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CHEG 341-011: Mini Project #2
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EXECUTIVE SUMMARY

Three different decorative water element designs are proposed to a client who is an admirer of Pierre S. du Pont's work. On the given one acre of land, a water fountain which can vertically jet water up to 100 ft, surrounded by four 45° angled jets within its radius are designed at field #2. The supply of water from the pond uphill flows at 5.73 GPM, which then splits up into 5 separate pipes connected to each jet at a rate of 1.15 GPM each. The type of pipes used are the Schedule 40 commercial steel pipes of 2 inches in nominal size. The overall frictional losses of field #2 piping system is 16,162.74 $\frac{ft^2}{s^2}$ with a pressure drop of 99.08 psi. The same volumetric flow rate of 5.73 GPM is recirculated to field #1 by using a 100 HP pump, where only a minimum of 0.37 HP pump is needed to do so, assuming 100 % pump efficiency. The frictional losses from the recirculation is calculated to be 5008.11 $\frac{ft^2}{s^2}$ with a pressure drop of 111.02 psi. At field #1 at the same time, a statue which resembles Pierre S. du Pont is placed in the middle of the pool, which receives water supply from the pond directly at a rate of 4.34 GPM, with the frictional losses of only 4.61 $\frac{ft^2}{s^2}$ and a pressure drop of 0.55 psi. A spillway of 80 ft x 1.5 inch in dimension is placed at the edge of field #1's pool, which is directly connected to the waterfall at hill #2, surrounded by a retaining wall to prevent water splashes onto the nearby land. The water is flowing out of the spillway with a volumetric flow rate of 10.00 GPM, which will eventually flow back into the pool at field #2. To compensate this water flow rate flowing back into the pool, another piping outlet is designed at field #2, which will carry away the same volume of water to a storage unit or a well for other purposes to avoid rising in water level at the pool.

INTRODUCTION

This design report includes the series of decorative fountain designs assigned by a wealthy Delawarean who is an admirer of Pierre S. du Pont. As a UD alumnus himself, the current chemical engineering students at UD are expected to propose a design that reflects firm understanding of all the general knowledge of pipe flow and the correct application of macroscopic mass, energy, and momentum balances concepts learnt in fluid dynamics courses. As per request, a large fountain, a waterfall, and an extra water element based on creativity of the students at three distinct locations on the one acre of land are presented in the designs, in which all of these water elements receive supplies of water from a pond uphill that constantly gets a supply from a stream. The three different locations on the land are field #2, field #1, and hill #2, in which their water elements' designs will be discussed in detail under the ***Design Details*** header in the same order. Based on the client's request, a large fountain with one vertical jet that can shoot water up to maximum height of 100 ft with at least 3 angled jets that collect water into the same pool are should be designed at field #2. Moreover, a maximum of two 100 HP pumps are also provided by the client and an additional creative water element should be proposed at field #1. At the same time, a cascading waterfall should be built at hill #2 with retaining walls around it. As per safety considerations of each of these elements, a system to monitor the flow of water into each location should be established and discussed further under the ***Discussion*** header. All his requests were inspired by Pierre S. du Pont's work at Longwood Gardens. Pierre was greatly influenced by his frequent travels around the world, attending world's fairs and expositions, where he is widely exposed to grand architecture and the latest technology, including the huge display of water pumps at the 1876 Centennial Exposition in Philadelphia. At the age of 36, he bought the Peirce farm and then began to build a garden in which is now known as the Longwood Garden at Chester County, Pennsylvania [1]. From the culmination of Pierre's legacy and visions, the Main Fountain Garden at Longwoods is established, which drives the inspiration that leads the client to build a similar fountain and waterfall at the given land [2].

DESIGN DETAILS

The design of a series of decorative water fountains on the one acre of land are as shown in **Figure 1** below, where the discussion following each water element are separated into three different locations on the land, which are ***Field #2***, ***Field #1***, and ***Hill #2***.

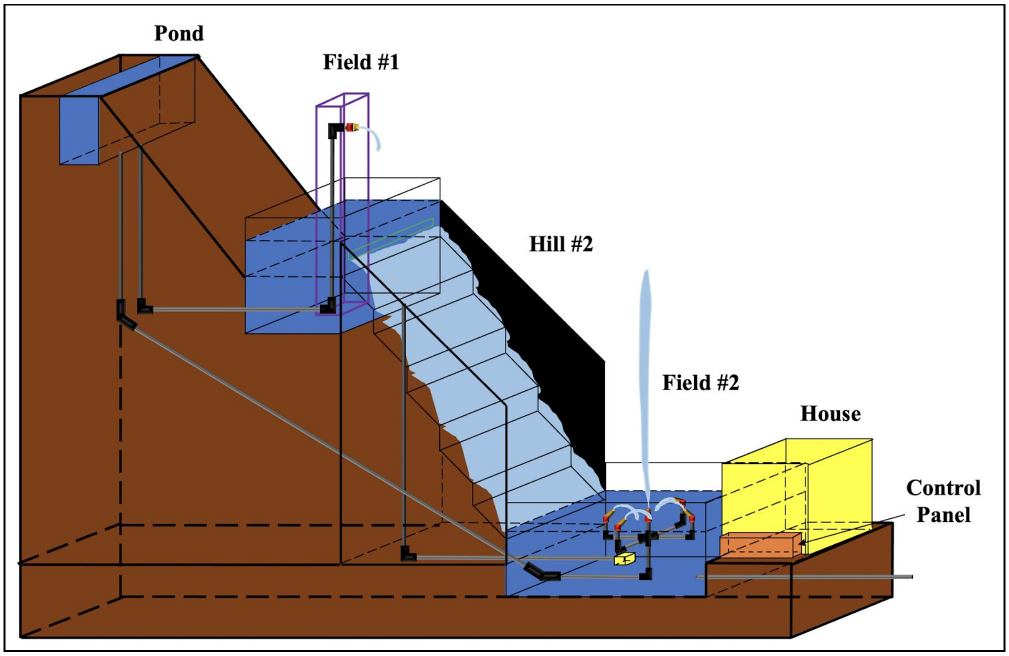

Figure 1: Overview of The Design Series of Decorative Water Fountains on The Land

Field #2 - Large Fountain with 5 Jets

One large fountain is located at field #2, surrounded by a 200 x 100 x 3 ft pool size, directly in front of the house and control panel. It is inspired by the Main Fountain Garden at Longwoods Garden [2]. The fountain is designed with one vertical jet that can shoot up water with a velocity of 80.25 $\frac{ft}{s}$ to reach 100 ft height and four 45° angled jets aimed towards the vertical jet with water flowing out with 39.30 $\frac{ft}{s}$ velocity determined by using the simple kinematics and projectile motion equations as provided in **Eq. 1** and **2** below, which all collect into the same pool as shown in **Figure 2**, carrying water flow rate of 1.15 GPM into each nozzle calculated by using **Eq. 3**.

$$v_{final}^2 = v_{out\ of\ nozzle}^2 + 2g\Delta s \qquad \textbf{(Eq. 1)}$$

$$R = \frac{v_{out\ of\ nozzle}^2 sin(2\theta)}{g} \ || \ R* = v_{out\ of\ nozzle}\sqrt{\frac{2H}{g}} \qquad \textbf{(Eq. 2)}$$

$$Q = 448.86vA \qquad \textbf{(Eq. 3)}$$

v_{final} : $Final\ velocity\ as\ it\ lands\ on\ the\ surface \left(\frac{ft}{s}\right)$

$v_{out\ of\ nozzle}$: $Velocity\ out\ of\ the\ nozzle \left(\frac{ft}{s}\right)$

g : $Gravitational\ acceleration \ \left(32.2\ \frac{ft}{s^2}\right)$

Δs : $Vertical\ distance\ travelled\ (ft)$

R : $Horizontal\ distance\ travelled\ (ft)$

H : $Height\ of\ the\ Launch\ Position$

$R*$: $Horizontal\ distance\ travelled\ for\ 0^\circ launch\ (ft)$

Q : $Volumetric\ flow\ rate\ (GPM)$

v : $Velocity\ of\ fluid\ flowing\ through\ the\ pipe \left(\frac{ft}{s}\right)$

θ : $Angle\ of\ launch\ (\circ)$

A : $Cross-sectional\ Area\ of\ the\ Pipe \left(ft^2\right)$

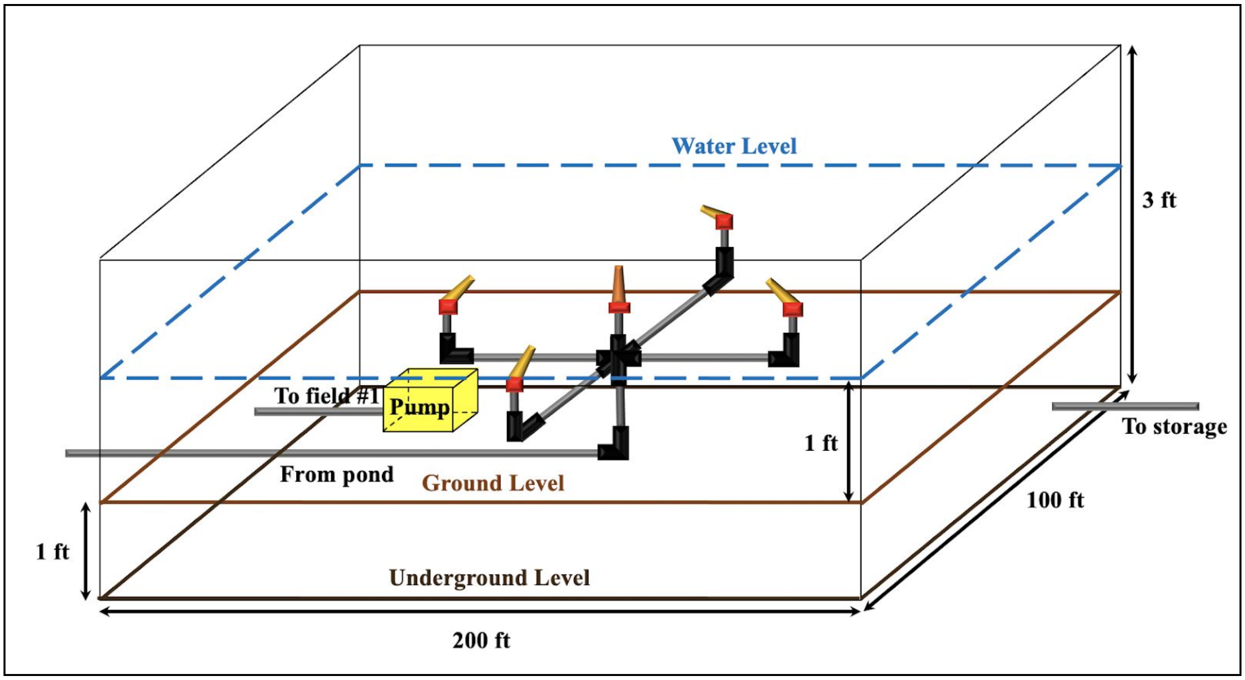

Figure 2: 3-dimensional View of the Pool at Field #2

The functionality and characteristics of the control panel will be discussed further under ***Discussion*** header. From **Figure 2** above, the pool is built as 3 ft tall, with 2 ft deep filled with water, where 1 ft is built from underground. The extra 1 ft above the water level is to ensure no overflow of water from the pool to the surrounding land. The inlet of each jet is placed at the water level. From the same pool, the water is recirculated to the water element at field #1 with a submersible pump of 100 HP. The design will be discussed further under ***Field #1 - Water Fountain Statue*** subheader. At the same time, water is also designed to flow out of the pool to be stored somewhere else, which is beyond the area of design, to be collected for other usages, such as to water the client's garden. If the client must consider the design of the piping system to the storage, it is up to the client to determine the direction and the number of pipe fittings needed to reach the allocated storage area. It is out of this land scope that its frictional losses and any relevant calculation associated with it is not carried out in this analysis. However, to achieve the target of water level in the pool and based on the given dimensions itself, the volumetric flow rate flowing out to the storage should be about the same as the flow rate of water flowing from the waterfall, which is discussed further under ***Hill #2 - Cascading Waterfall*** subheader, with a minimum length of pipe of 20 ft, which will be directly installed under the house branching out of the pool. This design is included to ensure that the water flowing in from the main pond and recirculated from field #1 and hill #2 will not cause any water overflowing. Without this design, it will be a closed system where the water will overflow in time. Next, each angled jet is positioned within a 48 ft radius around the vertical jet and 67.9 ft from each other as illustrated in **Figure 3** below.

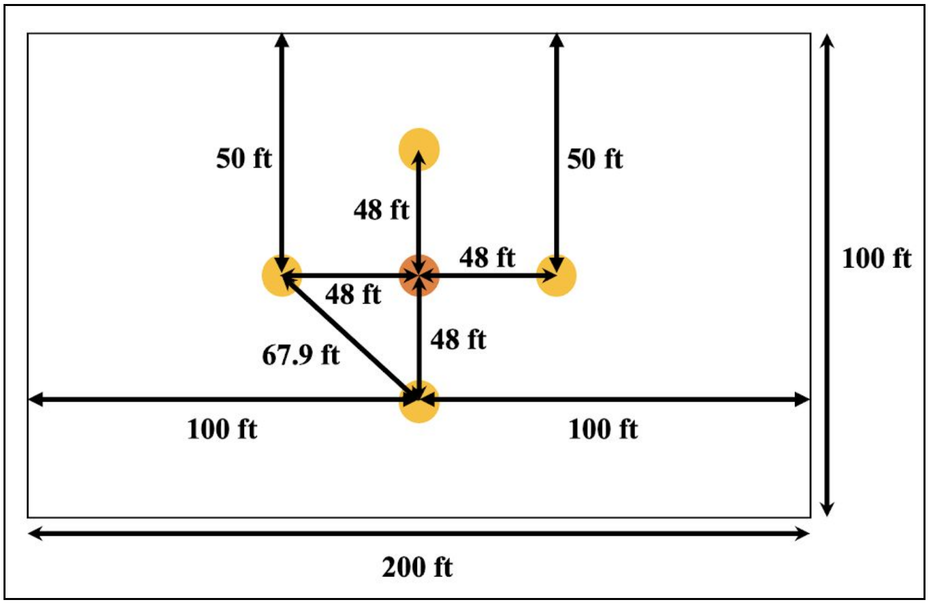

Figure 3: Plan View of the Pool at Field #2

The vertical and angled jets have an outlet diameter of 0.5 and 0.7 inch respectively, connected to the schedule 40 commercial steel pipe with a nominal diameter of 2 inches, as shown in the drawing in **Figure 4**.

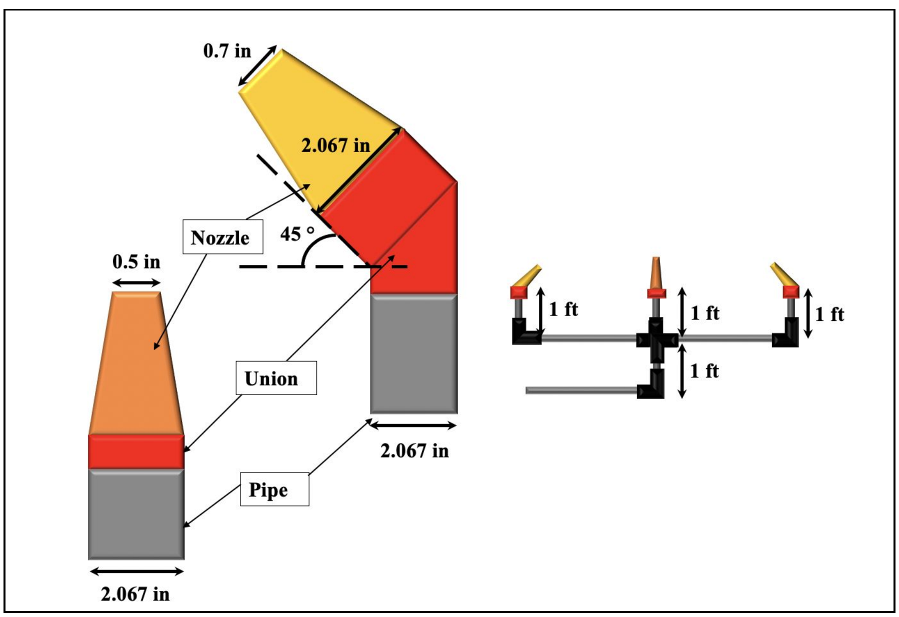

Figure 4: Schematic Drawing of the Jets and Their Positions With Respect to the 5-Way Splitter

The connection between the jets and the pipes require unions to securely attach these two equipments. All 5 branches of pipes to the jets have water flowing with velocity of $4.70\frac{ft}{s}$, which are connected to a 5-way splitter from the main pipe connected to the pond, in which the water is flowing with a velocity of $23.50\frac{ft}{s}$, which are computed by using **Eq. 4** and **5** respectively, with a flow rate of 5.73 GPM determined from **Eq. 3**.

$$v_{into\ jet} = \frac{v_{out\ of\ jet} D^2_{out\ of\ jet}}{D^2_{into\ jet}} \quad \textbf{(Eq. 4)}$$

$$v_{from\ pond} = \frac{v_{into\ each\ jet}\left(D^2_{into\ vertical\ jet} + 4D^2_{into\ angled\ jet}\right)}{D^2_{from\ pond}} \quad \textbf{(Eq. 5)}$$

$$v : Velocity\ of\ fluid\left(\frac{ft}{s}\right) \qquad D : Diameter\ of\ the\ Cross-Sectional\ Area\ (ft)$$

Both **Eq. 4** and **5** are derived from mass balance between the splitter and each of the jet, by assuming steady state condition and incompressible fluid flowing in the system. Note that $D^2_{from\ pond} = D^2_{into\ vertical\ jet} = D^2_{into\ angled\ jet}$, where **Eq. 5** can be simplified further into $v_{from\ pond} = 5v_{into\ each\ jet}$. All of the jets are positioned 1 ft higher than the 5-way splitter, where 90° elbows are used to connect the pipes branching out of the splitter to 4 of the angled jets. No elbow is needed for the vertical jet as it branches directly out of the splitter. The splitter on the other hand is positioned 1 ft higher than the base of the pool. A total of 471 ft long of pipe is used to transport the water from the main pond up to the 5-way splitter, with a total of two 155° elbows and one 90° elbow as shown in **Figure 5** below.

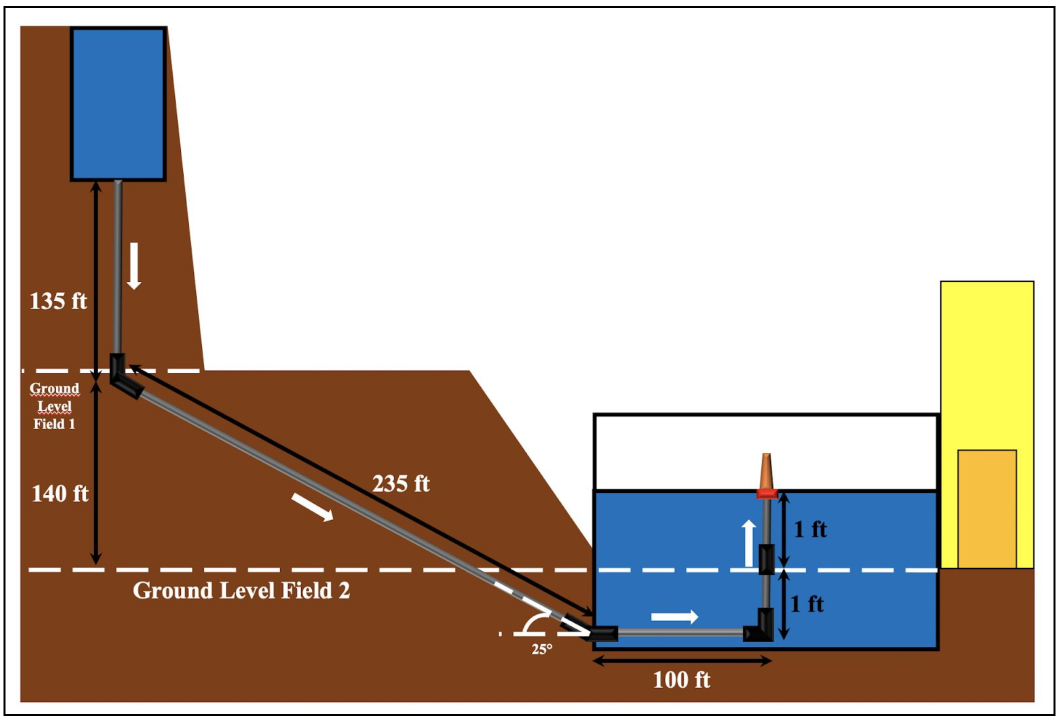

Figure 5: Elevation view of the piping system at Field #2

A total of 197 ft pipe is needed to connect all of the jets with the 5-way splitter. Since commercial steel pipes are used entirely in this design, the pipes are generally sold in a single-random and double-random lengths, which average into 20 and 40 ft respectively [3]. Worst case scenario, if manufacturers are only able to manufacture 20 ft-long pipe each, unions are needed to connect these pipes along the way, aside from the elbows and splitter which have been previously mentioned [4]. **Table 1** summarizes the number of pipe fittings and equipment built into the piping system for field #2's fountain.

Table 1: Pipe Fittings and Equipments Built For Field #2 Fountain

Nozzles		
Type	**Size (inch)**	**Quantity**
Upward Jet	0.5	1
Angled Jet	0.7	4
Pipes		
Total Length (ft)	668	
Fittings		
Type	**Description**	**Quantity**
Unions	-	26
90° Elbow	Standard (R/D = 1), screwed	5
155° Elbow	Standard, screwed	2
5-way Splitter	Screwed	1

Since the fountain uses a lot of pipes, significant losses in friction are expected. Several equations are used to determine the overall frictional losses due to both pipes and their fittings. **Eq. 6** to **9** listed below are the Churchill equation to determine the fanning friction factor of the pipe, the frictional losses due to the length of pipe and the fittings, and the value of K from the Hooper 2K Method respectively.

$$f_F = \left\{-4log_{10}\left[0.27\left(\frac{\varepsilon}{D}\right)+\left(\frac{7}{Re}\right)^{0.9}\right]\right\}^{-2} \qquad \textbf{(Eq. 6)}$$

$$F_{pipe} = 2f_F v^2\left(\frac{L_{pipe}}{D}\right) \qquad \textbf{(Eq. 7)}$$

$$F_{fittings} = \frac{v^2}{2}\sum_i^n K_i \qquad \textbf{(Eq. 8)}$$

$$K_i = \frac{K_{1,i}}{Re} + K_{\infty,i}\left(1+\frac{1}{D*}\right) \qquad \textbf{(Eq. 9)}$$

f_F : $Fanning\ Friction\ Factor$

ε : $Pipe\ Roughness\ Factor$ $(1.5 \times 10^{-4} ft)$

v : $Velocity\ of\ Fluid\left(\frac{ft}{s}\right)$

L_{pipe} : $Length\ of\ Pipe\ (ft)$

Re : $Reynolds\ Number\left(\frac{D\rho v}{\mu}\right)$

D : $Diameter\ of\ Cross-Sectional\ Area\ (ft)$

$D*$: $Diameter\ of\ Cross-Sectional\ Area\ (inch)$

$K_{1,i}, K_{\infty,i}$: $K\ values\ of\ Fitting\ i\ for\ Hooper\ 2K\ Method$

A few assumptions are made when calculating the K values in **Eq. 9**. First, any connections to the pipes using unions are ignored as the Hooper 2K method does not have the values for unions, which are then assumed to be zero. The 5-way splitter is approximated as two screwed run-through tee, provided by the same method. Moreover, since a 155° elbow has a closer dimension to 135° elbow, the K value for it can be approximated with one 90° and 45° elbow. **Table 2** lists the values of K from the 2K method [5].

Table 2: K values for Pipe Fittings of Hooper 2K Method

Fittings	Description	K_1	K_∞
90° Elbow	Standard (R/D = 1), screwed	800	0.4
Run-through Tee	Screwed	200	0.1
45° Elbow	Standard (R/D = 1) all angles	500	0.2

In spite of that, the viscosity and density of water used in the overall frictional losses determination are averaged from their values at 50 and 90 °F, which result in $6.91 \times 10^{-4} \frac{lb_m}{ft \cdot s}$ [6] and 62.26 $\frac{lb_m}{ft^3}$ [7] respectively. By using all **Eq. 6** to **9**, the overall frictional losses due to both pipes and fittings are found to be 16,162.74 $\frac{ft^2}{s^2}$ with a pressure drop of 99.08 psi calculated in Excel, where the table of values used to calculate these parameters are as shown in **Appendix: Table A**.

Field #1 - Water Fountain Statue

A 100 x 100 x 3 ft pool size is built at field #1, placing a 3 x 3 x 10 ft large statue at the center of the pool. The pool has the same design as the pool at field #2, where the water is 2 ft deep in the pool, with 1 ft deep built underground, with an extra 1 ft tall in the pool to prevent overflowing of water, totalling up to 3 ft tall of pool, as depicted in **Figure 6** below.

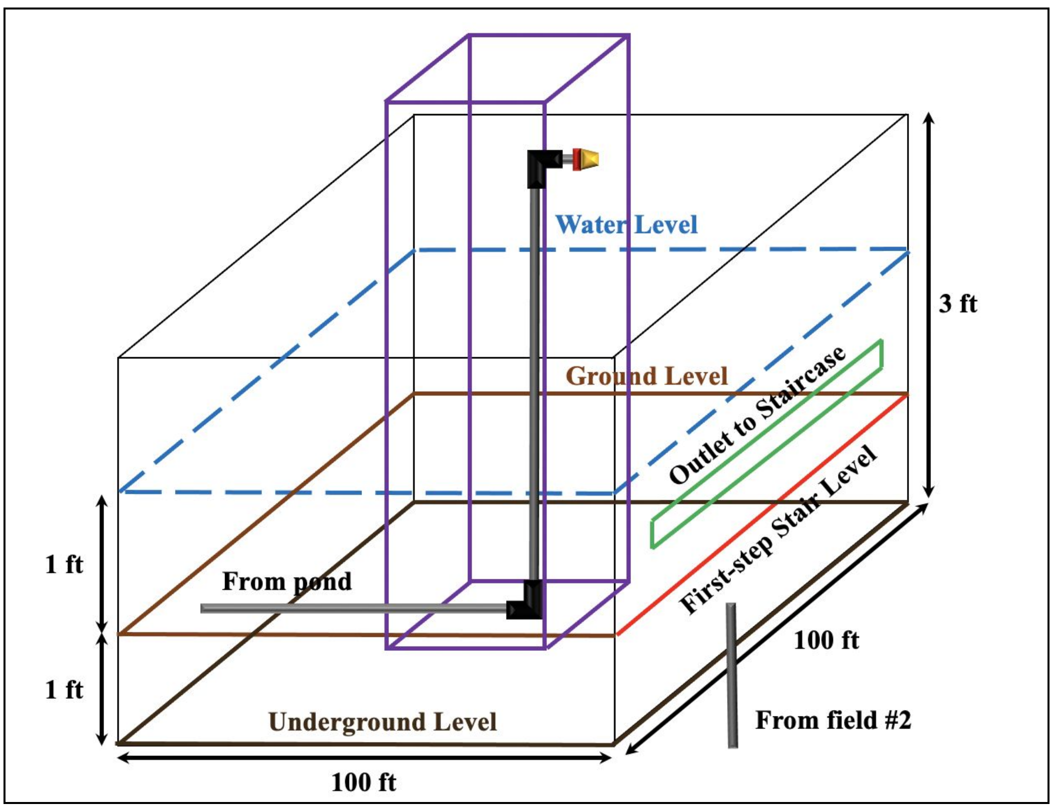

Figure 6: 3-dimensional View of Pool at Field #1

A nozzle with 0.5 inch outlet diameter is placed at the oral cavity of the statue at 8 ft tall. Water is flowing out of the nozzle to reach a horizontal distance of 5 ft away from the statue with a velocity of $7.09\,\frac{ft}{s}$, computed by using **Eq. 2**, to be collected in the same pool, in which 4.34 GPM flow rate of water is flowing from the pond calculated from **Eq. 3**. The nozzle is connected to the same type of pipe used in the previous design, a nominal diameter of 2 inches of schedule 40 commercial steel pipes. A clear depiction of the statue is as provided in **Figure 7** below.

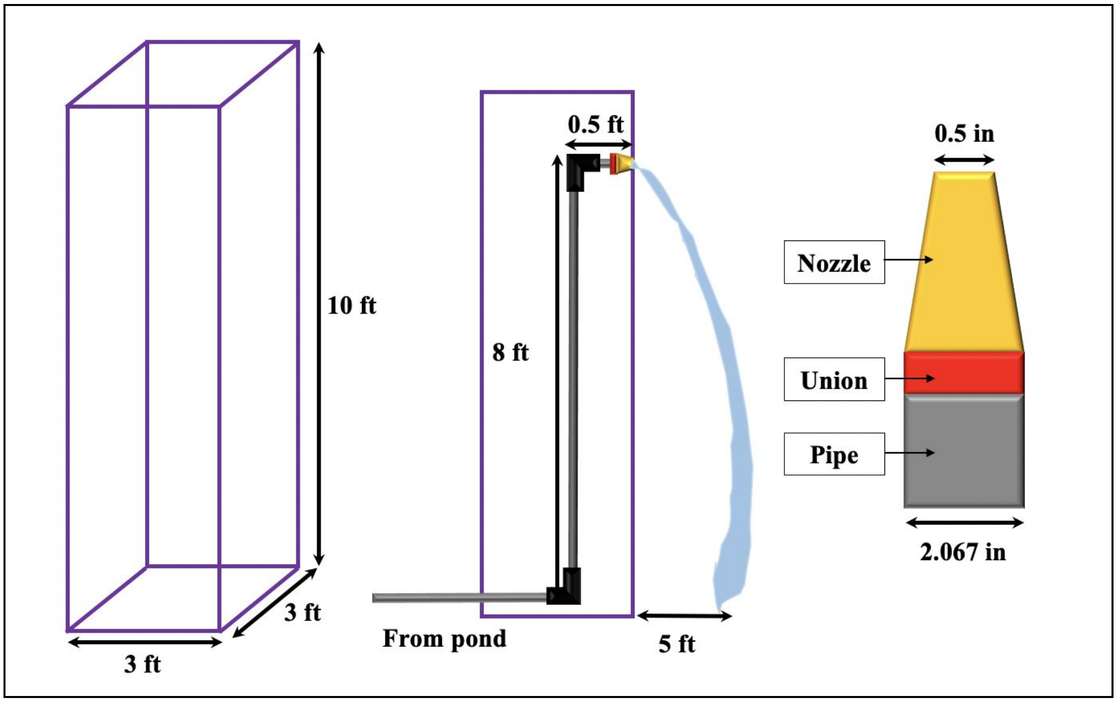

Figure 7: Schematic Diagram of the Statue

The statue can be designed as a large figurine of Pierre S. du Pont, to commemorate his great work and art as an inspiration to build this water element at field #1. The water is flowing with a velocity of $0.41\,\frac{ft}{s}$ from the main pond into the statue calculated from **Eq. 4**. A sum of 243.5 ft long pipes are used to carry the water from the pond up to the oral cavity of the statue. Three 90° elbows are used to connect all of the pipes, as shown in **Figure 8**.

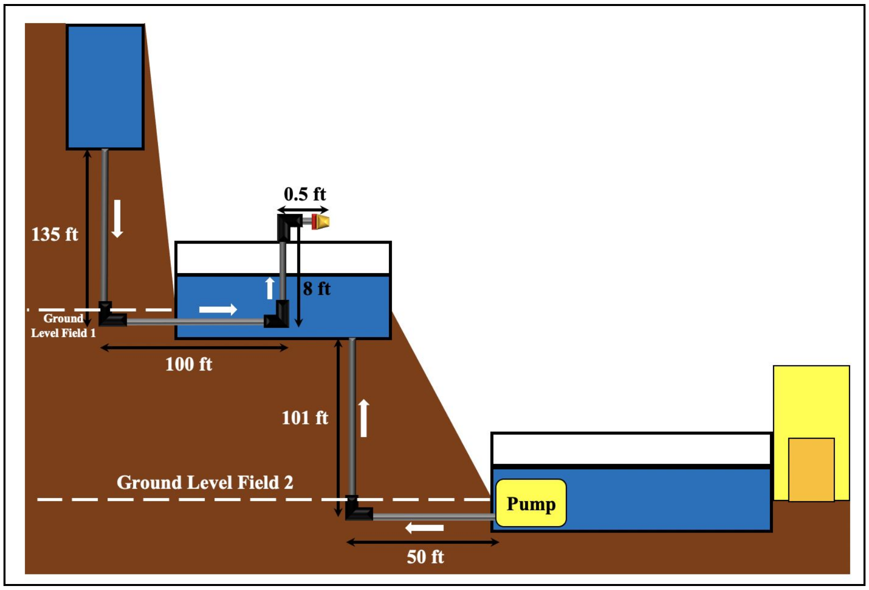

Figure 8: Elevation View of the Piping System in Field #1

As previously mentioned, water is recirculated from the pool at field #2 to fill up the water at field #1 pool. The piping system is connected to a submersible pump of 100 HP submerged in the base of field #2 pool. As shown in **Figure 8**, a total of 151 ft long pipes are used to transport the water up to field #1, with only one 90° elbow used to connect these pipes. The pump is expected to flow in water with the same volumetric flow rate of water flowing into field #2 from the pond, which was determined previously as 5.73 GPM from **Eq. 3**, to ensure that the water can be maintained inside the pool at all times without overflowing into the land. The waterfall at hill #2 is directly connected to the pool, which is 1 ft tall from the base of the pool. A spillway with an area of 80 ft x 1.5 in is built 5.25 inches away from the first step of the waterfall stairs, as shown in **Figure 9** below.

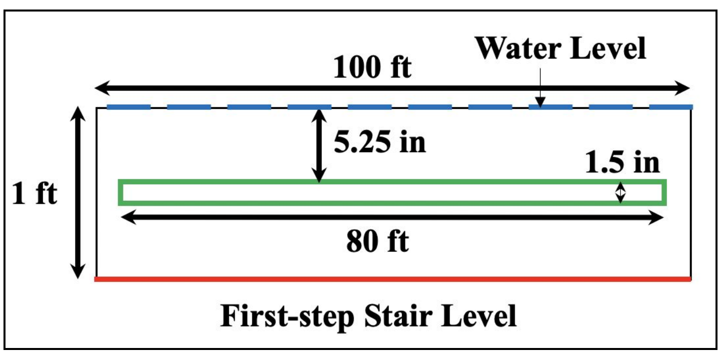

Figure 9: Side View of the Pool at Field #1 of the Spillway

The frictional losses due to the pipes and their fittings are again calculated for field #1 piping system by using the same method and equations used for field #2. By using **Eq. 6** to **9** and constants values tabulated in **Table 2**, the total frictional losses at field #1 for the water supply from the pond and the recirculation are 4.61 and 5008.11 $\frac{ft^2}{s^2}$ with a pressure drop of 0.55 and 111.02 psi respectively, with the parameters used in computing these values as tabulated in **Appendix: Table B and C** respectively, calculated in Excel. **Table 3** below summarizes the equipments and total length of pipe used at field #1, both into the statue and the water recirculation.

Table 3: Pipe Fittings and Equipments Built For Field #1 Water Element

Nozzles		
Type	**Size (inch)**	**Quantity**
Horizontal	0.5	1
Pipe		
Total Length (ft)	394.5	
Fittings		
Type	**Description**	**Quantity**
Unions	-	18
90° Elbow	Standard (R/D = 1), screwed	4

The number of unions are again determined by using the fact of the worst case scenario where a manufacturer can only produce a pipe of 20 ft long. Previously described, a pump is used to recirculate the water from field #2 to field #1. In order to determine if the pump is able to pump the water up the proposed distance, a minimum amount of power needed for a pump to do so should be computed. The total dynamic head (TDH) of the pump is calculated by using **Eq. 10** as provided below.

$$TDH = \frac{F}{g} + \Delta\left(\frac{p}{\rho g} + \frac{v^2}{2g} + z\right) \qquad \textbf{(Eq. 10)}$$

Eq. 10 is derived from the general Bernoulli equation with 1 inlet and outlet and incompressible fluid assumption, and rearranged into its head equation form. TDH is then determined to be 256.53 ft. The power needed for a pump to achieve the calculated TDH is determined by using **Eq. 11**.

$$P = \frac{Q \times TDH \times \rho}{3960\eta} \qquad \textbf{(Eq. 11)}$$ [8]

P : $Power\ of\ Pump\ (HP)$

TDH : $Total\ Dynamic\ Head\ (ft)$

Δp : $Change\ in\ Pressure\left(\frac{lb_m}{ft \cdot s^2}\right)$

Δv : $Change\ in\ Velocity\ of\ fluid\left(\frac{ft}{s}\right)$

ρ : $Average\ density\ of\ water\left(\frac{lb_m}{ft^3}\right)$

g : $Gravitational\ acceleration\ \left(32.2\ \frac{ft}{s^2}\right)$

Δz : $Distance\ travelled\ \ (ft)$

Q : $Volumetric\ Flow\ Rate\ (GPM)$

η : $Pump\ Efficiency\ \ (0 \leq \eta \leq 1)$

From the values obtained above, assuming 100 % efficiency, the minimum power of the pump needed to achieve the computed TDH is only about 0.37 HP, which is computed in Excel and the table of values is as provided in **Appendix: Table C.** The 100 HP pump will suffice to recirculate the water back up to field #1.

Hill #2 - Cascading Waterfall
A 50 ft long and 100 ft tall cascading waterfall is built at hill #2, directly connected from the pool at field #1 to the pool at field #2, as shown in **Figure 10**.

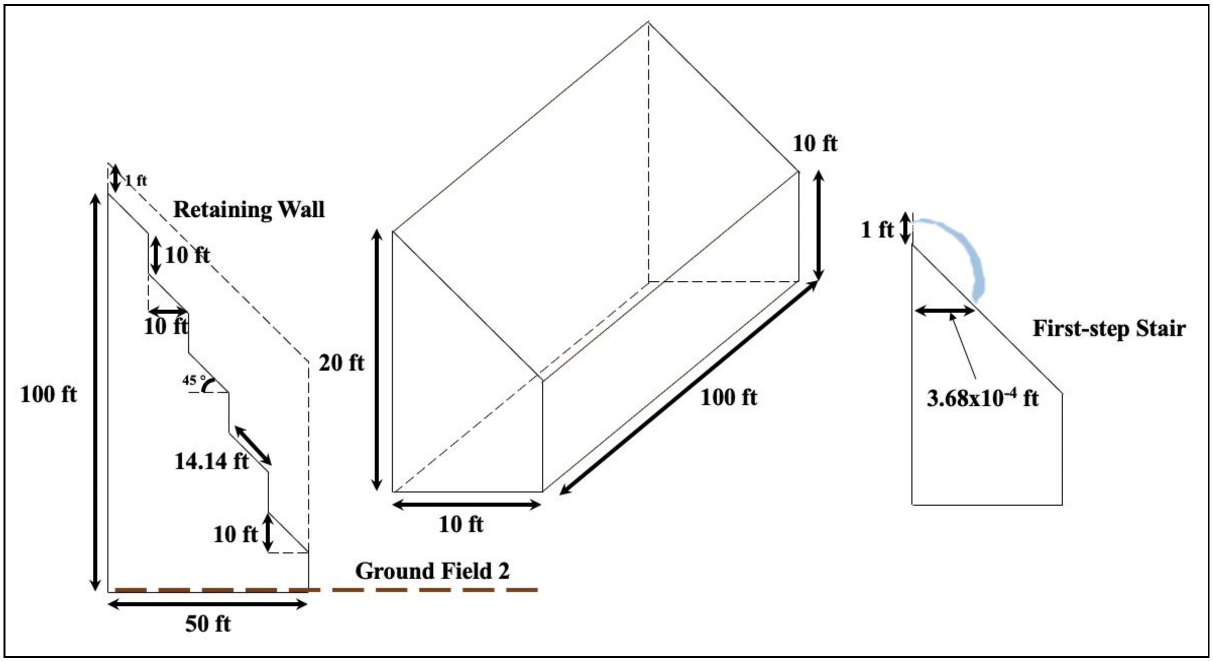

Figure 10: Schematic Diagram of the Cascading Waterfall at Hill #2

Approximately, the flow rate of water coming into the pool at field #1 from the pond and the recirculation is about 10 GPM. To have the same volume of water flowing out to hill #2 by using the dimensions of spillways as illustrated in **Figure 9**, the water should be flowing out a horizontal distance of 3.68×10^{-4} ft away, hitting the first step of the waterfall stairs, as shown in **Figure 10**, which is determined from the Solver software integrated in Excel, as shown in **Appendix: Table D**. The water is flowing with a velocity of $2.23 \times 10^{-3} \frac{ft}{s}$ computed from **Eq. 2**, with a volumetric flow rate of 10.00 GPM as priorly set. Since the water recirculated from the pool at field #2 with a volumetric flow rate of 5.27 GPM is lower than the flow rate out of the spillway, the pool at field #2 is expected to be filled with water quicker than the water supplied from the pond. This is the reason why an extra piping system out of the pool at field #2 is needed to make sure that the water will not overflow in time. The cascading waterfall staircase has 5 steps, built in an angle of 45° and 100 ft wide, to ensure that the water is constantly flowing down the stairs by gravity. The length of the stair surface is 14.14 ft, and each of the steps has the same dimensions as each other. A retaining wall is built around the waterfall to enclose the falling of water directly into the pool at field #2 to avoid any water splashing to the side of the stairs. No frictional losses are computed for the design and hill #2 as it does not have any piping system installed directly to it.

DISCUSSION

Certain recommendations should be implemented to ensure the water elements at all three places will run smoothly. Specifically at field #2, since a submersible pump is used to recirculate the water, a few procedures need to be done on the pump in order to avoid its burnt out, which will prevent the water from recirculating totally. Pump burnt out is mainly due to improper installation and care by the maintenance team. Submersible pumps in general require water to keep it cool and maintain the proper operating temperature, in which when the water level drops below the impeller level of the pump, the motor will overheat and eventually burn out. It is to be made sure that the pump is fully submerged in water at all times during warm weather and to properly store it somewhere else during the winter season to increase the overall performance. Since the client wants the fountains to be operational between May and September, the pump should be removed prior to water freezing during winter season as frozen water will expand in particles and break the pump and its mechanisms. For a large fountain, using a pump that has an automatic low water shut off feature would be recommended to prevent the pump from running dry, such as 170 GPH Auto Shut-Off Fountain Pump or 400 GPH Auto Shut-Off Fountain Pump with LED Light, which will not only prevent the burnt out, but also creates a great night time ambience [9]. For a regular maintenance of the pump to ensure that it is working on an optimal level, a process known as 'priming the pump' should be performed, where the pump is turned on and off several times to make sure all of the air is discharged out of the line before usage. Moreover, routine maintenance which includes getting rid of any debris stuck on the outside of the pump should also be carried out. For a small pump, it is quicker and easier to disassemble the pump to clean the inside. However for a large pump, Fountain Cleaner Tablets should be used to clean, which will break down the waste and other pollutants to prevent any clog and damage to the pump, which will keep the fountain clean and beautiful at all times [9].

On top of that, the right level of cleanliness, clearness, and acidity characteristics of the water should be maintained all the time [10]. As guidelines, the pH level of the water should be between 7.2 and 7.6. To approximate the pH level of water in the fountain, analyzer test kits should be used since they are reliable and inexpensive. If the pH value is more than 8, the water will become cloudy and promote deposits in pipes and nozzles, which can cause irritation to eyes, ears, nose and throat when come in contact. Plus, it will be useless to add chlorine into the water as the high value of pH will prevent it from working properly. On the flip side, if the water has high acidity, which has a low pH value, the commercial steel pipe will get corroded easily. At the same time, high impurity content in the water , which should be maintained below 0.0031 $\frac{lb_m}{ft^3}$ in concentration, will cause deposits and blockages at the nozzle outlet of the jets and the pump impeller, which will reduce the output current and overall performance [10]. It is advised to add flint-sand filters or similar devices to it to filter all the water in less than 4 hours daily. The electrical outlet of these devices should be left at the base of the pool in order to connect to the cleaning device easily to absorb the bottom dirt. Also, higher levels of water hardness will cause salt deposits on the lights located in the fountain, which will only provide less light with the same energy expenditure, incurring more costs than what it should have. The water hardness should not be over and 0.011 $\frac{lb_m}{ft^3}$ in concentration [10]. Calcium can also be deposited at the screw-in connectors of the pipes and nozzles, making it more difficult to be repaired. Due to all of these reasons, resin-softeners should be mounted in the fountain in order to facilitate the interchange of calcium and magnesium ions for sodium or hydrogen ions to 'soften' the water. Nevertheless, as chlorine addition in the water can cause further corrosion in the metals of the nozzles, pipes, and lights, the risk is much lower if the dosage is lower than 0.0003 $\frac{lb_m}{ft^3}$ [10]. It is commonly used as water disinfectants, making it possible to eradicate most of the microbes, viruses, bacteria, and germs for many diseases.

Moreover, unless a regular monitoring of water levels against a fixed point is done at all of the water fountains manually, the pools will appear to have adequate amounts of water, where a drop in volume will be so gradual that a change will not be noticeable [11]. An easy method to oversee the water level problem is by employing the electronic water control alarm system. It is used to maintain a constant water level in the pool, which has the best long term investments for pools. It utilizes a sophisticated control box, water probe, and electronic anti-siphon valve to maintain efficient water levels with easy installation requirements. The control box to this equipment is geared into the overall control panel located next to the house right in front of the fountain. The information on the current water level and whether or not the system is currently operational will be shown at the box, as well as a sensor alarm to indicate a lower water level, which works via a small electronic probe added to the pool at the desired water level. The sensor works by sending a voltage signal to the electronic valve connected to the main water supply from the main pond, in which the valve will automatically close itself once the water level rises. Other than that, to preserve the aesthetics of the original design and inspirations from the Longwood Gardens fountains, lightings should be added in the fountain to provide a magical view of water jetting and flowing, especially during night time. Airmax RGBW Color Changing LED submersible lightings should be used in the fountain [12]. Other than that, it is recommended to paint the inside of the pool with a darker shade so that the piping network below the water surface is not visible to people. All of these effects and control in the implementation of design should be managed digitally. Digital control has all of the control needed that has been mentioned previously, from the filtration and chemical treatment up to the management of jets and supply of water from the ponds, although the digital control itself will need old-school maintenance. A Programmable Logic Controller (PLC) device should be installed at the control panels located next to the house as priorly mentioned [11].

Nonetheless, there are a few potential pitfalls and challenges that may arise in implementing the design proposed previously. Firstly, the nozzle of each jet located at field #2 water fountains can be blocked due to calcium buildup from higher levels of water hardness, or dirt and mold manifestation on the entire piping system as discussed priorly. Although there might not be any trees within a close proximity to the fountain, wind is expected to carry leaves or small twigs from other places and will eventually flood the pool, destroying both the aesthetics of the fountain and clogging the nozzle in time. Due to blockage, it will not be easy to change the nozzles as the pool is too wide to reach and these jets are located in the middle of the pool. Secondly, the design of jets are unstable as all 5 jets are only supported by one main pipe of the same diameter from the main pond. It has a higher center of gravity, which will cause them to fall apart and crush into each other. Thirdly, the recommendations mentioned earlier on the installation of the pump should be strictly followed to prevent any air entrainment in the pump which will cause its poor performance. The pump should be put in a separate enclosure, protected from physical damage from the surrounding, except the water itself since it will be fully submerged in the water. In addition to that, since water is supplied directly from the pond and to be discharged out of the oral cavity of the statue at field #2, it will be difficult to access the piping in the statue. Plus, with the current dimensions of the statue, it is not stable enough to be freely standing in the pool, where it will fall down into the pool in time. It should be noted that the statue is properly screwed to the base of the pool to avoid this issue. Other than that, hill #2 also has several challenges in implementing its waterfall design. Each step of the staircase is built at a 45° angle, which will be difficult to cement the steps on a hill that already has a significant gradient to be working at. Plus, it will be intricate to build the retaining wall that surrounds the waterfall due to the same reasons. Safety considerations should be taken into account when trying to implement this design. Moreover, algae and mold buildup at each of the steps of the waterfall would make it harder to be cleaned as one could not stand on the slippery and slanted surface for a long time. Landslides will also be a possible challenge at the hill. A chemical agent such as the soil stabilizers to reinforce the soil strength should be used to avoid this problem overall [13].

With these suggested designs, the clients should take a few next steps before actually implementing this design. The most important priority is the budget to be considered. If more money is allocated in this project design, a more intricate, expensive and high quality control system and nozzles can be used. Hiring the finance team will be useful in aiding the budget allocation in building these fountains. Other than that, as mentioned in the design description, for a single-random length pipe of schedule 40 commercial steel type, a single pipe is approximated to be only manufactured for 20 ft long. The client is responsible for determining the actual length of pipe that the manufacturer of choice is able to produce, and the number of pipes themselves needed in building the entire piping systems. At the same time, the client is responsible for determining what other types of elbows and unions available in the market to be used underground and fully submerged in water to still maintain their intended purpose of carrying water to the desired locations. Moreover, to keep the clean environment and image of the surrounding, the client should consider subcontracting with the cleaning service company and giving them autonomy in handling the cleanliness of the environment to attract more people to visit. Technicians should also be hired to take care of the control panel that manages all of the equipment used at all locations, as it will be out of scope of the client's expertise.

With that, there are a few possible alternative approaches on implementing the proposed design that the client can change himself. It is more common to have different pipe sizes used in a big industry in the entire system. For this fountain system, a bigger diameter pipe from the pond should be used to carry more water at a time, which will be connected to a smaller diameter pipe to increase the speed of the water flowing through it. A reducer fitting is used to connect these two pipes of different diameters [14]. These alternatives can ensure that the water can be jetted higher and faster out of the nozzle. For aesthetic purposes, rotating angled jets should be installed instead, to create a pattern of water flowing out of the jets, plus the addition of lights on each of the jets.

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APPENDICES

Table A: Frictional Losses in Piping System of Field #2

Above Splitter			Below Splitter
Type of jets	Upward	Angled	
Q (GPM)	**1.15**		**5.73**
v ($\frac{ft}{s}$)	4.70		23.50
D (ft)	0.17		0.17
$\mu\left(\frac{lb_m}{ft \cdot s}\right)$	6.91 x 10^{-4}		6.91 x 10^{-4}
$\rho\left(\frac{lb_m}{ft^3}\right)$	62.26		62.26
Re	72958		364788
ε **(ft)**	1.50 x 10^{-4}		1.50 x 10^{-4}
f_F	5.67 x 10^{-3}		5.00 x 10^{-3}
L_{pipe} **(ft)**	1.00	196.80	471.00
$F_{pipe}\left(\frac{ft^2}{s^2}\right)$	1.45	285.98	15108.24
K	0.00	2.42	2.68
$F_{Fittings}\left(\frac{ft^2}{s^2}\right)$	0.00	26.71	740.36
$F_{Total}\left(\frac{ft^2}{s^2}\right)$	1.45	312.69	15848.60
$g\left(\frac{ft}{s^2}\right)$	32.20		32.20
Δz **(ft)**	1.00		-275.00
Δp **(psi)**	-0.45	-4.64	
$\Delta p_{overall}$ **(psi)**	-5.09		-93.99
Combined Values			
$\Delta p_{combined}$ **(psi)**		**-99.08**	
$F_{Overall}\left(\frac{ft^2}{s^2}\right)$		**16162.74**	

Table B: Frictional Losses in Piping System of the Statue at Field #1

Q (GPM)	**4.34**
v ($\frac{ft}{s}$)	0.41
D (ft)	0.17
$\mu \left(\frac{lb_m}{ft \cdot s}\right)$	6.91 x 10^{-4}
$\rho \left(\frac{lb_m}{ft^3}\right)$	62.26
Re	6440
ε **(ft)**	1.50 x 10^{-4}
$\mathbf{f_F}$	9.09 x 10^{-3}
$\mathbf{L_{pipe}}$ **(ft)**	243.50
$\mathbf{F_{pipe}} \left(\frac{ft^2}{s^2}\right)$	4.42
K	2.15
$\mathbf{F_{Fittings}} \left(\frac{ft^2}{s^2}\right)$	0.19
$\mathbf{F_{Total}} \left(\frac{ft^2}{s^2}\right)$	**4.61**
g $\left(\frac{ft}{s^2}\right)$	32.20
Δz **(ft)**	-127.00
Δp **(psi)**	**-0.55**

Table C: Frictional Losses in Piping System of Field #1 For Water Recirculation from Field #2

Q (GPM)	**5.73**
v ($\frac{ft}{s}$)	23.50
D (ft)	0.17
μ $\left(\frac{lb_m}{ft \cdot s}\right)$	6.91 x 10^{-4}
ρ $\left(\frac{lb_m}{ft^3}\right)$	62.26
Re	364788
ε (ft)	1.50 x 10^{-4}
f_F	5.00 x 10^{-3}
L_{pipe} (ft)	151.00
$F_{pipe}\left(\frac{ft^2}{s^2}\right)$	4843.62
K	0.60
$F_{Fittings}\left(\frac{ft^2}{s^2}\right)$	164.49
$F_{Total}\left(\frac{ft^2}{s^2}\right)$	**5008.11**
g $\left(\frac{ft}{s^2}\right)$	32.20
Δz (ft)	101.00
Δp (psi)	**-111.02**
TDH (ft)	256.53
P (HP)	**0.37**

Table D: Parameters Associated to Water Flowing Out of Spillway To Waterfall

Q (GPM)	**10.00**
v_{Target} ($\frac{ft}{s}$)	**2.23 x 10^{-3}**
Area of Outlet (ft^2)	10.00
R_{Solver} (ft)	**3.68 x 10^{-4}**
g $\left(\frac{ft}{s^2}\right)$	32.20
Initial Height (ft)	0.4375
v_{Solver} ($\frac{ft}{s}$)	2.23E-03