Burns & McDonnell
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April 24, 2006

Mr. Charles Nickle, P.E.
President
USI-Arkansas, Inc.
4847 Kaylee Ave., Suite B
Springdale, AR 72762

Dear Mr. Nickle:

The purpose of this letter is to provide you, as the lead Engineer on the Cabot WWTP Expansion and Upgrade project, with a firm understanding of the sizing and performance expectations of the two new final clarifiers that are to be installed as part of the new construction.

The two (2) clarifiers, each measuring 115-feet in diameter, are to use equipment supplied by USFilter as part of a pre-negotiated, performance-based contract. The equipment shall be for a center-feed, hydraulic suction sludge withdrawl or "Tow-Bro" system. The equipment shall incorporate a energy dissipating inlet design and has been specified to perform (in conjunction with the Orbal biological treatment system) in such a manner as to meet the performance criteria below:

Average Daily Flow: 6 MGD
Max Daily Flow: 16.4 MGD

Influent BOD (lb/day)
Average Daily: 12,000
Max Day: 20,800
Max Month: 16,500

Influent TSS (lb/day)
Average Day: 8,300
Max Day: 21,700
Max Month: 15,900

Effluent Requirements (mg/l monthly average)
BOD: 10
TSS: 10

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Kansas City, Missouri 64114-3319
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The original specification required that sizing for both the biological treatment system and the clarifiers be established in general agreement with the GLUMRB "10-States" Standards. In addition, performance testing has been specified and accepted by the manufacturer through their bid. This testing has been developed to allow, as much as is possible, for the completed system to operated under a simulated peak loading condition so as to allow observation of the performance of the system. This is to be accomplished by operating the system using a reduced operating volume and aeration capacity (to be determined at the time of testing).

It should be noted that the original design for the clarifiers submitted by USFilter was for two 102-foot diameter clarifiers. This design used an interpretation of the 10 State's Standards recommended values for hydraulic and solids loading that Burns & McDonnell did not feel were adequately conservative. We therefore revised the sizing based on the established standard of 35 lbs solids/sqft/day and 1,000 gpd/sqft hydraulic loading. Using a value of 4,000 ml/g MLSS, the revised clarifiers measure 115 feet in diameter. Under higher solids loading, the current clarifier design would not meet and explicit interpretation of the 10-State's Standard, but the following considerations should be made:

1. The hydraulic withdrawal system, rather than a conventional rake or spiral arm system, has a considerable operational history showing successful clarification at solids loading above 4,000 mg/l. The direct withdrawal of sludge, rather than driving the sludge to the center of the basin, produces fewer disturbances to the blanket, maintaining a more quiescent condition. A "white paper" report produced by USFilter is attached to this letter for further reference and reports that successful clarification has been achieved using the hydraulic withdrawal of solids at loading rates well above 35 lbs solids/sqft/day.
2. Wet weather conditions, where the risk of solids washout from the Orbal basin might be considered, may be mitigated by using the wet weather bypass capacity of the Orbal, where a large majority of the mixed liquor is held in the basin, while dilute wet weather flow is routed to the second or third treatment channel. This will help to reduce the amount of solids that would be otherwise washed out of the basin and into the clarifiers.

The current sizing will therefore meet the 10-State's Standards requirements for both hydraulic and solids loading when an MLSS concentration of 4,000 mg/l or less is used at influent rates of up to 16.4 MGD. Using an MLSS concentration of 4,500 mg/l the solids loading appears to exceed the 35 lbs/day/sqft criteria at influent flows over approximately 13.5 MGD. This flow rate is well over the anticipated influent rate of pure sewage, and would most certainly be a more dilute wet weather flow that would be managed by the wet-weather bypass system described previously.

In summary, this letter serves to notify USI-Arkansas and their Client, the City of Cabot, Arkansas, that the clarifier design to be provided as part of the wastewater treatment plant project will meet the general requirements of the 10-State's Standards under most conditions, but that it is possible that under higher flowrates, calculation of solids loading rate may result in values over 35 lbs solids/sqft/day. USFilter has provided substantial documentation that this condition should not substantially affect performance of the system, and that the system should still meet the water quality performance criteria established in the technical specifications.

I hope this documentation is adequate for your needs. If you are in need of additional information or clarification, please do not hesitate to call me at 816-822-4371 or at jkeller@burnsmcd.com .

Sincerely,

Jeffrey J. Keller
Project Manager

attachment

cc: File
John Mitchell

Tow-Bro® Clarifier
Evaluation

When evaluating sludge removal devices for your Activated Sludge Secondary Clarifier you will need to consider their ability to perform the following functions:

Rapidly return solids to aeration
Return concentrated solids
Respond quickly to changing return rates
Perform well when solids compaction properties deteriorate
Maximize solids loading potential of the clarifier

We believe the Tow-Bro® Clarifier is uniquely suited to meet all these needs.

<u>Rapid Sludge Removal</u>

Solids should not be stored in the secondary clarifier. This is particularly true for installations with restricted nutrient discharge permits. Returning a fresh sludge will reduce aeration requirements, eliminate rising solids produced from denitrification in the clarifier, limits phosphate release to the effluent and limits growth of filamentous bacteria. Even when returning solids to an anoxic selector it is important to keep biological solids in contact with the food source in an adequately mixed reactor.

Researchers have shown (IAWQ TR No. 6 – "Secondary Settling Tanks: Theory, Modelling, Design and Operation") that the onset of denitrification can occur from 5 minutes to 1 hour, with an average of 35-minutes (Crabtree 1983). Elevated sludge blankets have been found to increase the denitrification in the secondary clarifier by 15-20% at 10-degree C but this can increase significantly at higher temperatures. Others have demonstrated an immediate release of orthophosphate when settled sludge is removed from a supply of air.

Joseph Shapiro, et. al. report in the article "Anoxically Induced Release of Phoshhate in Wastewater Treatment" (Journal WPCF, Vol. 39, No. 11, pp 1810-1818, Nov. 1967) at the cities of Baltimore and Washington, DC that, even though soluble phosphate was reduced during aeration, the effluent from the clarifier frequently contained higher concentrations of phosphate than from the aeration basins. They demonstrate that as settled sludge nears the bottom of the clarifier it begins to release its phosphate into solution. The dissolved phosphate concentration was demonstrated to be greater near the center of the scraper equipped basin presumably because the older sludge is in greater concentration there. As scraper blades move through the sludge blanket they cause turbulence and mixing upward. The sludge solids settle again but the phosphate, being in solution, does not. The authors note further that suction-type clarifiers at York, PA showed less phosphate accumulation in the lower sludge blanket than did parallel scraper-type clarifiers. This underscores the importance of assuring a rapid sludge removal, particularly for installations with biological nutrient removal.

Dye tracer studies have been conducted on Tow-Bro clarifiers demonstrating unitube headers remove the bulk of sludge in less than 30 minutes. Similar tracer tests have not been conducted with spiral scraper collectors to field verify the removal characteristics.

Concentrated Return Solids

Even though the RAS concentration is greatly influenced by the amount of solids applied to the clarifier vs the removal rate from the clarifier (State Point Analysis), the removal mechanism you choose will determine how close the actual return concentration will approach the theoretical concentration.

The USFilter, Envirex Products' Tow-Bro sludge collector has been demonstrated to produce a denser sludge than competitive hydraulic removal collectors. Several side-by side comparisons are presented in the enclosed booklet. It is reported in Secondary Settling Tanks: Theory, Modeling, Design and Operation, Technical Report No. 6, (IAWQ, 1997, Page 170) that the Tow-Bro collectors at the Weyerhaeuser/Longview, WA site are able to achieve a 67% increase in RAS solids concentration compared to a similarly operated collector. As a result the Operators have adopted a practice of wasting solids exclusively from the Tow-Bro clarifier to minimize sludge handling costs. A denser RAS concentration is also necessary for maintaining higher MLSS concentrations in the aeration basins.

Robert Crosby's solids distribution studies clearly show that solids in a secondary clarifier settle uniformly across the full radius of the tank and compact with the heaviest solids concentration nearest the floor. The unique shape of the Tow-Bro unitube header allows these heavy solids to be gently vacuumed up without upward mixing. IAWQ Technical Report No. 6 points out that scraper equipped tanks, even spiral scraper tanks, develop deeper (less compact) sludge blankets. This is due to the continual disturbance of the settled solids as they are plowed to the center of the tank for removal.

The video "Studies on Sludge Removal Equipment for Rex Chain Belt Co.", (June 1954) is a useful tool for visualizing how settled activated sludge is transported in a secondary clarifier and why scraping is not recommended. A spillover of sludge which limits scraper capacity is noted, particularly with lighter sludges. Note that even though a low level blade is shown the scraper speeds are much slower compared to circular collectors (1 or 2 FPM vs 10 to 15 FPM tip speeds in circles) and a great many solids are re-suspended with counter-current scraping (all scraping is counter-current in circles). Solids are not disturbed with the unitube header once they have settled and compacted on the floor.

Changing Return Rates

Secondary clarifiers need to operate over a wide range of withdrawal rates and sludge blanket depths to be able to respond to peaks in the influent flow. Flow adjustment for Tow-Bro clarifiers is as easy as changing the RAS pump setting. Unlike scraper collectors, sludge transport is independent of the rotational speed so collector rotational speed adjustment is not necessary to assure removal of the bulk of the sludge mass that resides at the outer radius of the tank. Uniform sludge withdrawal across the full radius of the tank and the unique shape of the unitube header prevents "worm holing" through the sludge blanket, even at low blanket depth so short circuiting from the inlet ports to an open sludge hopper is eliminated. Because of these features the Tow-Bro collector is the only "zero blanket" sludge collector available. IAWQ Technical Report No. 6 (Page 169) points out that even deep blade scraper collectors develop sludge blankets in conditions under which they would not develop in clarifiers equipped with unitube headers. Higher sludge blankets take away from the clear water zone required in Center-feed clarifiers and result in increased solids loss. When higher sludge blankets need to be carried in the clarifier the tapered design of the unitube header and a slower rotational speed minimize disturbance of the settled solids to minimize re-suspension and loss to dispersed solids to the effluent.

Sludge Properties

The benefit of the gentle vacuum action of the unitube header will be most obvious during times when a plant is experiencing sludge bulking. When sludge does not compact well RAS rates may need to be increased to maintain adequate MLSS concentrations. Operators have reported to us that installation of a well-designed hydraulic header allows them to recover from biological upsets much quicker. By comparison, sludge transport in a scraper collector can be expected to deteriorate as sludge properties deteriorate, thus hindering the ability to maintain adequate MLSS levels.

Solids Loading

Solids loading capacity (lbs/sq-ft of floor area) is the most often ignored design parameter in studies of scraper equipped clarifiers. The uniform removal feature of the Tow-Bro header maximizes the mass loading capacity by using the entire floor area. Field verified design of the header orifices assures solids are removed in proportion to the floor area swept. Research by Crosby clearly demonstrates solids settle uniformly across the full basin radius of a flat floor. Scraper equipped circular clarifiers on the other hand must continually plow settled solids from the region of greatest area near the wall to the area of least floor area at the center of the tank. If an adequate sludge cone (floor slope) is not provided the mass accumulation of solids is limited to the point where they build up and encroach on the inlet flow stream. Tow-Bro clarifiers have been demonstrated to be able to handle solids loads as high as 60 lbs/sq-ft whereas data for scraper equipped clarifiers is not available beyond 35 lbs/sq-ft.

How do spiral scraper collectors compare? A recent study compared the effluent suspended solids (ESS) from two identical clarifiers, one equipped with a unitube hydraulic header and one with a spiral scraper. The study showed the unit with the hydraulic header did not increase dramatically in ESS under stress conditions. The spiral scraper equipped unit dramatically increased dramatically in ESS under identical stress conditions and rising solids were observed trailing the blade (Ref. "Rerating Study for Chambers Creek Wastewater Treatment Facility, Pierce County Utilities Authority", Brown and Caldwell, 1999).

Scraper collectors cannot operate with a flat floor. This increases excavation costs for new tanks compared to Tow-Bro clarifiers. Orry Albertson recommends spiral scraper floor slopes be 1.5-inch/ft for the inner 50 ft radius (100 ft diameter). Side water depth may also need to be increased to assure a minimum 5-ft sludge depth is maintained over the center hopper to prevent short circuiting from the center inlet well to the RAS pipe ("Energy Considerations in Circular Clarifier Design", Albertson, 65th WEF Annual Conference, 1992). Spiral scraper designers claim tip speeds as high as 15-18 fpm are acceptable to assure sludge transport but studies have shown a loss of solids over the weirs at these higher speeds and have lowered speeds to 10 fpm (Ref. Upgrading Existing Secondary Clarifiers to Enhance Process Controllabiity to Support Nitrification, G. Wheeler, R. Hegg, WEFTEC'99 Proceedings).

Sanitaire

ITT Industries

SANITAIRE®

FINE BUBBLE 9" SILVER SERIES II MEMBRANE GRID AERATION EQUIPMENT

Cabot, AR
Post Aeration

USI - Arkansas, Inc.

SANITAIRE #15837-04
December 13, 2005
dl c:\setups\15837

NPDES PERMIT FILE
NPDES # ____________
AFIN # ____________
____________ Permit PN
____________ Correspondence
____________ Technical Backup
____________ Date Scanned

TANKAGE

1 TRAINS EACH CONSISTING OF:

PASS NO.	PARALLEL REACTORS	ZONE PROCESS	SUBMERGENCE (FEET)	REACTOR DIMENSIONS (FEET)	VOLUME (KCF/PASS)
1	1	AEROBIC	3.68	15.00 L X 10.00 W X 4.50 D	0.68
2	1	AEROBIC	3.68	15.00 L X 10.00 W X 4.50 D	0.68

TOTAL VOLUME PER TRAIN 1.35
AERATED VOLUME PER TRAIN 1.35

DESIGN DATA

COND.	NO. TRAINS	BOD (#/DAY)	NH3-N (#/DAY)	OXYGEN (#/DAY)		AIR (SCFM)	WATER TEMP. (DEG. C.)
6MGD	1			200.34	A		27

DESIGN PARAMETERS

COND.	AOR/SOR	ALPHA	BETA	THETA	D.O. (ppm)	AMB. (PSIA)	O2/ BOD5	O2/ NH3	SRT (DAYS)
6MGD		.80	.980	1.024	2.42	14.341			

NOTES: @-PRECEEDING A VALUE INDICATES AN ASSUMPTION BY SANITAIRE
A-INDICATES ACTUAL (AOR) OXYGEN REQUIREMENT
S-INDICATES STANDARD CONDITION (SOR) OXYGEN REQUIREMENT
ROUND TANKS ARE EVALUATED AS SQUARE TANKS OF EQUAL SURFACE AREA
IF THE AOR/SOR PARAMETER IS NOT GIVEN, THEN ITS VALUE WILL BE CALCULATED BASED ON GIVEN OR ASSUMED ALPHA, BETA, D.O., THETA, PRESSURE, AND TEMPERATURE VALUES.

PERFORMANCE SUMMARY

EQUIPMENT:
- TYPE: FINE BUBBLE MEMBRANE GRID AERATION:
  (9 INCH DIAMETER DISCS; we v. 9/99)
- NUMBER OF GRIDS: 2
- NUMBER DIFFUSERS IN ALL GRIDS: 120

OXYGEN TRANSFER PERFORMANCE BASED ON:
DIFFUSER SUBMERGENCE OF 3.68 FEET WITH THE INDICATED AIR RATE PER DIFFUSER, AND RATIO OF TANK HORIZONTAL AREA TO DIFFUSER HORIZONTALLY PROJECTED AREA, (AT/AD), AS LISTED IN THE DETAILED SUMMARY.

CONDITION:	6MGD
TANKAGE:	
NO. TRAINS	1
AERATED VOLUME/TRAIN (KCF)	1.35
TOTAL AERATED VOLUME (KCF)	1.35
OXYGEN TRANSFER:	
REQ'D O2 #/DAY AOR	200.3
AOR/SOR	.54219
DELV'D O2 #/DAY SOR	369.4
REQ'D O2 #/DAY SOR	369.5
DELV'D SOTE (%)	8.40
SAFETY FACTOR (%)	
AIR RATES:	
TOTAL SCFM	175.4
SCFM/DIFFUSER	1.46
PSIG REQUIRED AT TOP OF DROPLEG (NOTE 1)	2.3
POWER ESTIMATES:	
*TOTAL BHP REQUIRED (NOTE 2)	2.73
DELV'D #O2/BHP/HR SOR	5.62
REQ'D #O2/BHP/HR SOR	5.62
REQ'D #O2/BHP/HR AOR	3.05

NOTES:

(1) BLOWER PRESSURE CAPACITY ALSO REQUIRES CONSIDERATION OF:
  A. THE AIR MAIN HEADLOSS (PIPING, FITTINGS, VALVES, INSTRUMENTATION, ETC.) BETWEEN THE BLOWER AND THE AERATION ASSEMBLY DROPLEG CONNECTIONS.
  B. POTENTIAL FOR INCREASED HEADLOSS RESULTING FROM DIFFUSER FOULING AND/OR AGING. PLEASE REFER TO THE US EPA FINE PORE DESIGN MANUAL (EPA/351/1-89-023), WEF MANUAL OF PRACTICE FD-13, AND OTHER TECHNICAL PUBLICATIONS FOR A DETAILED DISCUSSION ON THIS SUBJECT. NOTE THAT THIS HEADLOSS CONSIDERATION RELATES TO ALL FINE PORE SYSTEMS REGARDLESS OF SUPPLIER OR TYPE OF DIFFUSER ELEMENT.
  C. INCREASED DIFFUSER SUBMERGENCE DURING PEAK FLOW CONDITIONS.

(2) BHP QUOTED ASSUMES CLEAN DIFFUSERS, 0.3 PSI AIR MAIN HEADLOSS, ADIABATIC COMPRESSION, AND 70% MECHANICAL EFFICIENCY. MORE ACCURATE VALUES FOR POWER WILL DEPEND ON ACTUAL BLOWER, MOTOR, AND PLANT PIPING DESIGN.

DETAILED PERFORMANCE SUMMARY

```
TOTAL NUMBER OF PARALLEL AERATION TRAINS=   1 EACH WITH 2 PASSES.
   PASS  1  1 PARALLEL TANKS,  15.00 FT LONG,  10.00 FT WIDE CONTAINS:
     ZONE  1 -- AEROBIC; LENGTH= 15 FT
     GRID TYPE  1 WITH   4" DROPLEG:
       1 GRIDS/REACTOR WITH   60 DIFFUSERS/GRID
       AT/AD =  6.0976, 0.00 SCFM/FT2 MIXING AIR =   0.00 SCFM/GRID
   PASS  2  1 PARALLEL TANKS,  15.00 FT LONG,  10.00 FT WIDE CONTAINS:
     ZONE  2 -- AEROBIC; LENGTH= 15 FT
     GRID TYPE  2 WITH   4" DROPLEG:
       1 GRIDS/REACTOR WITH   60 DIFFUSERS/GRID
       AT/AD =  6.0976, 0.00 SCFM/FT2 MIXING AIR =   0.00 SCFM/GRID
```

CONDITION:	6MGD
COMPOSITE INFORMATION	
NUMBER TRAINS	1
TOTAL SCFM	175.4
DELV'D O2 #/DAY SOR	369.4
REQ'D O2 #/DAY SOR	369.5
TOTAL SOTE%	8.40
(DETAILED INFORMATION)	
GRID TYPE 1	
NO OPERATING GRIDS	1
SCFM THESE GRIDS	87.7
SCFM/DIFFUSER	1.46
DELV'D O2 #/DAY SOR	184.7
SOTE%	8.40
PSIG REQ'D AT DROP	2.3
GRID TYPE 2	
NO OPERATING GRIDS	1
SCFM THESE GRIDS	87.7
SCFM/DIFFUSER	1.46
DELV'D O2 #/DAY SOR	184.7
SOTE%	8.40
PSIG REQ'D AT DROP	2.3

NOTE: SOR IS OXYGEN AT "STANDARD CONDITIONS": ZERO D.O., 20 DEG.C. WATER, 1 ATMOSPHERE AMBIENT PRESSURE, AND CLEARWATER (IE:ALPHA & BETA=1).

OXYGEN TRANSFER CORRECTION FACTOR: AOR/SOR

THE RATIO OF ACTUAL SITE OXYGEN TRANSFER TO STANDARD CONDITION OXYGEN TRANSFER, (AOR/SOR), IS DEPENDENT ON A NUMBER OF FACTORS:

- 20 : STANDARD CONDITION TEMPERATURE (DEG.C)
- T : OPERATING WATER TEMPERATURE (DEG. C)
- P_{SC} : STD. COND. AMBIENT PRESSURE (1 ATMOSPHERE)
- P_{SITE} : OPERATING AMBIENT PRESSURE (PSIA)
- ALPHA : FIELD/STD.COND. KLA RATIO
- BETA : FIELD/STD.COND. O2 SATURATION RATIO
- THETA : OPERATING WATER TEMPERATURE FACTOR
- D.O. : OPERATING OXYGEN CONCENTRATION (MG/L)
- $C\ SURF_T$: CLEARWATER SURFACE O2 SATURATION AT OPERATING TEMPERATURE (MG/L)
- 9.07 : CLEARWATER SURFACE O2 SATURATION AT 20 DEG. C. (MG/L)
- $C^*\ SAT_{20}$: STD. COND. AERATED O2 SATURATION IN THE TANK (MG/L)

$$AOR/SOR = \frac{(THETA)^{T-20}\ (ALPHA)\left[(BETA)(C^*\ SAT_{20})(CSURF_T/9.07)(P_{SITE}/P_{SC}) - (D.O.)\right]}{(C^*\ SAT_{20})}$$

COND.	ALPHA	BETA	THETA	DO ppm	P_{site}	WATER TEMP. deg.C	$C^*\ SAT_{20}$	$C\ SURF_T$	AOR/SOR
6MGD	.80	.980	1.024	2.42	14.341	27	9.305	7.920	0.5422

NOTE: @-PRECEEDING A VALUE INDICATES AN ASSUMPTION

STANDARD CONDITIONS FOR OXYGEN TRANSFER IMPLIES: CLEARWATER AT 20 DEG. C., ZERO DISSOLVED OXYGEN AND 1 ATMOSPHERE AMBIENT PRESSURE.

POST AERATION PERFORMANCE SIMULATION
UTILIZING DISPERSION ESTIMATION

FLOW: 6.000E+00 (MGD), INFLUENT DO= 0.00 (mg-O2/l)
WATER TEMP= 27.0 (deg.C), alpha= .800, beta= 0.980, Amb. Press= 14.34 (Psia)
FINE BUBBLE AERATION, DIFFUSER SUBMERGENCE= 3.7 (ft)
AT/AD= 6.097561 , 120 DIFFUSERS EACH AT 1.462334 SCFM.
Csat(sc)= 9.3048 Csat(actual)= 7.7684
...DESIGN TO YIELD EFFLUENT DO OF 4.00 (mg-O2/l)
BOD DEMAND OF WATER= 0 MG/L/HR

>>>POST AERATION PASS 1<<<
LENGTH= 15.0 (ft), WIDTH= 10.0 (ft), DEPTH= 4.5 (ft)
AT 130.0 (SCFM/KCF), THE DISPERSION NUMBER= 1.010E-01

TANK LENGTH (FT)	ACCUMULATED DETENTION (MIN)	D.O. DEFICIT (mg/l)	OXYGEN CONCENTRATION (mg/l)	AOR (mg/l/hr)	SOR (mg/l/hr)
0.0	0.00	7.50	0.27	138.82	182.47
1.5	0.12	7.23	0.54	133.90	182.47
3.0	0.24	6.97	0.80	129.15	182.47
4.5	0.36	6.73	1.04	124.58	182.47
6.0	0.48	6.49	1.28	120.16	182.47
7.5	0.61	6.26	1.51	115.92	182.47
9.0	0.73	6.04	1.73	111.85	182.47
10.5	0.85	5.83	1.94	107.98	182.47
12.0	0.97	5.64	2.13	104.44	182.47
13.5	1.09	5.48	2.29	101.54	182.47
15.0	1.21	5.41	2.36	100.16	182.47

>>>POST AERATION PASS 2<<<
LENGTH= 15.0 (ft), WIDTH= 10.0 (ft), DEPTH= 4.5 (ft)
AT 130.0 (SCFM/KCF), THE DISPERSION NUMBER= 1.010E-01

TANK LENGTH (FT)	ACCUMULATED DETENTION (MIN)	D.O. DEFICIT (mg/l)	OXYGEN CONCENTRATION (mg/l)	AOR (mg/l/hr)	SOR (mg/l/hr)
0.0	1.21	5.22	2.55	96.64	182.47
1.5	1.33	5.03	2.74	93.21	182.47
3.0	1.45	4.85	2.91	89.91	182.47
4.5	1.58	4.68	3.09	86.72	182.47
6.0	1.70	4.52	3.25	83.65	182.47
7.5	1.82	4.36	3.41	80.70	182.47
9.0	1.94	4.20	3.56	77.86	182.47
10.5	2.06	4.06	3.71	75.17	182.47
12.0	2.18	3.93	3.84	72.71	182.47
13.5	2.30	3.82	3.95	70.69	182.47
15.0	2.42	3.76	4.00	69.73	182.47

Post Aeration Air Rate= 130.0 (SCFM/KCF)= 175.5 SCFM (TOTAL)
Kla(actual) = 18.522 (1/hr)
AOR total = 200.3 (lbs-O2/day)
Kla(sc) = 19.611 (1/hr)
SOR total = 369.5 (lbs-O2/day)

WEIGHTED MEAN DO = 2.427 (PPM-O2)

ONE AERATION ASSEMBLY HEADLOSS

GRID TYPE 1 WITH 60 DIFFUSERS
CALCULATED FOR THE 6MGD CONDITION

AIR RATE PER GRID= 87.74 SCFM
ASSUMED OPERATING TEMPERATURE= 100 DEG. F.
ASSUMED PRESSURE AT THE TOP OF DROPLEG= 1.993 PSIG

MANIFOLD IS INLINE, END FEED - DROPLEG AT CENTER OF MANIFOLD
7.0 FT LONG WITH 5 HEADERS AT 1.75 FT
HEADERS EACH 13.4 FT WITH 12 DIFFUSERS
HEADERS ARE PARALLEL TO LENGTH OF TANK

(STATIC HEADER PRESSURE DIFFERENTIAL IN ASSEMBLY =	2.17E-03	(PSI)
(AVERAGE HEADER PRESSURE IN ASSEMBLY =	1.99	PSIG)
A: AVERAGE HEADLOSS FROM TOP OF DROPLEG TO HEADERS =	3.26E-03	PSI
B: DIFFUSER ORIFICE HEADLOSS WITH ONE 13/64" PORT =	1.24E-01	PSI
C: DIFFUSER DYNAMIC WET PRESSURE AT 1.462 SCFM =	5.16E-01	PSI
D: 3.680 FEET OF SUBMERGENCE =	1.59	PSIG
TOTAL PRESSURE REQUIRED AT TOP OF DROP (A+B+C+D) =	2.24	PSIG
(FRICTION HEADLOSS (A+B) = 1.27E-01 PSI)		

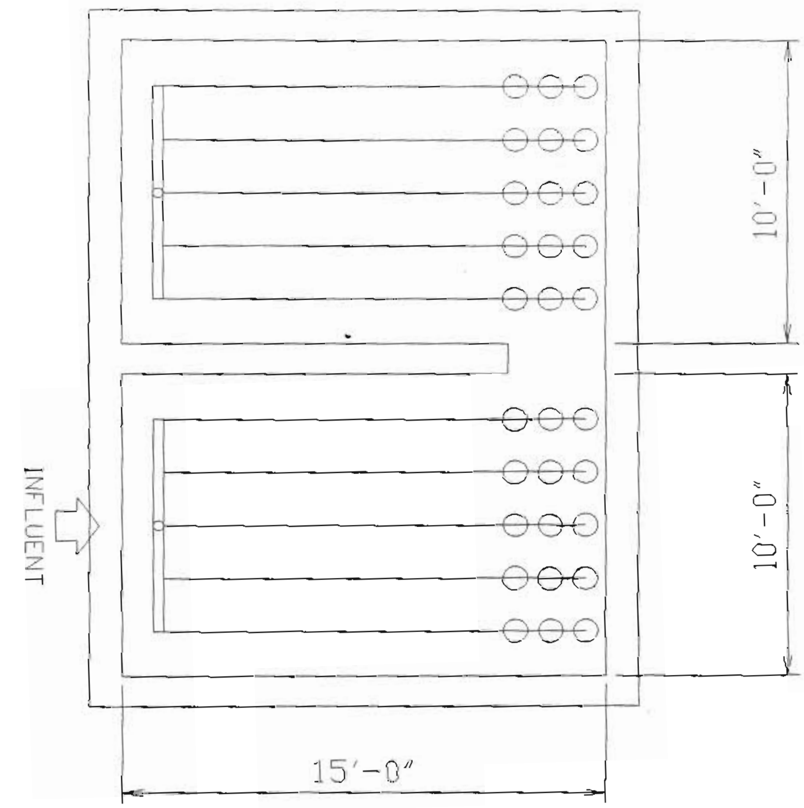
ONE AERATION ASSEMBLY HEADLOSS

GRID TYPE 2 WITH 60 DIFFUSERS
CALCULATED FOR THE 6MGD CONDITION

AIR RATE PER GRID= 87.74 SCFM
ASSUMED OPERATING TEMPERATURE= 100 DEG. F.
ASSUMED PRESSURE AT THE TOP OF DROPLEG= 1.993 PSIG

MANIFOLD IS INLINE, END FEED - DROPLEG AT CENTER OF MANIFOLD
7.0 FT LONG WITH 5 HEADERS AT 1.75 FT
HEADERS EACH 13.4 FT WITH 12 DIFFUSERS
HEADERS ARE PARALLEL TO LENGTH OF TANK

(STATIC HEADER PRESSURE DIFFERENTIAL IN ASSEMBLY =	2.17E-03	(PSI)
(AVERAGE HEADER PRESSURE IN ASSEMBLY =	1.99	PSIG)
A: AVERAGE HEADLOSS FROM TOP OF DROPLEG TO HEADERS =	3.26E-03	PSI
B: DIFFUSER ORIFICE HEADLOSS WITH ONE 13/64" PORT =	1.24E-01	PSI
C: DIFFUSER DYNAMIC WET PRESSURE AT 1.462 SCFM =	5.16E-01	PSI
D: 3.680 FEET OF SUBMERGENCE =	1.59	PSIG
TOTAL PRESSURE REQUIRED AT TOP OF DROP (A+B+C+D) =	2.24	PSIG
(FRICTION HEADLOSS (A+B) = 1.27E-01 PSI)		



PRELIMINARY

This drawing is not intended for Contract Documents, Submittals or Construction

Single Train Information

Grid No	No Grids	Drop Leg Ø"	No Headers	Header Spc,ft.	Header Len,ft.	Discs Grid	At Ad	Discs Train
1	1	4	5	1.75	13.4	60	6.09	60
2	1	4	5	1.75	13.4	60	6.09	60

Total Discs/Train 120

Note: Some headers may be omitted for clarity

Sanitaire ITT Industries BROWN DEER, WISCONSIN 53223	CUST NO DWG NO	THIS DRAWING IS THE PROPERTY OF SANITAIRE CORPORATION AND IS SUBMITTED IN CONFIDENCE. IT IS NOT TO BE DISCLOSED, USED OR DUPLICATED WITHOUT PERMISSION OF SANITAIRE CORPORATION.	Cabot, AR 9' Disc Aeration System	DRAWN BY CHKD BY APPVD BY	DATE 12/13/05 DATE DATE	MODEL	JOB 15837-04 SHEET

III. CLARIFIER BASIN SIZING

Design Flows - 6.0 MGD Ave. Daily Flow
16.4 MGD Peak Daily Flow

Aeration Basin Design Criteria

- 6.0 MGD Max RAS
- 2,500 mg/l MLSS at Daily Flow Rates

Design Standards (Ten States) for Single Stage Nitrification

- 1,000 GPD/ft² at Peak Flow
- 35/day/ft² Maximum Solids Load

Clarifier Sizing – Hydraulic Loading

$$Ft^2\ Req'd = \frac{Q}{1{,}000\ GPD/ft^2} = \frac{16.4 \times 10^6 G/D}{1{,}000 G/D/ft^2} = 16{,}400\, ft^2$$

Assume 2 clarifiers: Area/Clarifier = 8,200 ft²

$$\text{Clarifier Diameter} = \sqrt{\frac{A}{.7854}} = \sqrt{\frac{8{,}200}{.7854}} = 102.2'$$

Say two (2) 102' diameter clarifiers.

Clarifier Sizing – Solids Loading

$$Ft^2\ Req'd = \frac{W\#/D}{35\#/D/ft^2} = \frac{Q_{MLSS} 8.34}{35\#/D/ft^2} = 16.4 + 6.0)\frac{(2500)8.34}{35\#/D/ft^2} = 13{,}344\, ft^2$$

Assume 2 clarifiers: Area/Clarifier = 6,672 ft²

$$\text{Clarifier Diameter} = \sqrt{\frac{A}{.7854}} = \sqrt{\frac{6{,}672}{.7854}} = 92.2'$$

Say two (2) 95' diameter clarifiers.

Use two (2) 102' diameter center feed Tow-Bro clarifiers.

Note: Spiral scraper clarifiers are limited to 27#/D/ft². Ten State standards require hydraulic sludge removal for activated sludge clarifiers greater than 60' diameter.

OZONIA®

UV Dose and Hydraulic Calculations

Aquaray® 40 High Output VLS Ultraviolet Disinfection System

November 14, 2005

Delivered UV Dose Calculations - ODI Aquaray 40 HO VLS
Secondary Effluent

The following calculations are based on the November 2001 BIOASSAY FOR PRIMARY/SECONDARY EFFLUENTS. The data has been linearly scaled (i.e. pilot flow to full-scale flow) within the bioassay report to represent the AQUARAY 40 HO SYSTEM.

System Design Parameters

Flow Rate (MGD)	Q=	16.4
Number of Channels	Nc=	2
Number of Modules Across	Nm=	1
Number of Banks in Series	B=	3
UV Transmittance (%)	UVT=	60
End-of-life Factor	Fp=	0.9
Fouling Factor*	Ft=	1.0
Design Dose (mJ/cm2)	Ddose=	25.0

(*) In addition to 10% loss of transmittance through the Quartz sleeve

Dosage Calculation

Flow per train (Qtrain). One train is defined as being a single row of modules. The total flow is divided equally between each channel and equally between each row of modules in each channel.

$$Q_{train} = \frac{Q}{N_C \cdot N_m}$$ with 1.15 MGD < Qtrain < 8.06 MGD

Qtrain= 8.2 MGD

The delivered dose per bank (D_B) at given UVT for the Aquaray 40 HO System is as follows,

$$D_B = 41.3 \cdot IF \cdot \frac{Fp}{0.8} \cdot \frac{Ft}{1.0} Qtrain \wedge (-.735) \cdot 1{,}000$$

D_B= 8,486 uWs/cm2

IF is the Intensity Factor calculated from a PSS simulation (UVDIS 3.1) of the Aquaray 10 HO

$$IF = \frac{0.0036 \cdot UVT(\%)^2 - 0.2283 \cdot UVT(\%) + 7.4121}{0.0036 \cdot 65^2 - 0.2283 \cdot 65 + 7.4121}$$ IF= 0.858

The total delivered dose is calculated by multiplying the delivered dose per bank (D_B) by the number of banks in series B. The result should be higher or equal to the design dose specified above

Dose= Db*B

Dose= 25,459 uWs/cm2 **Design Dose Safely Achieved**

HEADLOSS CALCULATIONS
AQUARAY 40 HO UV DISINFECTION SYSTEM

Cabot Wastewater Treatment Plant Upgrade & Expansion

FLOW RATE
Q = 16.4 MGD = 11389 GPM

NUMBER OF UV DISINFECTION CHANNELS
N = 2

NUMBER OF UV DISINFECTION MODLES PER UV REACTOR BANK
Nm = 1

NUMBER OF UV REACTOR BANKS IN SERIES PER UV CHANNEL
B = 3

RESIDENCE TIME (FROM UV DOSAGE CALCUATIONS)
T = 4.53 s

FLOW VELOCITY THROUGH UV CHANNEL AREA = B * Lm / T
FPS = 1.38 ft/s

HEAD LOSS PER UV REACTOR BANK = 0.58 * FPS ^ 1.9
Hb = 1.07 in

FACTOR OF SAFETY
Fs = 0.5 in

TOTAL HEAD LOSS PER CHANNEL = (B * Hb) + Fs
H = 3.70 in

Weir Calculations

Aquaray® 40 High Output VLS Ultraviolet Disinfection System

November 14, 2005

Francis Formula

Q = (3.33)x{(Le)-(0.2)x(H)}x(H)^[1.5]
Q = flow rate, cfs
Le = effective weir length, ft
H = weir crest, ft

Figure weir crest via iteration, given maximum flow rate and effective weir length

Description	Value	Units	Assigned variable	Formula
Maximum flow rate, mgd	8.20	mgd	Q,mgd	Job parameter
Maximum flow rate, cfs	12.69	cfs	Q,cfs	(Q,mgd)x(1.54723)
Length of weir trough(s) not including weir wall	9.00	feet	Lw	Job parameter
Number of weir trough(s)	3.00	---	N	Job parameter
Effective length of weir trough(s)	54.00	feet	Le	(Lw)x(2)x(N)
Weir crest, inches	2.000	inches	H,in	Job parameter
Weir crest, feet	0.17	feet	H,ft	(H,in)/(12)
Flow rate from Francis formula	12.23	cfs	Qcalc,cfs	(3.33)x{(Le)-(0.2)x(H)}x(H)^[1.5]

Critical Depth Formula
from "Open Channel Hydraulics" text book

C = {(Qt)^2/((B^2)x(g))}^[1/3]
C = critical depth, ft
Qt = trough flow rate, cfs
B = width of weir opening
g = gravitational constant, ft/ss

Figure critical depth of trough, given maximum flow rate and width of weir opening

Description	Value	Units	Assigned variable	Formula
Maximum flow rate, cfs	12.69	cfs	Qmax,cfs	(Qmax,mgd)x(1.54723)
Number of entrance weir troughs	3.00	---	N	Job parameter
Gravitational constant	32.19	ft/ss	g	Constant
Width of weir trough opening, inches	8.00	inches	B,in	Job parameter
Width of weir trough opening, feet	0.67	feet	B,ft	(B,in)/(12)
Maximum trough flow rate	4.23	cfs	Qt	(Qmax)/(N)
Critical depth of weir trough, ft	1.08	feet	Cf	{(Qt)^2/((B^2)x(g))}^[1/3]
Critical depth of weir trough, in	12.93	inches	Ci	(Cf)x(12)
Depth of trough with Safety Factor	18.00	inches	Csf	(Ci)x(1.5)

Bioassay

Aquaray® 40 High Output VLS Ultraviolet Disinfection System

November 14, 2005

Ondeo Degremont, Inc.
Richmond, Virginia

FINAL REPORT

ULTRAVIOLET DOSE BIOASSAY OF THE ONDEO DEGREMONT AQUARAY HO10 VERTICAL LAMP DISINFECTION SYSTEM

November 2001

Project No: IDIC0020

HydroQual

Environmental
Engineers & Scientists

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ULTRAVIOLET DOSE BIOASSAY OF THE ONDEO DEGREMONT HO10 VERTICAL LAMP DISINFECTION SYSTEM

An assay and related testing were conducted by HydroQual, Inc., on an ultraviolet disinfection system manufactured by Ondeo Degremont, Inc. (ODI), Richmond, Virginia. The equipment consisted of two 10-lamp modules in series, with the lamps in each assembled vertically in a staggered 2 x 5 array. All work was conducted at the Rockland County Sewer District No. 1 WWTP in Orangeburg, New York.

The objective of the bioassay was to develop a relationship between delivered UV dose and flow rate through a scaleable UV test reactor. Dose is defined as the product of UV intensity (I) and exposure time (t), or It. Intensity cannot be measured directly in a multilamp reactor, and time is, in fact, a distribution of residence times within the system, related to the degree of mixing. As such, it is difficult to estimate dose by separate evaluation of these two variables. As an alternative, the bioassay protocol uses an approach that implicitly estimates the delivered dose. In this method, a culture of bacteriophage is subjected to varying UV doses in a laboratory apparatus that allows direct and accurate measurement of time and intensity, yielding a dose-response calibration of the organisms. The culture is then injected into the test unit under specific operating conditions. The bacteriophage response is measured, from which a delivered dose estimate can be implied.

The bioassays were conducted with potable water. The UV transmittance (at 253.7 nm) of the water was adjusted to 58 percent. This represents a combined simulation of a wastewater transmittance of 65% and a 20% reduction in UV output equivalent to end-of-lamp-life operating conditions. Hydraulic tracer tests were also conducted to define the residence time distribution of the unit and its conformity with plug flow conditions that are required for disinfection.

MATERIALS AND METHODS

The following discussions present the procedures and materials that were used to conduct the bioassay and hydraulic tests on the Ondeo Degremont vertical lamp system. Specifically, these address the culturing and calibration of the bacteriophage, assembly and operation of the test unit, assay of the test unit with the calibrated bacteriophage, and hydraulic characterization of the test unit.

F-Specific RNA Bacteriophage Preparation

The organism that was used to assay the test unit was a F-specific RNA bacteriophage, a bacterial virus that can infect a specific host strain with F- or sex-pili, producing clear areas, or plaques within a confluent lawn of grown host strain. It has a relatively high tolerance to UV light and exhibits dose requirements that are typically higher than required by most bacterial organisms. This allows development of a dose-response relationship that encompasses dose levels required for most wastewater disinfection applications. Additionally, the response of the bacteriophage is fairly consistent over repeated applications.

The methodology for detection and enumeration of F-specific RNA bacteriophage was in accordance with ISO DIS 10705-1 (Havelaar): Water Quality - Detection and Enumeration of Bacteriophages. The host strain was *Escherichia coli (E. coli)* ATCC 23631. The bacteriophage stock was developed by HydroQual, Inc., grown to a density from 2 to 4 x 10^{11} pfp/mL.

Dose-Response Calibration

Dose is the product of the intensity of radiation and the time to which an organism is exposed to the radiation. Intensity can not be measured directly in a complex lamp unit because the light surrounds a receiving particle and commercial detectors are planar. Additionally, the exposure time in a system is, in fact, a distribution of times due to some degree of mixing in the unit. Thus, the bioassay relies on first calibrating the assay organism in the laboratory by defining its response to a given dose. The dose is measurable in this case because the radiation is collimated (unidirectional) and the test is run in a batch, completely mixed mode, such that time is measurable as discrete intervals of exposure.

A dose-response relationship was developed for the bacteriophage using a laboratory-scale collimated beam apparatus. The unit utilized a G64T5L germicidal lamp as the UV source. The lamp is enclosed in a non-reflective, air-cooled sleeve. The exposed portion[1] of the lamp (approximately 10 cm) was suspended above a 30-cm long, 10-cm diameter non-reflective collimating tube. A petri dish containing sufficient sample to give a liquid depth of 1 cm (79 mL) was placed approximately 2.3 cm below the bottom of the collimator.

Prior to exposure, the intensity of the ultraviolet radiation was adjusted to 200 :Watts/cm^2 at the surface of the sample. Intensity was measured with an IL1700 Radiometer using a SED-240 Detector with a W Quartz wide-eye diffuser and a NS254 filter. The detector was last calibrated by

International Light, Inc., of Newburyport, Massachusetts in November 2000. A copy of the calibration certificate can be found in Appendix A.

The stock bacteriophage aliquot was diluted with the same source water that was used for the assays. The water was first dechlorinated and phage were then added to yield a density between 1 and 2 x 10^5 pfp/mL. The sample was stirred gently and continuously during exposure using an insulated magnetic mixer with a micro-spinbar. After exposure, samples were plated immediately. The plates were incubated at 37°C for 16 to 20 hours, after which the number of plaque forming units were counted.

Dose-response runs were conducted throughout the test period. Four to five exposures times were used per run, ranging between 100 and 500 seconds and equivalent to dose levels between 20 and 100 mW-sec/cm^2. Control (no exposure) and exposed samples were sampled in triplicate, and two dilutions of each were plated in triplicate. Two control samples, with one sample representing time zero, were normally run for each dose run. Intensity was mapped at 20 locations over the plane of exposure. The intensity was also checked at each of the control exposure periods to verify that no variation in intensity occurred within a given run.

Test Unit

A 20 ft (6.1 m) long, stainless steel open-channel, 1 ft (0.30 m) wide, provided by Ondeo Degremont, Inc. was used for the test unit. A stilling plate was inserted into the upstream section of the channel, approximately 42 in (1.1 m) ahead of the lamp battery to break the energy of the inlet pipe. A adjustable rectangular weir was installed at the end of the channel (approximately 5 ft (1.5 m) downstream of the lamp battery). A stilling plate was inserted about 42 in (1.1 m) downstream of the second lamp bank and prior to the weir. The channel width in the disinfection zone was 7.25 in (18.4 cm).

Two UV disinfection modules were mounted in series in the channel. The lamp configuration for each module is shown schematically in Figure 1. The system utilized a staggered lamp array configuration, with the lamps placed vertically in the channel, perpendicular to the direction of flow, and on centerline spacings of 2.8 in (7.1 cm) across the width of the module and 5 in (12.7 cm) along the length of the module. The test unit had a total of 20 lamps.

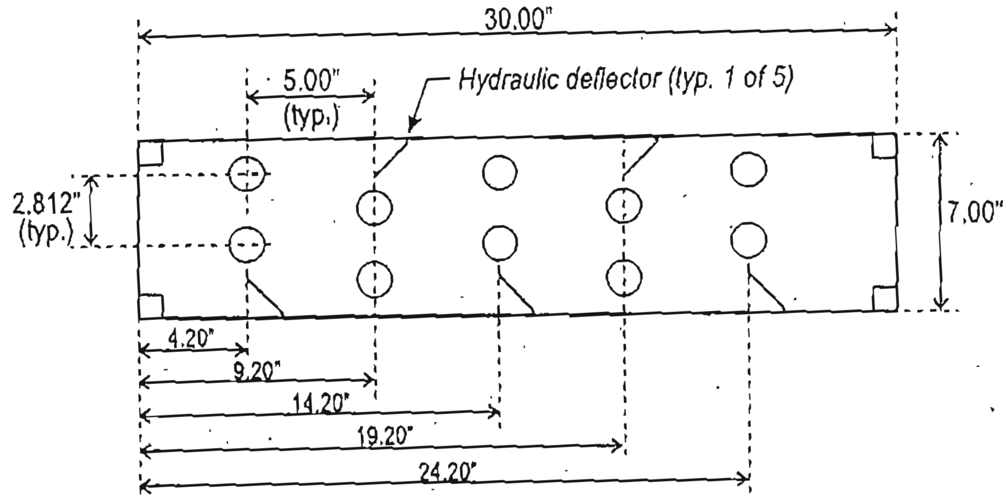


Figure 1. Lamp Module Schematic.

The high-intensity, low-pressure, germicidal lamps have a rated UV output of 52 watts (W) UV, and a total power draw of 165W. The lamps have a nominal length of 60 in (155 cm) and an effective arc length of 58 in (147 cm). The quartz sleeves were a test-tube type, with one sealed end, and an outer diameter of 1 inch (2.45 cm). The lamps were first "burned-in" for a minimum of 100 hours before testing. The lamps were driven by 10 electronic ballasts, each controlling 2 lamps. The ballasts were located inside a control box mounted on top of each lamp module. The nominal voltage to the system 230 VAC.

Test Unit Installation

Figure 2 is a schematic of the field test installation at the Rockland County Sewer District No. 1 Plant in Orangeburg, New York. A local potable water hydrant was used as the source of water for testing. A batch stock solution consisting of coffee (to alter transmittance), sodium thiosulfate (to ensure removal of residual chlorine) and bacteriophage was prepared in a large rectangular steel tank. The mixture was fed to the unit via a diesel-powered centrifugal pump. Water flow rates to the unit were set and measured by a Bailey-Fischer & Porter magnetic flow meter, Model 10D1465P-NS, which was installed on the influent line to the UV reactor.

The flow meter calibration was checked by comparing the flow readings from the in-line meter to flows implied from velocity measurements in the channel over the range of treated flows. These were within 5% of the direct meter readings. In all testing, the meter flows were used for reporting operating conditions.

Bioassay Analysis

A component of the bioassay protocol was to simulate end of lamp life conditions during testing. For this bioassay, a value equal to 80% of the nominal UV output of the lamp was simulated; where the nominal UV output represents the UV output at normal operating conditions (voltage, amperage, etc.) after approximately 100 hours burn-in. The commercial (and pilot) system's lamp-ballast configuration is not designed to allow direct electrical manipulation to reduce lamp output. As such, an alternate approach to simulate end-of-life conditions was developed. Using HydroQual's main-frame version of The Ultraviolet Light Intensity Program or TULIP, the Aquaray system configuration was modeled and a relationship of theoretical average intensity versus percent transmittance (at 254 nm) was developed. The numerical values of theoretical average intensity as a function of water transmittance is shown for both the full-scale 40HO module and the 10HO test module on Table 1. Figure 3 presents these relationships graphically.

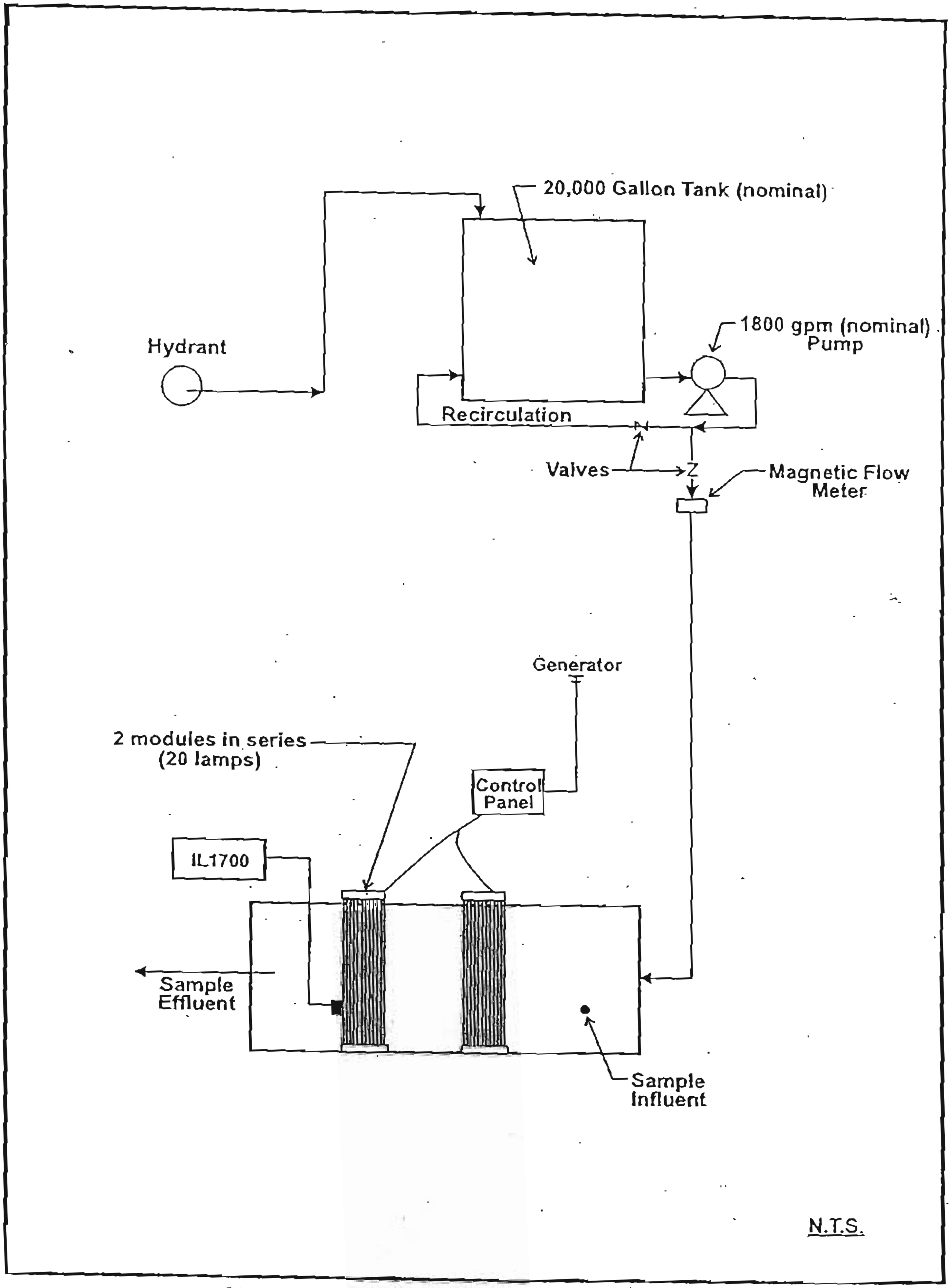


Figure 2. Schematic of the Test Installation for the ODI Disinfection System.

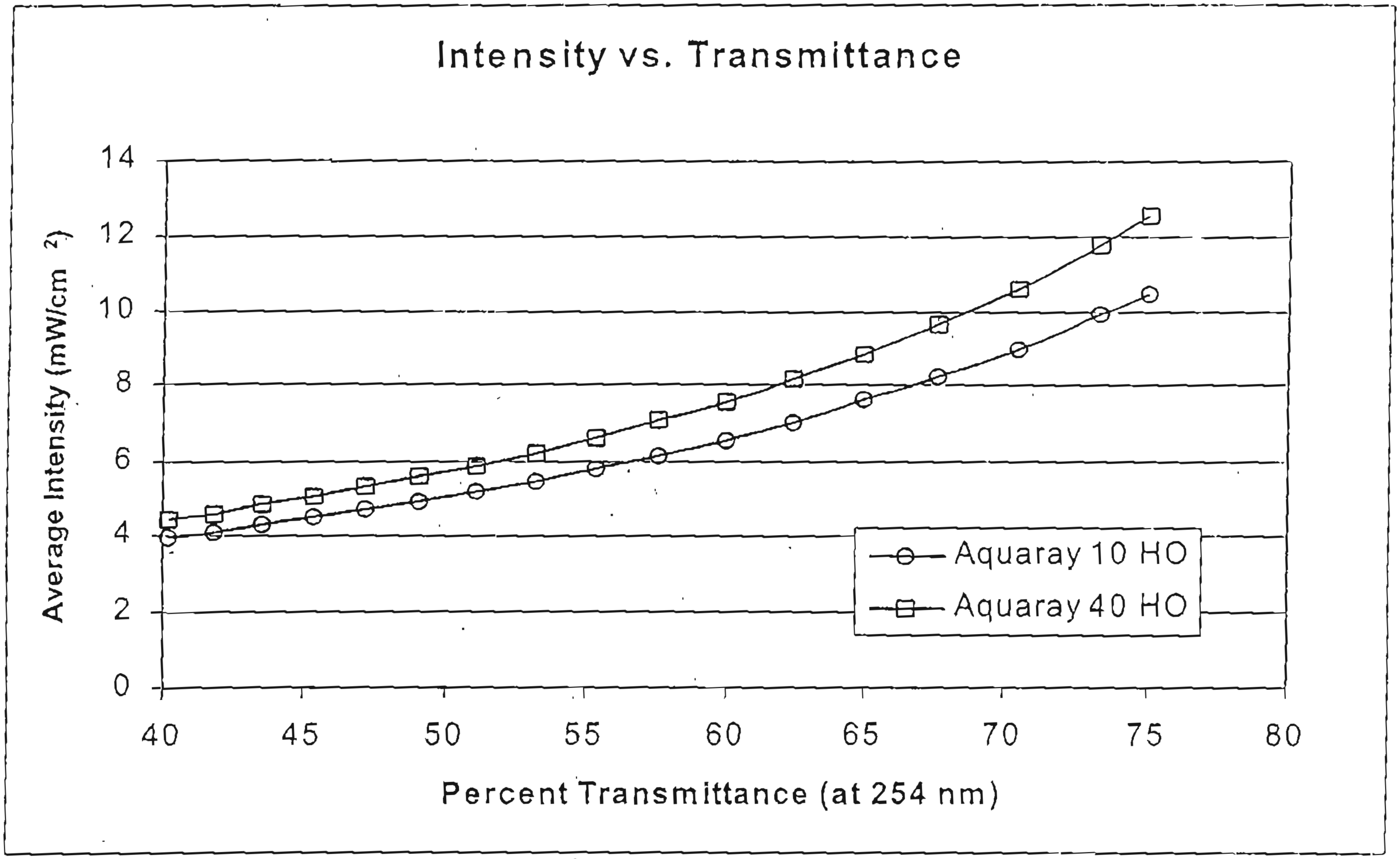


Figure 3. Intensity vs. Percent Transmittance ODI Aquaray HO10 and Aquaray 40HO

Table 1. Relationship of Theoretical Nominal Intensity vs. Water Transmittance and Absorbency at 254 nm

Transmittance (%)	Absorbance Coefficient (a.u./cm)	Aquaray 10HO Average Intensity (mW/cm²)	Aquaray 40HO Average Intensity (mW/cm²)
75.0	0.29	10.5	12.5
73.3	0.31	9.94	11.8
70.4	0.35	9.01	10.5
67.7	0.39	8.24	9.65
65.0	0.43	7.59	8.83
62.5	0.47	7.03	8.14
60.0	0.51	6.55	7.55
57.7	0.55	6.13	7.04
55.4	0.59	5.76	6.59
53.2	0.63	5.44	6.20
51.1	0.67	5.15	5.85
49.1	0.71	4.89	5.53
47.2	0.75	4.65	5.26
45.3	0.79	4.44	5.00
43.6	0.83	4.25	4.78
41.9	0.87	4.08	4.56
40.2	0.91	3.91	4.37

Using a baseline condition of 65% transmittance at 100% output, the theoretical nominal intensity corresponding to a 20% reduction in lamp output for the test unit was computed. This intensity is equivalent to a test condition transmittance of 58% (at 100% lamp output). This method conforms to the protocols for setting the minimum UV sensor level to conduct similar bioassay testing in NWRI/AWWARF Ultraviolet Disinfection Guidelines conforms to the protocols for setting the minimum UV sensor level to conduct similar bioassay testing in NWRI/AWWARF Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (National Water Research Institute, NWRI-00-03, Fountain Valley, CA, December 2000).

Flow rates of 200, 400, 600, 800 and 1000 gpm [757, 1514, 2271, 3028 and 3785 Lpm], were tested in quadruplicate:

1. Potable water from a hydrant was first fed directly to the test unit at a rate of approximately 200 gpm (760 Lpm). The UV system was turned on and allowed to operate for at least one and one-half hour prior to testing to ensure stable output from the lamps. This was verified by monitoring the intensity within the bank of lamps with the IL1700 detector located in a fixed position facing upstream into the lamp battery. The voltage was maintained 230 VAC, the nominal operating voltage for the system.

2. During the lamp stabilization period, a 20,000 gal (76,000-liter) batch of test water was prepared. A rectangular tank was filled with potable water from a hydrant. Instant coffee was added during fill-up to adjust the transmittance of the test water to 58 ±2% percent at 253.7 nm. Sodium thiosulfate was also added to remove any residual chlorine in the test water. The contents of the tank were continually mixed via recirculation through a 1800 gpm (7800 Lpm) pump. The bacteriophage suspension was added to the tank to yield a density of approximately 10^5 to 10^6 pfp/mL. The full tank was then mixed for at least 30 minutes.

3. Flow from the hydrant to the test unit was stopped and flow from the tank was initiated. A desired flow rate was set and monitored via the magnetic flow meter until a stable reading was obtained.

4. The system was operated under these conditions for a time interval sufficient to accomplish a minimum of five volume changes in the UV reactor before sampling, thereby ensuring steady-state conditions.

5. Samples were taken in triplicate at each flow setting before and after (post-weir) the lamp banks.

6. Once sampling was completed, the flow rate was adjusted to the next target flow rate.

This sequence was repeated for each batch run. Samples were returned to HydroQual's laboratory for analysis. Two dilutions of each sample were plated in triplicate. These were incubated at 37°C for 16 to 20 hours; plaques were then counted to estimate bacteriophage densities in the influent and effluent for each test run. UV transmittance at 253.7 nm was measured for each sample using a Shimadzu (Model UV-1201S) UV/Vis spectrophotometer. The calibration was checked in February 2001. A copy of the calibration report can be found in Appendix A.

Hydraulic Testing

Residence time distributions were developed at five test flow conditions (757-3785 Lpm). Protocols are established for the step-response method in the USEPA Design Manual for Municipal Wastewater Disinfection (EPA/625/1-86-921, 1986). The procedure is summarized as follows:

1. A concentrated coffee solution was continuously injected at a constant rate into the upstream end of the lamp bank. This injection point was positioned at mid-depth, approximately 3 in (8 cm) in front of the lamp battery.

2. A UV detector (IL SUD240, International Light) was mounted outside the second lamp rack, approximately 3 in (8 cm) from the down-stream end. UV intensity was monitored using an IL 1700 radiometer.

3. Coffee injection was continued until a new "steady-state" UV intensity was reached (from background).

4. The coffee solution was shut-off and the return of UV intensity to background conditions was traced on a chart recorder.

5. Chart recordings were digitized and used to develop residence time distribution curves.

RESULTS

Dose-Response Calibration

Data for each of the dose-response runs are presented in Appendix B, Tables B1 through B-4. Table 2 presents a summary of these data. Note that dose is calculated by the following expression:

$$D = I_o t\left[\left(1 - e^{-kd}\right)/kd\right] \tag{1}$$

Where:

D = UV Dose at 253.7 nm ($mW\text{-}s/cm^2$)
t = Exposure time (seconds)

I_0 = Incident Intensity at the surface of the sample (mW/cm^2)
k = Absorbance coefficient (cm^{-1}, base e)
d = Depth of the sample (cm)

TABLE 2 SUMMARY OF MS-2 COLIPHAGE DOSE-RESPONSE RESULTS: DOSE AND LOG SURVIVAL RATIO (N/N_0)

Dose	DR 1	DR 2	DR 3	DR 4	Average
20	-1.03	-1.01	-1.01	-0.93	-0.995
30				-1.47	-1.47
40	-1.98	-2.01	-2.02	-1.87	-1.97
50			-2.35	-2.23	-2.29
60			-2.74	-2.73	-2.74
80	-3.30	-3.33			-3.32
100	-3.91	-4.00			-3.96

Figure 4 presents the dose-response calibration developed for the bacteriophage. A best-fit line was developed using a quadratic expression (shown on Figure 4). Replication was good within a run (Appendix B) and among runs (Table 2), indicating that the bacteriophage responded consistently with respect to dose-response behavior. The correlation coefficient, r^2, was 0.9964. The correlation can be written as:

$$Log\left(\frac{N}{N_o}\right) = 15.2x10^{-4}D^2 - 5.47x10^{-2}D + 2.15x10^{-2} \quad (2)$$

Where:

N = Final density (pfp/mL)
N_0 = Initial density (pfp/mL)
D = Dose ($mW\text{-}s/cm^2$)

The correlation can also be expressed in terms of dose as:

$$D = 2.96\left(Log\frac{N}{N_o}\right)^2 - 12.51\left(Log\frac{N}{N_o}\right) + 4.59$$

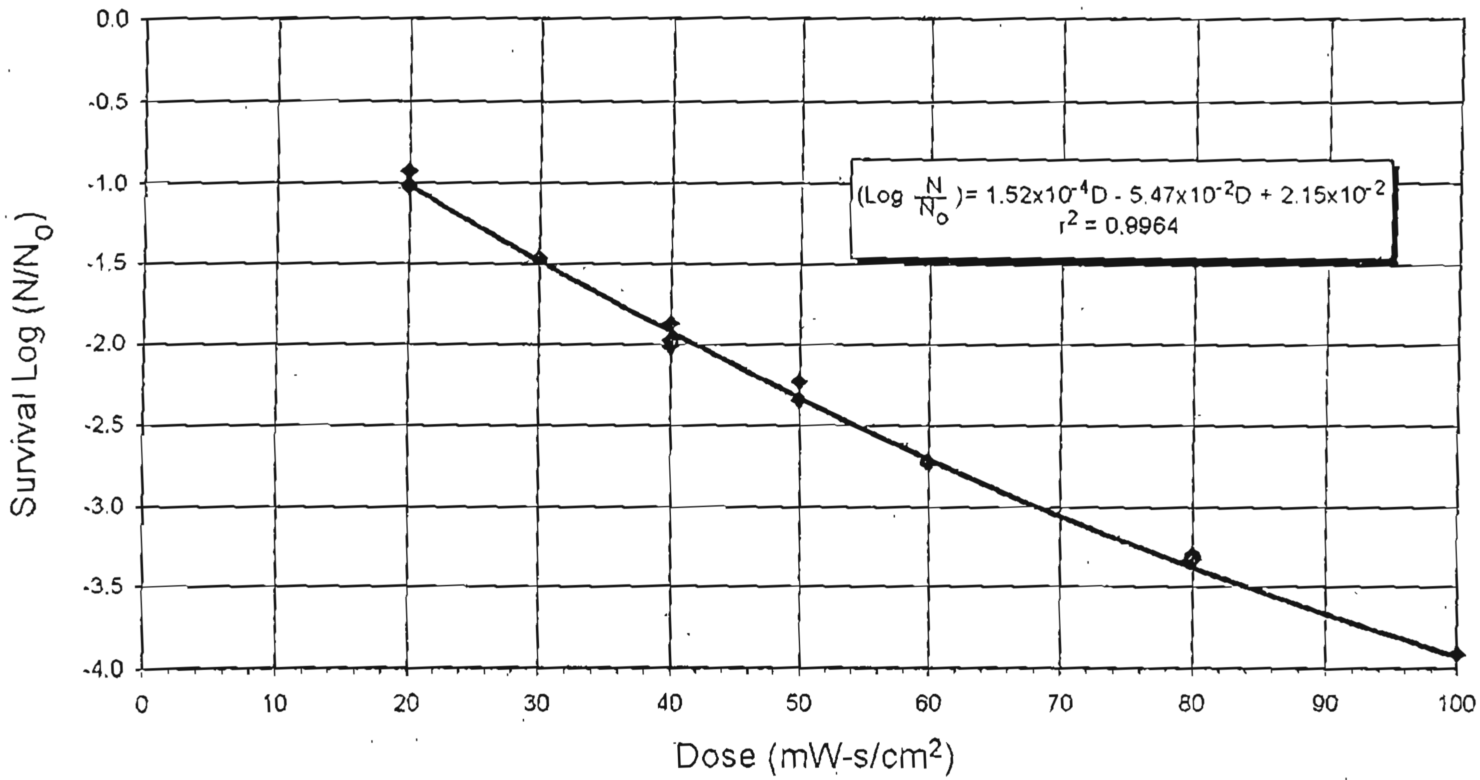


Figure 4. Dose-Response Calibration for Coliphage.

Hydraulic Characterization Test Results

Residence time distribution (RTD) analyses provide information on the actual or anticipated hydraulic behavior of a unit. Note that the critical hydraulic design requirement for UV reactors is that the system approach ideal plug-flow conditions and minimize any degree of advective mixing. Parameters that indicate these conditions are derived from an analysis of the RTD curves.

RTD curves developed for the test unit are presented in Appendix C. The top panel on each figure is the digitized tracer recording. The middle panel is the first derivative of the tracing showing the slope of the curve as a function of time. The lower panel plots the cumulative area under the residence time curve (middle panel) as a function of time, effectively showing the distribution of residence times in the system.

Table 3 summarizes key parameters derived from these RTD analyses. The flow rates and equivalent velocities through the lamp battery are given. The maximum velocity in this case was 0.71 ft/sec (22 cm/sec) at a flow of 1000 gpm (3785 Lpm). The theoretical detention time is computed as the volume (less the quartz/lamp assembly) divided by flow (V/Q), while the mean residence time (2) is computed as the first moment of the residence time curve (middle panel of the Appendix C figures). Note that the detention times shown in Table 2 do not reflect the actual detention times in the lamp modules, but the detention time between injector and detector. The computed liquid volumes also account for the head variations as a function of flow.

Several dimensionless ratios can be derived from the RTD analysis which are useful in evaluating hydraulic characteristics. These are also presented on Table 3:

?/T — The ratio of the mean residence time to the theoretical residence time. This should fall between 0.8 and 1.2; it averaged 0.95 for these tests.

t_p/? — The ratio of the time at which the peak tracer level occurs to the mean residence time. An acceptable level is greater than 0.9, indicating absence of any skew in the residence time due to back mixing, dead spaces or eddying effects. This averaged 0.95.

t_{50}/? — The ratio of the time for 50 percent of the tracer to pass to the mean residence time is also a measure of the skew and should be greater than 0.9 for effective plug flow. It averaged 0.98 for these tests, with a range of 0.93 to 1.10.

Table 3. Ondeo Degremont Hydraulic Testing - Summary of Residence Time Analyses

Run Number	Flow (gpm)	Flow (Lpm)	Velocity (fps)	Velocity (cm/sec)	Theoretical (sec)	Mean (sec)	Ratio Mean/Theo ?/T	$t_p/?$	$t_{50}/?$	$t_i/?$	t_{90}/t_{10}	d	E (cm²/sec)
1	200	757	0.15	4.59	44.9	40.5	0.90	1.04	1.01	0.62	2.0	0.037	40
2	200	757	0.15	4.57	44.9	39.2	0.87	0.92	0.96	0.62	2.0	0.037	41
3	200	757	0.15	4.57	44.9	41.9	0.93	0.92	1.10	0.53	2.3	0.048	50
4	400	1514	0.29	8.84	22.6	20.8	0.92	0.97	1.00	0.56	2.1	0.046	96
5	400	1514	0.29	8.84	22.6	21.7	0.96	0.94	0.97	0.51	1.9	0.013	25
6	400	1514	0.29	8.84	22.6	20.5	0.91	0.97	0.97	0.59	2.1	0.038	81
7	600	2271	0.43	13.11	15.1	14.5	0.96	1.00	0.97	0.62	1.9	0.033	100
8	600	2271	0.43	13.11	15.1	13.8	0.91	0.95	0.94	0.58	1.8	0.034	108
9	600	2271	0.43	13.11	15.1	13.9	0.92	1.20	1.00	0.58	2.3	0.050	157
10	800	3028	0.57	17.37	11.9	11.8	0.99	1.00	1.00	0.51	2.1	0.039	143
11	800	3028	0.57	17.37	11.9	12	1.01	1.10	1.00	0.58	1.9	0.032	116
12	800	3028	0.57	17.37	11.9	12.7	1.07	0.87	0.94	0.71	1.5	0.011	36
13	1000	3785	0.71	21.64	9.6	8.9	0.93	0.90	1.01	0.56	2.2	0.049	240
14	1000	3785	0.71	21.64	9.6	9.3	0.97	0.86	0.97	0.65	1.9	0.030	141
15	1000	3785	0.71	21.64	9.6	8.6	0.90	0.81	0.93	0.58	2.3	0.040	200
						Average	0.95	0.96	0.98	0.59	2.0	0.036	86*

* Geometric mean

Acceptable criteria

$0.8 \leq ?/T \leq 1.2$	$t_i/? > 0.50$
$t_p/? > 0.90$	$t_{90}/t_{10} \leq 2.0$
$t_{50}/? > 0.90$	$d < 0.50$
	$E < 100$ cm²/sec

t_i/θ The ratio of the time the tracer first appears to the mean residence time is a measure of short-circuiting, and should be greater than 0.5. This averaged 0.59 for these tests.

t_{90}/t_{10} The ratio of the time for 90 percent of the tracer to pass to the time for 10 percent of the tracer to pass. Also known as the Morrill Dispersion Index, it is a measure of the spread of the residence time distribution curve; a value of 1.0 would indicate ideal plug flow, and 21.9 for ideal complete mix. A value of 2.0 or less is generally required for UV systems; this index averaged 2.0 for this system, with a range of 1.5 to 2.3.

The dispersion coefficient, E, was also computed from the RTD analysis, yielding an average (geometric) value of 86 with a range of 25 to 240. E can vary from zero to infinity, approaching zero under ideal plug flow conditions. An E less than 100 cm^2/sec is generally targeted for UV disinfection reactors; the test results show levels below this guidance limit. An additional parameter, the dimensionless dispersion number, d, is given on Table 2; this averaged 0.036 which falls below the acceptable upper limit of 0.05 for plug-flow conditions.

Bioassay Test Results

The bacteriophage and UV transmittance data for each field run are presented in Appendix D, Tables D1 through D4. The dose and flow data are presented on Figure 5. The flow-dose relationship determine for each HO10 module at a 65% transmittance and a 0.8 lamp output reduction factor is:

$$D_B = 1828Q^{-0.735} \quad (3)$$

where D_B is dose per lamp bank, with units $mW\text{-}s/cm^2$, and Q is flow in gpm. The expression has a correlation coefficient, r^2, of 0.97.

Expressions were also calculated for dose-flow relationships at 55% and 75% transmittance, and are shown on Figure 5. These curves were developed by adjusting the coefficient from the flow-dose relationship observed at 65% transmittance. This was done by multiplying the ratio of the calculated reactor intensity at either 55% or 75% to the calculated reactor intensity at 65% transmittance (see Figure 3) times the coefficient in Equation (3):

$$\left(\frac{I_{avg} @ X\%T}{I_{avg} @ 65\%T}\right) x1828Q^{-0.735} \quad (4)$$

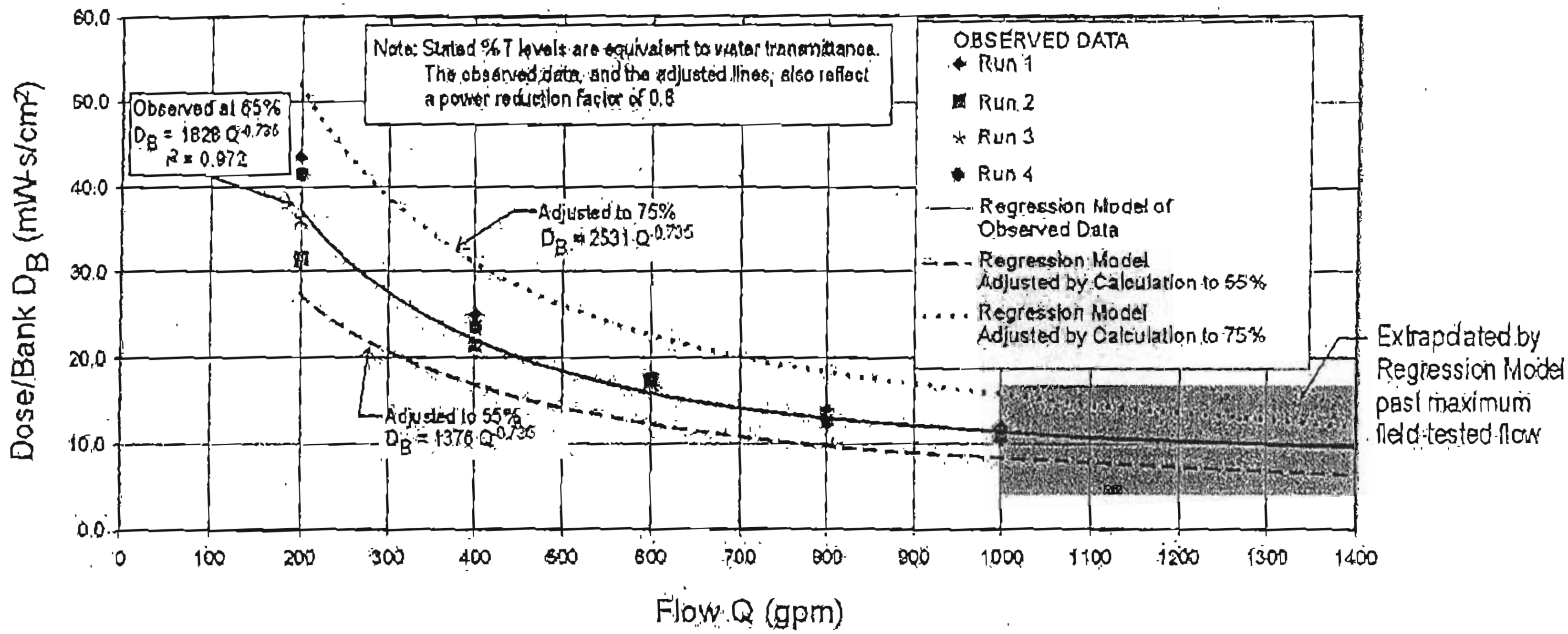


Figure 5. Flow-Dose Relationships for the Ondeo Degremont Aquarry HO10.

The resulting expressions are:

at 55% Transmittance

$$D_B = 1376Q^{-0.735} \quad (5)$$

at 75% Transmittance

$$D = 2531Q^{-0.735} \quad (6)$$

It should be noted that the bioassay testing was conducted on two hydraulically scaleable 10-lamp modules. The standard commercially available module, however is a 40-lamp module. The bioassay relationship, when analyzed on a per-bank basis, can be linearly scaled to represent a 40-lamp module. This is presented as Figure 6.

The equivalent flow-dose relationship for an HO40 module at 65% transmittance and a 0.8 lamp output reduction factor is:

$$D_B = 41.3Q^{-0.735} \quad (7)$$

where D_B is dose per lamp bank with units of mWs/cm^2 and Q is mgd. Similar for the 10-lamp modules, calculated doses were determined for an equivalent 40-lamp module for both 55% and 75% transmittance conditions. The resulting expression in this case are:

$$For\ T = 55\% \quad D_B = 31.0^{-0.735}$$

$$For\ T = 75\% \quad D_B = 57.2^{-0.735}$$

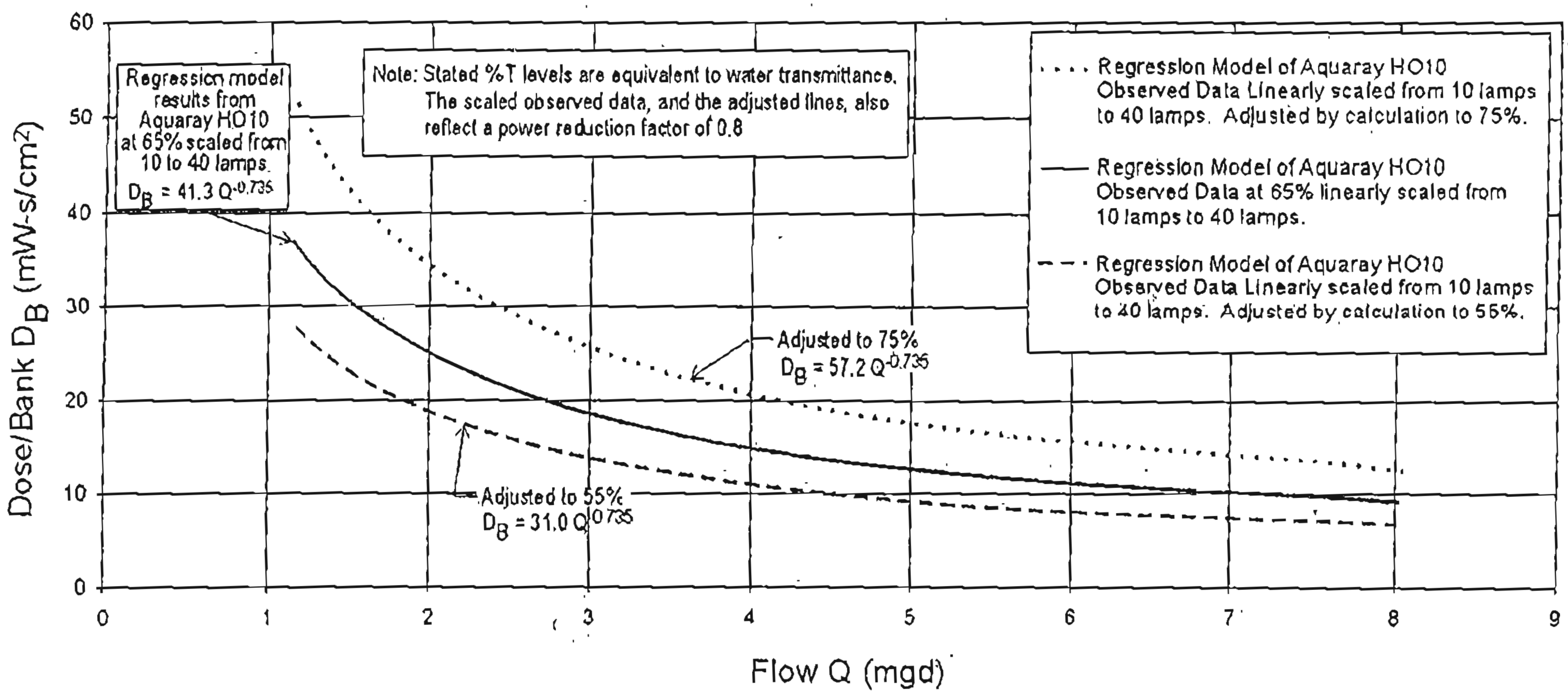


Figure 6. Flow-Dose Relationships for the Ondeo Degremont Aquaray HO40.

APPENDIX A

1. IL 1700 Radiometer Calibration Report
2. Shimadzu UV-1201 Spectrophotometer Calibration Report

HydroQual

Environmental Engineers & Scientists

CERTIFICATE OF INSTRUMENT PERFORMANCE

Study data has determined that the instruments described and tested in this document have met or exceeded all test criteria detailed in Section IV (Performance Test Protocol). This certificate must accompany all associated test data within this document. Test equipment utilized in the testing of your instrumentation is directly or indirectly traceable to N.I.S.T. (National Institute of Standards and Technology) calibration standards and is periodically returned for recalibration.

INSTRUMENTATION TESTED

MODEL	SERIAL NUMBER	DATE
UV-1201S	50052 JS	2-27-01

TEST EQUIPMENT UTILIZED

MODEL	SERIAL NUMBER	Calibration Date	Re-Cal Date
CRM-500 filterset	066	10-12-99	10-12-01
Mercury Lamp	62	1-12-99	1-12-06

TEST PROTOCOL PERFORMED BY: CJ Pappas/CJPappas DATE:

(Print name) CJ Pappas Feb 27 2001

LABORATORY MANAGER/DESIGNEE: Egon Weber DATE:

(Print name) EGON WEBER 2/27 2001

SHIMADZU

ISO 9001 CERTIFIED

COMMENTS:

Page 6: Filter set used was certified at 465.0 nm, not 440.0 nm
CP 2.27.01

Page 6: customer needs photometric accuracy performed at 250.0 nm, 280.0 nm

	WAVELENGTH	Abs (documented) @ 30% T
Acceptance Criteria	250.0 nm	0.4628 Abs (±0.006)
	280.0 nm	0.4837 Abs (±0.006)

Parameter Verification	WAVELENGTH	Actual Abs	Pass	Fail
	250.0 nm	0.464	✓	
	280.0 nm	0.483	✓	

CP 2.27.01

Page 7 This protocol did not include all wavelengths tested. Two additional wavelengths are listed at the bottom of page 7 CP 2.27.01

All tests pass CP 2.27.01

IV. Performance Test Protocol UV-1201

Test 2

Test Name: Wavelength Accuracy Test.

Purpose: Verify Wavelength Accuracy.

Method:

1) Remove all cuvettes from sample compartment.
2) Install the Maintenance Pack I.C. card [206-62029-05 for 1201(S) or 206-62029-26 for 1201V], then Press [POWER].
3) Select OPTICS CHECK.
4) Select Hg LAMP LINE λDetect .Wait ~5min for the instrument prompt to continue.
5) Instrument will prompt to install Hg lamp.
6) Visually align Hg lamp light beam on the lamp housing exit slit. Slowly rotate holder until display is maximized, then secure lamp holder base.
7) Press [ENTER]. BLANK is displayed and unit will perform [11] wavelength peak checks (~6min).
8) Four columns of data will be displayed, record values:
COLUMN #1 [NATURAL LINES OF Hg]
COLUMN #2 [ACTUAL ANALYZED PEAKS]
COLUMN #3 [WAVELENGTH VARIATION]
COLUMN #4 [SPECTRAL BANDWIDTH].
9) Press [RETURN] 3 times.
10) Remove Hg lamp/holder and Maintenance Pack IC card.
11) Turn OFF the instrument, then reinitialize.

Acceptance Criteria: Actual Wavelength Results are ±1.0nm of Expected results.

Parameter Verification:

EXPECTED λ	ACTUAL	PASS	FAIL
365.0	365.6	☑	☐
404.7	404.2	☑	☐
435.8	435.3	☑	☐
546.1	545.5	☑	☐
578.0	577.8	☑	☐
761.1	760.8	☑	☐
809.4	809.6	☑	☐
871.6	871.8	☑	☐
1014.0	1013.8	☑	☐
253.7	253.9	☑	
313.2	312.6	☑	

CP 2-27-01

PERFORMANCE TEST

III. INSTRUMENTATION LISTING

MODEL	SERIAL NUMBER	INITIAL/DATE
UV1201 S	50052 JS	CP 2.27.01

PERFORMANCE TEST

INSTRUCTIONS

This document is to be completed at time of instrument performance testing. All blank spaces must be completed with either test data or N/A (not applicable).

An authorized representative of Shimadzu Scientific Instruments will perform the various tests required for completion of certification and enter all pertinent acquired data in the appropriate sections.

An employee of (*account name*) __Hydroqual__ will review all acquired data and sign the attached *CERTIFICATE OF INSTRUMENT PERFORMANCE.*

All deviations from the acceptance criteria detailed in this document will be noted in the comments section at the end of each Performance Test protocol. Corrective action must to be implemented prior to issuance of the *CERTIFICATE OF INSTRUMENT PERFORMANCE.*

Any test data that does not meet the specified acceptance criteria will be submitted to the appropriate laboratory personnel for resolution. If repairs and retesting are performed at the time of the initial on-site visit, no additional testing costs will be incurred by the customer due to the initial failure. Should the customer postpone the repair until a later date, a $150.00 (one hundred fifty dollar) fee plus zone charge will apply.

All data acquired as a result of this testing will be entered in the appropriate sections of this document. The document will then be submitted to the appropriate laboratory manager or their designee for review, approval signature and archiving.

PERFORMANCE TEST

I. SCOPE

The goal of Shimadzu Scientific Instruments Inc. is to provide the end user of our instrumentation with practical performance testing at an affordable price. Test protocols have been developed utilizing N.I.S.T. (National Institute of Standards and Technology) traceable standard reference calibrated test equipment.

Performance Test protocols will be performed by qualified representatives of Shimadzu Scientific Instruments Inc. at the customer's location or a site deemed most practical by persons performing the tests.

Upon successful completion of the documented Performance Test protocols a *CERTIFICATE OF INSTRUMENT PERFORMANCE* will be issued stating that your instrumentation meets or exceeds the acceptance criteria detailed in each test protocol.

Any deviations from the acceptance criteria must be resolved prior to issuance of a *CERTIFICATE OF INSTRUMENT PERFORMANCE* and will be an additional cost to the purchasing institution (customer). This additional cost will be waived when instrument Performance Testing is conducted at time of initial instrument installation of new instruments.

Specific assay methods and software associated with data handling systems unique to your institution will not be tested as part of this protocol. Testing will be specific to Shimadzu Scientific Instruments Inc. manufactured instrumentation.

CATALOG # 220-98033-09

PERFORMANCE TEST PROTOCOL

UV-1201 Spectrophotometer

...INT: Hydroqual

...ESS: 65 Ramapo Valley Rd

Mahwah STATE: NJ ZIP: 07430

ROOM:

SHIMADZU SCIENTIFIC INSTRUMENTS INC.
7102 Riverwood Drive
Columbia, MD. 21046
(410) 381-1227

ISO 9001 CERTIFIED

...L 2001

CATALOG # 220-98033-09

PERFORMANCE TEST PROTOCOL

UV-1201 Spectrophotometer

...INT: Hydroqual

...ESS: 65 Ramapo Valley Rd

Mahwah STATE: NJ ZIP: 07430

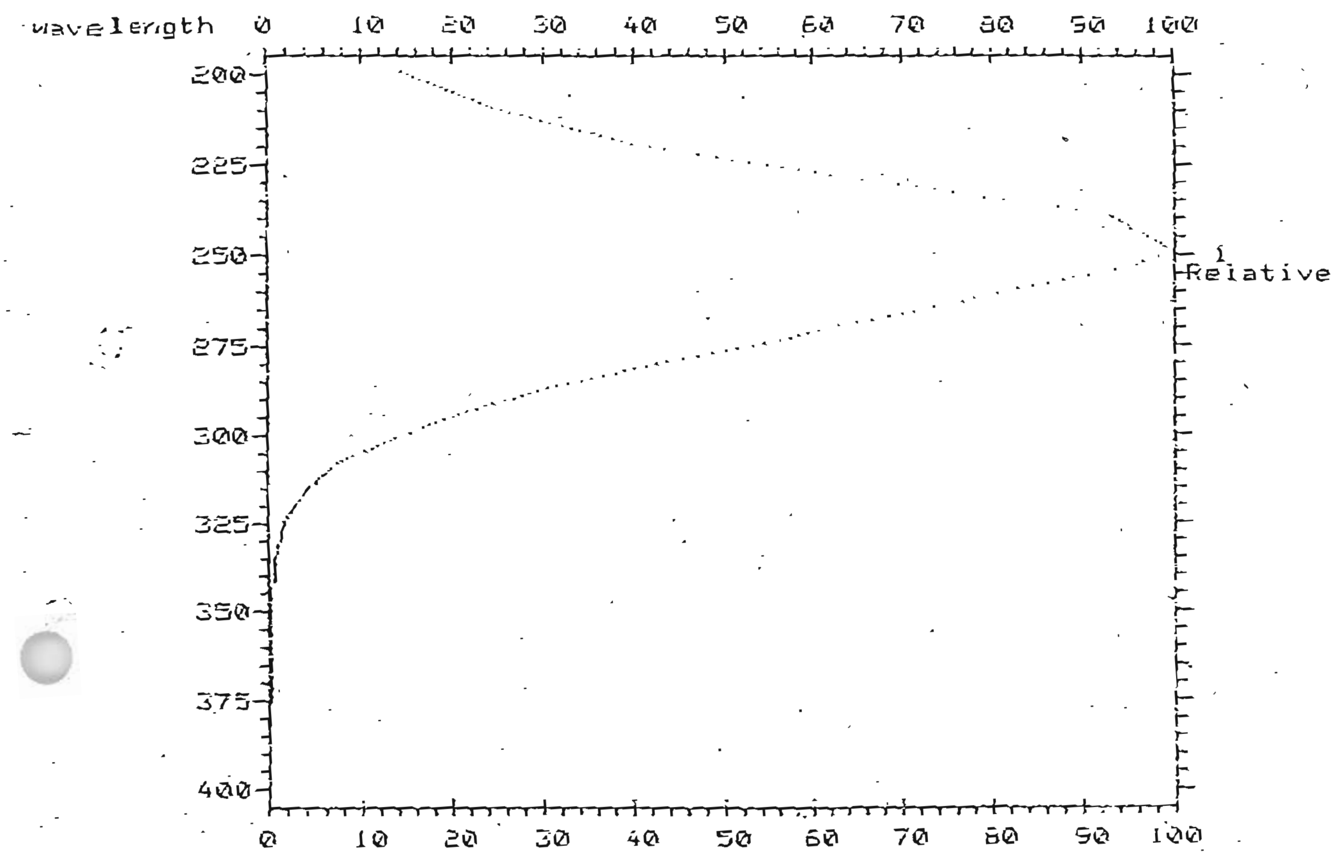
ROOM: ________.

SHIMADZU SCIENTIFIC INSTRUMENTS INC.
7102 Riverwood Drive
Columbia, MD. 21046
(410) 381-1227

ISO 9001 CERTIFIED

SED240/W TYPICAL RESPONSE 13MAY99

this is a spectral plot of file '50511772l' normalized to 100



international light inc.
17 Graf Road • Newburyport, MA 01950-4092 USA
Tel: 978.465.5923 • Fax: 978.462.0759
E-mail: ilsales@intl-light.com

PHOTODETECTOR CALIBRATION CERTIFICATE

International Light certifies that the instrument described below has been compared with the laboratory working standards whose calibrations are traceable to the U.S. National Institute of Standards and Technology and whose procedures are in accordance with the requirements of ANSI/NCSL Z540-1-1994, ISO 10012-1:1992(E) and ISO/IEC Guide 25:1990(E).

Rendered-to: HYDROQUAL

Detector: SED240 #5490 Input Optic: W #9819

Filter: NS254 #22640 Misc.: N/A

Spectral Response (half power points): ______

(PIR) PEAK IRRADIANCE RESPONSE SENSITIVITY FACTOR AS CALIBRATED ON: 07-Nov-2000

2.30e-4 (A)(cm2)(W-1) assuming monochromatic irradiance at 254nm

Unit will read directly in watts per square centimeter when used with an IL1700 and the Sensitivity Factor Above.

CALIBRATED WITH IL1700 +5V BIAS: ON ✓ OFF ______

REFERENCE PLANE: Groove ONE formed by filter or diffuser elements and next element, counted from front surface of assembly.

PRIMARY STANDARD: U.S. National Institute of Standards and Technology Detector Response
U1023 - January 1997 - NIST Test No. 844/257423-96/2 D204 - January 1997 - NIST Test No. 844/257423-96/1
N.I.S.T. Uncertainty: 200-250nm=5%;250-400nm=1.0%;400-900nm=0.31%;900-1000nm=0.58%;1000-1100nm=2.93%

INTERNATIONAL LIGHT PRIMARY TRANSFER STANDARDS:
IL D.R.I.P.#01,#02,#3275,#139,#1490,U522,H627 JAN 1998
IL Transfer Uncertainty to Customer = +/- 6.5 % plus NIST uncertainty above.

LIGHT SOURCE: 6a Low Pressure Mercury IRRADIANCE: 8.34e-5 W/cm2

INSTRUMENTATION: #1029 Radiometer PROCEDURE: PIR6a

TEMPERATURE: 21 degrees C HUMIDITY: 39 %

CALIBRATED BY: ______ CHECKED BY: ______

Calibration Technician QA Manager, Calibrations

FOR AUTHORIZED COPIES OF THIS CERTIFICATE OR OTHER INFORMATION PLEASE REFER TO THESE NUMBERS. THIS CERTIFICATE SHALL NOT BE REPRODUCED EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF INTERNATIONAL LIGHT, INC.

Calibration Date: 07-Nov-00 Certificate No.: 011079513 FO #: 60284a

IL RECOMMENDS AN ANNUAL CALIBRATION CONFIRMATION INTERVAL. INTERVALS OF CONFIRMATION MAY NEED TO BE ADJUSTED DEPENDING ON RESULTS OF PRECEDING CALIBRATIONS.

APPENDIX B

DOSE-RESPONSE DATA

HydroQual

Environmental
Engineers & Scientists

TABLE B-1. DOSE-RESPONSE FOR PHAGE HYDROQUAL STOCK VIII, RUN NUMBER 1 CONDUCTED ON MARCH 22, 2001

Dose (mW-sec/cm²)	Density,* N (pfp/mL)	Log N/N_o
20	8.0E+0.6	
	9.3E+0.6	
	1.0E+0.7	
	9.1E+0.6	-1.03
40	1.0E+06	
	1.1E+06	
	9.8E+05	
	1.0E+06	-1.98
80	4.2E+04	
	4.5E+04	
	6.1E+04	
	4.9E+04	-3.30
100	9.5E+03	
	1.4E+04	
	1.3E+04	
	1.2E+04	-3.91
Control, N_o* (1)	1.0E+08	
(2)	9.3E+07	
	9.8E+07	

*geometric average

TABLE B-2. DOSE-RESPONSE FOR PHAGE HYDROQUAL STOCK VIII, RUN NUMBER 2
CONDUCTED ON MARCH 22, 2001

Dose (mW-sec/cm²)	Density,* N (pfp/mL)	Log N/N₀
20	1.3E+07	
	1.1E+07	
	1.3 E+07	
	1.2 E+07	-1.01
40	1.1 E+06	
	1.4 E+06	
	1.2 E+06	
	1.2 E+06	-2.01
80	5.8 E+04	
	6.0 E+04	
	5.9 E+04	
	5.9 E+04	-3.33
100	1.5 E+04	
	9.6 E+03	
	1.4 E+04	
	1.2 E+04	-4.00
Control, N_0* (1)	1.1E+08	
(2)	1.4E+08	
	1.3E+08	

*geometric average

TABLE B-3. DOSE-RESPONSE FOR PHAGE HYDROQUAL STOCK VIII, RUN NUMBER 3 CONDUCTED ON MARCH 27, 2001

Dose (mW-sec/cm²)	Density,* N (pfp/mL)	Log N/N_o
20	1.1E+07	
	1.3E+07	
	1.3E+07	
	1.2E+07	-1.01
40	1.2E+06	
	1.1E+06	
	1.4E+06	
	1.2E+06	-2.02
50	4.7E+05	
	6.0E+05	
	6.7E+05	
	5.7E+05	-2.35
60	2.6E+05	
	2.1E+05	
	2.4E+05	
	2.3E+05	-2.74
Control, N_0* (1)	1.2E+08	
(2)	1.4E+08	
	1.3E+08	

*geometric average

TABLE B-4. DOSE-RESPONSE FOR PHAGE HYDROQUAL STOCK VIII, RUN NUMBER 4 CONDUCTED ON MARCH 27, 2001

Dose (mW-sec/cm²)	Density,* N (pfp/mL)	Log N/N₀
20	1.1E+07	
	1.1E+07	
	1.1E+07	
	1.1E+07	-0.93
30	2.3E+06	
	2.5E+06	
	2.6e+06	
	5.2E+06	
	3.0E+06	
	3.7E+06	
	3.1E+06	-1.47
40	1.2E+06	
	1.3E+06	
	1.1E+06	
	1.2E+06	-1.87
50	4.6E+05	
	5.0E+05	
	6.3E+05	
	5.3E+05	-2.23
60	1.6E+05	
	1.5E+05	
	2.0E+05	
	1.7E+05	-2.73
Control, N_o* (1)	8.0E+07	
(2)	1.0E+08	
	9.0E+07	

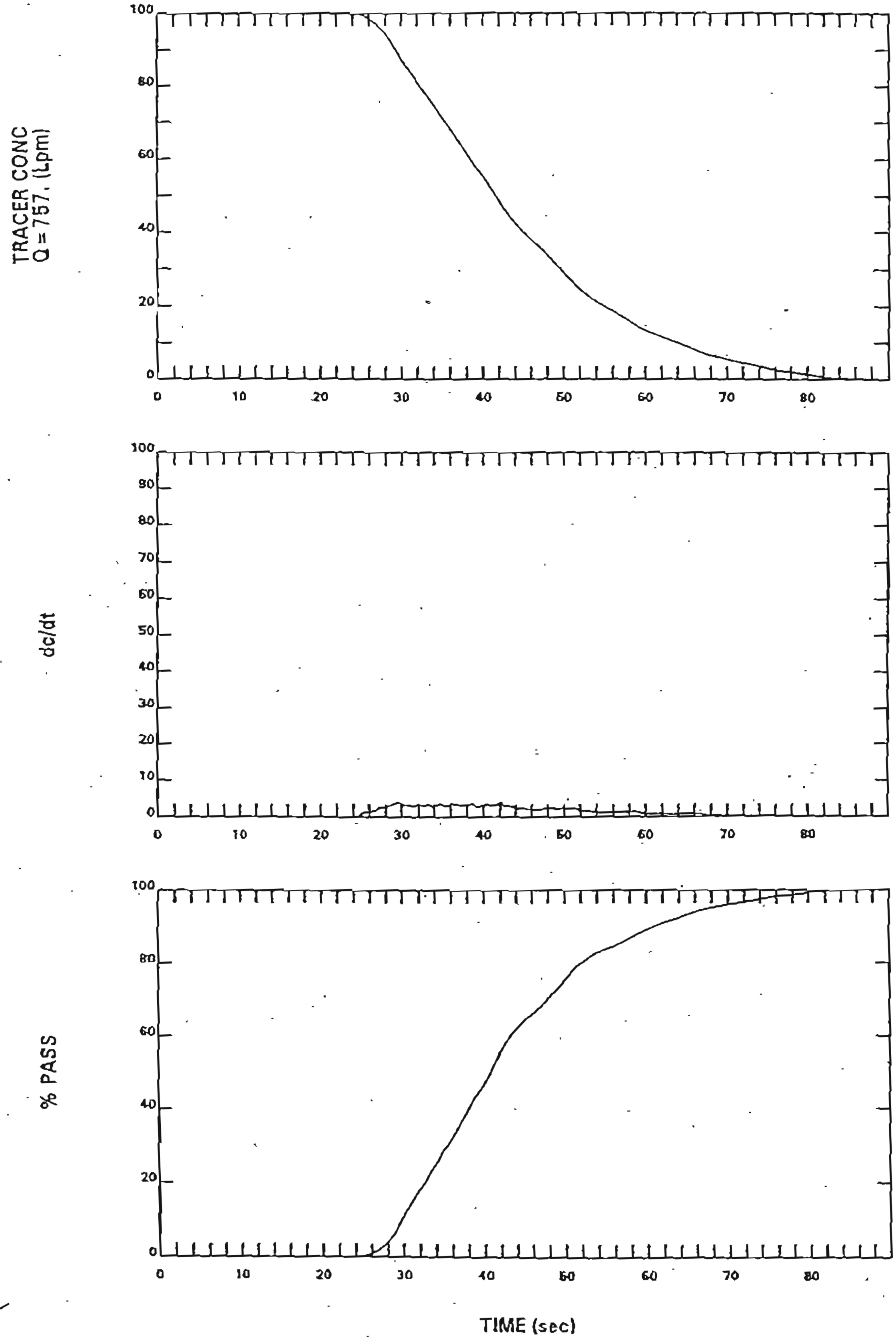
*geometric average

APPENDIX C

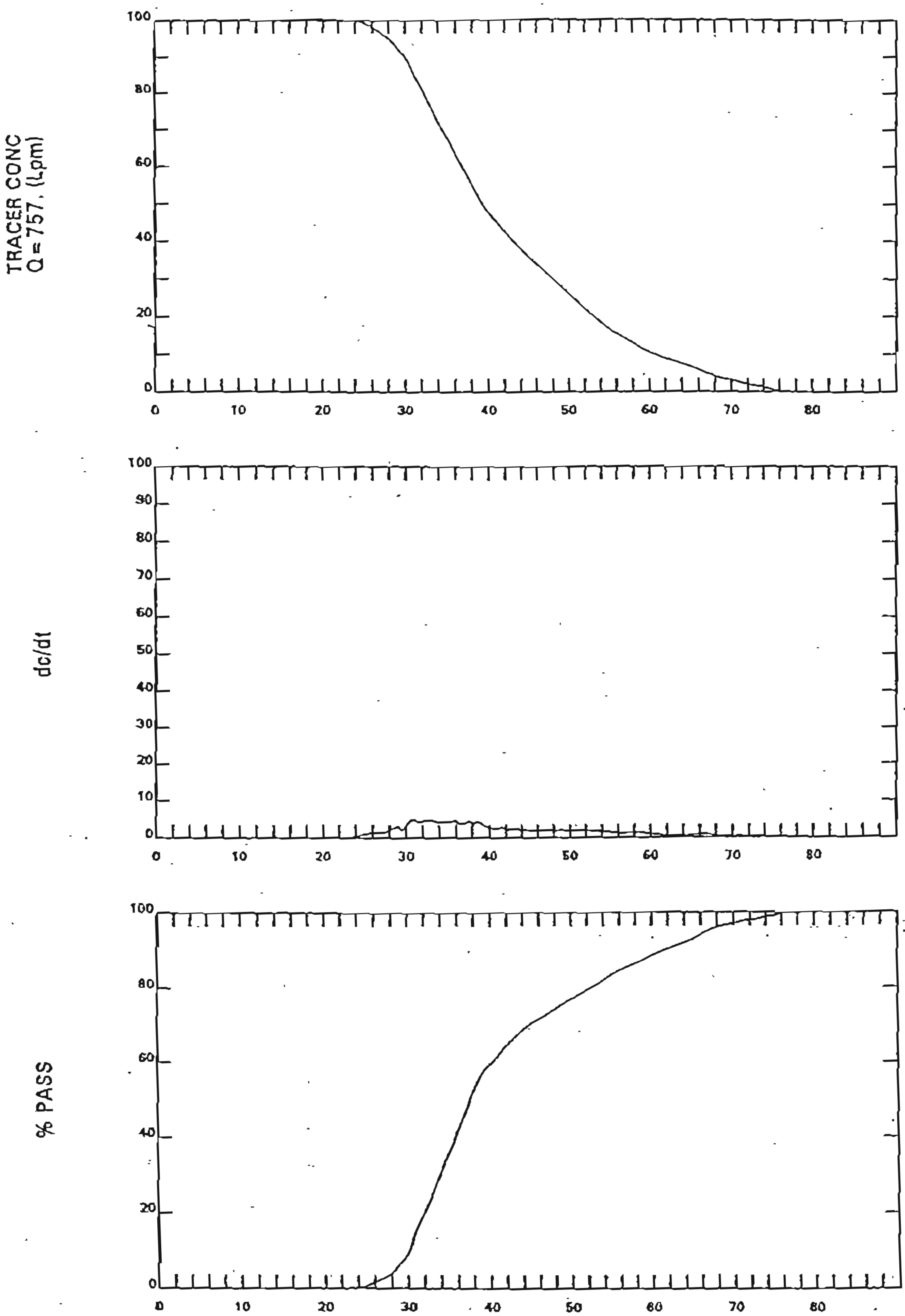
HYDRAULIC TRACER CURVES

HydroQual

Environmental
Engineers & Scientists

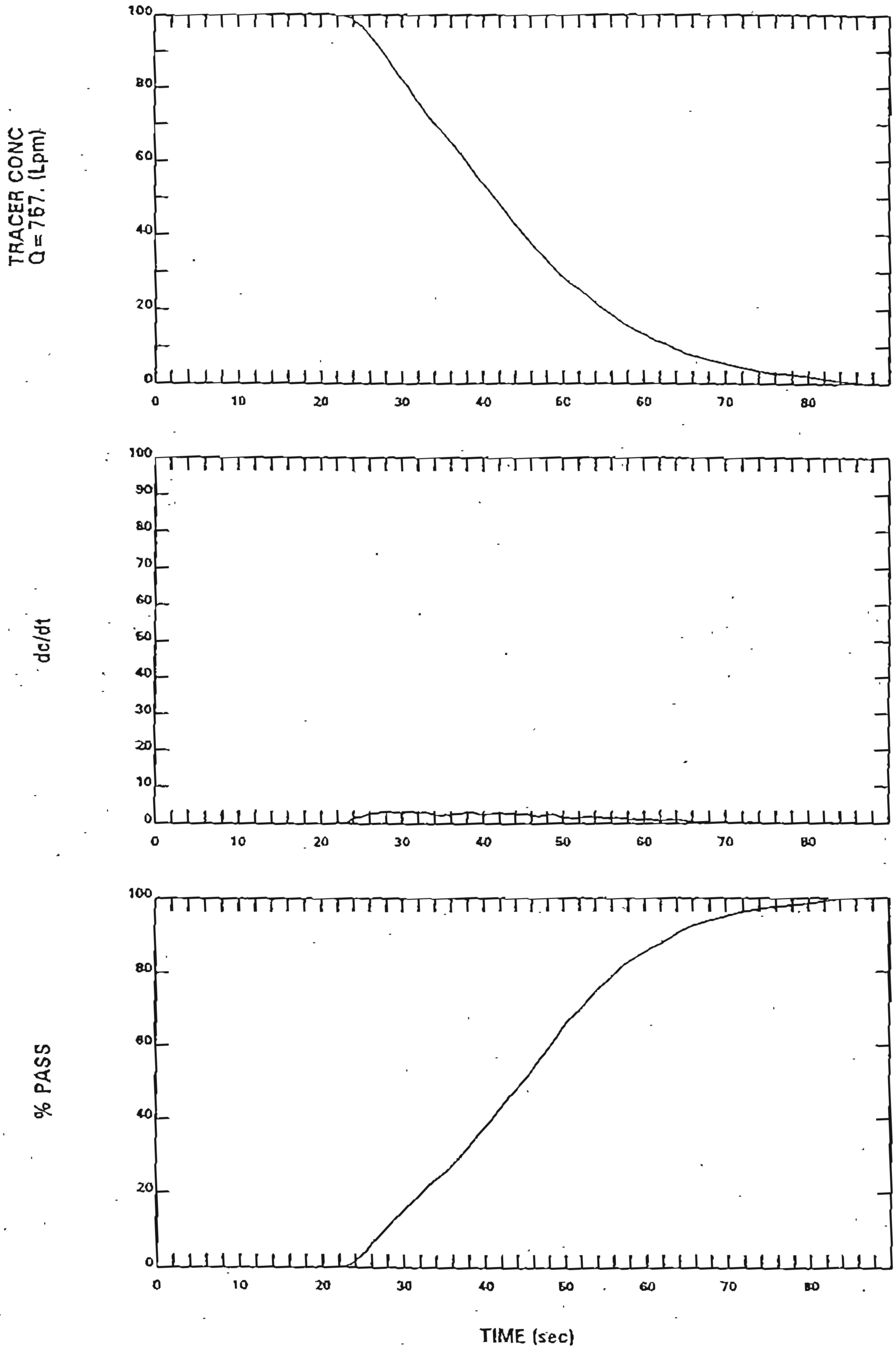


run1

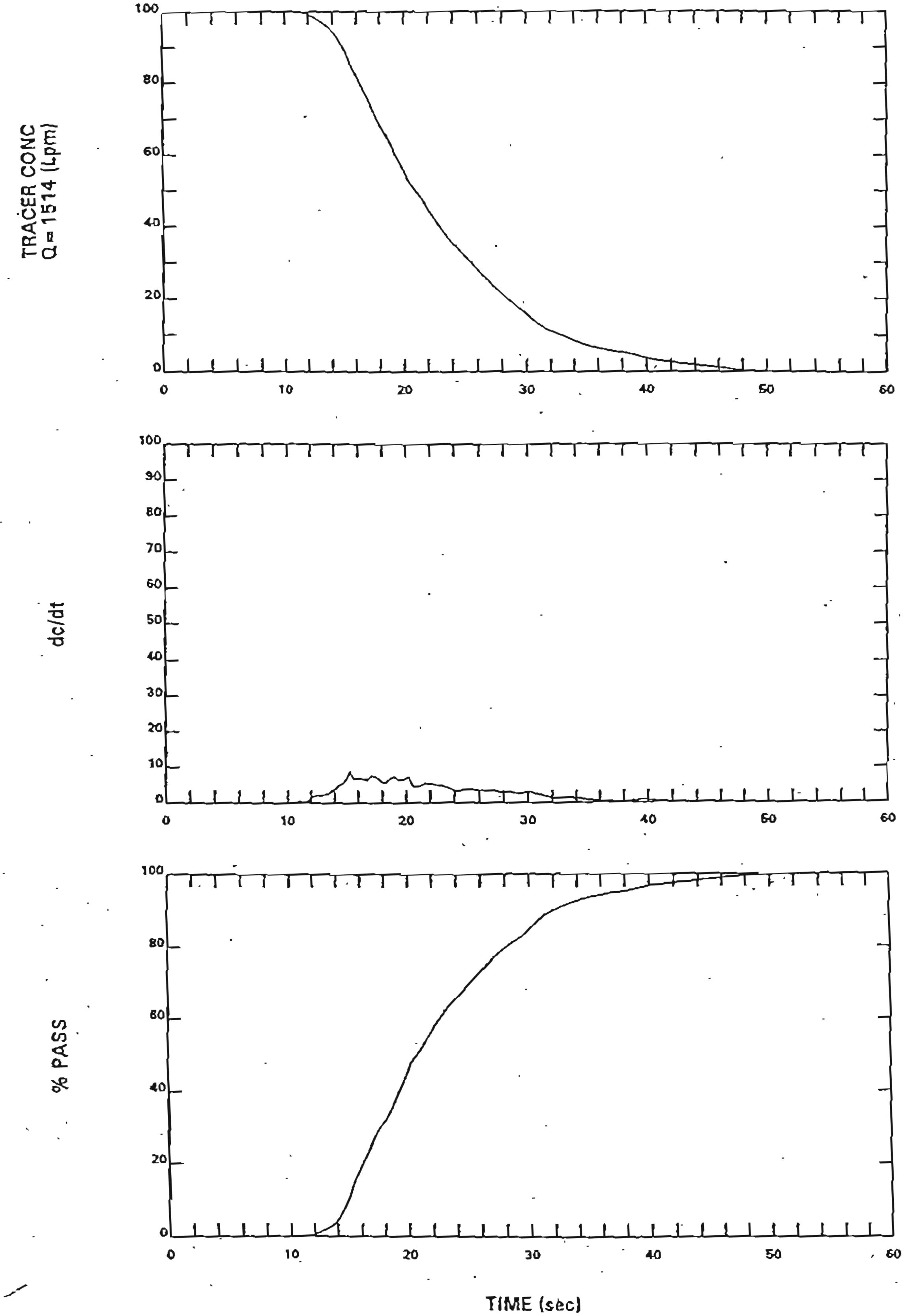


TIME (sec)

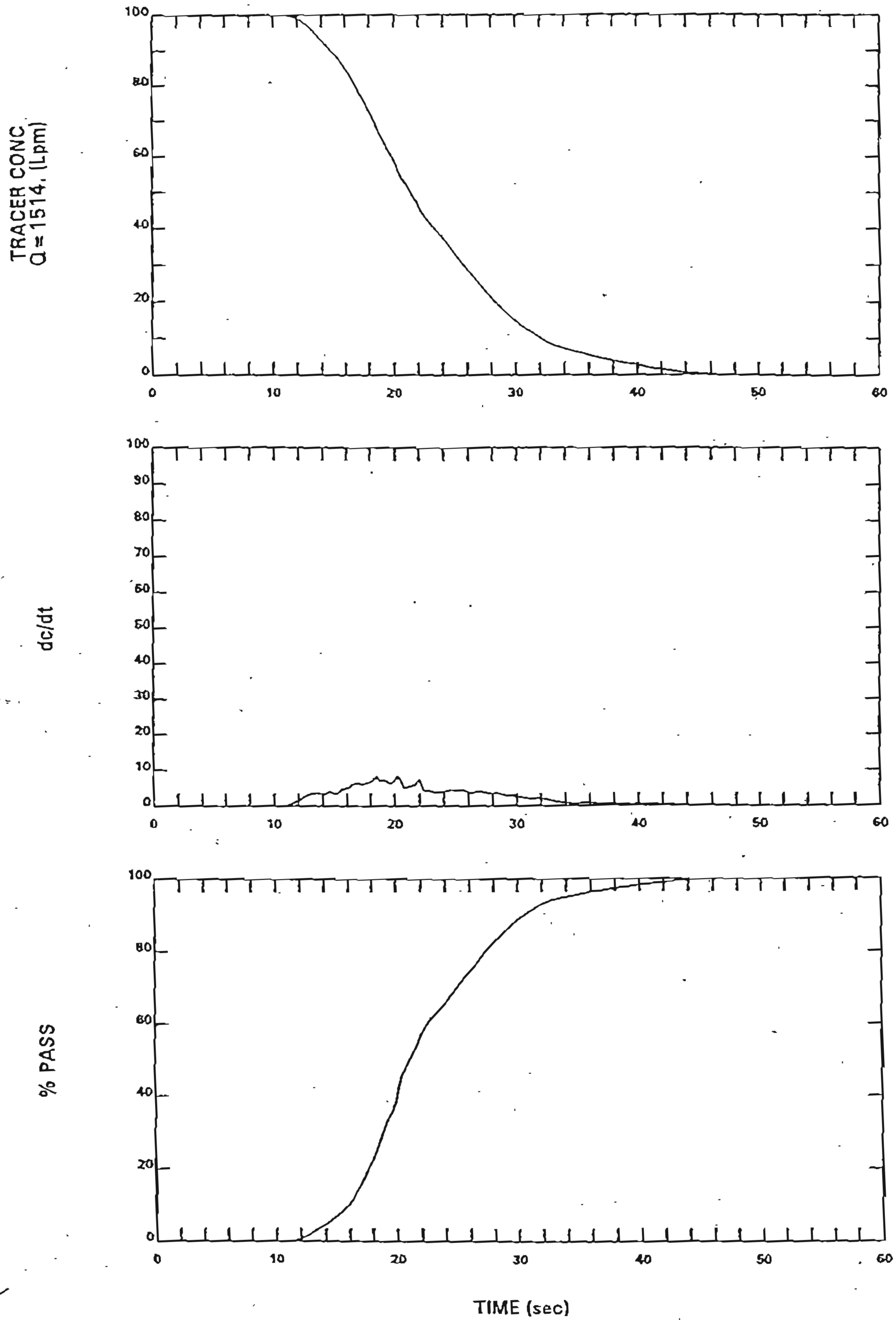
run2



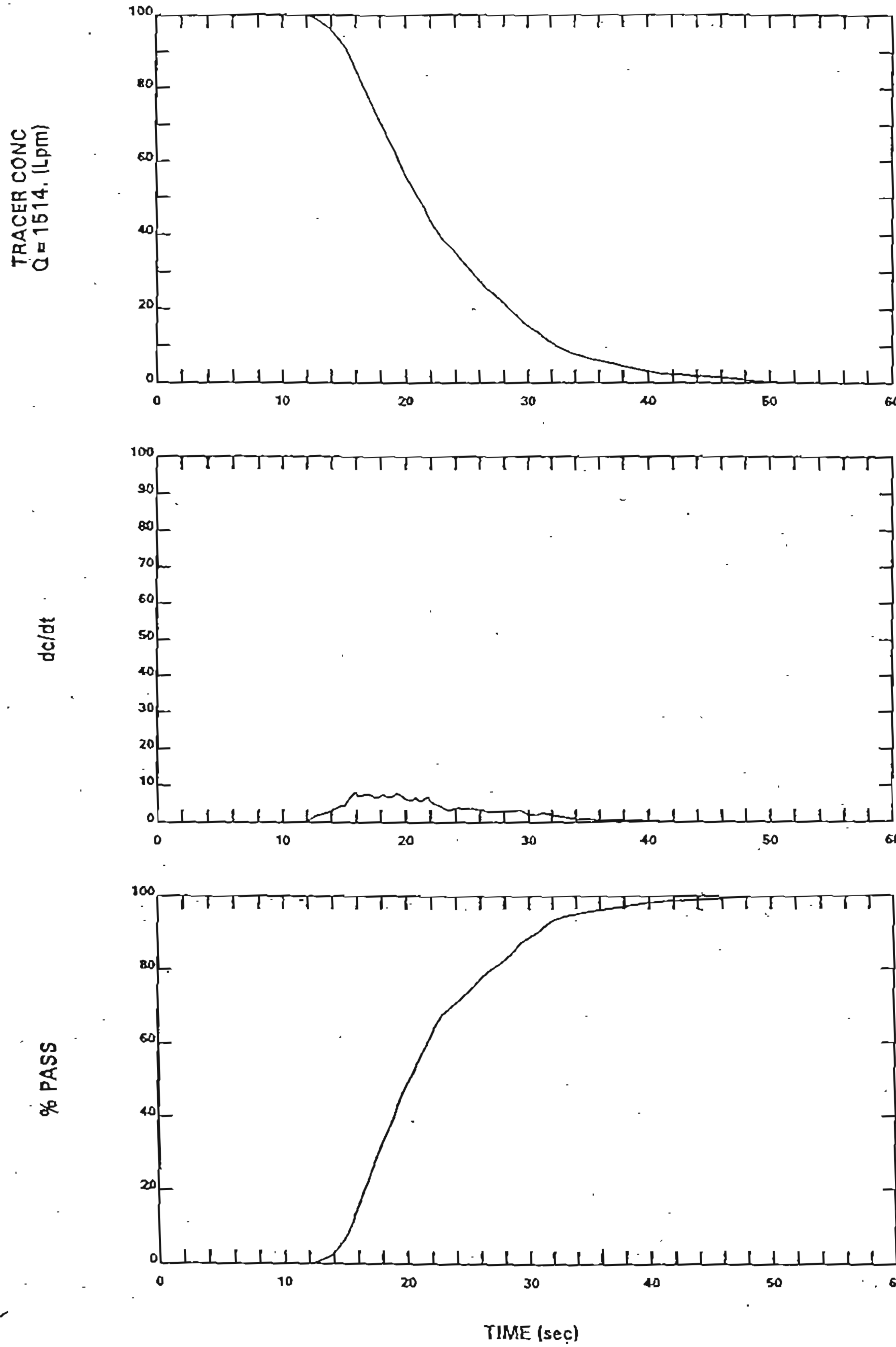
run3


TRACER CONC
Q=1514 (Lpm)
100
80
60
40
20
0
0
10
20
30
40
50
60
dc/dt
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
% PASS
100
80
60
40
20
0
0
10
20
30
40
50
60
TIME (sec)

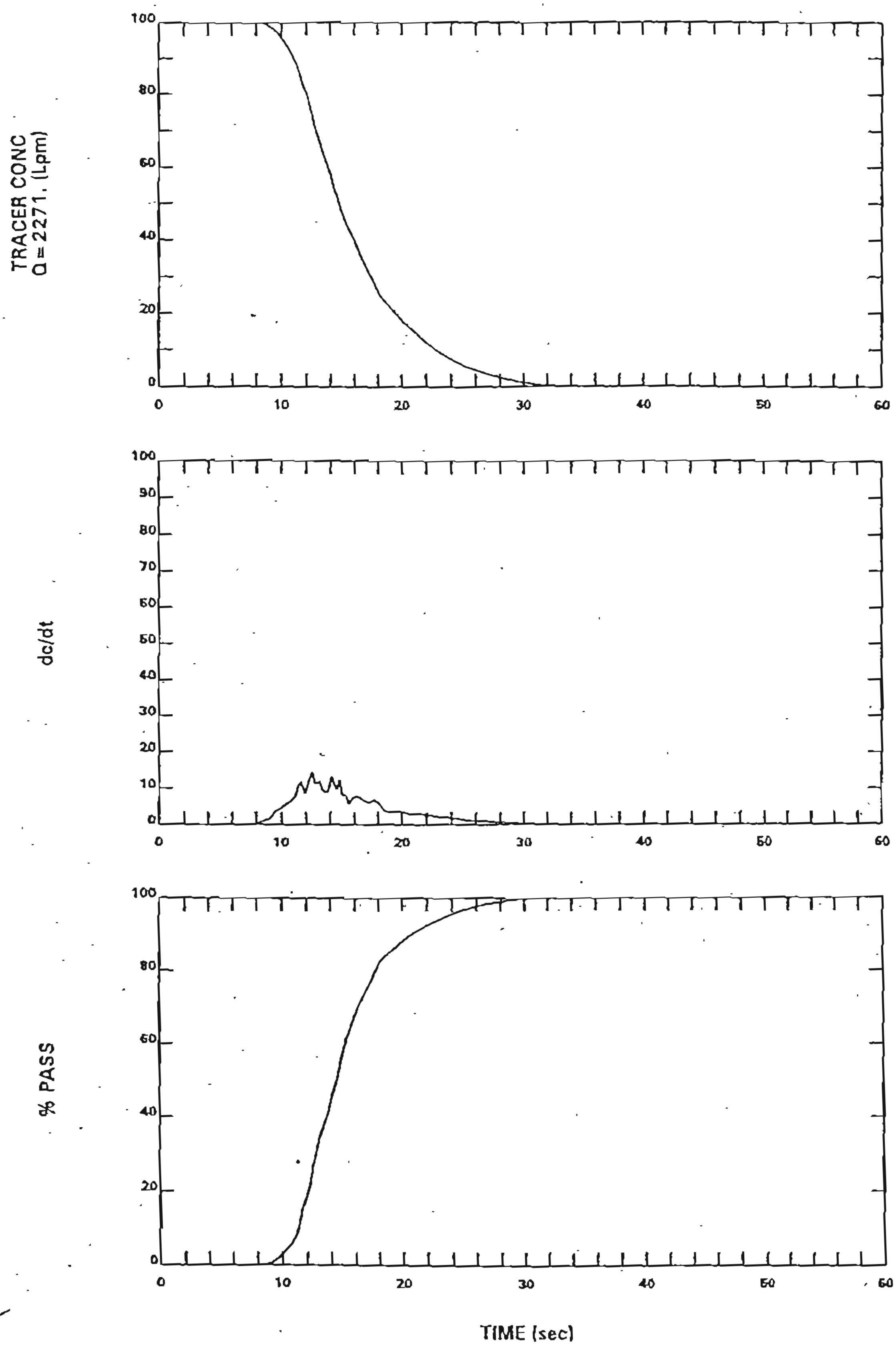
run4


TRACER CONC.
Q = 1514. (Lpm)
dc/dt
% PASS
TIME (sec)
0
10
20
30
40
50
60
70
80
90
100

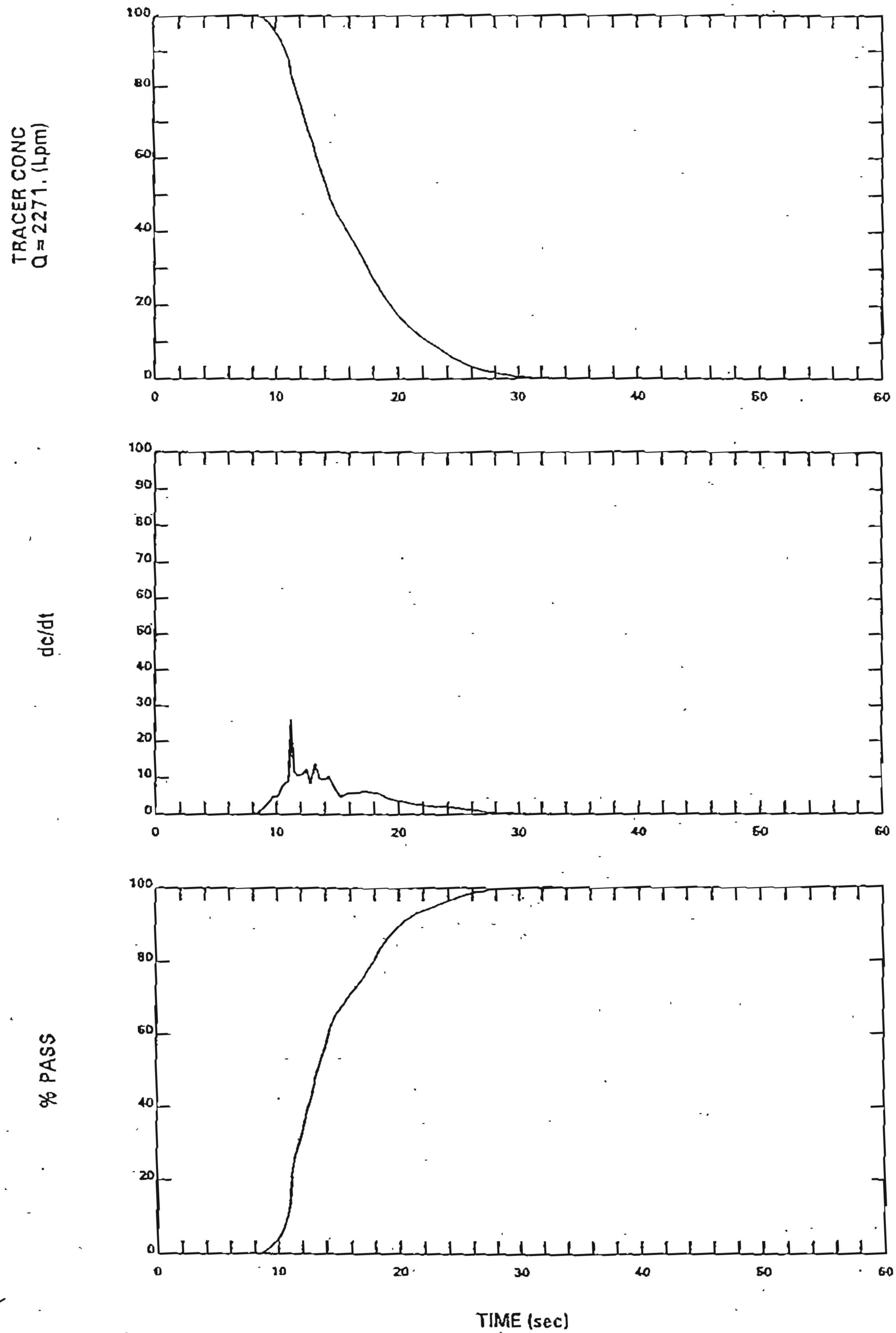
run5


TRACER CONC
Q = 1514. (Lpm)
dc/dt
% PASS
TIME (sec)
0
10
20
30
40
50
60
80
90
100

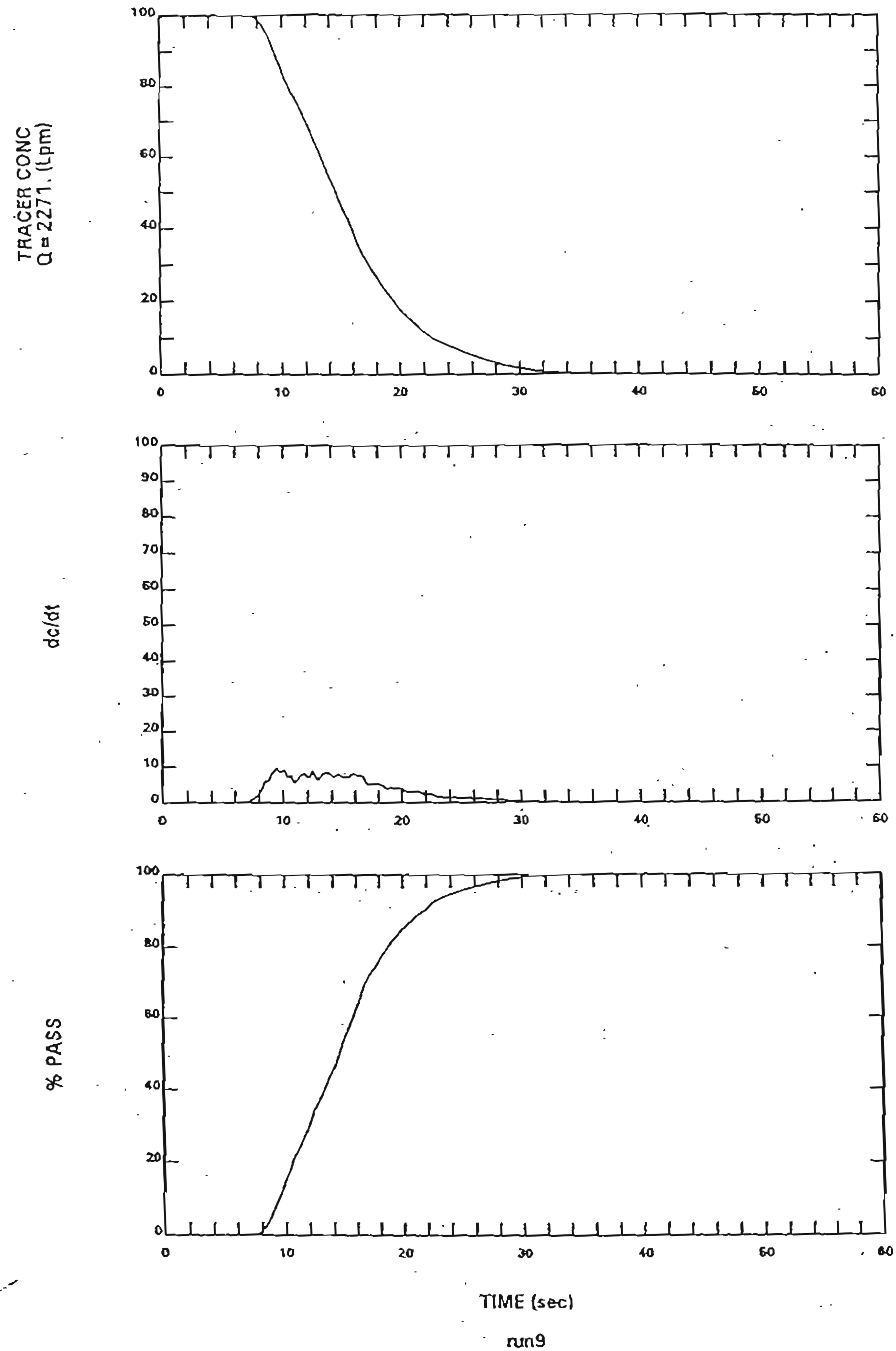
run6

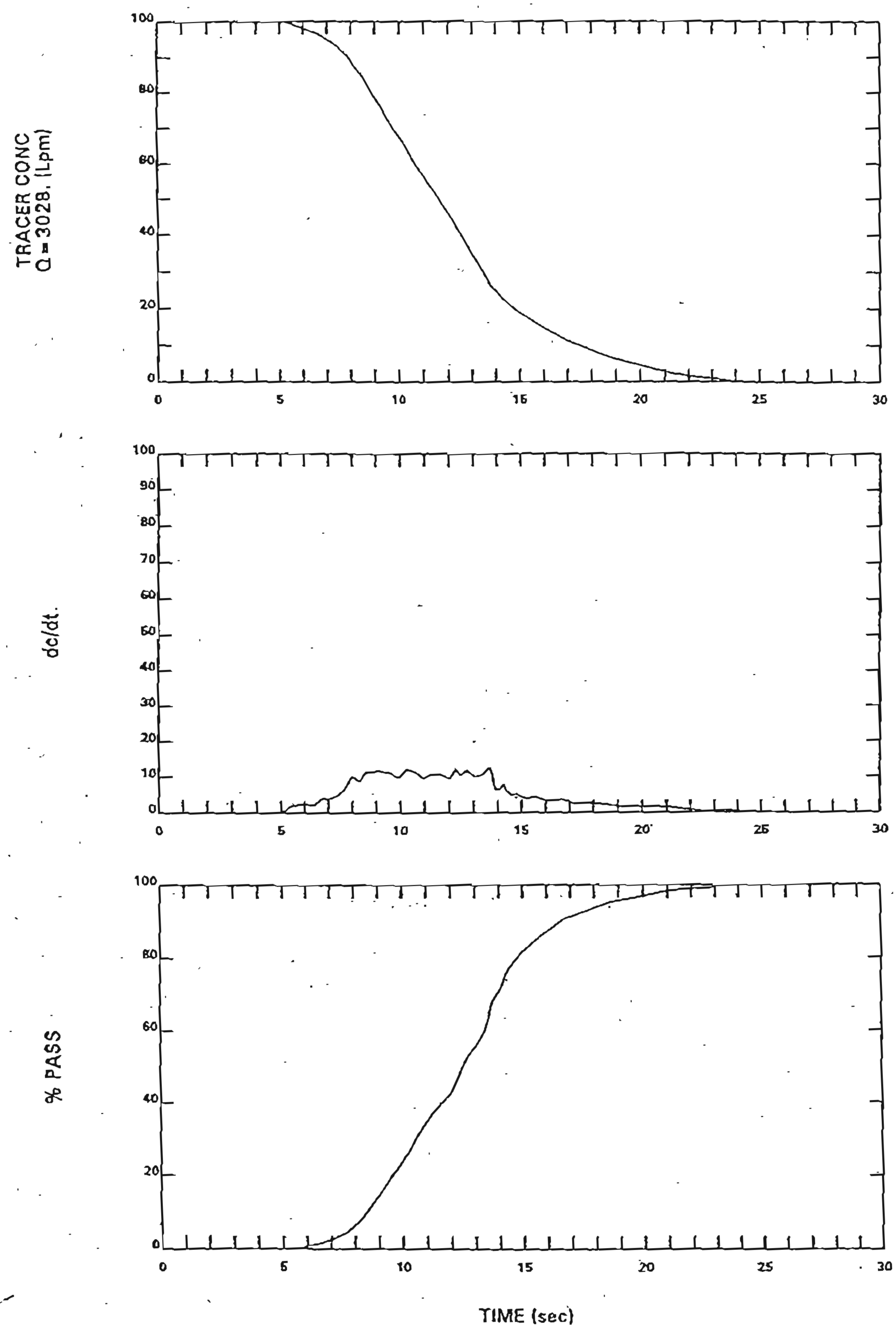


run7

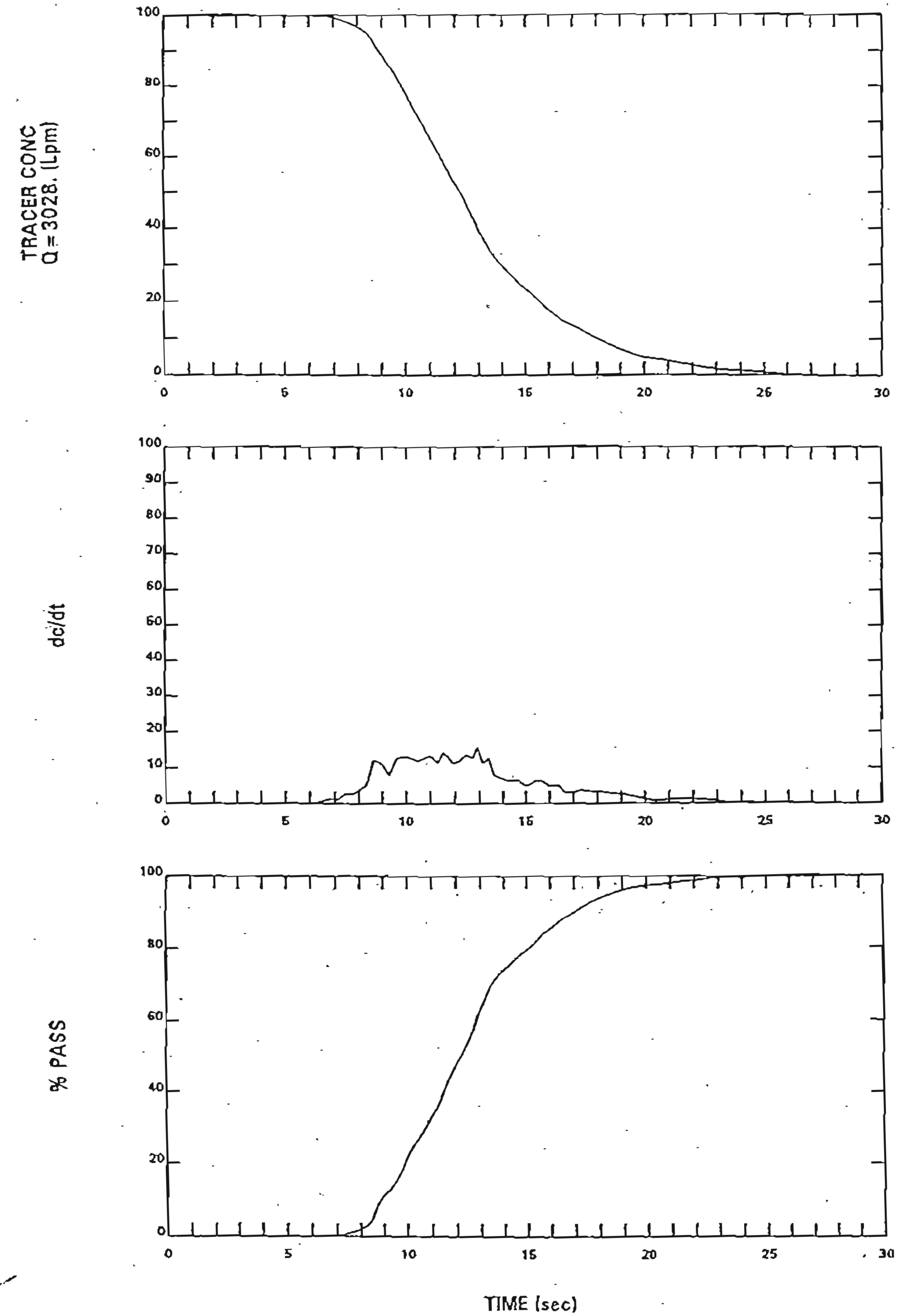


run8

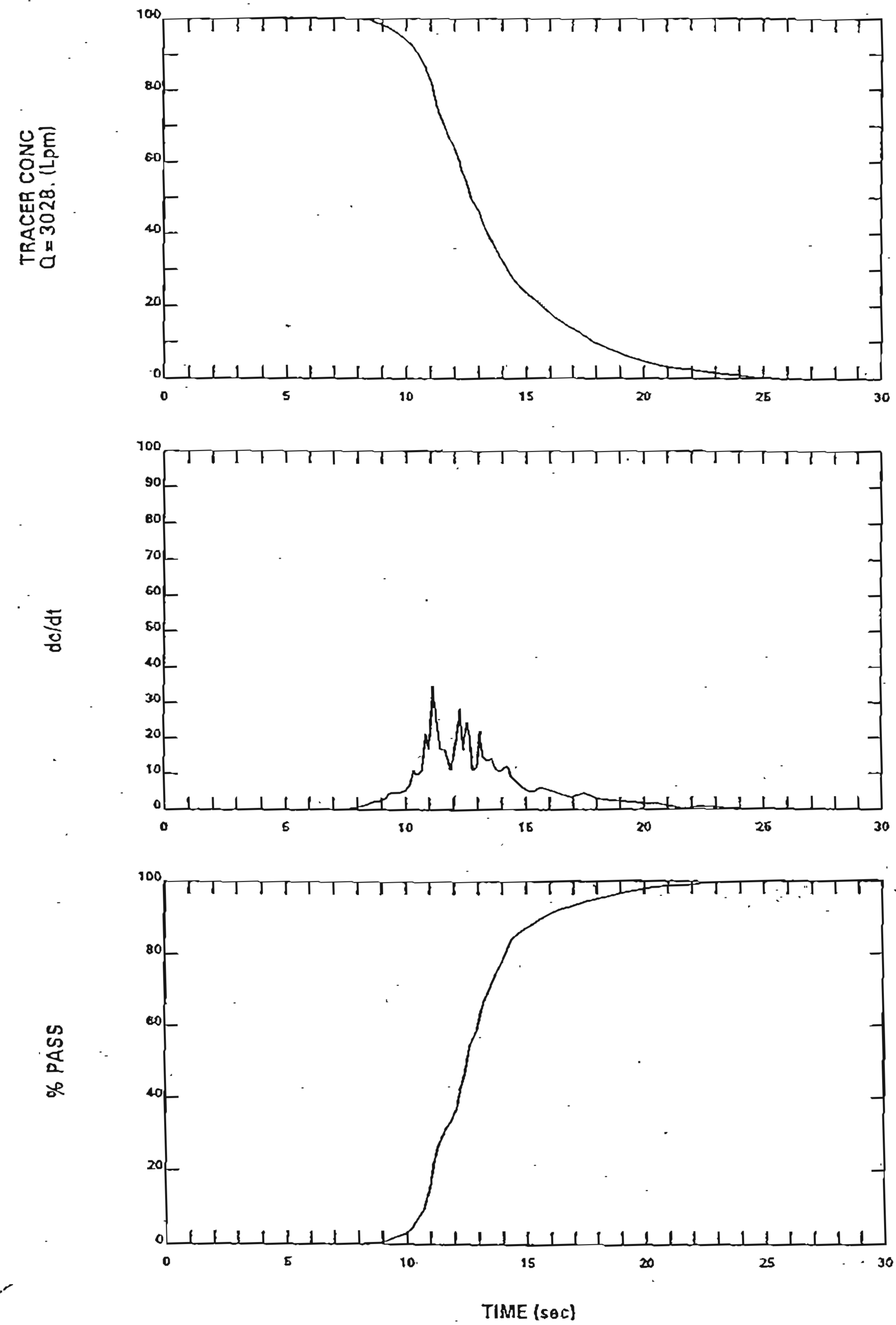

TRACER CONC
Q = 2271. (Lpm)
dc/dt
% PASS
0
10
20
30
40
50
60
TIME (sec)
run9


TRACER CONC
Q = 3028. (Lpm)
dc/dt.
% PASS
0
20
40
60
80
100
10
30
50
70
90
0
5
10
15
20
25
30
TIME (sec)

run10

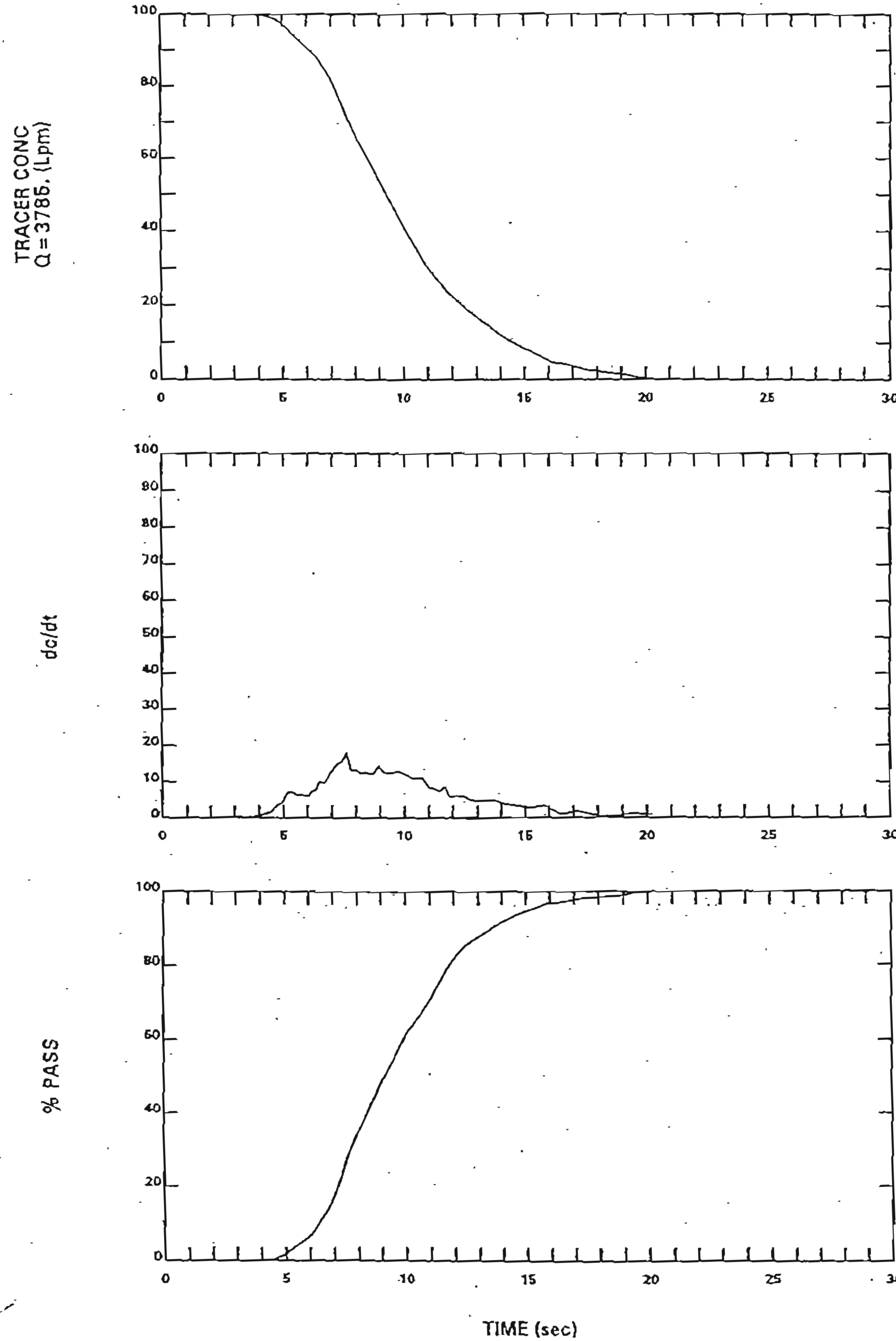

TRACER CONC
Q = 3028. (Lpm)
dc/dt
% PASS
0
20
40
60
80
100
0
5
10
15
20
25
30
TIME (sec)

run11

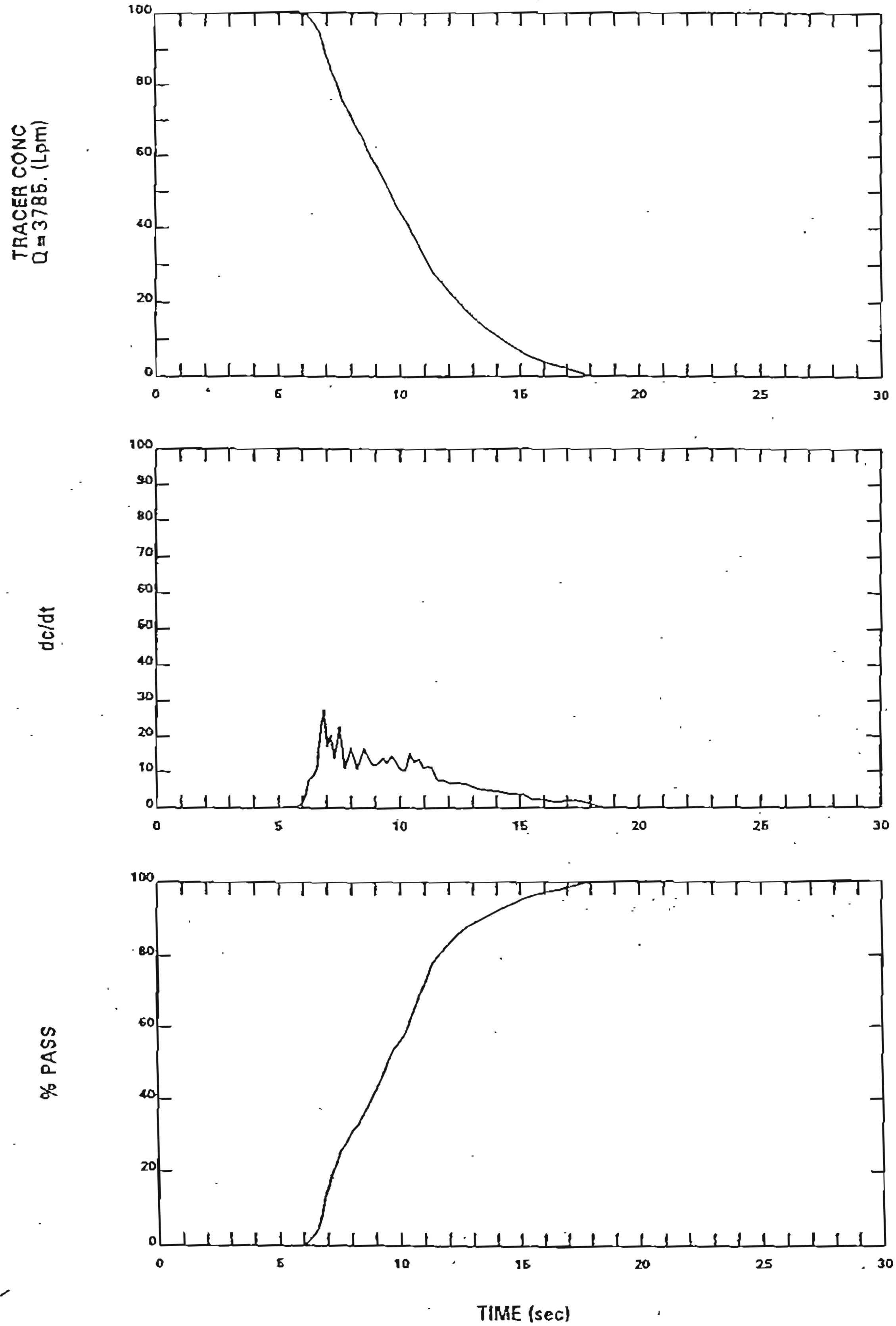


TRACER CONC
Q = 3028. (Lpm)
dc/dt
% PASS
100
80
60
40
20
0
90
70
50
30
10
5
15
25
TIME (sec)

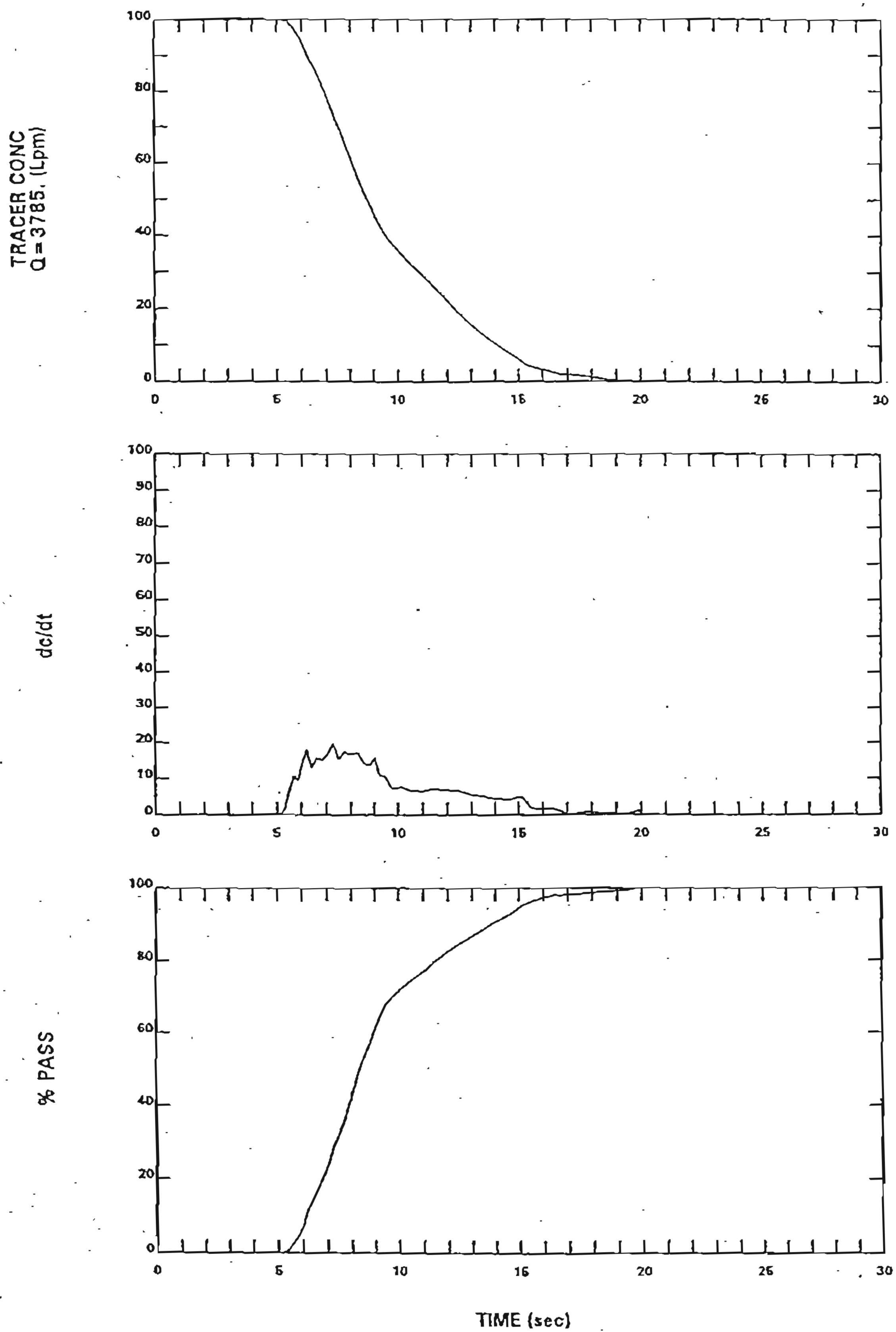
run12


TRACER CONC
Q = 3785. (Lpm)
dc/dt
% PASS
0
20
40
60
80
100
10
30
50
70
90
5
15
25
30
TIME (sec)

run13


TRACER CONC
Q=3785. (Lpm)
dc/dt
% PASS
100
80
60
40
20
0
90
70
50
30
10
0
5
10
15
20
25
30
TIME (sec)

run14



TRACER CONC
Q=3785. (Lpm)
100
80
60
40
20
0
0
5
10
15
20
25
30
dc/dt
100
90
80
70
60
50
40
30
20
10
0
% PASS
TIME (sec)

run15

APPENDIX D

BIOASSAY TEST - RUN DATA

HydroQual

Environmental
Engineers & Scientists

TABLE D1. ONDEO DEGREMONT VERTICAL DISINFECTION UNIT: RUN 1 CONDUCTED ON MARCH 20, 2001

Target Flow (gpm/Lpm)	UV Transmittance (%)	Average Influent Phage, No (pfp/mL)	Average Effluent Phage, N (pfp/mL)	Log N/N_o	Dose mW-sec/cm^2
200/757	58	2.0E+06	5.1E+02		
		2.0E+06	5.5E+02		
		2.0E+06			
		2.0E+06	5.3E+02	-3.58	87
400/1514	58	1.6E+06	7.5E+03		
		1.6E+06	5.7E+03		
		1.6E+06	8.5E+03		
		1.6E+06	7.2E+03	-2.34	50
600/2271	58	1.6E+06	5.7E+04		
		2.2E+06	4.7E+04		
		2.6E+06	3.4E+04		
		2.1E+06	4.6e+04	-1.63	33
800/3028	58	2.7E+06	9.4E+04		
		2.6E+06	1.5E+05		
		2.8E+06	9.6E+04		
		2.7E+06	1.1E+05	-1.38	28
1000/3785	58	1.8E+06	1.3E+05		
		2.0E+06	1.3E+05		
		1.7E+06	1.0E+05		
		1.8E+06	1.2E+05	-1.19	24
200/757	58	1.7E+06	2.4E+03		
		1.6E+06	N/A		
		1.4E+06	2.7E+03		
		1.5E+06	2.6E+03	-2.78	62

Bolded values reflect geometric average

TABLE D2. ONDEO DEGREMONT VERTICAL DISINFECTION UNIT: RUN 2 CONDUCTED ON MARCH 20, 2001

Target Flow (gpm/Lpm)	UV Transmittance (%)	Average Influent Phage, No (pfp/mL)	Average Effluent Phage, N (pfp/mL)	Log N/N$_o$	Dose mW-sec/cm^2
200/757	58	1.8E+06	3.1E+03		
		2.0E+06	2.8E+03		
		2.0E+06	3.5E+03		
		1.9E+06	3.1E+03	-2.79	63
400/1514	58	2.2E+06	1.1E+04		
		1.5E+06	1.3E+04		
		1.9E+06	1.1E+04		
		1.9E+06	1.1E+04	-2.21	47
600/2271	58	2.0E+6	4.2E+04		
		2.0E+06	4.2E+04		
		3.5E+06	7.0E+4		
		2.5E+06	5.1E+04	-1.69	34
800/3028	58	2.6E+06	1.0E+05		
		2.5E+06	1.0E+05		
		2.4E+06	1.0E+05		
		2.5E+06	1.0E+05	-1.39	27
1000/3785	58	1.7E+06	1.3E+05		
		1.9E+06	1.4E+05		
		1.7E+06	N/A		
		1.8E+06	1.4E+05	-1.11	22
400/1514	58	2.4E+06	1.6E+04		
		1.8E+06	1.6E+04		
		1.5E+06	1.8E+04		
		1.9E+06	1.6E+04	-2.07	43

Bolded values reflect geometric average

TABLE D3. ONDEO DEGREMONT VERTICAL DISINFECTION UNIT: RUN 3 CONDUCTED ON MARCH 28, 2001

Target Flow (gpm/Lpm)	UV Transmittance (%)	Average Influent Phage, No (pfp/mL)	Average Effluent Phage, N (pfp/mL)	Log N/N.	Dose mW-sec/cm²
200/757	59	1.6E+06	1.8E+03		
		3.2E+06	1.6E+03		
		1.8E+06	1.8E+03		
		2.2E+06	1.7E+03	-3.10	72
400/1514	59	1.4E+06	1.5E+04		
		1.5E+06	1.1E+04		
		1.5E+06	1.4E+04		
		1.5E+06	1.3E+04	-2.05	43
600/2271	59	2.2E+06	4.2E+04		
		1.3E+06	3.8E+04		
		2.2E+06	3.0E+04		
		1.9E+06	3.7E+04	-1.72	35
800/3028	59	1.7E+06	6.3E+04		
		1.4E+06	7.5E+04		
		1.7E+06	6.6E+04		
		1.6E+06	6.8E+04	-1.37	27
1000/3785	59	1.9E+06	1.4E+05		
		2.0E+06	1.5E+05		
		1.5E+06	1.1E+05		
		1.8E+06	1.3E+05	-1.14	23
800/3028	59	1.8E+06	7.9E+04		
		1.6E+06	5.6E+04		
		1.6E+06	5.6E+04		
		1.7E+06	6.4E+04	-1.42	28

Bolded values reflect geometric average

TABLE D4. ONDEO DEGREMONT VERTICAL DISINFECTION UNIT: RUN 4 CONDUCTED ON MARCH 28,2001

Target Flow (gpm/Lpm)	UV Transmittance (%)	Average Influent Phage, No (pfp/mL)	Average Effluent Phage, N (pfp/mL)	Log N/N₀	Dose mW-sec/cm²
200/757	57	1.5E+06	5.4E+02		
		1.6E+06	5.8E+02		
		2.0E+06	7.0E+02		
		1.7E+06	**6.0E+02**	-3.45	83
400/1514	57	1.7E+06	9.1E+03		
		1.6E+06	1.1E+04		
		1.9E+06	9.9E+03		
		1.7E+06	**1.0E+04**	-2.23	47
600/2271	57	1.6E+06	3.3E+04		
		1.7E+06	2.9E+04		
		1.8E+06	3.2E+04		
		1.7E+06	**3.1E+04**	-1.73	35
800/3028	57	1.6E+06	9.3E+04		
		1.8E+06	7.9E+04		
		1.4E+06	8.1E+04		
		1.6E+06	**8.4E+04**	-1.28	25
1000/3785	57	2.0E+06	1.7E+05		
		2.1E+06	1.6E+05		
		1.9E+06	1.7E+05		
		2.0E+06	**1.7E+05**	-1.07	21
1000/3785	57	2.0E+06	1.6E+05		
		2.4E+06	1.5E+05		
		1.5E+06	2.0E+05		
		2.0E+06	**1.7E+05**	-1.06	21

Bolded values reflect geometric average

Burns & McDonnell
SINCE 1898

011200 Form GCO-29B

Client ____ Page ____ of ____
Project ____ Date 6/15/56 Made By ____
____ Checked By ____
____ Preliminary ____ Final ____

Final Clarifier Design Sizing

Hydraulic Sizing: 1000 gpd/ft²

Q: 16.4 mgd → 8.2 mgd per clarifier

8.2 mgd = 5,700 gpm (Max daily flow including wet weath

NPDES PERMIT FILE
NPDES # ____
AFIN # ____ 8,200,000/1000 = 8200 ft² = πr^2

____ Permit PN
____ Correspondence ∴ Φ = 102'
____ Technical Backup
____ Date Scanned

Solids Loading: 35 lb/day/ft²

Assume MLSS =

Q: 8.2 mgd + 6/2 mgd = 11.2 MGD
Qmax day ½ RAS

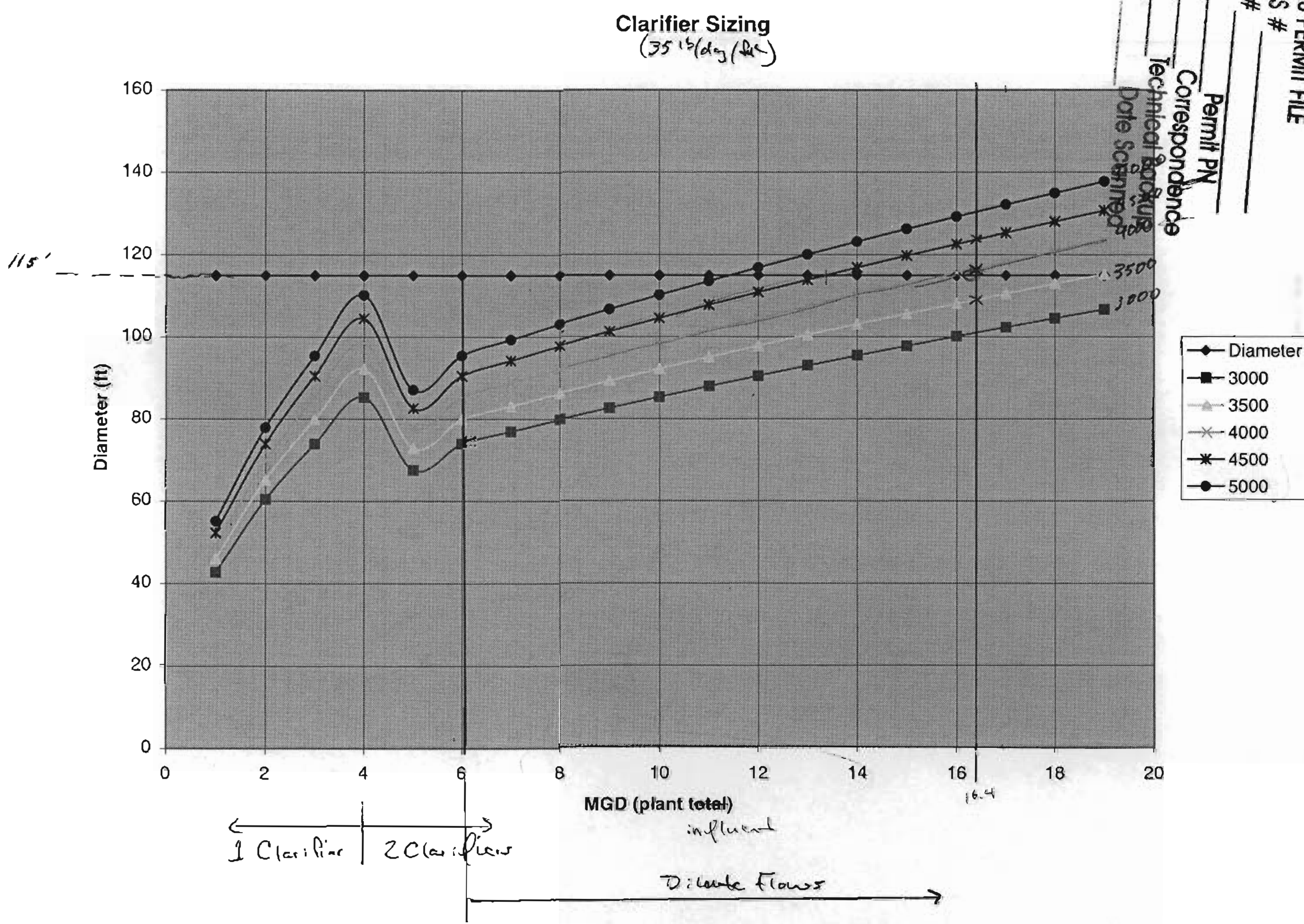
For MLSS = 3000

(3000 mg/L)(8.34 lb/MG/mg/L)(11.2 MGD) = 280,224 lb/day

280224/35 = 8006 = πr^2 ∴ Φ = 101'

For MLSS = 4500 Φ = 123' ±

For MLSS 4000 ← Φ = 116' ±



Clarifier Sizing
(35 lb/day/ft²)
Diameter (ft)
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
18
20
MGD (plant total)
influent
16.4
115'
3500
3000
Diameter
3000
3500
4000
4500
5000
1 Clarifier
2 Clarifiers
Dilute Flows

From: Olson, John E (WT) [John.E.Olson@siemens.com]
Sent: Tuesday, April 04, 2006 2:04 PM
To: Barnes, Dennis J (WT); Houtz, Alan E (WT); Keller, Jeff
Cc: Kaufman, John G (WT); Sheridan, John P (WT)
Subject: RE: Cabot WWTP - Orbal Design

Jeff;

The two state point analysis attached indicate the settling characteristics of the 115 foot diameter clarifiers under two operational modes. Condition one is with 4500 mg/l MLSS and all three Orbal channels operating in series at peak flow conditions. The solids loading rate on the clarifiers is about 45 lbs./ft²/day. Condition 2 indicates the operating conditions at peak flow loading if a Stormflow diversion is made to the middle channel during peak flows. Solids loading is reduced to 30 lbs/ft²/day. This is well below the 35 lbs./ft²/day that is stated in 10 States Standards.

It should also be noted that Metcalf & Eddy reports design maximum loading conditions on secondary activated sludge clarifiers of up to 48 lbs./ft²/day.

To produce a 4500 mg/l MLSS requires the plant be operated at about a 21.5 day sludge age, which is well above the level needed in this design for BNR operation. Operating at lower sludge ages would greatly reduce the solids loading on the clarifiers and still produce excellent treatment.

Please let me know if you have any questions regarding this evaluation.

John E. Olson, P.E.
Senior Process Engineer - Biological Products Group
US Filter, Envirex Products
1901 S. Prairie Ave.
Waukesha, WI 53189
Phone: 262.521.8495
Cell Phone: 262 488 5996
Fax: 262.521.8553
john.e.olson@siemens.com
www.usfilter.com

From: Barnes, Dennis J (WT)
Sent: Tuesday, April 04, 2006 7:50 AM
To: Houtz, Alan E (WT); Olson, John E (WT)
Cc: Kaufman, John G (WT); Sheridan, John P (WT)
Subject: RE: Cabot WWTP - Orbal Design

Oly and Alan – could you put something together for Jeff Keller to support our clarifier sizing?

From: Keller, Jeff [mailto:jkeller@burnsmcd.com]
Sent: Monday, April 03, 2006 6:53 PM
To: Kaufman, John G (WT); Barnes, Dennis J (WT); Brian Johnson
Subject: Cabot WWTP - Orbal Design

Gentlemen-

USFilter
A Siemens Business
Envirex Products

Secondary Clarifier Design Prepared: 10/31/2005
Project: Central AR WWTP (no Cannibal)
Engineer: Burns & McDonnell Designer: Dennis Barnes

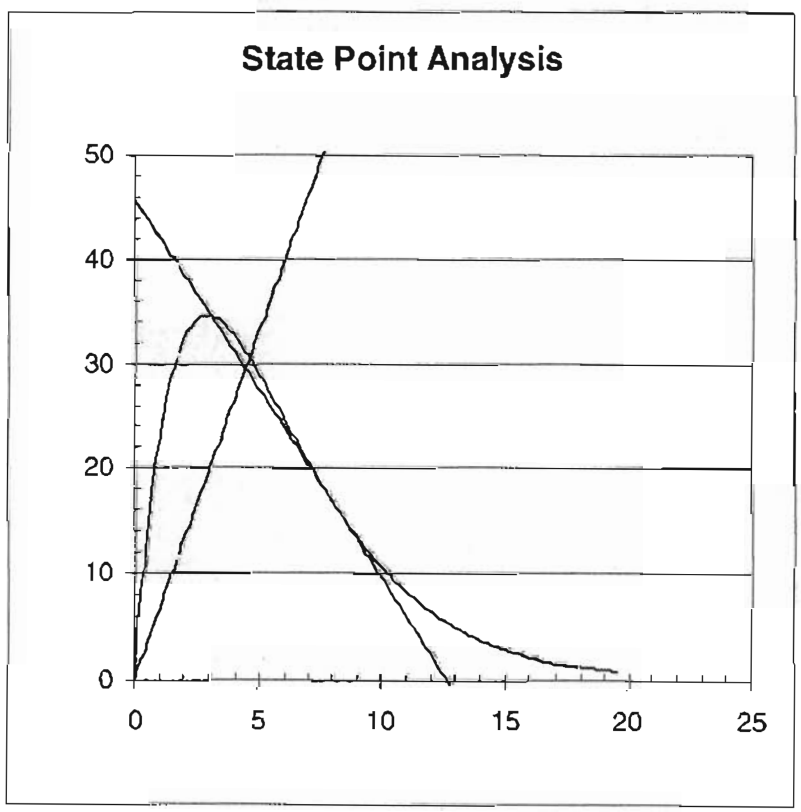
Number of aeration channels:	3
For normal mode, influent directed to channel #	1
For stormflow mode, influent directed to channel #	1

Design MLSS in aeration, mg/l	4500.742	Stormflow MLSS to clarifiers, mg/l	4,500.7
Design RAS conc., mg/l	7501.237	Stormflow, RAS conc, mg/l	12,702
		Reaeration tank conc., mg/l	8,016
number of clarifiers	2		
Diameter, feet	115	In stormflow mode, % volume of aeration tanks that influent flows through	100.0%
design flow, mgd	6.0		
peak flow, mgd	16.4	Design SOR, gal/day/sf	288.7
RAS, mgd	9.0	Peak SOR, gal/day/sf	789.2
Recycle (MLSS w/nitrates), mgd	12.00	Underflow Rate, gal/ft^2/day	433.2
Design solids loading, lb/sf/d	27.1	design lbs to clarifier(s)	563,043
Peak solids loading, lb/sf/d without stormflow mode, lb/sf/d	45.9	peak lbs to clarifier(s) without stormflow mode	953,419
Peak solids loading with stormflow mode, lb/sf/d	45.9	peak lbs to clarifier(s) with stormflow mode	953,419

CLARIFIER STATE POINT ANALYSIS - PEAK FLOW IN STORMFLOW MODE

Total clarifier area, ft^2	20773.78	
Loading, lb/ft^2/day	45.84028	
Flux, lb/ft^2/day	29.59766	
Vo	511.4	ft/day
SVI	110	ml/gm
k	0.33906	L/g
increment	0.1	g/L

$G = (Vo)(X)(e^{-kX})$



USFilter A Siemens Business
Envirex Products

Secondary Clarifier Design | Prepared: 10/31/2005
Project: Central AR WWTP (no Cannibal)
Engineer: Burns & McDonnell | Designer: Dennis Bames

Number of aeration channels: 3
For normal mode, influent directed to channel # 1
For stormflow mode, influent directed to channel # 2

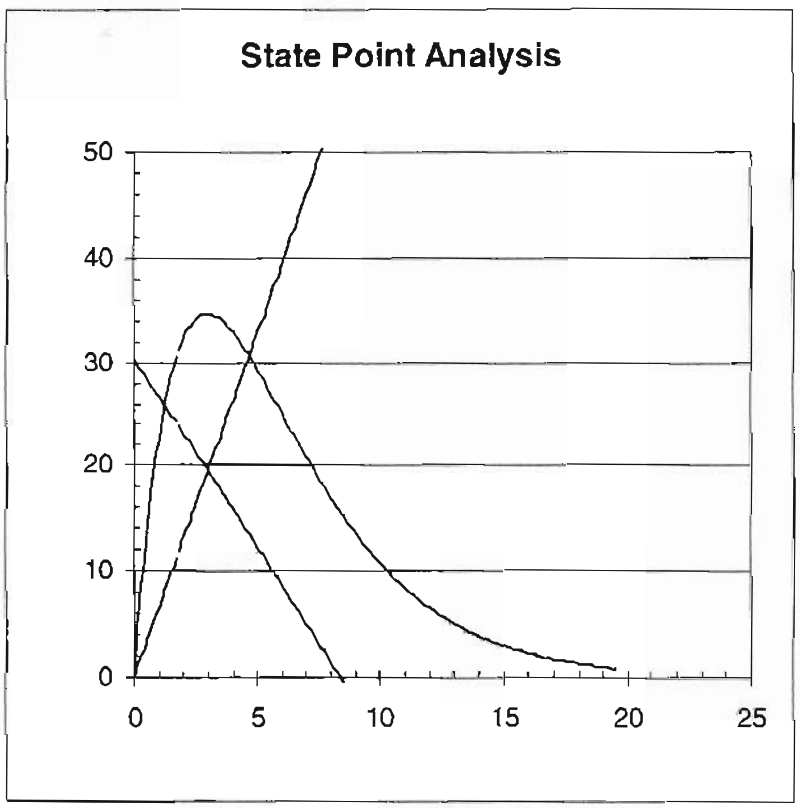
Design MLSS in aeration, mg/l	4500.742
Design RAS conc., mg/l	7501.237
number of clarifiers	2
Diameter, feet	115
design flow, mgd	6.0
peak flow, mgd	16.4
RAS, mgd	9.0
Recycle (MLSS w/nitrates), mgd	12.00
Design solids loading, lb/sf/d	27.1
Peak solids loading, lb/sf/d without stormflow mode, lb/sf/d	45.9
Peak solids loading with stormflow mode, lb/sf/d	30.4

Stormflow MLSS to clarifiers, mg/l	2,978.3
Stormflow, RAS conc, mg/l	8,405
Reaeration tank conc., mg/l	5,304
In stormflow mode, % volume of aeration tanks that influent flows through	34.5%
Design SOR, gal/day/sf	288.7
Peak SOR, gal/day/sf	789.2
Underflow Rate, gal/ft^2/day	433.2
design lbs to clarifier(s)	563,043
peak lbs to clarifier(s) without stormflow mode	953,419
peak lbs to clarifier(s) with stormflow mode	630,903

CLARIFIER STATE POINT ANALYSIS - PEAK FLOW IN STORMFLOW MODE

Total clarifier area, ft^2	20773.78	
Loading, lb/ft^2/day	30.33374	
Flux, lb/ft^2/day	19.58556	
Vo	511.4	ft/day
SVI	110	ml/gm
k	0.33906	L/g
increment	0.1	g/L

$G = (Vo)(X)(e^{-kX})$



Check ok'd

Copy Pic

to CRN

TW

Wade

Vern

JPm

CABOT WASTEWATER TREATMENT PLANT
CONTROL CAPABILITY SUMMARY
(Preliminary)

General Description:

There is a SCADA system at the existing Cabot wastewater treatment plant. The SCADA system is comprised of three programmable logic controllers (PLCs) and one computer workstation running user interface software called Wonderware. Communication between the programmable logic controllers is based on serial wireless technology. This system is approximately one year old.

The SCADA system for the new wastewater treatment plant will be comprised of existing and new PLCs. The existing PLC in the Administration Building will be re-utilized for the new system. The PLC in the existing Headworks Building will be relocated to the new Headworks Building. The PLC in the existing influent pump station will be kept in service. New PLCs will be installed in the new Influent Pump Station and Electrical Building. In addition, a new computer workstation will be added to improve the reliability of the system. The new workstation will be licensed to run Wonderware so that it is fully compatible with the existing workstation and will be located with the existing workstation in the Administration Building. Each workstation will be capable of operating independently and each will have a separate database for data logging and storage. In addition, each workstation will allow the operator to navigate between different process screens to monitor and control process equipment.

The SCADA system will communicate via serial wireless technology and Ethernet fiber/copper connections. In addition to the plant PLCs, the oxidation basin and UV disinfection equipment will be supplied with vendor supplied PLC's. The UV disinfection PLC will allow only monitoring capability at the operator workstation. The oxidation basin PLC will allow monitoring and limited control from the operator workstation.

In case the new SCADA system ceases to function, the operator will be able to operate the plant manually with the use of "Hand-Off-Auto" (H-O-A) and "On-Off" switches.

Influent Pump Station:

Equipment List:
(3) Submersible influent pumps using variable speed drives (VFD).
(1) Future submersible influent pump for VFD operation.
(1) Possible future wet-weather submersible pump – single speed or variable speed.
(1) Level transmitter in the wet-well.
(1) High level float switch in the valve pit.
(1) Diesel generator.
(1) PLC.

Capabilities at the Computer Workstation:

1. Monitor (run, fault, in-auto, seal leak, high winding temperature, speed) and control (speed command, start, stop) the influent pumps.
2. Set level setpoints and adjust time delay for pump starting.
3. Monitor wet-well level, high level in the valve pit and generator operation.
4. Monitor (loss of power, fail) the PLC.
5. Monitor, acknowledge and reset all alarm conditions.
6. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.

Capabilities at the Influent Pump Station:

1. Monitor (run, fault, H-O-A position, speed) and control (speed command, H-O-A operation, start, stop) the influent pumps via the front panels of the VFDs.

Headworks:

Equipment List:
(2) Screens.
(1) Compactor.
(1) Control panel for the screens and compactor.
(1) Combustible gas detector (CGD) controller and sensors.
(3) Flow transmitters – one for each influent source.
(1) High level float switch in the influent channel.
(1) PLC.

Capabilities at the Computer Workstation:

1. Monitor (run, fault) the screens and compactor.
2. Monitor individual influent flow and totalized flow through the Headworks Building.
3. Monitor loss of ventilation and high combustible gas level alarms.
4. Monitor high water level in the influent channel.
5. Monitor (loss of power, fail) the PLC.
6. Monitor, acknowledge and reset all alarm conditions.
7. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.

Capabilities at the Headworks Building:

1. Monitor (run, fault) and control (start, stop) the screens and compactor.
2. Monitor loss of ventilation and high combustible gas level alarms.
3. Silence building alarms associated with combustible gas alarms and loss of ventilation.
4. Monitor individual influent flow.

Electrical Building:

Equipment List: (Electrical Building)
(1) Motor control center (MCC) including VFDs for RAS pumps and single-speed starters for WAS pumps, scum pump, final clarifiers, oxidation basin recycle pump, and re-aeration blower.
(1) Diesel generator.
(1) PLC.

Note: The oxidation basin control panel and VFDs for aeration disc motors are physically located in the Electrical Building.

Capabilities at the Computer Workstation:

1. Monitor (run, fail, low fuel, loss of normal power) the generator operation.
2. Monitor, acknowledge and reset all alarm conditions.
3. Monitor (loss of power, fail) the PLC.
4. Monitor, acknowledge and reset all alarm conditions.
5. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.
6. Control (start, stop) all single-speed motors when the "H-O-A" switch for each respective pump is set to "Auto" position. Only exception is the scum pump which can only be operated locally at the scum pit and the recycle pump. The recycle pump will be automatically operated from the oxidation basin control panel.

Capabilities at the Electrical Building:

1. Control (start, stop) all single-speed motors at the MCC.
2. Monitor (run) all single-speed motors at the MCC.
3. Monitor (run, fail, H-O-A position, speed) and control (speed command, H-O-A operation, start, stop) RAS pumps via the front panels of the VFDs.
4. Monitor (run, fail, H-O-A position, speed) and control (speed command, H-O-A operation, start, stop) the oxidation basin drives via the front panels of the VFDs.

Oxidation Basin:

Equipment List: (Oxidation Basin) (2) (1)
(10)Aeration disk motors (vendor supplied).
(1) Oxidation basin control panel with PLC (vendor supplied).
(1) Dissolved oxygen (DO) analyzer with sensors (vendor supplied).
(1) Oxidation reduction potential (ORP) analyzer with sensors (vendor supplied).
(10) VFDs for the aeration disk motors (vendor supplied).

Note: The oxidation basin control panel and VFDs for aeration disc motors are physically located in the Electrical Building.

Capabilities at the Computer Workstation: (Based on vendor data)

1. Monitor (run, fault, H-O-A position, speed) the VFDs.
2. Control (H-O-A operation, speed setpoint) the VFDs.
3. Monitor (middle and inner channels, inner channel setpoint) the DO levels.
4. Control (inner channel) the DO setpoint.
5. Monitor (outer and middle channels, outer channel setpoint) the ORP levels.
6. Control (outer channel) the ORP setpoint.
7. Monitor (fail) the DO and ORP analyzers.
8. Monitor (run, seal leak, over-temperature) the recycle pump.
9. Monitor, acknowledge and reset all alarm conditions.
10. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading

Capabilities at the Oxidation Basin:

1. None. Refer to "Capabilities at the Electrical Building".

RAS/WAS Pump Station:

Equipment List: (RAS/WAS Pump Station)
(1) Level transmitter.
(3) RAS pumps.
(2) WAS pumps.
(1) RAS Flow transmitter.
(1) WAS Flow transmitter.

Note: The VFDs and single-speed starters for the RAS and WAS pumps are physically located in the Electrical Building.

<u>Capabilities at the Computer Workstation:</u>

1. Monitor (run, fault, ~~in auto~~, seal leak, high winding temperature, speed) and control (speed command, start, stop) the RAS pumps.
2. Monitor (run, seal leak, over-temperature) and control (start, stop) the WAS pumps.
3. Set level control setpoints for RAS pump operation and adjust time delay for pump starting.
4. Monitor sludge level.
5. Monitor RAS and WAS sludge flows.
6. Monitor, acknowledge and reset all alarm conditions.
7. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.

<u>Capabilities at the RAS Pump Station:</u>

1. Operate the WAS pumps locally when the "H-O-A" switches are placed in "Hand" position.

Final Clarifiers:

Equipment List: (Final Clarifiers)
(2) Clarifier drives.
(1) Scum pump.
(2) Torque switches.

Capabilities at the Computer Workstation:

1. Monitor (run, over-torque) and control (start, stop) of the clarifier drives.
2. Monitor, acknowledge and reset all alarm conditions.
3. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.

Capabilities at the Final Clarifiers:

1. Control (start, stop) the clarifier drives locally when the "H-O-A" switches are placed in "Hand" position.
2. Control (start, stop) the scum pump locally.

UV Disinfection:

Equipment List: (UV Disinfection)
(1) UV disinfection control panel with PLC (vendor supplied).
(1) UV disinfection equipment (vendor supplied).
(1) Effluent flow transmitter.
(1) Re-aeration blower.

Capabilities at the Computer Workstation:

1. Monitor the following alarms: (Subject to change)
   a. Flowmeter signal failure ~~per channel~~.
   b. UV intensity low per channel.
   c. UV intensity low-low per channel.
   d. PLC communication failure.
   e. Module communication failure.
   f. UV dose failure per channel.
   g. Adjacent lamp failure per channel.
   h. Module high temperature.
   i. Water high level per channel.
   j. Water low level per channel.
   k. Process Data.
   l. Water flow rate ~~per channel~~.
   m. UV intensity per channel.
   n. UV channel (no.) selected "on".
   o. Water level, feet per channel.
   p. Lamp rows "on" per channel.
   q. Does (microW/cm2) per channel.
   r. Plant effluent flow.
2. Monitor (run, overload) and control (start, stop) the re-aeration blower.
3. Monitor, acknowledge and reset all alarm conditions.
4. Automatically log all operator actions, equipment statuses, and process parameters to the workstation database for downloading.

Capabilities at the UV Disinfection:

1. Monitor (listed alarms) and control the UV disinfection equipment via the front panel touchscreen.
2. Control (start, stop) the re-aeration blower locally when the "H-O-A" switch is placed in "Hand" position.

Design Criteria:

PRIMARY INFLUENT PUMPING STATION (IPS)

- Average Day Flow: 2.92 MGD (2,033 gpm)
- Peak Day Flow: 8.00 MGD (5,555 gpm) based on a peaking factor of 2.73

Wet Well Size: The wet well was sized to accommodate four (4) submersible pumps to ultimately achieve the peak design of 8 mgd using three (3) pumps. Due to economics, initially only three (3) pumps are proposed to be installed with two (2) providing the peak flow of 7.2 mgd (5,000 gpm).

The wet well is approximately 12 feet by 20.5 feet with a normal operating range of 4 feet which gives an operating volume of 7,400 gallons. The fill time based on average day is 3.6 minutes. The wet well is equipped with sluice gates to provide isolation of the wet well compartments for maintenance.

The wet well is equipped with a wet weather overflow pipe which allows the overflow to flow into the wet well of the existing pumping station. The overflow is then pumped into the existing equalization pond. Once flows have returned to normal the existing pumping station will pump the stored wastewater to the headworks for treatment.

Pumps: Three (3) pumps are provided. Each pump is rated at 2,100 gpm @ 42 feet of total dynamic head (TDH), 1185 rpm, 460 volts, 30 hp. The pumps will be driven with variable speed drivers so that the pumps can be operated to provide a more uniform flow into the wastewater treatment plant. See attached pump system curves showing single pump and multiple pump operation. Also enclosed is a single pump system curve showing operating conditions under variable speed.

Under constant speed operation the proposed influent pumping station will operate as follows:

Single pump:	2,700 gpm @ 31' TDH (at maximum static water level)
	3,000 gpm @ 26' TDH (at minimum static water level)
Dual pumps:	4,600 gpm @ 39' TDH (at maximum static water level)
	5,000 gpm @ 35' TDH (at minimum static water level)
Triple pumps:	5,700 gpm @ 45' TDH (at maximum static water level)
	6,200 gpm @ 42' TDH (at minimum static water level)
Four pumps:	6,400 gpm @ 50' TDH (at maximum static water level)
	6,900 gpm @ 47' TDH (at minimum static water level)

Flowmeter: 12 inch magnetic meter (350 gpm to 10,600 gpm flow range)

Force Main: 20-inch cement lined ductile iron pipe

- Minimum velocity: 2 feet per second (except through meter)
- Maximum velocity: 6 to 8 feet per second (except through meter)

RETURN ACTIVATED SLUDGE (RAS) & WASTE ACTIVATED SLUDGE PUMPING STATION (WAS)

Wet Well Sizing: The wet well was sized to accommodate three (3) return activated sludge pumps and two (2) waste activated sludge pumps. The RAS pumps were sized to provide 50 to 150% of the average flow rate with all three pumps operating. Also, pumps will be operated with variable speed motors. The WAS pumps were sized to provide 25% of the design average daily flow. The wet well is equipped with two adjustable telescoping valves to modulate the sludge rate of return from each of the two clarifiers.

RAS Pumps: Three (3) pumps are provided. Each pump is rated at 2,100 gpm @ 42 feet of total dynamic head (TDH), 1185 rpm, 460 volts, 30 hp. The pumps will be driven with variable speed drivers so that the pumps can be operated to provide the necessary rate of return to the oxidation basin. See attached pump system curves showing single pump and multiple pump operation. Also enclosed is a single pump system curve showing operating conditions under variable speed.

The oxidation basin equipment manufacturer stated that they need only 100% return sludge capacity, therefore it was decided to provide 100% with two pumps and three pumps to provide the 150% sludge return.

Force Main: 18-inch cement lined ductile iron pipe

- Minimum velocity: 2 feet per second
- Maximum velocity: 8 feet per second

Flow Meter: 12-inch magnetic flow meter (350 gpm to 10,600 gpm capacity)

WAS Pumps: Two (2) pumps are provided. Each pump is rated at 700 gpm @ 15 feet of total dynamic head (TDH), 1155 rpm, 460 volts, 5 hp. The pumps will be constant speed. Amount of wasting will be controlled manually by the operator or by a timer.

One pump will operate at 700 gpm and two pumps at 1,040 gpm.

Force Main: 10-inch cement lined ductile iron pipe

- Minimum velocity: 2 feet per second
- Maximum velocity: 5 feet per second

The RAS/WAS pumping station will also be used to drain the clarifiers and oxidation basin for maintenance.

USI Arkansas, Inc.
. Terry W. Carpenter
WAS Pump Station--Cabot WWTP

H2Optimize ver: 6.041
04/14/06

PUMP DATA SHEET

Fairbanks Morse Pump, 60 Hz

Selection file: (untitled)
Catalog: FMSUB60.MPC v 2.0

Curve: 320406A

...gn Point: Flow: 700 US gpm
Head: 15.3 ft

Pump: 5430-NONCLOG - 1200 **Size: 4"5432M&W**
Speed: 1155 rpm Dia: 8.75 in

Limits: Temperature: 104 °F Sphere size: 3 in
Pressure: 60 psi_g Power: --- bhp

Specific Speed: Ns: 1920 Nss: 5429

Dimensions: Suction: 4 in Discharge: 4 in

Motor: 5 hp Speed: 1200 Frame: 210
SUBMRGD StandarcXPLPROF Enclosure
sized for Max Power on Design Curve

Fluid: Water
Temperature: 60 °F
SG: 1
Viscosity: 1.122 cP
Vapor pressure: 0.2568 psi_a
Atm pressure: 14.7 psi_a

NPSHa: --- ft

Piping: System: ---
Suction: --- in
Discharge: --- in

---- Data Point ----

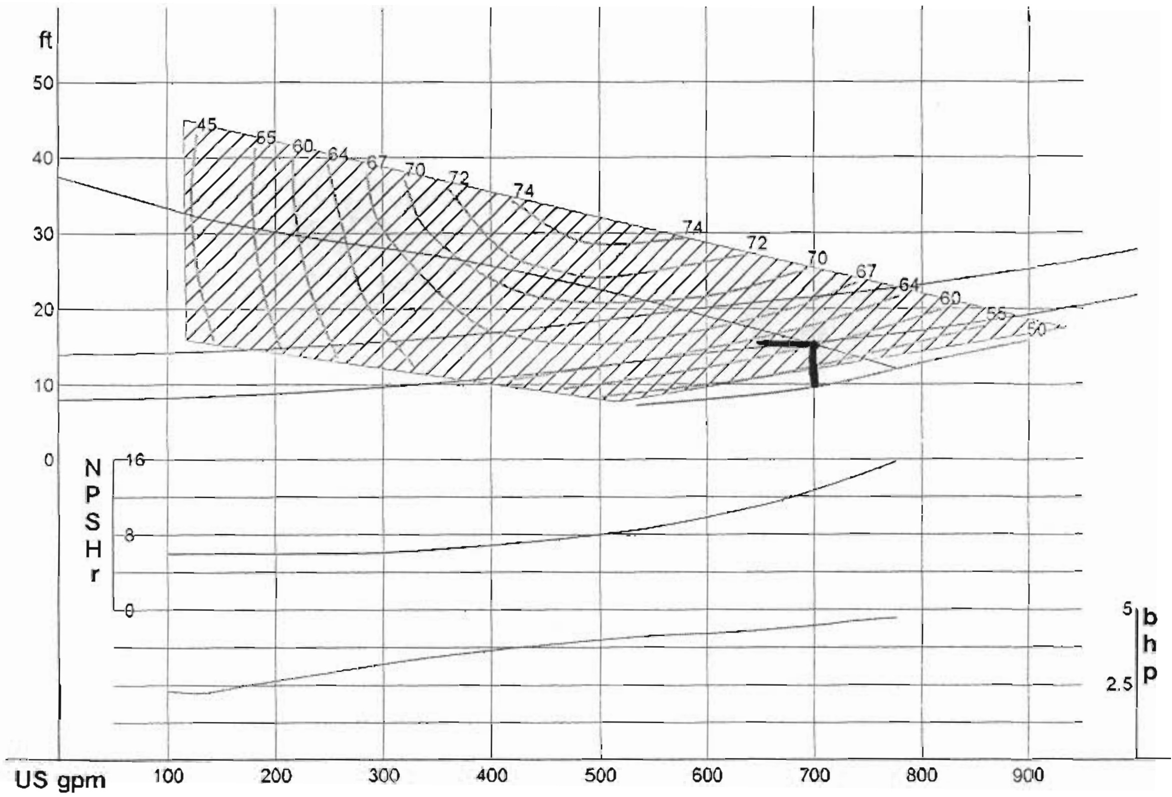
Flow: 700 US gpm
Head: 15.3 ft
Eff: 60%
Power: 4.48 bhp
NPSHr: 12.7 ft

-- Design Curve --

...utoff Head: 37.5 ft
Shutoff dP: 16.2 psi
Min Flow: 100 US gpm
BEP: 71% eff
@ 464 US gpm
NOL Pwr: 4.73 bhp
@ 776 US gpm

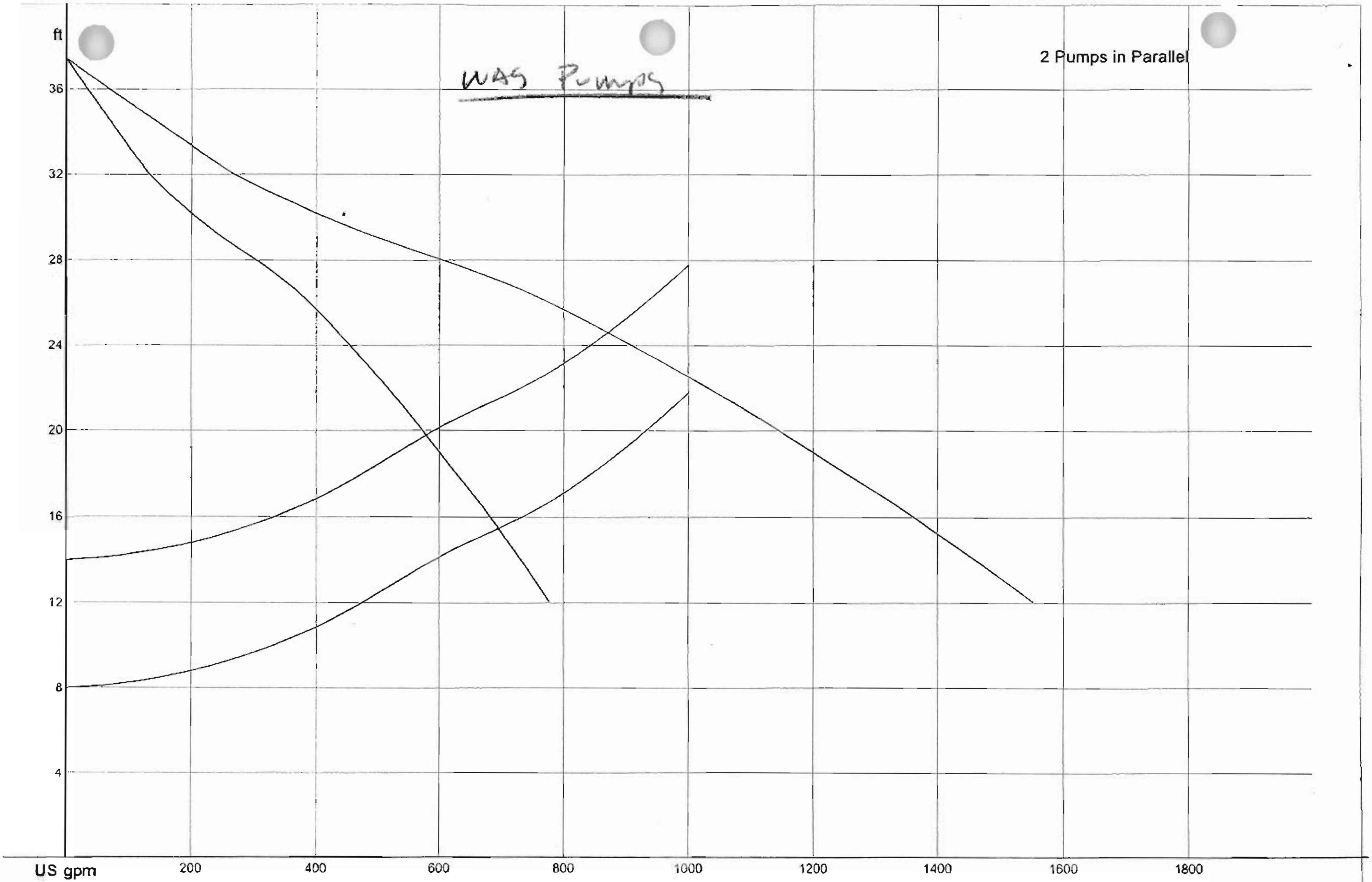
-- Max Curve --

Max Pwr: 7.16 bhp
@ 898 US gpm



--- PERFORMANCE EVALUATION ---

Flow US gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Motor kW	Hrs/yr	Cost /kWh
840	Flow Rate is Out of Range for this Pump								
700	1155	15.3	60	4.48	12.7				
560	1155	20.5	69	4.15	9.01				
420	1155	25	71	3.73	7.11				
280	1155	28.4	65	3.1	6.05				



USI Arkansas, Inc.
Terry W. Carpenter
04/14/06
Selection file: itled)

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 320406A

5430-NONCLOG - 1200
Size: 4"5432M&W
Speed: 1155 rpm
Impeller: 8.75 in

0501002 CABOT WWTP
RAS Pump Selection

H2Optimize ver: 6.041
04/14/06

PUMP DATA SHEET

Fairbanks Morse Pump, 60 Hz

Selection file: CRAS.UFS

Catalog: FMSUB60.MPC v 2.0

Curve: 34M806A

Design Point: Flow: 2100 US gpm
Head: 30.79 ft

Pump: 5430-NONCLOG - 1200 **Size: 8"5434SMV**
Speed: 1185 rpm Dia: 12.5 in

Limits: Temperature: 104 °F Sphere size: 4 in
Pressure: 75 psi_g Power: --- bhp

Specific Speed: Ns: 2698 Nss: 8391

Dimensions: Suction: 8 in Discharge: 8 in

Motor: 30 hp Speed: 1200 Frame: 320
SUBMRGD StandarcXPLPROF Enclosure
sized for Max Power on Design Curve

Fluid: Water Temperature: 60 °F
SG: 1
Viscosity: 1.122 cP
Vapor pressure: 0.2568 psi_a
Atm pressure: 14.7 psi_a

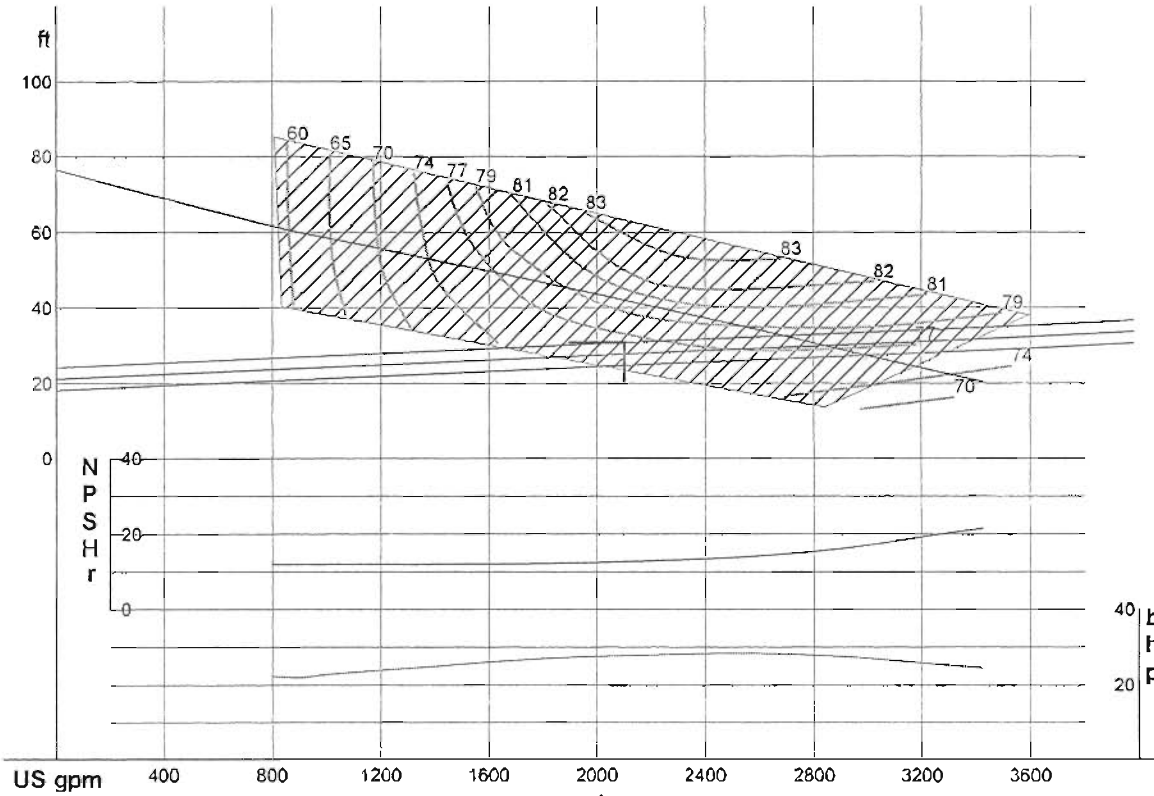
NPSHa: --- ft

Piping: System: ---
Suction: --- in
Discharge: --- in

---- Data Point ----
Flow: 2100 US gpm
Head: 42 ft
Eff: 80%
Power: 27.8 bhp
NPSHr: 12.8 ft

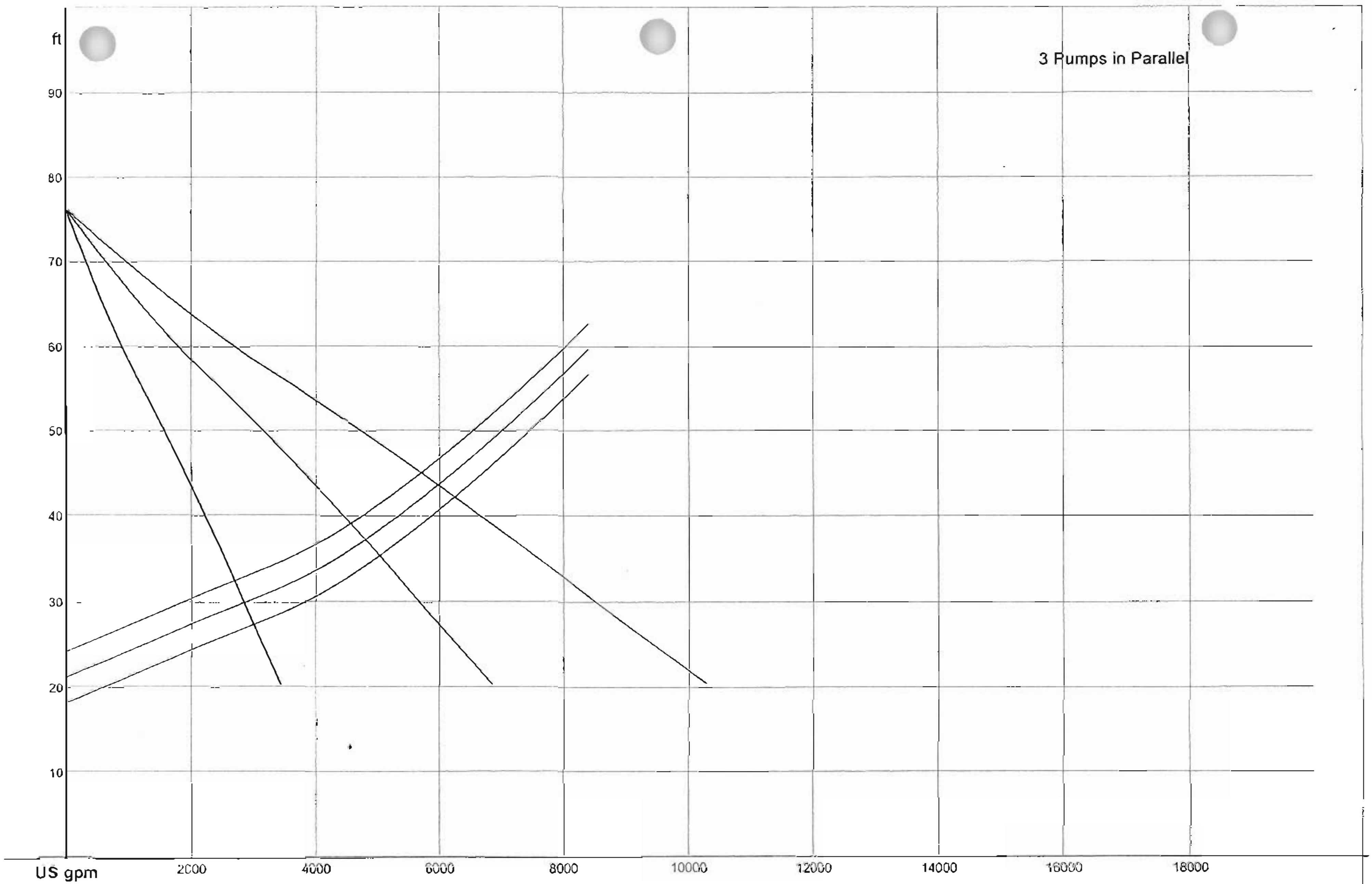
-- Design Curve --
Shutoff Head: 76.4 ft
Shutoff dP: 33.1 psi
Min Flow: 800 US gpm
BEP: 80% eff
@ 2175 US gpm
NOL Pwr: 28.4 bhp
@ 2538 US gpm

-- Max Curve --
Max Pwr: 43.6 bhp
@ 3020 US gpm

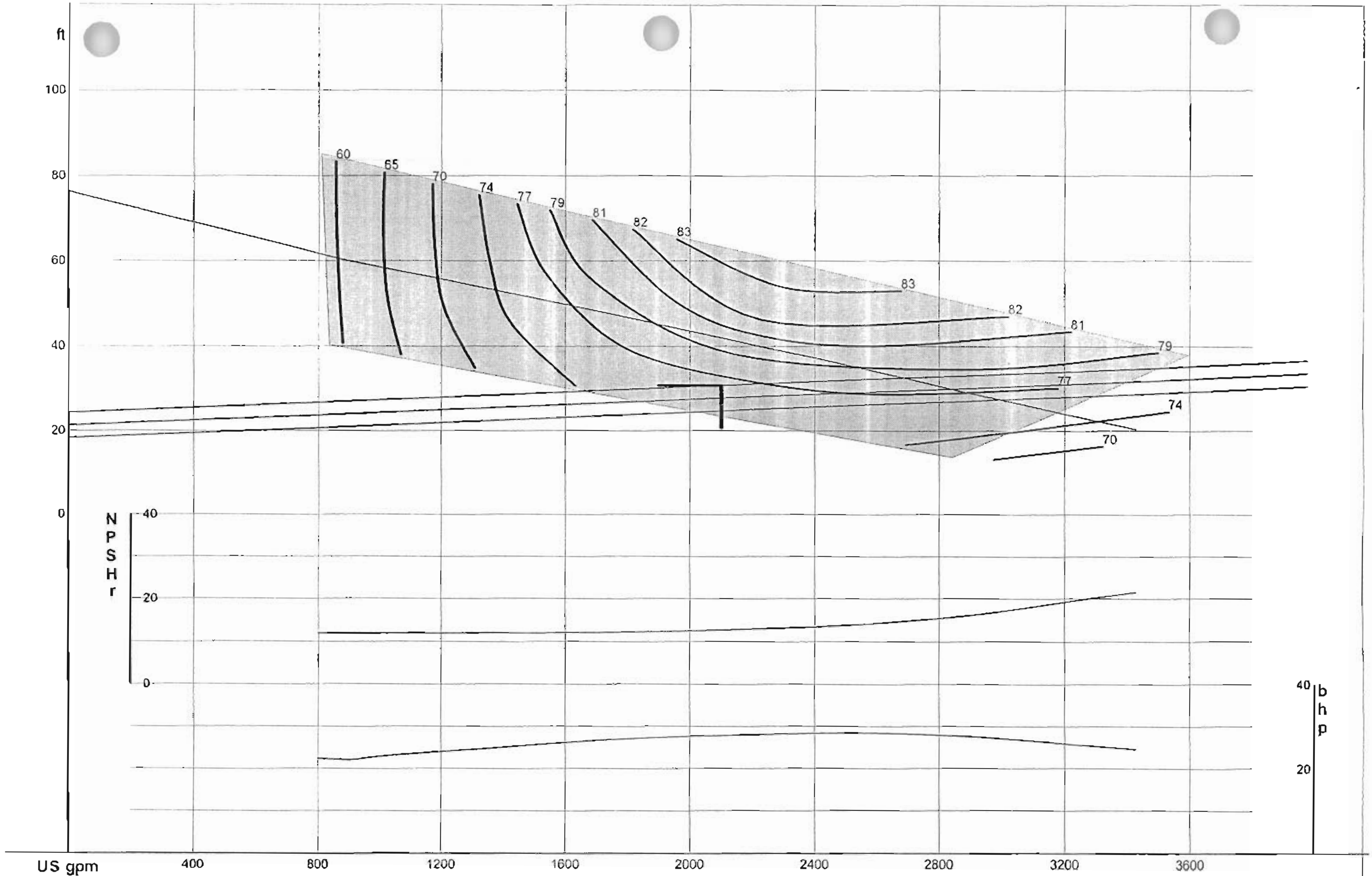


--- PERFORMANCE EVALUATION ---

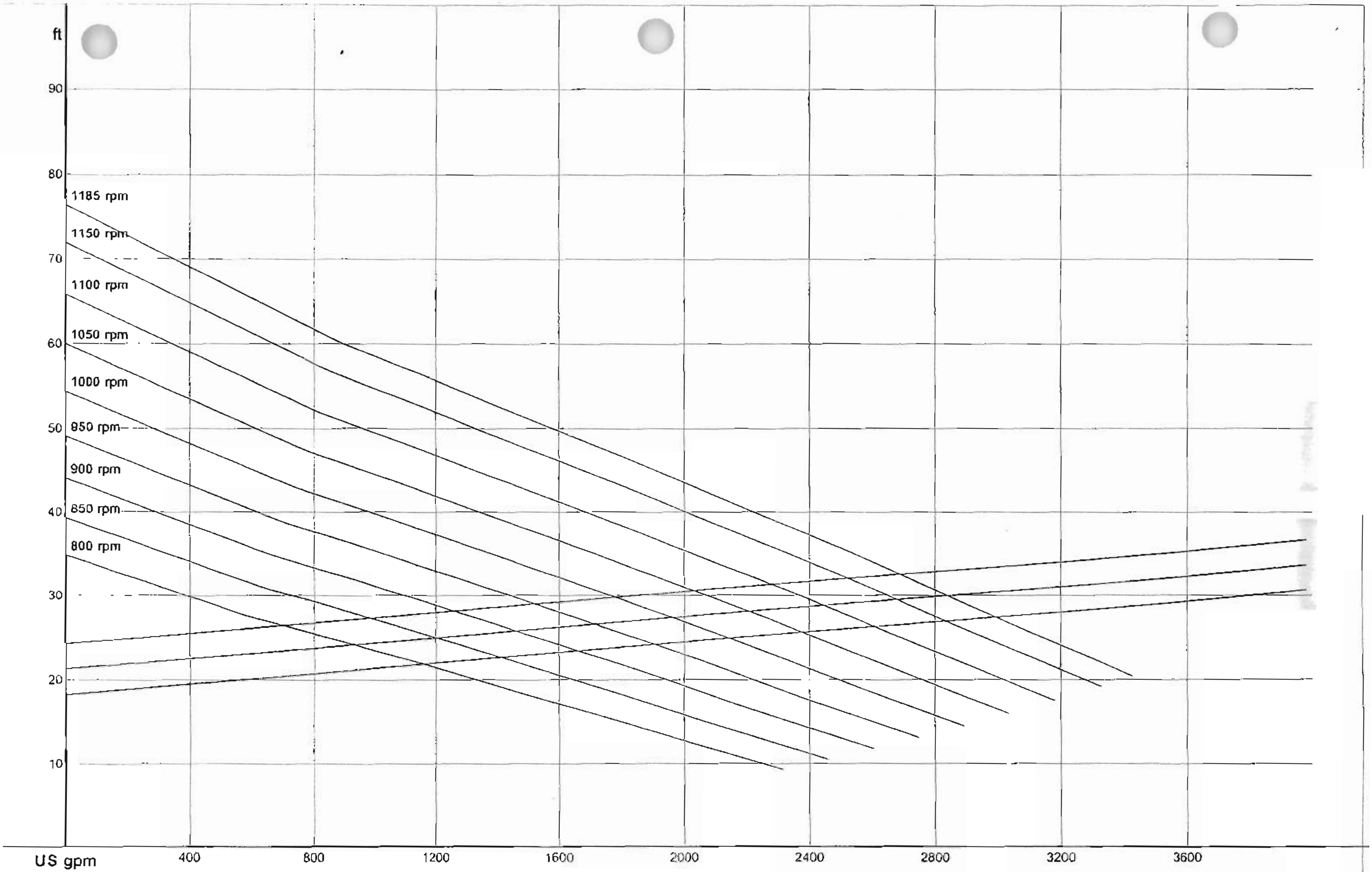
Flow US gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Motor kW	Hrs/yr	Cost /kWh
2520	1185	35.4	79	28.4	13.9				
2100	1185	42	80	27.8	12.8				
1680	1185	48.5	77	26.5	12.2				
1260	1185	54.8	72	24.3	12				
840	1185	61	58	22.1	12				



0501002 CABOT WWTP	Fairbanks Morse Pump, 60 Hz	5430-NONCLOG - 1200
RAS Pump Selection	Catalog: FMSUB60.MPC, vers 2.0	Size: 8"5434SMV
04/14/06	Curve: 34M806A	Speed: 1185 rpm



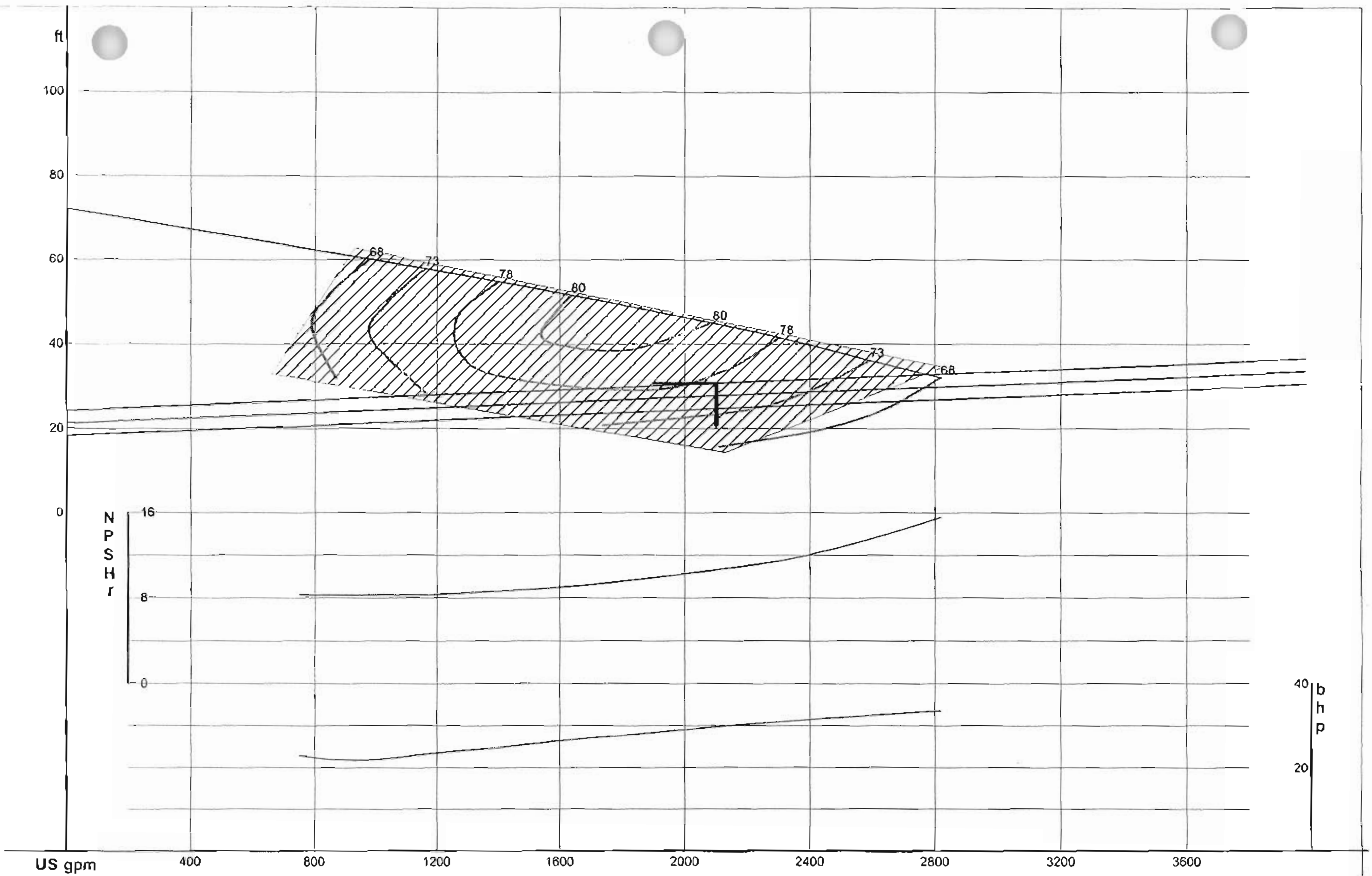
0501002 CABOT WWTP	Fairbanks Morse Pump, 60 Hz	5430-NONCLOG - 1200
RAS Pump Selection	Catalog: FMSUB60.MPC, vers 2.0	Size: 8"5434SMV
04/14/06	Curve: 34M806A	Speed: 1185 rpm



0501002 CABOT WWTP
RAS Pump Selection
04/14/06
Selection file: \AS.UFS

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 34M806A

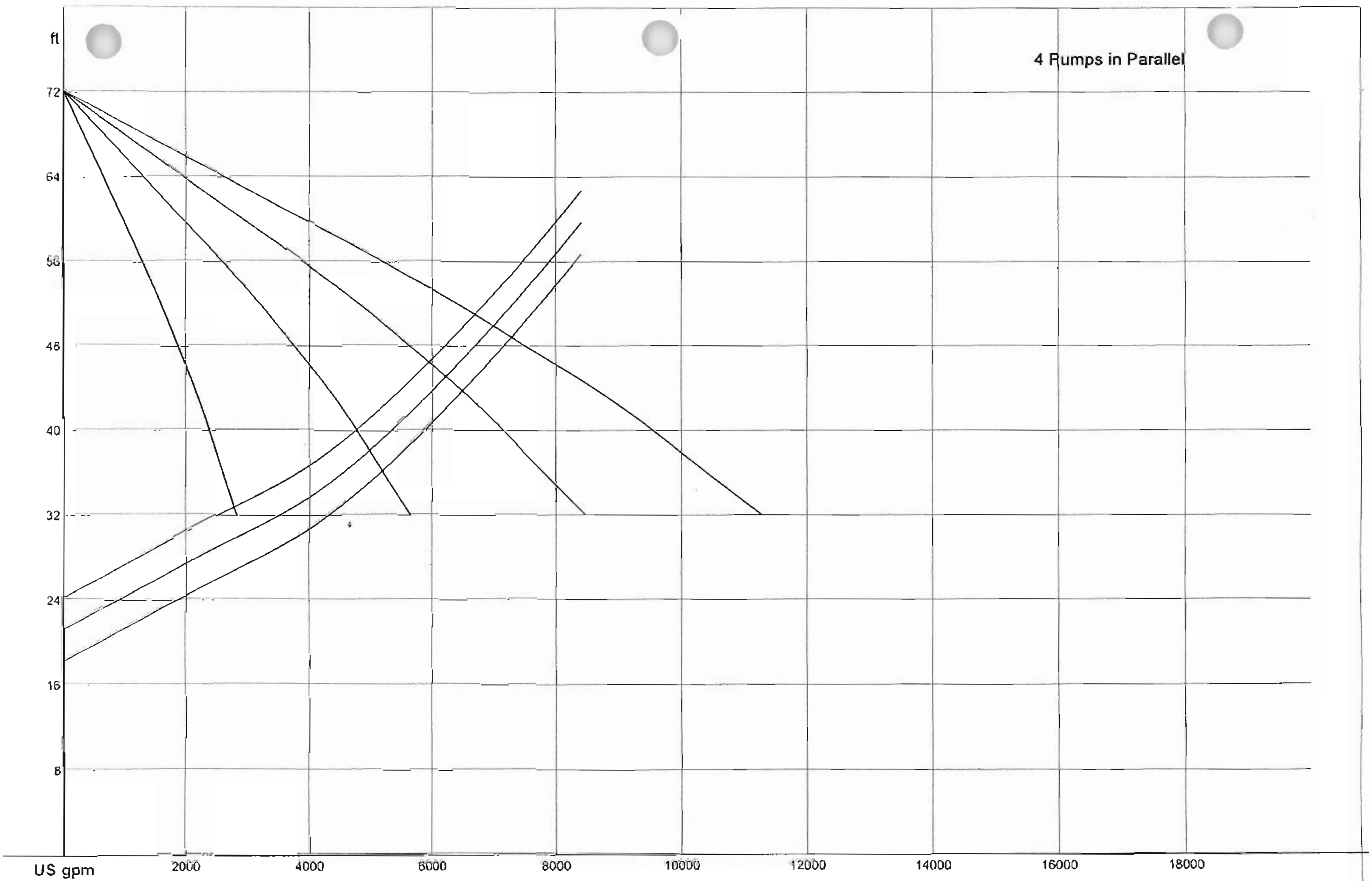
5430-NONCLOG - 1200
Size: 8"5434SMV
Speed: 1100 - 800 rpm
Impeller: 12.5 in



0501002 CABOT WWTP
RAS Pump Selection
04/13/06
Selection file: C S LIES

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 34M808D
Design Point: 2100 US gpm, 30 ft

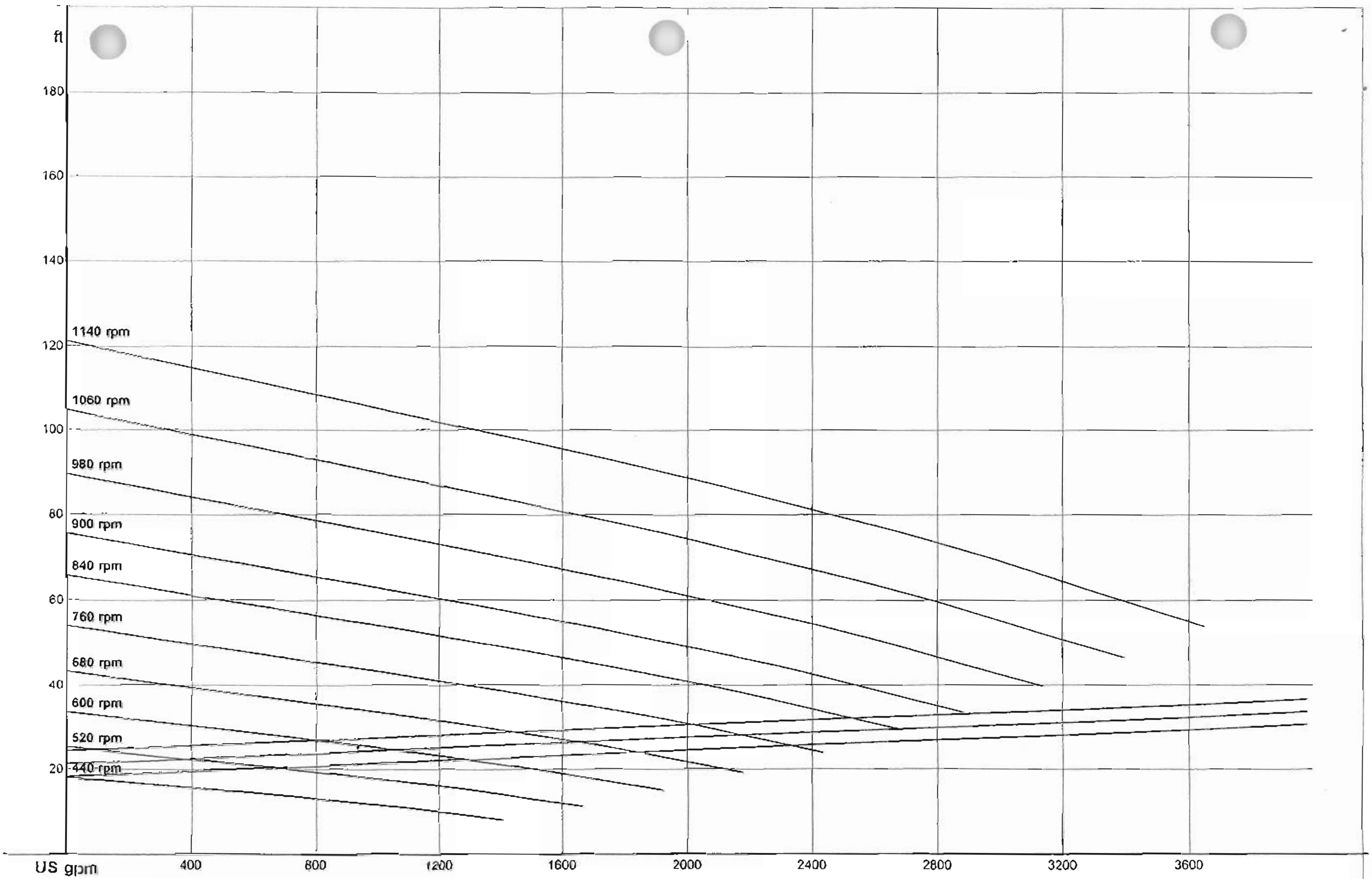
5430-NONCLOG - 900
Size: 8"5434LMV (D)
Speed: 880 rpm
Impeller: 16 in



0501002 CABOT WWTP
RAS Pump Selection
04/13/06

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 34M808D

5430-NONCLOG - 900
Size: 8"5434LMV (D)
Speed: 880 rpm



0501002 CABOT WWTP	Fairbanks Morse Pump, 60 Hz	5430-NONCLOG - 900
RAS Pump Selection	Catalog: FMSUB60.MPC, vers 2.0	Size: 8"5434LMV (D)
04/13/06	Curve: 34M808D	Speed: 1140 - 440 rpm
Selection file: C ... S UES		Impeller: 16 in

0501002 CABOT WWTP
Influent Lift Pump Station

H2Optimize ver: 6.041
04/14/06

PUMP DATA SHEET

Fairbanks Morse Pump, 60 Hz

Selection file: CIPS.UFS
Catalog: FMSUB60.MPC v 2.0

Curve: 34M806A

Design Point: Flow: 2100 US gpm
Head: 28.85 ft

Pump: 5430-NONCLOG - 1200 Size: 8"5434SMV
Speed: 1185 rpm Dia: 12.5 in

Limits: Temperature: 104 °F Sphere size: 4 in
Pressure: 75 psi_g Power: --- bhp

Specific Speed: Ns: 2698 Nss: 8391

Dimensions: Suction: 8 in Discharge: 8 in

Motor: 30 hp Speed: 1200 Frame: 320
SUBMRGD StandarcXPLPROF Enclosure
sized for Max Power on Design Curve

Fluid: Water Temperature: 60 °F
SG: 1
Viscosity: 1.122 cP
Vapor pressure: 0.2568 psi_a
Atm pressure: 14.7 psi_a

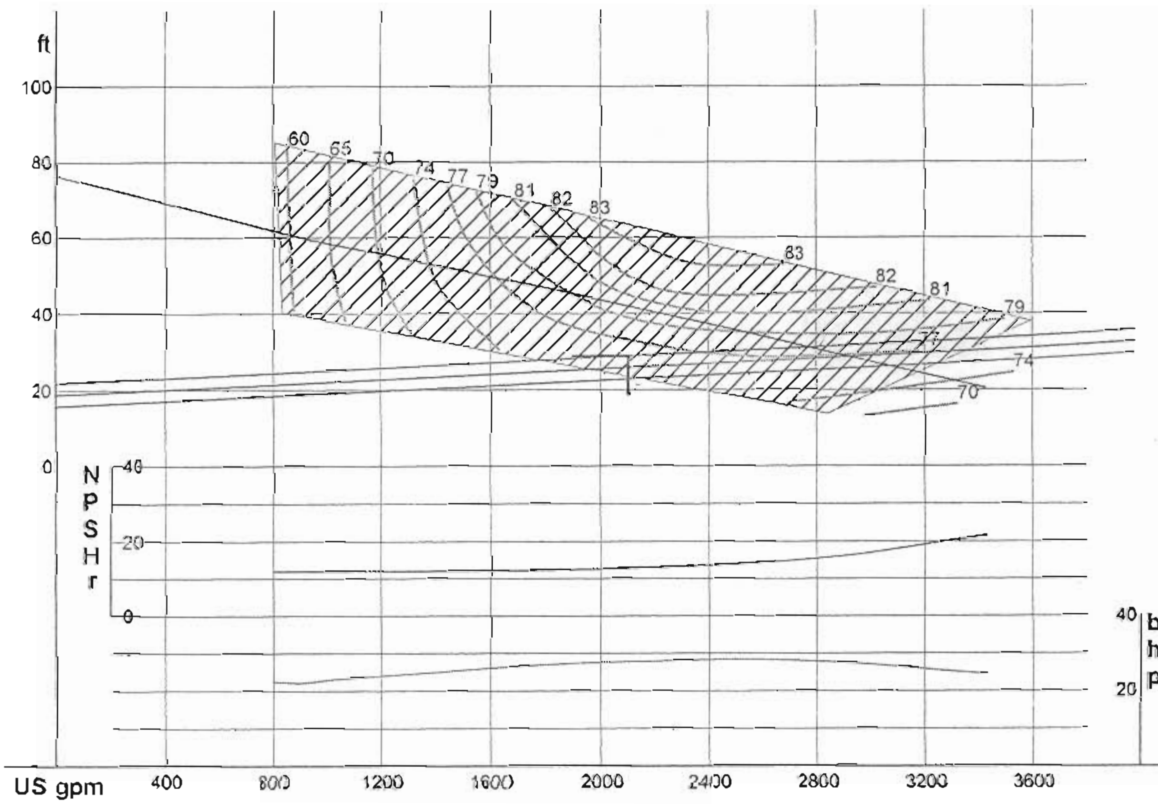
NPSHa: --- ft

Piping: System: ---
Suction: --- in
Discharge: --- in

---- Data Point ----
Flow: 2100 US gpm
Head: 42 ft
Eff: 80%
Power: 27.8 bhp
NPSHr: 12.8 ft

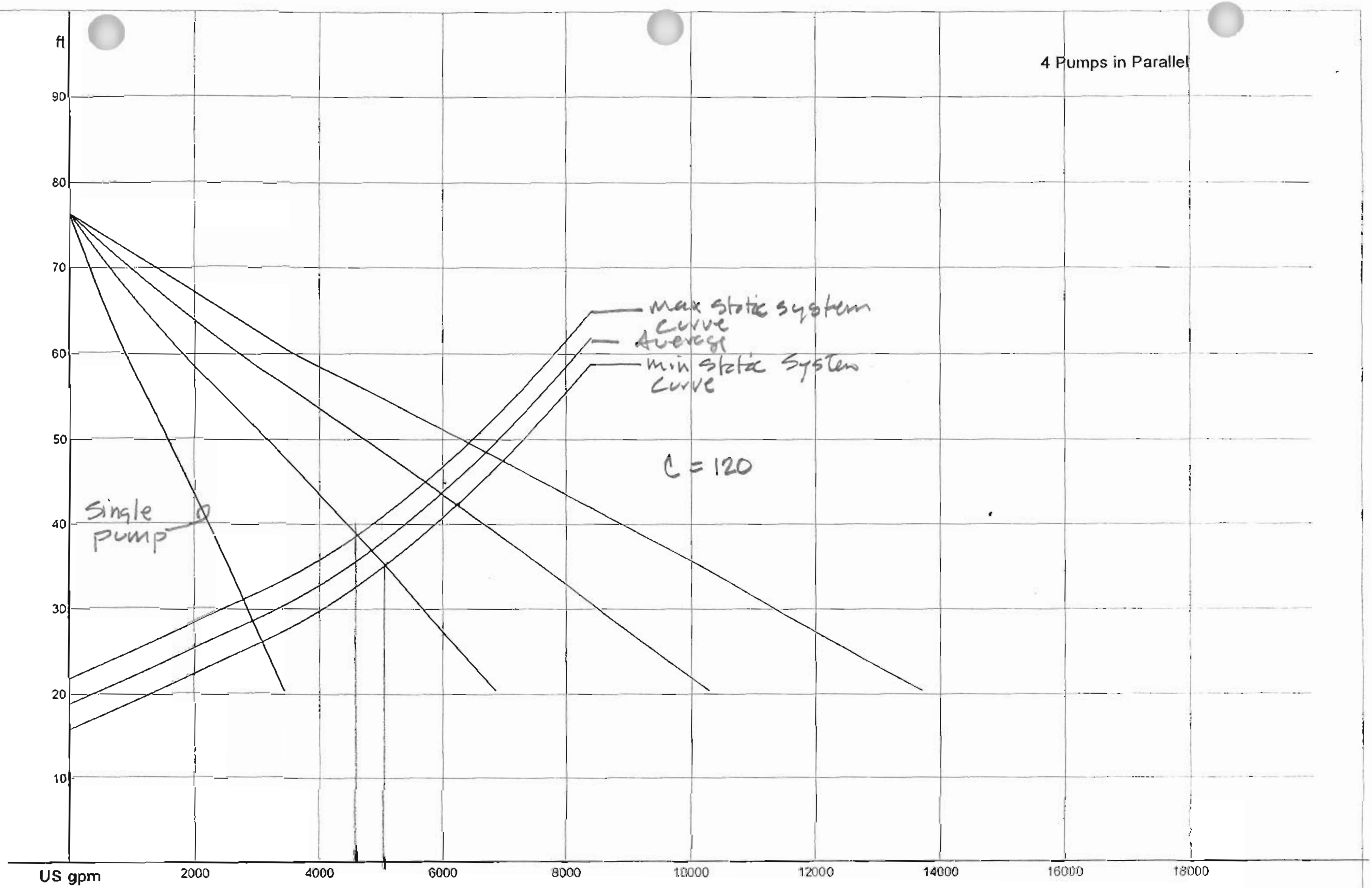
-- Design Curve --
Shutoff Head: 76.4 ft
Shutoff dP: 33.1 psi
Min Flow: 800 US gpm
BEP: 80% eff
@ 2175 US gpm
NOL Pwr: 28.4 bhp
@ 2538 US gpm

-- Max Curve --
Max Pwr: 43.6 bhp
@ 3020 US gpm



--- PERFORMANCE EVALUATION —

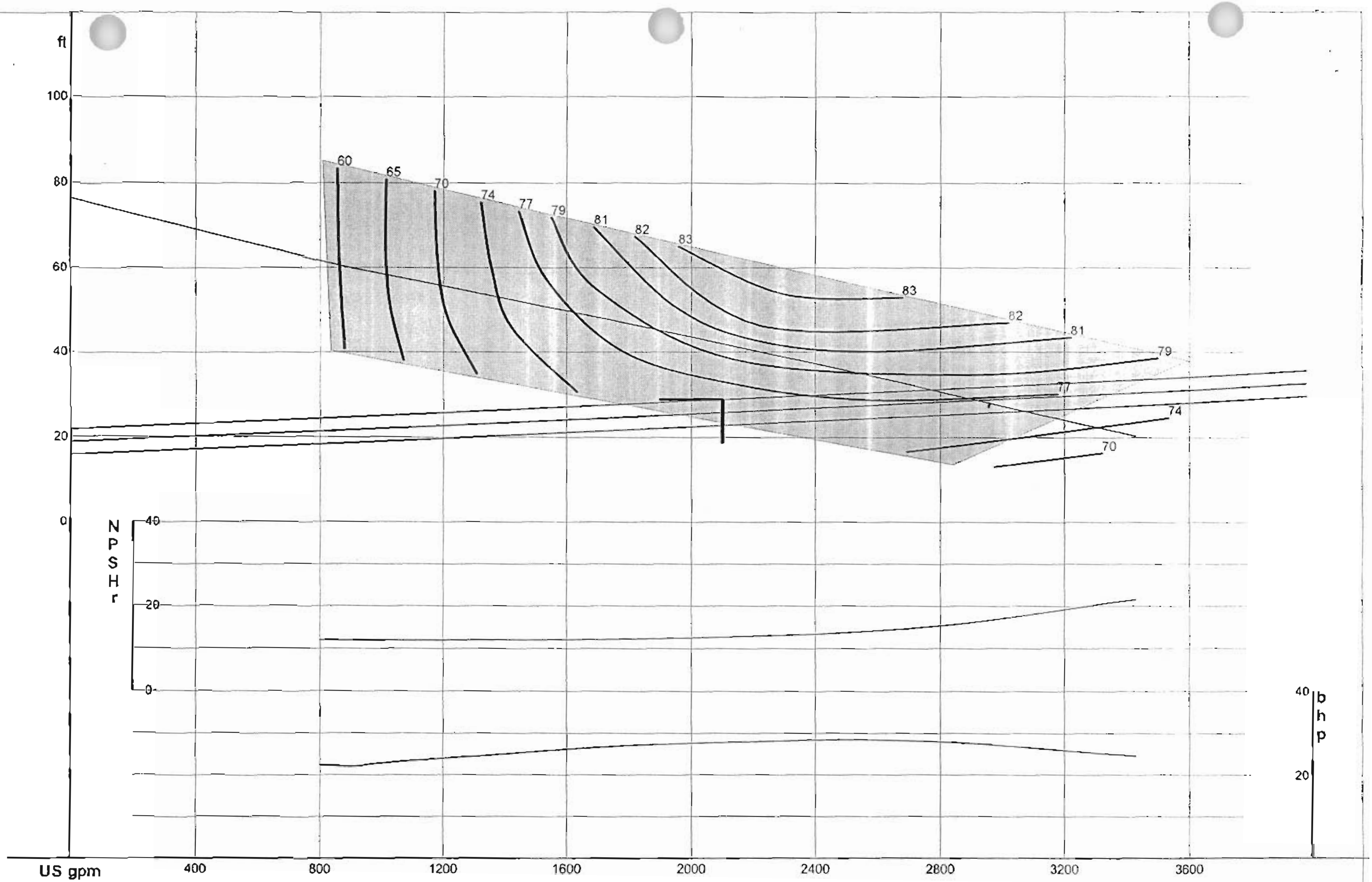
Flow US gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Motor kW	Hrs/yr	Cost /kWh
2520	1185	35.4	79	28.4	13.9				
2100	1185	42	80	27.8	12.8				
1680	1185	48.5	77	26.5	12.2				
1260	1185	54.8	72	24.3	12				
840	1185	61	58	22.1	12				



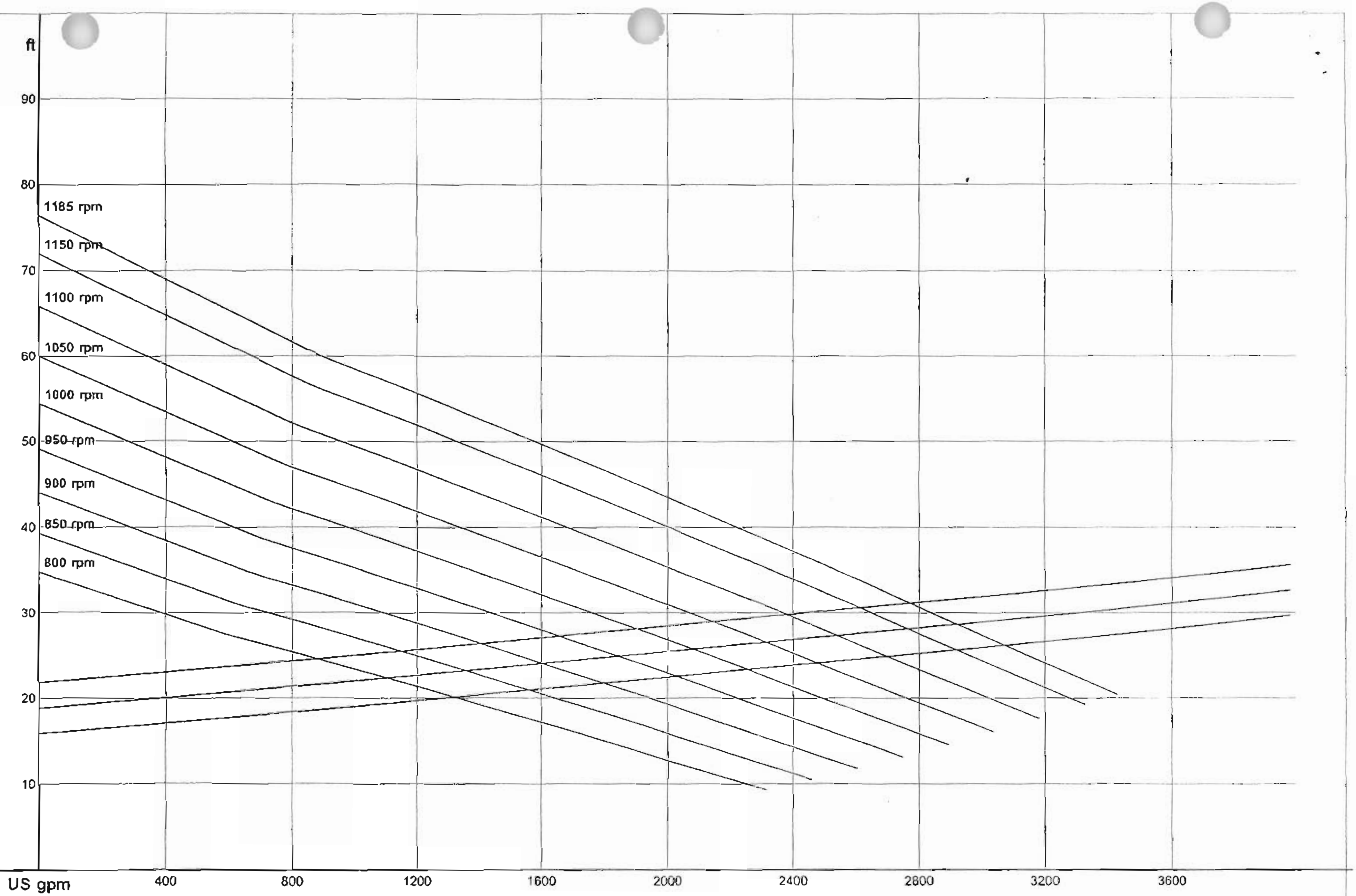
0501002 CABOT WWTP
Influent Lift Pump Station
04/14/06

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 34M806A

5430-NONCLOG - 1200
Size: 8"5434SMV
Speed: 1185 rpm



0501002 CABOT WWTP	Fairbanks Morse Pump, 60 Hz	5430-NONCLOG - 1200
Influent Lift Pump Station	Catalog: FMSUB60.MPC, vers 2.0	Size: 8"5434SMV
04/14/06	Curve: 34M806A	Speed: 1185 rpm



0501002 CABOT WWTP
Influent Lift Pump Station
04/14/06

Fairbanks Morse Pump, 60 Hz
Catalog: FMSUB60.MPC, vers 2.0
Curve: 34M806A

5430-NONCLOG - 1200
Size: 8"5434SMV
Speed: 1185 - 800 rpm

Hydraulics 1

$_{ak}$ (design peak flo[illegible] 6.4 MGD
(average daily desi[illegible]w rate) 6 MGD
(existing average flow rate) is 2.5 MGD
$_{AS}$ (return activated sludge flow rate) is 6 MGD **RAS flow is 100% Influent flow up to 6 MGD beyond which it remains 6 MGD**
(internal recycle flow rate) is 12 MGD
$_{AS}$ (waste activated sludge flow rate) is 0.2 MGD

[redacted]

charge weir elevation at downstream end of reaeration basin — 266.2 feet
charge weir length — 10 feet

ncis weir equation:

$$Q = \frac{2}{3} C_1 b \sqrt{2g} H^{\frac{3}{2}}$$

ere:
s flow rate is cfs
is a constant normally assumed to be 0.62 for sharp crested weirs
s the suppressed weir width (10 ft)
s the head over the weir

Flow	Q (MGD)	Q (cfs)	H (ft)	WSE at Post Aeration Basin *
Q_{peak} - Q_{WAS}	16.2	25.07	0.83	267.03
Q_A - Q_{WAS}	5.8	8.97	0.42	266.62
Q_{EA} - Q_{WAS}	2.3	3.56	0.23	266.43

he WSE in the post aeration basin is equal to the elevation of the top of the discharge weir plus the head over the weir.

 equation relating the flow rate (Q in cfs) and the depth of flow in the throat of the parshall flume (H_a in feet) is:

$$Q = 8H_a^{1.55}$$

urce: *Isco Open Channel Flow Measurement Handbook*, Table 4-3A

wing D12 shows the bottom elevation at the upstream portion of the parshall flume is: 266.16 feet

Flow	Q (MGD)	Q (cfs)	H_a (ft)	WSE at H_a*	DS WSE at 70% submergence
Q_{peak} - Q_{WAS}	16.2	25.07	2.09	268.25	267.62
Q_A - Q_{WAS}	5.8	8.97	1.08	267.24	266.91
Q_{EA} - Q_{WAS}	2.3	3.56	0.59	266.75	266.58

alysis assumes the WSE upstream of the flume is equivalent to the WSE at H_a.

sume normal mode of operation splits the flow between the two UV channels.
4-foot serpentine weir is installed at the end of each UV channel.

 of serpentine weir (Dwg. D17) — 268.8 feet
ective length of serpentine weir — 54 feet
lying on the Francis Weir equation the WSE upstream of the weir is:

Flow	Q/channel (MGD)	Q/channel (cfs)	H (ft)	WSE* upstream of serpentine weir (ft)
Q_{peak} - Q_{WAS}	8.1	12.53	0.17	268.97

$Q_A - Q_{WAS}$	2.9	4.49	0.09	268.89
$Q_{EA} - Q_{WAS}$	.15	1.78	0.05	268.85

*Analysis assumes the WSE upstream of the serpentine weir is the elevation of the top of the weir plus the head over the weir.

The headloss through the UV channel provided by Ozonia is 3.7 inches at peak flow rate.
The headloss allowances through the UV channel at lesser flow rates is based on a percentage of the peak headloss as determined by the flow rate ratios.

Flow	Q (MGD)	Q (cfs)	UV H_L (ft)	WSE upstream of UV
$Q_{peak} - Q_{WAS}$	16.2	25.07	0.31	269.28
$Q_A - Q_{WAS}$	5.8	8.97	0.11	269.00
$Q_{EA} - Q_{WAS}$	2.3	3.56	0.04	268.89

[redacted]

Length 27 feet

Item	Dia.	Number	K	Total
sharp cornered entrance		1	0.5	0.5
Plug Valve		1	0.91	0.91
Total				1.41

Flow	Q (MGD)	Q (gpm)	Q (cfs)	D (in)	ID (in)	A (sf)	V (fps)	Velocity Head (ft)	Friction Loss (ft/100ft)	Total Friction Loss (ft)	Minor Loss (ft)	Total Loss (ft)
1/2($Q_{peak} - Q_{WAS}$)	8.1	5625	12.53	36	37.54	7.69	1.63	0.041352001	0.01894	0.01	0.06	0.06
1/2($Q_A - Q_{WAS}$)	2.9	2014	4.49	36	37.54	7.69	0.58	0.005300569	0.00287	0.00	0.01	0.01
1/2($Q_{EA} - Q_{WAS}$)	1.15	799	1.78	36	37.54	7.69	0.23	0.000833532	0.00054	0.00	0.00	0.00

Pipe Length 6 feet

Item	Dia.	Number	K	Total
exit		1	1	1
Branch Tee		1	0.36	0.36
30 degree		1	0.19	0.19
Total				1 55

Flow	Q (MGD)	Q (cfs)	D (in)	ID (in)	A (sf)	V (fps)	Velocity Head (ft)	Friction Loss (ft/100ft)	Total Friction Loss (ft)	Minor Loss (ft)	Total Loss (ft)	WSE at Clarifier effluent chamber (ft)
$Q_{peak} - Q_{WAS}$	16.2	25.07	36	37.54	7.69	3.26	0.165408005	0.06931	0.00	0.26	0.26	269.60
$Q_A - Q_{WAS}$	5.8	8.97	36	37.54	7.69	1.17	0.021202276	0.01021	0.00	0.03	0.03	269.04
$Q_{EA} - Q_{WAS}$	2.3	3.56	36	37.54	7.69	0.46	0.003334127	0.00189	0.00	0.01	0.01	268.90

Assume the effluent chamber and the drop box are connected by a 3'X3' opening and that the launder and the drop box are connected by a 2'X4' opening.
The change in WSE between the effluent box and the launder is attributed to the head loss through these openings.

Head loss through the submerged openings is estimated assuming the fully submerged orifice equation applies (tailwater depth divided by the headwater depth is >0.8).

$Q = CA(2gH)^{1/2}$

is the discharge co nt (typically 0.8 for a fully submerged condition)
is the area of gate ng (9 and 8 sf)
is the change in head through the gate

Flow	Q (MGD)	Q (cfs)	H 2'X4' (ft)	H 3'X3' (ft)	WSE in launder at Drop Box (ft)
$1/2(Q_{peak} - Q_{WAS})$	8.1	12.53	0.06	0.05	269.71
$1/2(Q_A - Q_{WAS})$	2 9	4.49	0.01	0 01	269.05
$1/2(Q_{EA} - Q_{WAS})$	1.15	1.78	0.00120	0.00095	268.90

ottom Elevation of the launder at drop box is (S-18): 269.12 feet

larifier Diameter: 115 feet
side diameter to weir on launder (assuming an 8-inch wall thickness) 109.67 feet
aunder length 344.5 feet
he effective length to a point opposite the effluent drop box is 172.28 feet
aunder channel slope 0.005 feet/foot

ssume the change in WSE in the launder

Flow	Q (MGD)	Q (cfs)	WS depth in Launder at drop box (ft)	Channel slope (ft/ft)	Launder WSE opposite the drop box (ft)
$1/4(Q_{peak} - Q_{WAS})$	4.05	6.27	0.59	0.005	270.57
$1/4(Q_A - Q_{WAS})$	1.45	2.24	0.00	0.005	269.91
$1/4(Q_{EA} - Q_{WAS})$	0.575	0.89	0.00	0.005	269.76

ssume at PDF a min. freefall of 7-inches 0.58 feet
he elevation of the notch in the weir is 271.15 feet

o establish the WSE in the clarifier assume:

90 degree v-notch weir with a notch every 6 inches with 344 notches per half basin.
he head on a v-notch weir is approximated by the following relationship:

$$Q = 2.5 H^{2.5}$$

here Q is the flow rate is cfs
is the head over the weir in feet

Flow	Q (MGD)	Q (cfs)	Q/notch (cfs/notch)	H (ft)	WSE in Clarifier (ft)
$1/2(Q_{peak} - Q_{WAS})$	8.1	12.53	0.03643	0.18	271.34
$1/2(Q_A - Q_{WAS})$	2.9	4.49	0.01304	0.12	271.28
$1/2(Q_{EA} - Q_{WAS})$	1.15	1.78	0.00517	0.08	271.24

eadloss at the clarifier inlet structure as provided by US Filter:

. Inlet Port Losses

given:

port area 8.88 sf

Flow	Q (MGD)	Q (cfs)	Port Velocity (fps)	Headloss (ft)
$1/2(Q_{EA} + Q_{RAS})$	2.5	3.87	0.44	0.002
$1/2(Q_{A} + Q_{RAS})$	6	9.28	1.05	0.014
$1/2(Q_{peak} + Q_{RAS})$	11.2	17.33	1.95	0.047

2. Baffled Port Losses

given:

port area 15 sf

Flow	Q (MGD)	Q (cfs)	Port Velocity (fps)	Headloss (ft)
$1/2(Q_{EA} + Q_{RAS})$	2.5	3.87	0.26	0.001
$1/2(Q_{A} + Q_{RAS})$	6	9.28	0.62	0.005
$1/2(Q_{peak} + Q_{RAS})$	11.2	17.33	1.16	0.017

3. Energy Dissipating Baffle losses

given:

port area 15 sf
dissipating port area 37.67 sf

Flow	Q (MGD)	Q (cfs)	Dissipating Port Velocity (fps)	Headloss (ft)
$1/2(Q_{EA} + Q_{RAS})$	2.5	3.87	0.10	0.001
$1/2(Q_{A} + Q_{RAS})$	6	9.28	0.25	0.006
$1/2(Q_{peak} + Q_{RAS})$	11.2	17.33	0.46	0.021

Flow	Q (MGD)	Q (cfs)	Total inlet structure losses(ft)
$1/2(Q_{EA} + Q_{RAS})$	2.5	3.87	0.004
$1/2(Q_{A} + Q_{RAS})$	6	9.28	0.024
$1/2(Q_{peak} + Q_{RAS})$	11.2	17.33	0.085

Assume a pipe length of 182 feet

Item	Dia.	Number	K	Total
sharp cornered entrance		1	0.5	0.5
exit		1	1	1
regular 45 degree	30	1	0.19	0.19
regular 90 degree	30	1	0.19	0.19
Total				1.88

Flow	Q (MGD)	Q (gpm)	Q (cfs)	D (in)	ID (in)	A (sf)	V (fps)	Velocity Head (ft)	Friction Loss (ft/100ft)	Total Friction Loss (ft)	Minor Loss (ft)	Total Loss (ft)	WSE at Splitter Box Discharge (ft)

$1/2(Q_{EA} + Q_{RAS})$	2.5	1736	3.87	30	31.32	5.3	0.72	0.008130	0.00527	0.01	0.02	[illegible]	271.27
$1/2(Q_{A} + Q_{RAS})$	6	4167	9.28	30	31.32	5.35	1.74	0.046829	0.0264	0.04	0.09	0.13	271.43
$1/2(Q_{peak} + Q_{RAS})$	11.2	7778	17.33	30	31.32	5.35	3.24	0.163175	0.08489	0.14	0.31	0.44	271.87

Assume the freefall drop over the weir at peak flow is 0.55 feet
Elevation of top of weir is 272.42 feet
Assume:
Head over the 10 foot sharp crested weir is estimated using the Francis Equation

$$Q = \frac{2}{3} C_1 b \sqrt{2g} H^{\frac{3}{2}}$$

where:
Q is flow rate is cfs
C_1 is a constant normally assumed to be 0.62 for sharp crested weirs
b is the suppressed weir width (10 ft)
H is the head over the weir

Flow	Q (MGD)	Q (gpm)	Q (cfs)	H (ft)	WSE in influent chamber to the effluent box (ft)
$1/2(Q_{EA} + Q_{RAS})$	2.5	1736	3.87	0.24	272.66
$1/2(Q_{A} + Q_{RAS})$	6	4167	9.28	0.43	272.84
$1/2(Q_{peak} + Q_{RAS})$	11.2	7778	17.33	0.65	273.07

[redacted]

Length 95 feet

Item	Dia.	Number	K	Total
sharp cornered entrance		1	0.5	0.5
regular 90 degree		2	0.17	0.34
exit		1	1	1
Total				1.84

Flow	Q (MGD)	Q (gpm)	Q (cfs)	D (in)	ID (in)	A (sf)	V (fps)	Velocity Head (ft)	Friction Loss (ft/100ft)	Total Frictional Loss (ft)	Minor Loss (ft)	Total Loss (ft)	WSE at AB Discharge (ft)
$Q_{EA} + Q_{RAS}$	5	3472	7.74	42	43.68	10.41	0.74	0.008596	0.00372	0.00	0.02	0.02	272.67
$Q_{A} + Q_{RAS}$	12	8333	18.57	42	43.68	10.41	1.78	0.049515	0.01869	0.02	0.09	0.11	272.95
$Q_{peak} + Q_{RAS}$	22.4	15556	34.66	42	43.68	10.41	3.33	0.172532	0.06026	0.06	0.32	0.37	273.44

Assume a 7'8" sharp crested weir divides the inner and outer discharge chambers
Assume the 30 foot high-flow weir elevation is 274.1 feet
Assume a free fall at average flow over the weir of 0.50 feet
Elevation of the top of the low-flow (7'8") weir is 273.45 feet

Francis Weir Equation:

$$Q = \frac{2}{3} C_1 b_{effective} \sqrt{2g} H^{\frac{3}{2}}$$

67 feet
$b_{e}=b_{actual}-0.1*2*H$

Flow	$Q_{low\text{-}flow\ weir}$ (cfs)	$Q_{high\text{-}flow\ weir}$ (cfs)	Q_{total} (cfs)	Q_{total} (MGD)	H (ft)	WSE in outer discharge chamber (ft)
$Q_{EA} + Q_{RAS}$	7.72	0.00	7.72	5.0	0.46	273.91
$Q_A + Q_{RAS}$	15.72	2.90	18.62	12.0	0.74	274.19
$Q_{peak} + Q_{RAS}$	21.13	13.56	34 69	22.4	0.90	274.35

Head loss through the 5' X5' gate is estimated assuming the fully submerged orifice equation applies (tailwater depth divided by the headwater depth is >0.8).

$Q = CA(2gH)^{1/2}$

Where:
Q is the flow rate in cfs
C is the discharge coefficient (typically 0.8 for a fully submerged condition)
A is the area of gate opening (25 sf)
H is the change in head through the gate

Asume only the flow over the low -flow weir attributes to headloss through the 5'X5' opening. The flow over this weir is determined at various flows leaving the Orbal basin in the orbal weir layout speadsheet.

Flow	Q_{total} (MGD)	$Q_{low\text{-}flow\ weir}$ (cfs)	$Q_{high\text{-}flow\ weir}$ (cfs)	Q_{total} (cfs)	H_{gate} (ft)	WSE in inner basin channel (ft)
Q_{EA} plus RAS	5	7.72	0	7.72	0.0023	273.91
Q_A plus RAS	12.0	15.72	2.90	18.62	0.0096	274.20
Q_{peak} plus RAS	22.4	21.13	13.56	34.69	0.02	274.37

Assume a recycle flow from the inner channel to the outer channel of 2 X Q_{ave} or 12 MGD
so the peak flow condition includes 6 MGD RAS, 16.4 MGD influent and 12 MGD recycle flow.

The gates on the walls dividing the outer and middle channels and the middle and inner channels are 6'X6'

Head loss through the 6' X6' gate is estimated assuming the fully submerged orifice equation applies (tailwater depth divided by the headwater depth is >0.8)

$Q = CA(2gH)^{1/2}$

Where:
Q is the flow rate in cfs
C is the discharge coefficient (typically 0.8 for a fully submerged condition)
A is the area of gate opening (36 sf)
H is the change in head through the gate

Flow	Q_{total} (MGD)	Q_{total} (cfs)	H_{gate} (ft)	WSE in center basin channel (ft)	WSE in outer basin channel (ft)
$Q_{EA} + Q_{RAS} + Q_{IR}$	17	26.30	0.0130	273.92	273.94
$Q_A + Q_{RAS} + Q_{IR}$	24.0	37.14	0.0258	274.22	274.25
$Q_{peak} + Q_{RAS} + Q_{IR}$	34.4	53.23	0.0530	274.42	274.47

The gate on the wall dividing the influent box from the outer basin channel is 5'X5'

Head loss through the 5' X5' gate is estimated assuming the fully submerged orifice equation applies (tailwater depth divided by the headwater depth is >0.8).

$Q = CA(2gH)^{1/2}$

Where:
Q is the flow rate in cfs
C is the discharge coefficient (typically 0.8 for a fully submerged condition)
A is the area of gate opening (25 sf)
H is the change in head through the gate

Flow	Q_{total} (MGD)	Q_{total} (cfs)	H_{gate} (ft)	WSE in influent box (ft)
Q_{EA}	2.5	3.87	0.0006	273.94
Q_A	6.0	9.28	0.0033	274.25
Q_{peak}	16.4	25.38	0.0250	274.50

[redacted]

Length 350 feet

Item	Dia.	Number	K	Total
sharp cornered entrance		1	0.5	0.5
regular 90 degree		4	0.18	0.72
exit		1	1	1
Total				2.22

Flow	Q (MGD)	Q (gpm)	Q (cfs)	D (in)	ID (in)	A (sf)	V (fps)	Velocity Head (ft)	Friction Loss (ft/100ft)	Total Frictional Loss (ft)	Minor Loss (ft)	Total Loss (ft)	WSE at Screen Discharge (ft)
Q_{EA}	2.5	1736	3.87	36	37.54	7.69	0.50	0.003939	0.00063	0.00	0.01	0.01	273.95
Q_A	6	4167	9.28	36	37.54	7.69	1.21	0.022690	0.01087	0.04	0.05	0.09	274.34
Q_{peak}	16.4	11389	25.38	36	37.54	7.69	3.30	0.169517	0.07093	0.25	0.38	0.62	275.12

Assume the maximum headloss through the screen is: 1.00 feet

Flow	Q (MGD)	Q (gpm)	Q (cfs)	Q/channel (cfs)	WSE upstream of screen (ft)
Q_{peak}	16.4	11389	25.38	12.69	276.12

Set the level indicator upstream of the screen to cycle the screen at 276.12 feet

Operating floor elevation in headworks is 277.5 feet
Minimum freeboard is 1.38 feet
Maximum allowable headloss through the screen at Q_{EA} is 2.18 feet
Allowable headloss through the screen at Q_{peak} is 1.00 feet

Hydraulics 2

Set the weir elevations such that the difference between the max and min WSE is 1 foot.

Assume the internal recycle is 12 MGD or	18.57 cfs
The elevation of the 7'8" weir is set by the hydraulic profile at	273.45 feet
Assume this is the minimum WSE	
Elevation of 30' high-flow weir	274.1 feet
Minimum WSE (outer basin channel)	273.4654 feet
Maximum WSE (outer basin channel)	274.4710 feet
Difference	1.0056 feet

Model the flow over the weirs using the Francis equation

Francis Weir Equation:

$$Q = \frac{2}{3} C_1 b_{effective} \sqrt{2g} H^{\frac{3}{2}}$$

Assume:

C_1 is 0.62

b is 7.67 feet for the low-flow weir and 30 feet for the high-flow weir

the low-flow weir is contracted so use $b_{effective} = b_{actual} - 0.1 * 2 * H$

the high-flow weir is suppressed so use $b_{effective} = b_{actual} = 30$ feet

Each adjacent channel is separated by a submerged opening.

Head loss through the gate is estimated assuming the fully submerged orifice equation applies (tailwater depth divided by the headwater depth is >0.8).

$Q = CA(2gH)^{1/2}$

Where:

Q is the flow rate in cfs

C is the discharge coefficient (typically 0.8 for a fully submerged condition)

A is the area of gate opening (25 sf between the outer discharge chamber and the inner basin channel)

(36 sf between the inner basin channel and the middle basin channel and also between the middle and outer basin channels)

H is the change in head through the gate

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
273.4654	273.4590	273.4525	273.4525	0.0025	0	0.00	0.00	0.00	0.00
273.4679	273.4615	273.4550	273.4550	0.0050	0	0.01	0.00	0.01	0.01
273.4704	273.4640	273.4575	273.4575	0.0075	0	0.02	0.00	0.02	0.01
273.4729	273.4665	273.4600	273.4600	0.0100	0	0.03	0.00	0.03	0.02
273.4755	273.4690	273.4625	273.4625	0.0125	0	0.04	0.00	0.04	0.02
273.4780	273.4715	273.4650	273.4650	0.0150	0	0.05	0.00	0.05	0.03
273.4805	273.4740	273.4675	273.4675	0.0175	0	0.06	0.00	0.06	0.04
273.4830	273.4765	273.4700	273.4700	0.0200	0	0.07	0.00	0.07	0.05
273.4855	273.4790	273.4725	273.4725	0.0225	0	0.09	0.00	0.09	0.06
273.4880	273.4815	273.4750	273.4750	0.0250	0	0.10	0.00	0.10	0.06
273.4906	273.4840	273.4775	273.4775	0.0275	0	0.12	0.00	0.12	0.07
273.4931	273.4865	273.4800	273.4800	0.0300	0	0.13	0.00	0.13	0.09
273.4956	273.4891	273.4825	273.4825	0.0325	0	0.15	0.00	0.15	0.10
273.4981	273.4916	273.4850	273.4850	0.0350	0	0.17	0.00	0.17	0.11
273.5007	273.4941	273.4875	273.4875	0.0375	0	0.18	0.00	0.18	0.12
273.5032	273.4966	273.4900	273.4900	0.0400	0	0.20	0.00	0.20	0.13

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
273.5057	273.4991	273.4925	273.4925	0.0425	0	0.22	0.00	0.22	0.14
273.5083	273.5016	273.4950	273.4950	0.0450	0	0.24	0.00	0.24	0.16
273.5108	273.5041	273.4975	273.4975	0.0475	0	0.26	0.00	0.26	0.17
273.5133	273.5067	273.5000	273.5000	0.0500	0	0.28	0.00	0.28	0.18
273.5158	273.5092	273.5025	273.5025	0.0525	0	0.31	0.00	0.31	0.20
273.5184	273.5117	273.5050	273.5050	0.0550	0	0.33	0.00	0.33	0.21
273.5209	273.5142	273.5075	273.5075	0.0575	0	0.35	0.00	0.35	0.23
273.5234	273.5167	273.5100	273.5100	0.0600	0	0.37	0.00	0.37	0.24
273.5260	273.5192	273.5125	273.5125	0.0625	0	0.40	0.00	0.40	0.26
273.5285	273.5218	273.5150	273.5150	0.0650	0	0.42	0.00	0.42	0.27
273.5310	273.5243	273.5175	273.5175	0.0675	0	0.45	0.00	0.45	0.29
273.5336	273.5268	273.5200	273.5200	0.0700	0	0.47	0.00	0.47	0.30
273.5361	273.5293	273.5225	273.5225	0.0725	0	0.50	0.00	0.50	0.32
273.5387	273.5318	273.5250	273.5250	0.0750	0	0.52	0.00	0.52	0.34
273.5412	273.5344	273.5275	273.5275	0.0775	0	0.55	0.00	0.55	0.35
273.5437	273.5369	273.5300	273.5300	0.0800	0	0.57	0.00	0.57	0.37
273.5463	273.5394	273.5325	273.5325	0.0825	0	0.60	0.00	0.60	0.39
273.5488	273.5419	273.5350	273.5350	0.0850	0	0.63	0.00	0.63	0.41
273.5514	273.5444	273.5375	273.5375	0.0875	0	0.66	0.00	0.66	0.42
273.5539	273.5470	273.5400	273.5400	0.0900	0	0.69	0.00	0.69	0.44
273.5564	273.5495	273.5425	273.5425	0.0925	0	0.71	0.00	0.71	0.46
273.5590	273.5520	273.5450	273.5450	0.0950	0	0.74	0.00	0.74	0.48
273.5615	273.5545	273.5475	273.5475	0.0975	0	0.77	0.00	0.77	0.50
273.5641	273.5570	273.5500	273.5500	0.1000	0	0.80	0.00	0.80	0.52
273.5666	273.5596	273.5525	273.5525	0.1025	0	0.83	0.00	0.83	0.54
273.5692	273.5621	273.5550	273.5550	0.1050	0	0.86	0.00	0.86	0.56
273.5717	273.5646	273.5575	273.5575	0.1075	0	0.89	0.00	0.89	0.58
273.5743	273.5671	273.5600	273.5600	0.1100	0	0.93	0.00	0.93	0.60
273.5768	273.5697	273.5625	273.5625	0.1125	0	0.96	0.00	0.96	0.62
273.5794	273.5722	273.5650	273.5650	0.1150	0	0.99	0.00	0.99	0.64
273.5819	273.5747	273.5675	273.5675	0.1175	0	1.02	0.00	1.02	0.66
273.5845	273.5773	273.5700	273.5700	0.1200	0	1.05	0.00	1.05	0.68
273.5870	273.5798	273.5725	273.5725	0.1225	0	1.09	0.00	1.09	0.70
273.5896	273.5823	273.5750	273.5750	0.1250	0	1.12	0.00	1.12	0.72
273.5921	273.5848	273.5776	273.5775	0.1275	0	1.15	0.00	1.15	0.75
273.5947	273.5874	273.5801	273.5800	0.1300	0	1.19	0.00	1.19	0.77
273.5972	273.5899	273.5826	273.5825	0.1325	0	1.22	0.00	1.22	0.79
273.5998	273.5924	273.5851	273.5850	0.1350	0	1.26	0.00	1.26	0.81
273.6023	273.5949	273.5876	273.5875	0.1375	0	1.29	0.00	1.29	0.84
273.6049	273.5975	273.5901	273.5900	0.1400	0	1.33	0.00	1.33	0.86
273.6074	273.6000	273.5926	273.5925	0.1425	0	1.36	0.00	1.36	0.88
273.6100	273.6025	273.5951	273.5950	0.1450	0	1.40	0.00	1.40	0.90
273.6126	273.6051	273.5976	273.5975	0.1475	0	1.44	0.00	1.44	0.93
273.6151	273.6076	273.6001	273.6000	0.1500	0	1.47	0.00	1.47	0.95
273.6177	273.6101	273.6026	273.6025	0.1525	0	1.51	0.00	1.51	0.98
273.6202	273.6127	273.6051	273.6050	0.1550	0	1.55	0.00	1.55	1.00
273.6228	273.6152	273.6076	273.6075	0.1575	0	1.58	0.00	1.58	1.02
273.6254	273.6177	273.6101	273.6100	0.1600	0	1.62	0.00	1.62	1.05
273.6279	273.6203	273.6126	273.6125	0.1625	0	1.66	0.00	1.66	1.07
273.6305	273.6228	273.6151	273.6150	0.1650	0	1.70	0.00	1.70	1.10
273.6331	273.6253	273.6176	273.6175	0.1675	0	1.74	0.00	1.74	1.12
273.6356	273.6279	273.6201	273.6200	0.1700	0	1.78	0.00	1.78	1.15
273.6382	273.6304	273.6226	273.6225	0.1725	0	1.81	0.00	1.81	1.17
273.6407	273.6329	273.6251	273.6250	0.1750	0	1.85	0.00	1.85	1.20
273.6433	273.6355	273.6276	273.6275	0.1775	0	1.89	0.00	1.89	1.22
273.6459	273.6380	273.6301	273.6300	0.1800	0	1.93	0.00	1.93	1.25

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
273.6485	273.6406	273.6327	273.6325	0.1825	0	1.97	0.00	1.97	1.28
273.6510	273.6431	273.6352	273.6350	0.1850	0	2.01	0.00	2.01	1.30
273.6536	273.6456	273.6377	273.6375	0.1875	0	2.06	0.00	2.06	1.33
273.6562	273.6482	273.6402	273.6400	0.1900	0	2.10	0.00	2.10	1.35
273.6587	273.6507	273.6427	273.6425	0.1925	0	2.14	0.00	2.14	1.38
273.6613	273.6532	273.6452	273.6450	0.1950	0	2.18	0.00	2.18	1.41
273.6639	273.6558	273.6477	273.6475	0.1975	0	2.22	0.00	2.22	1.44
273.6664	273.6583	273.6502	273.6500	0.2000	0	2.26	0.00	2.26	1.46
273.6690	273.6609	273.6527	273.6525	0.2025	0	2.31	0.00	2.31	1.49
273.6716	273.6634	273.6552	273.6550	0.2050	0	2.35	0.00	2.35	1.52
273.6742	273.6659	273.6577	273.6575	0.2075	0	2.39	0.00	2.39	1.55
273.6767	273.6685	273.6602	273.6600	0.2100	0	2.43	0.00	2.43	1.57
273.6793	273.6710	273.6627	273.6625	0.2125	0	2.48	0.00	2.48	1.60
273.6819	273.6736	273.6652	273.6650	0.2150	0	2.52	0.00	2.52	1.63
273.6845	273.6761	273.6678	273.6675	0.2175	0	2.57	0.00	2.57	1.66
273.6871	273.6787	273.6703	273.6700	0.2200	0	2.61	0.00	2.61	1.69
273.6896	273.6812	273.6728	273.6725	0.2225	0	2.65	0.00	2.65	1.72
273.6922	273.6838	273.6753	273.6750	0.2250	0	2.70	0.00	2.70	1.74
273.6948	273.6863	273.6778	273.6775	0.2275	0	2.74	0.00	2.74	1.77
273.6974	273.6888	273.6803	273.6800	0.2300	0	2.79	0.00	2.79	1.80
273.7000	273.6914	273.6828	273.6825	0.2325	0	2.83	0.00	2.83	1.83
273.7025	273.6939	273.6853	273.6850	0.2350	0	2.88	0.00	2.88	1.86
273.7051	273.6965	273.6878	273.6875	0.2375	0	2.93	0.00	2.93	1.89
273.7077	273.6990	273.6903	273.6900	0.2400	0	2.97	0.00	2.97	1.92
273.7103	273.7016	273.6929	273.6925	0.2425	0	3.02	0.00	3.02	1.95
273.7129	273.7041	273.6954	273.6950	0.2450	0	3.07	0.00	3.07	1.98
273.7155	273.7067	273.6979	273.6975	0.2475	0	3.11	0.00	3.11	2.01
273.7181	273.7092	273.7004	273.7000	0.2500	0	3.16	0.00	3.16	2.04
273.7207	273.7118	273.7029	273.7025	0.2525	0	3.21	0.00	3.21	2.07
273.7232	273.7143	273.7054	273.7050	0.2550	0	3.25	0.00	3.25	2.10
273.7258	273.7169	273.7079	273.7075	0.2575	0	3.30	0.00	3.30	2.13
273.7284	273.7194	273.7104	273.7100	0.2600	0	3.35	0.00	3.35	2.17
273.7310	273.7220	273.7129	273.7125	0.2625	0	3.40	0.00	3.40	2.20
273.7336	273.7245	273.7155	273.7150	0.2650	0	3.45	0.00	3.45	2.23
273.7362	273.7271	273.7180	273.7175	0.2675	0	3.50	0.00	3.50	2.26
273.7388	273.7296	273.7205	273.7200	0.2700	0	3.54	0.00	3.54	2.29
273.7414	273.7322	273.7230	273.7225	0.2725	0	3.59	0.00	3.59	2.32
273.7440	273.7348	273.7255	273.7250	0.2750	0	3.64	0.00	3.64	2.35
273.7466	273.7373	273.7280	273.7275	0.2775	0	3.69	0.00	3.69	2.39
273.7492	273.7399	273.7305	273.7300	0.2800	0	3.74	0.00	3.74	2.42
273.7518	273.7424	273.7331	273.7325	0.2825	0	3.79	0.00	3.79	2.45
273.7544	273.7450	273.7356	273.7350	0.2850	0	3.84	0.00	3.84	2.48
273.7570	273.7475	273.7381	273.7375	0.2875	0	3.89	0.00	3.89	2.52
273.7596	273.7501	273.7406	273.7400	0.2900	0	3.94	0.00	3.94	2.55
273.7622	273.7526	273.7431	273.7425	0.2925	0	3.99	0.00	3.99	2.58
273.7648	273.7552	273.7456	273.7450	0.2950	0	4.04	0.00	4.04	2.61
273.7674	273.7578	273.7482	273.7475	0.2975	0	4.10	0.00	4.10	2.65
273.7700	273.7603	273.7507	273.7500	0.3000	0	4.15	0.00	4.15	2.68
273.7726	273.7629	273.7532	273.7525	0.3025	0	4.20	0.00	4.20	2.71
273.7752	273.7655	273.7557	273.7550	0.3050	0	4.25	0.00	4.25	2.75
273.7778	273.7680	273.7582	273.7575	0.3075	0	4.30	0.00	4.30	2.78
273.7804	273.7706	273.7607	273.7600	0.3100	0	4.36	0.00	4.36	2.81
273.7830	273.7731	273.7633	273.7625	0.3125	0	4.41	0.00	4.41	2.85
273.7856	273.7757	273.7658	273.7650	0.3150	0	4.46	0.00	4.46	2.88
273.7882	273.7783	273.7683	273.7675	0.3175	0	4.51	0.00	4.51	2.92
273.7908	273.7808	273.7708	273.7700	0.3200	0	4.57	0.00	4.57	2.95

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
273.7935	273.7834	273.7733	273.7725	0.3225	0	4.62	0.00	4.62	2.99
273.7961	273.7860	273.7758	273.7750	0.3250	0	4.67	0.00	4.67	3.02
273.7987	273.7885	273.7784	273.7775	0.3275	0	4.73	0.00	4.73	3.06
273.8013	273.7911	273.7809	273.7800	0.3300	0	4.78	0.00	4.78	3.09
273.8039	273.7937	273.7834	273.7825	0.3325	0	4.84	0.00	4.84	3.13
273.8065	273.7962	273.7859	273.7850	0.3350	0	4.89	0.00	4.89	3.16
273.8091	273.7988	273.7884	273.7875	0.3375	0	4.94	0.00	4.94	3.20
273.8118	273.8014	273.7910	273.7900	0.3400	0	5.00	0.00	5.00	3.23
273.8144	273.8039	273.7935	273.7925	0.3425	0	5.05	0.00	5.05	3.27
273.8170	273.8065	273.7960	273.7950	0.3450	0	5.11	0.00	5.11	3.30
273.8196	273.8091	273.7985	273.7975	0.3475	0	5.16	0.00	5.16	3.34
273.8222	273.8117	273.8011	273.8000	0.3500	0	5.22	0.00	5.22	3.37
273.8249	273.8142	273.8036	273.8025	0.3525	0	5.28	0.00	5.28	3.41
273.8275	273.8168	273.8061	273.8050	0.3550	0	5.33	0.00	5.33	3.45
273.8301	273.8194	273.8086	273.8075	0.3575	0	5.39	0.00	5.39	3.48
273.8327	273.8219	273.8112	273.8100	0.3600	0	5.44	0.00	5.44	3.52
273.8354	273.8245	273.8137	273.8125	0.3625	0	5.50	0.00	5.50	3.55
273.8380	273.8271	273.8162	273.8150	0.3650	0	5.56	0.00	5.56	3.59
273.8406	273.8297	273.8187	273.8175	0.3675	0	5.61	0.00	5.61	3.63
273.8432	273.8322	273.8212	273.8200	0.3700	0	5.67	0.00	5.67	3.66
273.8459	273.8348	273.8238	273.8225	0.3725	0	5.73	0.00	5.73	3.70
273.8485	273.8374	273.8263	273.8250	0.3750	0	5.79	0.00	5.79	3.74
273.8511	273.8400	273.8288	273.8275	0.3775	0	5.84	0.00	5.84	3.78
273.8538	273.8426	273.8314	273.8300	0.3800	0	5.90	0.00	5.90	3.81
273.8564	273.8451	273.8339	273.8325	0.3825	0	5.96	0.00	5.96	3.85
273.8590	273.8477	273.8364	273.8350	0.3850	0	6.02	0.00	6.02	3.89
273.8617	273.8503	273.8389	273.8375	0.3875	0	6.07	0.00	6.07	3.93
273.8643	273.8529	273.8415	273.8400	0.3900	0	6.13	0.00	6.13	3.96
273.8669	273.8555	273.8440	273.8425	0.3925	0	6.19	0.00	6.19	4.00
273.8696	273.8580	273.8465	273.8450	0.3950	0	6.25	0.00	6.25	4.04
273.8722	273.8606	273.8490	273.8475	0.3975	0	6.31	0.00	6.31	4.08
273.8749	273.8632	273.8516	273.8500	0.4000	0	6.37	0.00	6.37	4.12
273.8775	273.8658	273.8541	273.8525	0.4025	0	6.43	0.00	6.43	4.15
273.8801	273.8684	273.8566	273.8550	0.4050	0	6.49	0.00	6.49	4.19
273.8828	273.8710	273.8592	273.8575	0.4075	0	6.55	0.00	6.55	4.23
273.8854	273.8736	273.8617	273.8600	0.4100	0	6.61	0.00	6.61	4.27
273.8881	273.8761	273.8642	273.8625	0.4125	0	6.67	0.00	6.67	4.31
273.8907	273.8787	273.8668	273.8650	0.4150	0	6.73	0.00	6.73	4.35
273.8934	273.8813	273.8693	273.8675	0.4175	0	6.79	0.00	6.79	4.39
273.8960	273.8839	273.8718	273.8700	0.4200	0	6.85	0.00	6.85	4.43
273.8987	273.8865	273.8744	273.8725	0.4225	0	6.91	0.00	6.91	4.47
273.9013	273.8891	273.8769	273.8750	0.4250	0	6.97	0.00	6.97	4.51
273.9040	273.8917	273.8794	273.8775	0.4275	0	7.03	0.00	7.03	4.54
273.9066	273.8943	273.8820	273.8800	0.4300	0	7.09	0.00	7.09	4.58
273.9093	273.8969	273.8845	273.8825	0.4325	0	7.15	0.00	7.15	4.62
273.9119	273.8995	273.8870	273.8850	0.4350	0	7.22	0.00	7.22	4.66
273.9146	273.9021	273.8896	273.8875	0.4375	0	7.28	0.00	7.28	4.70
273.9172	273.9047	273.8921	273.8900	0.4400	0	7.34	0.00	7.34	4.74
273.9199	273.9073	273.8946	273.8925	0.4425	0	7.40	0.00	7.40	4.78
273.9225	273.9099	273.8972	273.8950	0.4450	0	7.46	0.00	7.46	4.82
273.9252	273.9124	273.8997	273.8975	0.4475	0	7.53	0.00	7.53	4.86
273.9279	273.9150	273.9022	273.9000	0.4500	0	7.59	0.00	7.59	4.91
273.9305	273.9176	273.9048	273.9025	0.4525	0	7.65	0.00	7.65	4.95
273.9332	273.9202	273.9073	273.9050	0.4550	0	7.72	0.00	7.72	4.99
273.9358	273.9228	273.9098	273.9075	0.4575	0	7.78	0.00	7.78	5.03
273.9385	273.9254	273.9124	273.9100	0.4600	0	7.84	0.00	7.84	5.07

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
273.9412	273.9280	273.9149	273.9125	0.4625	0	7.91	0.00	7.91	5.11
273.9438	273.9306	273.9175	273.9150	0.4650	0	7.97	0.00	7.97	5.15
273.9465	273.9333	273.9200	273.9175	0.4675	0	8.03	0.00	8.03	5.19
273.9492	273.9359	273.9225	273.9200	0.4700	0	8.10	0.00	8.10	5.23
273.9518	273.9385	273.9251	273.9225	0.4725	0	8.16	0.00	8.16	5.27
273.9545	273.9411	273.9276	273.9250	0.4750	0	8.23	0.00	8.23	5.32
273.9572	273.9437	273.9302	273.9275	0.4775	0	8.29	0.00	8.29	5.36
273.9598	273.9463	273.9327	273.9300	0.4800	0	8.35	0.00	8.35	5.40
273.9625	273.9489	273.9353	273.9325	0.4825	0	8.42	0.00	8.42	5.44
273.9652	273.9515	273.9378	273.9350	0.4850	0	8.48	0.00	8.48	5.48
273.9679	273.9541	273.9403	273.9375	0.4875	0	8.55	0.00	8.55	5.53
273.9705	273.9567	273.9429	273.9400	0.4900	0	8.61	0.00	8.61	5.57
273.9732	273.9593	273.9454	273.9425	0.4925	0	8.68	0.00	8.68	5.61
273.9759	273.9619	273.9480	273.9450	0.4950	0	8.75	0.00	8.75	5.65
273.9786	273.9645	273.9505	273.9475	0.4975	0.0000	8.81	0.00	8.81	5.69
273.9813	273.9672	273.9531	273.9500	0.5000	0.0000	8.88	0.00	8.88	5.74
273.9839	273.9698	273.9556	273.9525	0.5025	0.0000	8.94	0.00	8.94	5.78
273.9866	273.9724	273.9582	273.9550	0.5050	0.0000	9.01	0.00	9.01	5.82
273.9893	273.9750	273.9607	273.9575	0.5075	0.0000	9.08	0.00	9.08	5.87
273.9920	273.9776	273.9632	273.9600	0.5100	0.0000	9.14	0.00	9.14	5.91
273.9947	273.9802	273.9658	273.9625	0.5125	0.0000	9.21	0.00	9.21	5.95
273.9974	273.9829	273.9683	273.9650	0.5150	0.0000	9.28	0.00	9.28	6.00
274.0001	273.9855	273.9709	273.9675	0.5175	0.0000	9.34	0.00	9.34	6.04
274.0027	273.9881	273.9734	273.9700	0.5200	0.0000	9.41	0.00	9.41	6.08
274.0054	273.9907	273.9760	273.9725	0.5225	0.0000	9.48	0.00	9.48	6.13
274.0081	273.9933	273.9785	273.9750	0.5250	0.0000	9.55	0.00	9.55	6.17
274.0108	273.9960	273.9811	273.9775	0.5275	0.0000	9.61	0.00	9.61	6.21
274.0135	273.9986	273.9836	273.9800	0.5300	0.0000	9.68	0.00	9.68	6.26
274.0162	274.0012	273.9862	273.9825	0.5325	0.0000	9.75	0.00	9.75	6.30
274.0189	274.0038	273.9887	273.9850	0.5350	0.0000	9.82	0.00	9.82	6.34
274.0216	274.0064	273.9913	273.9875	0.5375	0.0000	9.88	0.00	9.88	6.39
274.0243	274.0091	273.9938	273.9900	0.5400	0.0000	9.95	0.00	9.95	6.43
274.0270	274.0117	273.9964	273.9925	0.5425	0.0000	10.02	0.00	10.02	6.48
274.0297	274.0143	273.9990	273.9950	0.5450	0.0000	10.09	0.00	10.09	6.52
274.0324	274.0170	274.0015	273.9975	0.5475	0.0000	10.16	0.00	10.16	6.57
274.0351	274.0196	274.0041	274.0000	0.5500	0.0000	10.23	0.00	10.23	6.61
274.0378	274.0222	274.0066	274.0025	0.5525	0.0000	10.30	0.00	10.30	6.66
274.0405	274.0248	274.0092	274.0050	0.5550	0.0000	10.37	0.00	10.37	6.70
274.0432	274.0275	274.0117	274.0075	0.5575	0.0000	10.44	0.00	10.44	6.74
274.0459	274.0301	274.0143	274.0100	0.5600	0.0000	10.51	0.00	10.51	6.79
274.0486	274.0327	274.0168	274.0125	0.5625	0.0000	10.58	0.00	10.58	6.83
274.0514	274.0354	274.0194	274.0150	0.5650	0.0000	10.65	0.00	10.65	6.88
274.0541	274.0380	274.0220	274.0175	0.5675	0.0000	10.72	0.00	10.72	6.93
274.0568	274.0406	274.0245	274.0200	0.5700	0.0000	10.79	0.00	10.79	6.97
274.0595	274.0433	274.0271	274.0225	0.5725	0.0000	10.86	0.00	10.86	7.02
274.0622	274.0459	274.0296	274.0250	0.5750	0.0000	10.93	0.00	10.93	7.06
274.0649	274.0486	274.0322	274.0275	0.5775	0.0000	11.00	0.00	11.00	7.11
274.0676	274.0512	274.0348	274.0300	0.5800	0.0000	11.07	0.00	11.07	7.15
274.0704	274.0538	274.0373	274.0325	0.5825	0.0000	11.14	0.00	11.14	7.20
274.0731	274.0565	274.0399	274.0350	0.5850	0.0000	11.21	0.00	11.21	7.24
274.0758	274.0591	274.0424	274.0375	0.5875	0.0000	11.28	0.00	11.28	7.29
274.0785	274.0618	274.0450	274.0400	0.5900	0.0000	11.35	0.00	11.35	7.34
274.0812	274.0644	274.0476	274.0425	0.5925	0.0000	11.42	0.00	11.42	7.38
274.0840	274.0671	274.0501	274.0450	0.5950	0.0000	11.50	0.00	11.50	7.43
274.0867	274.0697	274.0527	274.0475	0.5975	0.0000	11.57	0.00	11.57	7.48
274.0894	274.0723	274.0553	274.0500	0.6000	0.0000	11.64	0.00	11.64	7.52

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
274.0922	274.0750	274.0578	274.0525	0.6025	0.0000	11.71	0.00	11.71	7.57
274.0949	274.0776	274.0604	274.0550	0.6050	0.0000	11.78	0.00	11.78	7.62
274.0976	274.0803	274.0630	274.0575	0.6075	0.0000	11.86	0.00	11.86	7.66
274.1003	274.0829	274.0655	274.0600	0.6100	0.0000	11.93	0.00	11.93	7.71
274.1031	274.0856	274.0681	274.0625	0.6125	0.0000	12.00	0.00	12.00	7.76
274.1058	274.0882	274.0707	274.0650	0.6150	0.0000	12.07	0.00	12.07	7.80
274.1085	274.0909	274.0732	274.0675	0.6175	0.0000	12.15	0.00	12.15	7.85
274.1113	274.0935	274.0758	274.0700	0.6200	0.0000	12.22	0.00	12.22	7.90
274.1140	274.0962	274.0784	274.0725	0.6225	0.0000	12.29	0.00	12.29	7.94
274.1168	274.0989	274.0809	274.0750	0.6250	0.0000	12.37	0.00	12.37	7.99
274.1195	274.1015	274.0835	274.0775	0.6275	0.0000	12.44	0.00	12.44	8.04
274.1222	274.1042	274.0861	274.0800	0.6300	0.0000	12.51	0.00	12.51	8.09
274.1250	274.1068	274.0886	274.0825	0.6325	0.0000	12.59	0.00	12.59	8.13
274.1277	274.1095	274.0912	274.0850	0.6350	0.0000	12.66	0.00	12.66	8.18
274.1305	274.1121	274.0938	274.0875	0.6375	0.0000	12.73	0.00	12.73	8.23
274.1332	274.1148	274.0964	274.0900	0.6400	0.0000	12.81	0.00	12.81	8.28
274.1360	274.1175	274.0989	274.0925	0.6425	0.0000	12.88	0.00	12.88	8.33
274.1387	274.1201	274.1015	274.0950	0.6450	0.0015	12.96	0.01	12.96	8.38
274.1415	274.1228	274.1041	274.0975	0.6475	0.0041	13.03	0.03	13.06	8.44
274.1444	274.1255	274.1067	274.1000	0.6500	0.0067	13.11	0.05	13.16	8.51
274.1472	274.1282	274.1092	274.1025	0.6525	0.0092	13.18	0.09	13.27	8.58
274.1500	274.1309	274.1118	274.1050	0.6550	0.0118	13.26	0.13	13.38	8.65
274.1529	274.1337	274.1144	274.1075	0.6575	0.0144	13.33	0.17	13.50	8.73
274.1558	274.1364	274.1170	274.1100	0.6600	0.0170	13.41	0.22	13.63	8.81
274.1587	274.1391	274.1196	274.1125	0.6625	0.0196	13.48	0.27	13.75	8.89
274.1616	274.1419	274.1221	274.1150	0.6650	0.0221	13.56	0.33	13.89	8.97
274.1645	274.1446	274.1247	274.1175	0.6675	0.0247	13.63	0.39	14.02	9.06
274.1674	274.1473	274.1273	274.1200	0.6700	0.0273	13.71	0.45	14.16	9.15
274.1703	274.1501	274.1299	274.1225	0.6725	0.0299	13.78	0.51	14.30	9.24
274.1733	274.1529	274.1325	274.1250	0.6750	0.0325	13.86	0.58	14.44	9.33
274.1762	274.1556	274.1350	274.1275	0.6775	0.0350	13.94	0.65	14.59	9.43
274.1792	274.1584	274.1376	274.1300	0.6800	0.0376	14.01	0.73	14.74	9.53
274.1821	274.1612	274.1402	274.1325	0.6825	0.0402	14.09	0.80	14.89	9.62
274.1851	274.1639	274.1428	274.1350	0.6850	0.0428	14.17	0.88	15.05	9.72
274.1881	274.1667	274.1454	274.1375	0.6875	0.0454	14.24	0.96	15.20	9.83
274.1911	274.1695	274.1480	274.1400	0.6900	0.0480	14.32	1.05	15.36	9.93
274.1941	274.1723	274.1505	274.1425	0.6925	0.0505	14.40	1.13	15.53	10.03
274.1971	274.1751	274.1531	274.1450	0.6950	0.0531	14.47	1.22	15.69	10.14
274.2001	274.1779	274.1557	274.1475	0.6975	0.0557	14.55	1.31	15.86	10.25
274.2031	274.1807	274.1583	274.1500	0.7000	0.0583	14.63	1.40	16.03	10.36
274.2062	274.1835	274.1609	274.1525	0.7025	0.0609	14.71	1.50	16.20	10.47
274.2092	274.1863	274.1635	274.1550	0.7050	0.0635	14.78	1.59	16.37	10.58
274.2123	274.1892	274.1661	274.1575	0.7075	0.0661	14.86	1.69	16.55	10.70
274.2153	274.1920	274.1687	274.1600	0.7100	0.0687	14.94	1.79	16.73	10.81
274.2184	274.1948	274.1713	274.1625	0.7125	0.0713	15.02	1.89	16.91	10.93
274.2215	274.1977	274.1738	274.1650	0.7150	0.0738	15.09	2.00	17.09	11.05
274.2245	274.2005	274.1764	274.1675	0.7175	0.0764	15.17	2.10	17.28	11.16
274.2276	274.2033	274.1790	274.1700	0.7200	0.0790	15.25	2.21	17.46	11.29
274.2307	274.2062	274.1816	274.1725	0.7225	0.0816	15.33	2.32	17.65	11.41
274.2338	274.2090	274.1842	274.1750	0.7250	0.0842	15.41	2.43	17.84	11.53
274.2370	274.2119	274.1868	274.1775	0.7275	0.0868	15.49	2.55	18.03	11.65
274.2401	274.2148	274.1894	274.1800	0.7300	0.0894	15.57	2.66	18.23	11.78
274.2432	274.2176	274.1920	274.1825	0.7325	0.0920	15.64	2.78	18.42	11.91
274.2464	274.2205	274.1946	274.1850	0.7350	0.0946	15.72	2.90	18.62	12.03
274.2495	274.2234	274.1972	274.1875	0.7375	0.0972	15.80	3.02	18.82	12.16
274.2527	274.2262	274.1998	274.1900	0.7400	0.0998	15.88	3.14	19.02	12.29

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
274.2559	274.2291	274.2024	274.1925	0.7425	0.1024	15.96	3.26	19.22	12.42
274.2590	274.2320	274.2050	274.1950	0.7450	0.1050	16.04	3.39	19.43	12.56
274.2622	274.2349	274.2076	274.1975	0.7475	0.1076	16.12	3.51	19.63	12.69
274.2654	274.2378	274.2102	274.2000	0.7500	0.1102	16.20	3.64	19.84	12.82
274.2686	274.2407	274.2128	274.2025	0.7525	0.1128	16.28	3.77	20.05	12.96
274.2718	274.2436	274.2154	274.2050	0.7550	0.1154	16.36	3.90	20.26	13.09
274.2751	274.2465	274.2180	274.2075	0.7575	0.1180	16.44	4.03	20.48	13.23
274.2783	274.2494	274.2206	274.2100	0.7600	0.1206	16.52	4.17	20.69	13.37
274.2815	274.2524	274.2232	274.2125	0.7625	0.1232	16.60	4.30	20.91	13.51
274.2848	274.2553	274.2258	274.2150	0.7650	0.1258	16.68	4.44	21.12	13.65
274.2881	274.2582	274.2284	274.2175	0.7675	0.1284	16.76	4.58	21.34	13.79
274.2913	274.2612	274.2310	274.2200	0.7700	0.1310	16.84	4.72	21.56	13.94
274.2946	274.2641	274.2336	274.2225	0.7725	0.1336	16.93	4.86	21.79	14.08
274.2979	274.2671	274.2362	274.2250	0.7750	0.1362	17.01	5.00	22.01	14.22
274.3012	274.2700	274.2388	274.2275	0.7775	0.1388	17.09	5.15	22.24	14.37
274.3045	274.2730	274.2414	274.2300	0.7800	0.1414	17.17	5.29	22.46	14.52
274.3078	274.2759	274.2441	274.2325	0.7825	0.1441	17.25	5.44	22.69	14.66
274.3111	274.2789	274.2467	274.2350	0.7850	0.1467	17.33	5.59	22.92	14.81
274.3144	274.2819	274.2493	274.2375	0.7875	0.1493	17.41	5.74	23.15	14.96
274.3178	274.2848	274.2519	274.2400	0.7900	0.1519	17.50	5.89	23.39	15.11
274.3211	274.2878	274.2545	274.2425	0.7925	0.1545	17.58	6.04	23.62	15.27
274.3245	274.2908	274.2571	274.2450	0.7950	0.1571	17.66	6.20	23.86	15.42
274.3279	274.2938	274.2597	274.2475	0.7975	0.1597	17.74	6.35	24.09	15.57
274.3312	274.2968	274.2623	274.2500	0.8000	0.1623	17.82	6.51	24.33	15.73
274.3346	274.2998	274.2649	274.2525	0.8025	0.1649	17.91	6.67	24.57	15.88
274.3380	274.3028	274.2676	274.2550	0.8050	0.1676	17.99	6.83	24.81	16.04
274.3414	274.3058	274.2702	274.2575	0.8075	0.1702	18.07	6.99	25.06	16.19
274.3449	274.3088	274.2728	274.2600	0.8100	0.1728	18.15	7.15	25.30	16.35
274.3483	274.3118	274.2754	274.2625	0.8125	0.1754	18.24	7.31	25.55	16.51
274.3517	274.3149	274.2780	274.2650	0.8150	0.1780	18.32	7.47	25.80	16.67
274.3552	274.3179	274.2806	274.2675	0.8175	0.1806	18.40	7.64	26.04	16.83
274.3586	274.3209	274.2833	274.2700	0.8200	0.1833	18.49	7.81	26.29	16.99
274.3621	274.3240	274.2859	274.2725	0.8225	0.1859	18.57	7.98	26.55	17.16
274.3656	274.3270	274.2885	274.2750	0.8250	0.1885	18.65	8.14	26.80	17.32
274.3691	274.3301	274.2911	274.2775	0.8275	0.1911	18.74	8.31	27.05	17.48
274.3726	274.3332	274.2938	274.2800	0.8300	0.1938	18.82	8.49	27.31	17.65
274.3761	274.3362	274.2964	274.2825	0.8325	0.1964	18.91	8.66	27.56	17.81
274.3796	274.3393	274.2990	274.2850	0.8350	0.1990	18.99	8.83	27.82	17.98
274.3831	274.3424	274.3016	274.2875	0.8375	0.2016	19.07	9.01	28.08	18.15
274.3866	274.3454	274.3042	274.2900	0.8400	0.2042	19.16	9.19	28.34	18.32
274.3902	274.3485	274.3069	274.2925	0.8425	0.2069	19.24	9.36	28.60	18.49
274.3938	274.3516	274.3095	274.2950	0.8450	0.2095	19.33	9.54	28.87	18.66
274.3973	274.3547	274.3121	274.2975	0.8475	0.2121	19.41	9.72	29.13	18.83
274.4009	274.3578	274.3148	274.3000	0.8500	0.2148	19.50	9.90	29.40	19.00
274.4045	274.3609	274.3174	274.3025	0.8525	0.2174	19.58	10.09	29.67	19.17
274.4081	274.3641	274.3200	274.3050	0.8550	0.2200	19.67	10.27	29.93	19.35
274.4117	274.3672	274.3226	274.3075	0.8575	0.2226	19.75	10.45	30.20	19.52
274.4153	274.3703	274.3253	274.3100	0.8600	0.2253	19.84	10.64	30.47	19.70
274.4190	274.3734	274.3279	274.3125	0.8625	0.2279	19.92	10.83	30.75	19.87
274.4226	274.3766	274.3305	274.3150	0.8650	0.2305	20.01	11.01	31.02	20.05
274.4263	274.3797	274.3332	274.3175	0.8675	0.2332	20.09	11.20	31.30	20.23
274.4299	274.3829	274.3358	274.3200	0.8700	0.2358	20.18	11.39	31.57	20.40
274.4336	274.3860	274.3384	274.3225	0.8725	0.2384	20.26	11.59	31.85	20.58
274.4373	274.3892	274.3411	274.3250	0.8750	0.2411	20.35	11.78	32.13	20.76
274.4410	274.3924	274.3437	274.3275	0.8775	0.2437	20.43	11.97	32.41	20.94
274.4447	274.3955	274.3463	274.3300	0.8800	0.2463	20.52	12.17	32.69	21.12

WSE outer channel (ft)	WSE center channel (ft)	WSE inner channel (ft)	WSE in outer discharge chamber (ft)	H_1 (ft)	H_2 (ft)	Q_1 (cfs)	Q_2 (cfs)	Q_t (cfs)	Q_t (MGD)
274.4484	274.3987	274.3490	274.3325	0.8825	0.2490	20.61	12.36	32.97	21.31
274.4522	274.4019	274.3516	274.3350	0.8850	0.2516	20.69	12.56	33.25	21.49
274.4559	274.4051	274.3543	274.3375	0.8875	0.2543	20.78	12.76	33.54	21.67
274.4597	274.4083	274.3569	274.3400	0.8900	0.2569	20.87	12.96	33.82	21.86
274.4634	274.4115	274.3595	274.3425	0.8925	0.2595	20.95	13.16	34.11	22.04
274.4672	274.4147	274.3622	274.3450	0.8950	0.2622	21.04	13.36	34.40	22.23
274.4710	274.4179	274.3648	274.3475	0.8975	0.2648	21.13	13.56	34.69	22.42