junctions @ 0.00 hr

Label	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
Connection to	333.11	5.67	13.11	0.00
HP at SLF 12	393.66	31.09	71.86	0.00
Leak Detect M	409.76	41.69	96.36	0.00
Leak Detect M	367.45	24.77	57.25	0.00
Riser	432.02	41.98	97.02	0.00

Pressure Pipes @ 0.00 hr

Label	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
Existing Filters	Open	496.28	7.09	333.11	245.00	-0.06	88.16	88.11	88,105.20
P-7	Open	496.28	7.09	393.66	367.45	25.70	0.51	26.21	26.10
P-8	Open	496.28	7.09	367.45	333.11	30.53	3.82	34.35	28.79
P-10	Open	496.28	7.09	432.02	409.76	20.73	1.53	22.26	27.48
P-13	Open	496.28	7.09	409.76	393.66	16.10	0.00	16.10	25.60
P-16	Open	496.28	5.63	309.00	308.76	0.24	0.00	0.24	23.50
P-17	Open	496.28	5.63	435.31	432.02	3.29	0.00	3.29	23.50

Reservoirs @ 0.00 hr

Label	Calculated Hydraulic Grade (ft)	Inflow (gpm)	Outflow (gpm)
Fac Pond 5	309.00	-496.28	496.28
Niagara River	245.00	496.28	-496.28

Pumps @ 0.00 hr

Label	Control Status	Intake Pump Grade (ft)	Discharge Pump Grade (ft)	Discharge (gpm)	Pump Head (ft)	Relative Speed	Calculated Water Power (Hp)
Flygt 2670 (B 2	On	308.76	435.31	496.28	126.55	1.00	15.86

Detailed Report for Pressure Junction: Connection to Filters

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	10,004.83 ft	Elevation	320.00 ft
Y	10,173.78 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	333.11	5.67	13.11	0.00

Detailed Report for Pressure Pipe: Existing Filters/Off-Site Discharge Piping

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	113.00
Check Valve?	false	Length	1.00 ft
From Node	Connection to Filters	To Node	Niagara River

Elevations			
From Elevation	320.00 ft	To Elevation	245.00 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	7.09	333.11	245.00	-0.06	88.16	88.11	88,105.20

Detailed Report for Reservoir: Fac Pond 5

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,780.48 ft	Elevation	309.00 ft
Y	10,411.02 ft	Zone	Zone-1

User Data			
Date Installed		Date Retired	
Inspection Date		Condition	
Clearwell Storage	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Inflow (gpm)	Outflow (gpm)
0.00	309.00	-496.28	496.28

Detailed Report for Pump: Flygt 2670 (B 253 HT)

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,781.04 ft	Upstream Pipe	P-16
Y	10,384.75 ft	Downstream Pipe	P-17
Elevation	309.00 ft		

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	240.00 ft	Shutoff Discharge	0.00 gpm
Design Head	140.00 ft	Design Discharge	450.00 gpm
Maximum Operating Head	30.00 ft	Maximum Operating Discharge	800.00 gpm

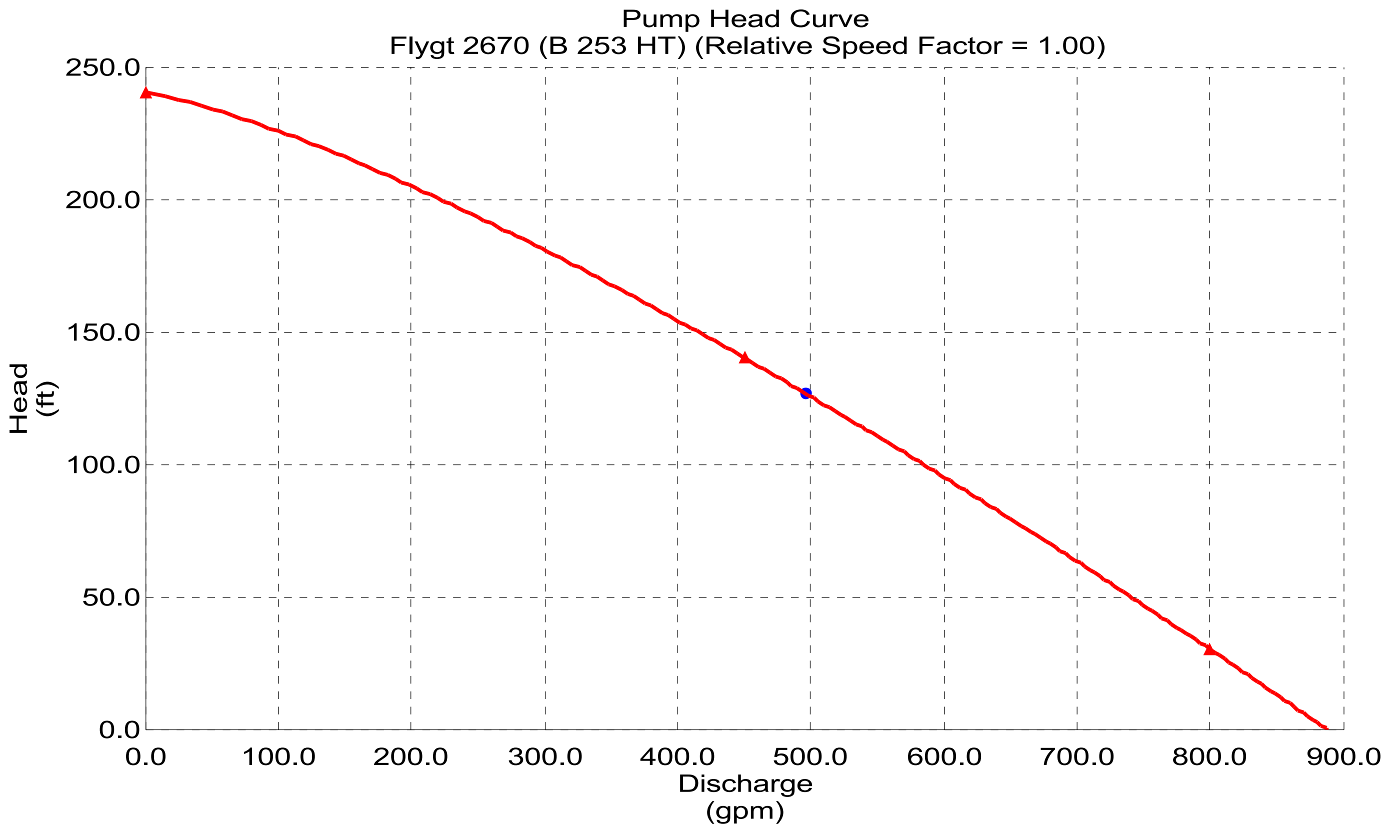
Initial Status			
Initial Pump Status	On	Initial Relative Speed Factor	1.00

User Data			
Date Installed		Date Retired	
Inspection Date		SCADA ID	
Rated Power	0 Hp	Condition	
Manufacturer		Model	
Serial Number		Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Intake Pump Grade (ft)	Discharge Pump Grade (ft)	Discharge (gpm)	Pump Head (ft)	Relative Speed	Calculated Water Power (Hp)
0.00	On	308.76	435.31	496.28	126.55	1.00	15.86

Detailed Report for Pump: Flygt 2670 (B 253 HT)



Detailed Report for Pressure Junction: HP at SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,781.21 ft	Elevation	321.80 ft
Y	10,257.42 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	393.66	31.09	71.86	0.00

Detailed Report for Pressure Junction: Leak Detect MH - SE Corner SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,780.77 ft	Elevation	313.40 ft
Y	10,299.08 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	409.76	41.69	96.36	0.00

Detailed Report for Pressure Junction: Leak Detect MH - SW Corner SLF 12

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,782.05 ft	Elevation	310.20 ft
Y	10,221.27 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	367.45	24.77	57.25	0.00

Detailed Report for Reservoir: Niagara River

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	10,055.80 ft	Elevation	245.00 ft
Y	10,346.31 ft	Zone	Zone-1

User Data			
Date Installed		Date Retired	
Inspection Date		Condition	
Clearwell Storage	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Inflow (gpm)	Outflow (gpm)
0.00	245.00	496.28	-496.28

Detailed Report for Pressure Pipe: P-7

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	0.65
Check Valve?	false	Length	1,004.00 ft
From Node	HP at SLF 12	To Node	Leak Detect MH - SW Corner SLF 12

Elevations			
From Elevation	321.80 ft	To Elevation	310.20 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	7.09	393.66	367.45	25.70	0.51	26.21	26.10

Detailed Report for Pressure Pipe: P-8

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	4.89
Check Valve?	false	Length	1,193.00 ft
From Node	Leak Detect MH - SW Corner SLF 12	To Node	Connection to Filters

Elevations			
From Elevation	310.20 ft	To Elevation	320.00 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	7.09	367.45	333.11	30.53	3.82	34.35	28.79

Detailed Report for Pressure Pipe: P-10

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	1.96
Check Valve?	false	Length	810.00 ft
From Node	Riser	To Node	Leak Detect MH - SE Corner SLF 12

Elevations			
From Elevation	335.00 ft	To Elevation	313.40 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	7.09	432.02	409.76	20.73	1.53	22.26	27.48

Detailed Report for Pressure Pipe: P-13

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	HDPE	Hazen- Williams C	155.0
Diameter	5.3 in	Minor Loss Coefficient	0.00
Check Valve?	false	Length	629.00 ft
From Node	Leak Detect MH - SE Corner SLF 12	To Node	HP at SLF 12

Elevations			
From Elevation	313.40 ft	To Elevation	321.80 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	7.09	409.76	393.66	16.10	0.00	16.10	25.60

Detailed Report for Pressure Pipe: P-16

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	flex hose	Hazen- Williams C	120.0
Diameter	6.0 in	Minor Loss Coefficient	0.00
Check Valve?	false	Length	10.00 ft
From Node	Fac Pond 5	To Node	Flygt 2670 (B 253 HT)

Elevations			
From Elevation	309.00 ft	To Elevation	309.00 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	5.63	309.00	308.76	0.24	0.00	0.24	23.50

Detailed Report for Pressure Pipe: P-17

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Pipe Characteristics			
Material	flex hose	Hazen- Williams C	120.0
Diameter	6.0 in	Minor Loss Coefficient	0.00
Check Valve?	false	Length	140.00 ft
From Node	Flygt 2670 (B 253 HT)	To Node	Riser

Elevations			
From Elevation	309.00 ft	To Elevation	335.00 ft

Initial Status	
Initial Status	Open

User Data			
Date Installed		Date Retired	
Inspection Date		Lining	
Pipe Class		Exterior Coating	
Nominal Diameter	0.00 in	Condition	
Skeletonized	false	Metered	false
Existing	false		

Calculated Results Summary

Time (hr)	Control Status	Discharge (gpm)	Velocity (ft/s)	Upstream Structure Hydraulic Grade (ft)	Downstream Structure Hydraulic Grade (ft)	Calculated Friction Headloss (ft)	Calculated Minor Headloss (ft)	Pressure Pipe Headloss (ft)	Headloss Gradient (ft/1000ft)
0.00	Open	496.28	5.63	435.31	432.02	3.29	0.00	3.29	23.50

Detailed Report for Pressure Junction: Riser

Scenario Summary	
Scenario	Base
Physical Alternative	Base-Physical
Active Topology Alternative	Base-Active Topology
Demand Alternative	Base-Average Daily
Initial Settings Alternative	Base-Initial Settings
Operational Alternative	Base-Operational
Logical Control Set Alternative	<All Logical Controls>
Age Alternative	Base-Age Alternative
Constituent Alternative	Base-Constituent
Trace Alternative	Base-Trace Alternative
Fire Flow Alternative	Base-Fire Flow
Capital Cost Alternative	Base-Capital Cost
Energy Cost Alternative	Base-Energy Cost
User Data Alternative	Base-User Data

Global Adjustments Summary			
Demand	<None>	Roughness	<None>

Geometric Summary			
X	9,780.77 ft	Elevation	335.00 ft
Y	10,349.89 ft	Zone	Zone-1

Demand Summary

Type	Base Flow (gpm)	Pattern
Demand	0.00	Fixed

User Data			
SCADA ID		Sampling Point	false
Hydrant Location	false	Existing	false

Calculated Results Summary

Time (hr)	Calculated Hydraulic Grade (ft)	Pressure (psi)	Pressure Head (ft)	Demand (Calculated) (gpm)
0.00	432.02	41.98	97.02	0.00

Attachment 2

References

PERFORMANCE PIPE
A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP

Revised 04-07-2009

IPS Size and Dimension Data

PE4710 (PE3408)

DriscoPlex® Municipal & Industrial & Energy Series/IPS Pipe Data

Pressure Ratings are calculated using 0.63 design factor for HDS at 73°F as listed in PPI TR-4 for PE 4710 materials.
Temperature, Chemical, and Environmental use considerations may require use of additional design factors.

Pressure Rating		317 psi DR 7.3			250 psi DR 9.0			200 psi DR 11.0			160 psi DR 13.5			
IPS Pipe Size	Nominal OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	IPS Pipe Size
1 1/4"	1.660	0.227	1.179	0.45	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26	1 1/4"
1 1/2"	1.900	0.260	1.349	0.59	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34	1 1/2"
2"	2.375	0.325	1.686	0.92	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	2"
3"	3.500	0.479	2.485	1.99	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	3"
4"	4.500	0.616	3.194	3.29	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	4"
6"	6.625	0.908	4.700	7.12	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	6"
8"	8.625	1.182	6.119	12.07	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	8"
10"	10.750	1.473	7.627	18.75	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	10"
12"	12.750	1.747	9.046	26.38	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	12"
14"	14.000	1.918	9.934	31.81	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	14"
16"	16.000	2.192	11.353	41.55	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	16"
18"	18.000	2.466	12.772	52.58	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	18"
20"	20.000	2.740	14.191	64.91	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	20"
22"	22.000	3.014	15.610	78.55	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	22"
24"	24.000	3.288	17.029	93.48	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	24"
26"	26.000				2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	26"
28"	28.000				3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	28"
30"	30.000				3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	30"
32"	32.000							2.909	25.833	116.58	2.370	26.976	96.87	32"
34"	34.000							3.091	27.447	131.61	2.519	28.660	109.36	34"
36"	36.000							3.273	29.061	147.55	2.667	30.346	122.60	36"
42"	42.000										3.111	35.405	166.88	42"
48"	48.000													48"
54"	54.000													54"

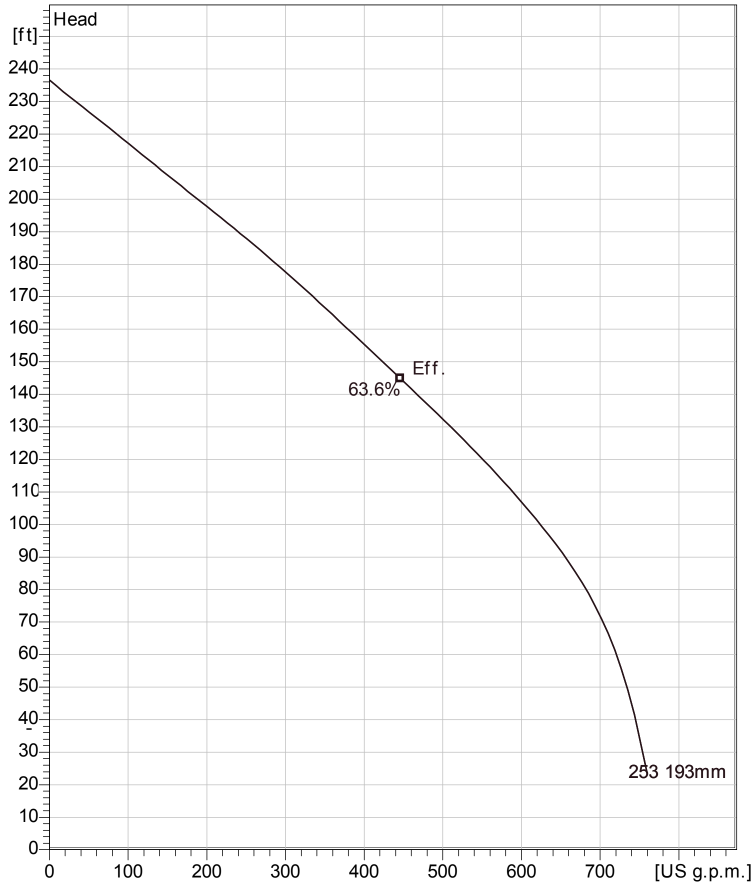
Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter is calculated using nomnal OD and Minimum wal plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimension and tolerances in the applicable pipe manufacturing specification.

Visit www.performancepipe.com for the most current literature.

Bulletin: PP 152-4710

BS 2670 HT 3~ 253

Technical specification



Curve according to: ISO 9906 grade 2 annex 1 or 2

Note: Picture might not correspond to the current configuration.

Installation: S - Portable Semi permanent, Wet

General

Portable pumps ideal for applications in which the water or liquid contains concentrations of abrasives.

Impeller

Impeller material	Hard-Iron ™
Outlet width	3 15/16 inch
Inlet diameter	103 mm
Impeller diameter	193 mm
Number of blades	3
Throughlet diameter	7/8 inch

Motor

Motor #	B2670.180 21-18-2BB-W 27hp
Stator variant	
Frequency	60 Hz
Rated voltage	460 V
Number of poles	2
Phases	3~
Rated power	27 hp
Rated current	31 A
Starting current	207 A
Rated speed	3490 rpm
Power factor	
1/1 Load	0.92
3/4 Load	0.89
1/2 Load	0.83
Efficiency	
1/1 Load	90.0 %
3/4 Load	91.5 %
1/2 Load	91.5 %

Configuration

Project	Project ID	Created by	Created on	Last update
			2012-01-25	

ARCADIS

Appendix K

Trailer Parking Area/Ramps
Structural Calculations

TRAILER PARKING AREAS/LEACHATE TRANSFER RAMPS:

TOTAL TRUCK WT > 80^k PER B. STONE

∴ PER ATTACHED NY DOT INFO, MAX AXLE LOAD = 22.4^k (SINGLE)

= 20^k (TANDEM)

USE ARMY TM 5-809-12, TECH MANUAL "CONCRETE FLOOR SLABS ON GRADE SUBJECTED TO HEAVY LOADS"

P. 3-1 LOAD DISTRIBUTION

FOR MAXIMUM AXLE LOAD = 22.4^k → CATEGORY III (UP TO 25 KIPS)

PER P. 5-1, CONVERT LOAD INTO DESIGN INDEX

SAY CATEGORY 8 PER TABLE 5-1

FIGURE 5-1 : DESIGN CURVES FOR SLABS CAN BE USED TO DETERMINE REQ'D t *

BUT NEED TO DETERMINE FLEXURAL STRENGTH OF CONC & SUBGRADE MODULUS

* t FOR UNREINFORCED SLAB

V. Maximum legal weight for State Highways and Designated Highways are:

A. Maximum load per tire. The lesser of manufacturer's tire rating or 800 pounds per inch of tire

B. Maximum wheel loading 11,200 pounds

C. Maximum weight, one axle 22,400 pounds

D. Maximum weight, any two consecutive axles, less that eight (8) feet apart 36,000 pounds

1. Axles less than 46 inches apart, measured from axles' center, are considered one axle.

E. Maximum weight, any two consecutive axles eight (8) to ten (10) feet apart. Weight cannot exceed formula:

**W = 500 (LN/N-1 + 12 N + 36); 40,000 pounds maximum

**See Item F. 1.b. for explanation of terms.

F. Maximum weight on all axles of a single vehicle or combination of vehicles having three (3) axles or more is 80,000 pounds based on one of the following formulas:

1. For any vehicle or combination of vehicles having a total gross weight less than 71,000 pounds, the higher of the following shall apply:

a. the total weight of all axles shall not exceed 34,000 pounds plus 1,000 pounds for each foot and major fraction of a foot of the distance from the center of the foremost axle to the center of the rear most axle, or

b. the overall gross weight on a group of two or more consecutive axles shall not exceed the weight produced by application of the following formula:

W = 500 (LN/N-1 + 12N + 36)

where W equals overall gross weight on any group of two or more consecutive axles to the nearest 500 pounds, L equals distance in feet from the center of the foremost axle to the center of the rear-most axle of any group of two or more consecutive axles, and N equals number of axles in group under consideration, except that two consecutive sets of tandem axles may carry a gross load 34,000 pounds each providing the overall distance between the first and last axles of such consecutive sets of tandem axles is thirty-six feet or more.

2. For any vehicle or combination of vehicles having a total gross weight of 71,000 pounds or greater, formula in section F.1.b. shall apply.

VI. Manufacturer's Tire Ratings:

1. Single Rating is used when there are two tires per axle one on each side. Use the number given on the sidewall of the tire and multiply the number given by 2 (2 tires)

2. Dual Rating is used when there are 4 tires per axle, two on each side. Use the Dual number given on the sidewall of the tire and multiply the number given by 4 (4 tires)

3. See following page for details regarding Manufacturers Tire Ratings

1-B

CHAPTER 3

DETERMINATION OF FLOOR SLAB REQUIREMENTS

3-1. Vehicular loads.

The following traffic data are required to determine the floor slab thickness requirements:

- Types of vehicles
- Traffic volume by vehicle type
- Wheel loads, including the maximum single-axle and tandem-axle loading for trucks, forklift trucks, and tracked vehicles
- The average daily volume of traffic (ADV) which, in turn, determines the total traffic volume anticipated during the design life of the floor slab.

For floor slabs, the magnitude of the axle load is of far greater importance than the gross weight. Axle spacings generally are large enough so that there is little or no interaction between axles. Forklift truck traffic is expressed in terms of maximum axle load. Under maximum load conditions, weight carried by the drive axle of a forklift truck is normally 87 to 94 percent of the total gross weight of the loaded vehicle.

For tracked vehicles, the gross weight is evenly divided between two tracks, and the severity of the load can easily be expressed in terms of gross weight. For moving live loads, axle loading is far more important than the number of load repetitions. Full-scale experiments have shown that changes as little as 10 percent in the magnitude of axle loading are equivalent to changes of 300 to 400 percent in the number of load repetitions.

3-2. Traffic distribution.

To aid in evaluating traffic for the purposes of floor slab design, typical forklift trucks have been divided into six categories as follows:

Forklift Truck Category	*Forklift Truck Maximum Axle Load, kips*	*Maximum Load Capacity, kips*
I	5 to 10	2 to 4
II	10 to 15	4 to 6
III	15 to 25	6 to 10
IV	25 to 36	10 to 16
V	36 to 43	16 to 20
VI	43 to 120	20 to 52

When forklift trucks have axle loads less than 5 kips and the stationary live loads are less than 400 pounds per square foot, the floor slab should be designed in accordance with TM 5-809-2/AFM 88-3, Chap. 2. Vehicles other than forklift trucks such as conventional trucks shall be evaluated by considering each axle as one forklift truck axle of approximate weight. For example, a three-axle truck with axle loads of 6, 14, and 14 kips will be considered as three forklift truck axles, one in Category I and two in Category II. Tracked vehicles are categorized as follows:

Forklift Truck Category	*Tracked Vehicles Maximum Bross Weight, kips*
I	less than 40
II	40 to 60
III	60 to 90
IV	90 to 120

Categories for tracked vehicles may be substituted for the same category for forklift trucks.

1-C

CHAPTER 5
DESIGN PROCEDURE

5-1. General.

Once the floor-slab design requirements have been established, i.e., the type of loadings, including wall loads and both stationary live and moving live loads, the requirements are translated into meaningful design data. These design data are then compared with the existing condition data, and a floor slab design is evolved. The design procedure covers sub-grade conditions, steel reinforcing, and various details such as jointing.

5-2. Floor slab loads.

a. Traffic loadings. In order to satisfy requirements of different types of vehicles and traffic volumes, all Category I, II, and III traffic has been expressed in terms of equivalent operations of a basic axle loading. The basic loading was assumed to be an 1 8,000-pound single-axle load with two sets of dual wheels spaced 58-1/2 inches apart with 13-1/2 inches between dual wheels. It should be noted that the basic loading was arbitrarily selected to provide a reasonable spread in the loadings and traffic volumes likely to be encountered under normal conditions. A design index (DI) was devised which expresses varying axle loads and traffic volume in terms of relative severity. The DI ranges from 1 to 10 with the higher number indicating a more severe design requirement. The basic loading described above was used to assign and rank the DI's. More information concerning the DI can be found in TM 5-822-6/AFM 88-7, Chap. 1. Table 5-1 shows the DI's for various traffic volumes. Thickness requirements for floor slabs which contain only temperature reinforcement for the ten DI's are shown in figure 5-1. The floor-slab thickness requirements are a function of concrete strength and subgrade modulus and DI. Larger forklifts having axle loads greater than 25 kips are treated separately. The required slab thickness for pavements designed for these loads are not significantly affected by vehicles having axle loads less than 25 kips (trucks, cars, buses, and small forklifts). These light loads are therefore ignored in determining requirements for pavements carrying axle loads greater than 25 kips. The thickness requirements for these loads are shown in figure 5-2.

Table 5-1. Traffic categories for design index

Maximum Operations Per Day Over 25 Years	Load	Design Index
50	10-kip axle-load forklift truck	4
250 10	10-kip axle-load forklift truck 15-kip axle-load forklift truck	5
250 100	10-kip axle-load forklift truck 15-kip axle-load forklift truck	7
250 5	15-kip axle-load forklift truck 25-kip axle-load forklift truck	8

FLEXURAL STRENGTH OF 4000 psi CONC

USE VALUE FROM ACI 318 CH. 9 EQ 9-10

$$f_r = 7.5\sqrt{f_c'} = 474 \text{ psi} \rightarrow 500 \text{ psi}$$

MODULUS OF SUBGRADE REACTION - FOR SILTS & CLAYS W/ LL<50, PER ATTACHED TABLE 4-1, USE 200#/in³

∴ PER FIGURE 5-1: 8½" UNREINFORCED SLAB REQ'D

(BY INSP. W/ FLEXURAL STRENGTH = 500 psi, W/ MIN K (25 pcf) & MAX DESIGN INDEX (10) t req'd ≈ 10" < 12" CURRENTLY PROPOSED)

2-A

Table 4-1. Typical values of modulus of subgrade reaction

	Modulus of Subgrade Reaction, k, in lb/in³ for Moisture Contents of							
Types of Materials	1 to 4%	5 to 8%	9 to 12%	13 to 16%	17 to 20%	21 to 24%	25 to 28%	Over 29%
Silts and clays Liquid limit > 50 (OH, CH, MH)	--	175	150	125	100	75	50	25
Silts and clays Liquid limit < 50 (OL, CL, ML)	--	200	175	150	125	100	75	50
Silty and clayey sands (SM & SC)	300	250	225	200	150	–	–	--
Gravelly sands (SW & SP)	300+	300	250	–	–	–	–	--
Silty and clayey gravels (GM & GC)	300+	300+	300	250	–	–	–	--
Gravel and sandy gravels (GW & GP)	300+	300+	–	–	–	–	–	--

NOTE: k values shown are typical for materials having dry densities equal to 90 to 95 percent of the maximum CE 55 density. For materials having dry densities less than 90 percent of maximum CE 55 density, values should be reduced by 50 lb/in³, except that a k of 25 lb/in³ will be the minimum used for design.

2-B

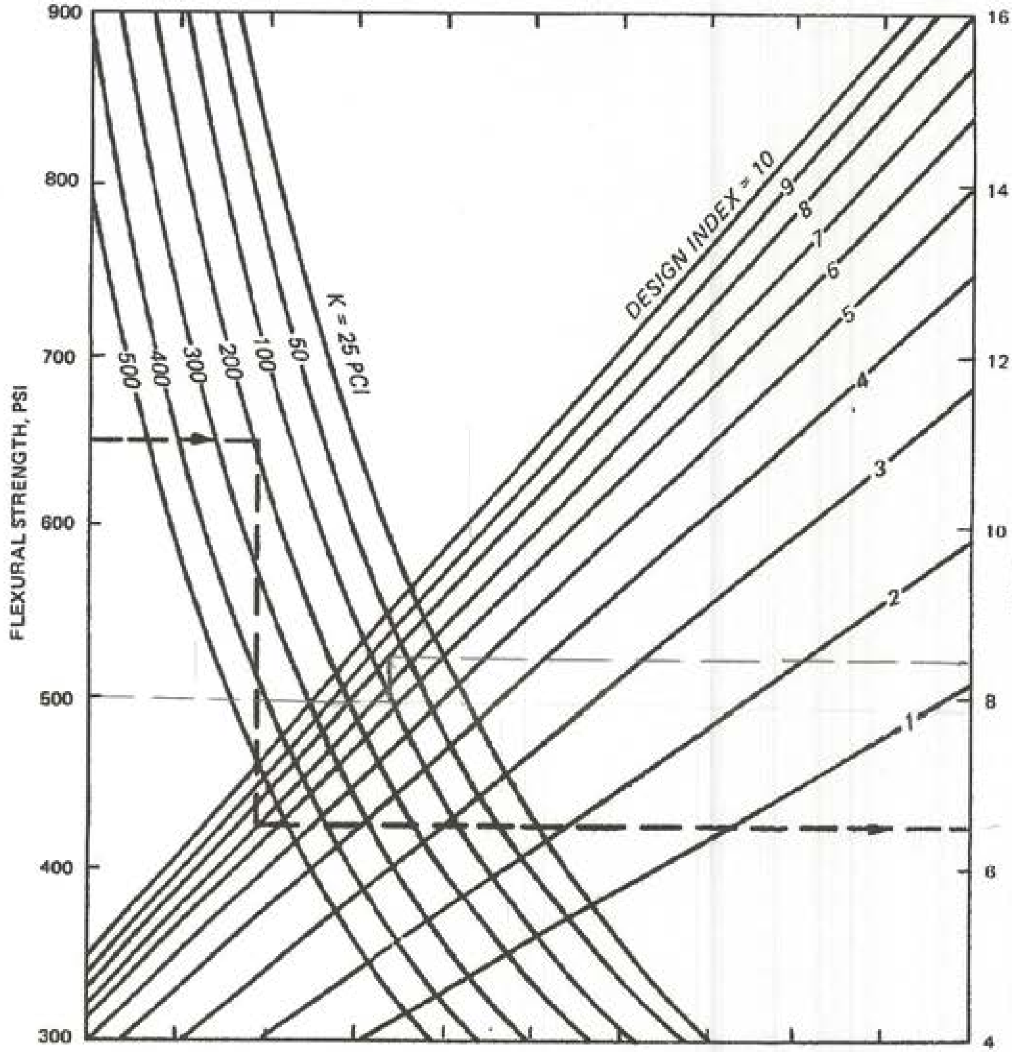


Figure 5-1. Design curves for concrete floor slabs by design index.

ADJUSTMENT FOR REINFORCED SLAB

REF. SECTION 5-6 & FIGURE 5-4

IF ONE LAYER OF REINFORCEMENT ADDED

#4@12" o/c = .20 in²/' , treq'd = 6½"

MAX JT SPACING = 75'

(W/ 10" UNREINFORCED SLAB & .20 in²/' , treq'd = 8")

ADDITION OF STEEL FIBERS TO MIX CAN PERMIT FURTHER THICKNESS REDUCTION HOWEVER 6" IS MIN. RECOMMENDED THICKNESS FOR REINFORCED SLABS THUS FIBER ADDITION NOT CONSIDERED IN SLAB DESIGN

FINAL DESIGN

USE 8" REINF SLAB LEACHATE TRANSFER RAMPS, 12" REINF SLAB FOR TRAILER PARKING AREAS

SAY PROVIDE SHRINKAGE & TEMPERATURE REINFORCING PER ACI 350 TABLE 7.12.2.1

FOR PARTIAL CONTRACTION JOINTS @ ≈ 23' MAX

USE JT SPACING OF 23×1.5 ~ 35' ∴ p = .004

t = 8": AS = .004×12×8 = .38 in²/' → #6@12 = .44

t = 12" AS = .004×12×12 = .58 in²/' /2 = .29

#5@12 T&B = .31

3-A

(2) Mismatched joints. A partial reinforcement of slab is required where the joint patterns of abutting or adjacent floor slabs do not match, and when the pavements are not positively separated by an expansion or slip-type joint. The floor slab directly opposite the mismatched joint should be reinforced with a minimum of 0.06 percent of steel in directions normal to each other for a distance of 3 feet back from the juncture, and for the full width or length of the slab in a direction normal to the mismatched joint. Mismatched joints normally will occur at intersections of floor slabs or between regular floor slab and fillet areas (fig 5-3).

d. Other uses. Reinforced and continuously reinforced floor slabs may be considered for reasons other than those described above provided a report containing a justification of the need for reinforcement is prepared and submit for approval to HQDA (DAEN-ECE-G), Washington, DC 20314-1 000, or Headquarters, Air Force Engineering and Services Center (DEMP), Tyndall AFB, Fla. 32403.

5-6. Reinforced design.

a. Thickness design on unbonded base or subbase. The design procedure for reinforced concrete floor slabs uses the principle of allowing a reduction in the required thickness of nonreinforced concrete floor slab due to the presence of the steel reinforcing. The design procedure has been developed empirically from a limited number of prototype test pavements subjected to accelerated traffic testing. Although it is anticipated that some cracking will occur in the floor slab under the design traffic loadings, the steel reinforcing will hold the cracks tightly closed. The reinforcing will prevent spalling or faulting at the cracks and provide a serviceable floor slab during the anticipated design life. Essentially, the design method consists of determining the percentage of steel required, the thickness of the reinforced floor slab, and the maximum allowable length of the slabs. Figure 5-4 presents a graphic solution for the design of reinforced floor slabs. Since the thickness of a reinforced floor slab is a function of the percentage of steel reinforcing, the designer may determine the required percentage of steel for a predetermined thickness of floor slab or determine the required thickness of floor slab for a predetermined percentage of steel. in either case, it is necessary first to determine the required thickness of nonreinforced floor slab by the method outlined previously (para 5-2) for non reinforced floor slabs. The exact thickness (to the nearest 1/10 inch) of the floor slab, h , is then used to enter the nomogram in figure 5-4. A straight line is then drawn from the value of h to the value selected for the thickness of reinforced floor slab, h_r ,and extended to the required percentage of reinforcing steel, S , or drawn from the value h to the value selected for the percentage of reinforcing steel, and extended to the thickness, h_r . The thickness, h_r , will always be equal to or less than the thickness, h. It should be noted that the S value indicated in figure 5-4 is the percentage to be used in the longitudinal direction only. For nomral designs, the percentage of nonreinforcing steel used in the transverse direction will be one-half of that to be used in the longitudinal dirction. Once the h_r and S values have been determined, the maximum allowable slab length L is obtained from the intersection of the straight line and the scale of L . Provision also is made in the nomograph for adjusting L on the basis of the yield strength f_s of the reinforcing steel. Difficulties may be encountered in sealing joints between very long slabs because of large volumetric changes caused by temperature changes.

3-B

b. Thickness design on stabilized base or subgrade. To determine the thickness requirements for reinforced concrete floor slabs on a stabilized foundation, it is first necessary to determine the thickness of nonreinforced concrete floor slab required for the design conditions. This thickness of nonreinforced floor slab is determined by the procedures set forth in paragraph 5-2*d*. Figure 5-4 is then entered with the values of h , h_r, and S

c. Limitations. The design criteria for reinforced concrete floor slabs on grade are subject to the following limitations:

(1) No reduction in the required thickness of nonreinforced floor slabs should be allowed for percentages of steel less than 0.05 percent.

(2) No further reduction in the required thickness of nonreinforced floor slabs should be allowed over that indicated in figure 5-4 for 0.50 percent steel, regardless of the percentage of steel used.

(3) The maximum length L of reinforced floor slabs should not exceed 75 feet regardless of the percentage of steel, yield strength of the steel, or thickness of the pavement.

(4) The minimum thickness of reinforced floor slabs should be 6 inches.

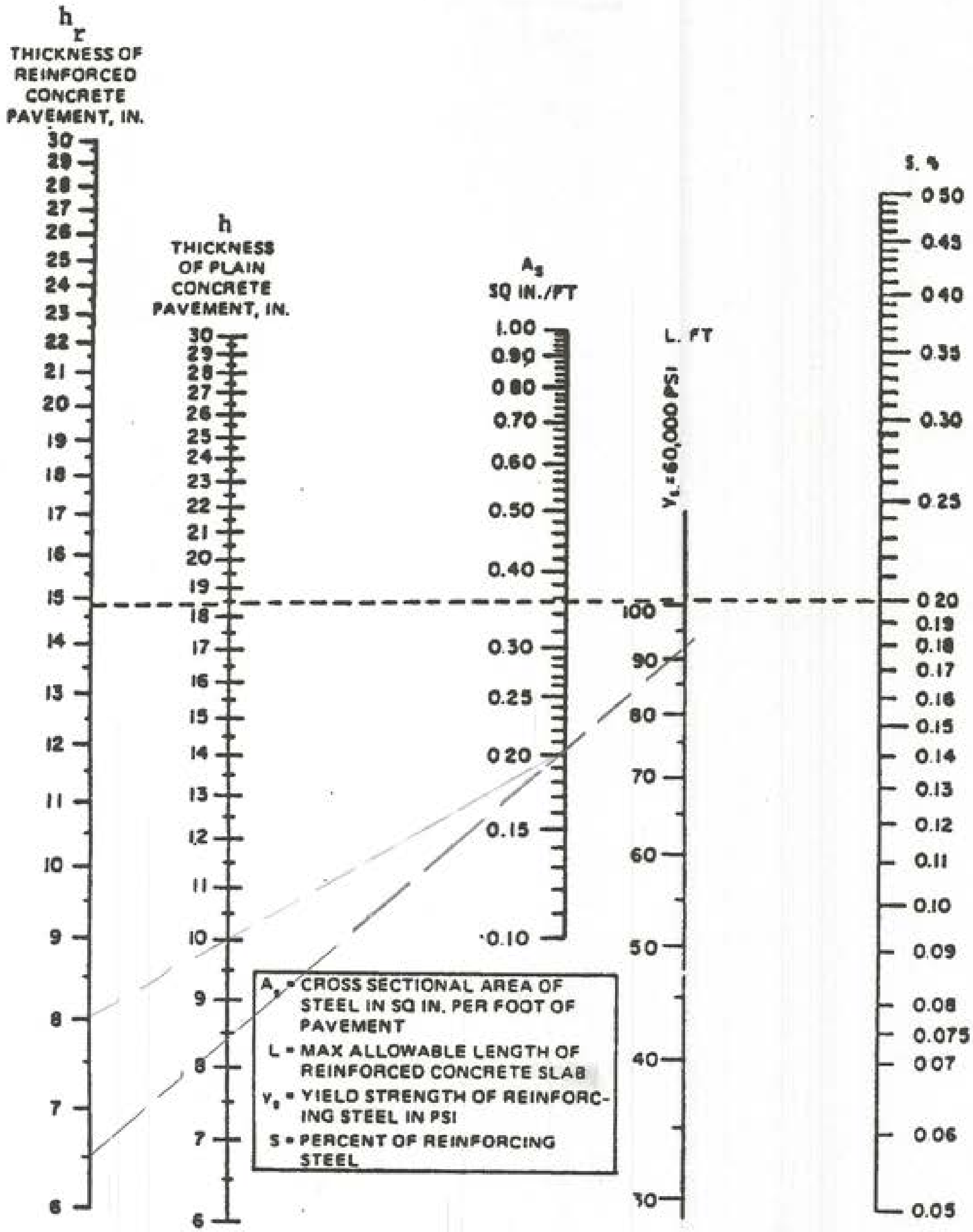
d. Reinforcing steel.

(1) Type. The reinforcing steel for floor slabs may be either deformed bars or welded wire fabric. Specifications for both types of reinforcement are given in TM 5-825-3/AFM 88-6, Chap. 3.

(2) Placement. Placement of the reinforcing steel in floor slabs should follow the criteria given in TM 5-825-3/AFM 88-6, Chap. 3. In addition, the following criteria regarding the maximum spacing of reinforcement should be observed. For welded wire fabric, the maximum spacing of the longitudinal wires and transverse wires should not exceed 6 inches and 12 inches, respectively; for bar mats, the maximum spacing of the longitudinal bars and the transverse bars should not exceed 15 inches and 30 inches, respectively.

5-7. Joint types and usage.

Joints are provided to permit contraction and expansion of the concrete resulting from temperature and moisture changes, to relieve warping and curling stresses due to temperature and moisture differentials, to prevent unsightly, irregular breaking of the floor slab; as a construction expedient, to separate sections or strips of concrete placed at different times; and to isolate the floor slab from other building components. The three general types of joints are contraction, construction, and isolation. A typical floor-slab joint layout is shown in figure 5-5.



REINFORCED CONCRETE PAVEMENT DESIGN

NOTE: MINIMUM THICKNESS OF REINFORCED CONCRETE FLOOR SLABS WILL BE 6 IN.

Figure 5-4. Design thickness for reinforced floor slabs.

3-D

CODE

in structural slabs and walls where the flexural reinforcement extends in one direction only.

7.12.1.1 — Shrinkage and temperature reinforcement shall be provided in accordance with either 7.12.2 or 7.12.3.

7.12.1.2 — Where shrinkage and temperature movements are significantly restrained, the requirements of 8.2.4 and 9.2.3 shall be considered.

7.12.2 — Deformed reinforcement conforming to 3.5.3 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

7.12.2.1 — For members subjected to environmental exposure conditions or required to be liquid-tight, the area of shrinkage and temperature reinforcement shall provide at least the ratios of reinforcement area to gross concrete area shown in Table 7.12.2.1:

Concrete sections that are at least 24 in. may have the minimum shrinkage and temperature reinforcement based on a 12 in. concrete layer at each face. The reinforcement in the bottom of base slabs in contact with soil may be reduced to 50 percent of that required in Table 7.12.2.1.

TABLE 7.12.2.1—MINIMUM SHRINKAGE AND TEMPERATURE REINFORCEMENT

Length between movement joints, ft	Minimum shrinkage and temperature reinforcement ratio	
	Grade 40	Grade 60
Less than 20	0.0030	0.0030
20 to less than 30	0.0040	0.0030
30 to less than 40	0.0050	0.0040
40 and greater	0.0060*	0.0050*

*Maximum shrinkage and temperature reinforcement where movement joints are not provided.

Note: This table applies to spacing between expansion joints and full contraction joints. When used with partial contraction joints, the minimum reinforcement ratio shall be determined by multiplying the actual length between partial contraction joints by 1.5.

COMMENTARY

cracking and to tie the structure together to ensure it is acting as assumed in the design. Where restraint is present to develop shrinkage and temperature stresses in the same direction as flexural stresses, the section may need to be checked for sufficient reinforcement for each kind of stress.

R7.12.1.2 — The area of shrinkage and temperature reinforcement required by 7.12 has been satisfactory where shrinkage and temperature movements are permitted to occur. For cases where structural walls or large columns provide significant restraints to shrinkage and temperature movements, it may be necessary to increase the amount of reinforcement normal to the flexural reinforcement in 7.12.1.2 (see Reference 7.15). Top and bottom reinforcement are both effective in controlling cracks. Control strips during the construction period, which permit initial shrinkage to occur without causing an increase in stresses, are also effective in reducing cracks caused by restraints.

R7.12.2 — The amounts given for deformed bars and welded wire fabric are empirical but have been used satisfactorily for many years. Splices and end anchorages of shrinkage and temperature reinforcement must be designed for the full specified yield strength in accordance with 12.1, 12.15, 12.18, and 12.19.

R7.12.2.1 — The required amount of shrinkage and temperature reinforcement is a function of the distance between the movement joints that will minimize cracking perpendicular to the reinforcement. In addition, the amount of shrinkage and temperature reinforcement is a function of the particular concrete mixture and other properties, the amount of aggregate, the member thickness, its reinforcement, and the environmental conditions of the site. These factors have been considered in applying the analysis method developed by Vetter[7.16] to environmental engineering concrete structures, and the recommendations contained in the remainder of this section are based on that work.[7.17]

When shrinkage-compensating concrete is used per manufacturer's recommendations, no less than 0.3 percent reinforcement should be provided.

Where positive means are taken to substantially reduce restraint, the amount of temperature and shrinkage reinforcement and the distance between movement joints may be adjusted accordingly.

Consideration may be given to reducing the amount of shrinkage and temperature reinforcement shown in Table 7.12.2.1 when details are developed in accordance with ACI 223 recommendations.

Where movement joints are not provided, shrinkage and temperature reinforcement need not exceed the values listed in Table 7.12.2.1 for greater than 40 ft joint spacing.

ARCADIS

SUBJECT: CWM CHEMICAL

JOB NO:

BY: LAB DATE: 8/29/11

CHKD: DATE:

PAGE 4

SHEET 1

RETAINING WALL AROUND PARKING AREA / LEACHATE TRANSFER RAMPS

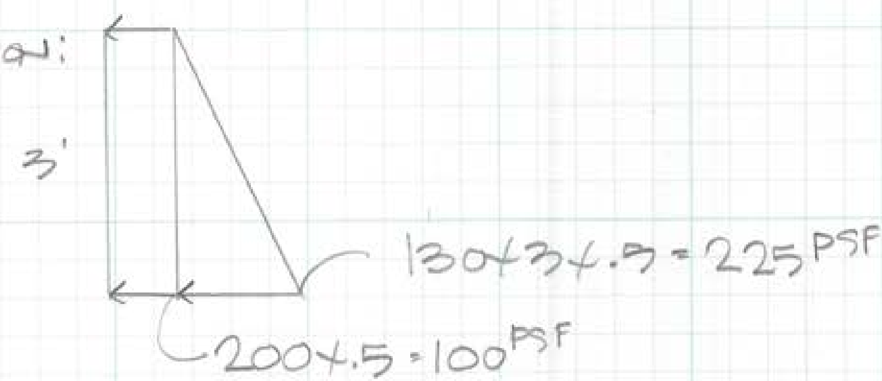
SAY 3' MAX W/ BACKFILL

FULL HT W/ $\gamma_{SOIL} = 130^{PCF}$

$K_a = .50$

SURCHARGE = 200 psf

LOAD DISTRIBUTION:



MMAX @ BASE OF WALL =

$100 \times \frac{3^2}{2} + 225 \times \frac{3^2}{6} = 788^{1\#/1}$

W/ LOAD FACTOR = 1.6 (FOR EARTH LOADS)

$M_u = 788 \times 1.6 = 1260^{1\#/1}$

FOR 8" WALL W/ $d \simeq 6.3"$, $b = 12"$, $\frac{M_u}{\phi b d^2} = 35.2$

W/ $f_c' = 4$ ksi
$f_y = 60$ ksi, ρreq'd IS VERY SMALL

USE SHRINKAGE & TEMPERATURE REINFORCING $\rho = .0018 \rightarrow A_s = .26^{in^2/1}$
SAY #4 @ 12" c/c EA FACE, EA WAY

ARCADIS

Appendix L

Facultative Pond Capacity Evaluation

NYSDEC OHMS Document No. 201469232-00007

Fac Pond Capacity Evaluation
Elimination of Fac Ponds 3 & 8
Construction of Fac Pond 5

Objective: To verify that the capacity of existing Fac Ponds 1&2 and New Fac Pond 5 are sufficient for storage for development of RMU-2.

Data: SPDES Discharges from FAC Ponds, AWTS volume of wastewater processed, and RMU-1 Leachate Generation Rates

Unit	Capacity (gallons)	Usable Capacity (gallons)	
Fac Ponds 1 / 2	22,881,000	19,345,100	
Fac Pond 3	51,355,000	43,845,300	
Fac Pond 8	43,414,000	38,834,500	Not Used Since 2004
Upon Development of RMU-2			
Fac Ponds 1 / 2	22,881,000	19,345,100	
Fac Pond 5	24,700,000	21,900,000	

Year	SPDES Discharge Event (gallons)	Total Leachate Processed at AWTS	RMU-1 Leachate (gallons)	RMU-1 Open Area (Acres)	RMU-1 Final Cover Events (Acres)
1997	25,614,700	11,120,682	14,079,610		
1998	23,986,400	13,889,894	5,924,828		
1999	26,272,100	14,699,323	6,785,396		
2000	19,046,000	16,646,143	7,490,388	32.61	6.99
2001	14,116,100	12,078,902	5,887,220	27.49	5.12
2002	22,271,300	13,405,497	9,282,814	24.47	3.02
2003	19,595,600	15,594,070	11,970,717	24.47	
2004	19,478,400	18,415,616	16,096,321	24.47	
2005	20,566,200	17,616,353	12,946,527	21.83	2.64
2006	30,433,600	14,500,137	9,606,283	21.83	
2007	22,632,015	12,553,074	10,520,174	21.83	
2008	15,066,861	14,347,001	11,878,570	21.83	
2009	14,215,564	15,543,238	14,116,427	21.83	
2010	12,846,231	16,194,812	14,666,777	21.83	
2011	18,457,879	18,208,174	15,485,141	11.8	11.2
2012	14,784,068	10,250,679	8,107,938	11.8	

Projected - Year	Projected Discharge Event (gallons)	Projected Total Leachate Processed	Projected RMU-1 Leachate (gallons)	Projected RMU-1 Open Area (Acres)	Projected RMU-1 Final Cover Events (Acres)	Projected RMU-2 Leachate (gallons)	Projected RMU-2 Open Area (Acres)	Projected RMU-2 Final Cover Events (Acres)
2013	12,872,899	8,789,333	6,592,000	7.30	4.5			
2014	10,312,899	6,229,333	4,672,000	7.30				
2015	12,898,136	8,814,570	2,336,000	-	7.3	4,274,927	6.7	-
2016	16,294,354	12,210,788	1,041,925	-		8,116,167	12.7	-
2017	15,776,897	11,693,331	653,832	-		8,116,167	12.7	-
2018	20,657,763	16,574,197	349,331	-		12,081,317	18.9	-
2019	20,465,624	16,382,058	205,227	-		12,081,317	18.9	-
2020	20,534,725	16,451,159	257,053	-		12,081,317	18.9	-

RMU-2 CELL APPROXIMATE OPEN WASTE AREA

CELL #	(ACRES)	CUMULATIVE ACRES
20	5.79	6.7
18	5.42	12.7
19	5.35	18.9
17	5.42	24.6
16	7.07	30.9
15	8.2	37.3

Conclusion: Fac Ponds 1&2 and Fac Pond 5 have sufficient capacity to store sitewide processed wastewater for development of RMU-2 through a minimum of the first three cells. It should be noted that this evaluation only assesses one SPDES discharge from the fac ponds per year. The SPDES permit allows for more than one discharge per year.

Assumptions:

1.) A conservative maximum volume of 640,000 gallons per open acre per year of landfill was used for projecting leachate generation rates for active landfill.
2.) 4.5 acres of RMU-1 final cover will be installed in 2013 and the remaining cover installed in 2015 and 2016.
3.) 75-percent of the wastewater processed at the AWTS is from an active landfill.
4.) Cell construction is anticipated to start in 2014 with the first cell open at the beginning of 2015 (best case scenario).
5.) Leachate generation rates for entirely capped/closed RMU-1 estimated based on the actual leachate generated from SFL-12 upon closure in 1995.
6.) The installation of final cover for RMU-2 will not be performed until the fourth cell is needed.
7.) Usable capacity Fac Ponds 1&2 and Fac Pond 5 are pond capacities with 2-foot of freeboard.