Design Data

Decision Matrix

Methodology

In order to propose a solution for the sanitary sewer runoff from the kennel space, a decision matrix was utilized for the design alternatives. The decision criteria and designs were evaluated through the use of a weighted decision matrix (see Figure 6-1). Each criteria was given a weight based on the criteria's ability to affect the clients feasibility to implement the design. Then each design was ranked one, two, or three with "one" being the design that best met the criteria and "three" being the design that least met the criteria. The weight of each decision criteria and the rank that the design was given were multiplied and summed together to give a weighted score for each design. The design that scored the least is the design that best met the decision criteria. The goal was to develop at least three design alternatives and decision criterias each to use in the weighted decision matrix.

Description of Criteria

Using engineering judgement, the designs were evaluated based on their ability to meet the criteria identified as critical to meeting project objectives. The decision criteria selected are as follows: Sanitation, Space Required, Construction Cost, and Maintenance Cost.

The Sanatitation criteria evaluates each design's ability to infiltrate/remove the sanitary sewer waste, minimize the waste smell, and keep the dogs from drinking/wading in the waste which has been a problem for the client in the past. The Space Required criteria evaluates the surface area each design would need to meet the project objective. The client expressed that maximizing the available surface area on the property was important due to the dogs and vehicles on the property needing space to move freely.

Since the Client would likely be paying for the design utilizing donations, the Construction and Maintenance Cost of each design was evaluated to determine what design would best suit the client's budget. It was assumed that lower cost designs would be more feasible to implement. It was also assumed that the cost of the construction should be weighted more than the other criteria because the cost would affect the client's ability to implement. This is due to the construction cost needing to be feasible to collect from donors over a period of time. All other criteria were weighted the same value because the feasibility of the design wouldn't be affected by the design's ability to meet the criteria.

Description of Alternatives

In order to investigate solutions to the sanitary sewer drainage, as per client request, three different designs were selected: a leach field and septic tank, a lagoon, and a LID retention pond. These designs were selected because they are designs meant to collect and infiltrate water.

These alternatives were developed because they are the most commonly used when dealing with wastewater that can not go to a treatment plant. A septic tank and leach field is the most common way to deal with wastewater when there is no access to a treatment plant. Septic tanks help settle out solids and through anaerobic process reduce solids and organics. After the water sits in a septic tank for the allotted time it is discharged into the ground, which slowly filtrates the discharge through infiltration. This makes the water clean enough by the time it reaches the ground water. Septic tanks and leach fields are also underground which benefits sanitation and aesthetics.

A lagoon is an aerated pond that uses microbial activity and oxygen to break down pollutants in water. The discharge of lagoons is controlled and only happens a few times every couple of years. This alternative does not promote sanitation and would take a large amount of surface area to hold the amount of water for the required amount of time.

An LID retention pond is similar to a lagoon. It employs the same processes of a lagoon to clean the wastewater, however an LID retention pond slowly discharges the water into the ground. The discharge from the pond infiltrates through the ground cleaning it further before it enters the groundwater.

Selection of Final Design

In order to evaluate how each design meets the decision criteria, research into each of the three designs in relation to the decision criteria were completed. Regarding the Sanitation of each design, the lagoon and retention pond allows water to infiltrate above ground; thus there is concern for smell and accessibility by the dogs on the property. The septic tank and leach field design is underground; thus preventing the smell and accessibility to the dogs. Space required for the lagoon and LID retention pond were assumed to be equal due to the similarity in function. The septic tank and leach field design has nearly a zero surface area footprint as it is an underground system, but it does require limitations on use of the surface above the leach field.

After speaking with other professionals and reviewing previous bids, the following construction costs for each design was approximated [18]. Septic Tank and Leach Field - $4,000 - $5,000, Lagoon - $2,000, LID retention pond - $2,000 [19, 20]. Maintenance for the lagoon and LID retention pond are similar, needing regular removal of debris and weeding yearly. It was assumed that the owner would take care of maintenance, therefore cost of maintenance is zero. Cost of maintenance for a septic tank and leach field is approximately $173 every 4.6 years [20].

Table 1 displays the weighted decision matrix. The design that best met the decision criteria is the leach field and septic tank.

Table 1: Decision Matrix

	Decision Criteria				
	Sanitation	Area Required	Construction Cost	Maintenance Cost	
Weight	**0.23**	**0.23**	**0.31**	**0.23**	**Total**
Septic Tank and Leach Field	1	1	2	2	**1.54**
Lagoon	3	2	1	1	**1.69**
LID Retention Pond	2	2	3	1	**2.08**

Design Calculations

Hydrology

The “sub-basin” used to analyze the hydrology of the site was the drainage area determined using the topography of the area. Figure 1 below shows the drainage area used to analyze the hydrology of the site. The drainage area is outlined in red and the kennel space is marked by a green star.

Figure 1: Drainage Area

Flow routing was done using the contours of the drainage area. Figure 2 below shows the flow of the water through the site. The dark blue line shows runoff that flows through the kennels. The light blue lines show runoff that is near the kennel but does not flow through them. The light blue line east of the kennel flow does go through the clients property and may cause flooding, but since it is not a part of this project, it will not be analyzed. The flow route is also known as the time of concentration flow path.

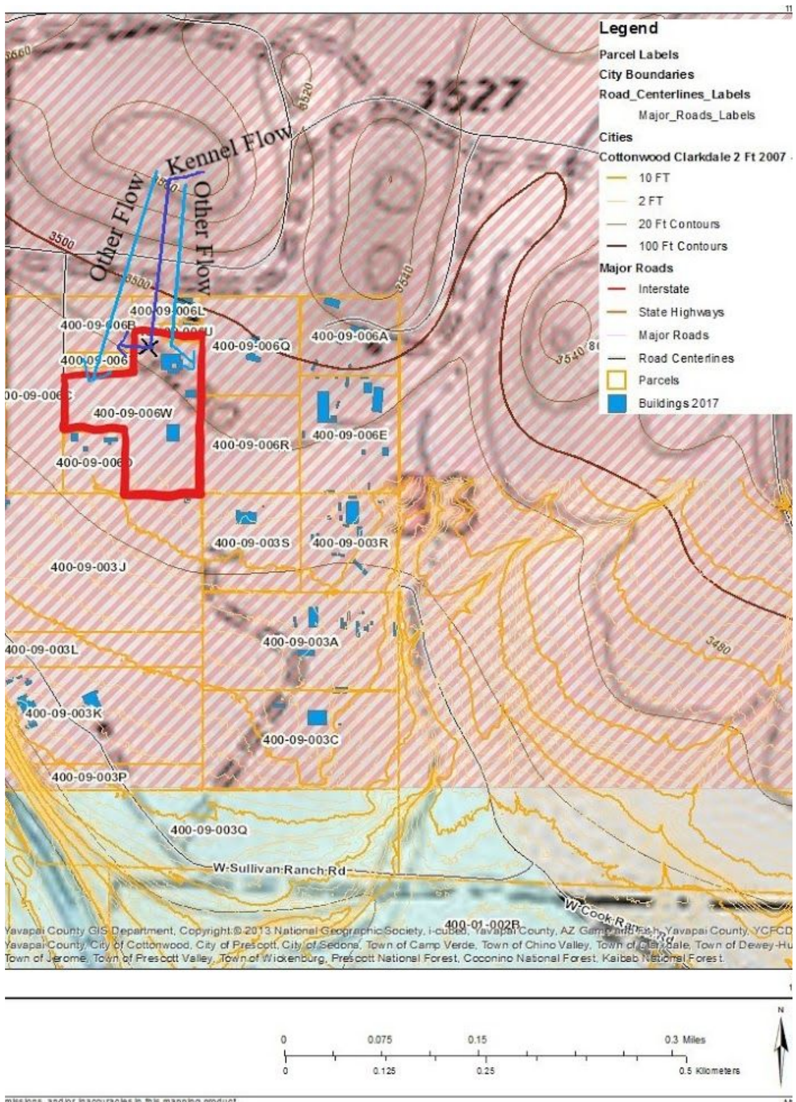


Figure 2: Flow Routing [13]

The weighted curve number was calculated using Table 7.6 in the Yavapai County Drainage Design Manual [14]. The curve number was found by determining the types of landscape, curve number for each landscape, and percentage of drainage area for landscape type. The table below shows the weighted curve number for the area that flows through the kennel space.

Equation 1: Weighted Curve Number

$$WC = \sum(C * \%A)$$

WC: Weighted Runoff Coefficient
C: Runoff Coefficient
%A: Percent of Total Area

Table 2: Weighted Curve Number

Percentage of Surface Type within Sub-Basin (%)				Weighted C
Natural Desert Rangeland	Hillslopes	Gravel Road	Roof	
66%	16%	16%	2%	0.58
0.48	0.67	0.84	0.95	
Runoff Coefficient				

The weighted runoff coefficient was determined to be 0.58.

The time of concentration (T_c) was calculated for the drainage area following Equation 7.2 in the Yavapai County Drainage Design Manual [14]. Based on Equation 5-2 the time of concentration was determined to be 30 minutes for the site. Since rainfall intensity is based on time of concentration, the theoretical time of concentration was used to determine the different rainfall intensities for each T_c for each storm. These were then used in the equation to determine the calculated time of concentration. The calculated time of concentrations that matched the theoretical time of concentrations were those used for further calculations. For every storm event, the time of concentrations that matched were for a 30 minute T_c. The rainfall intensities used to solve for time of concentration were found using NOAA Atlas 14 [15]. The length and slope of flow were determined through measurements found using Google Earth and contours provided by USGS. The equation and references used to calculate T_c can be found in Appendix D.

Equation 2: Time of Concentration

$$Tc = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-.038}$$

T_c: Time of Concentration (hr)
L: Length of Hydraulic Path (ft)
K_b: Watershed Resistance Coefficient
S: Slope of Hydraulic Path (ft/mi)
i: Average Rainfall Intensity (in/hr)

Table 3 below shows the calculation for time of concentration for the site for various storm events.

Table 3: Time of Concentration

Knowns	
Length of Flow Path - L (mi)	0.370
Watershed Resistance Coefficient - Kb	0.250
Slope - S (ft/mi)	378.4

Theoretical Time of Concentration (min)	Storm (yr)	Rainfall Intensity (in/hr)	Calculated Tc (hr)	Calculated Tc (min)
10	1	0.327	0.819	49
15	1	0.406	0.754	45
30	**1**	**0.546**	**0.674**	**40**
60	1	0.676	0.621	37
10	2	0.423	0.743	45
15	2	0.524	0.685	41
30	**2**	**0.705**	**0.612**	**37**
60	2	0.873	0.564	34
10	5	0.574	0.661	40
15	5	0.711	0.610	37
30	**5**	**0.957**	**0.545**	**33**
60	5	1.18	0.503	30
10	10	0.697	0.614	37
15	10	0.864	0.566	34
30	**10**	**1.16**	**0.506**	**30**
60	10	1.44	0.466	28
10	25	0.876	0.563	34
15	25	1.09	0.518	31
30	**25**	**1.46**	**0.464**	**28**
60	25	1.81	0.427	26
10	50	1.02	0.531	32
15	50	1.27	0.489	29
30	**50**	**1.71**	**0.437**	**26**
60	50	2.12	0.402	24
10	100	1.18	0.503	30
15	100	1.47	0.463	28
30	**100**	**1.98**	**0.413**	**25**
60	100	2.45	0.381	23

To determine the storm event runoff for the site, the Rational Method was used following Yavapai County Drainage Design Manual Equation 7.1 [14].

Equation 3: Storm Event Runoff

$$Q = CiA$$

Q: Runoff (cfs)
C: Weighted Runoff Coefficient
i: Rainfall Intensity (in/hr)
A: Drainage Area (acre)

The area used to calculate the flow was determined using Google Earth. The rainfall intensity values used are the 30 min duration intensities from NOAA Atlas 14 [15]. The storm event runoff was only calculated once because there is no change in the impervious area. At the location of the concrete pad the soil is already compacted which makes it impervious, so the addition of the concrete pad does not change the impervious area. Table 5-3 below shows the storm runoff for different storm events. The table is for both existing and proposed runoff. The impervious area does not change with the addition of the concrete pad because the ground is already compacted at the location the concrete pad will be placed. It was determined that the best storm to design for is the one correlating with a monsoon season storm. Research was done to determine which storm correlates with a monsoon level storm. The Cottonwood area gets approximately 5.37 inches of rain during monsoon season [16]. Out of 55 days of the monsoon season, Cottonwood only gets rain 10 of those days [17]. With this, it was determined that every day it rains during monsoon season, approximately 0.5 inches of rain falls. Monsoon storms last approximately one to two hours, which means the rainfall intensity in inches per hour most closely matches a 1 year storm event.

Table 4: Storm Event Runoff

Flow Through Kennels	
Storm (yr)	**Q (cfs)**
1	**0.58**
2	0.74
5	1.01
10	1.22
25	1.54
50	1.80
100	2.09

.

Hydraulics

Bernoulli's Equation (see Equation 6-1) was utilized to determine the volume of flow utilized to sanitize the kennel space. The client uses a well pump system north-east of the existing slab (see Figure 6-1) to supply water to his hose to wash the kennel space. The client informed us that the pump supplying pressure was of 60 psi.

Equation 4: Bernoulli's Equation

$$\frac{P_1}{\gamma} + \frac{V_1^{\,2}}{2g} + h_1 + h_P = \frac{P_2}{\gamma} + \frac{V_2^{\,2}}{2g} + h_2 + h_L$$

P = Pressure (psi)

V = Velocity (ft/s^2)

g = Acceleration due to gravity (32.2 ft/s)

h = Height (ft)

h_L = Head loss (ft)

h_P = Pump head (ft)

γ = Specific weight of water (62.4 lbs/ft^3)

Educated assumptions regarding the length and type of material for the pipe and hose were made to estimate flows according to what the team experienced during the site visits to the project location. Table 5 shows values for the assumptions made. The process of determining the velocity due to the pipe and hose material was iterative.

Table 5: Assumptions made for flow rate determination of hose at existing kennel space.

Hydraulic Assumptions	
Δ Elevation	0 ft
Δ Pressure	0 psi
Pipe Material	PVC
Pipe Diameter	0.75 in
Length of Pipe	200 ft
Hose Material	Rubber
Hose Diameter	0.75 inch
Length of Hose	100 ft

The figure below shows the hand calculations done to determine the flow rate of the water when it leaves the hose at the kennels.

found on wells SS that the site shares a well with the property just north

I is Assumed that this property Has a 3/4" pvc p feeding the Home and this pipe is 90 feet long if the water traveled another distance of 110 feet through 1" pipe and fixtures And then through a 3/4 rubber Hose to Clean existing kennels

we Assume that ELEVation from well to End of Hose is the Same

FE HAnd Book 106

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + \text{Pump} = \frac{P_2}{\gamma} + z_2 + \frac{V^2}{2g} + h_f \longrightarrow h_f = f\frac{L}{D}\frac{V^2}{2g}$$

$$\frac{144\ in^2}{1\ ft^2}\ \frac{ft^3}{62.3\ lb} = 2.311\ ft$$

$$138.7 = \frac{V^2}{2g} + \underbrace{f\frac{L}{D}\frac{V^2}{2g}}_{\text{PVC}} + \underbrace{f\frac{L}{D}\frac{V^2}{2g}}_{\text{Hose}}$$

f of pvc

f of Rubber Hose

2.311 feet of water 1 PSI

No pressure due to tank

No Elevation Change

No V_1 No Change A Base of well

Pump = 138.7 feet

Pump 60 psi need Head

$$60\ psi \cdot \frac{2.811\ \text{feet}}{1\ psi} = 138.7\ \text{feet}$$

P_2 No pressure At end of Hose

Z_2 no ELEV. Change

Have V_2

need to find h_f So we Start to Assume

And run through needing Reynolds Number with A Assumed Velocity

So try 16 gallons per min

$$\frac{5\ gall}{Min}\ \frac{ft^3}{7.48\ gall} = \frac{0.668\ ft^3}{Min}$$

3/4" pipe = Area in ft^2

Kinematic Viscosity @ 60°F 0.000012 ft^2/s

$$\frac{(3/4/12)^2 \cdot \pi}{4} = 0.00307\ ft^2 \qquad \phi = 0.0625\ ft$$

for Bath

$$18888 = Re = \frac{VD}{\nu} = \frac{3.63\ ft}{s} \cdot 0.0625\ ft^2 \left(\frac{s}{0.000012\ ft^2}\right) \qquad \frac{0.668\ ft^3}{Min}\ \frac{1}{0.00307\ ft^2} = \frac{217.6\ ft}{M}$$

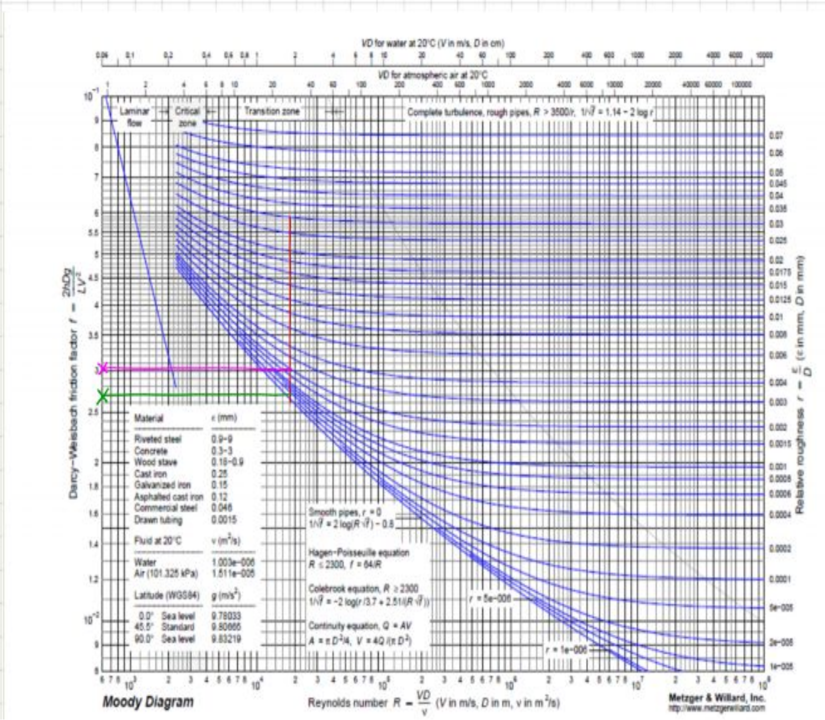
1.9×10^4

$$\frac{217.6\ ft}{M}\ \frac{M}{60\ s} = \frac{3.63\ ft}{s}$$

PVC	Roughness (mm)	in	RR
pvc	0.00575	0.000226	0.000301
Flexible Rub tubing	0.038	0.00150	0.00200

PVC $f = 2.7 \times 10^{-2}$ 0.027

FRT $f = 3.0 \times 10^{-2} = 0.031$



$$138.7 \text{ ft} = \frac{V^2}{2g} + \underbrace{f \frac{L}{D} \frac{V^2}{2g}}_{\text{PVC}} + \underbrace{f \frac{L}{D} \frac{V^2}{2g}}_{\text{Hose}}$$

PVC $f = 2.7 \times 10^{-2}$ 0.027 $\quad \frac{3.63 \text{ ft}}{s}$

FRT $f = 3.1 \times 10^{-2} = 0.031$

$g = 32.17$ ft/s

$2g = 64.34$ ft/s

$\phi = 3/4'' = 0.0625'$

$$138.7 = \frac{V^2}{64.34} + \frac{0.27 \cdot 200}{0.0625 \cdot 64.34} V^2 + \frac{0.30 \cdot 100}{0.0625 \cdot 64.34} V^2$$

$$138.7 = 0.02\ V^2 + 13.43 V^2 + 7.46\ V^2 = 20.91\ V^2 = \frac{2.58 \text{ ft}}{s}$$

And our Assuming speed was $\frac{3.63 \text{ ft}}{s}$

with this we try Again But $\frac{2.56 + 3.63}{2} = 3.10$ ft/s New Assumed Velocity

$$Re = \frac{VD}{\nu} = \frac{3.63 \text{ ft}}{s} \cdot 0.0625 \text{ ft}^2 \left(\frac{s}{0.000012 \text{ ft}^2}\right)$$

But using 3.10 ft/s

$$\frac{3.10 \text{ ft}}{s} \cdot \frac{0.0625 \text{ ft}}{} \frac{s}{0.000012 \text{ ft}^2} = 16146 = 1.6 \times 10^4$$

PVC - f of 0.28

tubing - f of 0.31

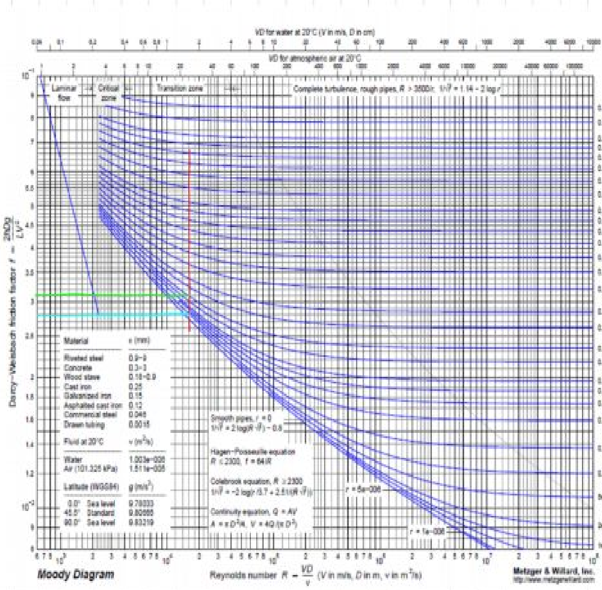
$$138.7 = \frac{V^2}{64.34} + \frac{0.28 \cdot 200}{0.0625 \cdot 64.34} V^2 + \frac{0.31 \cdot 100}{0.0625 \cdot 64.34} V^2$$

$$138.7 = 0.02 V^2 + 13.93 V^2 + 7.71 V^2$$

$$\sqrt{\frac{138.7}{21.66}} = V = 2.53 \frac{ft}{s}$$

with $3.10 \frac{ft}{s}$

Next Assumption of $2.45 \frac{ft}{s}$



$$Re \quad \frac{2.45 \, ft}{s} \cdot 0.0625 \, ft \quad \frac{s}{0.000012} = 1.2760 \quad 1.3 \times 10^4$$

PVC - f - 0.295

Tube - f - 0.32

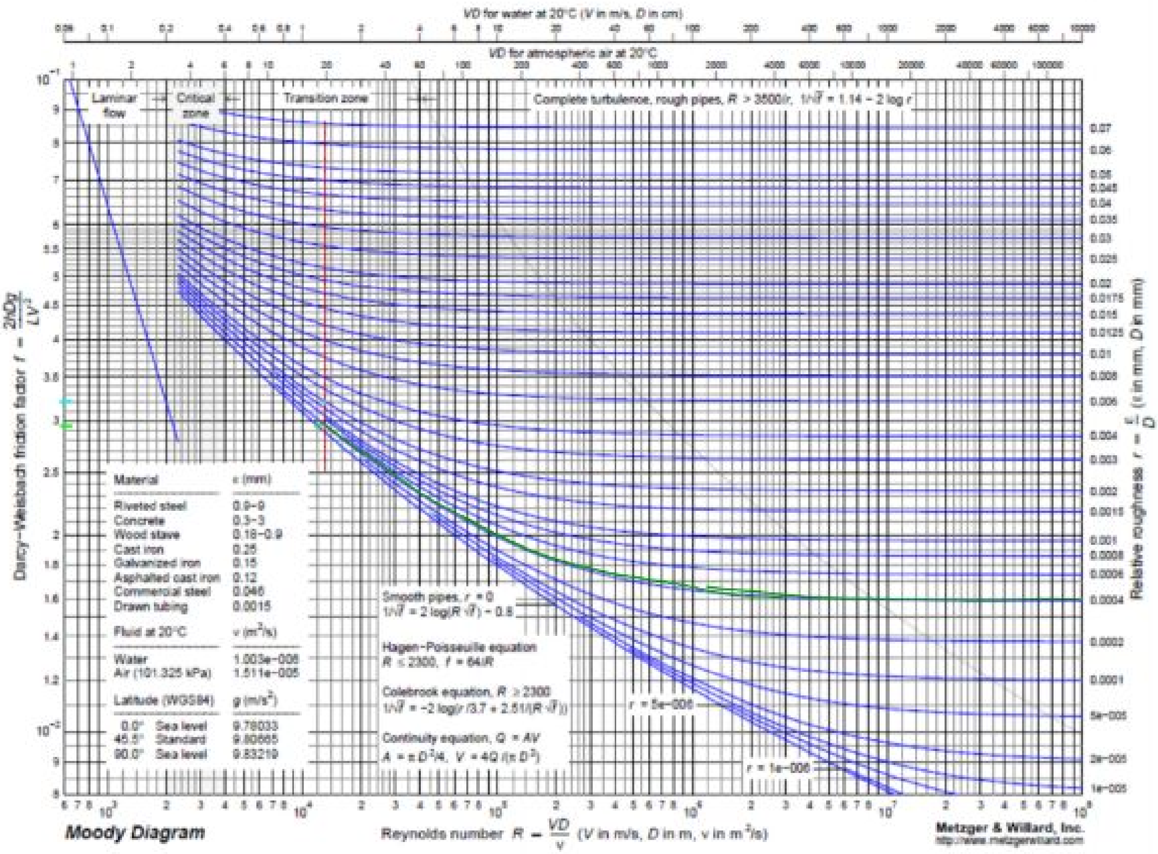
$$138.7 = 0.02 V^2 + \frac{0.295 \cdot 200}{0.0625 \cdot 64.34} V^2 + \frac{0.32 \cdot 100}{0.0625 \cdot 64.34} V^2$$

$$138.7 = 0.02 V^2 + 14.67 V^2 + 7.96 V^2$$

$$\sqrt{\frac{138.7}{22.65}} = V = 2.47$$

with Start of 2.45

$$V = 2.47 \frac{ft}{s}$$



$$\frac{3"}{4} \cdot \frac{ft}{12"} = 0.0625\ ft$$

$$V = \frac{2.47\ ft}{s}\ 0.00307\ ft^2 \qquad \frac{(0.0625\ ft)^2}{4}\pi = 0.00307\ ft^2$$

$$\frac{2.47\ ft}{s}\ 0.00307\ ft^2 = \frac{0.00757\ ft^3}{s}$$

$$\frac{0.00787\ ft^3}{s}\ \frac{60\ s}{M} = \frac{0.455\ ft^3}{M} \cdot \frac{7.48\ gall}{M} = \frac{3.4\ gall}{Min}$$

$$\frac{3.4\ gall}{Min}$$

Figure 3: Hydraulic Hand Calculations

Results of the hydraulic analysis show that a total of 3.4 gpm are supplied to the hose used to wash the kennel space. According to Yavapai County Standards, a 1000 gallon septic tank is needed for this flow. The final design drawings can be found under “Drawings and Photos”.

Final Cost of Implementation

The cost of implementing the design can be seen below in Table 2. The materials for the construction plans include the cost of the cement and the vapor barrier. The materials included for the drainage plan are the septic tank, the 4 inch PVC pipe and associated fitting, and the catch basins. The physical labor of both designs is assumed to be completed by the client, so there will be no cost of labor. Installation of the septic tank is based on previous installation costs [20,22].

Table 2: Cost of Design

Materials	**Unit price**	**Units**	**Total**
Vapor Barrier [23]	$60.00	1	$60.00
Cement ($/per bag) [24]	$4.55	312.5	$1,421.88
1000 gal Septic Tank ($/per tank) [25]	$1,000.00	1	$1,000.00
4 inch PVC pipe ($/per 10 feet length) [26]	$20.00	104.5	$2,090.00
Steel frame for catch basin ($/per unit) [27]	$240.00	2	$480.00
Septic Tank Installation [20,22]	$5,000.00	1	$5,000.00
			$10,051.88