HYDRAULIC MODEL STUDY
Downriver Tunnel
Pumping Station
Report CEE 98-2

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EXECUTIVE SUMMARY

A 1:7 scale physical hydraulic model was constructed of the Downriver Tunnel Pumping Station. The emphasis of the model testing was on pump intake conditions although other hydraulic conditions associated with the flow within the wet well were investigated as well. Testing was performed for various combinations of wet well water levels and number of pumps in operation to simulate the proposed operating rules for the pump station. An investigation of surge conditions within the wet well associated with pump startup and shutdown was carried out by development of a numerical model of the unsteady flow as water fills and drains from the pump discharge line. This model was run for assumed worst case flow conditions associated with pump operation.

Results of the initial hydraulic model testing indicated moderately high swirl angles associated with the lowest wet well water levels (near the pump Off level for one pump in operation). Under those flow conditions, swirl angles approached ten degrees in magnitude. Although this may be acceptable for the low specific speed pumps to be used in this pump station, it is above the often-stated limit of five degrees. It was found that by modifying the inlet from the tunnel into the wet well, swirl angles could be reduced to below five degrees for all flow conditions.

The tunnel inlet modification was instigated by a desire to distribute the inflow at low wet well water levels more uniformly across the bar screens. In order to accomplish this objective, two specific modifications were found to be necessary: a transition from a circular cross-section to a flat bottom in the inner ring wall and a wedge-shaped diverter installed in this transition. The details of this proposed transition are included in the report as Figure 7. Since this transition also reduced the magnitudes of the intake swirl angles at the low water level conditions, it is recommended to incorporate this into the pump station design to accomplish both flow improvements.

A qualitative investigation was performed on the transport of both buoyant and negatively buoyant particles within the wet well. Buoyant (floating) particles tended to be circulated within the wet well in a pair of counter-rotating surface vortices and did not appear to accumulate in any particular locations. Concern had been initially expressed about the potential for accumulation of floating debris in the locations of float level sensors, but this does not appear to be a problem. Deposition of negatively buoyant sediment will depend on the size and specific gravity of particles that are transported into the pumping station but some deposition is inevitable. The model did not indicate any regions of excess deposition. Rather the deposition appeared to be broadly distributed over the downward sloping station floor where the velocities are reduced due to flow separation. The flow separation is caused by too steep a drop in the floor, but there appears to be little that can be done to alter the overall geometry of the pump station.

The numerical investigation of surge effects indicates very little problem in this regard. No problem was indicated on pump startup with a fairly continuous change in wet well elevation depending on the exact tunnel inflow rate. The pump discharge will be subject to some fluctuations due to the discharge pipe geometry. The analysis assuming instantaneous pump startup is not realistic but a conservative, worst-case situation. Under this assumed condition, the pump would reach a maximum discharge almost instantaneously and then fall off as the water column is pushed through the discharge pipe. A slower pump startup time due to the actual pump inertia will reduce the magnitude of these flow fluctuations.

In the case of pump shutdown, the assumption of instantaneous pump shutdown (no pump inertia) led to a prediction of significant cavitation within the discharge pipe. This assumption was modified to assume a linear decrease in pump head over 1.5 seconds. Under this assumption, the predicted pressures within the pipeline still indicated cavitation but not as pronounced. So long as the actual time for the pump to spin down is greater than about 4 seconds, there should be no problem with cavitation in the system. Otherwise high pressure spikes may be experienced in the system upon vapor cavity collapse. It is anticipated that actual spin-down times will be sufficient to avoid cavitation. Another solution to guarantee protection against cavitation is to install air relief valves at the bend prior to the horizontal run of pipe in each pump discharge line.

INTRODUCTION

The Downriver Regional Storage and Transport System serves 13 communities in southern Wayne County, Michigan. As part of a system expansion project, a 6.5 to 7.5 foot diameter, ten mile long tunnel ending at the Tunnel Pump Station at the Wyandotte wastewater treatment plant will be constructed. A proposed design has been developed for the Tunnel Pump Station. The purpose of the proposed physical model study was to examine the flow conditions within the wet well of the Tunnel Pump Station with specific emphasis on the pump intake conditions. Vortices and inlet swirl have a detrimental effect on the operation of pumps, lowering efficiency and increasing wear. Severe vortexing can also lead to pump vibration, cavitation and impeller pitting. The testing sequence included the following components:

- Examination of surface vortex patterns
- Examination of subsurface vortex patterns
- Measurement of swirl in flow into individual suction inlets

The model was also used to examine the potential for solids deposition within the wet well. An additional issue examined in the hydraulic modeling relates to the location of the float for the level sensor to determine whether floating debris would accumulate at that location.

Finally, a request was made to examine the issue of surge within the wet well due to pump start-up or shut-down. This is an issue that is not easily resolved within the constraints of a conventional physical hydraulic model. A numerical model of conditions associated with pump start-up or shut-down was developed to address the surge issue; results of this analysis are presented in Appendix 1.

GENERAL SYSTEM DETAIL

Flow enters the Tunnel Pump Station through the 7.5 foot diameter tunnel at an invert elevation of 535 ft. The pump station is to be constructed in the interior of a 50 foot diameter circular caisson with a three foot thick inner ring wall resulting in a 44 foot diameter wet well.

After the flow passes through a twelve foot wide, three inch spacing bar screen set with a bottom elevation of 532 ft, the floor slopes down to an elevation of approximately 528 ft. The pumps are to be installed in a six foot wide channel in the station floor; the channel axis is oriented perpendicular to the inflow and has a bottom elevation of approximately 525 ft. A raised wall on the back side of the channel was added to the design to provide for better flow conditions into the pumps. Plan and cross sectional views of the wet well layout are included in Figure 1. The pump discharge lines are described in Appendix 1.

The pump capacity for each of the four pumps is intended to be 25 mgd. The two central pumps (Pumps 2 and 3) in the array are intended to be variable speed pumps and one of these is intended to be the first to be operated during any pumping operation. The outer two pumps (Pumps 1 and 4) are designed as constant speed pumps and will be operated as needed following the first variable speed pump. The use of all four pumps will be restricted to emergency situations and the remaining variable speed pump would be the fourth pump in operation.

Normal system operation would involve switching the operation sequence of Pumps 2 and 3 so that they are alternately the first to be used during a pumping event. Under the scenario where Pump 2 is the first to be operated, the operating sequence on the fixed speed pumps is Pump 4 and then Pump 1. Initial operation of Pump 3 will similarly entail the sequential operation of Pumps 1, then Pump 4. It is anticipated that the Tunnel Pump Station will only be operated an average of 66 hours per year and only once every six or seven years will a pumping capacity of 75 mgd (three pumps) be required.

MODEL DESCRIPTION

Modeling Criteria

Physical models to examine flow behavior in free surface flow are performed using Froude number similarity, which fixes the relations between model and prototype conditions once the physical model scale has been selected. Dynamic similarity requires keeping all Froude numbers defined by $V/(gL)^{1/2}$ equal in the model and prototype, where V refers to any representative fluid velocity, g the acceleration due to gravity, and L is any system length. The relations between prototype and model parameters are related to the scale ratio $\mathbf{L_r}$ which is the geometric ratio between any length in the model and the corresponding one in the prototype ($\mathbf{L_r} = \text{Length}_{\text{model}} / \text{Length}_{\text{prototype}}$). For a Froude scaled model, assuming the same fluid in model and prototype, the following relations must hold in which the ratio $\mathbf{Q_r}$ for example, represents the ratio of the discharge in the model to the corresponding prototype flow rate:

PARAMETER		**RATIO**
Length	$\mathbf{L_r}$	$\mathbf{L_r}$
Velocity	$\mathbf{V_r}$	$\mathbf{L_r}^{1/2}$
Discharge	$\mathbf{Q_r}$	$\mathbf{L_r}^{5/2}$
Time	$\mathbf{T_r}$	$\mathbf{L_r}^{1/2}$

The critical factors with respect to model testing facilities are the model size and discharge. If the scale ratio is too small, both viscous effects and surface tension may become too great in the model. This consideration generally fixes the minimum model size required to avoid distortion of the model flow. Padmanabhan and Hecker (1984) suggest from the results of previous studies that a minimum Reynolds number of greater than 30,000 be maintained in the physical model to correctly reproduce the effect of viscosity on the flow behavior. This Reynolds number is to be defined in terms of the flow in the suction pipe as $Re = Q/(Sv)$, with Q the flow rate in the suction pipe, S the pump intake submergence in the wet well, and v the kinematic viscosity. They also found no Reynolds number effects for Reynolds numbers $Re = VD/v$, (with V the flow velocity in the suction pipe and D the suction pipe diameter) greater than about 70,000. No influence due to surface tension effects was indicated in these results. The Reynolds number constraints become instrumental in the selection of the minimum physical model size. In keeping with these constraints and other considerations, the model scale selected was 1:7. This scale ratio maintains the model Reynolds number (based on the suction pipe diameter) for a pump intake at its capacity of 25 mgd at a value of approximately 170,000 which is above the limit discussed above with some margin for allowing the study of operation of the variable speed pumps at lower discharges.

Model Testing Facilities

The model study was conducted in the Civil Engineering Hydraulics Laboratory located in the G.G. Brown Building at the North Campus of The University of Michigan.

Model Construction

The physical model was constructed at a scale ratio of 1:7. The pump suction lines were constructed from Plexiglas so that the rotating cruciforms (swirl meters) used to measure the inlet swirl angles could be observed to determine the swirl angles. A proposed design for the pump suction bells was provided and an inside mold was prepared for the suction bell. The model bells were then manufactured by heating Plexiglas conduit until flexible and forming over the molds. Figures 2a-b are photographs of the Plexiglas bells as constructed with the rotating cruciform installed in Figure 2b. The bells have a pair of guide vanes on the inside that can be observed in the model intakes. Although all details of the pumps were not reproduced in the model, the proposed details of the pump discharge lines up to an elevation of 535 ft were reproduced in the model. Figure 3 indicates the model detail of the installed pump intakes; the white PVC piping represents the discharge lines on the prototype pumps whereas the actual model flow continues vertically through the Plexiglas conduit.

All four pump suction lines were joined into a common manifold connected to a recirculating pump which removes the flow from the wet well through the desired pump suction lines, and back around to the inlet conduit.

Figure 4 is a schematic of the model layout while Figures 5a-b are photographs of the overall model including the recirculation piping. The flow was regulated by means of a butterfly valve on each of the pump suction lines. The flows were metered in each individual line by means of an installed pipe orifice meter.

Instrumentation

Flow rates were measured using pipe orifice meters constructed to ASME specifications. There was a ten foot section of four inch PVC pipe upstream of each orifice meter and the downstream sections were at least five feet in length. Pressure differences were measured with water-air differential manometers. The orifice meters were calibrated prior to installing in the model by installing them in series with a calibrated venturi meter and correlating the flow determined by the venturi meter against the manometer deflection. This procedure produced flow coefficients which were within one percent of those recommended for this type of orifice meter by Brater and King (1977). The orifice meters were sized to provide a total manometer deflection of 32 inches at the model discharge corresponding to 25 mgd; at this deflection; a metering precision on the order of two percent is estimated.

The presence of surface and subsurface vortices was investigated visually by the injection of dye into the model.

The swirl angles were measured with a rotating cruciform (swirl meter), the function of which is to rotate with the component of tangential flow in the pump suction line. Standard specifications of 0.8 of the pipe diameter for the length and diameter of the cruciforms were utilized in the construction. The cruciform is mounted so that it rotates freely on a hub installed along the pipe centerline, see Figure 1b. One vane was painted to orient the cruciform, especially in a rapidly rotating flow. For the Phase I studies performed, the rotation rates were often in excess of one per second. At this high a rotation rate, it was most convenient to measure the time required to count a specified number of rotations, generally 100. This often took on the order of one to two minutes. These counts were repeated up to five times and the individual times averaged to give a mean rotation rate.

Potential interference of floating debris interfering with the floats for the level sensors was examined by introducing Styrofoam “peanuts” into the model at the inflow section. The motion of the Styrofoam was observed for several minutes and recorded on videotape for a permanent record.

“Sediment” was introduced into the model to observe deposition patterns within the wet well. This consisted of the introduction of constant diameter, black, silicon carbide grinding powder into the inflow in the wet well at a controlled rate and observing the transport through the wet well. This sediment was selected to be marginally transported by the velocities experienced within the wet well. It would be scoured by the high velocities immediately under the pump intakes but would generally be deposited throughout the remainder of the wet well. The videotape also records details of the sediment introduction and deposition within the model.

TESTING PROCEDURES

Generally, the worst flow conditions appear at maximum flow rates and/or minimum water levels. There are only seven general conditions that need to be tested, each at two water levels. These would involve one pump in operation (either of Pumps 2 and 3), two pumps (Pumps 2 and 4 or Pumps 3 and 1), three pumps (Pumps 2 or 3 and Pumps 1 and 4) and four pumps in operation. The two and three pump operation conditions each involve two different conditions that are symmetric with respect to each other and similar results would be expected for them. Pump On and Off levels have been specified for these according to the following table:

Table 1. Proposed sequence of pump operation.

# of Pumps Operating	Off Elevation (ft)	On Elevation (ft)
1 (Pumps 2 or 3)	535	538.5
2 (Pumps 2 and 4 or 3 and 1)	539	541
3 (Pumps 2 or 3 and 1 and 4)	540	542
4	547	550

Since the worst conditions were anticipated at maximum flows, the variable speed pumps were primarily tested at their maximum flow rate of 25 mgd. Checks at a lower flow rate of 70 percent the maximum capacity were performed to verify this assumption.

Tests included the following:

1. All observations of surface vortices were classified with respect to their appearance. Specifically, this involves a designation of the visual appearance of the vortex strength ranging from surface swirl to an air core vortex that exists all the way to the pump intake. Following Padmanabhan and Hecker (1984) the classification system is as follows:

Type 1: Surface swirl
Type 2: Surface dimple: coherent swirl
Type 3: Dye core to intake; coherent swirl throughout water column
Type 4: Vortex pulling floating trash but not air to intake
Type 5: Vortex pulling air bubbles to intake
Type 6: Solid air or vapor core to intake

No surface vortex more severe than an intermittent Type 2 dye core is generally regarded as an acceptable flow state. This is determined by visually examining the water surface for dimples and injecting dye to look for organized motions extending downwards to one of the suction intakes. Any vortices persisting less than about 10 seconds are considered to be intermittent.

2. Observations of subsurface vortices were made by dye injections in and observing the tendency for any organized vortex motion. Acceptance criteria allow no coherent subsurface vortex with organized swirl and core (Type 2).

3. With respect to entrance condition into the pump suction lines, the swirl angle of the entering flow was measured in all discharging intake lines with a rotating cruciform. The swirl angle is defined by counting the rotations per unit time and computing the angle as

$$\theta = \tan^{-1}\left(\frac{\pi N D}{U}\right)$$

with θ the swirl angle, N the revolutions per unit time of the rotating cruciform, D the pipe diameter and U the average axial flow velocity (the line discharge divided by the pipe cross sectional area). Swirl angles of less than 5 degrees are generally considered as acceptable for axial flow pumps. For the centrifugal pumps to be used in this application, higher swirl angles are considered to be acceptable although there is some debate in the literature on this issue (p. 9 of *Swirling Flow Problems at Intakes*, J. Knauss, ed., IAHR Hydraulic Structures Design Manual, A.A. Balkema, 1987 states “prerotation expressed by the indicated swirl angle shall normally not exceed 5°...”) regardless of the type of pump.

PHASE I TEST RESULTS

Vortices and Other Flow Conditions

Very little surface vortex activity was observed in the model under any flow condition. Intermittent Type II vortices were observed under various low water level conditions and were associated with the inflow from the entrance pipe. In this situation, the expanding flow from the

7.5 foot tunnel into the region bounded by the walls confining the flow through the bar screen produced Type II vortices that were intermittently observed on the water surface near the pump intakes. However, these were not persistent and only a minor surface dimple was observed.

Under similar low flow conditions (one pump operation near the pump Off level), intermittent organized submerged vortices could be located near the pump intake. These were more pronounced in the preliminary tests and less significant after the modifications to the tunnel entrance were implemented. Dye surveys did not indicate an organized core to these vortices.

The inflow into the wet well from the 7.5 ft diameter tunnel produced a number of apparently undesirable flow conditions, particularly at low water level conditions. At wet well elevations near the single pump Off elevation of 535 feet, the wet well water surface elevation is at the tunnel invert elevation. The water depth in the tunnel at the entrance to the wet well is therefore controlled by the combination of tunnel hydraulic resistance/critical flow at the tunnel exit. At higher wet well water levels, the backwater from the wet well will increase the flow depth in the tunnel. The low water depth in the tunnel at a given inflow rate at low water levels produces a significantly greater inflow velocity due to the smaller flow area near the tunnel invert. This also produces a more concentrated flow near the center of the inflow section. Strong recirculation eddies were formed upstream of the bar screens and the inflow is concentrated over a small portion of the bar screen. This flow also had an adverse impact on pump intake swirl at low water levels as discussed below. As water levels within the wet well were increased to the pump On level of 538.5 ft, a much higher cross-sectional flow area along with a greater lateral distribution of the inflow resulted in improved flow conditions.

Swirl Angles

Swirl angles were measured for various combinations of one, two, and three pumps in operation. Table 2 summarizes the results of this testing.

For some flow conditions, the swirl meters would switch rotation directions consistently throughout the measurements and the indicated sign indicates the prevailing rotation direction; this is an issue only at small swirl angles. These results are probably accurate to within one or two degrees as there could be differences between two consecutive times required for the counting of 100 revolutions. This was primarily due to the fact that there were intermittencies in each flow in which the rotation would be at a fairly consistent rate and then suddenly come to a rest or even reverse direction of rotation. The number of these drop-outs had the most influence on a count as a measurement in which there were none could result in half the time for 100 revolutions compared to a measurement in which there were several. Longer counting intervals would probably yield more repeatable results. Nevertheless, the results appear to be fairly consistent and those flows which are symmetric (For example, Two pump operation of Pumps 2 and 4 and Pumps 3 and 1 are symmetric with respect to flow in the wet well) were generally within one degree and the opposite rotation. There are a few flow conditions in which swirl angles of more than five degrees were observed; these were at the lowest water level and the water level appeared to be a more important variable than the number of pumps in operation. With all other test conditions investigated, the swirl angles were below three degrees with the exception of one single pump intake at one flow condition (two pump operation, Pump 2 at a wet well level of 541 ft). Operation at the lower flow (70 percent of rated discharge) for the variable speed pumps only slightly reduced the swirl angle but does indicate that the maximum flow rate is the most critical with respect to inlet swirl.

Table 2. Swirl angles associated with various flow conditions for initial proposed design.

# of Pumps	Pump	Water Level (ft)	Swirl Angle (degrees)
One	2	535	-8.2
One	2 (17.5 mgd)	535	-6.7
One	3	535	+9.9
One	3 (17.5 mgd)	535	+7.7
One	2	538.5	2.6
One	2 (17.5 mgd)	538.5	1.7
One	3	538.5	–1.6
One	3 (17.5 mgd)	538.5	–1.1
Two	2	539	1.1
	4		0.9
Two	1	539	-1.6
	3		-1.6
Two	2	541	-3.6
	4		+2.0
Two	3	541	+1.1
	1		-1.5
Three	3	540	-2.3
	1		-1.4
	4		-1.5
Three	2	540	2.3
	1		1.9
	4		2.1
Three	3	542	2.6
	1		-2.1
	4		1.1
Three	2	542	-2.8
	1		-1.3
	4		+2.8

Note: negative sign denotes counterclockwise rotation when looking down on model, positive sign denotes clockwise rotation.

Due to observations of reversals in inlet swirl directions with water level, a more detailed investigation was performed to understand this occurrence. The following discussion follows for the operation of the single pump 3. At a level slightly below 535 ft, the rotation of the swirl meter was consistently in a clockwise sense and at a high rate of rotation. As the water level was increased to about 535 ft, the rotation direction become less well defined with rapid rotations in either the clockwise or counterclockwise directions with periods of no rotation. Raising the water level further produced consistently counterclockwise rotation, with almost as high a rotation rate as the lower water levels. At a water level between 536 and 536.5 ft, another reversal in flow direction occurred with primarily clockwise rotation but at much lower rates than at the lower water levels. Finally, at an elevation of about 538 ft, another reversal occurred with a counterclockwise rotation at higher water levels. A consistent pattern occurred with pump 2 but with opposite rotation directions.

The flow phenomena that led to the above observations were investigated in some qualitative detail. There appears to be two major factors that led to the observation noted above. The first is the influence of the inflow into the wet well. At low water levels, the inflow is over the bottom portion of the inflow pipe and therefore tends to be concentrated into a stronger jet across the wet well. This strong jet crosses the wet well without much diffusion and strikes the wall behind the pump intakes and spreads laterally, setting up a strong circulation within the wet well. As a water level of 535 ft is surpassed, some of this flow overtops the wall, altering the nature of the flow. At still higher wet well levels, the inflow occupies a larger portion of the inlet tunnel, resulting in a lower inlet velocity and a more diffused flow across the wet well. The recirculation set up within the wet well is not as pronounced with this flow condition. The second factor was the occurrence of submerged vortices near the pump intakes at some water levels. Their appearance and disappearance with changing water levels altered the direction of rotation within the pump intakes.

The combination of the various factors noted above can apparently explain the complicated behavior of rotation within the pump intakes. The swirl angles recorded in the table for an elevation of 535 ft were actually performed at an elevation just below that (approximately 534.7 ft) where the swirl was more pronounced. However, at elevations of about 535.5 ft, the swirl was almost as severe but in the opposite direction. Therefore, in subsequent tests, the water levels were varied slightly from the nominal values to ensure the attainment of worst case swirl directions. At high water levels, this was not an issue.

Although the swirl angles in Table 2 may be acceptable for the centrifugal pumps to be used in this application, minor modifications to the wet well geometry could potentially reduce these magnitudes. In particular, modification of the inlet condition at low wet well levels could reduce the large swirl angles found at those flow conditions.

Float Level Sensor Function

Since the floats for the level sensors are installed in stagnant zones on the outside of the inlet walls, there was concern relating to the possibility of floating debris building up in the corner of the model outside the walls supporting the bar screen. During the course of the model testing, Styrofoam "peanuts" were introduced into the model at the free surface in the inflow into the wet well. The general motion of these floating particles was similar at all wet well water surface elevations and discharges. They traveled more or less directly across the wet well to the far side and then divided into oppositely rotating cells that carried the Styrofoam back around the sides of the wet well until it was re-entrained into the inflow. Figure 6 indicates a schematic of the surface circulation patterns within the wet well. There was no real tendency for the Styrofoam to stagnate anywhere within the model. Even particles that were manually placed in the back corners of the model were not retained there for any length of time. It may be best if the float for the level sensor is not located in the exact corner of the wet well.

Sedimentation Patterns

The introduction of the model sediment into the inflow resulted in generally uniform sedimentation patterns. The downslope from the inflow section to the pump intakes is too steep to prevent flow separation and a stagnant zone exists over the entire surface. The sediment tended to accumulate in a fairly uniform pattern over the downslope surface. Similar accumulations were observed on the hroizontal surfaces near the pump intakes. The videotape can be reviewed for observations on this process. It is therefore concluded that there are no particular locations with excessive sedimentation compared to other locations within the wet well. A less steep downslope within the wet well would avoid the flow separation and presumably some of the sedimentation that was observed there.

WET WELL MODIFICATIONS

Based on the preliminary observations, it appears that the wet well will function adequately with the possible exception of the flow conditions at the lowest water levels. The largest swirl angles were observed in the two inner pump (2 and 3) intakes, because these are the ones to be operated at the lowest water levels. At higher water levels, all pumps have lower magnitudes of swirl angles. Minor modifications to the proposed design may serve to reduce the swirl angles at low water levels. In addition, concern was expressed regarding the concentration of the inflow at the position of the bar screens, again primarily associated with low water levels. Consideration of these two issues led to two potential modifications to the wet well:

- placement of flow straighteners beneath the suction bells to pumps 2 and 3;
- placement of a flow diverter at the tunnel exit as it enters the wet well. The purpose of this diverter is to spread the flow laterally at low wet well water surface elevations.

Two different types of flow straighteners which could be installed beneath the pump intakes were investigated. While both of these were roughly equally effective in reducing the magnitudes of the swirl angles, it was found that the installation of the flow diverter had the most dramatic effect on the pump intake conditions as well as serving the purpose of diffusing the flow at the bar screens. It was concluded that this alternative alone would suffice to sufficiently reduce the swirl angles.

Flow Straighteners

Two different types of flow straighteners were investigated: 1.) a triangular plate attached to the back side of the channel with the pump intakes and extending to the centerline of the pump intake and 2.) a cone to be installed directly beneath the pump intake. A schematic of these two alternatives is indicated in Figure 7; the cone can be seen installed in Figure 3 under the Pump 2 intake. Both alternatives were investigated simultaneously by initially installing the triangular plate under Pump 2 while installing the cone under Pump 3. Water levels within the wet well were slowly adjusted to find the worst conditions for rotation and swirl angles were measured at these water levels. Table 3 summarizes the results of this testing.

Table 3. Swirl angles associated with various flow conditions for flow straighteners under Pumps 2 and 3.

# of Pumps	Pump	Water Level (ft)	Swirl Angle (degrees)
One	2	<535	-2.3
One	2	>535	+2.8
One	3	<535	+4.4
One	3	>535	-3.8
One	2	538.5	-1.0
One	3	538.5	+0.9

The results of this testing indicates that both types of flow straighteners could be used to significantly reduce the magnitudes of the swirl angles and that apparently the triangular plate was superior to the cone in reducing the intake swirl. This was checked by switching the locations of the flow straighteners and repeating the experiments. The results were somewhat ambiguous in that it the results for the triangular plate were still better than the cone but with less difference between the two. Since higher swirl angles were also measured at Pump 3 during the initial testing at low water levels compared to the symmetrical condition for pump 2, it was concluded that there may be a slight asymmetry in the approach flow that led to this result. Therefore, both flow straighteners appear to be nearly equally effective in reducing swirl angles with a slight advantage to the triangular plate.

Final testing was performed once the flow diverter configuration was developed. Testing was performed over the entire range of test conditions to ensure that the flow diverter did not lead to detrimental changes in swirl angle. One immediate observation was the reduction in the rotation direction reversals at the low wet well levels. The swirl meter in Pump 2 consistently rotated clockwise over the entire elevation range from 535 to 538.5 ft while Pump 3 indicated consistently counterclockwise rotation. This indicates the disappearance of the submerged vortices that led to some of the previous results and therefore a generally better pump intake condition. Table 4 provides the results of this testing with the flow straighteners in place beneath the pump intakes.

Table 4. Swirl angles associated with various flow conditions with flow diverter at tunnel exit installed.

# of Pumps	Pump	Water Level (ft)	Swirl Angle (degrees)
One	2	535	2.5
One	2	536	2.6
One	2	537	1.9
One	2	538.5	0.9
One	3	535	-4.3
One	3	536	-3.7
One	3	537	-1.3
One	3	538.5	-0.6
Two	3	539	-0.4
	1		-1.5
Two	3	541	-0.1
	1		-1.2
Three	3	540	-2.6
	1		-1.7
	4		0.8
Three	3	542	-3.6
	1		-1.8
	4		1.6
Four	2	547	2.3
	3		-2.0
	1		-0.1
	4		0.1

Note: negative sign denotes counterclockwise rotation when looking down on model, positive sign denotes clockwise rotation.

The performance is fairly similar to that of the preliminary testing at the higher water levels with a reduction in swirl angles at the lower water levels. With the change in the flow rotations at the lower water levels (no rotation reversals), it was decided to remove the flow straighteners from the Pump 2 and 3 intakes to determine the swirl angles with no flow straighteners. At a water level of 535 ft, the swirl angles under both Pumps 2 and 3 were approximately 3.7 degrees or similar to those observed with the flow straighteners. The water levels were increased slowly from 535 to 538.5 ft and no adverse rotation conditions were observed. Therefore, it is concluded that the flow diverter serves to reduce the swirl angles sufficiently at low wet well water levels so that the installation of flow straighteners is not necessary.

Flow Diverter

The purpose of the flow diverter was to spread the flow entering the wet well laterally to diffuse the flow impinging on the bar screens. A primary constraint in this endeavor was the very short distance between the inlet from the tunnel and the bar screen; any diverter could extend no more than about three feet into the wet well. This is insufficient distance to guide the flow smoothly and prevent flow separation. The resulting flow separation will create a wake region on the downstream side of the diverter with recirculating flows. There is also an additional area of flow separation inherent in the initial design due to the tunnel invert elevation of 535 ft located 3 ft higher than the floor elevation of 532 ft at the bar screen. This flow separation also cannot be avoided due to the short distance to the bar screen making a guided flow expansion impossible. The objective in the design of the flow diverter was to minimize the size of these separation zones while still maintaining a sufficient spreading of the inflow so that it covered most of the twelve foot width of the bar screen. This was mainly accomplished by a trial-and-error procedure until an optimum configuration was found.. It was also necessary to check with structural design constraints at each step in the process to ensure that proposed modifications were feasible within the existing structural configuration.

Since the flow was more concentrated at the center of the inlet at low water levels, it was decided to design a diverter with a height of only 1.5 ft. At higher wet well water levels, the greater width of the tunnel was observed to spread the flow adequately in the lateral direction. The final configuration proposed from the testing is indicated in the photograph in Figure 8 as well as the dimension drawing in Figure 9. There are two major elements to this design. The wedge projecting into the oncoming flow serves to divert the flow laterally and spread it to the approximate width of the bar screen within the available distance. The wake zone on the downstream side of this wedge extends to approximately the location of the bar screen so long as the wedge is installed within the inner ring wall of the caisson. Placement of the wedge within a circular cross section through the inner ring wall did not, however, provide sufficient lateral spreading of the flow. Therefore, it was also required to use the ring wall thickness to provide a transition from a circular cross section to a flat bottom the same width as the tunnel diameter. The most important feature is to provide the additional width at the bottom of the cross section, so it is not necessary to provide a flat top to the transition, rather the top can be maintained as a circular section. Dye surveys indicated this to be an optimal configuration compared to all others tested in that the flow entering the wet well is much more diffused compared to the initial design and other configurations tested. Some of the other configurations tested are included on the videotape and their performance viewed. It can be seen that there is a reverse flow along the floor under all configurations tested but this cannot be avoided. Compared to the other diverters tested, the one recommended minimizes the size of the eddy downstream of the diverter while still maintaining a sufficient spreading of the flow to distribute it over the width of the bar screen.

CONCLUSIONS

Generally, the hydraulic performance of the initial design proposed for the wet well appears to be acceptable. The only conditions that represent any cause for concern appears to be at low wet well water levels near the single pump shutoff level. At low water level conditions, the intake swirl angle for the single variable speed pump that is operating will approach 10°. This would appear to be acceptable for the low specific speed pumps to be installed in this pumping station. However, there is some disagreement in the literature about the acceptable limits for swirl angles, with some authors recommending limits lower than the above mentioned results, regardless of the type of pump. A second hydraulic condition at low wet well water levels is the concentration of the flow from the inlet tunnel over a small section of the bar screen. Fortunately, a solution to both of these problems can be attained by a single modification to the station design. This involves the design of a transition section to be located in the ring wall of the pump station. The transition section that proved most successful in meeting both objectives included a wedge-shaped flow diverter which spreads the inflow more laterally plus a transition of the circular tunnel cross-section to a section with a flat bottom. Both of these are required in order to achieve sufficient spreading of the flow in the limited longitudinal distance from the inside of the caisson to the bar screen. With this configuration, the flow is spread more laterally both at the bar screen and further into the wet well near the pump intakes. This served to reduce the swirl angles to below 5° for all flow conditions. In this configuration, flow straighteners installed beneath the pump intakes did not significantly affect the measured swirl angles and therefore, their installation is not recommended.

With regards to floating debris within the wet well, it was observed that floating material would be continuously circulated through the wet well with little tendency for accumulation in any stagnation zones. There is no concern with regards to floating debris accumulating in the vicinity of the float level sensors.

Finally, with regards to debris that could settle out of the flow, the exact deposition patterns will depend on the size and specific gravity of the debris. However, the flow passing through the bar screen will separate off the down-sloping wet well bottom leaving a near stagnation condition there. This will facilitate deposition of heavier particles on that section of the pump station floor. Given the present layout of the station, there is little that can be done to prevent this flow separation and the deposition observed in the model was broadly and uniformly distributed over the floor of the wet well. Therefore, no recommendations are made to alter this situation.

The issue of surge due to pump startup and shutdown is addressed in the following Appendix. The only obvious concern appears to be associated with pump shutdown. The analysis assumes a linear decrease in pump head over a specified time interval. If the pump impellers spin down in less than about two seconds, there will be a potential for cavitation in the vertical portion of the pump discharge line. The cavitation itself is not such a concern, but the subsequent pressure spikes that result from the vapor pocket collapse could potentially be a problem in this system. The pump manufacturers representatives have estimated impeller stopping times on the order of 3-6 seconds. An analysis with a linear decrease in pump head over a four second interval indicates no cavitation and it therefore appears to not be a concern for this installation. Air relief valves could be installed at the bend preceding the horizontal run of pipe on each pump discharge line to provide protection against any potential caviation phenomena.

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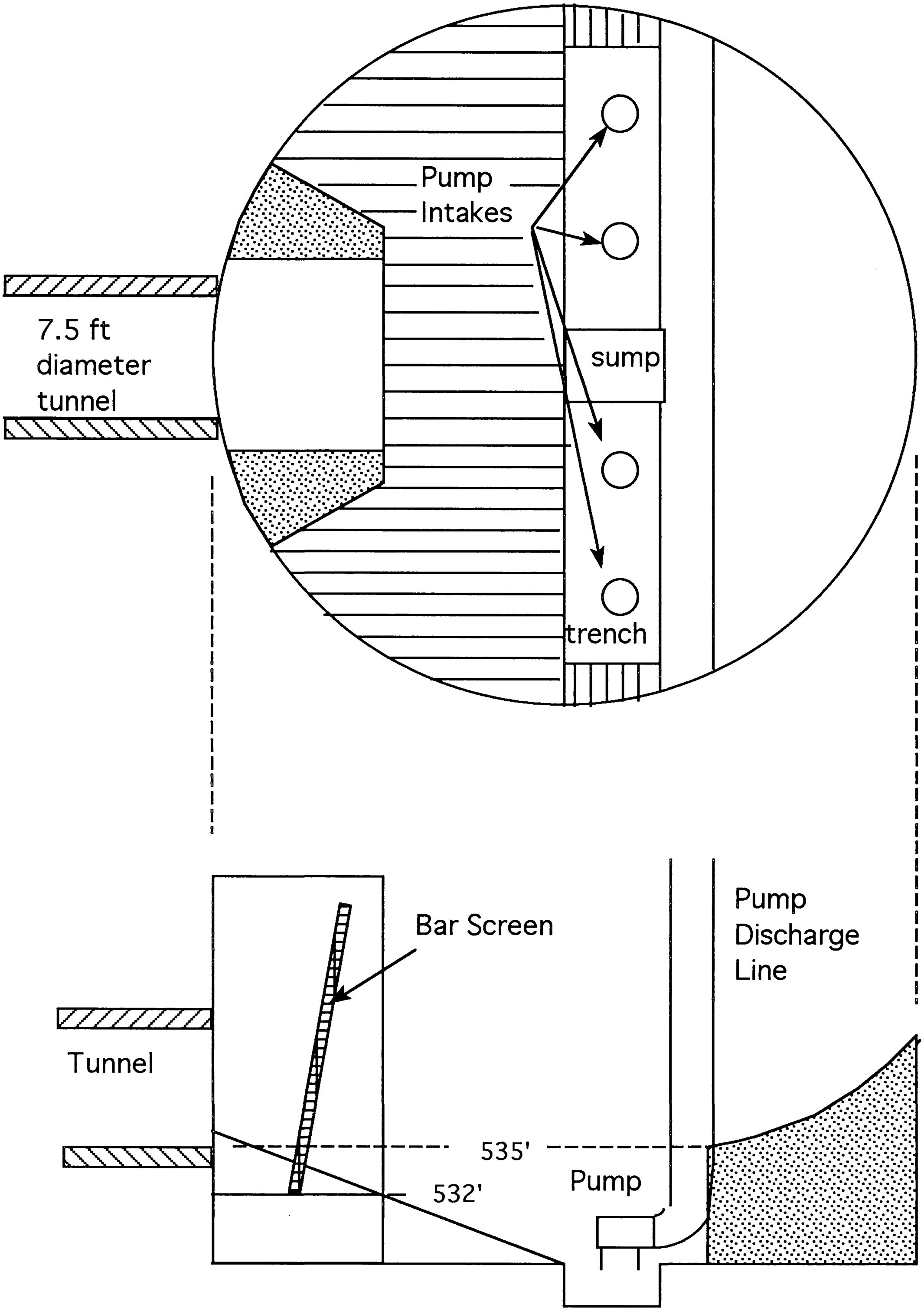


Figure 1. Plan and Cross-Sectional of Wet Well.

Figure 2a. Model Suction Bell, Without Swirl Meter.

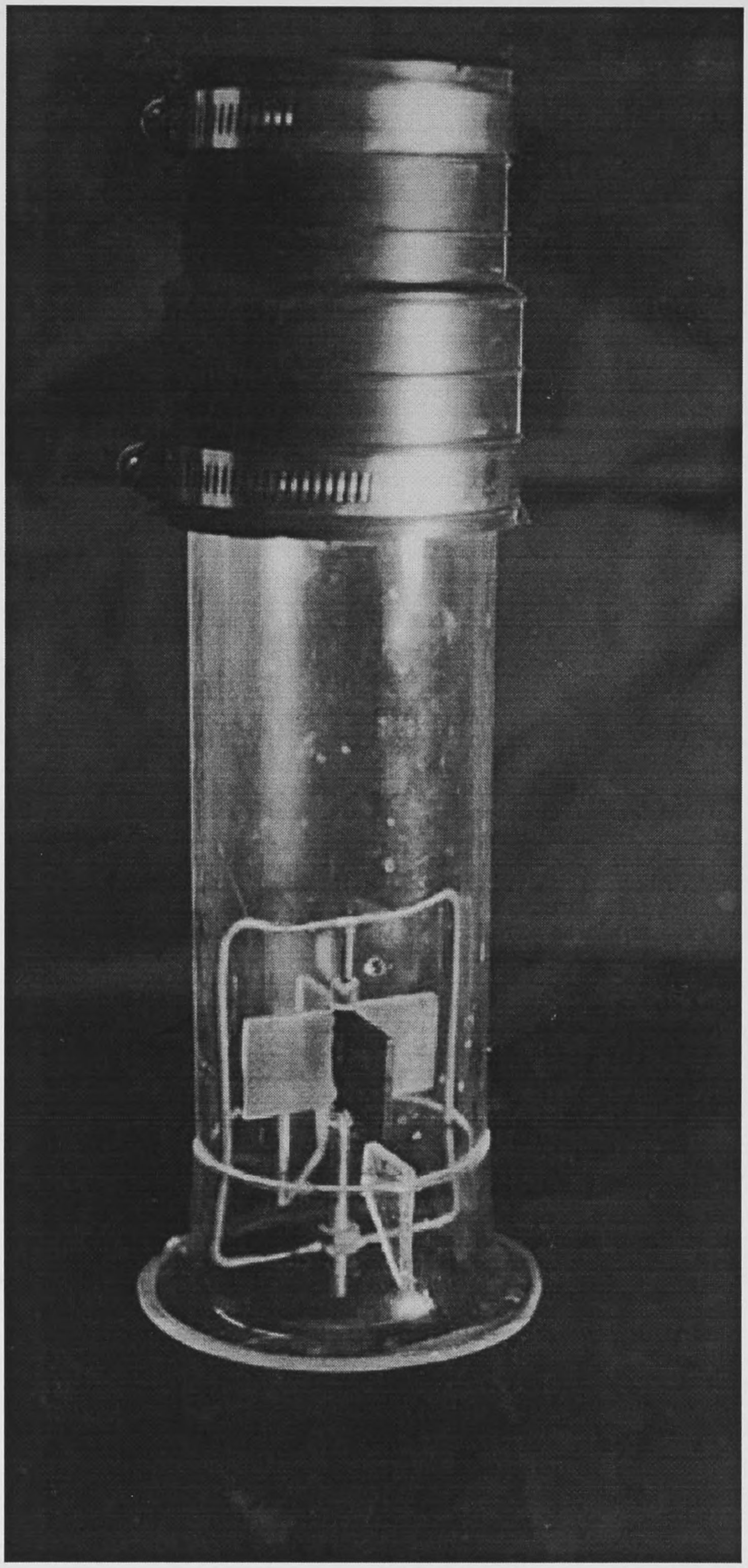


Figure 2b. Model Suction Bell, With Swirl Meter Installed.

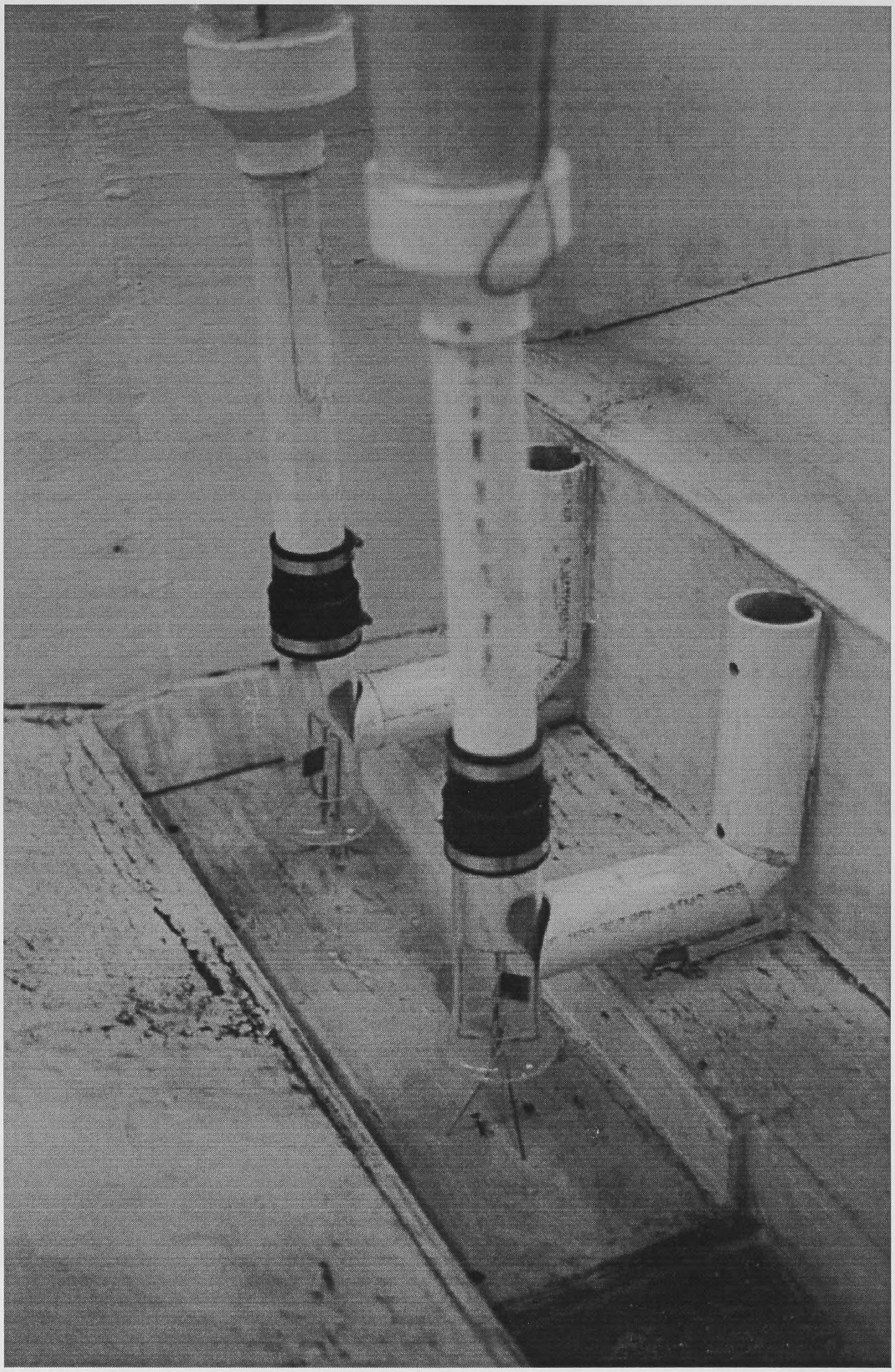


Figure 3. Model Pump Discharge Line.

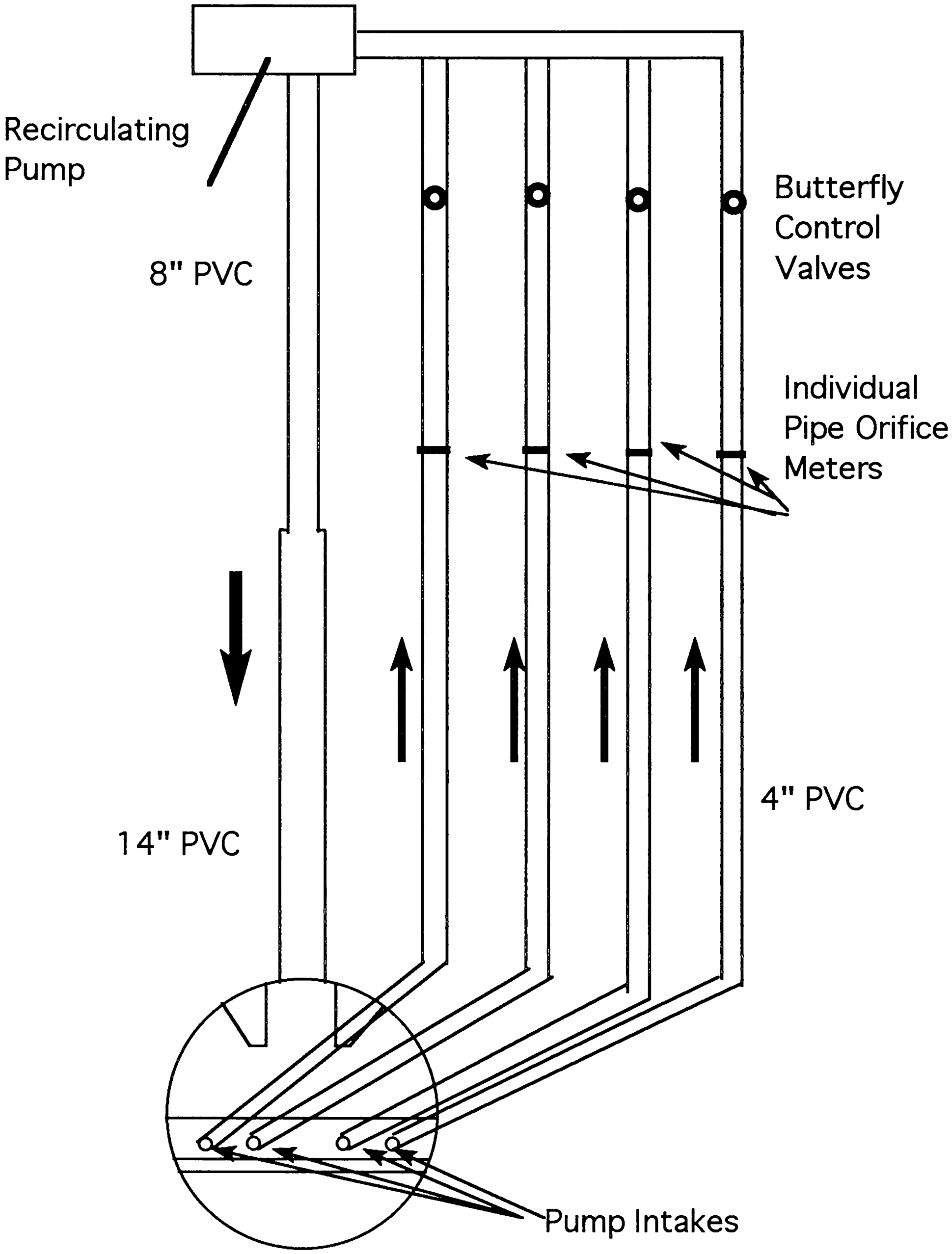


Figure 4. Plan View Schematic of Hydraulic Model.

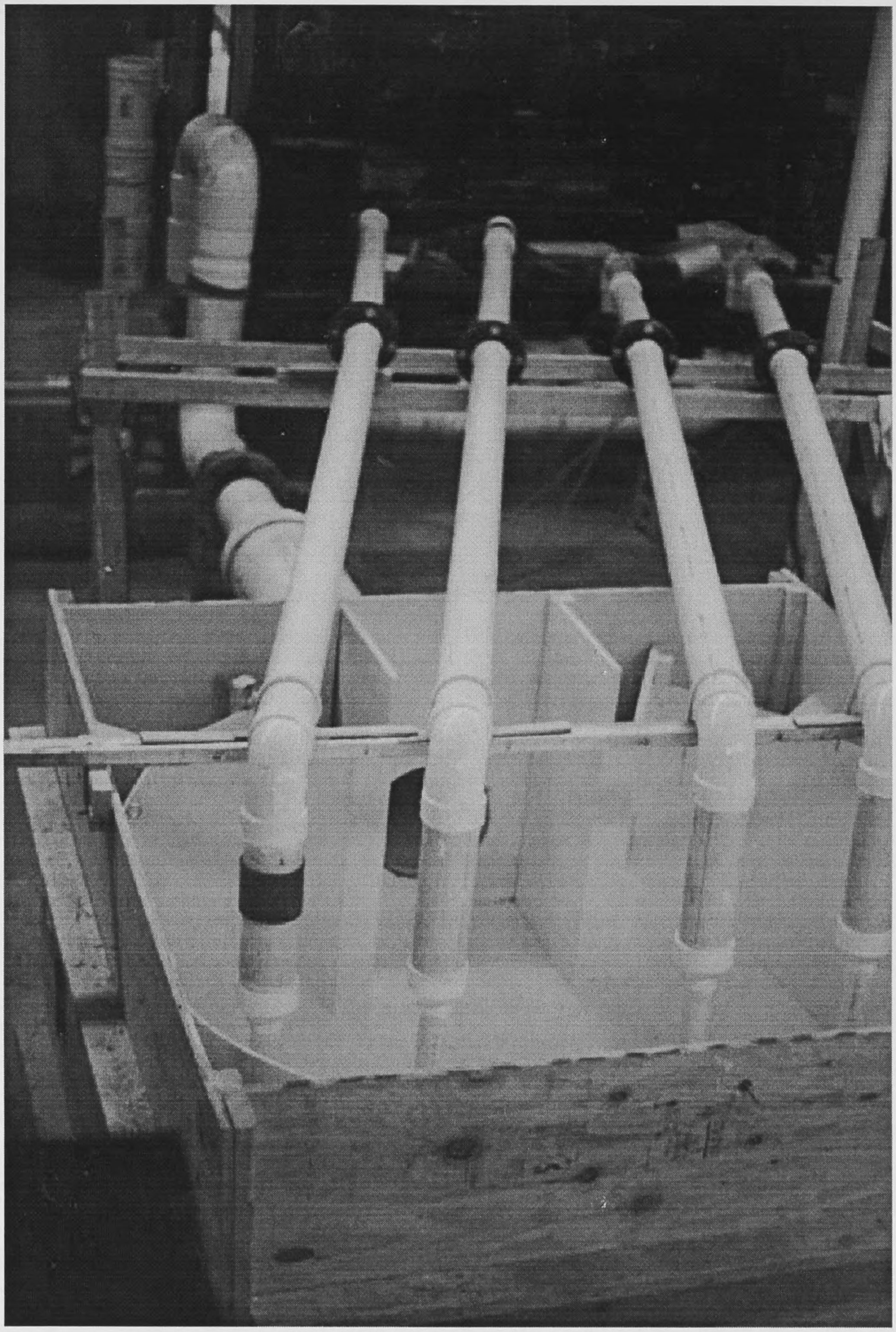


Figure 5a. Wet Well Model With Individual Pump Discharge Lines.

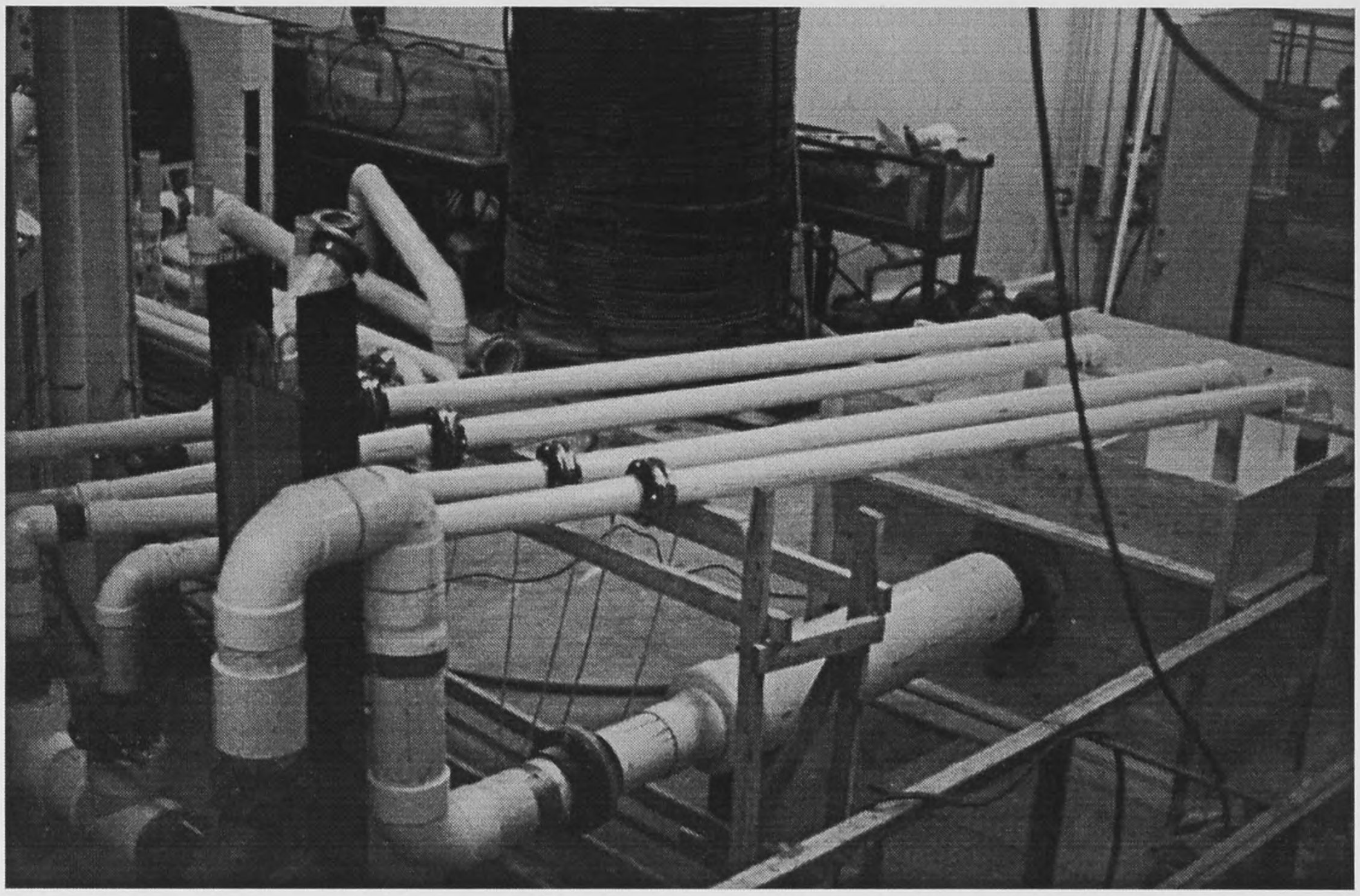


Figure 5b. Wet Well Model Showing Water Recirculation System.

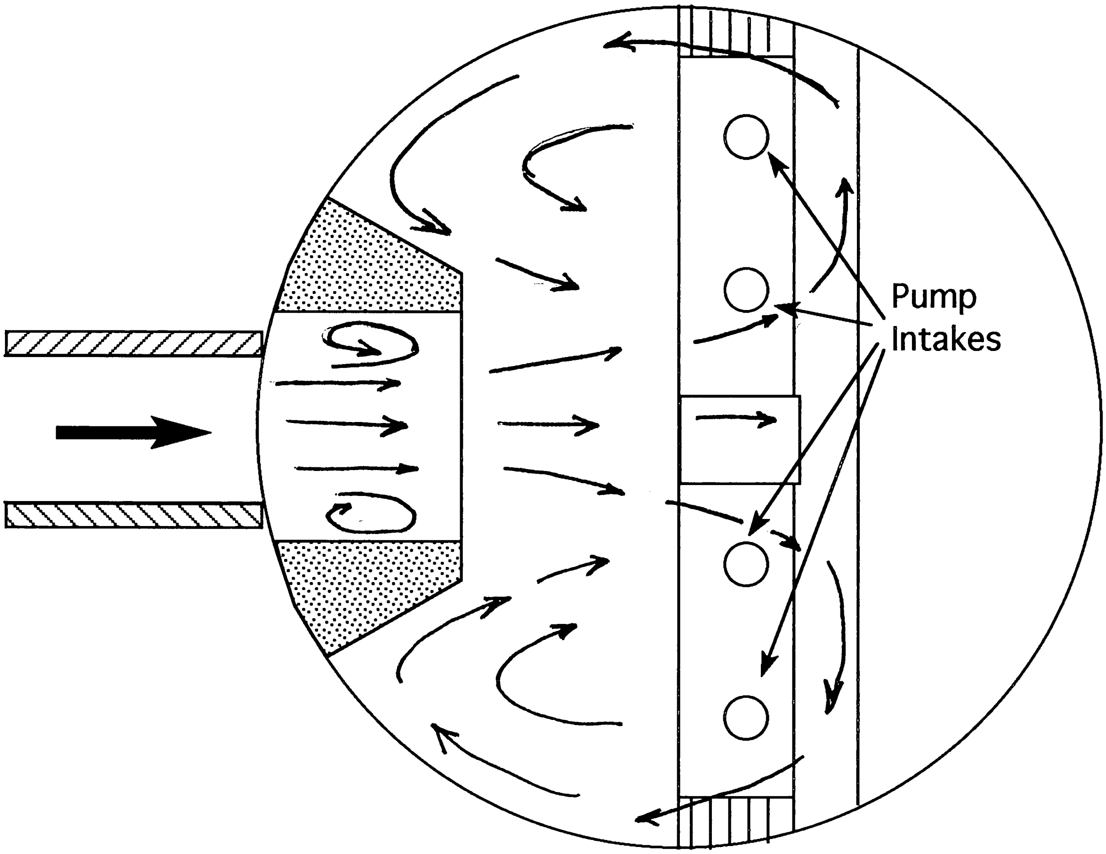


Figure 6. Surface Circulation Patterns in Wet Well.

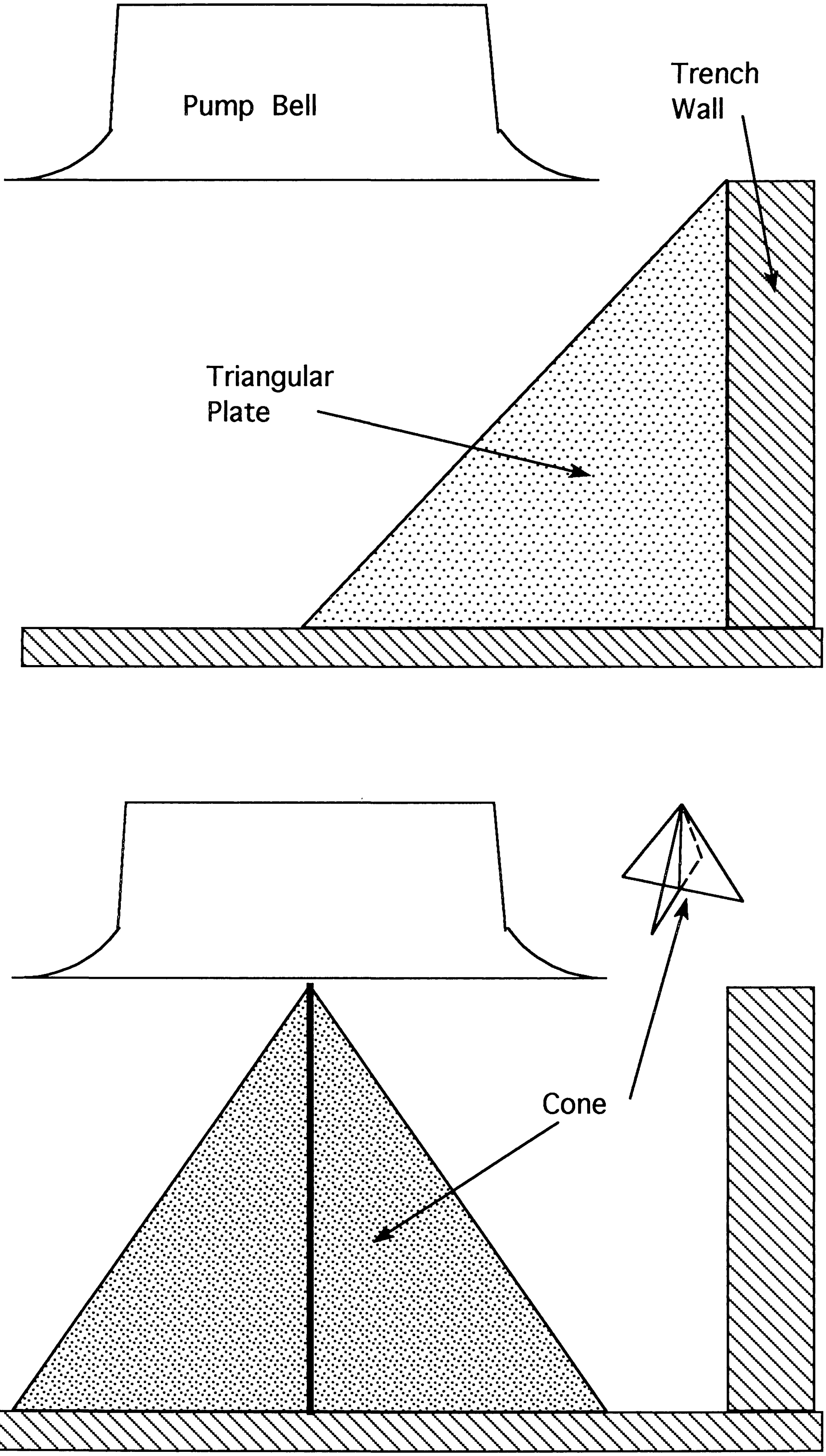


Figure 7. Flow Straighteners; a.) Triangular Plate b.) Cone.

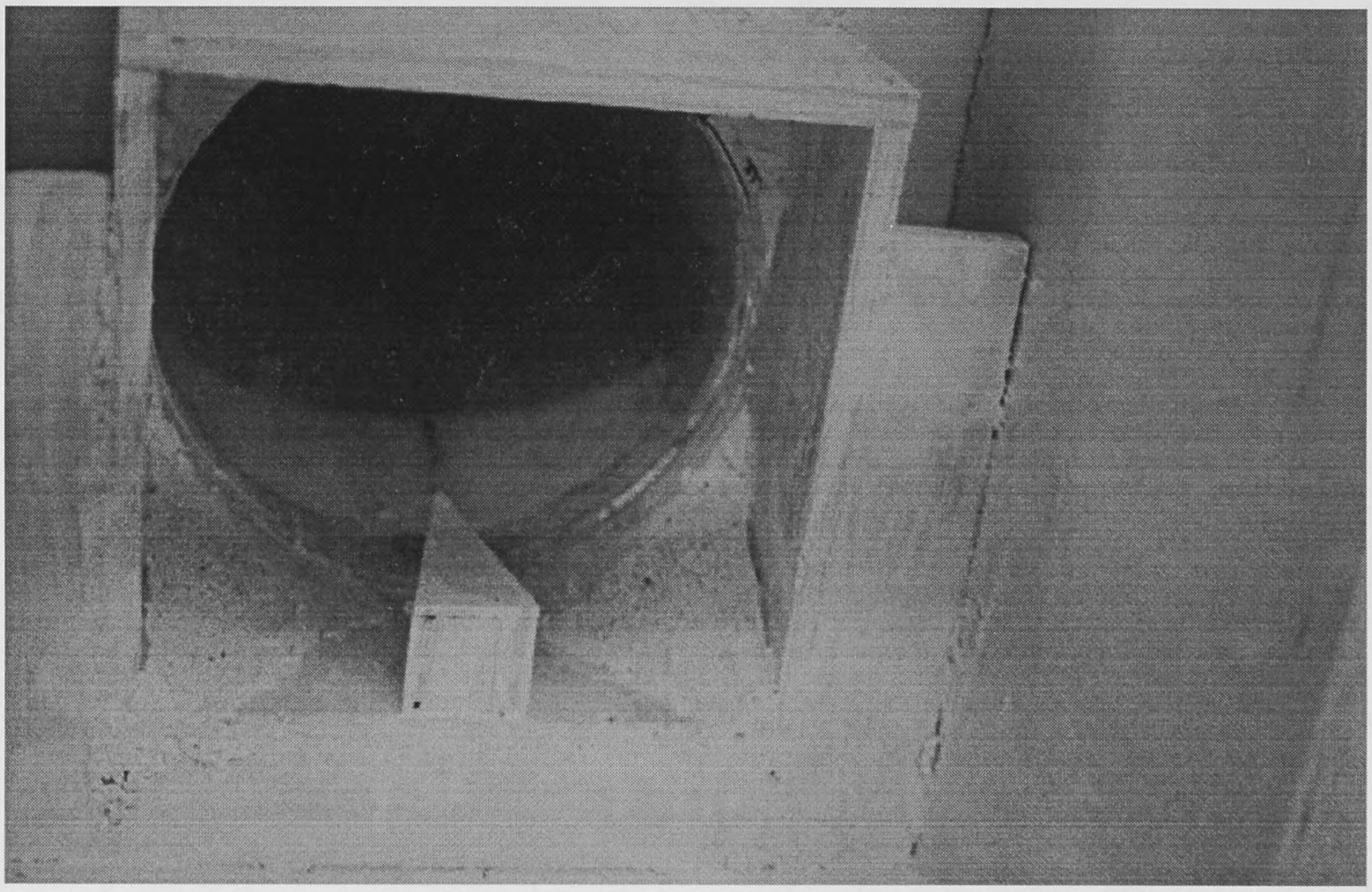


Figure 8. Flow Diverter Installed at Tunnel Exit Along with Contour Concrete.

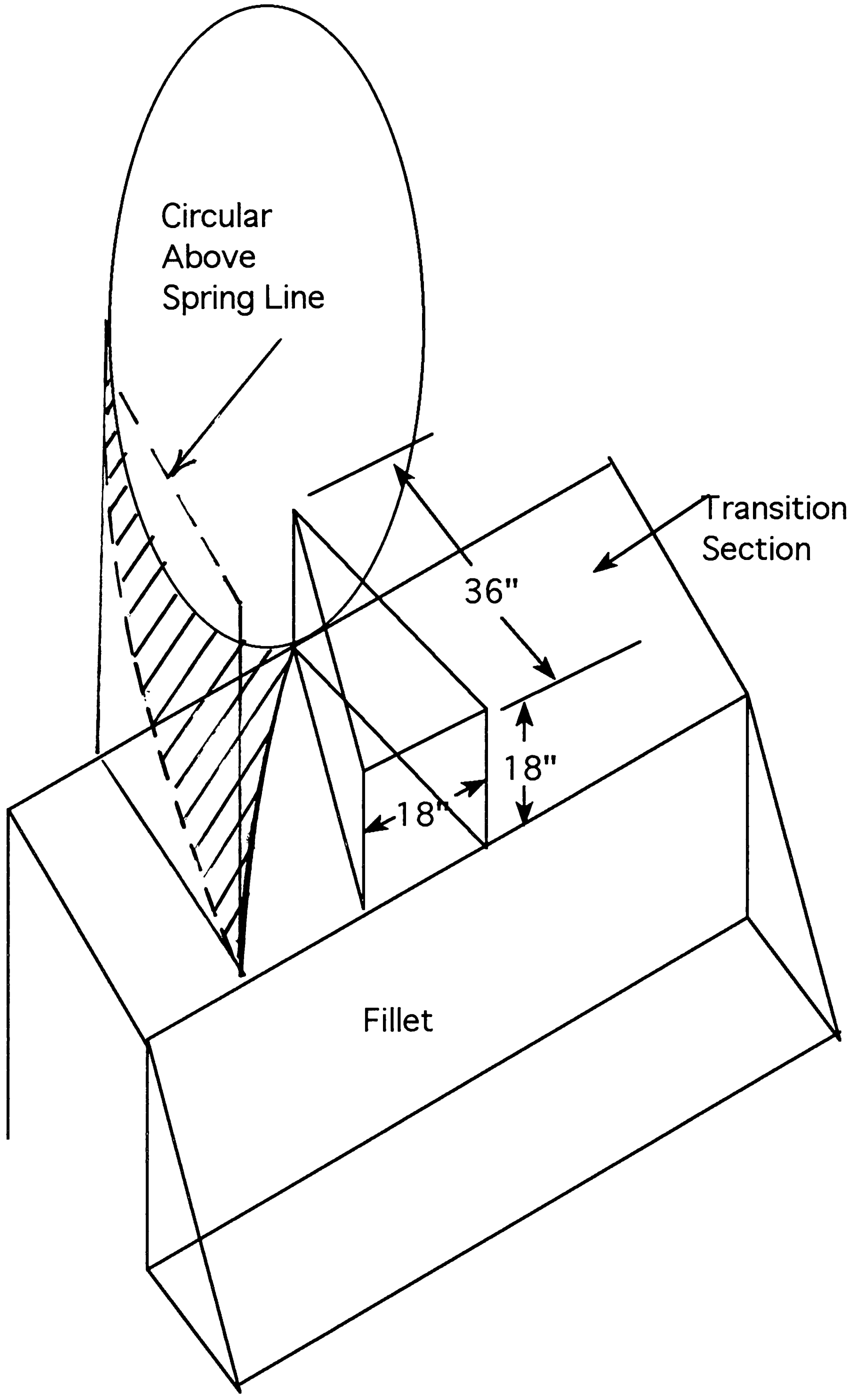


Figure 9. Flow Diverter and Contour Concrete to Diffuse Inlet Flow.

APPENDIX

Downriver Tunnel Pump Station: Analysis of Pump Startup and Shutdown

OBJECTIVE

This analysis was performed to examine the potential for surge problems within the wet well associated with pump startup and shutdown. There are a wide variety of operating conditions that could be analyzed for this purpose and an approach was taken which defined a "worst case" condition. Since all of the pumps have the same pumping capacity, they will all behave in a generally similar condition if operated at rated speed; if the variable speed pumps are starting at lower speeds, there will be less surge. In addition, the cross sectional area of the wet well is least at lower water level, exacerbating any potential for surge effects. Therefore an analysis was performed for the startup or shutdown of one of the two variable speed pumps (Pumps 2 or 3) but at their rated speed. The inflow into the wet well at a startup or shutdown condition for a single pump in operation can vary between the range 0-25 mgd. In order to separate out the surge effect, the analysis was performed considering no inflow during the pump operation. The effect of storage within the inflow tunnel was also ignored. At low wet well water levels, this is a realistic assumption since the occurrence of critical flow at the inlet to the wet well will limit the flow into the wet well and negate any tunnel storage effects. Finally, it was assumed that the pump impellers have negligible inertia, thereby allowing instantaneous startup or shutdown. This is clearly a very conservative assumption, and in the case of pump shutdown analysis leads to cavitation conditions within the pipeline. More detailed knowledge of the pump inertia would be required to assess whether or not this is a real effect.

Additional analyses were performed by assuming more realistic shutdown conditions and cavitation is not indicated if the pump spins down slowly.

METHOD OF ANALYSIS

Many fluid transient problems are analyzed using the method of characteristics. This method is derived from the unsteady momentum and continuity equations, and tracks pressure waves traveling through the fluid, with the appropriate boundary conditions applied. This method of analysis works extremely well in the case of a conduit flowing full over the entire length. However, in this particular application, the length of the water column is constantly changing during pump startup and shutdown since the outlet pipe is either filling or draining. Therefore, a wave will travel a different distance depending on the amount of water in the pipe. The method of characteristics is not easily applied in the situation of a variable length of fluid. Therefore, an alternate method must be utilized, which is possible if a few simplifying assumptions are made. These assumptions are:

1) The mass of water in the outlet pipe has a constant velocity along the entire length of pipe, instead of varying along the length as it would in the exact application of the method of characteristics.
2) The capacitance (the elasticity of the pipe and the compressibility of the fluid) is negligible in comparison to inertia.

If these assumptions are made, the liquid mass is treated as a solid, and the equation of motion is used to describe the unsteady flow behavior of this slug of water. This analysis is termed “rigid water column”, “lumped mass”, or “lumped inertia”. Since this is a one-dimensional analysis, and the forces change depending on whether the water column is in the vertical or horizontal run of pipe, the analysis will change depending on the location of the water column. Also, in order to consider the head losses at elbows, it is necessary to analyze certain regions individually. Therefore, for both startup and shutdown, the analysis is split into three distinct regimes, depending on the location of the water column front.

VALIDITY OF LUMPED MASS ANALYSIS

As mentioned above, some aspects of the analysis are inherently imprecise. These include assuming the pump is brought to speed instantaneously upon startup. However, to determine if the lumped mass assumption is valid, Streeter and Wylie (1) propose an empirical relation between the period of the excitation element to the length of the pipeline. A conservative estimate requires that the element length be about 4 percent less than the period times the wavespeed. Since the main interest of this analysis is the overall system characteristics, the period should be that of the pipeline. When assuming lumped mass, the period is given as

$$T = \frac{L\,Q}{g\,A_p\,\Delta H} \text{ seconds}$$

A typical value of this period for the discharge system is about 4 seconds. Assuming a wavespeed (represented as 'a') of 3,000 ft/sec, which is a typical value for closed conduit flow, we have

$$L < 0.04 \times T \times a \cong 0.04 \times 4 \times 3{,}000 \cong 480 \text{ ft}$$

Since L is only 164 feet for this case, it is expected that the lumped mass analysis is adequate to describe the overall system characteristics.

SYSTEM DESCRIPTION

Each of the four independent pump lines have essentially the same characteristics although there are some minor differences in piping length. Figure 1 is a schematic of the idealized piping system. The pipe diameter is approximated as a constant 2.5 ft diameter although there is actually an expansion on the downstream side of the pump. The effect of the smaller diameter pump suction entrance and pipe expansion was included in the analysis by describing an effective entrance loss consistent with the system curve provided by Hubbell, Roth & Clark for this system. The piping system rises approximately 44 ft vertically, undergoes a 90° bend (actually two 45° bends) to a horizontal run of on the order of 100 ft, undergoes another 90° bend, rises another 20 ft vertically, and undergoes a final 90° bend to a free discharge. This free discharge ensures that air at atmospheric pressure can freely exit or enter the pipe at the downstream end.

DEPTH vs. STORAGE VOLUME RELATION

To begin the analysis, a relation between depth and volume in the pump station is required. This permits the analysis of the water surface fluctuation occurring during pump startup and shutdown. Because of the somewhat complex pump station geometry, it was determined that the most direct and accurate method to find the volume was through triple integrals. The overall system was broken down into individual shapes for which the volume could be found. The volume of these shapes were found using triple integrals, and the volume of the entire system was then found by combining these geometries. Therefore, the only inaccuracies were caused by measurement precision. The volume was found for particular water surface elevations, which were then fitted with a curve. The results are as follows:

Below an elevation of 535', the volume is given as

$$\forall = (\text{WSEL} - 528.495) \times 953.9 \ \ \text{ft}^3$$

A more useful representation for later calculations is in terms of the depth above the centerline of the centrifugal pump impellers, denoted as z:

$$z = \text{WSEL} - 529.6 \text{ ft}$$

where 529.6' is the elevation of the impeller. The relation for volume now becomes

$$\forall = (z + 1.105) \times 953.9 \ \ \text{ft}^3$$

Or in terms of z,

$$z = \left(\frac{1}{953.9}\right) \times \forall - 1.105 \ \ \text{ft}$$

Above an elevation of 535', the relation is approximated by

$$\text{WSEL} = -9.0 \times 10^{-9} \forall^2 + 0.098 \forall + 529.2849$$

Or in terms of the depth,

$$z = -9.0 \times 10^{-9} \forall^2 + 0.098 \forall - 0.3151$$

It should be noted that this volume is only that in the pump station, and neglects that of the 7.5 ft diameter inflow pipeline. Although this storm sewer provides a large storage volume, it is not considered in this analysis. Therefore, the results obtained below will tend to overestimate the change in volume since the storage in the storm sewer is not taken into account.

PUMP STARTUP

As discussed previously, the equation of motion will be applied to determine the transient behavior of the pump system. For pump startup, three different conditions must be analyzed in order to account for the different forces and head losses acting on the slug of water. The analysis is subdivided as:

1) The water column in the vertical section of discharge pipe
2) The surge front moving along the horizontal length
3) The surge front in the 20' vertical section at the outlet.

1) Vertical Section

In this section of the pipe, the naming convention is as given below in Figure A-1.

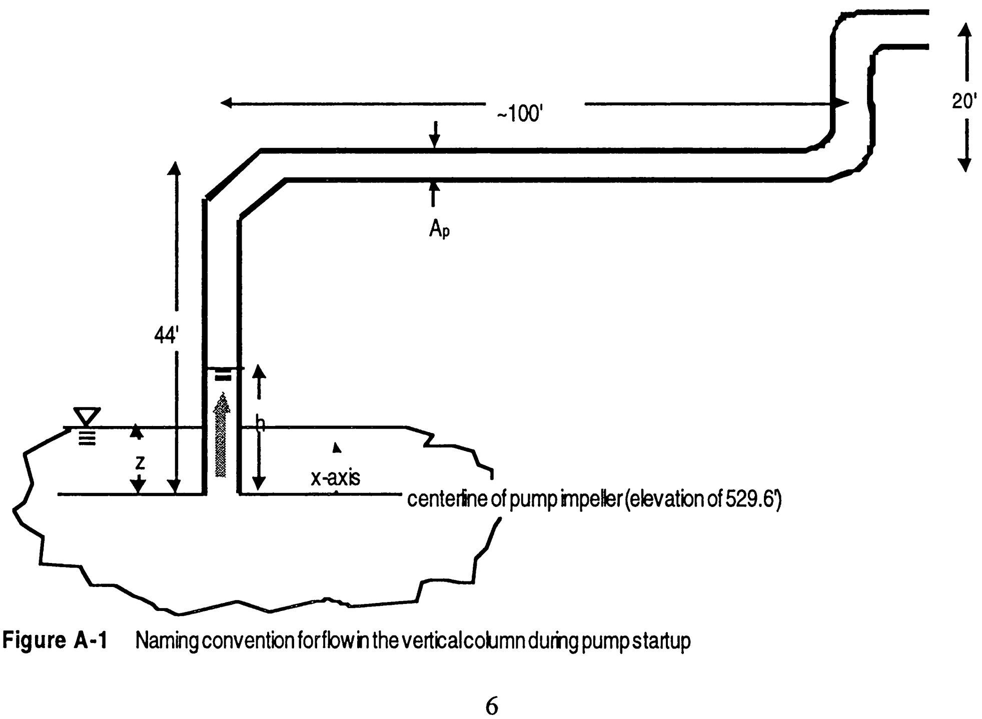


Figure A-1 Naming convention for flow in the vertical column during pump startup

The water column is strictly vertical, and the forces acting on the liquid mass are the hydrostatic pressure caused by the water depth, the head supplied by the pump, the downward acting force resulting from the mass of the water column, and the losses due to friction, the entrance, and the elbow immediately downstream of the centrifugal pump. Therefore, the equation of motion is applied as follows:

$$\sum \text{Forces} = \text{mass} \times \text{acceleration}$$

$$A_p\left[\gamma z + \gamma H_{\text{pump}} - \gamma h - \gamma\left(\frac{f\,h}{D} + k_{L\,\text{elbow}} + k_{L\,\text{entrance}}\right)\frac{Q^2}{2g\,A_p^2}\right] = \left(\frac{\gamma\,\forall_{\text{water}}}{g}\right)\times\frac{dV}{dt}$$

$$A_p\left[z + H_{\text{pump}} - h - \left(\frac{f\,h}{D} + k_{L\,\text{elbow}} + k_{L\,\text{entrance}}\right)\frac{Q^2}{2g\,A_p^2}\right] = \left(\frac{A_p\,h}{g}\right)\times\frac{dQ}{A_p\,dt}$$

$$\frac{dQ}{dt} = \left[z + H_{\text{pump}} - h - \left(\frac{f\,h}{D} + k_{L\,\text{elbow}} + k_{L\,\text{entrance}}\right)\frac{Q^2}{2g\,A_p^2}\right]\times\frac{g\,A_p}{h}$$

Euler's formula can be used to approximate the derivative:

$$Q(t) = Q_{\text{prev}} + dQ$$

$$\text{where } dQ = \left[z + H_{\text{pump}} - h - \left(\frac{f\,h}{D} + k_{L\,\text{elbow}} + k_{L\,\text{entrance}}\right)\frac{Q^2}{2g\,A_p^2}\right]\times\frac{g\,A_p}{h}\times dt$$

In general, H_{pump} is also a function of flowrate and speed since for pump startup, the steady-state operating speed has not been attained. However, for this analysis, it is assumed that the pump is brought to speed instantaneously, and it is therefore only a function of flow rate. This will provide the worst case scenario because the pump immediately begins to supply a larger head than physically occurs, thus accelerating the fluid mass with a greater force. The head supplied by the pump is therefore that for the pump operating at 875 RPM:

$$H_{pump} = \left[-0.0003\,Q^3 + 0.0014\,Q^2 - 0.5266\,Q + 102.31\right]\ \text{ft}$$

for the flow rate in cfs.

Since both z and h are also time-dependent, the equation for dQ must be solved simultaneously with the relations for these two variables. The relation for z can be found from conservation of mass as

$$\frac{d\forall_{storage}}{dt} = Q_{\text{inflow from storm sewer}} - Q$$

For this analysis, no inflow is considered, but this could easily be modified if the effects of inflow were to be investigated. Applying Euler's method to this ordinary differential equation, we have that

$$\forall(t) = \forall_{prev.} + d\forall \ \text{ where } d\forall = \left(Q_{\text{inflow from storm sewer}} - Q\right) \times dt$$

The previous relation between $\forall_{storage}$ and z can be used to find z for each time step.

The relation for h as a function of time is also a simple ODE:

$$\frac{dh}{dt} = \frac{Q}{A_p}, \text{ with } h(t) = h_{prev.} + dh$$

These three ODE's can therefore be solved simultaneously using Euler's method. The following initial conditions and constants were used when solving these equations:

Constants:		
f=	0.011	, which is assumed to be constant for all Reynolds numbers (approximately valid because the friction term is much smaller in magnitude than the other terms in the dQ equation).
$k_{L\ elbow}$ =	0.1	
$k_{L\ entrance}$ =	6.3	This is actually an equivalent loss coefficient to account for the entrance diameter being 18.5" while the diameter of the pipe is 30". A loss coefficient of 0.90 was assumed for this configuration, which becomes 6.3 when it is to be multiplied by the velocity in the larger pipe. These two loss coefficients and the friction factor seem to be appropriate in that they determine system curves which are similar to those provided by Hubbell, Roth & Clark
viscosity=	0.00003 ft^2/sec	
D=	2.5 ft	
A=	4.908 ft^2	

Initial Conditions:	
V_o=	0.0 ft/sec
Q_o=	0.0 ft^3/sec
z_o=	8.9 ft
$\forall_o$=	10,475 ft^3

The numerical results are tabulated in Appendix A, and are graphed in Appendix C as Figures A-7, A-8, and A-9. To verify that the time steps used in the Euler equations were small enough, the time steps were halved, and it is seen that the two solutions are identical. A discussion is postponed until after the following descriptions of the other flow regimes.

2) Horizontal Section

After the water column has reached a height of 44', it flows horizontally. To account for this, the analysis proceeds as before, but the additional loss at the elbow must be considered. The naming convention is given below in Figure A-2.

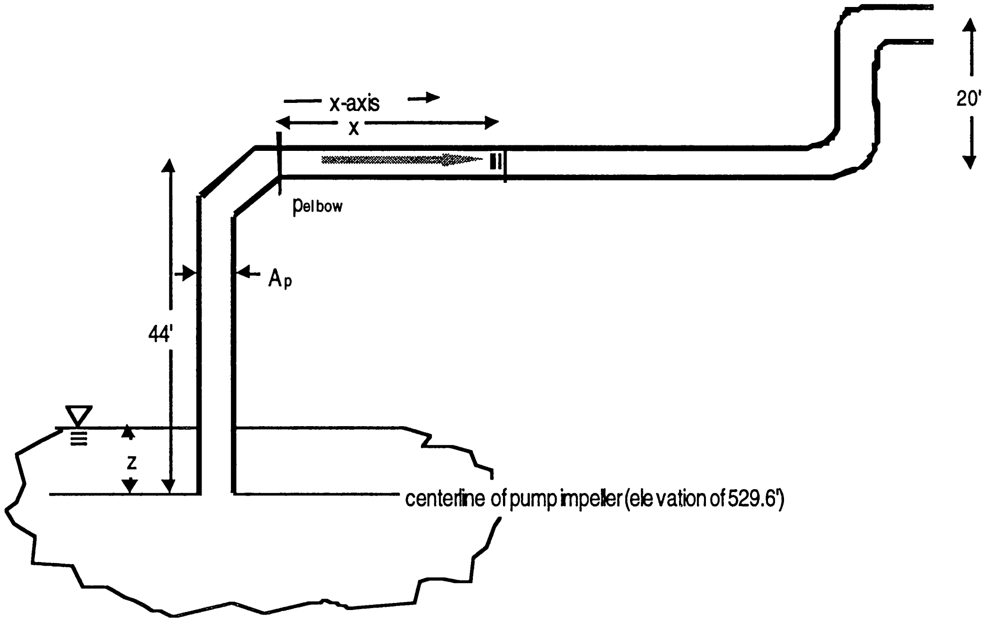


Figure A-2 Naming convention for flow in the horizontal length during pump startup

For this scenario, the equation of motion becomes

$$A_p\left[p_{elbow} - \gamma\left(\frac{f\,x}{D}\right)\frac{Q^2}{2g\,A_p^{\,2}}\right] = \left(\frac{\gamma A_p\,(44 + x)}{g}\right)\times\frac{dQ}{A_p\,dt}$$

$$\text{where } p_{elbow} = \gamma\left[z - 44 + H_{pump} - h - \left(\frac{44\,f}{D} + 2k_{L\,elbow} + k_{L\,entrance}\right)\frac{Q^2}{2g\,A_p^2} - \frac{V^2}{2g}\right]$$

Solving for dQ:

$$dQ = \left[\frac{p_{elbow}}{\gamma} - \left(\frac{f\,x}{D}\right)\frac{Q^2}{2g\,A_p{}^2}\right] \times \frac{g\,A_p}{(44 + x)} \times dt$$

$$\text{with } \frac{p_{elbow}}{\gamma} = \left[z - 44 + H_{pump} - h - \left(\frac{44\,f}{D} + 2k_{L\,elbow} + k_{L\,entrance}\right)\frac{Q^2}{2g\,A_p^2} - \frac{Q^2}{2g\,A_p^2}\right]$$

The additional relations are again

$$\forall(t) = \forall_{prev.} + d\forall \text{ where } d\forall = \left(Q_{\text{inflow from storm sewer}} - Q\right) \times dt$$

and

$$x(t) = x_{prev.} + dx \text{ where } dx = \frac{Q}{A_p} \times dt$$

The initial conditions for this portion of the analysis come from the analysis of the vertical section of the pipe when the column has attained a height of 44 feet. These values are given as:

Initial Conditions:	
t_o=	3.205 sec
Q_o=	49.02 ft^3/sec
V_o=	9.986 ft/sec
z_o=	8.77 ft
$\forall_o$=	10302.71 ft^3

The results are also given in Figures A-7, A-8, and A-9, with the numerical results again in Appendix A.

3) Vertical Section at Outlet

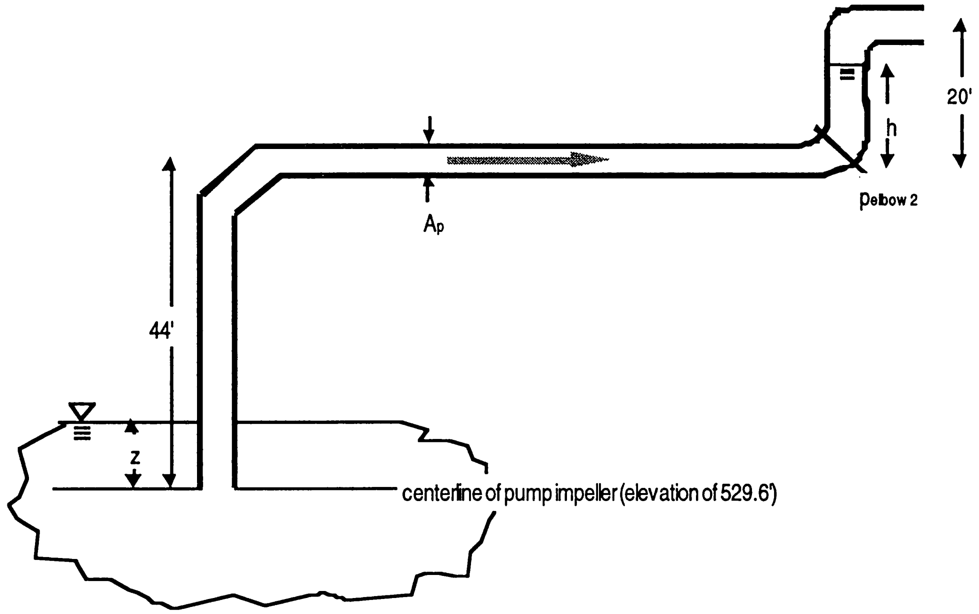


Figure A-3. Naming convention for flow in the 20' vertical section during pump startup

Again, the analysis proceeds as before, with the system as sketched above in Figure A-3. In this case, the equations and initial conditions are:

$$dQ = \left[\frac{p_{\text{elbow 2}}}{\gamma} - h - \left(\frac{f\,h}{D}\right)\frac{Q^2}{2g\,A_p^{\,2}}\right] \times \frac{g\,A_p}{(44 + 100 + h)} \times dt$$

$$\text{with } \frac{p_{\text{elbow 2}}}{\gamma} = \left[z - 44 + H_{\text{pump}} - \left(\frac{(44+100)\,f}{D} + 3k_{L\,\text{elbow}} + k_{L\,\text{entrance}}\right)\frac{Q^2}{2g\,A_p^2} - \frac{Q^2}{2g\,A_p^2}\right]$$

$$d\forall = \left(Q_{\text{inflow from storm sewer}} - Q\right) \times dt$$

$$dh = \frac{Q}{A_p} \times dt$$

Initial Conditions	
$t_o =$	13.445 sec
$Q_o =$	47.80 ft^3/sec
$V_o =$	9.738 ft/sec
$z_o =$	8.39 ft
$\forall_o =$	9811.38 ft^3

PUMP SHUTDOWN

Again, a rigid water column analysis is performed for the case of pump shutdown. Here, the problem must be divided into four distinct analyses. These include:

1) Time required for the column of fluid to come to rest
2) Reverse flow through the 20' vertical section of pipe
3) Reverse flow through the horizontal reach of pipe
4) Reverse flow through the 44' vertical section of pipe

Preliminary analysis assuming an instantaneous pump spin down indicated severe cavitation conditions within the pipeline. Consequently, it was assumed that the pump will retain some inertia at the time of shutdown. In order to account for this without knowing the extensive pump characteristics, it was assumed that the head supplied by the pump will decay linearly with time. For this case, it was assumed that the head will fall from the steady state operating point (66 feet) to zero in 1.5 seconds.

Furthermore, it is assumed that when reverse flow does occur through the pump, the pump turbines with no losses.

The analysis is as follows.

1) Time Required for the Column of Fluid to Come to Rest

This analysis determines the flow characteristics until the fluid has come to rest in the forward direction, up until just prior to flow reversal. The equations used are identical to those used in part 4 of the previous section, but the initial conditions change. To solve this portion of the flow, we have:

$$dQ = \left[\frac{p_{\text{elbow 2}}}{\gamma} - 20 - \left(\frac{20\,f}{D} + k_{\text{L elbow}} \right) \frac{Q^2}{2g\,A_p{}^2} \right] \times \frac{g\,A_p}{(44+100+20)} \times dt$$

$$\text{with } \frac{p_{\text{elbow 2}}}{\gamma} = \left[z - 44 + H_{\text{pump}} - \left(\frac{(44+100)\,f}{D} + 3k_{\text{L elbow}} + k_{\text{L entrance}} \right) \frac{Q^2}{2g\,A_p^2} - \frac{Q^2}{2g\,A_p^2} \right]$$

$$d\forall = \left(Q_{\text{inflow from storm sewer}} - Q \right) \times dt\,, \text{ Assume that } Q_{\text{inflow}} = 0.0$$

$$dh = 0.0$$

$$H_{\text{pump}} = 66.0 - \frac{t \times 66.0}{t_{\text{shutdown}}} \quad \text{where } t_{\text{shutdown}} = 1.5 \text{ seconds (assumed)}$$

Initial Conditions	
$t_o =$	0.0 sec
$Q_o =$	38.77 ft^3/sec
$V_o =$	7.898 ft/sec
$z_o =$	5.4 ft
$\forall_o =$	6205 ft^3

2) Reverse Flow Through the 20' Vertical Section of Pipe

This portion of the analysis accounts for when reverse flow begins to occur. It is assumed that the pump turbines with no losses once water flows through it backwards. In deriving the following equations, the flow rate is taken to be positive when it flows into the pump station. The naming convention is given in Figure A-4.

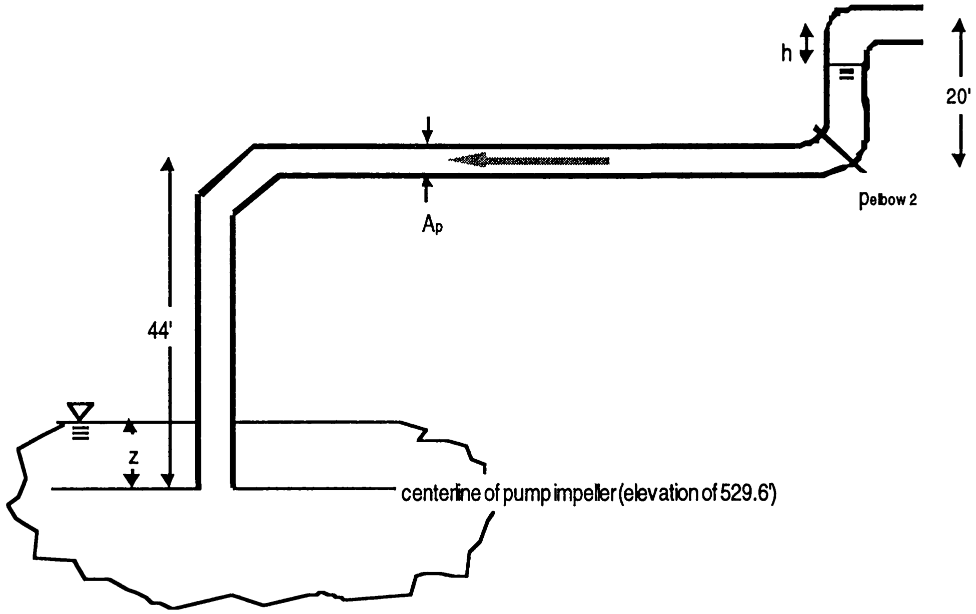


Figure A-4. Naming convention for flow in the 20' vertical section during pump shutdown

The governing equations are therefore

$$dQ = \left[(20-h) - \frac{p_{\text{elbow 2}}}{\gamma} - \left(\frac{(20-h)\,f}{D} + k_{\text{L elbow}} \right) \frac{Q^2}{2g\,A_p{}^2} \right] \times \frac{g\,A_p}{\left(44 + 100 + (20-h)\right)} \times dt$$

$$\text{with } \frac{p_{\text{elbow 2}}}{\gamma} = \left[z - 44 + H_{\text{pump}} - \left(\frac{(44+100)\,f}{D} + 3k_{\text{L elbow}} + k_{\text{L entrance}} \right) \frac{Q^2}{2g\,A_p^2} - \frac{Q^2}{2g\,A_p^2} \right]$$

$$d\forall = \left(Q_{\text{inflow from storm sewer}} + Q\right) \times dt, \text{ Assume that } Q_{\text{inflow}} = 0.0$$

$$dh = \frac{Q}{A_p} \times dt$$

$$H_{\text{pump}} = 66.0 - \frac{t \times 66.0}{t_{\text{shutdown}}} \quad \text{for } t < t_{\text{shutdown}}$$

$$H_{\text{pump}} = 0.0 \qquad \text{for } t > t_{\text{shutdown}}$$

The following initial conditions are used:

Initial Conditions	
t_o =	1.43 sec
Q_o=	0.0 ft^3/sec
V_o=	0.0 ft/sec
z_o=	5.36 ft
$\forall_o$=	6168.38 ft^3

3) Reverse flow through the horizontal reach of pipe

Again, Q is positive entering the pump station, and the naming convention is provided in Figure A-5.

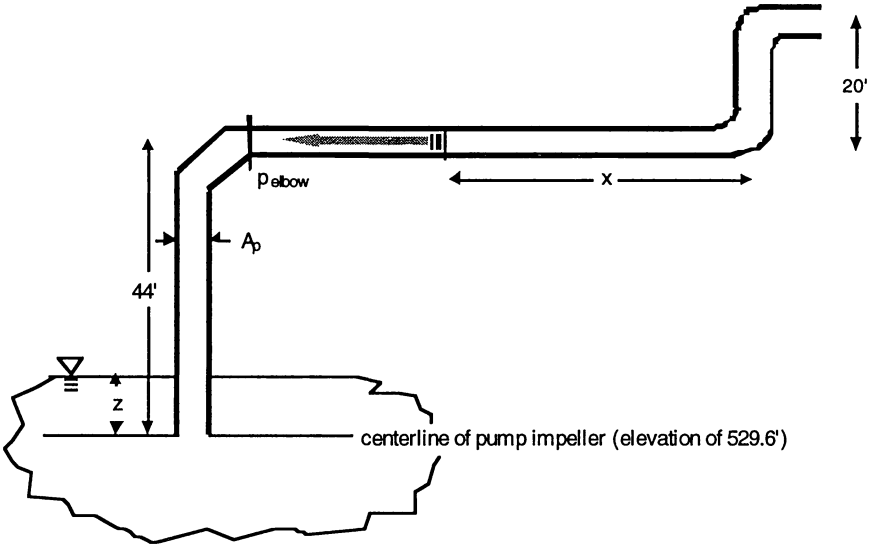


Figure A-5. Naming convention for reverse flow in the horizontal length during pump shutdown

With this nomenclature, the equations to be solved simultaneously are

$$dQ = \left[0 - \frac{p_{\text{elbow}}}{\gamma} - \left(\frac{(100-x)\, f}{D} \right) \frac{Q^2}{2g\, A_p^{\,2}} \right] \times \frac{g\, A_p}{\left(44 + (100-x)\right)} \times dt$$

$$\text{with } \frac{p_{\text{elbow}}}{\gamma} = \left[z - 44 + H_{\text{pump}} - \left(\frac{(44)\, f}{D} + 2k_{L\,\text{elbow}} + k_{L\,\text{entrance}} \right) \frac{Q^2}{2g\, A_p^2} - \frac{Q^2}{2g\, A_p^2} \right]$$

$$d\forall = \left(Q_{\text{inflow from storm sewer}} + Q\right) \times dt\,, \text{ Assume that } Q_{\text{inflow}} = 0.0$$

$$dh = \frac{Q}{A_p} \times dt$$

$$H_{\text{pump}} = 66.0 - \frac{t \times 66.0}{t_{\text{shutdown}}} \quad \text{for } t < t_{\text{shutdown}}$$

$$H_{\text{pump}} = 0.0 \qquad \text{for } t > t_{\text{shutdown}}$$

The initial conditions are:

Initial Conditions	
$t_o =$	3.48 sec
$Q_o =$	80.85 ft^3/sec
$V_o =$	16.47 ft/sec
$z_o =$	5.45 ft
$\forall_o =$	6266.6 ft^3

4) Reverse flow through the 44' vertical section of pipe

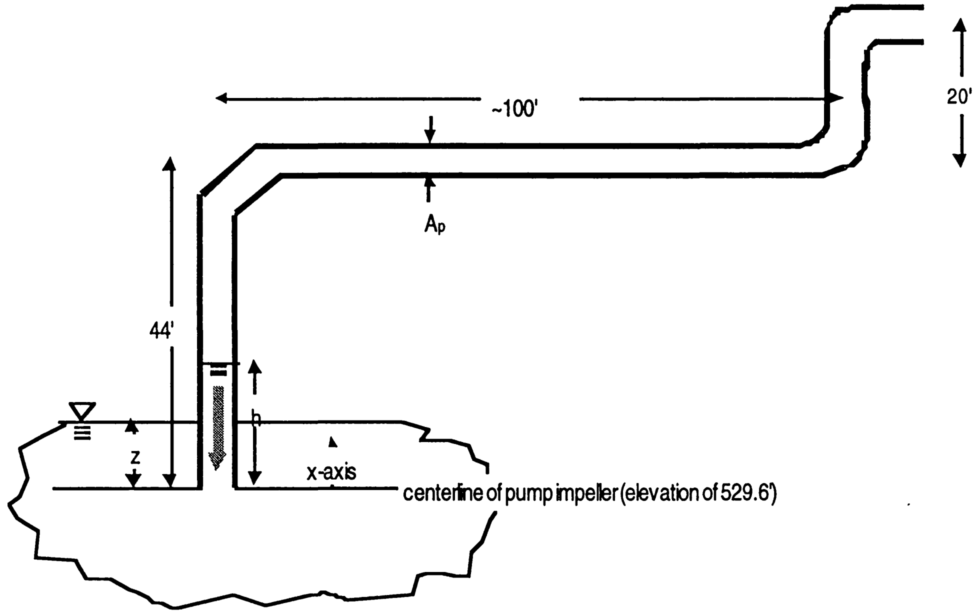


Figure A-6 Naming convention for reverse flow in the 44' vertical column during pump shutdown

The governing equations and initial conditions are:

$$dQ = \left[44 - h - z - H_{pump} - \left(\frac{(44-h)\,f}{D}\right)\frac{Q^2}{2g\,A_p^{\;2}} + k_{L\,elbow} + k_{L\,entrance}\right] \times \frac{g\,A_p}{(44-h)} \times dt$$

$$d\forall = \left(Q_{\text{inflow from storm sewer}} + Q\right) \times dt\,,\ \text{Assume that } Q_{inflow} = 0.0$$

$$dh = \frac{Q}{A_p} \times dt$$

$$H_{pump} = 0.0$$

Initial Conditions	
t_o =	8.6 sec
Q_o=	101.58 ft^3/sec
V_o=	20.69 ft/sec
z_o=	5.87 ft
$\forall_o$=	6758.2 ft^3

The numerical results of the above analyses are presented in Appendix B and the pipe discharge, the pressure head at the bend preceding the horizontal run of pipe, and the wet well water surface elevation are presented in Figures A-10, A-11 and A-12, respectively. Although the surge within the wet well is seen to be small, the pressure head at the bend is computed to drop below the vapor pressure of the fluid. Under these circumstances, a vapor cavity would form at the bend and grow until the fluid is brought to rest and reverses direction. Upon flow reversal, the vapor cavity collapse would result in a pressure spike that could be sufficient to cause system damage. This process was not simulated in the analysis presented as the fluid pressure was allowed to decrease below vapor pressure which is not physically realistic.

As a side note, the area under the curve in Figure A-10 represents the volume of fluid flowing in the reverse direction. Since there is no source of water at the downstream end, this volume should be expected to be equal to the amount of possible storage in the discharge pipe. In fact, these two volumes do end up being approximately the same. Although the lumped mass analysis does not explicitly account for the total discharge volume, it provides the correct volume. This seems to further validate the lumped mass analysis

The results presented above are very sensitive to the assumed conditions on the pump spin down. A preliminary analysis which assumed instantaneous pump shutdown indicated even more severe cavitation. Pump manufacturer representatives were consulted for estimates of the stopping time for pumps that could be used in this pump station. Estimated stopping times ranged from three to six seconds. A second analysis was performed under the assumption of a linear decrease in pump head over a four second interval. The results of this analysis are presented in Figures A-13 and A-14. Under these circumstances, cavitation is not predicted to occur and no problems associated with pump shutdown are expected. Therefore, any potential problems with system cavitation are dependent on the pump impeller inertia, but given the projected pump characteristics, cavitation does not appear to be a problem.

RESULTS AND CONCLUSIONS

Pump Startup

Using the lumped mass analysis, it is seen that the system tends to run out on the pump curve at a very early time. The discharge increases to about 59 cfs and the pump head decreases to about 15 feet at a time of only about 0.1 seconds. However, these values should be viewed with caution since although the pump was assumed to be operating at full speed instantaneously, this is not the case. In particular, at a time of only 0.1 seconds, it is most likely operating at a speed much smaller than the steady state speed. Therefore, the system will be limited to a smaller flow rate than that actually calculated, although the pump head will still tend to become very small. This will still occur because the system will still tend to run out on the pump curve, but the pump curve will be smaller for smaller rotational speeds.

Also, it is predicted that the column of fluid fills the vertical section of pipe in about 3.2 seconds. During this time, the flow rate has begun to gradually decrease towards the steady state value, whereas the pump head has begun to increase towards the operating point. The WSEL has decreased very little during this time, since this is such a short period.

It is predicted that the surge front will travel the horizontal distance of 100 feet in about 13.5 seconds, with a gradual increase in the pump head and decrease in the flow rate toward the operating point. The velocity of the water column through the pipeline is approximately 10 ft/s during this interval, which is higher than the steady state velocity. This will therefore result in larger forces on the pipe bends than indicated by a steady state analysis. It is understood that the pipe bend at the downstream end of the horizontal section is embedded in concrete and this would be adequate to avoid problems with these excess forces.

This analysis calculates that the time to fill the 20' vertical section is 15.5 seconds. Again, during this time, the flow rate is reduced and the pump head is increased.

Pump Shutdown

For pump shutdown, it was initially assumed that the head supplied by the pump decayed linearly to zero in 1.5 seconds. In general, the complete pump characteristics are necessary to solve a transient problem involving a turbomachine. Assuming this linear decay of pump head, the water column is expected to stop flowing in the forward direction after about 1.4 seconds. During this time, the pressure head at the elbow at the start of the horizontal length of pipe decreases drastically. It falls from a steady state head of 20 ft, down to below vapor pressure. Since this analysis does not account for the formation of a vapor cavity, the analysis becomes flawed after this occurs. After consultation with pump manufacturer's representatives, it was estimated that a longer spin down time would be more appropriate. A simulation with a four second interval for a linear decay of pump head indicated no cavitation. Therefore, this occurrence would not appear to be a concern for the pump station operation. A low cost solution to absolutely avoid any potential for pipeline cavitation would be to install air relief valves at the bends preceding the horizontal run of each pump discharge line. These relief valves would admit sufficient air to minimize the sudden pressure drops associated with the pump shutdown. Since the discharge pipes drain completely after pump stoppage, no special design considerations would be required to avoid potential problems associated with expelling air from the pipeline on subsequent pump startup, so this would be a straightforward design modification.

Neither analysis for pump startup or shutdown indicated significant surges within the wet well. It is concluded that this combination of system geometry and pumps will not result in significant wet well surging.

REFERENCE

(1) V.L. Streeter and E.B. Wylie, *Hydraulic Transients*, Prentice-Hall, New Jersey, 1993.

Appendix A

Pump Startup Calculations

PUMP STARTUP

NOTE: Only the original dt time steps are shown here. These time steps were halved to determine that the original size were adequate to apply Euler's method, but are not shown here due to the repetitiveness.

g= 32.17 ft/sec^2
f= 0.011 (assume constant for all Re)
k= 0.00015
k_{Lelbow} = 0.1
$k_{Lentrance}$ = 6.3
viscosity= 0.00003 ft^2/sec
D= 2.5 ft
A= 4.908738521 ft^2
H_{pump}= [$-0.0003Q^3 + 0.0014Q^2 - 0.5266Q + 102.31$] ft, for Q in cfs

V_o= 0 ft/sec
Q_o= 0 ft^3/sec
z_o= 8.9 ft (pump starts at WSEL of 538.5 ft)
$Ꝟ_o$= 10475 ft^3

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(z + Hpump - h - (f*h/D + kLelbow + kLentrance) * Q^2/(2g\ A^2)) * A * (g/h) * dt$
$h(t)=h_{prev.} + dh$ $dh=(Q/A)*dt$
$Ꝟ(t)=Ꝟ_{prev.} + dꝞ$ $dꝞ=(Q_{inflow}-Q)*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)
$z(t) = -9.5E\text{-}09Ꝟ^2 + 0.00098Ꝟ - 0.3151$

t (sec)	Q (cfs)	h (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	dQ	dh	dꝞ
0	0.00	8.90	10475.00	8.90	538.50	102.3	1.815	0.0000	0.000
0.001	1.82	8.90	10475.00	8.91	538.51	101.4	1.798	0.0004	-0.002
0.002	3.61	8.90	10475.00	8.91	538.51	100.4	1.781	0.0007	-0.004
0.003	5.39	8.90	10474.99	8.91	538.51	99.5	1.763	0.0011	-0.005
0.004	7.16	8.90	10474.99	8.91	538.51	98.5	1.744	0.0015	-0.007
0.005	8.90	8.90	10474.98	8.91	538.51	97.5	1.724	0.0018	-0.009
0.006	10.62	8.91	10474.97	8.91	538.51	96.5	1.703	0.0022	-0.011
0.007	12.33	8.91	10474.96	8.91	538.51	95.5	1.681	0.0025	-0.012
0.008	14.01	8.91	10474.95	8.91	538.51	94.4	1.658	0.0029	-0.014
0.009	15.67	8.91	10474.94	8.91	538.51	93.2	1.634	0.0032	-0.016
0.01	17.30	8.92	10474.92	8.91	538.51	92.1	1.608	0.0035	-0.017
0.011	18.91	8.92	10474.90	8.91	538.51	90.8	1.581	0.0039	-0.019
0.012	20.49	8.92	10474.88	8.91	538.51	89.5	1.553	0.0042	-0.020
0.013	22.04	8.93	10474.86	8.91	538.51	88.2	1.523	0.0045	-0.022
0.014	23.57	8.93	10474.84	8.91	538.51	86.7	1.492	0.0048	-0.024
0.015	25.06	8.94	10474.82	8.91	538.51	85.3	1.460	0.0051	-0.025
0.016	26.52	8.94	10474.79	8.91	538.51	83.7	1.427	0.0054	-0.027
0.017	27.95	8.95	10474.77	8.91	538.51	82.1	1.392	0.0057	-0.028
0.018	29.34	8.95	10474.74	8.91	538.51	80.5	1.356	0.0060	-0.029
0.019	30.69	8.96	10474.71	8.91	538.51	78.8	1.319	0.0063	-0.031
0.02	32.01	8.97	10474.68	8.91	538.51	77.0	1.281	0.0065	-0.032
0.021	33.29	8.97	10474.65	8.91	538.51	75.3	1.242	0.0068	-0.033
0.022	34.54	8.98	10474.61	8.91	538.51	73.4	1.203	0.0070	-0.035
0.023	35.74	8.99	10474.58	8.91	538.51	71.6	1.163	0.0073	-0.036
0.024	36.90	8.99	10474.54	8.91	538.51	69.7	1.123	0.0075	-0.037
0.025	38.03	9.00	10474.51	8.91	538.51	67.8	1.083	0.0077	-0.038
0.026	39.11	9.01	10474.47	8.91	538.51	65.9	1.042	0.0080	-0.039
0.027	40.15	9.02	10474.43	8.91	538.51	64.0	1.002	0.0082	-0.040
0.028	41.15	9.02	10474.39	8.91	538.51	62.1	0.962	0.0084	-0.041
0.029	42.11	9.03	10474.35	8.91	538.51	60.2	0.922	0.0086	-0.042
0.03	43.04	9.04	10474.31	8.91	538.51	58.3	0.882	0.0088	-0.043
0.031	43.92	9.05	10474.26	8.91	538.51	56.5	0.843	0.0089	-0.044
0.032	44.76	9.06	10474.22	8.91	538.51	54.6	0.805	0.0091	-0.045
0.033	45.57	9.07	10474.17	8.91	538.51	52.8	0.767	0.0093	-0.046
0.034	46.33	9.08	10474.13	8.91	538.51	51.1	0.730	0.0094	-0.046
0.035	47.06	9.09	10474.08	8.91	538.51	49.4	0.695	0.0096	-0.047
0.036	47.76	9.10	10474.03	8.91	538.51	47.7	0.660	0.0097	-0.048
0.037	48.42	9.11	10473.99	8.91	538.51	46.0	0.626	0.0099	-0.048
0.038	49.04	9.12	10473.94	8.91	538.51	44.5	0.593	0.0100	-0.049
0.039	49.64	9.13	10473.89	8.91	538.51	42.9	0.562	0.0101	-0.050
0.04	50.20	9.14	10473.84	8.91	538.51	41.5	0.532	0.0102	-0.050

0.041	50.73	9.15	10473.79	8.91	538.51	40.0	0.502	0.0103	-0.051
0.042	51.23	9.16	10473.74	8.91	538.51	38.7	0.474	0.0104	-0.051
0.043	51.71	9.17	10473.69	8.91	538.51	37.3	0.448	0.0105	-0.052
0.044	52.16	9.18	10473.64	8.91	538.51	36.1	0.422	0.0106	-0.052
0.045	52.58	9.19	10473.58	8.91	538.51	34.9	0.397	0.0107	-0.053
0.046	52.97	9.20	10473.53	8.91	538.51	33.7	0.374	0.0108	-0.053
0.047	53.35	9.21	10473.48	8.91	538.51	32.7	0.352	0.0109	-0.053
0.048	53.70	9.22	10473.43	8.91	538.51	31.6	0.331	0.0109	-0.054
0.049	54.03	9.23	10473.37	8.91	538.51	30.6	0.311	0.0110	-0.054
0.05	54.34	9.24	10473.32	8.91	538.51	29.7	1.459	0.0554	-0.272
0.055	55.80	9.30	10473.05	8.91	538.51	25.2	1.005	0.0568	-0.279
0.06	56.81	9.35	10472.77	8.91	538.51	21.9	0.681	0.0579	-0.284
0.065	57.49	9.41	10472.48	8.91	538.51	19.7	0.456	0.0586	-0.287
0.07	57.94	9.47	10472.20	8.91	538.51	18.1	0.302	0.0590	-0.290
0.075	58.24	9.53	10471.91	8.91	538.51	17.1	0.198	0.0593	-0.291
0.08	58.44	9.59	10471.61	8.91	538.51	16.4	0.128	0.0595	-0.292
0.085	58.57	9.65	10471.32	8.91	538.51	16.0	0.081	0.0597	-0.293
0.09	58.65	9.71	10471.03	8.90	538.50	15.7	0.050	0.0597	-0.293
0.095	58.70	9.77	10470.74	8.90	538.50	15.5	0.029	0.0598	-0.294
0.1	58.73	9.83	10470.44	8.90	538.50	15.4	0.029	0.1196	-0.587
0.11	58.76	9.95	10469.86	8.90	538.50	15.3	-0.009	0.1197	-0.588
0.12	58.75	10.07	10469.27	8.90	538.50	15.4	-0.022	0.1197	-0.588
0.13	58.73	10.19	10468.68	8.90	538.50	15.4	-0.027	0.1196	-0.587
0.14	58.70	10.31	10468.09	8.90	538.50	15.5	-0.029	0.1196	-0.587
0.15	58.67	10.43	10467.51	8.90	538.50	15.6	-0.030	0.1195	-0.587
0.16	58.64	10.55	10466.92	8.90	538.50	15.7	-0.030	0.1195	-0.586
0.17	58.61	10.67	10466.33	8.90	538.50	15.8	-0.030	0.1194	-0.586
0.18	58.58	10.79	10465.75	8.90	538.50	16.0	-0.030	0.1193	-0.586
0.19	58.55	10.90	10465.16	8.90	538.50	16.1	-0.030	0.1193	-0.586
0.2	58.52	11.02	10464.58	8.90	538.50	16.2	-0.030	0.1192	-0.585
0.21	58.49	11.14	10463.99	8.90	538.50	16.3	-0.030	0.1192	-0.585
0.22	58.46	11.26	10463.41	8.90	538.50	16.4	-0.030	0.1191	-0.585
0.23	58.43	11.38	10462.82	8.90	538.50	16.5	-0.030	0.1190	-0.584
0.24	58.40	11.50	10462.24	8.90	538.50	16.6	-0.030	0.1190	-0.584
0.25	58.37	11.62	10461.65	8.90	538.50	16.7	-0.030	0.1189	-0.584
0.26	58.34	11.74	10461.07	8.90	538.50	16.8	-0.030	0.1189	-0.583
0.27	58.31	11.86	10460.48	8.90	538.50	16.9	-0.030	0.1188	-0.583
0.28	58.28	11.98	10459.90	8.90	538.50	17.0	-0.030	0.1187	-0.583
0.29	58.25	12.09	10459.32	8.90	538.50	17.1	-0.030	0.1187	-0.583
0.3	58.22	12.21	10458.74	8.90	538.50	17.2	-0.030	0.1186	-0.582
0.31	58.19	12.33	10458.15	8.89	538.49	17.3	-0.030	0.1185	-0.582
0.32	58.16	12.45	10457.57	8.89	538.49	17.4	-0.030	0.1185	-0.582
0.33	58.13	12.57	10456.99	8.89	538.49	17.5	-0.030	0.1184	-0.581
0.34	58.10	12.69	10456.41	8.89	538.49	17.6	-0.030	0.1184	-0.581
0.35	58.07	12.81	10455.83	8.89	538.49	17.7	-0.030	0.1183	-0.581
0.36	58.04	12.92	10455.25	8.89	538.49	17.8	-0.030	0.1182	-0.580
0.37	58.01	13.04	10454.67	8.89	538.49	17.9	-0.030	0.1182	-0.580
0.38	57.98	13.16	10454.09	8.89	538.49	18.0	-0.030	0.1181	-0.580
0.39	57.95	13.28	10453.51	8.89	538.49	18.1	-0.030	0.1180	-0.579
0.4	57.92	13.40	10452.93	8.89	538.49	18.2	-0.030	0.1180	-0.579
0.41	57.89	13.51	10452.35	8.89	538.49	18.3	-0.030	0.1179	-0.579
0.42	57.86	13.63	10451.77	8.89	538.49	18.4	-0.030	0.1179	-0.579
0.43	57.83	13.75	10451.19	8.89	538.49	18.5	-0.030	0.1178	-0.578
0.44	57.80	13.87	10450.61	8.89	538.49	18.6	-0.030	0.1177	-0.578
0.45	57.77	13.99	10450.04	8.89	538.49	18.7	-0.030	0.1177	-0.578
0.46	57.74	14.10	10449.46	8.89	538.49	18.8	-0.030	0.1176	-0.577
0.47	57.70	14.22	10448.88	8.89	538.49	18.9	-0.030	0.1176	-0.577
0.48	57.67	14.34	10448.30	8.89	538.49	19.0	-0.030	0.1175	-0.577
0.49	57.64	14.46	10447.73	8.89	538.49	19.1	-0.030	0.1174	-0.576
0.5	57.61	14.57	10447.15	8.89	538.49	19.2	-0.030	0.1174	-0.576
0.51	57.58	14.69	10446.57	8.89	538.49	19.3	-0.030	0.1173	-0.576
0.52	57.55	14.81	10446.00	8.89	538.49	19.5	-0.030	0.1172	-0.576
0.53	57.52	14.93	10445.42	8.88	538.48	19.6	-0.030	0.1172	-0.575
0.54	57.49	15.04	10444.85	8.88	538.48	19.7	-0.030	0.1171	-0.575
0.55	57.46	15.16	10444.27	8.88	538.48	19.8	-0.030	0.1171	-0.575
0.56	57.43	15.28	10443.70	8.88	538.48	19.9	-0.030	0.1170	-0.574
0.57	57.40	15.39	10443.12	8.88	538.48	20.0	-0.030	0.1169	-0.574
0.58	57.37	15.51	10442.55	8.88	538.48	20.1	-0.031	0.1169	-0.574
0.59	57.34	15.63	10441.98	8.88	538.48	20.2	-0.031	0.1168	-0.573
0.6	57.31	15.74	10441.40	8.88	538.48	20.3	-0.031	0.1167	-0.573
0.61	57.28	15.86	10440.83	8.88	538.48	20.4	-0.031	0.1167	-0.573
0.62	57.25	15.98	10440.26	8.88	538.48	20.5	-0.031	0.1166	-0.572
0.63	57.22	16.09	10439.68	8.88	538.48	20.6	-0.031	0.1166	-0.572
0.64	57.19	16.21	10439.11	8.88	538.48	20.7	-0.031	0.1165	-0.572
0.65	57.16	16.33	10438.54	8.88	538.48	20.8	-0.031	0.1164	-0.572
0.66	57.13	16.44	10437.97	8.88	538.48	20.9	-0.031	0.1164	-0.571

0.67	57.09	16.56	10437.40	8.88	538.48	21.0	-0.031	0.1163	-0.571
0.68	57.06	16.68	10436.83	8.88	538.48	21.1	-0.031	0.1163	-0.571
0.69	57.03	16.79	10436.26	8.88	538.48	21.2	-0.031	0.1162	-0.570
0.7	57.00	16.91	10435.69	8.88	538.48	21.3	-0.031	0.1161	-0.570
0.71	56.97	17.03	10435.12	8.88	538.48	21.4	-0.031	0.1161	-0.570
0.72	56.94	17.14	10434.55	8.88	538.48	21.5	-0.031	0.1160	-0.569
0.73	56.91	17.26	10433.98	8.88	538.48	21.6	-0.031	0.1159	-0.569
0.74	56.88	17.37	10433.41	8.88	538.48	21.7	-0.031	0.1159	-0.569
0.75	56.85	17.49	10432.84	8.88	538.48	21.8	-0.031	0.1158	-0.569
0.76	56.82	17.60	10432.27	8.87	538.47	21.9	-0.031	0.1158	-0.568
0.77	56.79	17.72	10431.70	8.87	538.47	22.0	-0.031	0.1157	-0.568
0.78	56.76	17.84	10431.13	8.87	538.47	22.1	-0.031	0.1156	-0.568
0.79	56.73	17.95	10430.57	8.87	538.47	22.2	-0.031	0.1156	-0.567
0.8	56.70	18.07	10430.00	8.87	538.47	22.3	-0.031	0.1155	-0.567
0.81	56.67	18.18	10429.43	8.87	538.47	22.4	-0.031	0.1154	-0.567
0.82	56.64	18.30	10428.87	8.87	538.47	22.5	-0.031	0.1154	-0.566
0.83	56.60	18.41	10428.30	8.87	538.47	22.6	-0.031	0.1153	-0.566
0.84	56.57	18.53	10427.73	8.87	538.47	22.7	-0.031	0.1153	-0.566
0.85	56.54	18.64	10427.17	8.87	538.47	22.8	-0.031	0.1152	-0.565
0.86	56.51	18.76	10426.60	8.87	538.47	22.9	-0.031	0.1151	-0.565
0.87	56.48	18.87	10426.04	8.87	538.47	23.0	-0.031	0.1151	-0.565
0.88	56.45	18.99	10425.47	8.87	538.47	23.1	-0.031	0.1150	-0.565
0.89	56.42	19.10	10424.91	8.87	538.47	23.2	-0.031	0.1149	-0.564
0.9	56.39	19.22	10424.34	8.87	538.47	23.3	-0.031	0.1149	-0.564
0.91	56.36	19.33	10423.78	8.87	538.47	23.4	-0.031	0.1148	-0.564
0.92	56.33	19.45	10423.22	8.87	538.47	23.5	-0.031	0.1147	-0.563
0.93	56.30	19.56	10422.65	8.87	538.47	23.6	-0.031	0.1147	-0.563
0.94	56.27	19.68	10422.09	8.87	538.47	23.7	-0.031	0.1146	-0.563
0.95	56.24	19.79	10421.53	8.87	538.47	23.8	-0.031	0.1146	-0.562
0.96	56.20	19.91	10420.96	8.87	538.47	23.9	-0.031	0.1145	-0.562
0.97	56.17	20.02	10420.40	8.87	538.47	24.0	-0.031	0.1144	-0.562
0.98	56.14	20.14	10419.84	8.86	538.46	24.1	-0.031	0.1144	-0.561
0.99	56.11	20.25	10419.28	8.86	538.46	24.2	-0.031	0.1143	-0.561
1	56.08	20.37	10418.72	8.86	538.46	24.3	-0.031	0.1142	-0.561
1.01	56.05	20.48	10418.16	8.86	538.46	24.4	-0.031	0.1142	-0.560
1.02	56.02	20.59	10417.60	8.86	538.46	24.5	-0.031	0.1141	-0.560
1.03	55.99	20.71	10417.04	8.86	538.46	24.6	-0.031	0.1141	-0.560
1.04	55.96	20.82	10416.48	8.86	538.46	24.7	-0.031	0.1140	-0.560
1.05	55.93	20.94	10415.92	8.86	538.46	24.8	-0.031	0.1139	-0.559
1.06	55.90	21.05	10415.36	8.86	538.46	24.9	-0.031	0.1139	-0.559
1.07	55.86	21.16	10414.80	8.86	538.46	25.0	-0.031	0.1138	-0.559
1.08	55.83	21.28	10414.24	8.86	538.46	25.1	-0.031	0.1137	-0.558
1.09	55.80	21.39	10413.68	8.86	538.46	25.2	-0.031	0.1137	-0.558
1.1	55.77	21.51	10413.12	8.86	538.46	25.3	-0.031	0.1136	-0.558
1.11	55.74	21.62	10412.57	8.86	538.46	25.4	-0.031	0.1136	-0.557
1.12	55.71	21.73	10412.01	8.86	538.46	25.5	-0.031	0.1135	-0.557
1.13	55.68	21.85	10411.45	8.86	538.46	25.5	-0.031	0.1134	-0.557
1.14	55.65	21.96	10410.89	8.86	538.46	25.6	-0.031	0.1134	-0.556
1.15	55.62	22.07	10410.34	8.86	538.46	25.7	-0.031	0.1133	-0.556
1.16	55.59	22.19	10409.78	8.86	538.46	25.8	-0.031	0.1132	-0.556
1.17	55.55	22.30	10409.23	8.86	538.46	25.9	-0.031	0.1132	-0.556
1.18	55.52	22.41	10408.67	8.86	538.46	26.0	-0.031	0.1131	-0.555
1.19	55.49	22.53	10408.12	8.86	538.46	26.1	-0.031	0.1130	-0.555
1.2	55.46	22.64	10407.56	8.86	538.46	26.2	-0.031	0.1130	-0.555
1.21	55.43	22.75	10407.01	8.85	538.45	26.3	-0.031	0.1129	-0.554
1.22	55.40	22.86	10406.45	8.85	538.45	26.4	-0.031	0.1129	-0.554
1.23	55.37	22.98	10405.90	8.85	538.45	26.5	-0.031	0.1128	-0.554
1.24	55.34	23.09	10405.34	8.85	538.45	26.6	-0.031	0.1127	-0.553
1.25	55.31	23.20	10404.79	8.85	538.45	26.7	-0.031	0.1127	-0.553
1.26	55.27	23.32	10404.24	8.85	538.45	26.8	-0.031	0.1126	-0.553
1.27	55.24	23.43	10403.68	8.85	538.45	26.9	-0.031	0.1125	-0.552
1.28	55.21	23.54	10403.13	8.85	538.45	27.0	-0.031	0.1125	-0.552
1.29	55.18	23.65	10402.58	8.85	538.45	27.1	-0.031	0.1124	-0.552
1.3	55.15	23.77	10402.03	8.85	538.45	27.2	-0.031	0.1123	-0.551
1.31	55.12	23.88	10401.48	8.85	538.45	27.3	-0.031	0.1123	-0.551
1.32	55.09	23.99	10400.93	8.85	538.45	27.4	-0.031	0.1122	-0.551
1.33	55.06	24.10	10400.37	8.85	538.45	27.5	-0.031	0.1122	-0.551
1.34	55.02	24.21	10399.82	8.85	538.45	27.6	-0.031	0.1121	-0.550
1.35	54.99	24.33	10399.27	8.85	538.45	27.7	-0.031	0.1120	-0.550
1.36	54.96	24.44	10398.72	8.85	538.45	27.8	-0.031	0.1120	-0.550
1.37	54.93	24.55	10398.17	8.85	538.45	27.9	-0.031	0.1119	-0.549
1.38	54.90	24.66	10397.63	8.85	538.45	28.0	-0.031	0.1118	-0.549
1.39	54.87	24.77	10397.08	8.85	538.45	28.1	-0.031	0.1118	-0.549
1.4	54.84	24.89	10396.53	8.85	538.45	28.2	-0.031	0.1117	-0.548
1.41	54.81	25.00	10395.98	8.85	538.45	28.3	-0.031	0.1116	-0.548
1.42	54.77	25.11	10395.43	8.85	538.45	28.4	-0.031	0.1116	-0.548
1.43	54.74	25.22	10394.88	8.85	538.45	28.5	-0.031	0.1115	-0.547
1.44	54.71	25.33	10394.34	8.84	538.44	28.6	-0.031	0.1115	-0.547
1.45	54.68	25.44	10393.79	8.84	538.44	28.7	-0.031	0.1114	-0.547
1.46	54.65	25.56	10393.24	8.84	538.44	28.7	-0.031	0.1113	-0.546

1.47	54.62	25.67	10392.70	8.84	538.44	28.8	-0.031	0.1113	-0.546
1.48	54.59	25.78	10392.15	8.84	538.44	28.9	-0.031	0.1112	-0.546
1.49	54.56	25.89	10391.60	8.84	538.44	29.0	-0.031	0.1111	-0.546
1.5	54.52	26.00	10391.06	8.84	538.44	29.1	-0.031	0.1111	-0.545
1.51	54.49	26.11	10390.51	8.84	538.44	29.2	-0.031	0.1110	-0.545
1.52	54.46	26.22	10389.97	8.84	538.44	29.3	-0.031	0.1109	-0.545
1.53	54.43	26.33	10389.42	8.84	538.44	29.4	-0.031	0.1109	-0.544
1.54	54.40	26.44	10388.88	8.84	538.44	29.5	-0.031	0.1108	-0.544
1.55	54.37	26.56	10388.33	8.84	538.44	29.6	-0.031	0.1108	-0.544
1.56	54.34	26.67	10387.79	8.84	538.44	29.7	-0.031	0.1107	-0.543
1.57	54.30	26.78	10387.25	8.84	538.44	29.8	-0.031	0.1106	-0.543
1.58	54.27	26.89	10386.70	8.84	538.44	29.9	-0.031	0.1106	-0.543
1.59	54.24	27.00	10386.16	8.84	538.44	30.0	-0.031	0.1105	-0.542
1.6	54.21	27.11	10385.62	8.84	538.44	30.1	-0.031	0.1104	-0.542
1.61	54.18	27.22	10385.08	8.84	538.44	30.2	-0.032	0.1104	-0.542
1.62	54.15	27.33	10384.54	8.84	538.44	30.3	-0.032	0.1103	-0.541
1.63	54.11	27.44	10383.99	8.84	538.44	30.4	-0.032	0.1102	-0.541
1.64	54.08	27.55	10383.45	8.84	538.44	30.5	-0.032	0.1102	-0.541
1.65	54.05	27.66	10382.91	8.84	538.44	30.6	-0.032	0.1101	-0.541
1.66	54.02	27.77	10382.37	8.84	538.44	30.7	-0.032	0.1100	-0.540
1.67	53.99	27.88	10381.83	8.84	538.44	30.8	-0.032	0.1100	-0.540
1.68	53.96	27.99	10381.29	8.83	538.43	30.8	-0.032	0.1099	-0.540
1.69	53.93	28.10	10380.75	8.83	538.43	30.9	-0.032	0.1099	-0.539
1.7	53.89	28.21	10380.21	8.83	538.43	31.0	-0.032	0.1098	-0.539
1.71	53.86	28.32	10379.67	8.83	538.43	31.1	-0.032	0.1097	-0.539
1.72	53.83	28.43	10379.14	8.83	538.43	31.2	-0.032	0.1097	-0.538
1.73	53.80	28.54	10378.60	8.83	538.43	31.3	-0.032	0.1096	-0.538
1.74	53.77	28.65	10378.06	8.83	538.43	31.4	-0.032	0.1095	-0.538
1.75	53.74	28.76	10377.52	8.83	538.43	31.5	-0.032	0.1095	-0.537
1.76	53.70	28.87	10376.98	8.83	538.43	31.6	-0.032	0.1094	-0.537
1.77	53.67	28.98	10376.45	8.83	538.43	31.7	-0.032	0.1093	-0.537
1.78	53.64	29.09	10375.91	8.83	538.43	31.8	-0.032	0.1093	-0.536
1.79	53.61	29.20	10375.37	8.83	538.43	31.9	-0.032	0.1092	-0.536
1.8	53.58	29.30	10374.84	8.83	538.43	32.0	-0.032	0.1091	-0.536
1.81	53.55	29.41	10374.30	8.83	538.43	32.1	-0.032	0.1091	-0.535
1.82	53.51	29.52	10373.77	8.83	538.43	32.2	-0.032	0.1090	-0.535
1.83	53.48	29.63	10373.23	8.83	538.43	32.3	-0.032	0.1090	-0.535
1.84	53.45	29.74	10372.70	8.83	538.43	32.4	-0.032	0.1089	-0.535
1.85	53.42	29.85	10372.16	8.83	538.43	32.4	-0.032	0.1088	-0.534
1.86	53.39	29.96	10371.63	8.83	538.43	32.5	-0.032	0.1088	-0.534
1.87	53.36	30.07	10371.09	8.83	538.43	32.6	-0.032	0.1087	-0.534
1.88	53.32	30.18	10370.56	8.83	538.43	32.7	-0.032	0.1086	-0.533
1.89	53.29	30.28	10370.03	8.83	538.43	32.8	-0.032	0.1086	-0.533
1.9	53.26	30.39	10369.49	8.83	538.43	32.9	-0.032	0.1085	-0.533
1.91	53.23	30.50	10368.96	8.83	538.43	33.0	-0.032	0.1084	-0.532
1.92	53.20	30.61	10368.43	8.82	538.42	33.1	-0.032	0.1084	-0.532
1.93	53.16	30.72	10367.90	8.82	538.42	33.2	-0.032	0.1083	-0.532
1.94	53.13	30.83	10367.37	8.82	538.42	33.3	-0.032	0.1082	-0.531
1.95	53.10	30.94	10366.83	8.82	538.42	33.4	-0.032	0.1082	-0.531
1.96	53.07	31.04	10366.30	8.82	538.42	33.5	-0.032	0.1081	-0.531
1.97	53.04	31.15	10365.77	8.82	538.42	33.6	-0.032	0.1080	-0.530
1.98	53.01	31.26	10365.24	8.82	538.42	33.7	-0.032	0.1080	-0.530
1.99	52.97	31.37	10364.71	8.82	538.42	33.7	-0.032	0.1079	-0.530
2	52.94	31.48	10364.18	8.82	538.42	33.8	-0.032	0.1079	-0.529
2.01	52.91	31.58	10363.65	8.82	538.42	33.9	-0.032	0.1078	-0.529
2.02	52.88	31.69	10363.12	8.82	538.42	34.0	-0.032	0.1077	-0.529
2.03	52.85	31.80	10362.60	8.82	538.42	34.1	-0.032	0.1077	-0.528
2.04	52.81	31.91	10362.07	8.82	538.42	34.2	-0.032	0.1076	-0.528
2.05	52.78	32.01	10361.54	8.82	538.42	34.3	-0.032	0.1075	-0.528
2.06	52.75	32.12	10361.01	8.82	538.42	34.4	-0.032	0.1075	-0.528
2.07	52.72	32.23	10360.48	8.82	538.42	34.5	-0.032	0.1074	-0.527
2.08	52.69	32.34	10359.96	8.82	538.42	34.6	-0.032	0.1073	-0.527
2.09	52.65	32.44	10359.43	8.82	538.42	34.7	-0.032	0.1073	-0.527
2.1	52.62	32.55	10358.90	8.82	538.42	34.8	-0.032	0.1072	-0.526
2.11	52.59	32.66	10358.38	8.82	538.42	34.9	-0.032	0.1071	-0.526
2.12	52.56	32.77	10357.85	8.82	538.42	34.9	-0.032	0.1071	-0.526
2.13	52.53	32.87	10357.33	8.82	538.42	35.0	-0.032	0.1070	-0.525
2.14	52.49	32.98	10356.80	8.82	538.42	35.1	-0.032	0.1069	-0.525
2.15	52.46	33.09	10356.28	8.82	538.42	35.2	-0.032	0.1069	-0.525
2.16	52.43	33.19	10355.75	8.81	538.41	35.3	-0.032	0.1068	-0.524
2.17	52.40	33.30	10355.23	8.81	538.41	35.4	-0.032	0.1067	-0.524
2.18	52.37	33.41	10354.70	8.81	538.41	35.5	-0.032	0.1067	-0.524
2.19	52.33	33.51	10354.18	8.81	538.41	35.6	-0.032	0.1066	-0.523
2.2	52.30	33.62	10353.66	8.81	538.41	35.7	-0.032	0.1065	-0.523
2.21	52.27	33.73	10353.13	8.81	538.41	35.8	-0.032	0.1065	-0.523
2.22	52.24	33.83	10352.61	8.81	538.41	35.9	-0.032	0.1064	-0.522
2.23	52.21	33.94	10352.09	8.81	538.41	36.0	-0.032	0.1064	-0.522
2.24	52.17	34.05	10351.56	8.81	538.41	36.0	-0.032	0.1063	-0.522
2.25	52.14	34.15	10351.04	8.81	538.41	36.1	-0.032	0.1062	-0.521
2.26	52.11	34.26	10350.52	8.81	538.41	36.2	-0.032	0.1062	-0.521
2.27	52.08	34.36	10350.00	8.81	538.41	36.3	-0.032	0.1061	-0.521
2.28	52.04	34.47	10349.48	8.81	538.41	36.4	-0.032	0.1060	-0.520

2.29	52.01	34.58	10348.96	8.81	538.41	36.5	-0.032	0.1060	-0.520
2.3	51.98	34.68	10348.44	8.81	538.41	36.6	-0.032	0.1059	-0.520
2.31	51.95	34.79	10347.92	8.81	538.41	36.7	-0.032	0.1058	-0.519
2.32	51.92	34.89	10347.40	8.81	538.41	36.8	-0.032	0.1058	-0.519
2.33	51.88	35.00	10346.88	8.81	538.41	36.9	-0.032	0.1057	-0.519
2.34	51.85	35.11	10346.36	8.81	538.41	36.9	-0.032	0.1056	-0.519
2.35	51.82	35.21	10345.84	8.81	538.41	37.0	-0.032	0.1056	-0.518
2.36	51.79	35.32	10345.33	8.81	538.41	37.1	-0.032	0.1055	-0.518
2.37	51.75	35.42	10344.81	8.81	538.41	37.2	-0.032	0.1054	-0.518
2.38	51.72	35.53	10344.29	8.81	538.41	37.3	-0.032	0.1054	-0.517
2.39	51.69	35.63	10343.77	8.81	538.41	37.4	-0.032	0.1053	-0.517
2.4	51.66	35.74	10343.26	8.80	538.40	37.5	-0.032	0.1052	-0.517
2.41	51.63	35.84	10342.74	8.80	538.40	37.6	-0.032	0.1052	-0.516
2.42	51.59	35.95	10342.22	8.80	538.40	37.7	-0.032	0.1051	-0.516
2.43	51.56	36.05	10341.71	8.80	538.40	37.8	-0.032	0.1050	-0.516
2.44	51.53	36.16	10341.19	8.80	538.40	37.8	-0.032	0.1050	-0.515
2.45	51.50	36.26	10340.68	8.80	538.40	37.9	-0.032	0.1049	-0.515
2.46	51.46	36.37	10340.16	8.80	538.40	38.0	-0.032	0.1048	-0.515
2.47	51.43	36.47	10339.65	8.80	538.40	38.1	-0.032	0.1048	-0.514
2.48	51.40	36.58	10339.13	8.80	538.40	38.2	-0.032	0.1047	-0.514
2.49	51.37	36.68	10338.62	8.80	538.40	38.3	-0.032	0.1046	-0.514
2.5	51.33	36.79	10338.10	8.80	538.40	38.4	-0.032	0.1046	-0.513
2.51	51.30	36.89	10337.59	8.80	538.40	38.5	-0.032	0.1045	-0.513
2.52	51.27	37.00	10337.08	8.80	538.40	38.6	-0.032	0.1044	-0.513
2.53	51.24	37.10	10336.57	8.80	538.40	38.7	-0.032	0.1044	-0.512
2.54	51.20	37.21	10336.05	8.80	538.40	38.7	-0.032	0.1043	-0.512
2.55	51.17	37.31	10335.54	8.80	538.40	38.8	-0.032	0.1042	-0.512
2.56	51.14	37.41	10335.03	8.80	538.40	38.9	-0.032	0.1042	-0.511
2.57	51.11	37.52	10334.52	8.80	538.40	39.0	-0.033	0.1041	-0.511
2.58	51.07	37.62	10334.01	8.80	538.40	39.1	-0.033	0.1040	-0.511
2.59	51.04	37.73	10333.50	8.80	538.40	39.2	-0.033	0.1040	-0.510
2.6	51.01	37.83	10332.99	8.80	538.40	39.3	-0.033	0.1039	-0.510
2.61	50.98	37.93	10332.48	8.80	538.40	39.4	-0.033	0.1038	-0.510
2.62	50.94	38.04	10331.97	8.80	538.40	39.5	-0.033	0.1038	-0.509
2.63	50.91	38.14	10331.46	8.80	538.40	39.5	-0.033	0.1037	-0.509
2.64	50.88	38.25	10330.95	8.80	538.40	39.6	-0.033	0.1036	-0.509
2.65	50.85	38.35	10330.44	8.79	538.39	39.7	-0.033	0.1036	-0.508
2.66	50.81	38.45	10329.93	8.79	538.39	39.8	-0.033	0.1035	-0.508
2.67	50.78	38.56	10329.42	8.79	538.39	39.9	-0.033	0.1035	-0.508
2.68	50.75	38.66	10328.91	8.79	538.39	40.0	-0.033	0.1034	-0.507
2.69	50.72	38.76	10328.41	8.79	538.39	40.1	-0.033	0.1033	-0.507
2.7	50.68	38.87	10327.90	8.79	538.39	40.2	-0.033	0.1033	-0.507
2.71	50.65	38.97	10327.39	8.79	538.39	40.2	-0.033	0.1032	-0.507
2.72	50.62	39.07	10326.89	8.79	538.39	40.3	-0.033	0.1031	-0.506
2.73	50.59	39.18	10326.38	8.79	538.39	40.4	-0.033	0.1031	-0.506
2.74	50.55	39.28	10325.87	8.79	538.39	40.5	-0.033	0.1030	-0.506
2.75	50.52	39.38	10325.37	8.79	538.39	40.6	-0.033	0.1029	-0.505
2.76	50.49	39.49	10324.86	8.79	538.39	40.7	-0.033	0.1029	-0.505
2.77	50.45	39.59	10324.36	8.79	538.39	40.8	-0.033	0.1028	-0.505
2.78	50.42	39.69	10323.85	8.79	538.39	40.9	-0.033	0.1027	-0.504
2.79	50.39	39.79	10323.35	8.79	538.39	40.9	-0.033	0.1027	-0.504
2.8	50.36	39.90	10322.85	8.79	538.39	41.0	-0.033	0.1026	-0.504
2.81	50.32	40.00	10322.34	8.79	538.39	41.1	-0.033	0.1025	-0.503
2.82	50.29	40.10	10321.84	8.79	538.39	41.2	-0.033	0.1025	-0.503
2.83	50.26	40.20	10321.34	8.79	538.39	41.3	-0.033	0.1024	-0.503
2.84	50.23	40.31	10320.83	8.79	538.39	41.4	-0.033	0.1023	-0.502
2.85	50.19	40.41	10320.33	8.79	538.39	41.5	-0.033	0.1023	-0.502
2.86	50.16	40.51	10319.83	8.79	538.39	41.6	-0.033	0.1022	-0.502
2.87	50.13	40.61	10319.33	8.79	538.39	41.6	-0.033	0.1021	-0.501
2.88	50.09	40.72	10318.83	8.79	538.39	41.7	-0.033	0.1021	-0.501
2.89	50.06	40.82	10318.33	8.79	538.39	41.8	-0.033	0.1020	-0.501
2.9	50.03	40.92	10317.83	8.79	538.39	41.9	-0.033	0.1019	-0.500
2.91	50.00	41.02	10317.32	8.78	538.38	42.0	-0.033	0.1018	-0.500
2.92	49.96	41.12	10316.83	8.78	538.38	42.1	-0.033	0.1018	-0.500
2.93	49.93	41.22	10316.33	8.78	538.38	42.2	-0.033	0.1017	-0.499
2.94	49.90	41.33	10315.83	8.78	538.38	42.3	-0.033	0.1016	-0.499
2.95	49.86	41.43	10315.33	8.78	538.38	42.3	-0.033	0.1016	-0.499
2.96	49.83	41.53	10314.83	8.78	538.38	42.4	-0.033	0.1015	-0.498
2.97	49.80	41.63	10314.33	8.78	538.38	42.5	-0.033	0.1014	-0.498
2.98	49.77	41.73	10313.83	8.78	538.38	42.6	-0.033	0.1014	-0.498
2.99	49.73	41.83	10313.33	8.78	538.38	42.7	-0.033	0.1013	-0.497
3	49.70	41.94	10312.84	8.78	538.38	42.8	-0.033	0.1012	-0.497
3.01	49.67	42.04	10312.34	8.78	538.38	42.9	-0.033	0.1012	-0.497
3.02	49.63	42.14	10311.84	8.78	538.38	42.9	-0.033	0.1011	-0.496
3.03	49.60	42.24	10311.35	8.78	538.38	43.0	-0.033	0.1010	-0.496
3.04	49.57	42.34	10310.85	8.78	538.38	43.1	-0.033	0.1010	-0.496
3.05	49.53	42.44	10310.36	8.78	538.38	43.2	-0.033	0.1009	-0.495
3.06	49.50	42.54	10309.86	8.78	538.38	43.3	-0.033	0.1008	-0.495
3.07	49.47	42.64	10309.37	8.78	538.38	43.4	-0.033	0.1008	-0.495
3.08	49.44	42.74	10308.87	8.78	538.38	43.5	-0.033	0.1007	-0.494
3.09	49.40	42.84	10308.38	8.78	538.38	43.5	-0.033	0.1006	-0.494
3.1	49.37	42.94	10307.88	8.78	538.38	43.6	-0.033	0.1006	-0.494

3.11	49.34	43.05	10307.39	8.78	538.38	43.7	-0.033	0.1005	-0.493
3.12	49.30	43.15	10306.90	8.78	538.38	43.8	-0.033	0.1004	-0.493
3.13	49.27	43.25	10306.40	8.78	538.38	43.9	-0.033	0.1004	-0.493
3.14	49.24	43.35	10305.91	8.78	538.38	44.0	-0.033	0.1003	-0.492
3.15	49.20	43.45	10305.42	8.78	538.38	44.1	-0.033	0.1002	-0.492
3.16	49.17	43.55	10304.93	8.77	538.37	44.1	-0.033	0.1002	-0.492
3.17	49.14	43.65	10304.43	8.77	538.37	44.2	-0.033	0.1001	-0.491
3.18	49.10	43.75	10303.94	8.77	538.37	44.3	-0.033	0.1000	-0.491
3.19	49.07	43.85	10303.45	8.77	538.37	44.4	-0.033	0.1000	-0.491
3.2	49.04	43.95	10302.96	8.77	538.37	44.5	-0.017	0.0499	-0.245
3.205	49.02	44.00	10302.72	8.77	538.37	44.5	-0.017	0.0499	-0.245
3.21									

Start of horizontal run of pipeline:

FLOW IN HORIZONTAL SECTION OF PIPE

Q_o=	49.02 π /sec
V_o=	9.986 ft/sec
z_o=	8.77 ft
$Ꝟ_o$=	10302.71 π

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(p_{elbow}/\gamma - (f^*(x)/D) * Q^2/(2g\, A^2)) * A * (g/(L+x)) * dt$

$p_{elbow}/\gamma = z + H_{pump} - 44 - (f^*(44)/D + k_{Lentrance} + 2^*k_{Lelbow}) * Q^2/(2g\, A^2) - Q^2/(2gA^2)$

$x(t)=x_{prev.} + dx$ $dx=(Q/A)^*dt$

$Ꝟ(t)=Ꝟ_{prev.} + dꝞ$ $dꝞ=(Q_{inflow}-Q)^*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151$

t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow}/γ	dQ	dx	dꝞ
3.205	49.02	0.00	10302.71	8.77	538.37	44.5	-2.632	-0.094	0.0999	-0.490
3.215	48.93	0.10	10302.22	8.77	538.37	44.8	-2.346	-0.084	0.0997	-0.489
3.225	48.84	0.20	10301.73	8.77	538.37	45.0	-2.092	-0.075	0.0995	-0.488
3.235	48.77	0.30	10301.25	8.77	538.37	45.2	-1.867	-0.067	0.0993	-0.488
3.245	48.70	0.40	10300.76	8.77	538.37	45.3	-1.666	-0.059	0.0992	-0.487
3.255	48.64	0.50	10300.27	8.77	538.37	45.5	-1.488	-0.053	0.0991	-0.486
3.265	48.59	0.60	10299.78	8.77	538.37	45.6	-1.330	-0.047	0.0990	-0.486
3.275	48.54	0.70	10299.30	8.77	538.37	45.7	-1.189	-0.042	0.0989	-0.485
3.285	48.50	0.79	10298.81	8.77	538.37	45.8	-1.063	-0.038	0.0988	-0.485
3.295	48.46	0.89	10298.33	8.77	538.37	45.9	-0.951	-0.034	0.0987	-0.485
3.305	48.43	0.99	10297.84	8.77	538.37	46.0	-0.851	-0.030	0.0987	-0.484
3.315	48.40	1.09	10297.36	8.77	538.37	46.1	-0.762	-0.027	0.0986	-0.484
3.325	48.37	1.19	10296.88	8.77	538.37	46.2	-0.682	-0.024	0.0985	-0.484
3.335	48.35	1.29	10296.39	8.77	538.37	46.2	-0.610	-0.022	0.0985	-0.483
3.345	48.33	1.39	10295.91	8.77	538.37	46.3	-0.547	-0.019	0.0984	-0.483
3.355	48.31	1.48	10295.42	8.77	538.37	46.3	-0.490	-0.017	0.0984	-0.483
3.365	48.29	1.58	10294.94	8.77	538.37	46.4	-0.438	-0.016	0.0984	-0.483
3.375	48.27	1.68	10294.46	8.77	538.37	46.4	-0.393	-0.014	0.0983	-0.483
3.385	48.26	1.78	10293.98	8.77	538.37	46.4	-0.352	-0.013	0.0983	-0.483
3.395	48.25	1.88	10293.49	8.77	538.37	46.5	-0.315	-0.011	0.0983	-0.482
3.405	48.24	1.98	10293.01	8.77	538.37	46.5	-0.282	-0.010	0.0983	-0.482
3.415	48.23	2.07	10292.53	8.77	538.37	46.5	-0.252	-0.009	0.0982	-0.482
3.425	48.22	2.17	10292.05	8.76	538.36	46.5	-0.226	-0.008	0.0982	-0.482
3.435	48.21	2.27	10291.56	8.76	538.36	46.6	-0.202	-0.007	0.0982	-0.482
3.445	48.20	2.37	10291.08	8.76	538.36	46.6	-0.180	-0.007	0.0982	-0.482
3.455	48.19	2.47	10290.60	8.76	538.36	46.6	-0.161	-0.006	0.0982	-0.482
3.465	48.19	2.57	10290.12	8.76	538.36	46.6	-0.143	-0.005	0.0982	-0.482
3.475	48.18	2.66	10289.64	8.76	538.36	46.6	-0.128	-0.005	0.0982	-0.482
3.485	48.18	2.76	10289.15	8.76	538.36	46.6	-0.113	-0.004	0.0981	-0.482
3.495	48.17	2.86	10288.67	8.76	538.36	46.7	-0.101	-0.040	0.9814	-4.817
3.595	48.13	3.84	10283.86	8.76	538.36	46.8	0.015	-0.004	0.9806	-4.813
3.695	48.13	4.82	10279.04	8.75	538.35	46.8	0.021	-0.003	0.9805	-4.813
3.795	48.13	5.80	10274.23	8.75	538.35	46.8	0.027	-0.003	0.9804	-4.813
3.895	48.12	6.78	10269.42	8.75	538.35	46.8	0.034	-0.003	0.9803	-4.812
3.995	48.12	7.76	10264.60	8.74	538.34	46.8	0.040	-0.003	0.9803	-4.812
4.095	48.12	8.74	10259.79	8.74	538.34	46.8	0.046	-0.003	0.9802	-4.812
4.195	48.11	9.72	10254.98	8.74	538.34	46.8	0.052	-0.003	0.9801	-4.811
4.295	48.11	10.70	10250.17	8.73	538.33	46.8	0.059	-0.003	0.9801	-4.811
4.395	48.11	11.68	10245.36	8.73	538.33	46.8	0.065	-0.003	0.9800	-4.811
4.495	48.10	12.66	10240.55	8.72	538.32	46.8	0.071	-0.003	0.9799	-4.810
4.595	48.10	13.64	10235.74	8.72	538.32	46.8	0.077	-0.003	0.9799	-4.810
4.695	48.10	14.62	10230.93	8.72	538.32	46.8	0.083	-0.003	0.9798	-4.810
4.795	48.09	15.60	10226.12	8.71	538.31	46.9	0.090	-0.003	0.9797	-4.809
4.895	48.09	16.58	10221.31	8.71	538.31	46.9	0.096	-0.003	0.9797	-4.809
4.995	48.09	17.56	10216.50	8.71	538.31	46.9	0.102	-0.003	0.9796	-4.809
5.095	48.08	18.54	10211.69	8.70	538.30	46.9	0.108	-0.003	0.9795	-4.808
5.195	48.08	19.52	10206.88	8.70	538.30	46.9	0.114	-0.003	0.9794	-4.808
5.295	48.07	20.50	10202.08	8.69	538.29	46.9	0.121	-0.003	0.9794	-4.807
5.395	48.07	21.48	10197.27	8.69	538.29	46.9	0.127	-0.003	0.9793	-4.807
5.495	48.07	22.46	10192.46	8.69	538.29	46.9	0.133	-0.003	0.9792	-4.807
5.595	48.06	23.44	10187.65	8.68	538.28	46.9	0.139	-0.003	0.9792	-4.806
5.695	48.06	24.42	10182.85	8.68	538.28	46.9	0.145	-0.003	0.9791	-4.806
5.795	48.06	25.40	10178.04	8.68	538.28	46.9	0.152	-0.003	0.9790	-4.806
5.895	48.05	26.38	10173.24	8.67	538.27	46.9	0.158	-0.003	0.9790	-4.805
5.995	48.05	27.36	10168.43	8.67	538.27	47.0	0.164	-0.003	0.9789	-4.805
6.095	48.05	28.33	10163.63	8.66	538.26	47.0	0.170	-0.003	0.9788	-4.805
6.195	48.04	29.31	10158.82	8.66	538.26	47.0	0.176	-0.003	0.9788	-4.804
6.295	48.04	30.29	10154.02	8.66	538.26	47.0	0.183	-0.003	0.9787	-4.804

6.395	48.04	31.27	10149.21	8.65	538.25	47.0	0.189	-0.003	0.9786	-4.804
6.495	48.03	32.25	10144.41	8.65	538.25	47.0	0.195	-0.003	0.9785	-4.803
6.595	48.03	33.23	10139.61	8.65	538.25	47.0	0.201	-0.003	0.9785	-4.803
6.695	48.03	34.21	10134.80	8.64	538.24	47.0	0.207	-0.003	0.9784	-4.803
6.795	48.02	35.19	10130.00	8.64	538.24	47.0	0.213	-0.003	0.9783	-4.802
6.895	48.02	36.16	10125.20	8.63	538.23	47.0	0.220	-0.003	0.9783	-4.802
6.995	48.02	37.14	10120.39	8.63	538.23	47.0	0.226	-0.003	0.9782	-4.802
7.095	48.01	38.12	10115.59	8.63	538.23	47.0	0.232	-0.003	0.9781	-4.801
7.195	48.01	39.10	10110.79	8.62	538.22	47.1	0.238	-0.003	0.9781	-4.801
7.295	48.01	40.08	10105.99	8.62	538.22	47.1	0.244	-0.003	0.9780	-4.801
7.395	48.00	41.05	10101.19	8.61	538.21	47.1	0.250	-0.003	0.9779	-4.800
7.495	48.00	42.03	10096.39	8.61	538.21	47.1	0.256	-0.003	0.9779	-4.800
7.595	48.00	43.01	10091.59	8.61	538.21	47.1	0.263	-0.003	0.9778	-4.800
7.695	47.99	43.99	10086.79	8.60	538.20	47.1	0.269	-0.003	0.9777	-4.799
7.795	47.99	44.97	10081.99	8.60	538.20	47.1	0.275	-0.003	0.9777	-4.799
7.895	47.99	45.94	10077.19	8.60	538.20	47.1	0.281	-0.003	0.9776	-4.799
7.995	47.98	46.92	10072.39	8.59	538.19	47.1	0.287	-0.003	0.9775	-4.798
8.095	47.98	47.90	10067.59	8.59	538.19	47.1	0.293	-0.003	0.9774	-4.798
8.195	47.98	48.88	10062.80	8.58	538.18	47.1	0.299	-0.003	0.9774	-4.798
8.295	47.97	49.85	10058.00	8.58	538.18	47.1	0.306	-0.003	0.9773	-4.797
8.395	47.97	50.83	10053.20	8.58	538.18	47.2	0.312	-0.003	0.9772	-4.797
8.495	47.97	51.81	10048.40	8.57	538.17	47.2	0.318	-0.003	0.9772	-4.797
8.595	47.96	52.78	10043.61	8.57	538.17	47.2	0.324	-0.003	0.9771	-4.796
8.695	47.96	53.76	10038.81	8.57	538.17	47.2	0.330	-0.003	0.9770	-4.796
8.795	47.96	54.74	10034.01	8.56	538.16	47.2	0.336	-0.003	0.9770	-4.796
8.895	47.95	55.72	10029.22	8.56	538.16	47.2	0.342	-0.003	0.9769	-4.795
8.995	47.95	56.69	10024.42	8.55	538.15	47.2	0.348	-0.003	0.9768	-4.795
9.095	47.95	57.67	10019.63	8.55	538.15	47.2	0.355	-0.003	0.9768	-4.795
9.195	47.94	58.65	10014.83	8.55	538.15	47.2	0.361	-0.003	0.9767	-4.794
9.295	47.94	59.62	10010.04	8.54	538.14	47.2	0.367	-0.003	0.9766	-4.794
9.395	47.94	60.60	10005.25	8.54	538.14	47.2	0.373	-0.003	0.9766	-4.794
9.495	47.93	61.58	10000.45	8.54	538.14	47.2	0.379	-0.003	0.9765	-4.793
9.595	47.93	62.55	9995.66	8.53	538.13	47.3	0.385	-0.003	0.9764	-4.793
9.695	47.93	63.53	9990.87	8.53	538.13	47.3	0.391	-0.003	0.9763	-4.793
9.795	47.92	64.51	9986.07	8.52	538.12	47.3	0.397	-0.003	0.9763	-4.792
9.895	47.92	65.48	9981.28	8.52	538.12	47.3	0.403	-0.003	0.9762	-4.792
9.995	47.92	66.46	9976.49	8.52	538.12	47.3	0.410	-0.003	0.9761	-4.792
10.095	47.91	67.43	9971.70	8.51	538.11	47.3	0.416	-0.003	0.9761	-4.791
10.195	47.91	68.41	9966.91	8.51	538.11	47.3	0.422	-0.003	0.9760	-4.791
10.295	47.91	69.39	9962.12	8.50	538.10	47.3	0.428	-0.003	0.9759	-4.791
10.395	47.90	70.36	9957.32	8.50	538.10	47.3	0.434	-0.003	0.9759	-4.790
10.495	47.90	71.34	9952.53	8.50	538.10	47.3	0.440	-0.003	0.9758	-4.790
10.595	47.90	72.31	9947.74	8.49	538.09	47.3	0.446	-0.003	0.9757	-4.790
10.695	47.89	73.29	9942.95	8.49	538.09	47.3	0.452	-0.003	0.9757	-4.789
10.795	47.89	74.27	9938.17	8.49	538.09	47.4	0.458	-0.003	0.9756	-4.789
10.895	47.89	75.24	9933.38	8.48	538.08	47.4	0.464	-0.003	0.9755	-4.789
10.995	47.88	76.22	9928.59	8.48	538.08	47.4	0.470	-0.003	0.9755	-4.788
11.095	47.88	77.19	9923.80	8.47	538.07	47.4	0.476	-0.003	0.9754	-4.788
11.195	47.88	78.17	9919.01	8.47	538.07	47.4	0.482	-0.003	0.9753	-4.788
11.295	47.87	79.14	9914.22	8.47	538.07	47.4	0.489	-0.003	0.9753	-4.787
11.395	47.87	80.12	9909.44	8.46	538.06	47.4	0.495	-0.003	0.9752	-4.787
11.495	47.87	81.09	9904.65	8.46	538.06	47.4	0.501	-0.003	0.9751	-4.787
11.595	47.86	82.07	9899.86	8.46	538.06	47.4	0.507	-0.003	0.9750	-4.786
11.695	47.86	83.04	9895.08	8.45	538.05	47.4	0.513	-0.003	0.9750	-4.786
11.795	47.86	84.02	9890.29	8.45	538.05	47.4	0.519	-0.003	0.9749	-4.786
11.895	47.85	84.99	9885.51	8.44	538.04	47.4	0.525	-0.003	0.9748	-4.785
11.995	47.85	85.97	9880.72	8.44	538.04	47.5	0.531	-0.003	0.9748	-4.785
12.095	47.85	86.94	9875.94	8.44	538.04	47.5	0.537	-0.003	0.9747	-4.785
12.195	47.84	87.92	9871.15	8.43	538.03	47.5	0.543	-0.003	0.9746	-4.784
12.295	47.84	88.89	9866.37	8.43	538.03	47.5	0.549	-0.003	0.9746	-4.784
12.395	47.84	89.87	9861.58	8.43	538.03	47.5	0.555	-0.003	0.9745	-4.784
12.495	47.83	90.84	9856.80	8.42	538.02	47.5	0.561	-0.003	0.9744	-4.783
12.595	47.83	91.82	9852.02	8.42	538.02	47.5	0.567	-0.003	0.9744	-4.783
12.695	47.83	92.79	9847.23	8.41	538.01	47.5	0.573	-0.003	0.9743	-4.783
12.795	47.82	93.76	9842.45	8.41	538.01	47.5	0.579	-0.003	0.9742	-4.782
12.895	47.82	94.74	9837.67	8.41	538.01	47.5	0.585	-0.003	0.9742	-4.782
12.995	47.82	95.71	9832.89	8.40	538.00	47.5	0.591	-0.003	0.9741	-4.782
13.095	47.81	96.69	9828.10	8.40	538.00	47.5	0.597	-0.003	0.9740	-4.781
13.195	47.81	97.66	9823.32	8.40	538.00	47.6	0.603	-0.003	0.9740	-4.781
13.295	47.81	98.63	9818.54	8.39	537.99	47.6	0.609	-0.003	0.9739	-4.781
13.395	47.80	99.61	9813.76	8.39	537.99	47.6	0.615	-0.002	0.4382	-2.151
13.44	47.80	100.05	9811.61	8.39	537.99	47.6	0.618	-0.002	0.5843	-2.868
13.5										

FLOW IN THE 20' VERTICAL SECTION OF PIPE

Q_o= 47.80 ft^3/sec
V_o= 9.738 ft/sec
z_o= 8.39 ft
Ꝟ_o= 9811.38 ft^3

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(p_{elbow2}/\gamma - h - (f*(h)/D) * Q^2/(2g\ A^2)) * A * (g/(100+44+h)) * dt$

$p_{elbow2}/\gamma = z + H_{pump} - 44 - (f*(100+44)/D + k_{Lentrance} + 3*k_{Lelbow}) * Q^2/(2g\ A^2) - Q^2/(2gA^2)$

$h(t)=h_{prev.} + dh$ $dh=(Q/A)*dt$

$\text{Ꝟ}(t)=\text{Ꝟ}_{prev.} + d\text{Ꝟ}$ $d\text{Ꝟ}=(Q_{inflow}-Q)*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t) = -9.5E-09\text{Ꝟ}^2 + 0.00098\text{Ꝟ} - 0.3151$

t (sec)	Q (cfs)	h (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow2}/γ	dQ	dh	dꝞ
13.445	47.80	0.00	9811.38	8.39	537.99	47.6	-0.177	-0.011	0.5356	-2.629
13.5	47.79	0.54	9808.75	8.38	537.98	47.6	0.648	0.006	0.4868	-2.389
13.55	47.80	1.02	9806.36	8.38	537.98	47.6	0.628	-0.022	0.4868	-2.390
13.6	47.77	1.51	9803.97	8.38	537.98	47.6	0.690	-0.045	0.4866	-2.389
13.65	47.73	2.00	9801.58	8.38	537.98	47.7	0.820	-0.064	0.4862	-2.386
13.7	47.66	2.48	9799.20	8.38	537.98	47.9	1.005	-0.080	0.4855	-2.383
13.75	47.58	2.97	9796.81	8.37	537.97	48.1	1.237	-0.094	0.4847	-2.379
13.8	47.49	3.45	9794.43	8.37	537.97	48.3	1.508	-0.105	0.4837	-2.375
13.85	47.38	3.94	9792.06	8.37	537.97	48.6	1.810	-0.115	0.4827	-2.369
13.9	47.27	4.42	9789.69	8.37	537.97	48.9	2.139	-0.123	0.4815	-2.363
13.95	47.15	4.90	9787.33	8.37	537.97	49.2	2.489	-0.129	0.4802	-2.357
14	47.02	5.38	9784.97	8.36	537.96	49.5	2.857	-0.135	0.4789	-2.351
14.05	46.88	5.86	9782.62	8.36	537.96	49.8	3.240	-0.140	0.4775	-2.344
14.1	46.74	6.34	9780.27	8.36	537.96	50.1	3.634	-0.144	0.4761	-2.337
14.15	46.60	6.81	9777.94	8.36	537.96	50.5	4.038	-0.147	0.4746	-2.330
14.2	46.45	7.29	9775.61	8.36	537.96	50.8	4.450	-0.150	0.4731	-2.323
14.25	46.30	7.76	9773.29	8.36	537.96	51.2	4.869	-0.153	0.4716	-2.315
14.3	46.15	8.23	9770.97	8.35	537.95	51.5	5.292	-0.155	0.4701	-2.307
14.35	45.99	8.70	9768.66	8.35	537.95	51.9	5.719	-0.157	0.4685	-2.300
14.4	45.84	9.17	9766.36	8.35	537.95	52.2	6.149	-0.159	0.4669	-2.292
14.45	45.68	9.64	9764.07	8.35	537.95	52.6	6.581	-0.160	0.4653	-2.284
14.5	45.52	10.10	9761.79	8.35	537.95	53.0	7.015	-0.161	0.4636	-2.276
14.55	45.36	10.57	9759.51	8.34	537.94	53.3	7.450	-0.162	0.4620	-2.268
14.6	45.19	11.03	9757.24	8.34	537.94	53.7	7.885	-0.163	0.4603	-2.260
14.65	45.03	11.49	9754.98	8.34	537.94	54.0	8.321	-0.164	0.4587	-2.252
14.7	44.87	11.95	9752.73	8.34	537.94	54.4	8.757	-0.165	0.4570	-2.243
14.75	44.70	12.40	9750.49	8.34	537.94	54.8	9.193	-0.166	0.4553	-2.235
14.8	44.54	12.86	9748.25	8.34	537.94	55.1	9.628	-0.166	0.4536	-2.227
14.85	44.37	13.31	9746.03	8.33	537.93	55.5	10.062	-0.167	0.4519	-2.218
14.9	44.20	13.77	9743.81	8.33	537.93	55.9	10.496	-0.167	0.4502	-2.210
14.95	44.03	14.22	9741.60	8.33	537.93	56.2	10.928	-0.168	0.4485	-2.202
15	43.87	14.66	9739.40	8.33	537.93	56.6	11.359	-0.168	0.4468	-2.193
15.05	43.70	15.11	9737.20	8.33	537.93	56.9	11.789	-0.169	0.4451	-2.185
15.1	43.53	15.56	9735.02	8.32	537.92	57.3	12.218	-0.169	0.4434	-2.176
15.15	43.36	16.00	9732.84	8.32	537.92	57.7	12.646	-0.170	0.4417	-2.168
15.2	43.19	16.44	9730.67	8.32	537.92	58.0	13.072	-0.170	0.4399	-2.160
15.25	43.02	16.88	9728.52	8.32	537.92	58.4	13.496	-0.170	0.4382	-2.151
15.3	42.85	17.32	9726.36	8.32	537.92	58.7	13.919	-0.171	0.4365	-2.142
15.35	42.68	17.76	9724.22	8.32	537.92	59.1	14.341	-0.171	0.4347	-2.134
15.4	42.51	18.19	9722.09	8.31	537.91	59.4	14.761	-0.172	0.4330	-2.125
15.45	42.34	18.62	9719.96	8.31	537.91	59.8	15.179	-0.172	0.4312	-2.117
15.5	42.16	19.05	9717.85	8.31	537.91	60.1	15.596	-0.172	0.4295	-2.108
15.55	41.99	19.48	9715.74	8.31	537.91	60.5	16.011	-0.172	0.4277	-2.100
15.6	41.82	19.91	9713.64	8.31	537.91	60.8	16.424	-0.035	0.0852	-0.418
15.61	41.79	20.00	9713.22	8.31	537.91	60.9	16.506	-0.173	0.4256	-2.089
15.66										

TIME TO REACH STEADY STATE

Q_o=	41.79 ft^3/sec
V_o=	8.512 ft/sec
z_o=	8.31 ft
Ꝟ$_o$=	9713.22 ft^3

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(p_{elbow2}/\gamma - 20 - (f^*(20)/D+k_{Lelbow}) * Q^2/(2g\ A^2)) * A * (g/(100+44+20)) * dt$

$p_{elbow2}/\gamma = z + H_{pump} - 44 - (f^*(100+44)/D + k_{Lentrance} + 3^*k_{Lelbow}) * Q^2/(2g\ A^2) - Q^2/(2gA^2)$

$h(t)=h_{prev.} + dh$ dh=0

Ꝟ(t)=Ꝟ$_{prev.}$ + dꝞ dꝞ=(Q_{inflow}-Q)*dt (Assume Q_{inflow}, the flow into the pump station, is zero)

z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151

t (sec)	Q (cfs)	h (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow2}/γ	dQ	dh	dꝞ
15.61	41.79	20.00	9713.22	8.31	537.91	60.9	15.898	-0.161	0.0000	-1.671
15.65	41.62	20.00	9711.55	8.31	537.91	61.2	16.890	-0.154	0.0000	-2.081
15.7	41.47	20.00	9709.47	8.30	537.90	61.5	17.254	-0.136	0.0000	-2.074
15.75	41.33	20.00	9707.39	8.30	537.90	61.7	17.574	-0.121	0.0000	-2.067
15.8	41.21	20.00	9705.33	8.30	537.90	62.0	17.857	-0.107	0.0000	-2.061
15.85	41.11	20.00	9703.27	8.30	537.90	62.2	18.107	-0.095	0.0000	-2.055
15.9	41.01	20.00	9701.21	8.30	537.90	62.4	18.327	-0.084	0.0000	-2.051
15.95	40.93	20.00	9699.16	8.30	537.90	62.5	18.522	-0.075	0.0000	-2.046
16	40.85	20.00	9697.11	8.29	537.89	62.7	18.695	-0.067	0.0000	-2.043
16.05	40.78	20.00	9695.07	8.29	537.89	62.8	18.848	-0.059	0.0000	-2.039
16.1	40.73	20.00	9693.03	8.29	537.89	62.9	18.983	-0.053	0.0000	-2.036
16.15	40.67	20.00	9691.00	8.29	537.89	63.0	19.104	-0.047	0.0000	-2.034
16.2	40.63	20.00	9688.96	8.29	537.89	63.1	19.210	-0.042	0.0000	-2.031
16.25	40.58	20.00	9686.93	8.29	537.89	63.2	19.305	-0.037	0.0000	-2.029
16.3	40.55	20.00	9684.90	8.29	537.89	63.3	19.389	-0.033	0.0000	-2.027
16.35	40.51	20.00	9682.87	8.28	537.88	63.3	19.464	-0.030	0.0000	-2.026
16.4	40.48	20.00	9680.85	8.28	537.88	63.4	19.530	-0.026	0.0000	-2.024
16.45	40.46	20.00	9678.82	8.28	537.88	63.4	19.589	-0.024	0.0000	-2.023
16.5	40.43	20.00	9676.80	8.28	537.88	63.5	19.641	-0.021	0.0000	-2.022
16.55	40.41	20.00	9674.78	8.28	537.88	63.5	19.688	-0.019	0.0000	-2.021
16.6	40.39	20.00	9672.76	8.28	537.88	63.6	19.729	-0.017	0.0000	-2.020
16.65	40.38	20.00	9670.74	8.27	537.87	63.6	19.766	-0.015	0.0000	-2.019
16.7	40.36	20.00	9668.72	8.27	537.87	63.6	19.799	-0.013	0.0000	-2.018
16.75	40.35	20.00	9666.70	8.27	537.87	63.6	19.828	-0.012	0.0000	-2.017
16.8	40.34	20.00	9664.69	8.27	537.87	63.7	19.854	-0.011	0.0000	-2.017
16.85	40.33	20.00	9662.67	8.27	537.87	63.7	19.877	-0.010	0.0000	-2.016
16.9	40.32	20.00	9660.65	8.27	537.87	63.7	19.898	-0.009	0.0000	-2.016
16.95	40.31	20.00	9658.64	8.26	537.86	63.7	19.916	-0.008	0.0000	-2.015
17	40.30	20.00	9656.62	8.26	537.86	63.7	19.932	-0.007	0.0000	-2.015
17.05	40.29	20.00	9654.61	8.26	537.86	63.7	19.947	-0.006	0.0000	-2.015
17.1	40.29	20.00	9652.59	8.26	537.86	63.8	19.959	-0.006	0.0000	-2.014
17.15	40.28	20.00	9650.58	8.26	537.86	63.8	19.971	-0.005	0.0000	-2.014
17.2	40.27	20.00	9648.56	8.26	537.86	63.8	19.981	-0.005	0.0000	-2.014
17.25	40.27	20.00	9646.55	8.25	537.85	63.8	19.990	-0.004	0.0000	-2.013
17.3	40.27	20.00	9644.54	8.25	537.85	63.8	19.998	-0.004	0.0000	-2.013
17.35	40.26	20.00	9642.52	8.25	537.85	63.8	20.005	-0.004	0.0000	-2.013
17.4	40.26	20.00	9640.51	8.25	537.85	63.8	20.012	-0.003	0.0000	-2.013
17.45	40.25	20.00	9638.50	8.25	537.85	63.8	20.018	-0.003	0.0000	-2.013
17.5	40.25	20.00	9636.48	8.25	537.85	63.8	20.023	-0.003	0.0000	-2.013
17.55	40.25	20.00	9634.47	8.24	537.84	63.8	20.027	-0.002	0.0000	-2.012
17.6	40.25	20.00	9632.46	8.24	537.84	63.8	20.031	-0.002	0.0000	-2.012
17.65	40.24	20.00	9630.45	8.24	537.84	63.8	20.035	-0.002	0.0000	-2.012
17.7	40.24	20.00	9628.43	8.24	537.84	63.8	20.038	-0.002	0.0000	-2.012
17.75	40.24	20.00	9626.42	8.24	537.84	63.8	20.041	-0.002	0.0000	-2.012
17.8	40.24	20.00	9624.41	8.24	537.84	63.8	20.043	-0.002	0.0000	-2.012
17.85	40.24	20.00	9622.40	8.24	537.84	63.8	20.046	-0.002	0.0000	-2.012
17.9	40.24	20.00	9620.39	8.23	537.83	63.8	20.048	-0.001	0.0000	-2.012
17.95	40.23	20.00	9618.38	8.23	537.83	63.9	20.049	-0.001	0.0000	-2.012
18	40.23	20.00	9616.36	8.23	537.83	63.9	20.051	-0.001	0.0000	-2.012
18.05	40.23	20.00	9614.35	8.23	537.83	63.9	20.052	0.001	0.0000	2.012
18	40.23	20.00	9616.36	8.23	537.83	63.9	20.051	-0.013	0.0000	-20.116
18.5	40.22	20.00	9596.25	8.21	537.81	63.9	20.065	-0.006	0.0000	-20.110
19	40.21	20.00	9576.14	8.20	537.80	63.9	20.064	-0.007	0.0000	-20.106
19.5	40.21	20.00	9556.03	8.18	537.78	63.9	20.064	-0.007	0.0000	-20.103
20	40.20	20.00	9535.93	8.17	537.77	63.9	20.064	-0.007	0.0000	-20.099

20.5	40.19	20.00	9515.83	8.15	537.75	63.9	20.064	-0.007	0.0000	-20.096
21	40.18	20.00	9495.73	8.13	537.73	63.9	20.064	-0.007	0.0000	-20.092
21.5	40.18	20.00	9475.64	8.12	537.72	64.0	20.064	-0.007	0.0000	-20.089
22	40.17	20.00	9455.55	8.10	537.70	64.0	20.064	-0.007	0.0000	-20.085
22.5	40.16	20.00	9435.47	8.09	537.69	64.0	20.064	-0.007	0.0000	-20.082
23	40.16	20.00	9415.39	8.07	537.67	64.0	20.063	-0.007	0.0000	-20.078
23.5	40.15	20.00	9395.31	8.05	537.65	64.0	20.063	-0.007	0.0000	-20.074
24	40.14	20.00	9375.23	8.04	537.64	64.0	20.063	-0.007	0.0000	-20.071
24.5	40.13	20.00	9355.16	8.02	537.62	64.0	20.063	-0.007	0.0000	-20.067
25	40.13	20.00	9335.10	8.01	537.61	64.0	20.063	-0.007	0.0000	-20.064
25.5	40.12	20.00	9315.03	7.99	537.59	64.1	20.063	-0.007	0.0000	-20.060
26	40.11	20.00	9294.97	7.97	537.57	64.1	20.063	-0.007	0.0000	-20.057
26.5	40.11	20.00	9274.91	7.96	537.56	64.1	20.063	-0.007	0.0000	-20.053
27	40.10	20.00	9254.86	7.94	537.54	64.1	20.063	-0.007	0.0000	-20.050
27.5	40.09	20.00	9234.81	7.92	537.52	64.1	20.063	-0.007	0.0000	-20.046
28	40.08	20.00	9214.77	7.91	537.51	64.1	20.063	-0.007	0.0000	-20.042
28.5	40.08	20.00	9194.72	7.89	537.49	64.1	20.063	-0.007	0.0000	-20.039
29	40.07	20.00	9174.68	7.88	537.48	64.2	20.063	-0.007	0.0000	-20.035
29.5	40.06	20.00	9154.65	7.86	537.46	64.2	20.063	-0.007	0.0000	-20.032
30	40.06	20.00	9134.62	7.84	537.44	64.2	20.063	-0.007	0.0000	-20.028
30.5	40.05	20.00	9114.59	7.83	537.43	64.2	20.063	-0.007	0.0000	-20.025
31	40.04	20.00	9094.56	7.81	537.41	64.2	20.063	-0.007	0.0000	-20.021
31.5	40.03	20.00	9074.54	7.80	537.40	64.2	20.063	-0.007	0.0000	-20.017
32	40.03	20.00	9054.53	7.78	537.38	64.2	20.063	-0.007	0.0000	-20.014
32.5	40.02	20.00	9034.51	7.76	537.36	64.2	20.063	-0.007	0.0000	-20.010
33	40.01	20.00	9014.50	7.75	537.35	64.3	20.063	-0.007	0.0000	-20.007
33.5	40.01	20.00	8994.50	7.73	537.33	64.3	20.063	-0.007	0.0000	-20.003
34	40.00	20.00	8974.49	7.71	537.31	64.3	20.063	-0.007	0.0000	-20.000
34.5	39.99	20.00	8954.49	7.70	537.30	64.3	20.063	-0.007	0.0000	-19.996
35	39.98	20.00	8934.50	7.68	537.28	64.3	20.063	-0.007	0.0000	-19.992
35.5	39.98	20.00	8914.50	7.67	537.27	64.3	20.063	-0.007	0.0000	-19.989
36	39.97	20.00	8894.52	7.65	537.25	64.3	20.063	-0.007	0.0000	-19.985
36.5	39.96	20.00	8874.53	7.63	537.23	64.4	20.063	-0.007	0.0000	-19.982
37	39.96	20.00	8854.55	7.62	537.22	64.4	20.062	-0.007	0.0000	-19.978
37.5	39.95	20.00	8834.57	7.60	537.20	64.4	20.062	-0.007	0.0000	-19.974
38	39.94	20.00	8814.60	7.59	537.19	64.4	20.062	-0.007	0.0000	-19.971
38.5	39.93	20.00	8794.63	7.57	537.17	64.4	20.062	-0.007	0.0000	-19.967
39	39.93	20.00	8774.66	7.55	537.15	64.4	20.062	-0.007	0.0000	-19.964
39.5	39.92	20.00	8754.70	7.54	537.14	64.4	20.062	-0.007	0.0000	-19.960
40	39.91	20.00	8734.74	7.52	537.12	64.4	20.062	-0.007	0.0000	-19.956
40.5	39.91	20.00	8714.78	7.50	537.10	64.5	20.062	-0.007	0.0000	-19.953
41	39.90	20.00	8694.83	7.49	537.09	64.5	20.062	-0.007	0.0000	-19.949
41.5	39.89	20.00	8674.88	7.47	537.07	64.5	20.062	-0.007	0.0000	-19.946
42	39.88	20.00	8654.93	7.46	537.06	64.5	20.062	-0.007	0.0000	-19.942
42.5	39.88	20.00	8634.99	7.44	537.04	64.5	20.062	-0.007	0.0000	-19.938
43	39.87	20.00	8615.05	7.42	537.02	64.5	20.062	-0.007	0.0000	-19.935
43.5	39.86	20.00	8595.12	7.41	537.01	64.5	20.062	-0.007	0.0000	-19.931
44	39.85	20.00	8575.19	7.39	536.99	64.6	20.062	-0.007	0.0000	-19.927
44.5	39.85	20.00	8555.26	7.37	536.97	64.6	20.062	-0.007	0.0000	-19.924
45	39.84	20.00	8535.33	7.36	536.96	64.6	20.062	-0.007	0.0000	-19.920
45.5	39.83	20.00	8515.41	7.34	536.94	64.6	20.062	-0.007	0.0000	-19.917
46	39.83	20.00	8495.50	7.32	536.92	64.6	20.062	-0.007	0.0000	-19.913
46.5	39.82	20.00	8475.59	7.31	536.91	64.6	20.062	-0.007	0.0000	-19.909
47	39.81	20.00	8455.68	7.29	536.89	64.6	20.062	-0.007	0.0000	-19.906
47.5	39.80	20.00	8435.77	7.28	536.88	64.6	20.062	-0.007	0.0000	-19.902
48	39.80	20.00	8415.87	7.26	536.86	64.7	20.062	-0.007	0.0000	-19.898
48.5	39.79	20.00	8395.97	7.24	536.84	64.7	20.062	-0.007	0.0000	-19.895
49	39.78	20.00	8376.08	7.23	536.83	64.7	20.062	-0.007	0.0000	-19.891
49.5	39.77	20.00	8356.18	7.21	536.81	64.7	20.062	-0.007	0.0000	-19.887
50	39.77	20.00	8336.30	7.19	536.79	64.7	20.062	-0.007	0.0000	-19.884
50.5	39.76	20.00	8316.41	7.18	536.78	64.7	20.062	-0.007	0.0000	-19.880
51	39.75	20.00	8296.53	7.16	536.76	64.7	20.061	-0.007	0.0000	-19.876
51.5	39.75	20.00	8276.66	7.15	536.75	64.8	20.061	-0.007	0.0000	-19.873
52	39.74	20.00	8256.78	7.13	536.73	64.8	20.061	-0.007	0.0000	-19.869
52.5	39.73	20.00	8236.91	7.11	536.71	64.8	20.061	-0.007	0.0000	-19.865
53	39.72	20.00	8217.05	7.10	536.70	64.8	20.061	-0.007	0.0000	-19.862
53.5	39.72	20.00	8197.19	7.08	536.68	64.8	20.061	-0.007	0.0000	-19.858
54	39.71	20.00	8177.33	7.06	536.66	64.8	20.061	-0.007	0.0000	-19.854
54.5	39.70	20.00	8157.47	7.05	536.65	64.8	20.061	-0.007	0.0000	-19.851
55	39.69	20.00	8137.62	7.03	536.63	64.8	20.061	-0.007	0.0000	-19.847
55.5	39.69	20.00	8117.78	7.01	536.61	64.9	20.061	-0.007	0.0000	-19.843
56	39.68	20.00	8097.93	7.00	536.60	64.9	20.061	-0.007	0.0000	-19.840
56.5	39.67	20.00	8078.09	6.98	536.58	64.9	20.061	-0.007	0.0000	-19.836
57	39.66	20.00	8058.26	6.97	536.57	64.9	20.061	-0.007	0.0000	-19.832
57.5	39.66	20.00	8038.43	6.95	536.55	64.9	20.061	-0.007	0.0000	-19.829
58	39.65	20.00	8018.60	6.93	536.53	64.9	20.061	-0.007	0.0000	-19.825

58.5	39.64	20.00	7998.77	6.92	536.52	64.9	20.061	-0.007	0.0000	-19.821
59	39.64	20.00	7978.95	6.90	536.50	65.0	20.061	-0.007	0.0000	-19.818
59.5	39.63	20.00	7959.13	6.88	536.48	65.0	20.061	-0.007	0.0000	-19.814
60	39.62	20.00	7939.32	6.87	536.47	65.0	20.061	-0.007	0.0000	-19.810
60.5	39.61	20.00	7919.51	6.85	536.45	65.0	20.061	-0.007	0.0000	-19.807
61	39.61	20.00	7899.70	6.83	536.43	65.0	20.061	-0.007	0.0000	-19.803
61.5	39.60	20.00	7879.90	6.82	536.42	65.0	20.061	-0.007	0.0000	-19.799
62	39.59	20.00	7860.10	6.80	536.40	65.0	20.061	-0.007	0.0000	-19.796
62.5	39.58	20.00	7840.30	6.78	536.38	65.1	20.061	-0.007	0.0000	-19.792
63	39.58	20.00	7820.51	6.77	536.37	65.1	20.061	-0.007	0.0000	-19.788
63.5	39.57	20.00	7800.72	6.75	536.35	65.1	20.061	-0.007	0.0000	-19.784
64	39.56	20.00	7780.94	6.74	536.34	65.1	20.061	-0.007	0.0000	-19.781
64.5	39.55	20.00	7761.16	6.72	536.32	65.1	20.060	-0.007	0.0000	-19.777
65	39.55	20.00	7741.38	6.70	536.30	65.1	20.060	-0.007	0.0000	-19.773
65.5	39.54	20.00	7721.61	6.69	536.29	65.1	20.060	-0.007	0.0000	-19.770
66	39.53	20.00	7701.84	6.67	536.27	65.1	20.060	-0.007	0.0000	-19.766
66.5	39.52	20.00	7682.07	6.65	536.25	65.2	20.060	-0.007	0.0000	-19.762
67	39.52	20.00	7662.31	6.64	536.24	65.2	20.060	-0.007	0.0000	-19.759
67.5	39.51	20.00	7642.55	6.62	536.22	65.2	20.060	-0.007	0.0000	-19.755
68	39.50	20.00	7622.80	6.60	536.20	65.2	20.060	-0.007	0.0000	-19.751
68.5	39.49	20.00	7603.05	6.59	536.19	65.2	20.060	-0.007	0.0000	-19.747
69	39.49	20.00	7583.30	6.57	536.17	65.2	20.060	-0.007	0.0000	-19.744
69.5	39.48	20.00	7563.55	6.55	536.15	65.2	20.060	-0.007	0.0000	-19.740
70	39.47	20.00	7543.81	6.54	536.14	65.3	20.060	-0.007	0.0000	-19.736
70.5	39.46	20.00	7524.08	6.52	536.12	65.3	20.060	-0.007	0.0000	-19.732
71	39.46	20.00	7504.35	6.50	536.10	65.3	20.060	-0.007	0.0000	-19.729
71.5	39.45	20.00	7484.62	6.49	536.09	65.3	20.060	-0.007	0.0000	-19.725
72	39.44	20.00	7464.89	6.47	536.07	65.3	20.060	-0.007	0.0000	-19.721
72.5	39.44	20.00	7445.17	6.45	536.05	65.3	20.060	-0.007	0.0000	-19.718
73	39.43	20.00	7425.45	6.44	536.04	65.3	20.060	-0.007	0.0000	-19.714
73.5	39.42	20.00	7405.74	6.42	536.02	65.3	20.060	-0.007	0.0000	-19.710
74	39.41	20.00	7386.03	6.40	536.00	65.4	20.060	-0.007	0.0000	-19.706
74.5	39.41	20.00	7366.32	6.39	535.99	65.4	20.060	-0.007	0.0000	-19.703
75	39.40	20.00	7346.62	6.37	535.97	65.4	20.060	-0.007	0.0000	-19.699
75.5	39.39	20.00	7326.92	6.36	535.96	65.4	20.060	-0.008	0.0000	-19.695
76	39.38	20.00	7307.23	6.34	535.94	65.4	20.060	-0.008	0.0000	-19.691
76.5	39.38	20.00	7287.54	6.32	535.92	65.4	20.060	-0.008	0.0000	-19.688
77	39.37	20.00	7267.85	6.31	535.91	65.4	20.060	-0.008	0.0000	-19.684
77.5	39.36	20.00	7248.16	6.29	535.89	65.5	20.060	-0.008	0.0000	-19.680
78	39.35	20.00	7228.48	6.27	535.87	65.5	20.059	-0.008	0.0000	-19.676
78.5	39.35	20.00	7208.81	6.26	535.86	65.5	20.059	-0.008	0.0000	-19.673
79	39.34	20.00	7189.13	6.24	535.84	65.5	20.059	-0.008	0.0000	-19.669
79.5	39.33	20.00	7169.47	6.22	535.82	65.5	20.059	-0.008	0.0000	-19.665
80	39.32	20.00	7149.80	6.21	535.81	65.5	20.059	-0.008	0.0000	-19.661
80.5	39.31	20.00	7130.14	6.19	535.79	65.5	20.059	-0.008	0.0000	-19.657
81	39.31	20.00	7110.48	6.17	535.77	65.6	20.059	-0.008	0.0000	-19.654
81.5	39.30	20.00	7090.83	6.16	535.76	65.6	20.059	-0.008	0.0000	-19.650
82	39.29	20.00	7071.18	6.14	535.74	65.6	20.059	-0.008	0.0000	-19.646
82.5	39.28	20.00	7051.53	6.12	535.72	65.6	20.059	-0.008	0.0000	-19.642
83	39.28	20.00	7031.89	6.11	535.71	65.6	20.059	-0.008	0.0000	-19.639
83.5	39.27	20.00	7012.25	6.09	535.69	65.6	20.059	-0.008	0.0000	-19.635
84	39.26	20.00	6992.62	6.07	535.67	65.6	20.059	-0.008	0.0000	-19.631
84.5	39.25	20.00	6972.99	6.06	535.66	65.6	20.059	-0.008	0.0000	-19.627
85	39.25	20.00	6953.36	6.04	535.64	65.7	20.059	-0.008	0.0000	-19.623
85.5	39.24	20.00	6933.74	6.02	535.62	65.7	20.059	-0.008	0.0000	-19.620
86	39.23	20.00	6914.12	6.01	535.61	65.7	20.059	-0.008	0.0000	-19.616
86.5	39.22	20.00	6894.50	5.99	535.59	65.7	20.059	-0.008	0.0000	-19.612
87	39.22	20.00	6874.89	5.97	535.57	65.7	20.059	-0.008	0.0000	-19.608
87.5	39.21	20.00	6855.28	5.96	535.56	65.7	20.059	-0.008	0.0000	-19.605
88	39.20	20.00	6835.67	5.94	535.54	65.7	20.059	-0.008	0.0000	-19.601
88.5	39.19	20.00	6816.07	5.92	535.52	65.8	20.059	-0.008	0.0000	-19.597
89	39.19	20.00	6796.48	5.91	535.51	65.8	20.059	-0.008	0.0000	-19.593
89.5	39.18	20.00	6776.88	5.89	535.49	65.8	20.059	-0.008	0.0000	-19.589
90	39.17	20.00	6757.29	5.87	535.47	65.8	20.059	-0.008	0.0000	-19.586
90.5	39.16	20.00	6737.71	5.86	535.46	65.8	20.059	-0.008	0.0000	-19.582
91	39.16	20.00	6718.13	5.84	535.44	65.8	20.059	-0.008	0.0000	-19.578
91.5	39.15	20.00	6698.55	5.82	535.42	65.8	20.059	-0.008	0.0000	-19.574
92	39.14	20.00	6678.98	5.81	535.41	65.9	20.058	-0.008	0.0000	-19.570
92.5	39.13	20.00	6659.40	5.79	535.39	65.9	20.058	-0.008	0.0000	-19.566
93	39.13	20.00	6639.84	5.77	535.37	65.9	20.058	-0.008	0.0000	-19.563
93.5	39.12	20.00	6620.28	5.76	535.36	65.9	20.058	-0.008	0.0000	-19.559
94	39.11	20.00	6600.72	5.74	535.34	65.9	20.058	-0.008	0.0000	-19.555
94.5	39.10	20.00	6581.16	5.72	535.32	65.9	20.058	-0.008	0.0000	-19.551
95	39.09	20.00	6561.61	5.71	535.31	65.9	20.058	-0.008	0.0000	-19.547
95.5	39.09	20.00	6542.06	5.69	535.29	66.0	20.058	-0.008	0.0000	-19.544
96	39.08	20.00	6522.52	5.67	535.27	66.0	20.058	-0.008	0.0000	-19.540

96.5	39.07	20.00	6502.98	5.66	535.26	66.0	20.058	-0.008	0.0000	-19.536
97	39.06	20.00	6483.44	5.64	535.24	66.0	20.058	-0.008	0.0000	-19.532
97.5	39.06	20.00	6463.91	5.62	535.22	66.0	20.058	-0.008	0.0000	-19.528
98	39.05	20.00	6444.38	5.61	535.21	66.0	20.058	-0.008	0.0000	-19.524
98.5	39.04	20.00	6424.86	5.59	535.19	66.0	20.058	-0.008	0.0000	-19.521
99	39.03	20.00	6405.34	5.57	535.17	66.0	20.058	-0.008	0.0000	-19.517
99.5	39.03	20.00	6385.82	5.56	535.16	66.1	20.058	-0.008	0.0000	-19.513
100	39.02	20.00	6366.31	5.54	535.14	66.1	20.058	-0.008	0.0000	-19.509
100.5	39.01	20.00	6346.80	5.52	535.12	66.1	20.058	-0.008	0.0000	-19.505
101	39.00	20.00	6327.30	5.51	535.11	66.1	20.058	-0.008	0.0000	-19.501
101.5	38.99	20.00	6307.79	5.49	535.09	66.1	20.058	-0.008	0.0000	-19.497
102	38.99	20.00	6288.30	5.47	535.07	66.1	20.058	-0.008	0.0000	-19.494
102.5	38.98	20.00	6268.80	5.45	535.05	66.1	20.058	-0.008	0.0000	-19.490
103	38.97	20.00	6249.31	5.44	535.04	66.2	20.058	-0.008	0.0000	-19.486
103.5	38.96	20.00	6229.83	5.42	535.02	66.2	20.058	-0.008	0.0000	-19.482
104	38.96	20.00	6210.35	5.40	535.00	66.2	20.058	-0.002	0.0000	-3.896
104.1	38.95	20.00	6206.45	5.40	535.00	66.2	20.058	-0.008	0.0000	-19.477
104.6										

⇧

Pump shuts off

Appendix B

Pump Shutdown Calculations

PUMP SHUTDOWN

BEFORE COLUMN OF FLUID COMES TO REST

$g=$ 32.17 ft/sec^2
$f=$ 0.011 (assume constant for all Re)
$k_{Lelbow}=$ 0.1
$k_{Lentrance}=$ 6.3
$D=$ 2.5 ft
$A=$ 4.908739 ft^2

Assume the pump slows down linearly with time, from 66 TDH to 0.

$H_{pump}=$ =66. - t * 66./$t_{shutdown}$
$t_{shutdown}=$ 1.5 sec

$Q_o=$ 38.77 ft^3/sec
$V_o=$ 7.898 ft/sec
$z_o=$ 5.4 ft (pump shuts down at WSEL of 535 ft)
$Ꝟ_o=$ 6205 ft^3

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(p_{elbow2}/\gamma - 20 - (f*(20)/D+k_{Lelbow}) * Q^2/(2g\ A^2)) * A * (g/(100+44+20)) * dt$

$p_{elbow2}/\gamma = z + H_{pump} - 44 - (f*(100+44)/D + k_{Lentrance} + 3*k_{Lelbow}) * Q^2/(2g\ A^2) - Q^2/(2gA^2)$

$x(t)=x_{prev.} + dx$ $dx=0$

$Ꝟ(t)=Ꝟ_{prev.} + dꝞ$ $dꝞ=(Q_{inflow}-Q)*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151$ (valid for Ꝟ>6205 ft^3)

$z(t)=(1.17/1116)Ꝟ(t)- 1.105$ (valid for Ꝟ<6205 ft^3)

								-44			
t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow}/γ	p_{elbow2}/γ	dQ	dx	dꝞ
0	38.77	120.00	6205.00	5.40	535.00	66.0	19.94	19.417	-0.008	0.0000	-0.388
0.01	38.76	120.00	6204.61	5.40	535.00	65.6	19.50	18.980	-0.012	0.0000	-0.388
0.02	38.75	120.00	6204.22	5.40	535.00	65.1	19.07	18.545	-0.016	0.0000	-0.387
0.03	38.73	120.00	6203.84	5.40	535.00	64.7	18.63	18.111	-0.021	0.0000	-0.387
0.04	38.71	120.00	6203.45	5.40	535.00	64.2	18.20	17.679	-0.025	0.0000	-0.387
0.05	38.69	120.00	6203.06	5.40	535.00	63.8	17.77	17.249	-0.029	0.0000	-0.387
0.06	38.66	120.00	6202.68	5.40	535.00	63.4	17.34	16.820	-0.033	0.0000	-0.387
0.07	38.63	120.00	6202.29	5.40	535.00	62.9	16.91	16.393	-0.037	0.0000	-0.386
0.08	38.59	120.00	6201.90	5.40	535.00	62.5	16.49	15.968	-0.041	0.0000	-0.386
0.09	38.55	120.00	6201.52	5.40	535.00	62.0	16.06	15.545	-0.045	0.0000	-0.385
0.1	38.50	120.00	6201.13	5.40	535.00	61.6	15.64	15.123	-0.049	0.0000	-0.385
0.11	38.45	120.00	6200.75	5.40	535.00	61.2	15.22	14.703	-0.053	0.0000	-0.385
0.12	38.40	120.00	6200.36	5.40	535.00	60.7	14.80	14.284	-0.057	0.0000	-0.384
0.13	38.34	120.00	6199.98	5.39	534.99	60.3	14.38	13.867	-0.061	0.0000	-0.383
0.14	38.28	120.00	6199.59	5.39	534.99	59.8	13.96	13.451	-0.065	0.0000	-0.383
0.15	38.22	120.00	6199.21	5.39	534.99	59.4	13.55	13.038	-0.069	0.0000	-0.382
0.16	38.15	120.00	6198.83	5.39	534.99	59.0	13.13	12.625	-0.073	0.0000	-0.381
0.17	38.07	120.00	6198.45	5.39	534.99	58.5	12.72	12.215	-0.077	0.0000	-0.381
0.18	38.00	120.00	6198.07	5.39	534.99	58.1	12.31	11.805	-0.081	0.0000	-0.380
0.19	37.92	120.00	6197.69	5.39	534.99	57.6	11.90	11.398	-0.085	0.0000	-0.379
0.2	37.83	120.00	6197.31	5.39	534.99	57.2	11.49	10.992	-0.089	0.0000	-0.378
0.21	37.74	120.00	6196.93	5.39	534.99	56.8	11.08	10.587	-0.093	0.0000	-0.377
0.22	37.65	120.00	6196.55	5.39	534.99	56.3	10.68	10.184	-0.097	0.0000	-0.376
0.23	37.55	120.00	6196.18	5.39	534.99	55.9	10.27	9.782	-0.101	0.0000	-0.376
0.24	37.45	120.00	6195.80	5.39	534.99	55.4	9.87	9.382	-0.104	0.0000	-0.375
0.25	37.35	120.00	6195.43	5.39	534.99	55.0	9.47	8.983	-0.108	0.0000	-0.373
0.26	37.24	120.00	6195.05	5.39	534.99	54.6	9.07	8.585	-0.112	0.0000	-0.372
0.27	37.13	120.00	6194.68	5.39	534.99	54.1	8.67	8.189	-0.116	0.0000	-0.371
0.28	37.01	120.00	6194.31	5.39	534.99	53.7	8.27	7.794	-0.120	0.0000	-0.370
0.29	36.89	120.00	6193.94	5.39	534.99	53.2	7.87	7.401	-0.123	0.0000	-0.369
0.3	36.77	120.00	6193.57	5.39	534.99	52.8	7.48	7.009	-0.127	0.0000	-0.368
0.31	36.64	120.00	6193.20	5.39	534.99	52.4	7.09	6.618	-0.131	0.0000	-0.366
0.32	36.51	120.00	6192.84	5.39	534.99	51.9	6.69	6.228	-0.135	0.0000	-0.365
0.33	36.37	120.00	6192.47	5.39	534.99	51.5	6.30	5.840	-0.138	0.0000	-0.364
0.34	36.24	120.00	6192.11	5.39	534.99	51.0	5.91	5.453	-0.142	0.0000	-0.362
0.35	36.09	120.00	6191.74	5.39	534.99	50.6	5.52	5.067	-0.146	0.0000	-0.361
0.36	35.95	120.00	6191.38	5.39	534.99	50.2	5.13	4.683	-0.150	0.0000	-0.359
0.37	35.80	120.00	6191.02	5.39	534.99	49.7	4.75	4.299	-0.153	0.0000	-0.358
0.38	35.65	120.00	6190.67	5.39	534.99	49.3	4.36	3.917	-0.157	0.0000	-0.356
0.39	35.49	120.00	6190.31	5.38	534.98	48.8	3.97	3.536	-0.160	0.0000	-0.355
0.4	35.33	120.00	6189.95	5.38	534.98	48.4	3.59	3.156	-0.164	0.0000	-0.353
0.41	35.16	120.00	6189.60	5.38	534.98	48.0	3.21	2.777	-0.168	0.0000	-0.352
0.42	35.00	120.00	6189.25	5.38	534.98	47.5	2.83	2.399	-0.171	0.0000	-0.350
0.43	34.83	120.00	6188.90	5.38	534.98	47.1	2.44	2.022	-0.175	0.0000	-0.348
0.44	34.65	120.00	6188.55	5.38	534.98	46.6	2.06	1.647	-0.179	0.0000	-0.347
0.45	34.47	120.00	6188.21	5.38	534.98	46.2	1.69	1.272	-0.182	0.0000	-0.345
0.46	34.29	120.00	6187.86	5.38	534.98	45.8	1.31	0.898	-0.186	0.0000	-0.343
0.47	34.10	120.00	6187.52	5.38	534.98	45.3	0.93	0.525	-0.189	0.0000	-0.341
0.48	33.91	120.00	6187.18	5.38	534.98	44.9	0.55	0.153	-0.193	0.0000	-0.339
0.49	33.72	120.00	6186.84	5.38	534.98	44.4	0.18	-0.218	-0.196	0.0000	-0.337
0.5	33.52	120.00	6186.50	5.38	534.98	44.0	-0.20	-0.588	-0.200	0.0000	-0.335
0.51	33.32	120.00	6186.16	5.38	534.98	43.6	-0.57	-0.957	-0.204	0.0000	-0.333
0.52	33.12	120.00	6185.83	5.38	534.98	43.1	-0.94	-1.326	-0.207	0.0000	-0.331
0.53	32.91	120.00	6185.50	5.38	534.98	42.7	-1.32	-1.694	-0.211	0.0000	-0.329
0.54	32.70	120.00	6185.17	5.38	534.98	42.2	-1.69	-2.061	-0.214	0.0000	-0.327

0.55	32.49	120.00	6184.84	5.38	534.98	41.8	-2.06	-2.427	-0.218	0.0000	-0.325
0.56	32.27	120.00	6184.52	5.38	534.98	41.4	-2.43	-2.792	-0.221	0.0000	-0.323
0.57	32.05	120.00	6184.20	5.38	534.98	40.9	-2.80	-3.157	-0.225	0.0000	-0.321
0.58	31.83	120.00	6183.88	5.38	534.98	40.5	-3.17	-3.521	-0.228	0.0000	-0.318
0.59	31.60	120.00	6183.56	5.38	534.98	40.0	-3.54	-3.885	-0.232	0.0000	-0.316
0.6	31.37	120.00	6183.24	5.38	534.98	39.6	-3.91	-4.248	-0.235	0.0000	-0.314
0.61	31.13	120.00	6182.93	5.38	534.98	39.2	-4.27	-4.610	-0.238	0.0000	-0.311
0.62	30.89	120.00	6182.62	5.38	534.98	38.7	-4.64	-4.972	-0.242	0.0000	-0.309
0.63	30.65	120.00	6182.31	5.38	534.98	38.3	-5.01	-5.333	-0.245	0.0000	-0.307
0.64	30.41	120.00	6182.00	5.38	534.98	37.8	-5.37	-5.694	-0.249	0.0000	-0.304
0.65	30.16	120.00	6181.70	5.38	534.98	37.4	-5.74	-6.054	-0.252	0.0000	-0.302
0.66	29.90	120.00	6181.40	5.38	534.98	37.0	-6.10	-6.414	-0.256	0.0000	-0.299
0.67	29.65	120.00	6181.10	5.38	534.98	36.5	-6.47	-6.773	-0.259	0.0000	-0.296
0.68	29.39	120.00	6180.80	5.37	534.97	36.1	-6.83	-7.132	-0.263	0.0000	-0.294
0.69	29.13	120.00	6180.51	5.37	534.97	35.6	-7.20	-7.491	-0.266	0.0000	-0.291
0.7	28.86	120.00	6180.22	5.37	534.97	35.2	-7.56	-7.850	-0.269	0.0000	-0.289
0.71	28.59	120.00	6179.93	5.37	534.97	34.8	-7.92	-8.208	-0.273	0.0000	-0.286
0.72	28.32	120.00	6179.64	5.37	534.97	34.3	-8.29	-8.565	-0.276	0.0000	-0.283
0.73	28.04	120.00	6179.36	5.37	534.97	33.9	-8.65	-8.923	-0.280	0.0000	-0.280
0.74	27.76	120.00	6179.08	5.37	534.97	33.4	-9.01	-9.280	-0.283	0.0000	-0.278
0.75	27.48	120.00	6178.80	5.37	534.97	33.0	-9.37	-9.638	-0.287	0.0000	-0.275
0.76	27.19	120.00	6178.52	5.37	534.97	32.6	-9.74	-9.995	-0.290	0.0000	-0.272
0.77	26.90	120.00	6178.25	5.37	534.97	32.1	-10.10	-10.352	-0.293	0.0000	-0.269
0.78	26.61	120.00	6177.98	5.37	534.97	31.7	-10.46	-10.709	-0.297	0.0000	-0.266
0.79	26.31	120.00	6177.72	5.37	534.97	31.2	-10.82	-11.065	-0.300	0.0000	-0.263
0.8	26.01	120.00	6177.45	5.37	534.97	30.8	-11.19	-11.422	-0.304	0.0000	-0.260
0.81	25.71	120.00	6177.19	5.37	534.97	30.4	-11.55	-11.779	-0.307	0.0000	-0.257
0.82	25.40	120.00	6176.94	5.37	534.97	29.9	-11.91	-12.136	-0.310	0.0000	-0.254
0.83	25.09	120.00	6176.68	5.37	534.97	29.5	-12.27	-12.493	-0.314	0.0000	-0.251
0.84	24.78	120.00	6176.43	5.37	534.97	29.0	-12.64	-12.850	-0.317	0.0000	-0.248
0.85	24.46	120.00	6176.18	5.37	534.97	28.6	-13.00	-13.208	-0.321	0.0000	-0.245
0.86	24.14	120.00	6175.94	5.37	534.97	28.2	-13.36	-13.565	-0.324	0.0000	-0.241
0.87	23.82	120.00	6175.70	5.37	534.97	27.7	-13.73	-13.923	-0.328	0.0000	-0.238
0.88	23.49	120.00	6175.46	5.37	534.97	27.3	-14.09	-14.281	-0.331	0.0000	-0.235
0.89	23.16	120.00	6175.23	5.37	534.97	26.8	-14.45	-14.639	-0.334	0.0000	-0.232
0.9	22.82	120.00	6174.99	5.37	534.97	26.4	-14.82	-14.998	-0.338	0.0000	-0.228
0.91	22.49	120.00	6174.77	5.37	534.97	26.0	-15.18	-15.357	-0.341	0.0000	-0.225
0.92	22.14	120.00	6174.54	5.37	534.97	25.5	-15.55	-15.716	-0.345	0.0000	-0.221
0.93	21.80	120.00	6174.32	5.37	534.97	25.1	-15.91	-16.076	-0.348	0.0000	-0.218
0.94	21.45	120.00	6174.10	5.37	534.97	24.6	-16.28	-16.436	-0.352	0.0000	-0.215
0.95	21.10	120.00	6173.89	5.37	534.97	24.2	-16.64	-16.797	-0.355	0.0000	-0.211
0.96	20.74	120.00	6173.68	5.37	534.97	23.8	-17.01	-17.158	-0.358	0.0000	-0.207
0.97	20.39	120.00	6173.47	5.37	534.97	23.3	-17.38	-17.520	-0.362	0.0000	-0.204
0.98	20.02	120.00	6173.26	5.37	534.97	22.9	-17.74	-17.883	-0.365	0.0000	-0.200
0.99	19.66	120.00	6173.06	5.37	534.97	22.4	-18.11	-18.246	-0.369	0.0000	-0.197
1	19.29	120.00	6172.87	5.37	534.97	22.0	-18.48	-18.610	-0.372	0.0000	-0.193
1.01	18.92	120.00	6172.67	5.37	534.97	21.6	-18.85	-18.974	-0.376	0.0000	-0.189
1.02	18.54	120.00	6172.49	5.37	534.97	21.1	-19.22	-19.340	-0.379	0.0000	-0.185
1.03	18.16	120.00	6172.30	5.37	534.97	20.7	-19.59	-19.706	-0.383	0.0000	-0.182
1.04	17.78	120.00	6172.12	5.37	534.97	20.2	-19.96	-20.073	-0.386	0.0000	-0.178
1.05	17.39	120.00	6171.94	5.37	534.97	19.8	-20.34	-20.441	-0.390	0.0000	-0.174
1.06	17.00	120.00	6171.77	5.37	534.97	19.4	-20.71	-20.810	-0.393	0.0000	-0.170
1.07	16.61	120.00	6171.60	5.37	534.97	18.9	-21.08	-21.180	-0.397	0.0000	-0.166
1.08	16.21	120.00	6171.43	5.37	534.97	18.5	-21.46	-21.551	-0.401	0.0000	-0.162
1.09	15.81	120.00	6171.27	5.36	534.96	18.0	-21.84	-21.923	-0.404	0.0000	-0.158
1.1	15.41	120.00	6171.11	5.36	534.96	17.6	-22.21	-22.296	-0.408	0.0000	-0.154
1.11	15.00	120.00	6170.96	5.36	534.96	17.2	-22.59	-22.671	-0.411	0.0000	-0.150
1.12	14.59	120.00	6170.81	5.36	534.96	16.7	-22.97	-23.046	-0.415	0.0000	-0.146
1.13	14.17	120.00	6170.66	5.36	534.96	16.3	-23.35	-23.423	-0.418	0.0000	-0.142
1.14	13.76	120.00	6170.52	5.36	534.96	15.8	-23.73	-23.801	-0.422	0.0000	-0.138
1.15	13.33	120.00	6170.38	5.36	534.96	15.4	-24.12	-24.180	-0.426	0.0000	-0.133
1.16	12.91	120.00	6170.25	5.36	534.96	15.0	-24.50	-24.561	-0.429	0.0000	-0.129
1.17	12.48	120.00	6170.12	5.36	534.96	14.5	-24.89	-24.943	-0.433	0.0000	-0.125
1.18	12.05	120.00	6169.99	5.36	534.96	14.1	-25.28	-25.327	-0.437	0.0000	-0.120
1.19	11.61	120.00	6169.87	5.36	534.96	13.6	-25.67	-25.712	-0.440	0.0000	-0.116
1.2	11.17	120.00	6169.76	5.36	534.96	13.2	-26.06	-26.099	-0.444	0.0000	-0.112
1.21	10.73	120.00	6169.65	5.36	534.96	12.8	-26.45	-26.488	-0.448	0.0000	-0.107
1.22	10.28	120.00	6169.54	5.36	534.96	12.3	-26.84	-26.878	-0.452	0.0000	-0.103
1.23	9.83	120.00	6169.44	5.36	534.96	11.9	-27.24	-27.270	-0.455	0.0000	-0.098
1.24	9.37	120.00	6169.34	5.36	534.96	11.4	-27.63	-27.663	-0.459	0.0000	-0.094
1.25	8.91	120.00	6169.24	5.36	534.96	11.0	-28.03	-28.059	-0.463	0.0000	-0.089
1.26	8.45	120.00	6169.15	5.36	534.96	10.6	-28.43	-28.456	-0.467	0.0000	-0.084
1.27	7.98	120.00	6169.07	5.36	534.96	10.1	-28.83	-28.856	-0.471	0.0000	-0.080
1.28	7.51	120.00	6168.99	5.36	534.96	9.7	-29.24	-29.257	-0.474	0.0000	-0.075
1.29	7.04	120.00	6168.92	5.36	534.96	9.2	-29.64	-29.661	-0.478	0.0000	-0.070
1.3	6.56	120.00	6168.84	5.36	534.96	8.8	-30.05	-30.066	-0.482	0.0000	-0.066
1.31	6.08	120.00	6168.78	5.36	534.96	8.4	-30.46	-30.474	-0.486	0.0000	-0.061
1.32	5.59	120.00	6168.72	5.36	534.96	7.9	-30.87	-30.884	-0.490	0.0000	-0.056
1.33	5.10	120.00	6168.66	5.36	534.96	7.5	-31.29	-31.296	-0.494	0.0000	-0.051
1.34	4.61	120.00	6168.61	5.36	534.96	7.0	-31.70	-31.711	-0.498	0.0000	-0.046
1.35	4.11	120.00	6168.57	5.36	534.96	6.6	-32.12	-32.128	-0.502	0.0000	-0.041
1.36	3.61	120.00	6168.52	5.36	534.96	6.2	-32.54	-32.547	-0.506	0.0000	-0.036
1.37	3.10	120.00	6168.49	5.36	534.96	5.7	-32.97	-32.969	-0.510	0.0000	-0.031
1.38	2.59	120.00	6168.46	5.36	534.96	5.3	-33.39	-33.394	-0.514	0.0000	-0.026
1.39	2.08	120.00	6168.43	5.36	534.96	4.8	-33.82	-33.821	-0.518	0.0000	-0.021
1.4	1.56	120.00	6168.41	5.36	534.96	4.4	-34.25	-34.251	-0.522	0.0000	-0.016
1.41	1.04	120.00	6168.40	5.36	534.96	4.0	-34.68	-34.684	-0.527	0.0000	-0.010
1.42	0.51	120.00	6168.38	5.36	534.96	3.5	-35.12	-35.120	-0.265	0.0000	-0.003
1.425	0.24	120.00	6168.38	5.36	534.96	3.3	-35.34	-35.338	-0.266	0.0000	-0.001
1.43	-0.02	120.00	6168.38	5.36	534.96	3.1	-35.56	-35.558	-0.535	0.0000	0.000

Appendix B
PUMP SHUTDOWN

COLUMN OF FLUID FALLING THROUGH 20' VERTICAL SECTION OF PIPE

g=	32.17 ft/sec^2
f=	0.011 (assume constant for all Re)
k_{Lelbow} =	0.1
$k_{Lentrance}$ =	6.3
D=	2.5 ft
A=	4.909 ft^2
H_{pump}=	0 (assume that the pump has no inertia and turbines with no losses)
Q_o=	0 ft^3/sec
V_o=	0.000 ft/sec
z_o=	5.36 ft (pump shuts down at WSEL of 535 ft)
Ꝟ$_o$=	6168.38 ft^3

Q is positive entering the pump station

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=((20\text{-}x) - p_{elbow2}/\gamma - (f^*(20\text{-}x)/D + 1^*k_{Lelbow})^*Q^2/(2g\,A^2)) * A * (g/(44+100+20\text{-}x)) * dt$

$p_{elbow2}/\gamma = z - 44 + (f^*(100+44)/D + 3^*k_{Lelbow} + k_{Lentrance})^*Q^2/(2g\,A^2) - Q^2/(2gA^2) + H_{pump}$

$x(t)=x_{prev.} + dx$ $dx=(Q/A)^*dt$

Ꝟ(t)=Ꝟ$_{prev.}$ + dꝞ dꝞ=$(Q_{inflow} + Q)^*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151 (valid for Ꝟ>6205 ft^3)

z(t)=(1.17/1116)Ꝟ(t)- 1.105 (valid for Ꝟ<6205 ft^3)

t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow2}/γ	dQ	dx	dꝞ	p_{elbow}/γ	-Q
1.43	0.00	0.00	6168.38	5.36	534.96	3.1	-35.56	0.535	0.0	0.000	-35.56	0.00
1.44	0.53	0.00	6168.38	5.36	534.96	2.6	-36.00	0.539	0.0	0.005	-36.00	-0.53
1.45	1.07	0.00	6168.39	5.36	534.96	2.2	-36.43	1.358	0.0	0.027	-36.43	-1.07
1.475	2.43	0.01	6168.41	5.36	534.96	1.1	-37.51	1.384	0.0	0.061	-37.52	-2.43
1.5	3.82	0.02	6168.47	5.36	534.96	0.0	-38.58	1.410	0.0	0.095	-38.58	-3.82
1.525	5.23	0.04	6168.57	5.36	534.96	0.0	-38.53	1.408	0.0	0.131	-38.54	-5.23
1.55	6.64	0.07	6168.70	5.36	534.96	0.0	-38.46	1.406	0.0	0.166	-38.48	-6.64
1.575	8.04	0.10	6168.87	5.36	534.96	0.0	-38.38	1.404	0.0	0.201	-38.40	-8.04
1.6	9.44	0.14	6169.07	5.36	534.96	0.0	-38.28	1.400	0.0	0.236	-38.31	-9.44
1.625	10.85	0.19	6169.30	5.36	534.96	0.0	-38.16	1.397	0.1	0.271	-38.21	-10.85
1.65	12.24	0.24	6169.57	5.36	534.96	0.0	-38.03	1.393	0.1	0.306	-38.09	-12.24
1.675	13.63	0.31	6169.88	5.36	534.96	0.0	-37.89	1.388	0.1	0.341	-37.95	-13.63
1.7	15.02	0.37	6170.22	5.36	534.96	0.0	-37.73	1.383	0.1	0.376	-37.81	-15.02
1.725	16.41	0.45	6170.60	5.36	534.96	0.0	-37.55	1.378	0.1	0.410	-37.65	-16.41
1.75	17.78	0.53	6171.01	5.36	534.96	0.0	-37.36	1.372	0.1	0.445	-37.47	-17.78
1.775	19.16	0.63	6171.45	5.37	534.97	0.0	-37.16	1.365	0.1	0.479	-37.29	-19.16
1.8	20.52	0.72	6171.93	5.37	534.97	0.0	-36.94	1.358	0.1	0.513	-37.09	-20.52
1.825	21.88	0.83	6172.44	5.37	534.97	0.0	-36.71	1.351	0.1	0.547	-36.88	-21.88
1.85	23.23	0.94	6172.99	5.37	534.97	0.0	-36.46	1.343	0.1	0.581	-36.65	-23.23
1.875	24.57	1.06	6173.57	5.37	534.97	0.0	-36.20	1.334	0.1	0.614	-36.42	-24.57
1.9	25.91	1.18	6174.19	5.37	534.97	0.0	-35.93	1.326	0.1	0.648	-36.17	-25.91
1.925	27.23	1.31	6174.83	5.37	534.97	0.0	-35.65	1.316	0.1	0.681	-35.91	-27.23
1.95	28.55	1.45	6175.51	5.37	534.97	0.0	-35.35	1.307	0.1	0.714	-35.64	-28.55
1.975	29.86	1.60	6176.23	5.37	534.97	0.0	-35.05	1.297	0.2	0.746	-35.36	-29.86
2	31.15	1.75	6176.97	5.37	534.97	0.0	-34.73	1.286	0.2	0.779	-35.07	-31.15
2.025	32.44	1.91	6177.75	5.37	534.97	0.0	-34.40	1.275	0.2	0.811	-34.76	-32.44
2.05	33.71	2.07	6178.56	5.37	534.97	0.0	-34.06	1.264	0.2	0.843	-34.45	-33.71
2.075	34.98	2.25	6179.41	5.37	534.97	0.0	-33.71	1.253	0.2	0.874	-34.13	-34.98
2.1	36.23	2.42	6180.28	5.37	534.97	0.0	-33.35	1.241	0.2	0.906	-33.80	-36.23
2.125	37.47	2.61	6181.19	5.38	534.98	0.0	-32.98	1.228	0.2	0.937	-33.47	-37.47
2.15	38.70	2.80	6182.12	5.38	534.98	0.0	-32.60	1.216	0.2	0.967	-33.12	-38.70
2.175	39.91	3.00	6183.09	5.38	534.98	0.0	-32.22	1.202	0.2	0.998	-32.77	-39.91
2.2	41.12	3.20	6184.09	5.38	534.98	0.0	-31.82	1.189	0.2	1.028	-32.41	-41.12
2.225	42.31	3.41	6185.12	5.38	534.98	0.0	-31.42	1.175	0.2	1.058	-32.05	-42.31
2.25	43.48	3.62	6186.17	5.38	534.98	0.0	-31.02	1.161	0.2	1.087	-31.68	-43.48
2.275	44.64	3.85	6187.26	5.38	534.98	0.0	-30.60	1.147	0.2	1.116	-31.30	-44.64
2.3	45.79	4.07	6188.38	5.38	534.98	0.0	-30.19	1.133	0.2	1.145	-30.92	-45.79
2.325	46.92	4.31	6189.52	5.38	534.98	0.0	-29.76	1.118	0.2	1.173	-30.53	-46.92
2.35	48.04	4.55	6190.70	5.39	534.99	0.0	-29.33	1.103	0.2	1.201	-30.14	-48.04
2.375	49.14	4.79	6191.90	5.39	534.99	0.0	-28.90	1.087	0.3	1.229	-29.74	-49.14
2.4	50.23	5.04	6193.13	5.39	534.99	0.0	-28.47	1.072	0.3	1.256	-29.35	-50.23
2.425	51.30	5.30	6194.38	5.39	534.99	0.0	-28.03	1.056	0.3	1.283	-28.94	-51.30
2.45	52.36	5.56	6195.66	5.39	534.99	0.0	-27.59	1.040	0.3	1.309	-28.54	-52.36
2.475	53.40	5.82	6196.97	5.39	534.99	0.0	-27.14	1.024	0.3	1.335	-28.14	-53.40
2.5	54.42	6.10	6198.31	5.39	534.99	0.0	-26.70	1.007	0.3	1.361	-27.73	-54.42
2.525	55.43	6.37	6199.67	5.39	534.99	0.0	-26.25	0.991	0.3	1.386	-27.32	-55.43
2.55	56.42	6.66	6201.05	5.40	535.00	0.0	-25.80	0.974	0.3	1.411	-26.91	-56.42
2.575	57.39	6.94	6202.46	5.40	535.00	0.0	-25.36	0.957	0.3	1.435	-26.50	-57.39
2.6	58.35	7.24	6203.90	5.40	535.00	0.0	-24.91	0.940	0.3	1.459	-26.10	-58.35
2.625	59.29	7.53	6205.36	5.40	535.00	0.0	-24.46	0.923	0.3	1.482	-25.69	-59.29
2.65	60.22	7.83	6206.84	5.40	535.00	0.0	-24.02	0.906	0.3	1.505	-25.28	-60.22
2.675	61.12	8.14	6208.35	5.40	535.00	0.0	-23.58	0.888	0.3	1.528	-24.88	-61.12
2.7	62.01	8.45	6209.87	5.40	535.00	0.0	-23.14	0.871	0.3	1.550	-24.47	-62.01
2.725	62.88	8.77	6211.42	5.41	535.01	0.0	-22.70	0.853	0.3	1.572	-24.07	-62.88
2.75	63.73	9.09	6213.00	5.41	535.01	0.0	-22.26	0.835	0.3	1.593	-23.68	-63.73
2.775	64.57	9.41	6214.59	5.41	535.01	0.0	-21.83	0.818	0.3	1.614	-23.28	-64.57
2.8	65.39	9.74	6216.20	5.41	535.01	0.0	-21.40	0.800	0.3	1.635	-22.89	-65.39
2.825	66.19	10.08	6217.84	5.41	535.01	0.0	-20.98	0.782	0.3	1.655	-22.50	-66.19
2.85	66.97	10.41	6219.49	5.41	535.01	0.0	-20.55	0.764	0.3	1.674	-22.12	-66.97
2.875	67.73	10.75	6221.17	5.41	535.01	0.0	-20.14	0.746	0.3	1.693	-21.74	-67.73

2.9	68.48	11.10	6222.86	5.42	535.02	0.0	-19.73	0.728	0.3	1.712	-21.36	-68.48
2.925	69.21	11.45	6224.57	5.42	535.02	0.0	-19.32	0.710	0.4	1.730	-20.99	-69.21
2.95	69.92	11.80	6226.30	5.42	535.02	0.0	-18.93	0.692	0.4	1.748	-20.63	-69.92
2.975	70.61	12.16	6228.05	5.42	535.02	0.0	-18.53	0.675	0.4	1.765	-20.27	-70.61
3	71.28	12.52	6229.82	5.42	535.02	0.0	-18.15	0.657	0.4	1.782	-19.92	-71.28
3.025	71.94	12.88	6231.60	5.42	535.02	0.0	-17.77	0.639	0.4	1.799	-19.57	-71.94
3.05	72.58	13.24	6233.40	5.42	535.02	0.0	-17.39	0.621	0.4	1.815	-19.23	-72.58
3.075	73.20	13.61	6235.21	5.43	535.03	0.0	-17.03	0.603	0.4	1.830	-18.90	-73.20
3.1	73.80	13.99	6237.04	5.43	535.03	0.0	-16.67	0.585	0.4	1.845	-18.57	-73.80
3.125	74.39	14.36	6238.89	5.43	535.03	0.0	-16.32	0.568	0.4	1.860	-18.25	-74.39
3.15	74.96	14.74	6240.75	5.43	535.03	0.0	-15.98	0.550	0.4	1.874	-17.93	-74.96
3.175	75.51	15.12	6242.62	5.43	535.03	0.0	-15.64	0.532	0.4	1.888	-17.63	-75.51
3.2	76.04	15.51	6244.51	5.43	535.03	0.0	-15.32	0.515	0.4	1.901	-17.33	-76.04
3.225	76.55	15.90	6246.41	5.44	535.04	0.0	-15.00	0.497	0.4	1.914	-17.04	-76.55
3.25	77.05	16.29	6248.32	5.44	535.04	0.0	-14.69	0.480	0.4	1.926	-16.76	-77.05
3.275	77.53	16.68	6250.25	5.44	535.04	0.0	-14.39	0.463	0.4	1.938	-16.49	-77.53
3.3	77.99	17.07	6252.19	5.44	535.04	0.0	-14.10	0.446	0.4	1.950	-16.22	-77.99
3.325	78.44	17.47	6254.14	5.44	535.04	0.0	-13.82	0.429	0.4	1.961	-15.96	-78.44
3.35	78.87	17.87	6256.10	5.44	535.04	0.0	-13.55	0.412	0.4	1.972	-15.71	-78.87
3.375	79.28	18.27	6258.07	5.45	535.05	0.0	-13.28	0.395	0.4	1.982	-15.47	-79.28
3.4	79.67	18.67	6260.05	5.45	535.05	0.0	-13.03	0.378	0.4	1.992	-15.24	-79.67
3.425	80.05	19.08	6262.04	5.45	535.05	0.0	-12.78	0.362	0.4	2.001	-15.02	-80.05
3.45	80.41	19.49	6264.04	5.45	535.05	0.0	-12.55	0.345	0.4	2.010	-14.80	-80.41
3.475	80.76	19.90	6266.05	5.45	535.05	0.0	-12.32	0.066	0.1	0.404	-14.59	-80.76
3.48	80.83	19.98	6266.46	5.45	535.05	0.0	-12.28	0.026	0.0	0.162	-14.56	-80.83
3.482	80.85	20.01	6266.62	5.45	535.05	0.0	-12.26	0.234	0.3	1.455	-14.54	-80.85
3.5												

REVERSE FLOW THROUGH THE HORZONTAL SECTION OF PIPE

g=	32.17	ft/sec^2
f=	0.011	(assume constant for all Re)

D=	2.5	ft
A=	4.908739	ft^2
H_{pump}=	0	(assume that the pump has no inertia and turbines with no losses)
k_{Lelbow} =	0.1	
$k_{Lentrance}$ =	6.4	

Q_o=	80.85	ft^3/sec
V_o=	16.471	ft/sec
z_o=	5.45	ft
Ꝟ$_o$=	6266.62	ft^3

Q is positive entering the pump station

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(0 - p_{elbow}/\gamma - (f^*(100-x)/D)^*Q^2/(2g\ A^2)) * A * (g/(100-x+L)) * dt$

$p_{elbow}/\gamma = z - 44 + (f^*(44)/D + 2^*k_{Lelbow} + k_{Lentrance})^*Q^2/(2g\ A^2) - Q^2/(2gA^2) + H_{pump}$

$x(t)=x_{prev.} + dx$ $dx=(Q/A) * dt$

Ꝟ(t)=Ꝟ$_{prev.}$ + dꝞ dꝞ=(Q_{inflow} + Q)*dt (Assume Q_{inflow}, the flow into the pump station, is zero)

z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151 (valid for Ꝟ>6205 ft^3)

z(t)=(1.17/1116)Ꝟ(t)- 1.105 (valid for Ꝟ<6205 ft^3)

t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow}/γ	dQ	dx	dꝞ	-Q
3.482	80.85	0.00	6266.62	5.45	535.05	0.0	-14.54	0.250	0.30	1.455	-80.85
3.5	81.10	0.30	6268.08	5.45	535.05	0.0	-14.39	0.688	0.83	4.055	-81.10
3.55	81.79	1.12	6272.13	5.46	535.06	0.0	-13.97	0.669	0.83	4.089	-81.79
3.6	82.46	1.96	6276.22	5.46	535.06	0.0	-13.57	0.649	0.84	4.123	-82.46
3.65	83.11	2.80	6280.34	5.46	535.06	0.0	-13.17	0.630	0.85	4.155	-83.11
3.7	83.74	3.64	6284.50	5.47	535.07	0.0	-12.78	0.611	0.85	4.187	-83.74
3.75	84.35	4.50	6288.69	5.47	535.07	0.0	-12.40	0.593	0.86	4.217	-84.35
3.8	84.94	5.35	6292.90	5.48	535.08	0.0	-12.03	0.575	0.87	4.247	-84.94
3.85	85.52	6.22	6297.15	5.48	535.08	0.0	-11.66	0.557	0.87	4.276	-85.52
3.9	86.07	7.09	6301.43	5.48	535.08	0.0	-11.31	0.540	0.88	4.304	-86.07
3.95	86.61	7.97	6305.73	5.49	535.09	0.0	-10.96	0.523	0.88	4.331	-86.61
4	87.13	8.85	6310.06	5.49	535.09	0.0	-10.63	0.506	0.89	4.357	-87.13
4.05	87.64	9.74	6314.42	5.49	535.09	0.0	-10.30	0.490	0.89	4.382	-87.64
4.1	88.13	10.63	6318.80	5.50	535.10	0.0	-9.98	0.474	0.90	4.407	-88.13
4.15	88.60	11.53	6323.20	5.50	535.10	0.0	-9.67	0.459	0.90	4.430	-88.60
4.2	89.06	12.43	6327.63	5.51	535.11	0.0	-9.36	0.444	0.91	4.453	-89.06
4.25	89.51	13.34	6332.09	5.51	535.11	0.0	-9.07	0.429	0.91	4.475	-89.51
4.3	89.94	14.25	6336.56	5.51	535.11	0.0	-8.78	0.415	0.92	4.497	-89.94
4.35	90.35	15.16	6341.06	5.52	535.12	0.0	-8.50	0.401	0.92	4.518	-90.35
4.4	90.75	16.09	6345.58	5.52	535.12	0.0	-8.23	0.387	0.92	4.538	-90.75
4.45	91.14	17.01	6350.12	5.52	535.12	0.0	-7.97	0.374	0.93	4.557	-91.14
4.5	91.51	17.94	6354.67	5.53	535.13	0.0	-7.72	0.361	0.93	4.576	-91.51
4.55	91.87	18.87	6359.25	5.53	535.13	0.0	-7.47	0.349	0.94	4.594	-91.87
4.6	92.22	19.81	6363.84	5.54	535.14	0.0	-7.23	0.337	0.94	4.611	-92.22
4.65	92.56	20.75	6368.45	5.54	535.14	0.0	-7.00	0.325	0.94	4.628	-92.56
4.7	92.88	21.69	6373.08	5.54	535.14	0.0	-6.77	0.313	0.95	4.644	-92.88
4.75	93.20	22.63	6377.72	5.55	535.15	0.0	-6.55	0.302	0.95	4.660	-93.20
4.8	93.50	23.58	6382.38	5.55	535.15	0.0	-6.34	0.292	0.95	4.675	-93.50
4.85	93.79	24.54	6387.06	5.56	535.16	0.0	-6.14	0.281	0.96	4.690	-93.79
4.9	94.07	25.49	6391.75	5.56	535.16	0.0	-5.94	0.271	0.96	4.704	-94.07
4.95	94.34	26.45	6396.45	5.56	535.16	0.0	-5.75	0.261	0.96	4.717	-94.34
5	94.60	27.41	6401.17	5.57	535.17	0.0	-5.56	0.252	0.96	4.730	-94.60
5.05	94.86	28.37	6405.90	5.57	535.17	0.0	-5.38	0.243	0.97	4.743	-94.86
5.1	95.10	29.34	6410.64	5.58	535.18	0.0	-5.21	0.234	0.97	4.755	-95.10
5.15	95.33	30.31	6415.40	5.58	535.18	0.0	-5.04	0.225	0.97	4.767	-95.33
5.2	95.56	31.28	6420.16	5.59	535.19	0.0	-4.88	0.217	0.97	4.778	-95.56
5.25	95.77	32.25	6424.94	5.59	535.19	0.0	-4.72	0.209	0.98	4.789	-95.77
5.3	95.98	33.23	6429.73	5.59	535.19	0.0	-4.57	0.201	0.98	4.799	-95.98
5.35	96.19	34.21	6434.53	5.60	535.20	0.0	-4.43	0.194	0.98	4.809	-96.19
5.4	96.38	35.19	6439.34	5.60	535.20	0.0	-4.28	0.187	0.98	4.819	-96.38
5.45	96.57	36.17	6444.16	5.61	535.21	0.0	-4.15	0.180	0.98	4.828	-96.57
5.5	96.75	37.15	6448.99	5.61	535.21	0.0	-4.02	0.173	0.99	4.837	-96.75
5.55	96.92	38.14	6453.82	5.61	535.21	0.0	-3.89	0.167	0.99	4.846	-96.92
5.6	97.09	39.12	6458.67	5.62	535.22	0.0	-3.77	0.161	0.99	4.854	-97.09
5.65	97.25	40.11	6463.52	5.62	535.22	0.0	-3.65	0.155	0.99	4.862	-97.25
5.7	97.40	41.10	6468.39	5.63	535.23	0.0	-3.53	0.149	0.99	4.870	-97.40
5.75	97.55	42.10	6473.26	5.63	535.23	0.0	-3.42	0.144	0.99	4.878	-97.55
5.8	97.70	43.09	6478.13	5.63	535.23	0.0	-3.31	0.139	1.00	4.885	-97.70
5.85	97.83	44.08	6483.02	5.64	535.24	0.0	-3.21	0.134	1.00	4.892	-97.83
5.9	97.97	45.08	6487.91	5.64	535.24	0.0	-3.11	0.129	1.00	4.898	-97.97
5.95	98.10	46.08	6492.81	5.65	535.25	0.0	-3.01	0.124	1.00	4.905	-98.10
6	98.22	47.08	6497.71	5.65	535.25	0.0	-2.92	0.120	1.00	4.911	-98.22
6.05	98.34	48.08	6502.62	5.66	535.26	0.0	-2.83	0.115	1.00	4.917	-98.34
6.1	98.46	49.08	6507.54	5.66	535.26	0.0	-2.74	0.111	1.00	4.923	-98.46
6.15	98.57	50.08	6512.46	5.66	535.26	0.0	-2.66	0.108	1.00	4.928	-98.57
6.2	98.67	51.09	6517.39	5.67	535.27	0.0	-2.57	0.104	1.01	4.934	-98.67
6.25	98.78	52.09	6522.33	5.67	535.27	0.0	-2.49	0.100	1.01	4.939	-98.78
6.3	98.88	53.10	6527.27	5.68	535.28	0.0	-2.42	0.097	1.01	4.944	-98.88
6.35	98.98	54.11	6532.21	5.68	535.28	0.0	-2.34	0.094	1.01	4.949	-98.98

6.4	99.07	55.11	6537.16	5.69	535.29	0.0	-2.27	0.091	1.01	4.953	-99.07
6.45	99.16	56.12	6542.11	5.69	535.29	0.0	-2.20	0.088	1.01	4.958	-99.16
6.5	99.25	57.13	6547.07	5.69	535.29	0.0	-2.13	0.085	1.01	4.962	-99.25
6.55	99.33	58.14	6552.03	5.70	535.30	0.0	-2.07	0.082	1.01	4.967	-99.33
6.6	99.41	59.16	6557.00	5.70	535.30	0.0	-2.00	0.080	1.01	4.971	-99.41
6.65	99.49	60.17	6561.97	5.71	535.31	0.0	-1.94	0.077	1.01	4.975	-99.49
6.7	99.57	61.18	6566.94	5.71	535.31	0.0	-1.88	0.075	1.01	4.979	-99.57
6.75	99.65	62.20	6571.92	5.72	535.32	0.0	-1.82	0.073	1.01	4.982	-99.65
6.8	99.72	63.21	6576.90	5.72	535.32	0.0	-1.76	0.071	1.02	4.986	-99.72
6.85	99.79	64.23	6581.89	5.72	535.32	0.0	-1.71	0.069	1.02	4.989	-99.79
6.9	99.86	65.24	6586.88	5.73	535.33	0.0	-1.65	0.067	1.02	4.993	-99.86
6.95	99.93	66.26	6591.87	5.73	535.33	0.0	-1.60	0.065	1.02	4.996	-99.93
7	99.99	67.28	6596.87	5.74	535.34	0.0	-1.55	0.063	1.02	5.000	-99.99
7.05	100.05	68.30	6601.87	5.74	535.34	0.0	-1.49	0.062	1.02	5.003	-100.05
7.1	100.12	69.32	6606.87	5.74	535.34	0.0	-1.44	0.060	1.02	5.006	-100.12
7.15	100.18	70.34	6611.88	5.75	535.35	0.0	-1.40	0.059	1.02	5.009	-100.18
7.2	100.24	71.36	6616.89	5.75	535.35	0.0	-1.35	0.058	1.02	5.012	-100.24
7.25	100.29	72.38	6621.90	5.76	535.36	0.0	-1.30	0.057	1.02	5.015	-100.29
7.3	100.35	73.40	6626.91	5.76	535.36	0.0	-1.26	0.055	1.02	5.017	-100.35
7.35	100.40	74.42	6631.93	5.77	535.37	0.0	-1.21	0.054	1.02	5.020	-100.40
7.4	100.46	75.44	6636.95	5.77	535.37	0.0	-1.17	0.053	1.02	5.023	-100.46
7.45	100.51	76.47	6641.97	5.77	535.37	0.0	-1.12	0.052	1.02	5.026	-100.51
7.5	100.56	77.49	6647.00	5.78	535.38	0.0	-1.08	0.051	1.02	5.028	-100.56
7.55	100.62	78.51	6652.03	5.78	535.38	0.0	-1.04	0.051	1.02	5.031	-100.62
7.6	100.67	79.54	6657.06	5.79	535.39	0.0	-1.00	0.050	1.03	5.033	-100.67
7.65	100.72	80.56	6662.09	5.79	535.39	0.0	-0.95	0.049	1.03	5.036	-100.72
7.7	100.77	81.59	6667.13	5.80	535.40	0.0	-0.91	0.048	1.03	5.038	-100.77
7.75	100.81	82.62	6672.17	5.80	535.40	0.0	-0.87	0.048	1.03	5.041	-100.81
7.8	100.86	83.64	6677.21	5.81	535.41	0.0	-0.83	0.047	1.03	5.043	-100.86
7.85	100.91	84.67	6682.25	5.81	535.41	0.0	-0.79	0.047	1.03	5.045	-100.91
7.9	100.96	85.70	6687.29	5.81	535.41	0.0	-0.76	0.046	1.03	5.048	-100.96
7.95	101.00	86.73	6692.34	5.82	535.42	0.0	-0.72	0.046	1.03	5.050	-101.00
8	101.05	87.76	6697.39	5.82	535.42	0.0	-0.68	0.045	1.03	5.052	-101.05
8.05	101.09	88.79	6702.45	5.83	535.43	0.0	-0.64	0.045	1.03	5.055	-101.09
8.1	101.14	89.82	6707.50	5.83	535.43	0.0	-0.60	0.045	1.03	5.057	-101.14
8.15	101.18	90.85	6712.56	5.84	535.44	0.0	-0.57	0.044	1.03	5.059	-101.18
8.2	101.23	91.88	6717.62	5.84	535.44	0.0	-0.53	0.044	1.03	5.061	-101.23
8.25	101.27	92.91	6722.68	5.84	535.44	0.0	-0.49	0.044	1.03	5.064	-101.27
8.3	101.32	93.94	6727.74	5.85	535.45	0.0	-0.45	0.044	1.03	5.066	-101.32
8.35	101.36	94.97	6732.81	5.85	535.45	0.0	-0.42	0.044	1.03	5.068	-101.36
8.4	101.40	96.00	6737.87	5.86	535.46	0.0	-0.38	0.043	1.03	5.070	-101.40
8.45	101.45	97.04	6742.94	5.86	535.46	0.0	-0.34	0.043	1.03	5.072	-101.45
8.5	101.49	98.07	6748.02	5.87	535.47	0.0	-0.31	0.022	0.52	2.537	-101.49
8.525	101.51	98.59	6750.55	5.87	535.47	0.0	-0.29	0.022	0.52	2.538	-101.51
8.55	101.53	99.10	6753.09	5.87	535.47	0.0	-0.27	0.021	0.52	2.538	-101.53
8.575	101.55	99.62	6755.63	5.87	535.47	0.0	-0.25	0.021	0.52	2.539	-101.55
8.6	101.58	100.14	6758.17	5.87	535.47	0.0	-0.23	0.021	0.52	2.539	-101.58
8.625											

Appendix B
PUMP SHUTDOWN

WATER COLUMN NOW IN 44' VERTICAL SECTION OF PIPE ONLY

Q_o=	101.58 ft^3/sec	H_{pump}=	0 ft
V_o=	20.693 ft/sec		
z_o=	5.87 ft		
Ꝟ$_o$=	6758.17 ft^3	**Q is positive entering the pump station**	

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=((44-h) - z - Hpump - (f^*(44-h)/D + k_{Lelbow} + k_{Lentrance})^*Q^2/(2g\ A^2)) * A * (g/(44-h)) * dt$

$h(t)=h_{prev.} + dh$ $dh=(Q/A)^*dt$

Ꝟ$(t)=$Ꝟ$_{prev.}$ + dꝞ dꝞ$=(Q_{inflow}+ Q)^*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t)$ = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151 (valid for Ꝟ>6205 ft^3)

$z(t)$=(1.17/1116)Ꝟ(t)- 1.105 (valid for Ꝟ<6205 ft^3)

t (sec)	Q (cfs)	h (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	dQ	dh	dꝞ	-Q	44-h
8.6	101.58	0.00	6758.17	5.87	535.47	0.0	-0.207	0.2069	1.016	-101.58	44.00
8.61	101.37	0.21	6759.19	5.87	535.47	0.0	-0.208	0.2065	1.014	-101.37	43.79
8.62	101.16	0.41	6760.20	5.88	535.48	0.0	-0.210	0.2061	1.012	-101.16	43.59
8.63	100.95	0.62	6761.21	5.88	535.48	0.0	-0.212	0.2057	1.010	-100.95	43.38
8.64	100.74	0.83	6762.22	5.88	535.48	0.0	-0.214	0.2052	1.007	-100.74	43.17
8.65	100.53	1.03	6763.23	5.88	535.48	0.0	-0.215	0.2048	1.005	-100.53	42.97
8.66	100.31	1.24	6764.23	5.88	535.48	0.0	-0.217	0.2043	1.003	-100.31	42.76
8.67	100.09	1.44	6765.24	5.88	535.48	0.0	-0.218	0.2039	1.001	-100.09	42.56
8.68	99.87	1.64	6766.24	5.88	535.48	0.0	-0.220	0.2035	0.999	-99.87	42.36
8.69	99.65	1.85	6767.24	5.88	535.48	0.0	-0.222	0.2030	0.997	-99.65	42.15
8.7	99.43	2.05	6768.23	5.88	535.48	0.0	-0.223	0.2026	0.994	-99.43	41.95
8.71	99.21	2.25	6769.23	5.88	535.48	0.0	-0.224	0.2021	0.992	-99.21	41.75
8.72	98.99	2.45	6770.22	5.88	535.48	0.0	-0.226	0.2017	0.990	-98.99	41.55
8.73	98.76	2.66	6771.21	5.89	535.49	0.0	-0.227	0.2012	0.988	-98.76	41.34
8.74	98.53	2.86	6772.20	5.89	535.49	0.0	-0.229	0.2007	0.985	-98.53	41.14
8.75	98.30	3.06	6773.18	5.89	535.49	0.0	-0.230	0.2003	0.983	-98.30	40.94
8.76	98.07	3.26	6774.16	5.89	535.49	0.0	-0.231	0.1998	0.981	-98.07	40.74
8.77	97.84	3.46	6775.14	5.89	535.49	0.0	-0.232	0.1993	0.978	-97.84	40.54
8.78	97.61	3.66	6776.12	5.89	535.49	0.0	-0.234	0.1988	0.976	-97.61	40.34
8.79	97.38	3.86	6777.10	5.89	535.49	0.0	-0.235	0.1984	0.974	-97.38	40.14
8.8	97.14	4.05	6778.07	5.89	535.49	0.0	-0.236	0.1979	0.971	-97.14	39.95
8.81	96.91	4.25	6779.04	5.89	535.49	0.0	-0.237	0.1974	0.969	-96.91	39.75
8.82	96.67	4.45	6780.01	5.89	535.49	0.0	-0.238	0.1969	0.967	-96.67	39.55
8.83	96.43	4.65	6780.98	5.89	535.49	0.0	-0.239	0.1964	0.964	-96.43	39.35
8.84	96.19	4.84	6781.94	5.89	535.49	0.0	-0.240	0.1960	0.962	-96.19	39.16
8.85	95.95	5.04	6782.91	5.90	535.50	0.0	-0.241	0.1955	0.960	-95.95	38.96
8.86	95.71	5.23	6783.87	5.90	535.50	0.0	-0.243	0.1950	0.957	-95.71	38.77
8.87	95.47	5.43	6784.82	5.90	535.50	0.0	-0.244	0.1945	0.955	-95.47	38.57
8.88	95.22	5.62	6785.78	5.90	535.50	0.0	-0.244	0.1940	0.952	-95.22	38.38
8.89	94.98	5.82	6786.73	5.90	535.50	0.0	-0.245	0.1935	0.950	-94.98	38.18
8.9	94.73	6.01	6787.68	5.90	535.50	0.0	-0.246	0.1930	0.947	-94.73	37.99
8.91	94.49	6.20	6788.63	5.90	535.50	0.0	-0.247	0.1925	0.945	-94.49	37.80
8.92	94.24	6.40	6789.57	5.90	535.50	0.0	-0.248	0.1920	0.942	-94.24	37.60
8.93	93.99	6.59	6790.51	5.90	535.50	0.0	-0.249	0.1915	0.940	-93.99	37.41
8.94	93.74	6.78	6791.45	5.90	535.50	0.0	-0.250	0.1910	0.937	-93.74	37.22
8.95	93.49	6.97	6792.39	5.90	535.50	0.0	-0.251	0.1905	0.935	-93.49	37.03
8.96	93.24	7.16	6793.33	5.90	535.50	0.0	-0.251	0.1900	0.932	-93.24	36.84
8.97	92.99	7.35	6794.26	5.90	535.50	0.0	-0.252	0.1894	0.930	-92.99	36.65
8.98	92.74	7.54	6795.19	5.91	535.51	0.0	-0.253	0.1889	0.927	-92.74	36.46
8.99	92.48	7.73	6796.12	5.91	535.51	0.0	-0.254	0.1884	0.925	-92.48	36.27
9	92.23	7.92	6797.04	5.91	535.51	0.0	-0.254	0.1879	0.922	-92.23	36.08
9.01	91.98	8.11	6797.96	5.91	535.51	0.0	-0.255	0.1874	0.920	-91.98	35.89
9.02	91.72	8.29	6798.88	5.91	535.51	0.0	-0.256	0.1869	0.917	-91.72	35.71
9.03	91.47	8.48	6799.80	5.91	535.51	0.0	-0.257	0.1863	0.915	-91.47	35.52
9.04	91.21	8.67	6800.71	5.91	535.51	0.0	-0.257	0.1858	0.912	-91.21	35.33
9.05	90.95	8.85	6801.63	5.91	535.51	0.0	-0.258	0.1853	0.910	-90.95	35.15
9.06	90.69	9.04	6802.54	5.91	535.51	0.0	-0.258	0.1848	0.907	-90.69	34.96
9.07	90.44	9.22	6803.44	5.91	535.51	0.0	-0.259	0.1842	0.904	-90.44	34.78
9.08	90.18	9.41	6804.35	5.91	535.51	0.0	-0.260	0.1837	0.902	-90.18	34.59
9.09	89.92	9.59	6805.25	5.91	535.51	0.0	-0.260	0.1832	0.899	-89.92	34.41
9.1	89.66	9.77	6806.15	5.91	535.51	0.0	-0.261	0.1826	0.897	-89.66	34.23
9.11	89.40	9.96	6807.05	5.92	535.52	0.0	-0.261	0.1821	0.894	-89.40	34.04
9.12	89.13	10.14	6807.94	5.92	535.52	0.0	-0.262	0.1816	0.891	-89.13	33.86
9.13	88.87	10.32	6808.83	5.92	535.52	0.0	-0.262	0.1810	0.889	-88.87	33.68
9.14	88.61	10.50	6809.72	5.92	535.52	0.0	-0.263	0.1805	0.886	-88.61	33.50
9.15	88.35	10.68	6810.61	5.92	535.52	0.0	-0.264	0.1800	0.883	-88.35	33.32
9.16	88.08	10.86	6811.49	5.92	535.52	0.0	-0.264	0.1794	0.881	-88.08	33.14
9.17	87.82	11.04	6812.37	5.92	535.52	0.0	-0.265	0.1789	0.878	-87.82	32.96
9.18	87.55	11.22	6813.25	5.92	535.52	0.0	-0.265	0.1784	0.876	-87.55	32.78
9.19	87.29	11.40	6814.12	5.92	535.52	0.0	-0.265	0.1778	0.873	-87.29	32.60
9.2	87.02	11.58	6815.00	5.92	535.52	0.0	-0.266	0.1773	0.870	-87.02	32.42
9.21	86.76	11.75	6815.87	5.92	535.52	0.0	-0.266	0.1767	0.868	-86.76	32.25
9.22	86.49	11.93	6816.73	5.92	535.52	0.0	-0.267	0.1762	0.865	-86.49	32.07
9.23	86.23	12.11	6817.60	5.92	535.52	0.0	-0.267	0.1757	0.862	-86.23	31.89
9.24	85.96	12.28	6818.46	5.93	535.53	0.0	-0.268	0.1751	0.860	-85.96	31.72
9.25	85.69	12.46	6819.32	5.93	535.53	0.0	-0.268	0.1746	0.857	-85.69	31.54
9.26	85.42	12.63	6820.18	5.93	535.53	0.0	-0.268	0.1740	0.854	-85.42	31.37
9.27	85.15	12.81	6821.03	5.93	535.53	0.0	-0.269	0.1735	0.852	-85.15	31.19
9.28	84.89	12.98	6821.88	5.93	535.53	0.0	-0.269	0.1729	0.849	-84.89	31.02
9.29	84.62	13.15	6822.73	5.93	535.53	0.0	-0.270	0.1724	0.846	-84.62	30.85
9.3	84.35	13.33	6823.58	5.93	535.53	0.0	-0.270	0.1718	0.843	-84.35	30.67

9.31	84.08	13.50	6824.42	5.93	535.53	0.0	-0.270	0.1713	0.841	-84.08	30.50
9.32	83.81	13.67	6825.26	5.93	535.53	0.0	-0.271	0.1707	0.838	-83.81	30.33
9.33	83.54	13.84	6826.10	5.93	535.53	0.0	-0.271	0.1702	0.835	-83.54	30.16
9.34	83.26	14.01	6826.94	5.93	535.53	0.0	-0.271	0.1696	0.833	-83.26	29.99
9.35	82.99	14.18	6827.77	5.93	535.53	0.0	-0.272	0.1691	0.830	-82.99	29.82
9.36	82.72	14.35	6828.60	5.93	535.53	0.0	-0.272	0.1685	0.827	-82.72	29.65
9.37	82.45	14.52	6829.43	5.93	535.53	0.0	-0.272	0.1680	0.824	-82.45	29.48
9.38	82.18	14.68	6830.25	5.94	535.54	0.0	-0.273	0.1674	0.822	-82.18	29.32
9.39	81.90	14.85	6831.07	5.94	535.54	0.0	-0.273	0.1669	0.819	-81.90	29.15
9.4	81.63	15.02	6831.89	5.94	535.54	0.0	-0.273	0.1663	0.816	-81.63	28.98
9.41	81.36	15.18	6832.71	5.94	535.54	0.0	-0.273	0.1657	0.814	-81.36	28.82
9.42	81.09	15.35	6833.52	5.94	535.54	0.0	-0.274	0.1652	0.811	-81.09	28.65
9.43	80.81	15.52	6834.33	5.94	535.54	0.0	-0.274	0.1646	0.808	-80.81	28.48
9.44	80.54	15.68	6835.14	5.94	535.54	0.0	-0.274	0.1641	0.805	-80.54	28.32
9.45	80.26	15.84	6835.95	5.94	535.54	0.0	-0.275	0.1635	0.803	-80.26	28.16
9.46	79.99	16.01	6836.75	5.94	535.54	0.0	-0.275	0.1630	0.800	-79.99	27.99
9.47	79.71	16.17	6837.55	5.94	535.54	0.0	-0.275	0.1624	0.797	-79.71	27.83
9.48	79.44	16.33	6838.35	5.94	535.54	0.0	-0.275	0.1618	0.794	-79.44	27.67
9.49	79.16	16.50	6839.14	5.94	535.54	0.0	-0.275	0.1613	0.792	-79.16	27.50
9.5	78.89	16.66	6839.93	5.94	535.54	0.0	-0.276	0.1607	0.789	-78.89	27.34
9.51	78.61	16.82	6840.72	5.94	535.54	0.0	-0.276	0.1601	0.786	-78.61	27.18
9.52	78.34	16.98	6841.51	5.94	535.54	0.0	-0.276	0.1596	0.783	-78.34	27.02
9.53	78.06	17.14	6842.29	5.95	535.55	0.0	-0.276	0.1590	0.781	-78.06	26.86
9.54	77.78	17.30	6843.07	5.95	535.55	0.0	-0.277	0.1585	0.778	-77.78	26.70
9.55	77.51	17.45	6843.85	5.95	535.55	0.0	-0.277	0.1579	0.775	-77.51	26.55
9.56	77.23	17.61	6844.62	5.95	535.55	0.0	-0.277	0.1573	0.772	-77.23	26.39
9.57	76.95	17.77	6845.40	5.95	535.55	0.0	-0.277	0.1568	0.770	-76.95	26.23
9.58	76.68	17.93	6846.17	5.95	535.55	0.0	-0.277	0.1562	0.767	-76.68	26.07
9.59	76.40	18.08	6846.93	5.95	535.55	0.0	-0.278	0.1556	0.764	-76.40	25.92
9.6	76.12	18.24	6847.70	5.95	535.55	0.0	-0.278	0.1551	0.761	-76.12	25.76
9.61	75.84	18.39	6848.46	5.95	535.55	0.0	-0.278	0.1545	0.758	-75.84	25.61
9.62	75.57	18.55	6849.22	5.95	535.55	0.0	-0.278	0.1539	0.756	-75.57	25.45
9.63	75.29	18.70	6849.97	5.95	535.55	0.0	-0.278	0.1534	0.753	-75.29	25.30
9.64	75.01	18.86	6850.72	5.95	535.55	0.0	-0.279	0.1528	0.750	-75.01	25.14
9.65	74.73	19.01	6851.47	5.95	535.55	0.0	-0.279	0.1522	0.747	-74.73	24.99
9.66	74.45	19.16	6852.22	5.95	535.55	0.0	-0.279	0.1517	0.745	-74.45	24.84
9.67	74.17	19.31	6852.97	5.95	535.55	0.0	-0.279	0.1511	0.742	-74.17	24.69
9.68	73.89	19.46	6853.71	5.96	535.56	0.0	-0.279	0.1505	0.739	-73.89	24.54
9.69	73.61	19.61	6854.45	5.96	535.56	0.0	-0.279	0.1500	0.736	-73.61	24.39
9.7	73.33	19.76	6855.18	5.96	535.56	0.0	-0.280	0.1494	0.733	-73.33	24.24
9.71	73.06	19.91	6855.92	5.96	535.56	0.0	-0.280	0.1488	0.731	-73.06	24.09
9.72	72.78	20.06	6856.65	5.96	535.56	0.0	-0.280	0.1483	0.728	-72.78	23.94
9.73	72.50	20.21	6857.37	5.96	535.56	0.0	-0.280	0.1477	0.725	-72.50	23.79
9.74	72.22	20.36	6858.10	5.96	535.56	0.0	-0.280	0.1471	0.722	-72.22	23.64
9.75	71.94	20.50	6858.82	5.96	535.56	0.0	-0.280	0.1465	0.719	-71.94	23.50
9.76	71.65	20.65	6859.54	5.96	535.56	0.0	-0.281	0.1460	0.717	-71.65	23.35
9.77	71.37	20.80	6860.26	5.96	535.56	0.0	-0.281	0.1454	0.714	-71.37	23.20
9.78	71.09	20.94	6860.97	5.96	535.56	0.0	-0.281	0.1448	0.711	-71.09	23.06
9.79	70.81	21.09	6861.68	5.96	535.56	0.0	-0.281	0.1443	0.708	-70.81	22.91
9.8	70.53	21.23	6862.39	5.96	535.56	0.0	-0.281	0.1437	0.705	-70.53	22.77
9.81	70.25	21.38	6863.10	5.96	535.56	0.0	-0.281	0.1431	0.703	-70.25	22.62
9.82	69.97	21.52	6863.80	5.96	535.56	0.0	-0.281	0.1425	0.700	-69.97	22.48
9.83	69.69	21.66	6864.50	5.96	535.56	0.0	-0.281	0.1420	0.697	-69.69	22.34
9.84	69.41	21.80	6865.19	5.97	535.57	0.0	-0.282	0.1414	0.694	-69.41	22.20
9.85	69.13	21.94	6865.89	5.97	535.57	0.0	-0.338	0.1690	0.830	-69.13	22.06
9.862	68.79	22.11	6866.72	5.97	535.57	0.0	-0.338	0.1682	0.825	-68.79	21.89
9.874	68.45	22.28	6867.54	5.97	535.57	0.0	-0.338	0.1673	0.821	-68.45	21.72
9.886	68.11	22.45	6868.37	5.97	535.57	0.0	-0.339	0.1665	0.817	-68.11	21.55
9.898	67.77	22.62	6869.18	5.97	535.57	0.0	-0.339	0.1657	0.813	-67.77	21.38
9.91	67.43	22.78	6870.00	5.97	535.57	0.0	-0.339	0.1648	0.809	-67.43	21.22
9.922	67.09	22.95	6870.80	5.97	535.57	0.0	-0.339	0.1640	0.805	-67.09	21.05
9.934	66.75	23.11	6871.61	5.97	535.57	0.0	-0.339	0.1632	0.801	-66.75	20.89
9.946	66.42	23.27	6872.41	5.97	535.57	0.0	-0.339	0.1624	0.797	-66.42	20.73
9.958	66.08	23.44	6873.21	5.97	535.57	0.0	-0.340	0.1615	0.793	-66.08	20.56
9.97	65.74	23.60	6874.00	5.97	535.57	0.0	-0.340	0.1607	0.789	-65.74	20.40
9.982	65.40	23.76	6874.79	5.97	535.57	0.0	-0.340	0.1599	0.785	-65.40	20.24
9.994	65.06	23.92	6875.57	5.97	535.57	0.0	-0.340	0.1590	0.781	-65.06	20.08
10.006	64.72	24.08	6876.36	5.97	535.57	0.0	-0.340	0.1582	0.777	-64.72	19.92
10.018	64.38	24.23	6877.13	5.98	535.58	0.0	-0.340	0.1574	0.773	-64.38	19.77
10.03	64.04	24.39	6877.90	5.98	535.58	0.0	-0.341	0.1565	0.768	-64.04	19.61
10.042	63.70	24.55	6878.67	5.98	535.58	0.0	-0.341	0.1557	0.764	-63.70	19.45
10.054	63.35	24.70	6879.44	5.98	535.58	0.0	-0.341	0.1549	0.760	-63.35	19.30
10.066	63.01	24.86	6880.20	5.98	535.58	0.0	-0.341	0.1540	0.756	-63.01	19.14
10.078	62.67	25.01	6880.95	5.98	535.58	0.0	-0.341	0.1532	0.752	-62.67	18.99
10.09	62.33	25.17	6881.71	5.98	535.58	0.0	-0.341	0.1524	0.748	-62.33	18.83
10.102	61.99	25.32	6882.45	5.98	535.58	0.0	-0.341	0.1515	0.744	-61.99	18.68
10.114	61.65	25.47	6883.20	5.98	535.58	0.0	-0.342	0.1507	0.740	-61.65	18.53
10.126	61.31	25.62	6883.94	5.98	535.58	0.0	-0.342	0.1499	0.736	-61.31	18.38
10.138	60.97	25.77	6884.67	5.98	535.58	0.0	-0.342	0.1490	0.732	-60.97	18.23
10.15	60.62	25.92	6885.40	5.98	535.58	0.0	-0.342	0.1482	0.727	-60.62	18.08
10.162	60.28	26.07	6886.13	5.98	535.58	0.0	-0.342	0.1474	0.723	-60.28	17.93
10.174	59.94	26.22	6886.86	5.98	535.58	0.0	-0.342	0.1465	0.719	-59.94	17.78
10.186	59.60	26.36	6887.57	5.98	535.58	0.0	-0.342	0.1457	0.715	-59.60	17.64
10.198	59.25	26.51	6888.29	5.98	535.58	0.0	-0.342	0.1449	0.711	-59.25	17.49
10.21	58.91	26.65	6889.00	5.99	535.59	0.0	-0.343	0.1440	0.707	-58.91	17.35
10.222	58.57	26.80	6889.71	5.99	535.59	0.0	-0.343	0.1432	0.703	-58.57	17.20
10.234	58.23	26.94	6890.41	5.99	535.59	0.0	-0.343	0.1423	0.699	-58.23	17.06
10.246	57.88	27.08	6891.11	5.99	535.59	0.0	-0.343	0.1415	0.695	-57.88	16.92
10.258	57.54	27.22	6891.80	5.99	535.59	0.0	-0.343	0.1407	0.690	-57.54	16.78
10.27	57.20	27.36	6892.49	5.99	535.59	0.0	-0.343	0.1398	0.686	-57.20	16.64

10.282	56.85	27.50	6893.18	5.99	535.59	0.0	-0.343	0.1390	0.682	-56.85	16.50
10.294	56.51	27.64	6893.86	5.99	535.59	0.0	-0.343	0.1381	0.678	-56.51	16.36
10.306	56.17	27.78	6894.54	5.99	535.59	0.0	-0.344	0.1373	0.674	-56.17	16.22
10.318	55.82	27.92	6895.22	5.99	535.59	0.0	-0.344	0.1365	0.670	-55.82	16.08
10.33	55.48	28.06	6895.89	5.99	535.59	0.0	-0.344	0.1356	0.666	-55.48	15.94
10.342	55.14	28.19	6896.55	5.99	535.59	0.0	-0.344	0.1348	0.662	-55.14	15.81
10.354	54.79	28.33	6897.21	5.99	535.59	0.0	-0.344	0.1339	0.658	-54.79	15.67
10.366	54.45	28.46	6897.87	5.99	535.59	0.0	-0.344	0.1331	0.653	-54.45	15.54
10.378	54.10	28.59	6898.52	5.99	535.59	0.0	-0.344	0.1323	0.649	-54.10	15.41
10.39	53.76	28.72	6899.17	5.99	535.59	0.0	-0.344	0.1314	0.645	-53.76	15.28
10.402	53.42	28.86	6899.82	5.99	535.59	0.0	-0.344	0.1306	0.641	-53.42	15.14
10.414	53.07	28.99	6900.46	5.99	535.59	0.0	-0.345	0.1297	0.637	-53.07	15.01
10.426	52.73	29.12	6901.10	6.00	535.60	0.0	-0.345	0.1289	0.633	-52.73	14.88
10.438	52.38	29.25	6901.73	6.00	535.60	0.0	-0.345	0.1281	0.629	-52.38	14.75
10.45	52.04	29.37	6902.36	6.00	535.60	0.0	-0.345	0.1272	0.624	-52.04	14.63
10.462	51.69	29.50	6902.98	6.00	535.60	0.0	-0.345	0.1264	0.620	-51.69	14.50
10.474	51.35	29.63	6903.60	6.00	535.60	0.0	-0.345	0.1255	0.616	-51.35	14.37
10.486	51.00	29.75	6904.22	6.00	535.60	0.0	-0.345	0.1247	0.612	-51.00	14.25
10.498	50.66	29.88	6904.83	6.00	535.60	0.0	-0.345	0.1238	0.608	-50.66	14.12
10.51	50.31	30.00	6905.44	6.00	535.60	0.0	-0.345	0.1230	0.604	-50.31	14.00
10.522	49.97	30.12	6906.04	6.00	535.60	0.0	-0.345	0.1222	0.600	-49.97	13.88
10.534	49.62	30.25	6906.64	6.00	535.60	0.0	-0.346	0.1213	0.595	-49.62	13.75
10.546	49.28	30.37	6907.24	6.00	535.60	0.0	-0.346	0.1205	0.591	-49.28	13.63
10.558	48.93	30.49	6907.83	6.00	535.60	0.0	-0.346	0.1196	0.587	-48.93	13.51
10.57	48.59	30.61	6908.42	6.00	535.60	0.0	-0.346	0.1188	0.583	-48.59	13.39
10.582	48.24	30.73	6909.00	6.00	535.60	0.0	-0.346	0.1179	0.579	-48.24	13.27
10.594	47.89	30.84	6909.58	6.00	535.60	0.0	-0.346	0.1171	0.575	-47.89	13.16
10.606	47.55	30.96	6910.15	6.00	535.60	0.0	-0.346	0.1162	0.571	-47.55	13.04
10.618	47.20	31.08	6910.72	6.00	535.60	0.0	-0.346	0.1154	0.566	-47.20	12.92
10.63	46.86	31.19	6911.29	6.00	535.60	0.0	-0.346	0.1145	0.562	-46.86	12.81
10.642	46.51	31.31	6911.85	6.00	535.60	0.0	-0.346	0.1137	0.558	-46.51	12.69
10.654	46.16	31.42	6912.41	6.01	535.61	0.0	-0.346	0.1128	0.554	-46.16	12.58
10.666	45.82	31.53	6912.96	6.01	535.61	0.0	-0.347	0.1120	0.550	-45.82	12.47
10.678	45.47	31.65	6913.51	6.01	535.61	0.0	-0.347	0.1112	0.546	-45.47	12.35
10.69	45.12	31.76	6914.06	6.01	535.61	0.0	-0.347	0.1103	0.541	-45.12	12.24
10.702	44.78	31.87	6914.60	6.01	535.61	0.0	-0.347	0.1095	0.537	-44.78	12.13
10.714	44.43	31.98	6915.14	6.01	535.61	0.0	-0.347	0.1086	0.533	-44.43	12.02
10.726	44.08	32.09	6915.67	6.01	535.61	0.0	-0.347	0.1078	0.529	-44.08	11.91
10.738	43.74	32.19	6916.20	6.01	535.61	0.0	-0.347	0.1069	0.525	-43.74	11.81
10.75	43.39	32.30	6916.72	6.01	535.61	0.0	-0.347	0.1061	0.521	-43.39	11.70
10.762	43.04	32.41	6917.25	6.01	535.61	0.0	-0.347	0.1052	0.516	-43.04	11.59
10.774	42.69	32.51	6917.76	6.01	535.61	0.0	-0.347	0.1044	0.512	-42.69	11.49
10.786	42.35	32.62	6918.27	6.01	535.61	0.0	-0.347	0.1035	0.508	-42.35	11.38
10.798	42.00	32.72	6918.78	6.01	535.61	0.0	-0.348	0.1027	0.504	-42.00	11.28
10.81	41.65	32.82	6919.29	6.01	535.61	0.0	-0.348	0.1018	0.500	-41.65	11.18
10.822	41.30	32.92	6919.79	6.01	535.61	0.0	-0.348	0.1010	0.496	-41.30	11.08
10.834	40.96	33.03	6920.28	6.01	535.61	0.0	-0.348	0.1001	0.491	-40.96	10.97
10.846	40.61	33.13	6920.77	6.01	535.61	0.0	-0.348	0.0993	0.487	-40.61	10.87
10.858	40.26	33.22	6921.26	6.01	535.61	0.0	-0.348	0.0984	0.483	-40.26	10.78
10.87	39.91	33.32	6921.74	6.01	535.61	0.0	-0.348	0.0976	0.479	-39.91	10.68
10.882	39.56	33.42	6922.22	6.01	535.61	0.0	-0.348	0.0967	0.475	-39.56	10.58
10.894	39.22	33.52	6922.70	6.01	535.61	0.0	-0.348	0.0959	0.471	-39.22	10.48
10.906	38.87	33.61	6923.17	6.01	535.61	0.0	-0.348	0.0950	0.466	-38.87	10.39
10.918	38.52	33.71	6923.63	6.01	535.61	0.0	-0.348	0.0942	0.462	-38.52	10.29
10.93	38.17	33.80	6924.10	6.02	535.62	0.0	-0.348	0.0933	0.458	-38.17	10.20
10.942	37.82	33.90	6924.55	6.02	535.62	0.0	-0.348	0.0925	0.454	-37.82	10.10
10.954	37.48	33.99	6925.01	6.02	535.62	0.0	-0.349	0.0916	0.450	-37.48	10.01
10.966	37.13	34.08	6925.46	6.02	535.62	0.0	-0.349	0.0908	0.446	-37.13	9.92
10.978	36.78	34.17	6925.90	6.02	535.62	0.0	-0.349	0.0899	0.441	-36.78	9.83
10.99	36.43	34.26	6926.34	6.02	535.62	0.0	-0.349	0.0891	0.437	-36.43	9.74
11.002	36.08	34.35	6926.78	6.02	535.62	0.0	-0.349	0.0882	0.433	-36.08	9.65
11.014	35.73	34.44	6927.21	6.02	535.62	0.0	-0.349	0.0874	0.429	-35.73	9.56
11.026	35.38	34.53	6927.64	6.02	535.62	0.0	-0.349	0.0865	0.425	-35.38	9.47
11.038	35.03	34.61	6928.07	6.02	535.62	0.0	-0.349	0.0856	0.420	-35.03	9.39
11.05	34.68	34.70	6928.49	6.02	535.62	0.0	-0.349	0.0848	0.416	-34.68	9.30
11.062	34.34	34.78	6928.90	6.02	535.62	0.0	-0.349	0.0839	0.412	-34.34	9.22
11.074	33.99	34.87	6929.32	6.02	535.62	0.0	-0.349	0.0831	0.408	-33.99	9.13
11.086	33.64	34.95	6929.72	6.02	535.62	0.0	-0.349	0.0822	0.404	-33.64	9.05
11.098	33.29	35.03	6930.13	6.02	535.62	0.0	-0.349	0.0814	0.399	-33.29	8.97
11.11	32.94	35.11	6930.53	6.02	535.62	0.0	-0.350	0.0805	0.395	-32.94	8.89
11.122	32.59	35.19	6930.92	6.02	535.62	0.0	-0.350	0.0797	0.391	-32.59	8.81
11.134	32.24	35.27	6931.31	6.02	535.62	0.0	-0.350	0.0788	0.387	-32.24	8.73
11.146	31.89	35.35	6931.70	6.02	535.62	0.0	-0.350	0.0780	0.383	-31.89	8.65
11.158	31.54	35.43	6932.08	6.02	535.62	0.0	-0.350	0.0771	0.378	-31.54	8.57
11.17	31.19	35.51	6932.46	6.02	535.62	0.0	-0.350	0.0762	0.374	-31.19	8.49
11.182	30.84	35.58	6932.84	6.02	535.62	0.0	-0.350	0.0754	0.370	-30.84	8.42
11.194	30.49	35.66	6933.21	6.02	535.62	0.0	-0.350	0.0745	0.366	-30.49	8.34
11.206	30.14	35.73	6933.57	6.02	535.62	0.0	-0.350	0.0737	0.362	-30.14	8.27
11.218	29.79	35.81	6933.93	6.02	535.62	0.0	-0.350	0.0728	0.357	-29.79	8.19
11.23	29.44	35.88	6934.29	6.02	535.62	0.0	-0.350	0.0720	0.353	-29.44	8.12
11.242	29.09	35.95	6934.64	6.02	535.62	0.0	-0.350	0.0711	0.349	-29.09	8.05
11.254	28.74	36.02	6934.99	6.02	535.62	0.0	-0.350	0.0703	0.345	-28.74	7.98
11.266	28.39	36.09	6935.34	6.02	535.62	0.0	-0.350	0.0694	0.341	-28.39	7.91
11.278	28.04	36.16	6935.68	6.02	535.62	0.0	-0.351	0.0685	0.336	-28.04	7.84
11.29	27.69	36.23	6936.02	6.03	535.63	0.0	-0.351	0.0677	0.332	-27.69	7.77
11.302	27.34	36.30	6936.35	6.03	535.63	0.0	-0.351	0.0668	0.328	-27.34	7.70
11.314	26.99	36.37	6936.68	6.03	535.63	0.0	-0.351	0.0660	0.324	-26.99	7.63
11.326	26.64	36.43	6937.00	6.03	535.63	0.0	-0.351	0.0651	0.320	-26.64	7.57
11.338	26.28	36.50	6937.32	6.03	535.63	0.0	-0.351	0.0643	0.315	-26.28	7.50
11.35	25.93	36.56	6937.64	6.03	535.63	0.0	-0.351	0.0634	0.311	-25.93	7.44

11.362	25.58	36.62	6937.95	6.03	535.63	0.0	-0.351	0.0625	0.307	-25.58	7.38
11.374	25.23	36.69	6938.25	6.03	535.63	0.0	-0.351	0.0617	0.303	-25.23	7.31
11.386	24.88	36.75	6938.56	6.03	535.63	0.0	-0.351	0.0608	0.299	-24.88	7.25
11.398	24.53	36.81	6938.85	6.03	535.63	0.0	-0.351	0.0600	0.294	-24.53	7.19
11.41	24.18	36.87	6939.15	6.03	535.63	0.0	-0.351	0.0591	0.290	-24.18	7.13
11.422	23.83	36.93	6939.44	6.03	535.63	0.0	-0.351	0.0582	0.286	-23.83	7.07
11.434	23.48	36.99	6939.73	6.03	535.63	0.0	-0.351	0.0574	0.282	-23.48	7.01
11.446	23.12	37.04	6940.01	6.03	535.63	0.0	-0.351	0.0565	0.277	-23.12	6.96
11.458	22.77	37.10	6940.28	6.03	535.63	0.0	-0.352	0.0557	0.273	-22.77	6.90
11.47	22.42	37.16	6940.56	6.03	535.63	0.0	-0.352	0.0548	0.269	-22.42	6.84
11.482	22.07	37.21	6940.83	6.03	535.63	0.0	-0.352	0.0540	0.265	-22.07	6.79
11.494	21.72	37.26	6941.09	6.03	535.63	0.0	-0.352	0.0531	0.261	-21.72	6.74
11.506	21.37	37.32	6941.35	6.03	535.63	0.0	-0.352	0.0522	0.256	-21.37	6.68
11.518	21.01	37.37	6941.61	6.03	535.63	0.0	-0.352	0.0514	0.252	-21.01	6.63
11.53	20.66	37.42	6941.86	6.03	535.63	0.0	-0.352	0.0505	0.248	-20.66	6.58
11.542	20.31	37.47	6942.11	6.03	535.63	0.0	-0.352	0.0497	0.244	-20.31	6.53
11.554	19.96	37.52	6942.35	6.03	535.63	0.0	-0.352	0.0488	0.240	-19.96	6.48
11.566	19.61	37.57	6942.59	6.03	535.63	0.0	-0.352	0.0479	0.235	-19.61	6.43
11.578	19.25	37.62	6942.83	6.03	535.63	0.0	-0.352	0.0471	0.231	-19.25	6.38
11.59	18.90	37.67	6943.06	6.03	535.63	0.0	-0.352	0.0462	0.227	-18.90	6.33
11.602	18.55	37.71	6943.29	6.03	535.63	0.0	-0.352	0.0453	0.223	-18.55	6.29
11.614	18.20	37.76	6943.51	6.03	535.63	0.0	-0.352	0.0445	0.218	-18.20	6.24
11.626	17.84	37.80	6943.73	6.03	535.63	0.0	-0.353	0.0436	0.214	-17.84	6.20
11.638	17.49	37.84	6943.94	6.03	535.63	0.0	-0.353	0.0428	0.210	-17.49	6.16
11.65	17.14	37.89	6944.15	6.03	535.63	0.0	-0.353	0.0419	0.206	-17.14	6.11
11.662	16.79	37.93	6944.36	6.03	535.63	0.0	-0.353	0.0410	0.201	-16.79	6.07
11.674	16.43	37.97	6944.56	6.03	535.63	0.0	-0.353	0.0402	0.197	-16.43	6.03
11.686	16.08	38.01	6944.75	6.03	535.63	1.0	-0.669	0.0393	0.193	-16.08	5.99
11.698	15.41	38.05	6944.95	6.03	535.63	2.0	-0.977	0.0377	0.185	-15.41	5.95
11.71	14.44	38.09	6945.13	6.03	535.63	3.0	-1.277	0.0353	0.173	-14.44	5.91
11.722	13.16	38.12	6945.31	6.03	535.63	4.0	-1.572	0.0322	0.158	-13.16	5.88
11.734	11.59	38.16	6945.46	6.03	535.63	5.0	-1.863	0.0283	0.139	-11.59	5.84
11.746	9.72	38.18	6945.60	6.03	535.63	6.0	-2.153	0.0238	0.117	-9.72	5.82
11.758	7.57	38.21	6945.72	6.03	535.63	7.0	-2.446	0.0185	0.091	-7.57	5.79
11.77	5.12	38.23	6945.81	6.03	535.63	8.0	-2.746	0.0125	0.061	-5.12	5.77
11.782	2.38	38.24	6945.87	6.03	535.63	9.0	-3.057	0.0058	0.029	-2.38	5.76
11.794	-0.68	38.24	6945.90	6.03	535.63	10.0	-3.384	-0.0017	-0.008	0.68	5.76
11.806	-4.06	38.24	6945.89	6.03	535.63	11.0	-3.734	-0.0099	-0.049	4.06	5.76
11.818	-7.80	38.23	6945.84	6.03	535.63	12.0	-4.113	-0.0191	-0.094	7.80	5.77
11.83	-11.91	38.21	6945.75	6.03	535.63	13.0	-4.531	-0.0291	-0.143	11.91	5.79
11.842	-16.44	38.18	6945.61	6.03	535.63	14.0	-4.998	-0.0402	-0.197	16.44	5.82
11.854	-21.44	38.14	6945.41	6.03	535.63	15.0	-5.528	-0.0524	-0.257	21.44	5.86
11.866	-26.97	38.09	6945.15	6.03	535.63	16.0	-6.139	-0.0659	-0.324	26.97	5.91
11.878	-33.11	38.03	6944.83	6.03	535.63	17.0	-6.852	-0.0809	-0.397	33.11	5.97
11.89	-39.96	37.94	6944.43	6.03	535.63	18.0	-7.697	-0.0977	-0.479	39.96	6.06
11.902											

Appendix C

Results

Appendix B, Part 2
PUMP SHUTDOWN ASSUMING A 4 SECOND LOSS OF PUMP INERTIA

1.06	30.33	120.00	6167.00	5.36	534.96	48.5	5.30	4.984	-0.292	0.0000	-0.607
1.08	30.04	120.00	6166.40	5.36	534.96	48.2	5.06	4.747	-0.297	0.0000	-0.601
1.1	29.74	120.00	6165.80	5.36	534.96	47.9	4.82	4.510	-0.301	0.0000	-0.595
1.12	29.44	120.00	6165.20	5.36	534.96	47.5	4.58	4.274	-0.306	0.0000	-0.589
1.14	29.14	120.00	6164.61	5.36	534.96	47.2	4.33	4.039	-0.310	0.0000	-0.583
1.16	28.83	120.00	6164.03	5.36	534.96	46.9	4.09	3.804	-0.314	0.0000	-0.577
1.18	28.51	120.00	6163.45	5.36	534.96	46.5	3.85	3.569	-0.319	0.0000	-0.570
1.2	28.19	120.00	6162.88	5.36	534.96	46.2	3.61	3.334	-0.323	0.0000	-0.564
1.22	27.87	120.00	6162.32	5.36	534.96	45.9	3.37	3.100	-0.328	0.0000	-0.557
1.24	27.54	120.00	6161.76	5.35	534.95	45.5	3.13	2.866	-0.332	0.0000	-0.551
1.26	27.21	120.00	6161.21	5.35	534.95	45.2	2.89	2.632	-0.337	0.0000	-0.544
1.28	26.87	120.00	6160.67	5.35	534.95	44.9	2.65	2.398	-0.341	0.0000	-0.537
1.3	26.53	120.00	6160.13	5.35	534.95	44.6	2.41	2.164	-0.346	0.0000	-0.531
1.32	26.19	120.00	6159.60	5.35	534.95	44.2	2.17	1.931	-0.350	0.0000	-0.524
1.34	25.84	120.00	6159.07	5.35	534.95	43.9	1.93	1.697	-0.355	0.0000	-0.517
1.36	25.48	120.00	6158.56	5.35	534.95	43.6	1.69	1.463	-0.359	0.0000	-0.510
1.38	25.12	120.00	6158.05	5.35	534.95	43.2	1.45	1.229	-0.363	0.0000	-0.502
1.4	24.76	120.00	6157.55	5.35	534.95	42.9	1.21	0.995	-0.368	0.0000	-0.495
1.42	24.39	120.00	6157.05	5.35	534.95	42.6	0.97	0.760	-0.372	0.0000	-0.488
1.44	24.02	120.00	6156.56	5.35	534.95	42.2	0.73	0.525	-0.377	0.0000	-0.480
1.46	23.64	120.00	6156.08	5.35	534.95	41.9	0.48	0.290	-0.381	0.0000	-0.473
1.48	23.26	120.00	6155.61	5.35	534.95	41.6	0.24	0.055	-0.386	0.0000	-0.465
1.5	22.88	120.00	6155.14	5.35	534.95	41.3	0.00	-0.181	-0.390	0.0000	-0.458
1.52	22.49	120.00	6154.69	5.35	534.95	40.9	-0.24	-0.418	-0.395	0.0000	-0.450
1.54	22.09	120.00	6154.24	5.35	534.95	40.6	-0.48	-0.655	-0.399	0.0000	-0.442
1.56	21.69	120.00	6153.79	5.35	534.95	40.3	-0.73	-0.892	-0.404	0.0000	-0.434
1.58	21.29	120.00	6153.36	5.35	534.95	39.9	-0.97	-1.131	-0.408	0.0000	-0.426
1.6	20.88	120.00	6152.94	5.35	534.95	39.6	-1.22	-1.370	-0.413	0.0000	-0.418
1.62	20.47	120.00	6152.52	5.35	534.95	39.3	-1.46	-1.609	-0.417	0.0000	-0.409
1.64	20.05	120.00	6152.11	5.34	534.94	38.9	-1.71	-1.850	-0.422	0.0000	-0.401
1.66	19.63	120.00	6151.71	5.34	534.94	38.6	-1.96	-2.091	-0.427	0.0000	-0.393
1.68	19.20	120.00	6151.31	5.34	534.94	38.3	-2.21	-2.334	-0.431	0.0000	-0.384
1.7	18.77	120.00	6150.93	5.34	534.94	38.0	-2.45	-2.577	-0.436	0.0000	-0.375
1.72	18.33	120.00	6150.56	5.34	534.94	37.6	-2.70	-2.822	-0.441	0.0000	-0.367
1.74	17.89	120.00	6150.19	5.34	534.94	37.3	-2.96	-3.067	-0.445	0.0000	-0.358
1.76	17.45	120.00	6149.83	5.34	534.94	37.0	-3.21	-3.314	-0.450	0.0000	-0.349
1.78	17.00	120.00	6149.48	5.34	534.94	36.6	-3.46	-3.562	-0.455	0.0000	-0.340
1.8	16.54	120.00	6149.14	5.34	534.94	36.3	-3.72	-3.812	-0.459	0.0000	-0.331
1.82	16.08	120.00	6148.81	5.34	534.94	36.0	-3.97	-4.062	-0.464	0.0000	-0.322
1.84	15.62	120.00	6148.49	5.34	534.94	35.6	-4.23	-4.315	-0.469	0.0000	-0.312
1.86	15.15	120.00	6148.18	5.34	534.94	35.3	-4.49	-4.568	-0.474	0.0000	-0.303
1.88	14.68	120.00	6147.87	5.34	534.94	35.0	-4.75	-4.824	-0.479	0.0000	-0.294
1.9	14.20	120.00	6147.58	5.34	534.94	34.7	-5.01	-5.080	-0.484	0.0000	-0.284
1.92	13.71	120.00	6147.30	5.34	534.94	34.3	-5.27	-5.339	-0.489	0.0000	-0.274
1.94	13.23	120.00	6147.02	5.34	534.94	34.0	-5.54	-5.599	-0.494	0.0000	-0.265
1.96	12.73	120.00	6146.76	5.34	534.94	33.7	-5.81	-5.862	-0.249	0.0000	-0.127
1.97	12.48	120.00	6146.63	5.34	534.94	33.5	-5.94	-5.993	-0.251	0.0000	-0.125
1.98	12.23	120.00	6146.51	5.34	534.94	33.3	-6.07	-6.126	-0.252	0.0000	-0.122
1.99	11.98	120.00	6146.38	5.34	534.94	33.2	-6.21	-6.258	-0.253	0.0000	-0.120
2	11.73	120.00	6146.26	5.34	534.94	33.0	-6.34	-6.392	-0.254	0.0000	-0.117
2.01	11.47	120.00	6146.15	5.34	534.94	32.8	-6.48	-6.526	-0.256	0.0000	-0.115
2.02	11.22	120.00	6146.03	5.34	534.94	32.7	-6.62	-6.660	-0.257	0.0000	-0.112
2.03	10.96	120.00	6145.92	5.34	534.94	32.5	-6.75	-6.795	-0.258	0.0000	-0.110
2.04	10.70	120.00	6145.81	5.34	534.94	32.3	-6.89	-6.930	-0.259	0.0000	-0.107
2.05	10.44	120.00	6145.70	5.34	534.94	32.2	-7.03	-7.066	-0.261	0.0000	-0.104
2.06	10.18	120.00	6145.60	5.34	534.94	32.0	-7.17	-7.203	-0.262	0.0000	-0.102
2.07	9.92	120.00	6145.50	5.34	534.94	31.8	-7.31	-7.340	-0.263	0.0000	-0.099
2.08	9.66	120.00	6145.40	5.34	534.94	31.7	-7.44	-7.477	-0.265	0.0000	-0.097
2.09	9.39	120.00	6145.30	5.34	534.94	31.5	-7.59	-7.616	-0.266	0.0000	-0.094
2.1	9.13	120.00	6145.21	5.34	534.94	31.4	-7.73	-7.755	-0.267	0.0000	-0.091
2.11	8.86	120.00	6145.12	5.34	534.94	31.2	-7.87	-7.894	-0.269	0.0000	-0.089
2.12	8.59	120.00	6145.03	5.34	534.94	31.0	-8.01	-8.034	-0.270	0.0000	-0.086
2.13	8.32	120.00	6144.94	5.34	534.94	30.9	-8.15	-8.175	-0.271	0.0000	-0.083
2.14	8.05	120.00	6144.86	5.34	534.94	30.7	-8.29	-8.317	-0.273	0.0000	-0.080
2.15	7.78	120.00	6144.78	5.34	534.94	30.5	-8.44	-8.459	-0.274	0.0000	-0.078
2.16	7.50	120.00	6144.70	5.34	534.94	30.4	-8.58	-8.602	-0.275	0.0000	-0.075
2.17	7.23	120.00	6144.62	5.34	534.94	30.2	-8.73	-8.745	-0.277	0.0000	-0.072
2.18	6.95	120.00	6144.55	5.34	534.94	30.0	-8.87	-8.890	-0.278	0.0000	-0.069
2.19	6.67	120.00	6144.48	5.34	534.94	29.9	-9.02	-9.035	-0.280	0.0000	-0.067
2.2	6.39	120.00	6144.42	5.34	534.94	29.7	-9.17	-9.180	-0.281	0.0000	-0.064
2.21	6.11	120.00	6144.35	5.34	534.94	29.5	-9.31	-9.327	-0.282	0.0000	-0.061
2.22	5.83	120.00	6144.29	5.34	534.94	29.4	-9.46	-9.474	-0.284	0.0000	-0.058
2.23	5.54	120.00	6144.23	5.34	534.94	29.2	-9.61	-9.622	-0.285	0.0000	-0.055
2.24	5.26	120.00	6144.18	5.34	534.94	29.0	-9.76	-9.770	-0.287	0.0000	-0.053
2.25	4.97	120.00	6144.13	5.34	534.94	28.9	-9.91	-9.920	-0.288	0.0000	-0.050
2.26	4.68	120.00	6144.08	5.34	534.94	28.7	-10.06	-10.070	-0.290	0.0000	-0.047
2.27	4.39	120.00	6144.03	5.34	534.94	28.5	-10.21	-10.221	-0.291	0.0000	-0.044
2.28	4.10	120.00	6143.98	5.34	534.94	28.4	-10.37	-10.373	-0.292	0.0000	-0.041
2.29	3.81	120.00	6143.94	5.34	534.94	28.2	-10.52	-10.526	-0.294	0.0000	-0.038
2.3	3.52	120.00	6143.91	5.34	534.94	28.1	-10.68	-10.679	-0.295	0.0000	-0.035
2.31	3.22	120.00	6143.87	5.34	534.94	27.9	-10.83	-10.834	-0.297	0.0000	-0.032
2.32	2.92	120.00	6143.84	5.34	534.94	27.7	-10.99	-10.989	-0.298	0.0000	-0.029
2.33	2.63	120.00	6143.81	5.34	534.94	27.6	-11.14	-11.146	-0.300	0.0000	-0.026
2.34	2.33	120.00	6143.78	5.34	534.94	27.4	-11.30	-11.303	-0.301	0.0000	-0.023
2.35	2.02	120.00	6143.76	5.34	534.94	27.2	-11.46	-11.461	-0.303	0.0000	-0.020
2.36	1.72	120.00	6143.74	5.34	534.94	27.1	-11.62	-11.620	-0.304	0.0000	-0.017
2.37	1.42	120.00	6143.72	5.34	534.94	26.9	-11.78	-11.780	-0.306	0.0000	-0.014
2.38	1.11	120.00	6143.71	5.34	534.94	26.7	-11.94	-11.941	-0.308	0.0000	-0.011

Appendix B, Part 2
PUMP SHUTDOWN ASSUMING A 4 SECOND LOSS OF PUMP INERTIA

2.39	0.80	120.00	6143.70	5.34	534.94	26.6	-12.10	-12.102	-0.309	0.0000	-0.008
2.4	0.49	120.00	6143.69	5.34	534.94	26.4	-12.27	-12.265	-0.311	0.0000	-0.005
2.41	0.18	120.00	6143.68	5.34	534.94	26.2	-12.43	-12.429	-0.187	0.0000	-0.001
2.416	0.00	120.00	6143.68	5.34	534.94	26.1	-12.53	-12.528	-0.125	0.0000	0.000
2.42											

Appendix B, Part 2
PUMP SHUTDOWN ASSUMING A 4 SECOND LOSS OF PUMP INERTIA

COLUMN OF FLUID FALLING THROUGH 20' VERTICAL SECTION OF PIPE

g= 32.17 ft/sec^2
f= 0.011 (assume constant for all Re)
k_{Lelbow} = 0.1
$k_{Lentrance}$ = 6.3
D= 2.5 ft
A= 4.909 ft^2

H_{pump}= 0 (assume that the pump has no inertia and turbines with no losses)

Q_o= 0 ft^3/sec
V_o= 0 ft/sec
z_o= 5.34 ft (pump shuts down at WSEL of 535 ft)
Ꝟ$_o$= 6143.68 ft^3 **Q is positive entering the pump station**

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=((20-x) - p_{elbow2}/\gamma - (f*(20-x)/D + 1*k_{Lelbow})*Q^2/(2g\ A^2)) * A * (g/(44+100+20-x)) * dt$

$p_{elbow2}/\gamma = z - 44 + (f*(100+44)/D + 3*k_{Lelbow} + k_{Lentrance})*Q^2/(2g\ A^2) - Q^2/(2gA^2) + H_{pump}$

$x(t)=x_{prev.} + dx$ $dx=(Q/A)*dt$

Ꝟ$(t)=$Ꝟ$_{prev.}$ + dꝞ dꝞ$=(Q_{inflow} + Q)*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t)$ = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151 (valid for Ꝟ>6205 ft^3)

$z(t)$=(1.17/1116)Ꝟ(t)- 1.105 (valid for Ꝟ<6205 ft^3)

t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow2}/γ	dQ	dx	dꝞ	p_{elbow}/γ	-Q
2.416	0.00	0.00	6143.68	5.34	534.94	26.1	-12.53	0.125	0.0	0.000	-12.53	0.00
2.42	0.13	0.00	6143.68	5.34	534.94	26.1	-12.59	0.628	0.0	0.003	-12.59	-0.13
2.44	0.75	0.00	6143.69	5.34	534.94	25.7	-12.92	0.634	0.0	0.015	-12.92	-0.75
2.46	1.39	0.00	6143.70	5.34	534.94	25.4	-13.25	0.640	0.0	0.028	-13.25	-1.39
2.48	2.03	0.01	6143.73	5.34	534.94	25.1	-13.57	0.646	0.0	0.041	-13.57	-2.03
2.5	2.67	0.02	6143.77	5.34	534.94	24.8	-13.89	0.652	0.0	0.053	-13.89	-2.67
2.52	3.33	0.03	6143.82	5.34	534.94	24.4	-14.20	0.658	0.0	0.067	-14.20	-3.33
2.54	3.98	0.04	6143.89	5.34	534.94	24.1	-14.51	0.664	0.0	0.080	-14.52	-3.98
2.56	4.65	0.06	6143.97	5.34	534.94	23.8	-14.82	0.670	0.0	0.093	-14.82	-4.65
2.58	5.32	0.08	6144.06	5.34	534.94	23.4	-15.12	0.675	0.0	0.106	-15.13	-5.32
2.6	5.99	0.10	6144.17	5.34	534.94	23.1	-15.42	0.681	0.0	0.120	-15.43	-5.99
2.62	6.67	0.12	6144.29	5.34	534.94	22.8	-15.71	0.686	0.0	0.133	-15.73	-6.67
2.64	7.36	0.15	6144.42	5.34	534.94	22.4	-16.01	0.691	0.0	0.147	-16.02	-7.36
2.66	8.05	0.18	6144.57	5.34	534.94	22.1	-16.29	0.696	0.0	0.161	-16.32	-8.05
2.68	8.75	0.21	6144.73	5.34	534.94	21.8	-16.58	0.701	0.0	0.175	-16.60	-8.75
2.7	9.45	0.25	6144.90	5.34	534.94	21.5	-16.85	0.706	0.0	0.189	-16.89	-9.45
2.72	10.15	0.29	6145.09	5.34	534.94	21.1	-17.13	0.710	0.0	0.203	-17.16	-10.15
2.74	10.86	0.33	6145.30	5.34	534.94	20.8	-17.40	0.715	0.0	0.217	-17.44	-10.86
2.76	11.58	0.37	6145.51	5.34	534.94	20.5	-17.66	0.719	0.0	0.232	-17.71	-11.58
2.78	12.30	0.42	6145.74	5.34	534.94	20.1	-17.92	0.724	0.1	0.246	-17.98	-12.30
2.8	13.02	0.47	6145.99	5.34	534.94	19.8	-18.18	0.728	0.1	0.260	-18.24	-13.02
2.82	13.75	0.52	6146.25	5.34	534.94	19.5	-18.43	0.732	0.1	0.275	-18.50	-13.75
2.84	14.48	0.58	6146.53	5.34	534.94	19.1	-18.68	0.736	0.1	0.290	-18.75	-14.48
2.86	15.22	0.64	6146.82	5.34	534.94	18.8	-18.92	0.740	0.1	0.304	-19.00	-15.22
2.88	15.96	0.70	6147.12	5.34	534.94	18.5	-19.16	0.743	0.1	0.319	-19.25	-15.96
2.9	16.70	0.77	6147.44	5.34	534.94	18.2	-19.39	0.747	0.1	0.334	-19.49	-16.70
2.92	17.45	0.83	6147.77	5.34	534.94	17.8	-19.62	0.750	0.1	0.349	-19.72	-17.45
2.94	18.20	0.90	6148.12	5.34	534.94	17.5	-19.84	0.753	0.1	0.364	-19.95	-18.20
2.96	18.95	0.98	6148.49	5.34	534.94	17.2	-20.06	0.756	0.1	0.379	-20.18	-18.95
2.98	19.71	1.06	6148.86	5.34	534.94	16.8	-20.27	0.759	0.1	0.394	-20.40	-19.71
3	20.46	1.14	6149.26	5.34	534.94	16.5	-20.47	0.762	0.1	0.409	-20.62	-20.46
3.02	21.23	1.22	6149.67	5.34	534.94	16.2	-20.68	0.765	0.1	0.425	-20.83	-21.23
3.04	21.99	1.31	6150.09	5.34	534.94	15.8	-20.87	0.767	0.1	0.440	-21.04	-21.99
3.06	22.76	1.40	6150.53	5.34	534.94	15.5	-21.06	0.769	0.1	0.455	-21.24	-22.76
3.08	23.53	1.49	6150.99	5.34	534.94	15.2	-21.25	0.771	0.1	0.471	-21.44	-23.53
3.1	24.30	1.58	6151.46	5.34	534.94	14.9	-21.43	0.774	0.1	0.486	-21.64	-24.30
3.12	25.07	1.68	6151.94	5.34	534.94	14.5	-21.61	0.775	0.1	0.501	-21.83	-25.07
3.14	25.85	1.79	6152.45	5.35	534.95	14.2	-21.78	0.777	0.1	0.517	-22.01	-25.85
3.16	26.63	1.89	6152.96	5.35	534.95	13.9	-21.94	0.779	0.1	0.533	-22.19	-26.63
3.18	27.40	2.00	6153.50	5.35	534.95	13.5	-22.10	0.780	0.1	0.548	-22.37	-27.40
3.2	28.18	2.11	6154.04	5.35	534.95	13.2	-22.26	0.781	0.1	0.564	-22.54	-28.18
3.22	28.97	2.23	6154.61	5.35	534.95	12.9	-22.41	0.783	0.1	0.579	-22.70	-28.97
3.24	29.75	2.34	6155.19	5.35	534.95	12.5	-22.55	0.784	0.1	0.595	-22.86	-29.75
3.26	30.53	2.46	6155.78	5.35	534.95	12.2	-22.69	0.784	0.1	0.611	-23.02	-30.53
3.28	31.32	2.59	6156.39	5.35	534.95	11.9	-22.83	0.785	0.1	0.626	-23.17	-31.32
3.3	32.10	2.72	6157.02	5.35	534.95	11.6	-22.96	0.786	0.1	0.642	-23.32	-32.10
3.32	32.89	2.85	6157.66	5.35	534.95	11.2	-23.08	0.786	0.1	0.658	-23.46	-32.89
3.34	33.67	2.98	6158.32	5.35	534.95	10.9	-23.20	0.786	0.1	0.673	-23.59	-33.67
3.36	34.46	3.12	6158.99	5.35	534.95	10.6	-23.31	0.786	0.1	0.689	-23.73	-34.46
3.38	35.25	3.26	6159.68	5.35	534.95	10.2	-23.42	0.786	0.1	0.705	-23.85	-35.25
3.4	36.03	3.40	6160.39	5.35	534.95	9.9	-23.53	0.786	0.1	0.721	-23.98	-36.03
3.42	36.82	3.55	6161.11	5.35	534.95	9.6	-23.63	0.786	0.2	0.736	-24.10	-36.82
3.44	37.60	3.70	6161.84	5.35	534.95	9.2	-23.72	0.785	0.2	0.752	-24.21	-37.60
3.46	38.39	3.85	6162.59	5.36	534.96	8.9	-23.81	0.785	0.2	0.768	-24.32	-38.39
3.48	39.17	4.01	6163.36	5.36	534.96	8.6	-23.89	0.784	0.2	0.783	-24.43	-39.17
3.5	39.96	4.17	6164.15	5.36	534.96	8.2	-23.97	0.783	0.2	0.799	-24.53	-39.96
3.52	40.74	4.33	6164.95	5.36	534.96	7.9	-24.05	0.782	0.2	0.815	-24.63	-40.74

3.54	41.52	4.50	6165.76	5.36	534.96	7.6	-24.12	0.781	0.2	0.830	-24.72	-41.52
3.56	42.30	4.67	6166.59	5.36	534.96	7.3	-24.18	0.779	0.2	0.846	-24.81	-42.30
3.58	43.08	4.84	6167.44	5.36	534.96	6.9	-24.25	0.778	0.2	0.862	-24.89	-43.08
3.6	43.86	5.01	6168.30	5.36	534.96	6.6	-24.30	0.776	0.2	0.877	-24.97	-43.86
3.62	44.64	5.19	6169.18	5.36	534.96	6.3	-24.36	0.775	0.2	0.893	-25.05	-44.64
3.64	45.41	5.38	6170.07	5.36	534.96	5.9	-24.40	0.773	0.2	0.908	-25.12	-45.41
3.66	46.19	5.56	6170.98	5.36	534.96	5.6	-24.45	0.771	0.2	0.924	-25.19	-46.19
3.68	46.96	5.75	6171.90	5.37	534.97	5.3	-24.49	0.769	0.2	0.939	-25.26	-46.96
3.7	47.72	5.94	6172.84	5.37	534.97	4.9	-24.53	0.766	0.2	0.954	-25.32	-47.72
3.72	48.49	6.13	6173.79	5.37	534.97	4.6	-24.56	0.764	0.2	0.970	-25.38	-48.49
3.74	49.25	6.33	6174.76	5.37	534.97	4.3	-24.59	0.761	0.2	0.985	-25.43	-49.25
3.76	50.02	6.53	6175.75	5.37	534.97	4.0	-24.61	0.759	0.2	1.000	-25.48	-50.02
3.78	50.77	6.74	6176.75	5.37	534.97	3.6	-24.63	0.756	0.2	1.015	-25.53	-50.77
3.8	51.53	6.94	6177.76	5.37	534.97	3.3	-24.65	0.753	0.2	1.031	-25.58	-51.53
3.82	52.28	7.15	6178.80	5.37	534.97	3.0	-24.67	0.750	0.2	1.046	-25.62	-52.28
3.84	53.03	7.37	6179.84	5.37	534.97	2.6	-24.68	0.747	0.2	1.061	-25.66	-53.03
3.86	53.78	7.58	6180.90	5.37	534.97	2.3	-24.69	0.743	0.2	1.076	-25.69	-53.78
3.88	54.52	7.80	6181.98	5.38	534.98	2.0	-24.69	0.740	0.2	1.090	-25.73	-54.52
3.9	55.26	8.02	6183.07	5.38	534.98	1.6	-24.69	0.736	0.2	1.105	-25.76	-55.26
3.92	56.00	8.25	6184.17	5.38	534.98	1.3	-24.69	0.733	0.2	1.120	-25.78	-56.00
3.94	56.73	8.48	6185.29	5.38	534.98	1.0	-24.69	0.729	0.2	1.135	-25.81	-56.73
3.96	57.46	8.71	6186.43	5.38	534.98	0.7	-24.68	0.725	0.2	1.149	-25.83	-57.46
3.98	58.19	8.94	6187.58	5.38	534.98	0.3	-24.67	0.721	0.2	1.164	-25.85	-58.19
4	58.91	9.18	6188.74	5.38	534.98	0.0	-24.66	0.717	0.2	1.178	-25.87	-58.91
4.02	59.62	9.42	6189.92	5.38	534.98	0.0	-24.32	0.706	0.2	1.192	-25.56	-59.62
4.04	60.33	9.66	6191.11	5.39	534.99	0.0	-23.98	0.695	0.2	1.207	-25.25	-60.33
4.06	61.03	9.91	6192.32	5.39	534.99	0.0	-23.64	0.684	0.2	1.221	-24.94	-61.03
4.08	61.71	10.16	6193.54	5.39	534.99	0.0	-23.30	0.673	0.3	1.234	-24.63	-61.71
4.1	62.38	10.41	6194.77	5.39	534.99	0.0	-22.96	0.662	0.3	1.248	-24.32	-62.38
4.12	63.05	10.66	6196.02	5.39	534.99	0.0	-22.63	0.651	0.3	1.261	-24.01	-63.05
4.14	63.70	10.92	6197.28	5.39	534.99	0.0	-22.29	0.640	0.3	1.274	-23.71	-63.70
4.16	64.34	11.18	6198.55	5.39	534.99	0.0	-21.96	0.629	0.3	1.287	-23.41	-64.34
4.18	64.97	11.44	6199.84	5.39	534.99	0.0	-21.64	0.617	0.3	1.299	-23.11	-64.97
4.2	65.58	11.71	6201.14	5.40	535.00	0.0	-21.31	0.606	0.3	1.312	-22.81	-65.58
4.22	66.19	11.97	6202.45	5.40	535.00	0.0	-20.99	0.595	0.3	1.324	-22.51	-66.19
4.24	66.78	12.24	6203.78	5.40	535.00	0.0	-20.67	0.584	0.3	1.336	-22.22	-66.78
4.26	67.37	12.51	6205.11	5.40	535.00	0.0	-20.35	0.572	0.3	1.347	-21.93	-67.37
4.28	67.94	12.79	6206.46	5.40	535.00	0.0	-20.04	0.561	0.3	1.359	-21.65	-67.94
4.3	68.50	13.07	6207.82	5.40	535.00	0.0	-19.73	0.550	0.3	1.370	-21.37	-68.50
4.32	69.05	13.34	6209.19	5.40	535.00	0.0	-19.43	0.538	0.3	1.381	-21.09	-69.05
4.34	69.59	13.63	6210.57	5.40	535.00	0.0	-19.12	0.527	0.3	1.392	-20.81	-69.59
4.36	70.12	13.91	6211.96	5.41	535.01	0.0	-18.83	0.516	0.3	1.402	-20.54	-70.12
4.38	70.63	14.20	6213.36	5.41	535.01	0.0	-18.53	0.505	0.3	1.413	-20.27	-70.63
4.4	71.14	14.48	6214.78	5.41	535.01	0.0	-18.24	0.493	0.3	1.423	-20.01	-71.14
4.42	71.63	14.77	6216.20	5.41	535.01	0.0	-17.96	0.482	0.3	1.433	-19.75	-71.63
4.44	72.11	15.06	6217.63	5.41	535.01	0.0	-17.68	0.471	0.3	1.442	-19.49	-72.11
4.46	72.58	15.36	6219.07	5.41	535.01	0.0	-17.41	0.460	0.3	1.452	-19.24	-72.58
4.48	73.04	15.65	6220.53	5.41	535.01	0.0	-17.13	0.449	0.3	1.461	-18.99	-73.04
4.5	73.49	15.95	6221.99	5.41	535.01	0.0	-16.87	0.437	0.3	1.470	-18.75	-73.49
4.52	73.93	16.25	6223.46	5.42	535.02	0.0	-16.61	0.426	0.3	1.479	-18.51	-73.93
4.54	74.35	16.55	6224.93	5.42	535.02	0.0	-16.35	0.415	0.3	1.487	-18.28	-74.35
4.56	74.77	16.86	6226.42	5.42	535.02	0.0	-16.10	0.404	0.3	1.495	-18.05	-74.77
4.58	75.17	17.16	6227.92	5.42	535.02	0.0	-15.86	0.393	0.3	1.503	-17.83	-75.17
4.6	75.57	17.47	6229.42	5.42	535.02	0.0	-15.62	0.382	0.3	1.511	-17.61	-75.57
4.62	75.95	17.77	6230.93	5.42	535.02	0.0	-15.38	0.372	0.3	1.519	-17.39	-75.95
4.64	76.32	18.08	6232.45	5.42	535.02	0.0	-15.16	0.361	0.3	1.526	-17.18	-76.32
4.66	76.68	18.39	6233.98	5.43	535.03	0.0	-14.93	0.350	0.3	1.534	-16.98	-76.68
4.68	77.03	18.71	6235.51	5.43	535.03	0.0	-14.71	0.339	0.3	1.541	-16.78	-77.03
4.7	77.37	19.02	6237.05	5.43	535.03	0.0	-14.50	0.328	0.3	1.547	-16.59	-77.37
4.72	77.70	19.34	6238.60	5.43	535.03	0.0	-14.30	0.318	0.3	1.554	-16.40	-77.70
4.74	78.02	19.65	6240.15	5.43	535.03	0.0	-14.10	0.307	0.3	1.560	-16.22	-78.02
4.76	78.32	19.97	6241.71	5.43	535.03	0.0	-13.90	0.059	0.1	0.313	-16.04	-78.32
4.764	78.38	20.03	6242.03	5.43	535.03	0.0	-13.86	0.295	0.3	1.568	-16.00	-78.38
4.784												

REVERSE FLOW THROUGH THE HORZONTAL SECTION OF PIPE

$g=$ 32.17 ft/sec^2
$f=$ 0.011 (assume constant for all Re)

$D=$ 2.5 ft
$A=$ 4.91 ft^2
$H_{pump}=$ 0 (assume that the pump has no inertia and turbines with no losses)
$k_{Lelbow}=$ 0.1
$k_{Lentrance}=$ 6.4

$Q_o=$ 78.38 ft^3/sec
$V_o=$ 15.97 ft/sec
$z_o=$ 5.43 ft
$Ꝟ_o=$ 6242.03 ft^3

Q is positive entering the pump station

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=(0 - p_{elbow}/\gamma - (f^*(100-x)/D)^*Q^2/(2g\ A^2)) * A * (g/(100-x+L)) * dt$

$p_{elbow}/\gamma = z - 44 + (f^*(44)/D + 2^*k_{Lelbow} + k_{Lentrance})^*Q^2/(2g\ A^2) - Q^2/(2gA^2) + H_{pump}$

$x(t)=x_{prev.} + dx$ $dx=(Q/A) * dt$

$Ꝟ(t)=Ꝟ_{prev.} + dꝞ$ $dꝞ=(Q_{inflow} + Q)^*dt$ (Assume Q_{inflow} the flow into the pump station, is zero)

$z(t) = -9.5\text{E-}09Ꝟ^2 + 0.00098Ꝟ - 0.3151$ (valid for $Ꝟ>6205$ ft^3)

$z(t)=(1.17/1116)Ꝟ(t)- 1.105$ (valid for $Ꝟ<6205$ ft^3)

t (sec)	Q (cfs)	x (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	p_{elbow}/γ	dQ	dx	dꝞ	-Q
4.764	78.38	0.00	6242.03	5.43	535.03	0.0	-16.00	0.094	0.10	0.470	-78.38
4.77	78.48	0.10	6242.50	5.43	535.03	0.0	-15.95	0.468	0.48	2.354	-78.48
4.8	78.95	0.58	6244.85	5.43	535.03	0.0	-15.68	0.766	0.80	3.947	-78.95
4.85	79.71	1.38	6248.80	5.44	535.04	0.0	-15.23	0.745	0.81	3.986	-79.71
4.9	80.46	2.19	6252.78	5.44	535.04	0.0	-14.79	0.723	0.82	4.023	-80.46
4.95	81.18	3.01	6256.81	5.44	535.04	0.0	-14.35	0.702	0.83	4.059	-81.18
5	81.88	3.84	6260.87	5.45	535.05	0.0	-13.93	0.682	0.83	4.094	-81.88
5.05	82.56	4.67	6264.96	5.45	535.05	0.0	-13.51	0.661	0.84	4.128	-82.56
5.1	83.22	5.51	6269.09	5.46	535.06	0.0	-13.11	0.641	0.85	4.161	-83.22
5.15	83.87	6.36	6273.25	5.46	535.06	0.0	-12.71	0.622	0.85	4.193	-83.87
5.2	84.49	7.21	6277.44	5.46	535.06	0.0	-12.32	0.603	0.86	4.224	-84.49
5.25	85.09	8.08	6281.67	5.47	535.07	0.0	-11.94	0.584	0.87	4.255	-85.09
5.3	85.67	8.94	6285.92	5.47	535.07	0.0	-11.57	0.566	0.87	4.284	-85.67
5.35	86.24	9.81	6290.21	5.47	535.07	0.0	-11.21	0.548	0.88	4.312	-86.24
5.4	86.79	10.69	6294.52	5.48	535.08	0.0	-10.86	0.530	0.88	4.339	-86.79
5.45	87.32	11.58	6298.86	5.48	535.08	0.0	-10.52	0.513	0.89	4.366	-87.32
5.5	87.83	12.47	6303.22	5.48	535.08	0.0	-10.18	0.496	0.89	4.392	-87.83
5.55	88.33	13.36	6307.61	5.49	535.09	0.0	-9.86	0.480	0.90	4.416	-88.33
5.6	88.81	14.26	6312.03	5.49	535.09	0.0	-9.54	0.464	0.90	4.440	-88.81
5.65	89.27	15.17	6316.47	5.50	535.10	0.0	-9.24	0.448	0.91	4.464	-89.27
5.7	89.72	16.07	6320.93	5.50	535.10	0.0	-8.94	0.433	0.91	4.486	-89.72
5.75	90.15	16.99	6325.42	5.50	535.10	0.0	-8.65	0.419	0.92	4.508	-90.15
5.8	90.57	17.91	6329.93	5.51	535.11	0.0	-8.37	0.404	0.92	4.529	-90.57
5.85	90.98	18.83	6334.46	5.51	535.11	0.0	-8.09	0.390	0.93	4.549	-90.98
5.9	91.37	19.76	6339.01	5.52	535.12	0.0	-7.83	0.377	0.93	4.568	-91.37
5.95	91.74	20.69	6343.57	5.52	535.12	0.0	-7.57	0.363	0.93	4.587	-91.74
6	92.11	21.62	6348.16	5.52	535.12	0.0	-7.32	0.351	0.94	4.605	-92.11
6.05	92.46	22.56	6352.77	5.53	535.13	0.0	-7.08	0.338	0.94	4.623	-92.46
6.1	92.79	23.50	6357.39	5.53	535.13	0.0	-6.85	0.326	0.95	4.640	-92.79
6.15	93.12	24.45	6362.03	5.54	535.14	0.0	-6.62	0.314	0.95	4.656	-93.12
6.2	93.44	25.40	6366.68	5.54	535.14	0.0	-6.40	0.303	0.95	4.672	-93.44
6.25	93.74	26.35	6371.36	5.54	535.14	0.0	-6.19	0.292	0.95	4.687	-93.74
6.3	94.03	27.30	6376.04	5.55	535.15	0.0	-5.98	0.281	0.96	4.702	-94.03
6.35	94.31	28.26	6380.74	5.55	535.15	0.0	-5.78	0.271	0.96	4.716	-94.31
6.4	94.58	29.22	6385.46	5.56	535.16	0.0	-5.59	0.261	0.96	4.729	-94.58
6.45	94.84	30.18	6390.19	5.56	535.16	0.0	-5.41	0.251	0.97	4.742	-94.84
6.5	95.09	31.15	6394.93	5.56	535.16	0.0	-5.23	0.242	0.97	4.755	-95.09
6.55	95.34	32.12	6399.69	5.57	535.17	0.0	-5.05	0.233	0.97	4.767	-95.34
6.6	95.57	33.09	6404.45	5.57	535.17	0.0	-4.89	0.224	0.97	4.778	-95.57
6.65	95.79	34.06	6409.23	5.58	535.18	0.0	-4.72	0.216	0.98	4.790	-95.79
6.7	96.01	35.04	6414.02	5.58	535.18	0.0	-4.57	0.208	0.98	4.800	-96.01
6.75	96.22	36.02	6418.82	5.58	535.18	0.0	-4.42	0.200	0.98	4.811	-96.22
6.8	96.42	37.00	6423.63	5.59	535.19	0.0	-4.27	0.192	0.98	4.821	-96.42
6.85	96.61	37.98	6428.45	5.59	535.19	0.0	-4.13	0.185	0.98	4.831	-96.61
6.9	96.80	38.96	6433.28	5.60	535.20	0.0	-3.99	0.178	0.99	4.840	-96.80
6.95	96.97	39.95	6438.12	5.60	535.20	0.0	-3.86	0.172	0.99	4.849	-96.97
7	97.15	40.94	6442.97	5.60	535.20	0.0	-3.74	0.165	0.99	4.857	-97.15
7.05	97.31	41.93	6447.83	5.61	535.21	0.0	-3.61	0.159	0.99	4.866	-97.31
7.1	97.47	42.92	6452.70	5.61	535.21	0.0	-3.50	0.153	0.99	4.873	-97.47
7.15	97.62	43.91	6457.57	5.62	535.22	0.0	-3.38	0.147	0.99	4.881	-97.62
7.2	97.77	44.90	6462.45	5.62	535.22	0.0	-3.27	0.142	1.00	4.888	-97.77
7.25	97.91	45.90	6467.34	5.63	535.23	0.0	-3.17	0.136	1.00	4.896	-97.91
7.3	98.05	46.90	6472.23	5.63	535.23	0.0	-3.07	0.131	1.00	4.902	-98.05
7.35	98.18	47.90	6477.14	5.63	535.23	0.0	-2.97	0.127	1.00	4.909	-98.18
7.4	98.31	48.90	6482.05	5.64	535.24	0.0	-2.87	0.122	1.00	4.915	-98.31
7.45	98.43	49.90	6486.96	5.64	535.24	0.0	-2.78	0.118	1.00	4.921	-98.43

7.5	98.54	50.90	6491.88	5.65	535.25	0.0	-2.69	0.113	1.00	4.927	-98.54
7.55	98.66	51.90	6496.81	5.65	535.25	0.0	-2.60	0.109	1.00	4.933	-98.66
7.6	98.77	52.91	6501.74	5.66	535.26	0.0	-2.52	0.105	1.01	4.938	-98.77
7.65	98.87	53.91	6506.68	5.66	535.26	0.0	-2.44	0.102	1.01	4.944	-98.87
7.7	98.97	54.92	6511.62	5.66	535.26	0.0	-2.36	0.098	1.01	4.949	-98.97
7.75	99.07	55.93	6516.57	5.67	535.27	0.0	-2.28	0.095	1.01	4.954	-99.07
7.8	99.17	56.94	6521.53	5.67	535.27	0.0	-2.21	0.092	1.01	4.958	-99.17
7.85	99.26	57.95	6526.48	5.68	535.28	0.0	-2.14	0.089	1.01	4.963	-99.26
7.9	99.35	58.96	6531.45	5.68	535.28	0.0	-2.07	0.086	1.01	4.967	-99.35
7.95	99.43	59.97	6536.42	5.68	535.28	0.0	-2.01	0.083	1.01	4.972	-99.43
8	99.52	60.99	6541.39	5.69	535.29	0.0	-1.94	0.080	1.01	4.976	-99.52
8.05	99.60	62.00	6546.36	5.69	535.29	0.0	-1.88	0.078	1.01	4.980	-99.60
8.1	99.67	63.01	6551.34	5.70	535.30	0.0	-1.82	0.075	1.02	4.984	-99.67
8.15	99.75	64.03	6556.33	5.70	535.30	0.0	-1.76	0.073	1.02	4.987	-99.75
8.2	99.82	65.04	6561.31	5.71	535.31	0.0	-1.70	0.071	1.02	4.991	-99.82
8.25	99.89	66.06	6566.30	5.71	535.31	0.0	-1.64	0.069	1.02	4.995	-99.89
8.3	99.96	67.08	6571.30	5.71	535.31	0.0	-1.59	0.067	1.02	4.998	-99.96
8.35	100.03	68.10	6576.30	5.72	535.32	0.0	-1.53	0.065	1.02	5.001	-100.03
8.4	100.10	69.12	6581.30	5.72	535.32	0.0	-1.48	0.064	1.02	5.005	-100.10
8.45	100.16	70.14	6586.30	5.73	535.33	0.0	-1.43	0.062	1.02	5.008	-100.16
8.5	100.22	71.16	6591.31	5.73	535.33	0.0	-1.38	0.061	1.02	5.011	-100.22
8.55	100.28	72.18	6596.32	5.74	535.34	0.0	-1.33	0.059	1.02	5.014	-100.28
8.6	100.34	73.20	6601.34	5.74	535.34	0.0	-1.28	0.058	1.02	5.017	-100.34
8.65	100.40	74.22	6606.35	5.74	535.34	0.0	-1.24	0.057	1.02	5.020	-100.40
8.7	100.45	75.24	6611.37	5.75	535.35	0.0	-1.19	0.055	1.02	5.023	-100.45
8.75	100.51	76.27	6616.40	5.75	535.35	0.0	-1.15	0.054	1.02	5.026	-100.51
8.8	100.56	77.29	6621.42	5.76	535.36	0.0	-1.10	0.053	1.02	5.028	-100.56
8.85	100.62	78.31	6626.45	5.76	535.36	0.0	-1.06	0.052	1.02	5.031	-100.62
8.9	100.67	79.34	6631.48	5.77	535.37	0.0	-1.02	0.051	1.03	5.033	-100.67
8.95	100.72	80.36	6636.51	5.77	535.37	0.0	-0.97	0.051	1.03	5.036	-100.72
9	100.77	81.39	6641.55	5.77	535.37	0.0	-0.93	0.050	1.03	5.039	-100.77
9.05	100.82	82.42	6646.59	5.78	535.38	0.0	-0.89	0.049	1.03	5.041	-100.82
9.1	100.87	83.44	6651.63	5.78	535.38	0.0	-0.85	0.048	1.03	5.044	-100.87
9.15	100.92	84.47	6656.67	5.79	535.39	0.0	-0.81	0.048	1.03	5.046	-100.92
9.2	100.97	85.50	6661.72	5.79	535.39	0.0	-0.77	0.047	1.03	5.048	-100.97
9.25	101.01	86.53	6666.77	5.80	535.40	0.0	-0.73	0.047	1.03	5.051	-101.01
9.3	101.06	87.56	6671.82	5.80	535.40	0.0	-0.69	0.046	1.03	5.053	-101.06
9.35	101.11	88.59	6676.87	5.80	535.40	0.0	-0.65	0.046	1.03	5.055	-101.11
9.4	101.15	89.62	6681.93	5.81	535.41	0.0	-0.61	0.045	1.03	5.058	-101.15
9.45	101.20	90.65	6686.98	5.81	535.41	0.0	-0.58	0.045	1.03	5.060	-101.20
9.5	101.24	91.68	6692.04	5.82	535.42	0.0	-0.54	0.045	1.03	5.062	-101.24
9.55	101.29	92.71	6697.11	5.82	535.42	0.0	-0.50	0.044	1.03	5.064	-101.29
9.6	101.33	93.74	6702.17	5.83	535.43	0.0	-0.46	0.044	1.03	5.067	-101.33
9.65	101.38	94.77	6707.24	5.83	535.43	0.0	-0.43	0.044	1.03	5.069	-101.38
9.7	101.42	95.80	6712.31	5.83	535.43	0.0	-0.39	0.044	1.03	5.071	-101.42
9.75	101.46	96.84	6717.38	5.84	535.44	0.0	-0.35	0.044	1.03	5.073	-101.46
9.8	101.51	97.87	6722.45	5.84	535.44	0.0	-0.32	0.043	1.03	5.075	-101.51
9.85	101.55	98.91	6727.53	5.85	535.45	0.0	-0.28	0.043	1.03	5.078	-101.55
9.9	101.59	99.94	6732.60	5.85	535.45	0.0	-0.24	0.004	0.10	0.508	-101.59
9.905	101.60	100.04	6733.11	5.85	535.45	0.0	-0.24	0.004	0.10	0.508	-101.60
9.91											

Appendix B, Part 2
PUMP SHUTDOWN ASSUMING A 4 SECOND LOSS OF PUMP INERTIA

WATER COLUMN NOW IN 44' VERTICAL SECTION OF PIPE ONLY

Q_o= 101.60 ft^3/sec

V_o= 20.697 ft/sec

z_o= 5.85 ft

$Ꝟ_o$= 6733.11 ft^3

H_{pump}= 0 ft

Q is positive entering the pump station

Apply Euler's Formula:

$Q(t)=Q_{prev.} + dQ$ where $dQ=((44-h) - z - Hpump - (f*(44-h)/D + k_{Lelbow} + k_{Lentrance})*Q^2/(2g\ A^2)) * A * (g/(44-h)) * dt$

$h(t)=h_{prev.} + dh$ $dh=(Q/A)*dt$

$Ꝟ(t)=Ꝟ_{prev.} + dꝞ$ $dꝞ=(Q_{inflow}+ Q)*dt$ (Assume Q_{inflow}, the flow into the pump station, is zero)

$z(t) = -9.5E-09Ꝟ^2 + 0.00098Ꝟ - 0.3151$ (valid for Ꝟ>6205 ft^3)

$z(t)=(1.17/1116)Ꝟ(t)- 1.105$ (valid for Ꝟ<6205 ft^3)

t (sec)	Q (cfs)	h (ft)	Ꝟ (ft^3)	z (ft)	WSEL (ft)	H_{pump}	dQ	dh	dꝞ	-Q	44-h
9.905	101.60	0.00	6733.11	5.85	535.45	0.0	-0.103	0.1035	0.508	-101.60	44.00
9.91	101.49	0.10	6733.62	5.85	535.45	0.0	-0.207	0.2068	1.015	-101.49	43.90
9.92	101.29	0.31	6734.63	5.85	535.45	0.0	-0.209	0.2063	1.013	-101.29	43.69
9.93	101.08	0.52	6735.65	5.85	535.45	0.0	-0.211	0.2059	1.011	-101.08	43.48
9.94	100.87	0.72	6736.66	5.86	535.46	0.0	-0.213	0.2055	1.009	-100.87	43.28
9.95	100.65	0.93	6737.67	5.86	535.46	0.0	-0.214	0.2051	1.007	-100.65	43.07
9.96	100.44	1.13	6738.67	5.86	535.46	0.0	-0.216	0.2046	1.004	-100.44	42.87
9.97	100.22	1.34	6739.68	5.86	535.46	0.0	-0.218	0.2042	1.002	-100.22	42.66
9.98	100.01	1.54	6740.68	5.86	535.46	0.0	-0.219	0.2037	1.000	-100.01	42.46
9.99	99.79	1.75	6741.68	5.86	535.46	0.0	-0.221	0.2033	0.998	-99.79	42.25
10	99.57	1.95	6742.68	5.86	535.46	0.0	-0.222	0.2028	0.996	-99.57	42.05
10.01	99.34	2.15	6743.67	5.86	535.46	0.0	-0.224	0.2024	0.993	-99.34	41.85
10.02	99.12	2.35	6744.67	5.86	535.46	0.0	-0.225	0.2019	0.991	-99.12	41.65
10.03	98.90	2.56	6745.66	5.86	535.46	0.0	-0.227	0.2015	0.989	-98.90	41.44
10.04	98.67	2.76	6746.65	5.86	535.46	0.0	-0.228	0.2010	0.987	-98.67	41.24
10.05	98.44	2.96	6747.63	5.87	535.47	0.0	-0.229	0.2005	0.984	-98.44	41.04
10.06	98.21	3.16	6748.62	5.87	535.47	0.0	-0.231	0.2001	0.982	-98.21	40.84
10.07	97.98	3.36	6749.60	5.87	535.47	0.0	-0.232	0.1996	0.980	-97.98	40.64
10.08	97.75	3.56	6750.58	5.87	535.47	0.0	-0.233	0.1991	0.977	-97.75	40.44
10.09	97.52	3.76	6751.56	5.87	535.47	0.0	-0.234	0.1987	0.975	-97.52	40.24
10.1	97.28	3.96	6752.53	5.87	535.47	0.0	-0.235	0.1982	0.973	-97.28	40.04
10.11	97.05	4.15	6753.51	5.87	535.47	0.0	-0.237	0.1977	0.970	-97.05	39.85
10.12	96.81	4.35	6754.48	5.87	535.47	0.0	-0.238	0.1972	0.968	-96.81	39.65
10.13	96.57	4.55	6755.44	5.87	535.47	0.0	-0.239	0.1967	0.966	-96.57	39.45
10.14	96.33	4.75	6756.41	5.87	535.47	0.0	-0.240	0.1962	0.963	-96.33	39.25
10.15	96.09	4.94	6757.37	5.87	535.47	0.0	-0.241	0.1958	0.961	-96.09	39.06
10.16	95.85	5.14	6758.33	5.87	535.47	0.0	-0.242	0.1953	0.959	-95.85	38.86
10.17	95.61	5.33	6759.29	5.87	535.47	0.0	-0.243	0.1948	0.956	-95.61	38.67
10.18	95.37	5.53	6760.25	5.88	535.48	0.0	-0.244	0.1943	0.954	-95.37	38.47
10.19	95.12	5.72	6761.20	5.88	535.48	0.0	-0.245	0.1938	0.951	-95.12	38.28
10.2	94.88	5.92	6762.15	5.88	535.48	0.0	-0.246	0.1933	0.949	-94.88	38.08
10.21	94.63	6.11	6763.10	5.88	535.48	0.0	-0.247	0.1928	0.946	-94.63	37.89
10.22	94.39	6.30	6764.05	5.88	535.48	0.0	-0.248	0.1923	0.944	-94.39	37.70
10.23	94.14	6.49	6764.99	5.88	535.48	0.0	-0.249	0.1918	0.941	-94.14	37.51
10.24	93.89	6.69	6765.93	5.88	535.48	0.0	-0.249	0.1913	0.939	-93.89	37.31
10.25	93.64	6.88	6766.87	5.88	535.48	0.0	-0.250	0.1908	0.936	-93.64	37.12
10.26	93.39	7.07	6767.81	5.88	535.48	0.0	-0.251	0.1903	0.934	-93.39	36.93
10.27	93.14	7.26	6768.74	5.88	535.48	0.0	-0.252	0.1897	0.931	-93.14	36.74
10.28	92.89	7.45	6769.68	5.88	535.48	0.0	-0.253	0.1892	0.929	-92.89	36.55
10.29	92.64	7.64	6770.60	5.88	535.48	0.0	-0.253	0.1887	0.926	-92.64	36.36
10.3	92.38	7.83	6771.53	5.89	535.49	0.0	-0.254	0.1882	0.924	-92.38	36.17
10.31	92.13	8.01	6772.45	5.89	535.49	0.0	-0.255	0.1877	0.921	-92.13	35.99
10.32	91.87	8.20	6773.38	5.89	535.49	0.0	-0.255	0.1872	0.919	-91.87	35.80
10.33	91.62	8.39	6774.29	5.89	535.49	0.0	-0.256	0.1866	0.916	-91.62	35.61
10.34	91.36	8.58	6775.21	5.89	535.49	0.0	-0.257	0.1861	0.914	-91.36	35.42
10.35	91.10	8.76	6776.12	5.89	535.49	0.0	-0.258	0.1856	0.911	-91.10	35.24
10.36	90.85	8.95	6777.04	5.89	535.49	0.0	-0.258	0.1851	0.908	-90.85	35.05
10.37	90.59	9.13	6777.94	5.89	535.49	0.0	-0.259	0.1845	0.906	-90.59	34.87
10.38	90.33	9.32	6778.85	5.89	535.49	0.0	-0.259	0.1840	0.903	-90.33	34.68
10.39	90.07	9.50	6779.75	5.89	535.49	0.0	-0.260	0.1835	0.901	-90.07	34.50
10.4	89.81	9.69	6780.65	5.89	535.49	0.0	-0.261	0.1830	0.898	-89.81	34.31
10.41	89.55	9.87	6781.55	5.89	535.49	0.0	-0.261	0.1824	0.896	-89.55	34.13
10.42	89.29	10.05	6782.45	5.89	535.49	0.0	-0.262	0.1819	0.893	-89.29	33.95
10.43	89.03	10.23	6783.34	5.90	535.50	0.0	-0.262	0.1814	0.890	-89.03	33.77
10.44	88.77	10.41	6784.23	5.90	535.50	0.0	-0.263	0.1808	0.888	-88.77	33.59
10.45	88.50	10.59	6785.12	5.90	535.50	0.0	-0.263	0.1803	0.885	-88.50	33.41
10.46	88.24	10.77	6786.00	5.90	535.50	0.0	-0.264	0.1798	0.882	-88.24	33.23
10.47	87.98	10.95	6786.89	5.90	535.50	0.0	-0.264	0.1792	0.880	-87.98	33.05
10.48	87.71	11.13	6787.77	5.90	535.50	0.0	-0.265	0.1787	0.877	-87.71	32.87
10.49	87.45	11.31	6788.64	5.90	535.50	0.0	-0.265	0.1781	0.874	-87.45	32.69
10.5	87.18	11.49	6789.52	5.90	535.50	0.0	-0.266	0.1776	0.872	-87.18	32.51
10.51	86.92	11.67	6790.39	5.90	535.50	0.0	-0.266	0.1771	0.869	-86.92	32.33
10.52	86.65	11.85	6791.26	5.90	535.50	0.0	-0.267	0.1765	0.866	-86.65	32.15
10.53	86.38	12.02	6792.12	5.90	535.50	0.0	-0.267	0.1760	0.864	-86.38	31.98
10.54	86.12	12.20	6792.99	5.90	535.50	0.0	-0.267	0.1754	0.861	-86.12	31.80
10.55	85.85	12.37	6793.85	5.90	535.50	0.0	-0.268	0.1749	0.858	-85.85	31.63
10.56	85.58	12.55	6794.71	5.91	535.51	0.0	-0.268	0.1743	0.856	-85.58	31.45
10.57	85.31	12.72	6795.56	5.91	535.51	0.0	-0.269	0.1738	0.853	-85.31	31.28
10.58	85.04	12.90	6796.42	5.91	535.51	0.0	-0.269	0.1733	0.850	-85.04	31.10

10.59	84.78	13.07	6797.27	5.91	535.51	0.0	-0.269	0.1727	0.848	-84.78	30.93
10.6	84.51	13.24	6798.11	5.91	535.51	0.0	-0.270	0.1722	0.845	-84.51	30.76
10.61	84.24	13.41	6798.96	5.91	535.51	0.0	-0.270	0.1716	0.842	-84.24	30.59
10.62	83.97	13.59	6799.80	5.91	535.51	0.0	-0.270	0.1711	0.840	-83.97	30.41
10.63	83.70	13.76	6800.64	5.91	535.51	0.0	-0.271	0.1705	0.837	-83.70	30.24
10.64	83.42	13.93	6801.48	5.91	535.51	0.0	-0.271	0.1700	0.834	-83.42	30.07
10.65	83.15	14.10	6802.31	5.91	535.51	0.0	-0.271	0.1694	0.832	-83.15	29.90
10.66	82.88	14.27	6803.14	5.91	535.51	0.0	-0.272	0.1688	0.829	-82.88	29.73
10.67	82.61	14.44	6803.97	5.91	535.51	0.0	-0.272	0.1683	0.826	-82.61	29.56
10.68	82.34	14.60	6804.80	5.91	535.51	0.0	-0.272	0.1677	0.823	-82.34	29.40
10.69	82.07	14.77	6805.62	5.91	535.51	0.0	-0.273	0.1672	0.821	-82.07	29.23
10.7	81.79	14.94	6806.44	5.92	535.52	0.0	-0.273	0.1666	0.818	-81.79	29.06
10.71	81.52	15.11	6807.26	5.92	535.52	0.0	-0.273	0.1661	0.815	-81.52	28.89
10.72	81.25	15.27	6808.08	5.92	535.52	0.0	-0.274	0.1655	0.812	-81.25	28.73
10.73	80.97	15.44	6808.89	5.92	535.52	0.0	-0.274	0.1650	0.810	-80.97	28.56
10.74	80.70	15.60	6809.70	5.92	535.52	0.0	-0.274	0.1644	0.807	-80.70	28.40
10.75	80.43	15.77	6810.51	5.92	535.52	0.0	-0.274	0.1638	0.804	-80.43	28.23
10.76	80.15	15.93	6811.31	5.92	535.52	0.0	-0.275	0.1633	0.802	-80.15	28.07
10.77	79.88	16.09	6812.11	5.92	535.52	0.0	-0.275	0.1627	0.799	-79.88	27.91
10.78	79.60	16.26	6812.91	5.92	535.52	0.0	-0.275	0.1622	0.796	-79.60	27.74
10.79	79.33	16.42	6813.71	5.92	535.52	0.0	-0.275	0.1616	0.793	-79.33	27.58
10.8	79.05	16.58	6814.50	5.92	535.52	0.0	-0.276	0.1610	0.791	-79.05	27.42
10.81	78.78	16.74	6815.29	5.92	535.52	0.0	-0.276	0.1605	0.788	-78.78	27.26
10.82	78.50	16.90	6816.08	5.92	535.52	0.0	-0.276	0.1599	0.785	-78.50	27.10
10.83	78.22	17.06	6816.86	5.92	535.52	0.0	-0.276	0.1594	0.782	-78.22	26.94
10.84	77.95	17.22	6817.65	5.92	535.52	0.0	-0.277	0.1588	0.779	-77.95	26.78
10.85	77.67	17.38	6818.42	5.93	535.53	0.0	-0.277	0.1582	0.777	-77.67	26.62
10.86	77.39	17.54	6819.20	5.93	535.53	0.0	-0.277	0.1577	0.774	-77.39	26.46
10.87	77.12	17.70	6819.98	5.93	535.53	0.0	-0.277	0.1571	0.771	-77.12	26.30
10.88	76.84	17.85	6820.75	5.93	535.53	0.0	-0.277	0.1565	0.768	-76.84	26.15
10.89	76.56	18.01	6821.51	5.93	535.53	0.0	-0.278	0.1560	0.766	-76.56	25.99
10.9	76.28	18.17	6822.28	5.93	535.53	0.0	-0.278	0.1554	0.763	-76.28	25.83
10.91	76.01	18.32	6823.04	5.93	535.53	0.0	-0.278	0.1548	0.760	-76.01	25.68
10.92	75.73	18.48	6823.80	5.93	535.53	0.0	-0.278	0.1543	0.757	-75.73	25.52
10.93	75.45	18.63	6824.56	5.93	535.53	0.0	-0.278	0.1537	0.755	-75.45	25.37
10.94	75.17	18.78	6825.32	5.93	535.53	0.0	-0.278	0.1531	0.752	-75.17	25.22
10.95	74.89	18.94	6826.07	5.93	535.53	0.0	-0.279	0.1526	0.749	-74.89	25.06
10.96	74.62	19.09	6826.82	5.93	535.53	0.0	-0.279	0.1520	0.746	-74.62	24.91
10.97	74.34	19.24	6827.56	5.93	535.53	0.0	-0.279	0.1514	0.743	-74.34	24.76
10.98	74.06	19.39	6828.31	5.93	535.53	0.0	-0.279	0.1509	0.741	-74.06	24.61
10.99	73.78	19.54	6829.05	5.93	535.53	0.0	-0.279	0.1503	0.738	-73.78	24.46
11	73.50	19.69	6829.78	5.93	535.53	0.0	-0.280	0.1497	0.735	-73.50	24.31
11.01	73.22	19.84	6830.52	5.94	535.54	0.0	-0.280	0.1492	0.732	-73.22	24.16
11.02	72.94	19.99	6831.25	5.94	535.54	0.0	-0.280	0.1486	0.729	-72.94	24.01
11.03	72.66	20.14	6831.98	5.94	535.54	0.0	-0.280	0.1480	0.727	-72.66	23.86
11.04	72.38	20.29	6832.71	5.94	535.54	0.0	-0.280	0.1475	0.724	-72.38	23.71
11.05	72.10	20.44	6833.43	5.94	535.54	0.0	-0.280	0.1469	0.721	-72.10	23.56
11.06	71.82	20.58	6834.15	5.94	535.54	0.0	-0.280	0.1463	0.718	-71.82	23.42
11.07	71.54	20.73	6834.87	5.94	535.54	0.0	-0.281	0.1457	0.715	-71.54	23.27
11.08	71.26	20.88	6835.59	5.94	535.54	0.0	-0.281	0.1452	0.713	-71.26	23.12
11.09	70.98	21.02	6836.30	5.94	535.54	0.0	-0.281	0.1446	0.710	-70.98	22.98
11.1	70.70	21.17	6837.01	5.94	535.54	0.0	-0.281	0.1440	0.707	-70.70	22.83
11.11	70.42	21.31	6837.71	5.94	535.54	0.0	-0.281	0.1435	0.704	-70.42	22.69
11.12	70.13	21.45	6838.42	5.94	535.54	0.0	-0.281	0.1429	0.701	-70.13	22.55
11.13	69.85	21.60	6839.12	5.94	535.54	0.0	-0.281	0.1423	0.699	-69.85	22.40
11.14	69.57	21.74	6839.82	5.94	535.54	0.0	-0.282	0.1417	0.696	-69.57	22.26
11.15	69.29	21.88	6840.51	5.94	535.54	0.0	-0.338	0.1694	0.831	-69.29	22.12
11.162	68.95	22.05	6841.35	5.94	535.54	0.0	-0.338	0.1686	0.827	-68.95	21.95
11.174	68.61	22.22	6842.17	5.95	535.55	0.0	-0.338	0.1677	0.823	-68.61	21.78
11.186	68.28	22.39	6843.00	5.95	535.55	0.0	-0.339	0.1669	0.819	-68.28	21.61
11.198	67.94	22.55	6843.82	5.95	535.55	0.0	-0.339	0.1661	0.815	-67.94	21.45
11.21	67.60	22.72	6844.63	5.95	535.55	0.0	-0.339	0.1653	0.811	-67.60	21.28
11.222	67.26	22.88	6845.44	5.95	535.55	0.0	-0.339	0.1644	0.807	-67.26	21.12
11.234	66.92	23.05	6846.25	5.95	535.55	0.0	-0.339	0.1636	0.803	-66.92	20.95
11.246	66.58	23.21	6847.05	5.95	535.55	0.0	-0.339	0.1628	0.799	-66.58	20.79
11.258	66.24	23.37	6847.85	5.95	535.55	0.0	-0.340	0.1619	0.795	-66.24	20.63
11.27	65.90	23.54	6848.65	5.95	535.55	0.0	-0.340	0.1611	0.791	-65.90	20.46
11.282	65.56	23.70	6849.44	5.95	535.55	0.0	-0.340	0.1603	0.787	-65.56	20.30
11.294	65.22	23.86	6850.22	5.95	535.55	0.0	-0.340	0.1594	0.783	-65.22	20.14
11.306	64.88	24.02	6851.01	5.95	535.55	0.0	-0.340	0.1586	0.779	-64.88	19.98
11.318	64.54	24.18	6851.79	5.95	535.55	0.0	-0.340	0.1578	0.775	-64.54	19.82
11.33	64.20	24.33	6852.56	5.95	535.55	0.0	-0.341	0.1569	0.770	-64.20	19.67
11.342	63.86	24.49	6853.33	5.95	535.55	0.0	-0.341	0.1561	0.766	-63.86	19.51
11.354	63.52	24.65	6854.10	5.96	535.56	0.0	-0.341	0.1553	0.762	-63.52	19.35
11.366	63.18	24.80	6854.86	5.96	535.56	0.0	-0.341	0.1545	0.758	-63.18	19.20
11.378	62.84	24.96	6855.62	5.96	535.56	0.0	-0.341	0.1536	0.754	-62.84	19.04
11.39	62.50	25.11	6856.37	5.96	535.56	0.0	-0.341	0.1528	0.750	-62.50	18.89
11.402	62.16	25.26	6857.12	5.96	535.56	0.0	-0.341	0.1519	0.746	-62.16	18.74
11.414	61.82	25.41	6857.87	5.96	535.56	0.0	-0.342	0.1511	0.742	-61.82	18.59
11.426	61.47	25.57	6858.61	5.96	535.56	0.0	-0.342	0.1503	0.738	-61.47	18.43
11.438	61.13	25.72	6859.35	5.96	535.56	0.0	-0.342	0.1494	0.734	-61.13	18.28
11.45	60.79	25.87	6860.08	5.96	535.56	0.0	-0.342	0.1486	0.729	-60.79	18.13
11.462	60.45	26.01	6860.81	5.96	535.56	0.0	-0.342	0.1478	0.725	-60.45	17.99
11.474	60.11	26.16	6861.53	5.96	535.56	0.0	-0.342	0.1469	0.721	-60.11	17.84
11.486	59.76	26.31	6862.26	5.96	535.56	0.0	-0.342	0.1461	0.717	-59.76	17.69
11.498	59.42	26.46	6862.97	5.96	535.56	0.0	-0.342	0.1453	0.713	-59.42	17.54
11.51	59.08	26.60	6863.69	5.96	535.56	0.0	-0.343	0.1444	0.709	-59.08	17.40
11.522	58.74	26.74	6864.40	5.96	535.56	0.0	-0.343	0.1436	0.705	-58.74	17.26

11.534	58.39	26.89	6865.10	5.96	535.56	0.0	-0.343	0.1428	0.701	-58.39	17.11
11.546	58.05	27.03	6865.80	5.97	535.57	0.0	-0.343	0.1419	0.697	-58.05	16.97
11.558	57.71	27.17	6866.50	5.97	535.57	0.0	-0.343	0.1411	0.693	-57.71	16.83
11.57	57.37	27.31	6867.19	5.97	535.57	0.0	-0.343	0.1402	0.688	-57.37	16.69
11.582	57.02	27.45	6867.88	5.97	535.57	0.0	-0.343	0.1394	0.684	-57.02	16.55
11.594	56.68	27.59	6868.56	5.97	535.57	0.0	-0.343	0.1386	0.680	-56.68	16.41
11.606	56.34	27.73	6869.24	5.97	535.57	0.0	-0.344	0.1377	0.676	-56.34	16.27
11.618	55.99	27.87	6869.92	5.97	535.57	0.0	-0.344	0.1369	0.672	-55.99	16.13
11.63	55.65	28.01	6870.59	5.97	535.57	0.0	-0.344	0.1360	0.668	-55.65	15.99
11.642	55.30	28.14	6871.26	5.97	535.57	0.0	-0.344	0.1352	0.664	-55.30	15.86
11.654	54.96	28.28	6871.92	5.97	535.57	0.0	-0.344	0.1344	0.660	-54.96	15.72
11.666	54.62	28.41	6872.58	5.97	535.57	0.0	-0.344	0.1335	0.655	-54.62	15.59
11.678	54.27	28.55	6873.24	5.97	535.57	0.0	-0.344	0.1327	0.651	-54.27	15.45
11.69	53.93	28.68	6873.89	5.97	535.57	0.0	-0.344	0.1318	0.647	-53.93	15.32
11.702	53.58	28.81	6874.54	5.97	535.57	0.0	-0.344	0.1310	0.643	-53.58	15.19
11.714	53.24	28.94	6875.18	5.97	535.57	0.0	-0.344	0.1302	0.639	-53.24	15.06
11.726	52.90	29.07	6875.82	5.97	535.57	0.0	-0.345	0.1293	0.635	-52.90	14.93
11.738	52.55	29.20	6876.45	5.97	535.57	0.0	-0.345	0.1285	0.631	-52.55	14.80
11.75	52.21	29.33	6877.08	5.98	535.58	0.0	-0.345	0.1276	0.626	-52.21	14.67
11.762	51.86	29.46	6877.71	5.98	535.58	0.0	-0.345	0.1268	0.622	-51.86	14.54
11.774	51.52	29.58	6878.33	5.98	535.58	0.0	-0.345	0.1259	0.618	-51.52	14.42
11.786	51.17	29.71	6878.95	5.98	535.58	0.0	-0.345	0.1251	0.614	-51.17	14.29
11.798	50.83	29.83	6879.56	5.98	535.58	0.0	-0.345	0.1243	0.610	-50.83	14.17
11.81	50.48	29.96	6880.17	5.98	535.58	0.0	-0.345	0.1234	0.606	-50.48	14.04
11.822	50.14	30.08	6880.78	5.98	535.58	0.0	-0.345	0.1226	0.602	-50.14	13.92
11.834	49.79	30.21	6881.38	5.98	535.58	0.0	-0.345	0.1217	0.597	-49.79	13.79
11.846	49.44	30.33	6881.98	5.98	535.58	0.0	-0.346	0.1209	0.593	-49.44	13.67
11.858	49.10	30.45	6882.57	5.98	535.58	0.0	-0.346	0.1200	0.589	-49.10	13.55
11.87	48.75	30.57	6883.16	5.98	535.58	0.0	-0.346	0.1192	0.585	-48.75	13.43
11.882	48.41	30.69	6883.75	5.98	535.58	0.0	-0.346	0.1183	0.581	-48.41	13.31
11.894	48.06	30.81	6884.33	5.98	535.58	0.0	-0.346	0.1175	0.577	-48.06	13.19
11.906	47.72	30.92	6884.90	5.98	535.58	0.0	-0.346	0.1166	0.573	-47.72	13.08
11.918	47.37	31.04	6885.48	5.98	535.58	0.0	-0.346	0.1158	0.568	-47.37	12.96
11.93	47.02	31.16	6886.04	5.98	535.58	0.0	-0.346	0.1150	0.564	-47.02	12.84
11.942	46.68	31.27	6886.61	5.98	535.58	0.0	-0.346	0.1141	0.560	-46.68	12.73
11.954	46.33	31.38	6887.17	5.98	535.58	0.0	-0.346	0.1133	0.556	-46.33	12.62
11.966	45.98	31.50	6887.73	5.98	535.58	0.0	-0.347	0.1124	0.552	-45.98	12.50
11.978	45.64	31.61	6888.28	5.98	535.58	0.0	-0.347	0.1116	0.548	-45.64	12.39
11.99	45.29	31.72	6888.82	5.99	535.59	0.0	-0.347	0.1107	0.543	-45.29	12.28
12.002	44.94	31.83	6889.37	5.99	535.59	0.0	-0.347	0.1099	0.539	-44.94	12.17
12.014	44.60	31.94	6889.91	5.99	535.59	0.0	-0.347	0.1090	0.535	-44.60	12.06
12.026	44.25	32.05	6890.44	5.99	535.59	0.0	-0.347	0.1082	0.531	-44.25	11.95
12.038	43.90	32.16	6890.97	5.99	535.59	0.0	-0.347	0.1073	0.527	-43.90	11.84
12.05	43.56	32.27	6891.50	5.99	535.59	0.0	-0.347	0.1065	0.523	-43.56	11.73
12.062	43.21	32.37	6892.02	5.99	535.59	0.0	-0.347	0.1056	0.519	-43.21	11.63
12.074	42.86	32.48	6892.54	5.99	535.59	0.0	-0.347	0.1048	0.514	-42.86	11.52
12.086	42.52	32.58	6893.06	5.99	535.59	0.0	-0.347	0.1039	0.510	-42.52	11.42
12.098	42.17	32.69	6893.57	5.99	535.59	0.0	-0.347	0.1031	0.506	-42.17	11.31
12.11	41.82	32.79	6894.07	5.99	535.59	0.0	-0.348	0.1022	0.502	-41.82	11.21
12.122	41.47	32.89	6894.57	5.99	535.59	0.0	-0.348	0.1014	0.498	-41.47	11.11
12.134	41.13	32.99	6895.07	5.99	535.59	0.0	-0.348	0.1005	0.494	-41.13	11.01
12.146	40.78	33.09	6895.57	5.99	535.59	0.0	-0.348	0.0997	0.489	-40.78	10.91
12.158	40.43	33.19	6896.05	5.99	535.59	0.0	-0.348	0.0988	0.485	-40.43	10.81
12.17	40.08	33.29	6896.54	5.99	535.59	0.0	-0.348	0.0980	0.481	-40.08	10.71
12.182	39.73	33.39	6897.02	5.99	535.59	0.0	-0.348	0.0971	0.477	-39.73	10.61
12.194	39.39	33.49	6897.50	5.99	535.59	0.0	-0.348	0.0963	0.473	-39.39	10.51
12.206	39.04	33.58	6897.97	5.99	535.59	0.0	-0.348	0.0954	0.468	-39.04	10.42
12.218	38.69	33.68	6898.44	5.99	535.59	0.0	-0.348	0.0946	0.464	-38.69	10.32
12.23	38.34	33.77	6898.90	5.99	535.59	0.0	-0.348	0.0937	0.460	-38.34	10.23
12.242	37.99	33.87	6899.36	5.99	535.59	0.0	-0.348	0.0929	0.456	-37.99	10.13
12.254	37.64	33.96	6899.82	5.99	535.59	0.0	-0.349	0.0920	0.452	-37.64	10.04
12.266	37.30	34.05	6900.27	5.99	535.59	0.0	-0.349	0.0912	0.448	-37.30	9.95
12.278	36.95	34.14	6900.72	6.00	535.60	0.0	-0.349	0.0903	0.443	-36.95	9.86
12.29	36.60	34.23	6901.16	6.00	535.60	0.0	-0.349	0.0895	0.439	-36.60	9.77
12.302	36.25	34.32	6901.60	6.00	535.60	0.0	-0.349	0.0886	0.435	-36.25	9.68
12.314	35.90	34.41	6902.04	6.00	535.60	0.0	-0.349	0.0878	0.431	-35.90	9.59
12.326	35.55	34.50	6902.47	6.00	535.60	0.0	-0.349	0.0869	0.427	-35.55	9.50
12.338	35.20	34.59	6902.89	6.00	535.60	0.0	-0.349	0.0861	0.422	-35.20	9.41
12.35	34.85	34.67	6903.32	6.00	535.60	0.0	-0.349	0.0852	0.418	-34.85	9.33
12.362	34.51	34.76	6903.73	6.00	535.60	0.0	-0.349	0.0844	0.414	-34.51	9.24
12.374	34.16	34.84	6904.15	6.00	535.60	0.0	-0.349	0.0835	0.410	-34.16	9.16
12.386	33.81	34.93	6904.56	6.00	535.60	0.0	-0.349	0.0826	0.406	-33.81	9.07
12.398	33.46	35.01	6904.96	6.00	535.60	0.0	-0.349	0.0818	0.401	-33.46	8.99
12.41	33.11	35.09	6905.37	6.00	535.60	0.0	-0.349	0.0809	0.397	-33.11	8.91
12.422	32.76	35.17	6905.76	6.00	535.60	0.0	-0.350	0.0801	0.393	-32.76	8.83
12.434	32.41	35.25	6906.16	6.00	535.60	0.0	-0.350	0.0792	0.389	-32.41	8.75
12.446	32.06	35.33	6906.54	6.00	535.60	0.0	-0.350	0.0784	0.385	-32.06	8.67
12.458	31.71	35.41	6906.93	6.00	535.60	0.0	-0.350	0.0775	0.381	-31.71	8.59
12.47	31.36	35.49	6907.31	6.00	535.60	0.0	-0.350	0.0767	0.376	-31.36	8.51
12.482	31.01	35.56	6907.69	6.00	535.60	0.0	-0.350	0.0758	0.372	-31.01	8.44
12.494	30.66	35.64	6908.06	6.00	535.60	0.0	-0.350	0.0750	0.368	-30.66	8.36
12.506	30.31	35.71	6908.43	6.00	535.60	0.0	-0.350	0.0741	0.364	-30.31	8.29
12.518	29.96	35.79	6908.79	6.00	535.60	0.0	-0.350	0.0732	0.360	-29.96	8.21
12.53	29.61	35.86	6909.15	6.00	535.60	0.0	-0.350	0.0724	0.355	-29.61	8.14
12.542	29.26	35.93	6909.50	6.00	535.60	0.0	-0.350	0.0715	0.351	-29.26	8.07
12.554	28.91	36.01	6909.86	6.00	535.60	0.0	-0.350	0.0707	0.347	-28.91	7.99
12.566	28.56	36.08	6910.20	6.00	535.60	0.0	-0.350	0.0698	0.343	-28.56	7.92
12.578	28.21	36.15	6910.55	6.00	535.60	0.0	-0.350	0.0690	0.339	-28.21	7.85

Appendix B, Part 2

PUMP SHUTDOWN ASSUMING A 4 SECOND LOSS OF PUMP INERTIA

12.59	27.86	36.22	6910.88	6.00	535.60	0.0	-0.351	0.0681	0.334	-27.86		7.78
12.602	27.51	36.28	6911.22	6.00	535.60	0.0	-0.351	0.0672	0.330	-27.51		7.72
12.614	27.16	36.35	6911.55	6.00	535.60	0.0	-0.351	0.0664	0.326	-27.16		7.65
12.626	26.81	36.42	6911.87	6.00	535.60	0.0	-0.351	0.0655	0.322	-26.81		7.58
12.638	26.46	36.48	6912.20	6.00	535.60	0.0	-0.351	0.0647	0.317	-26.46		7.52
12.65	26.10	36.55	6912.51	6.01	535.61	0.0	-0.351	0.0638	0.313	-26.10		7.45
12.662	25.75	36.61	6912.83	6.01	535.61	0.0	-0.351	0.0630	0.309	-25.75		7.39
12.674	25.40	36.67	6913.14	6.01	535.61	0.0	-0.351	0.0621	0.305	-25.40		7.33
12.686	25.05	36.74	6913.44	6.01	535.61	0.0	-0.351	0.0612	0.301	-25.05		7.26
12.698	24.70	36.80	6913.74	6.01	535.61	0.0	-0.351	0.0604	0.296	-24.70		7.20
12.71	24.35	36.86	6914.04	6.01	535.61	0.0	-0.351	0.0595	0.292	-24.35		7.14
12.722	24.00	36.92	6914.33	6.01	535.61	0.0	-0.351	0.0587	0.288	-24.00		7.08
12.734	23.65	36.98	6914.62	6.01	535.61	0.0	-0.351	0.0578	0.284	-23.65		7.02
12.746	23.30	37.03	6914.90	6.01	535.61	0.0	-0.351	0.0569	0.280	-23.30		6.97
12.758	22.94	37.09	6915.18	6.01	535.61	0.0	-0.352	0.0561	0.275	-22.94		6.91
12.77	22.59	37.15	6915.46	6.01	535.61	0.0	-0.352	0.0552	0.271	-22.59		6.85
12.782	22.24	37.20	6915.73	6.01	535.61	0.0	-0.352	0.0544	0.267	-22.24		6.80
12.794	21.89	37.26	6915.99	6.01	535.61	0.0	-0.352	0.0535	0.263	-21.89		6.74
12.806	21.54	37.31	6916.26	6.01	535.61	0.0	-0.352	0.0527	0.258	-21.54		6.69
12.818	21.19	37.36	6916.52	6.01	535.61	0.0	-0.352	0.0518	0.254	-21.19		6.64
12.83	20.83	37.41	6916.77	6.01	535.61	0.0	-0.352	0.0509	0.250	-20.83		6.59
12.842	20.48	37.47	6917.02	6.01	535.61	0.0	-0.352	0.0501	0.246	-20.48		6.53
12.854	20.13	37.52	6917.27	6.01	535.61	0.0	-0.352	0.0492	0.242	-20.13		6.48
12.866	19.78	37.56	6917.51	6.01	535.61	0.0	-0.352	0.0483	0.237	-19.78		6.44
12.878	19.43	37.61	6917.74	6.01	535.61	0.0	-0.352	0.0475	0.233	-19.43		6.39
12.89	19.07	37.66	6917.98	6.01	535.61	0.0	-0.352	0.0466	0.229	-19.07		6.34
12.902	18.72	37.71	6918.21	6.01	535.61	0.0	-0.352	0.0458	0.225	-18.72		6.29
12.914	18.37	37.75	6918.43	6.01	535.61	0.0	-0.352	0.0449	0.220	-18.37		6.25
12.926	18.02	37.80	6918.65	6.01	535.61	0.0	-0.353	0.0440	0.216	-18.02		6.20
12.938	17.66	37.84	6918.87	6.01	535.61	0.0	-0.353	0.0432	0.212	-17.66		6.16
12.95	17.31	37.88	6919.08	6.01	535.61	0.0	-0.353	0.0423	0.208	-17.31		6.12
12.962	16.96	37.93	6919.29	6.01	535.61	0.0	-0.353	0.0415	0.203	-16.96		6.07
12.974	16.61	37.97	6919.49	6.01	535.61	0.0	-0.353	0.0406	0.199	-16.61		6.03
12.986	16.25	38.01	6919.69	6.01	535.61	1.0	-0.669	0.0397	0.195	-16.25		5.99
12.998	15.58	38.05	6919.88	6.01	535.61	2.0	-0.977	0.0381	0.187	-15.58		5.95
13.01	14.61	38.09	6920.07	6.01	535.61	3.0	-1.277	0.0357	0.175	-14.61		5.91
13.022	13.33	38.12	6920.25	6.01	535.61	4.0	-1.571	0.0326	0.160	-13.33		5.88
13.034	11.76	38.16	6920.41	6.01	535.61	5.0	-1.861	0.0287	0.141	-11.76		5.84
13.046	9.90	38.18	6920.55	6.01	535.61	6.0	-2.151	0.0242	0.119	-9.90		5.82
13.058	7.75	38.21	6920.67	6.01	535.61	7.0	-2.444	0.0189	0.093	-7.75		5.79
13.07	5.30	38.23	6920.76	6.01	535.61	8.0	-2.743	0.0130	0.064	-5.30		5.77
13.082	2.56	38.24	6920.82	6.01	535.61	9.0	-3.053	0.0063	0.031	-2.56		5.76
13.094	-0.49	38.25	6920.85	6.01	535.61	10.0	-3.379	-0.0012	-0.006	0.49		5.75
13.106	-3.87	38.25	6920.85	6.01	535.61	11.0	-3.728	-0.0095	-0.046	3.87		5.75
13.118	-7.60	38.24	6920.80	6.01	535.61	12.0	-4.105	-0.0186	-0.091	7.60		5.76
13.13	-11.71	38.22	6920.71	6.01	535.61	13.0	-4.521	-0.0286	-0.140	11.71		5.78
13.142	-16.23	38.19	6920.57	6.01	535.61	14.0	-4.987	-0.0397	-0.195	16.23		5.81
13.154	-21.21	38.15	6920.38	6.01	535.61	15.0	-5.514	-0.0519	-0.255	21.21		5.85
13.166	-26.73	38.10	6920.12	6.01	535.61	16.0	-6.122	-0.0653	-0.321	26.73		5.90
13.178	-32.85	38.03	6919.80	6.01	535.61	17.0	-6.832	-0.0803	-0.394	32.85		5.97
13.19	-39.68	37.95	6919.41	6.01	535.61	18.0	-7.673	-0.0970	-0.476	39.68		6.05
13.202												

FIGURE A-7: Flowrate vs. Time for Pump Startup

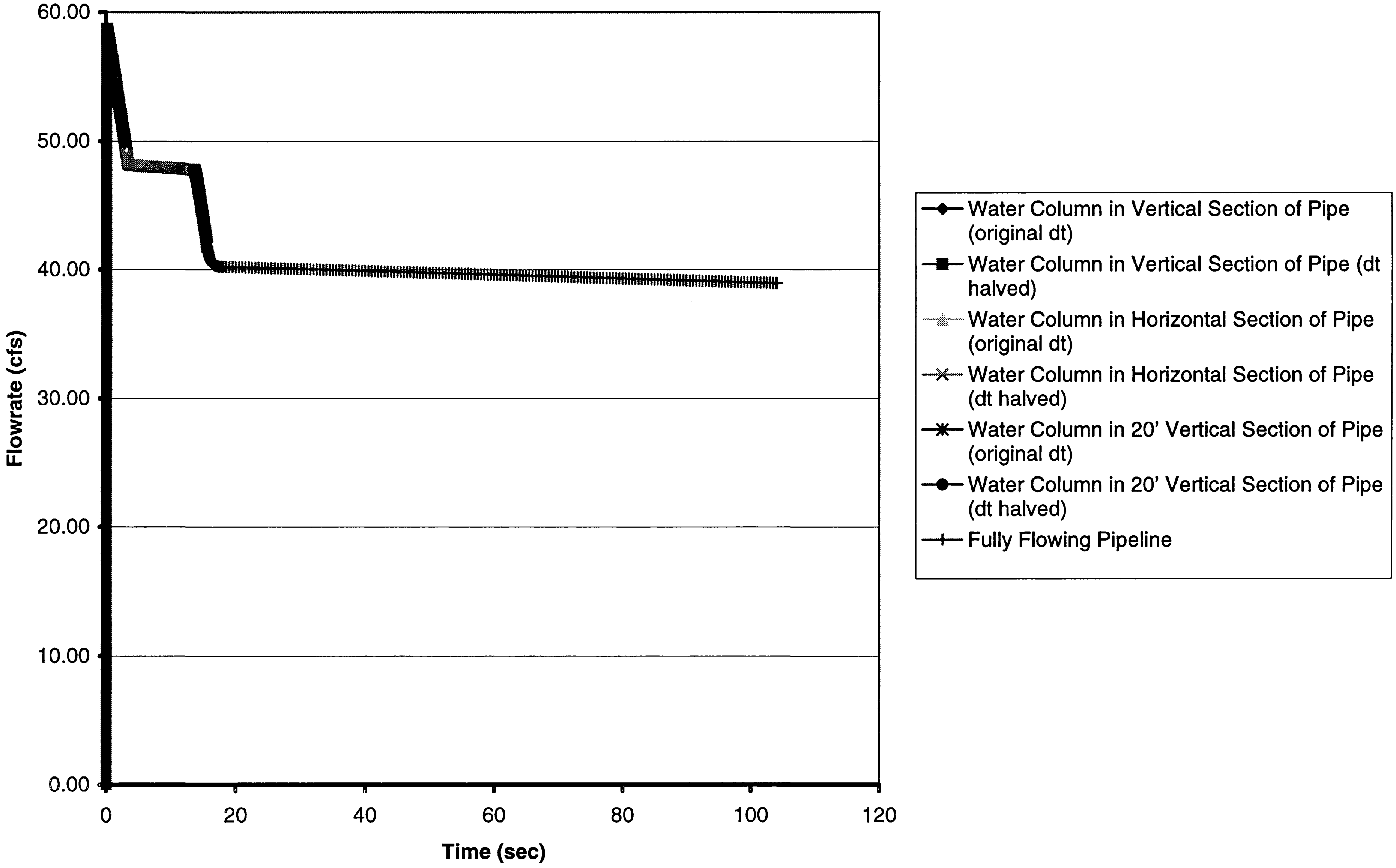


FIGURE A-8: Pump Head vs. Time for Pump Startup

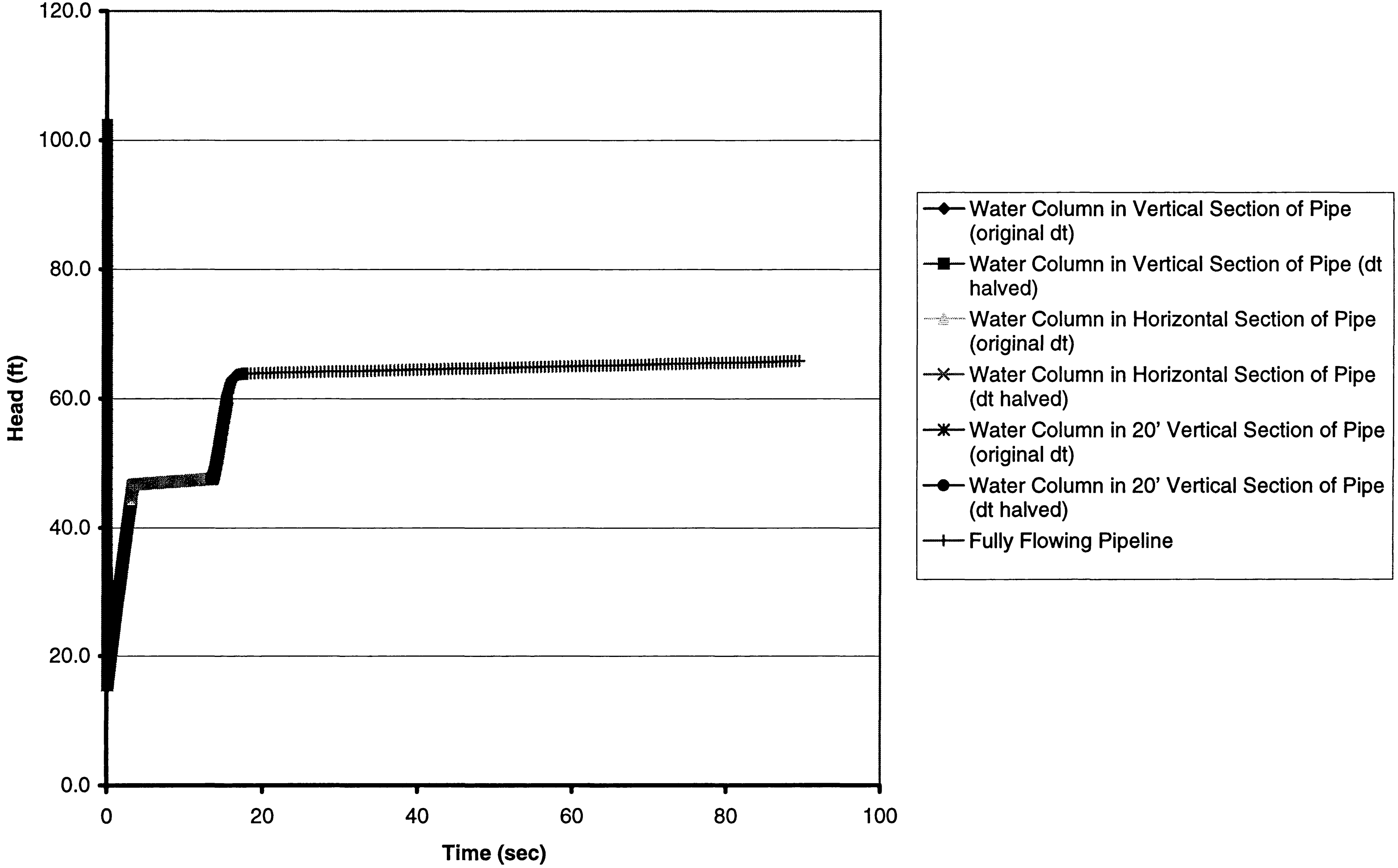


FIGURE A-9: WSEL vs. Time for Pump Startup

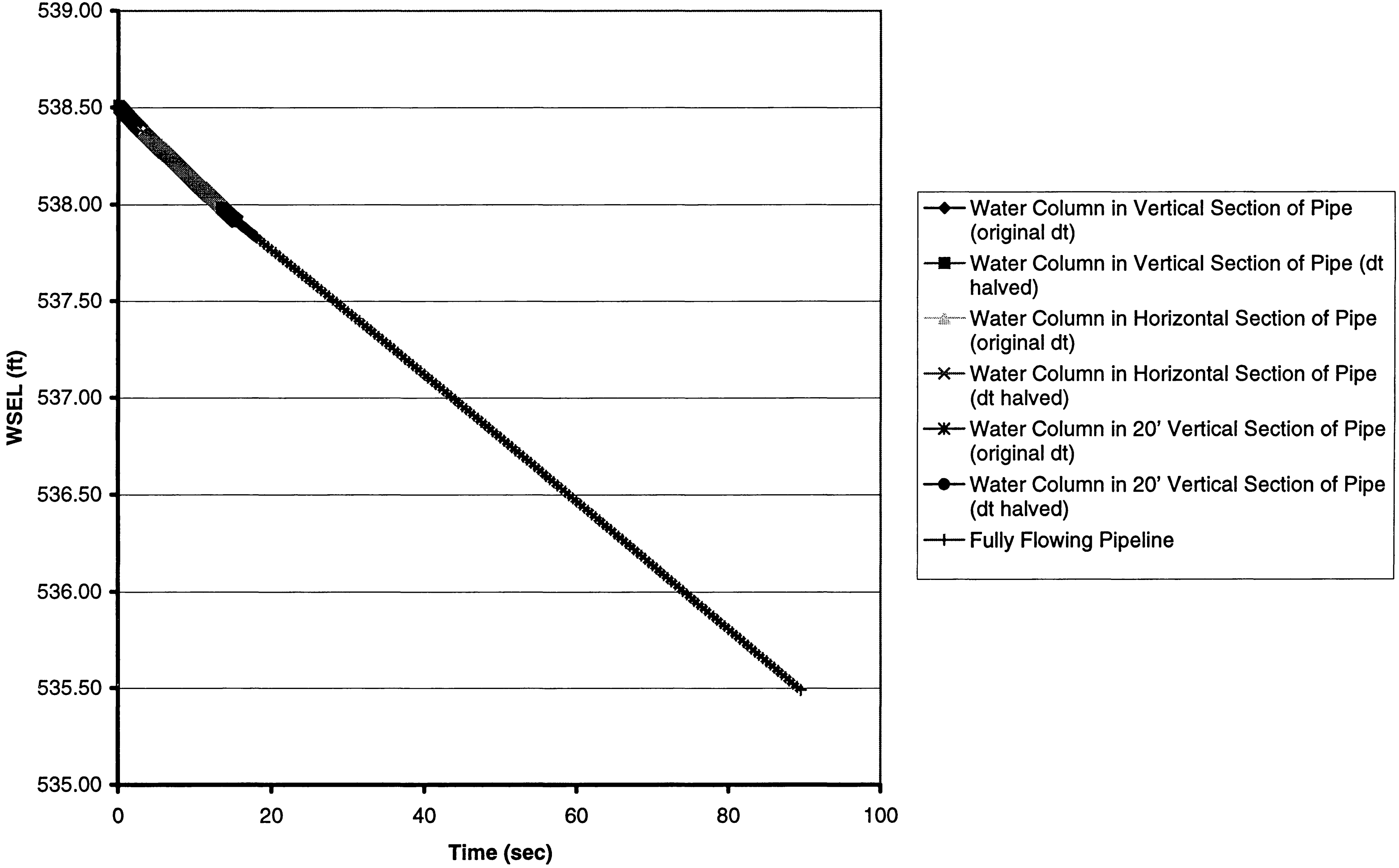


FIGURE A-10: Flowrate vs. Time for Pump Shutdown

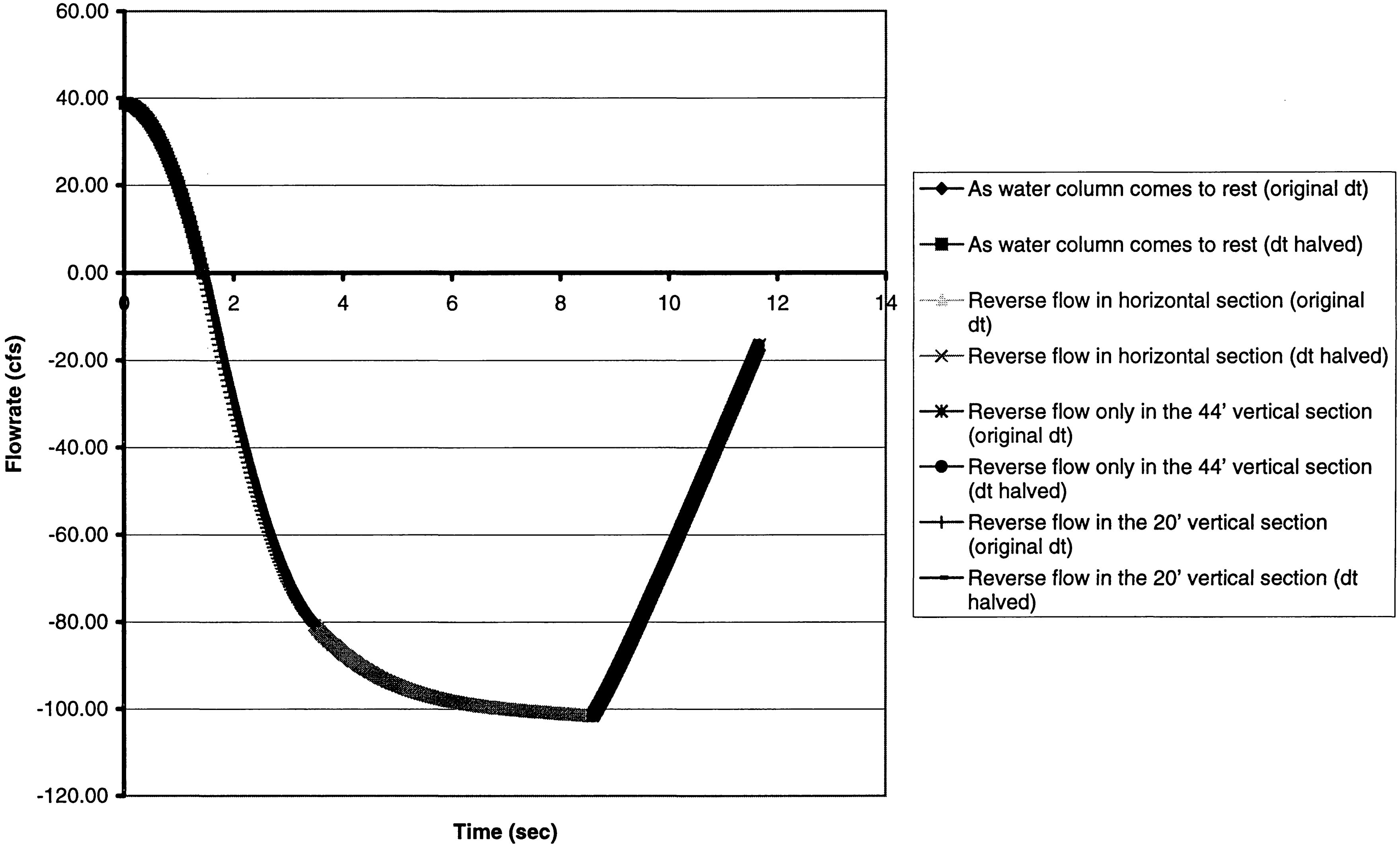


FIGURE A-11: Pressure Head at Elbow vs. Time for Pump Shutdown

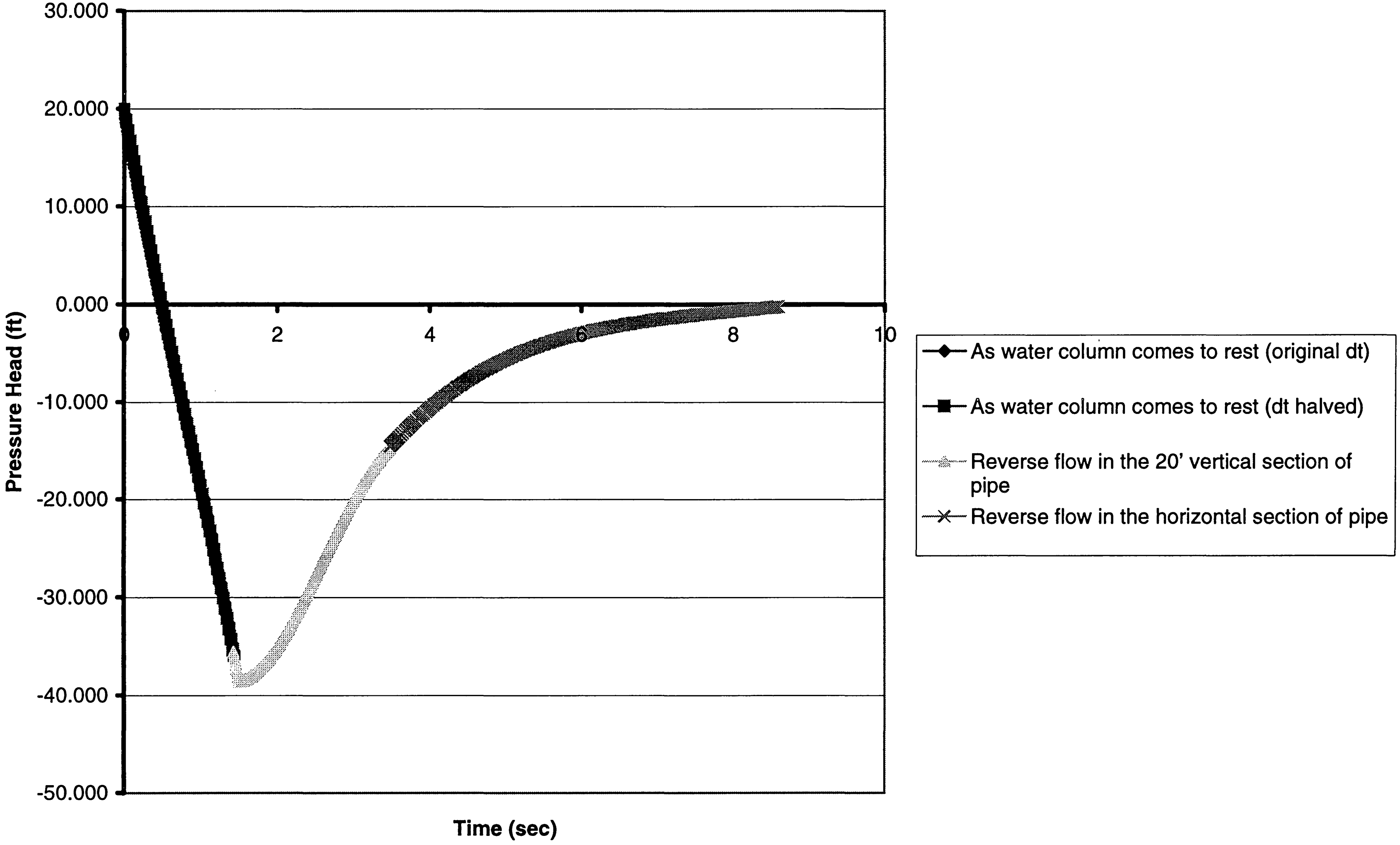


FIGURE A-12: WSEL vs. Time for Pump Shutdown

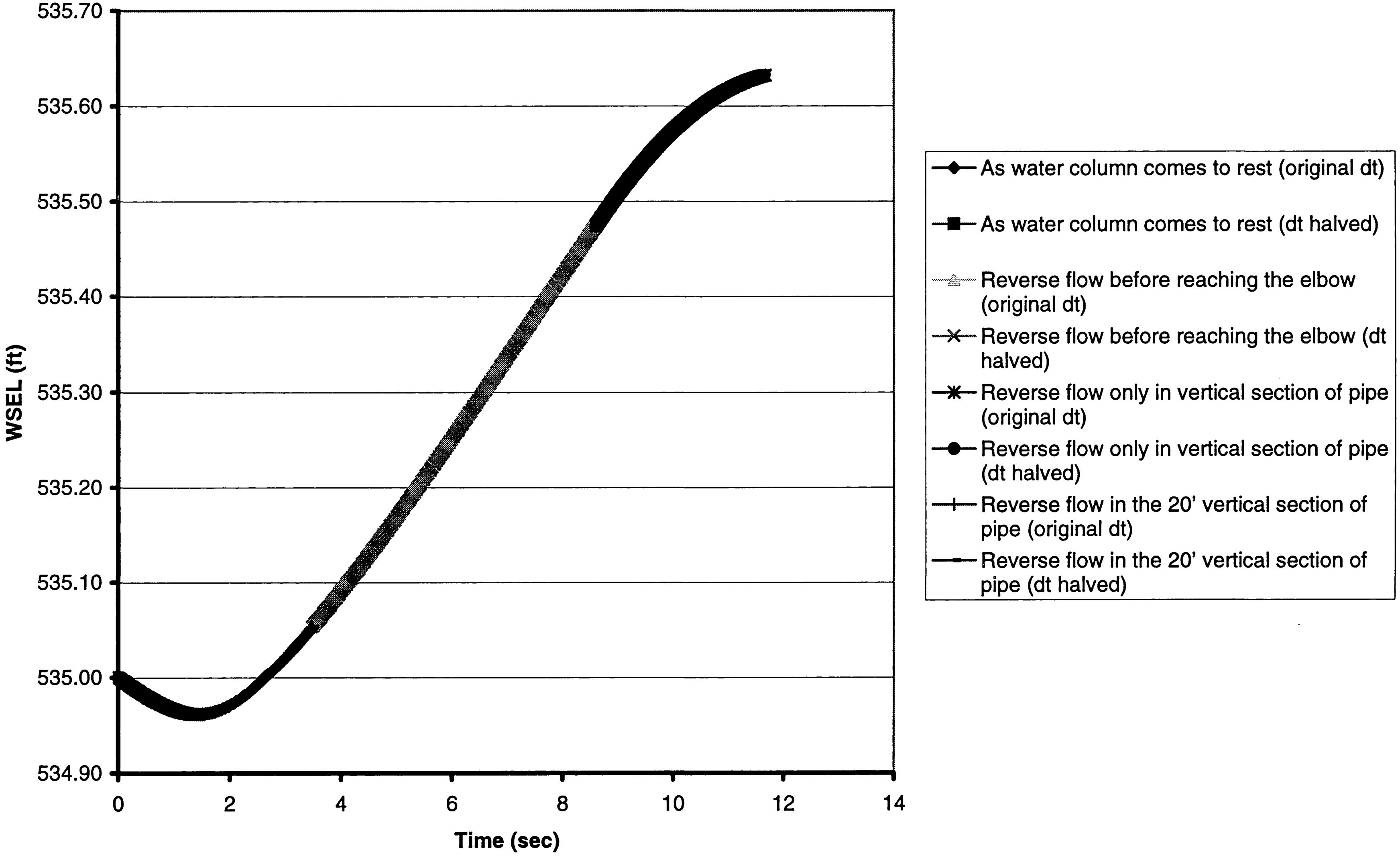


FIGURE A-13: Pressure Head at Elbow vs. Time for Pump Shutdown ($t_{shutdown}$=4.0 sec)

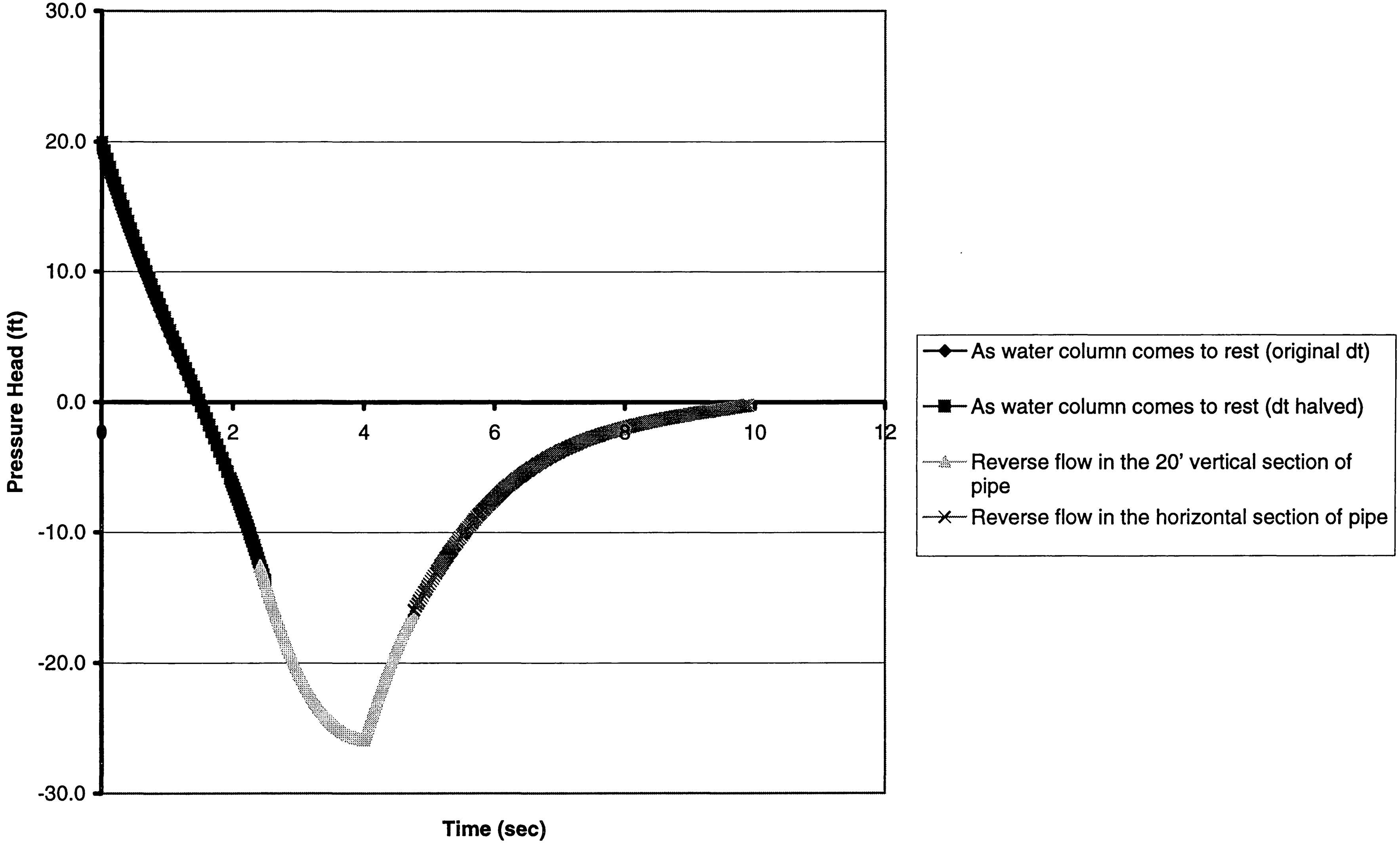


FIGURE A-14: Flowrate vs. Time for Pump Shutdown ($t_{shutdown}$=4.0 sec)

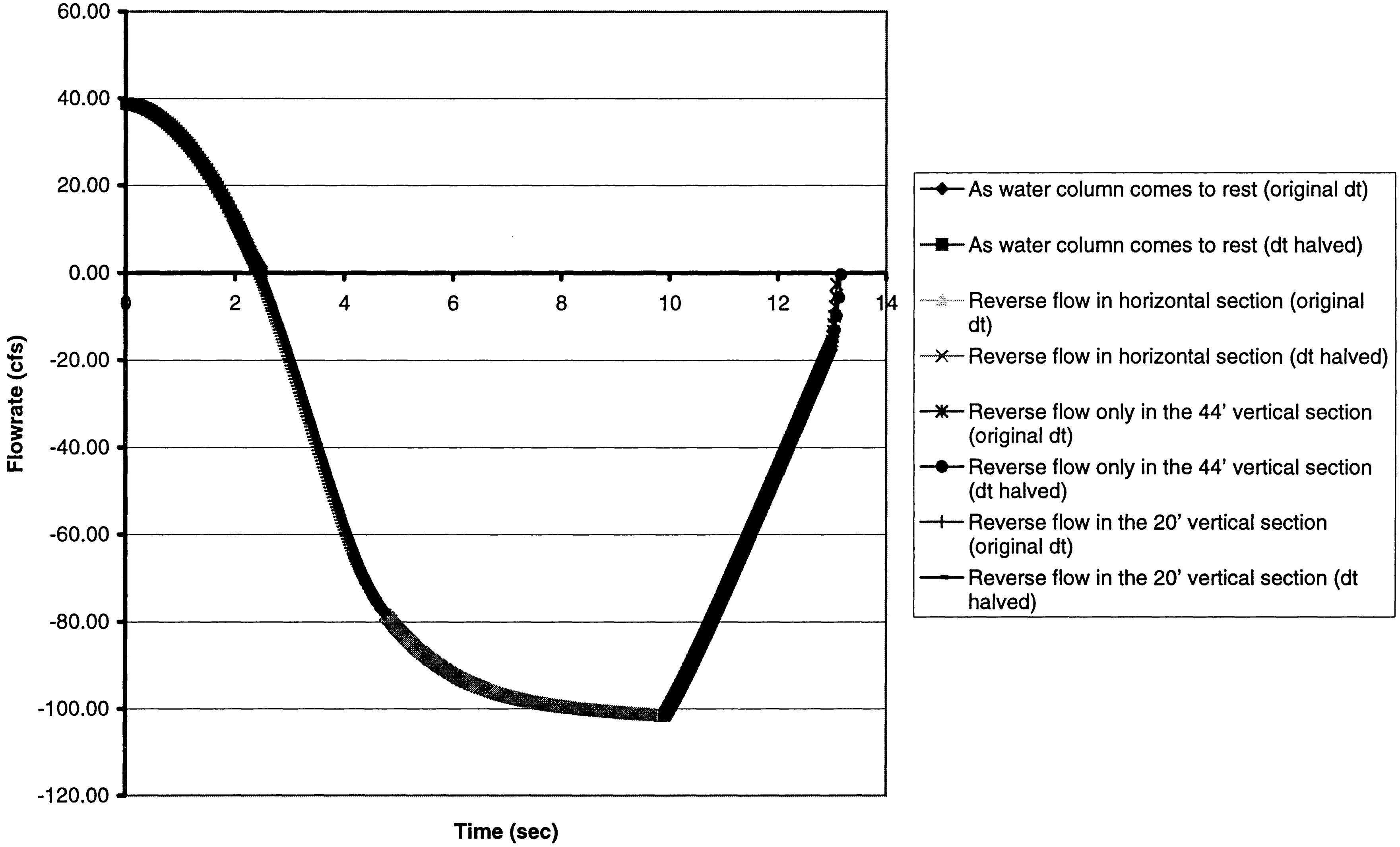
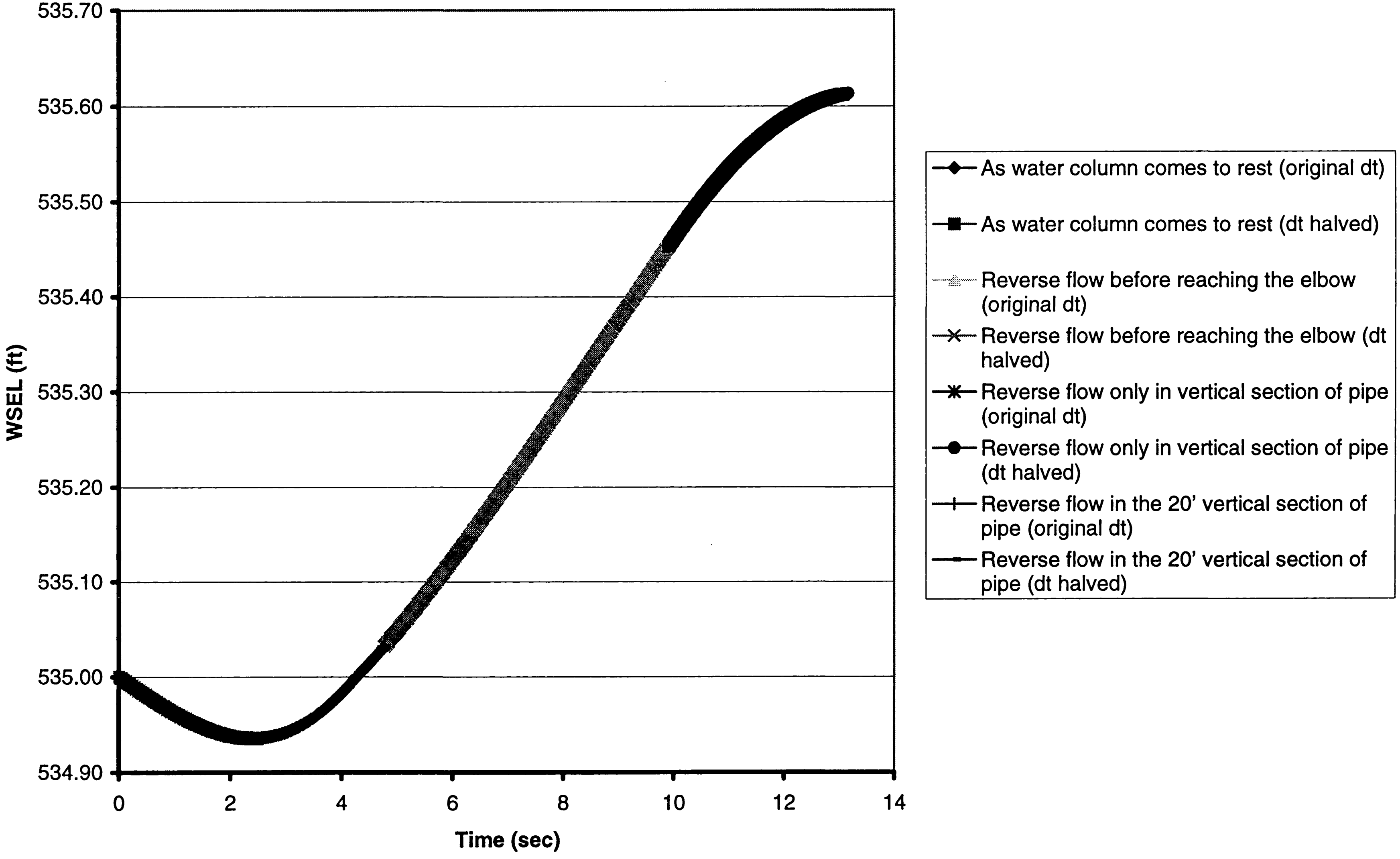


FIGURE A-15: WSEL vs. Time for Pump Shutdown ($t_{shutdown}$=4.0 sec)



AIIM SCANNER TEST CHART # 2

Spectra
4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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Times Roman
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10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789

Century Schoolbook Bold
4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789

News Gothic Bold Reversed
4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789

Bodoni Italic
4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789

Greek and Math Symbols
4 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋞≡
6 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋞≡
8 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋞≡
10 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋞≡

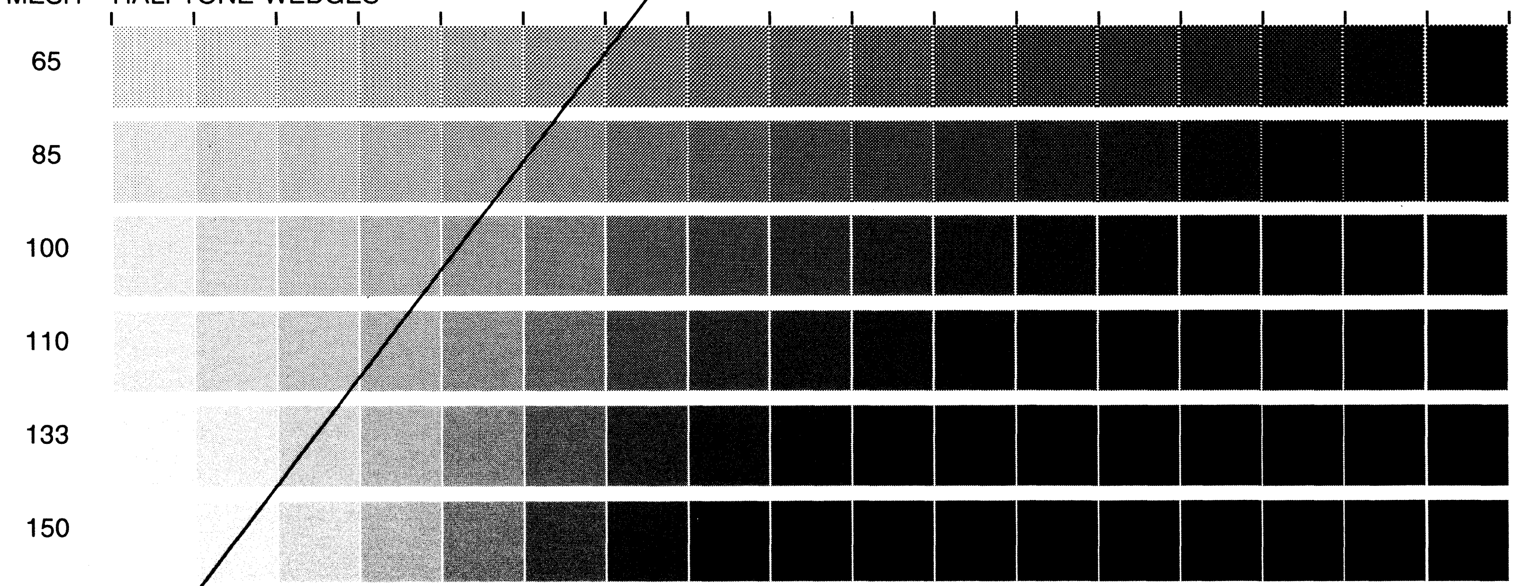
White

Black

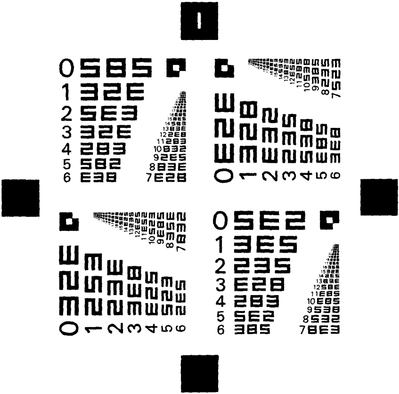
Isolated Characters

e m 1 2 3 a
4 5 6 7 o °
8 9 0 h l B

MESH HALFTONE WEDGES



RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71



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