RESIDENTIAL RAINWATER HARVESTING **PROJECT**

UGRAD CAPSTONE PRESENTATION

PRESENTED BY: BRETT HIGHTOWER, HAYLIE BREWER, AND ERICA KIESOW

DATE: FRIDAY, DECEMBER 9TH, 2016

PROJECT OVERVIEW

- Client: Alarick Reiboldt, EIT, MENG, Lecturer
- Located in Kachina Village

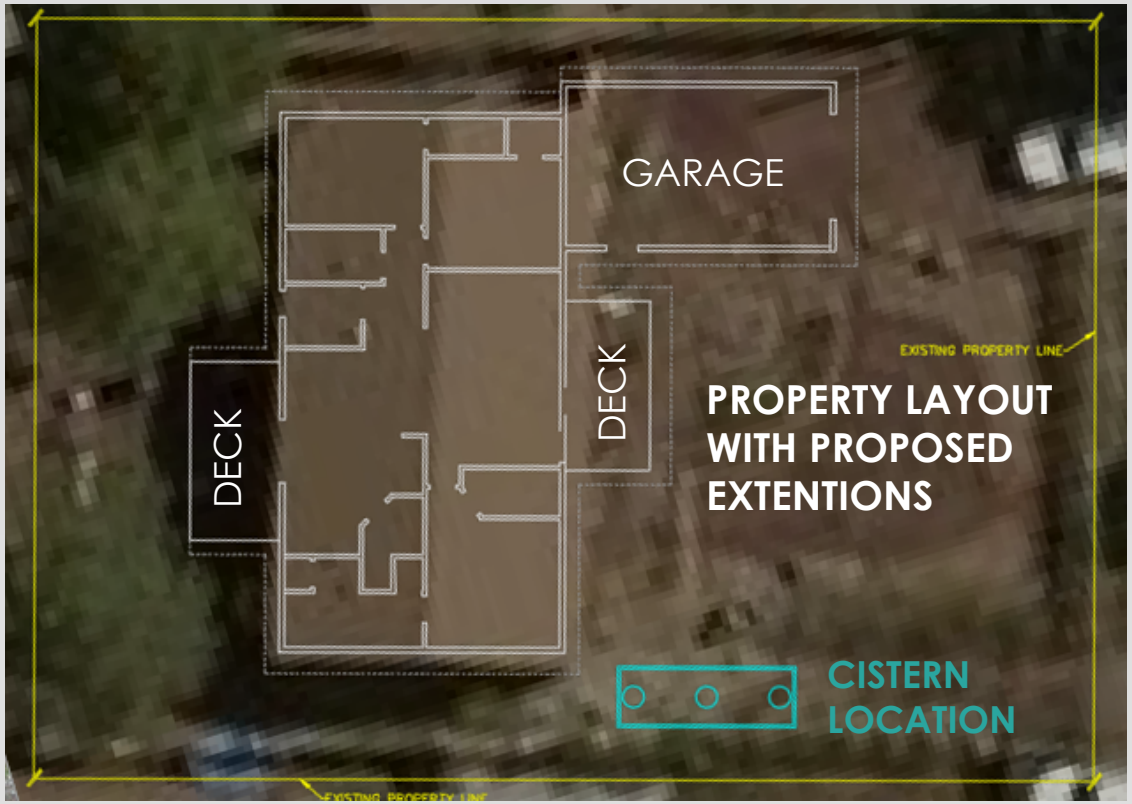

Figure 1: Aerial View of Proposed Property Layout [1]

Figure 2: Location of Kachina Village In Reference to the City of Flagstaff [2]

PROJECT OVERVIEW

- Design a rainwater harvesting and distribution system to facilitate residential water use.
- Intended use:
  - Vegetable garden irrigation
  - Bathroom distribution for toilet flushing water in two locations

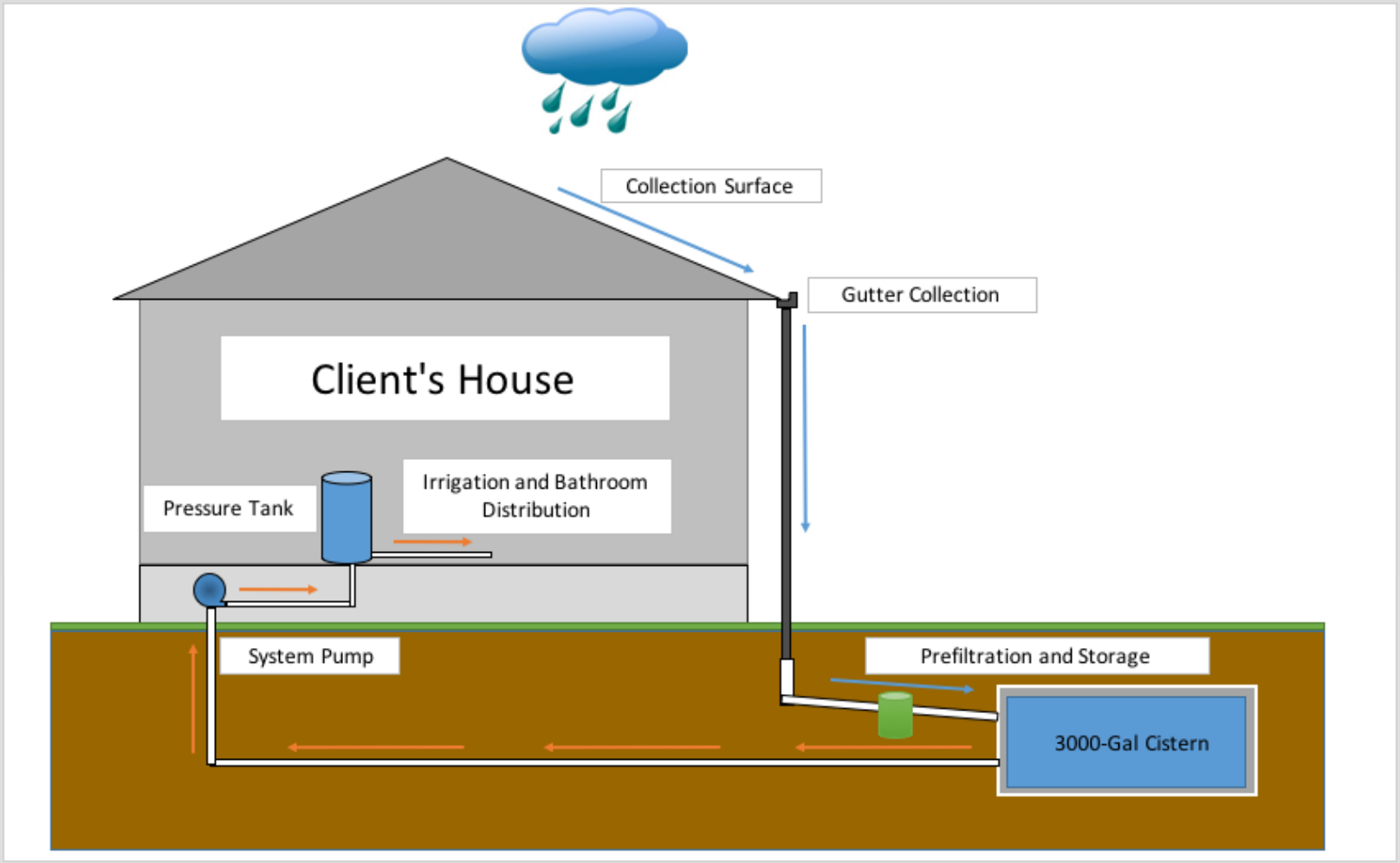

Figure 3: Rainwater Harvesting Schematic [3]

PROJECT SCHEDULE

Task Name	Duration	Start	Finish
1.0 Field Evaluation	1 day	Mon 8/29/16	Mon 8/29/16
1.1 Site Inspection	1 day	Mon 8/29/16	Mon 8/29/16
2.0 Design Standards, Specs, Codes	1 day	Mon 8/29/16	Mon 8/29/16
2.1 Research Coconino County Codes	1 day	Mon 8/29/16	Mon 8/29/16
3.0 Design Catchment System	9 days	Thu 9/1/16	Tue 9/13/16
3.1 Roof Runoff	2 days	Thu 9/1/16	Fri 9/2/16
3.2 Gutter Collection	3 days	Mon 9/5/16	Wed 9/7/16
3.3 Conveyance System	2 days	Thu 9/8/16	Fri 9/9/16
3.4 Filtration System Design	2 days	Mon 9/12/16	Tue 9/13/16
4.0 Cistern Design	13 days	Wed 9/14/16	Fri 9/30/16
4.1 Capacity	1 day	Wed 9/14/16	Wed 9/14/16
4.2 Location	1 day	Thu 9/15/16	Thu 9/15/16
4.3 Construction Material Specifications	4 days	Fri 9/16/16	Wed 9/21/16
4.4 Disinfection	4 days	Thu 9/22/16	Tue 9/27/16
4.5 Geotechnical Evaluation	1 day	Tues 9/27/16	Tues 9/27/16

Task Name	Duration	Start	Finish
4.6 Pump Selection and Specification	1 day	Fri 9/29/16	Fri 9/29/16
4.7 Slab Design	1 day	Fri 9/30/16	Fri 9/30/16
5.0 Pressure Tank	2 days	Mon 10/3/16	Tues 10/4/16
5.1 Research Components	1 day	Mon 10/3/16	Mon 10/3/16
5.2 Location	1 day	Tues 10/4/16	Tues 10/4/16
5.3 Disinfection	1 day	Tues 10/4/16	Tues 10/4/16
6.0 Bathroom Distribution Design	12 days	Mon 10/3/16	Tue 10/18/16
6.1 Distribution Design	4 days	Mon 10/3/16	Thu 10/6/16
6.2 Construction Material Specifications	2 days	Mon 10/17/16	Tue 10/18/16
7.0 Irrigation Distribution Design	7 days	Tue 10/18/16	Wed 10/26/16
7.1 Rain barrel selection	2 days	Tue 10/18/16	Wed 10/19/16
7.2 Pipe Design	3 days	Thu 10/20/16	Mon 10/24/16
7.3 Distribution System	2 days	Tue 10/25/16	Wed 10/26/16

PROJECT SCHEDULE

Task Name	Duration	Start	Finish
1.0 Field Evaluation	1 day	Mon 8/29/16	Mon 8/29/16
1.1 Site Inspection	1 day	Mon 8/29/16	Mon 8/29/16
2.0 Design Standards, Specs, Codes	1 day	Mon 8/29/16	Mon 8/29/16
2.1 Research Coconino County Codes	1 day	Mon 8/29/16	Mon 8/29/16
3.0 Design Catchment System	9 days	Thu 9/1/16	Tue 9/13/16
3.1 Roof Runoff	2 days	Thu 9/1/16	Fri 9/2/16
3.2 Gutter Collection	3 days	Mon 9/5/16	Wed 9/7/16
3.3 Conveyance System	2 days	Thu 9/8/16	Fri 9/9/16
3.4 Filtration System Design	2 days	Mon 9/12/16	Tue 9/13/16
4.0 Cistern Design	13 days	Wed 9/14/16	Fri 9/30/16
4.1 Capacity	1 day	Wed 9/14/16	Wed 9/14/16
4.2 Location	1 day	Thu 9/15/16	Thu 9/15/16
4.3 Construction Material Specifications	4 days	Fri 9/16/16	Wed 9/21/16
4.4 Disinfection	4 days	Thu 9/22/16	Tue 9/27/16
4.5 Geotechnical Evaluation	1 day	Tues 9/27/16	Tues 9/27/16
4.6 Pump Selection and Specification	1 day	Fri 9/29/16	Fri 9/29/16
4.7 Slab Design	1 day	Fri 9/30/16	Fri 9/30/16
5.0 Pressure Tank	2 days	Mon 10/3/16	Tues 10/4/16
5.1 Research Components	1 day	Mon 10/3/16	Mon 10/3/16
5.2 Location	1 day	Tues 10/4/16	Tues 10/4/16
5.3 Disinfection	1 day	Tues 10/4/16	Tues 10/4/16
6.0 Bathroom Distribution Design	12 days	Mon 10/3/16	Tue 10/18/16
6.1 Distribution Design	4 days	Mon 10/3/16	Thu 10/6/16
6.2 Construction Material Specifications	2 days	Mon 10/17/16	Tue 10/18/16
7.0 Irrigation Distribution Design	7 days	Tue 10/18/16	Wed 10/26/16
7.1 Rain barrel selection	2 days	Tue 10/18/16	Wed 10/19/16
7.2 Pipe Design	3 days	Thu 10/20/16	Mon 10/24/16
7.3 Distribution System	2 days	Tue 10/25/16	Wed 10/26/16

FIELD EVALUATION

- Cistern location
- Property setback
- Storm drain location

Figure 4: Existing Garden [3]

DESIGN STANDARDS AND CODES

COCONINO COUNTY CODE RESEARCH

- Collection limitations and restrictions
- Frost Depth
- Rational Method → $\boldsymbol{Q = (C_f)(C)(i)(A)}$

$\boldsymbol{Variables}$: $C_f = Antecedent\ Factor, C = Runoff\ Coefficient,$

$$i = rainfall\ intensity\ \left(\frac{in}{hour}\right), A = Area\ (ft^2)$$

LOW IMPACT DESIGN (LID) CONSIDERATIONS, CITY OF FLAGSTAFF

- Design volume
- Overflow
- Filtration
- Freeze prevention

2012 INTERNATIONAL RESIDENTIAL CODE (IRC)

- Toilet flow and pressure requirements

CATCHMENT SYSTEM DESIGN

- The catchment basin is split into 5 different areas
- The conveyance through the designated catchment areas are used to size the gutters, downspouts, and cistern.

Table 1: Catchment Areas (ft^2)

A1	A2	A3	A4	A5
384.1	472.5	584.9	630.5	99.5
Area (total)		**2,172** (ft^2)		

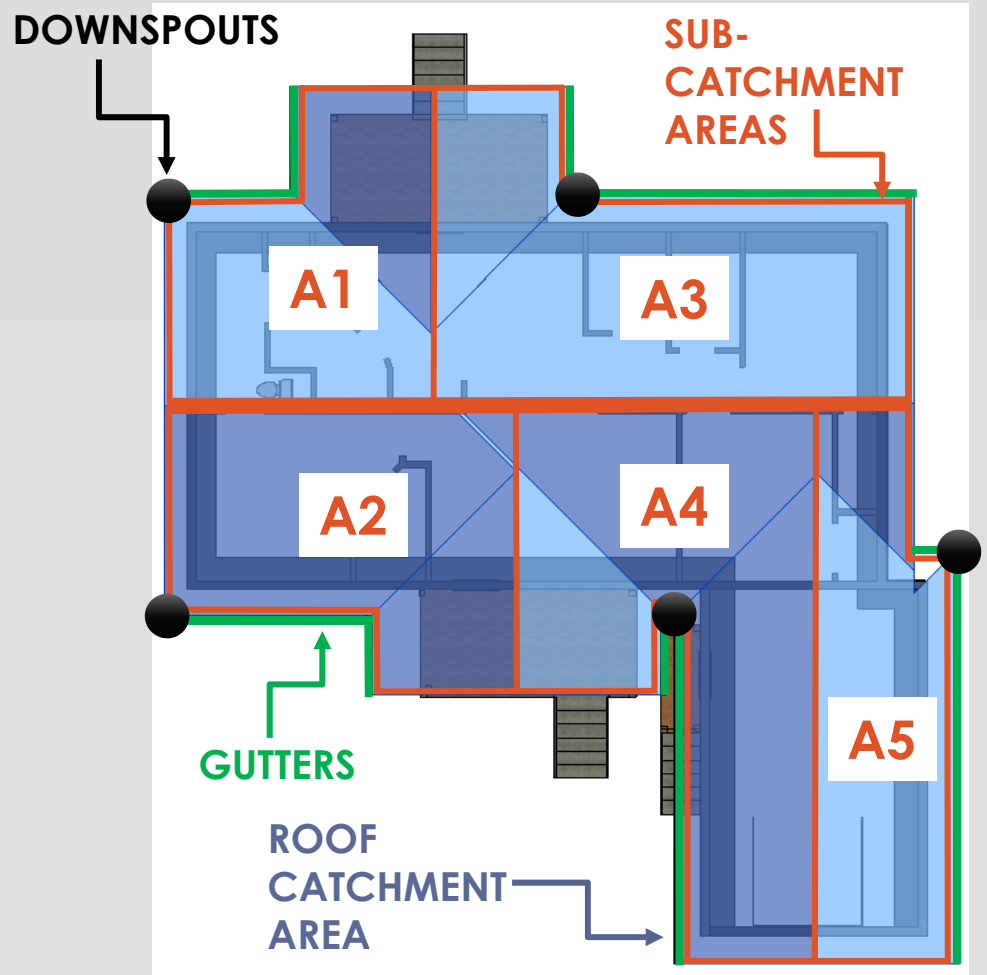

Figure 5: Top View of House With Proposed Extensions [4]

CATCHMENT SYSTEM DESIGN

AVAILABLE FLOW

- Based on precipitation trends of wet and dry seasons throughout the year.
- ***Wet Season:*** rainy, or monsoon season when most of a region's average annual rainfall occurs.
- ***Dry Season:*** period of low rainfall, less than 2.5 inches.

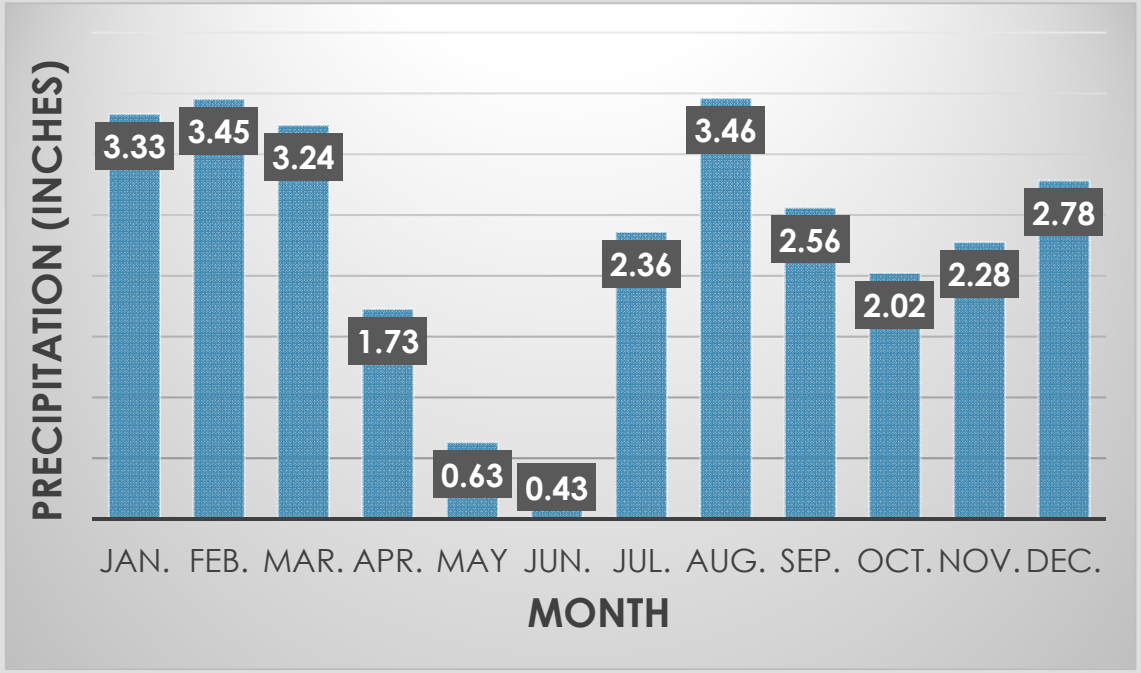

Figure 8: Flagstaff Average Precipitation Data [7]

CATCHMENT SYSTEM DESIGN

DEMAND

Table 2: Utility Specifications

Utility	Demand	Units
Bathroom 1	1.6	gal/flush
Bathroom 2	1.6	gal/flush
Irrigation	6	gal/min.

Table 3: Monthly Utility Usage

Utility	Demand	Units
Bathroom 1	36	flushes/month
Bathroom 2	36	flushes/month
Irrigation	120	minutes/month

Table 4: Average Seasonal Available Flow

	Wet Season	Dry Season
Total Rainwater (in.)	28.3	7.1
Q(Available) (gal/month)	**4,373**	**205**

Table 5: Average Seasonal Demand

	Wet Season	Dry Season
Utility	**Demand (gal/month)**	
Bathroom 1	57.6	57.6
Bathroom 2	57.6	57.6
Irrigation	38.6	720
Q (demand)	**154**	**835**

- ✓ *Additional storage collection is required during wet season to supply for dry season demand.*

CATCHMENT SYSTEM DESIGN

FILTRATION

- Filter collects water from all downspouts
- Basket Mesh = 0.35 mm
- Installation Depth = 21-41 inches

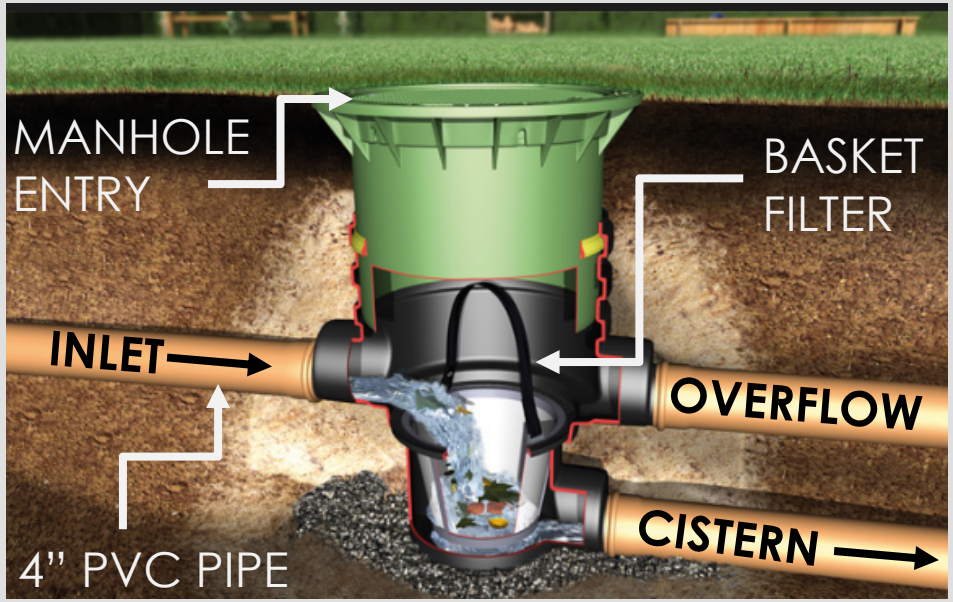

Figure 9: Filtration Device [8]

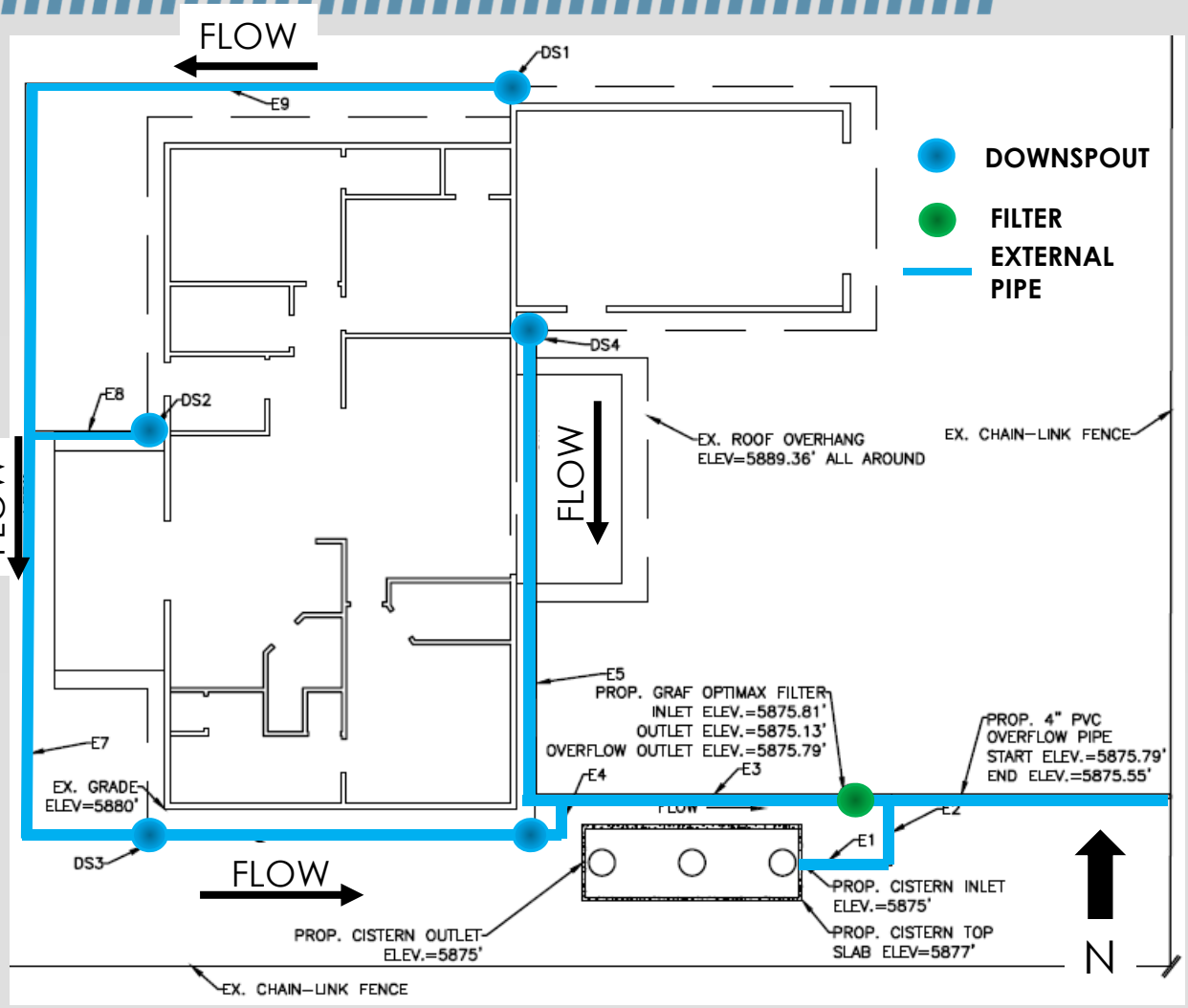

Figure 10: External Pipe Layout Schematic [9]

CISTERN DESIGN

Equation 1: Cistern Volume

$$V_{cistern} = V_{total} - V_{demand} + \Sigma V_{storage}$$

Variables:

$V_{cistern}$ = *Cistern Volume* $(gal/month)$

V_{total} = *Catchment Volume* $(gal/month)$

→ *based on average precipitation data*

V_{demand} = *Demand Volume* $(gal/month)$

→ *based on seasonal demand criteria*

$V_{storage}$ = *Storage Volume*$(gal/month)$

→ *based on dry season storage demand*

- Maximum Volumetric Capacity = 3,000 gallons
- Located 3 ft. below the ground surface on the southeast portion of the lot
- Disinfection = 3" chlorine tablets
- Foundation = 6" Aggregate Base

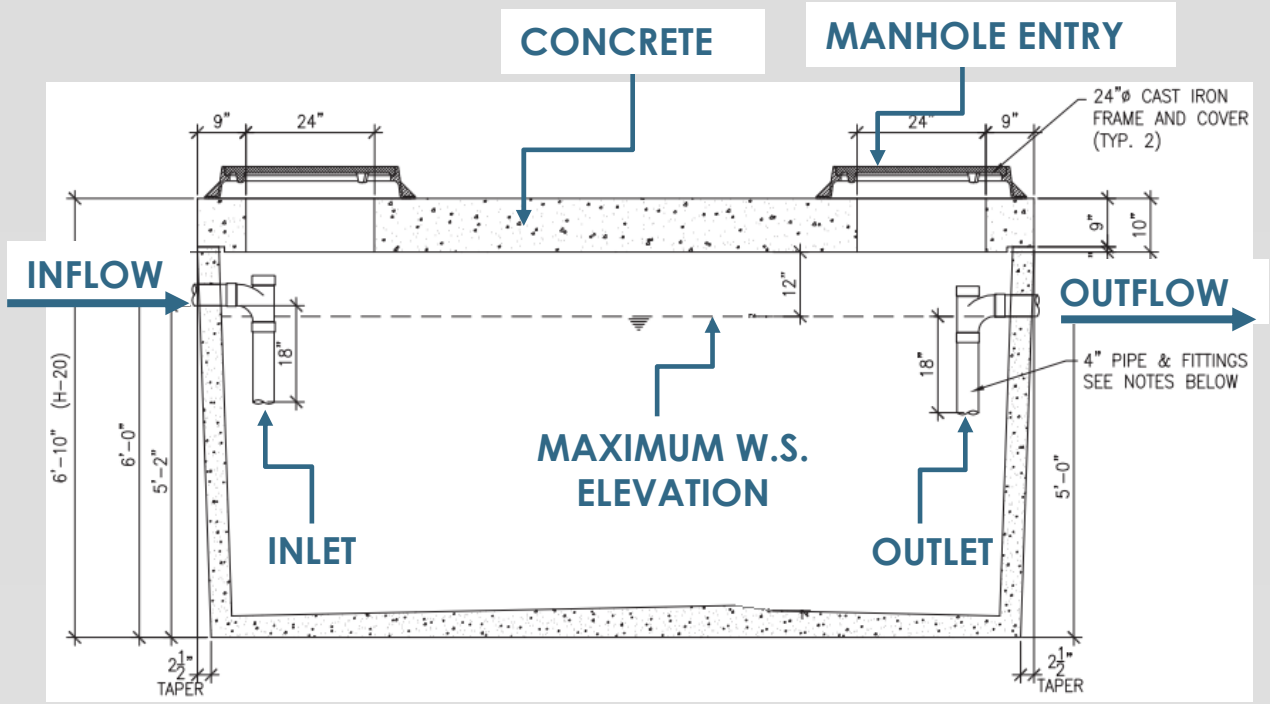

Figure 11: Concrete Cistern Section View [10]

BATHROOM & IRRIGATION DISTRIBUTION

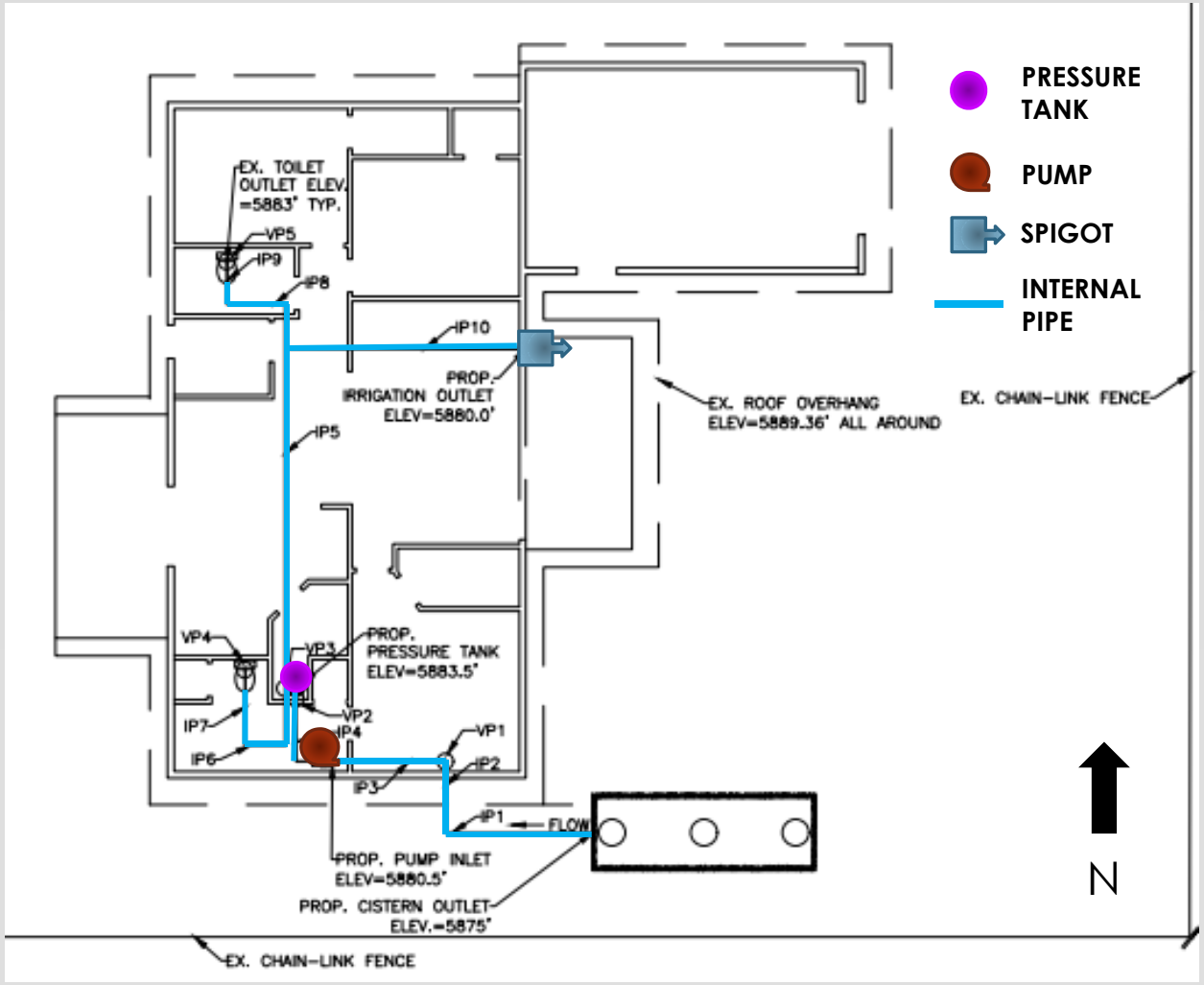

Figure 12: Internal Pipe Layout Schematic [9]

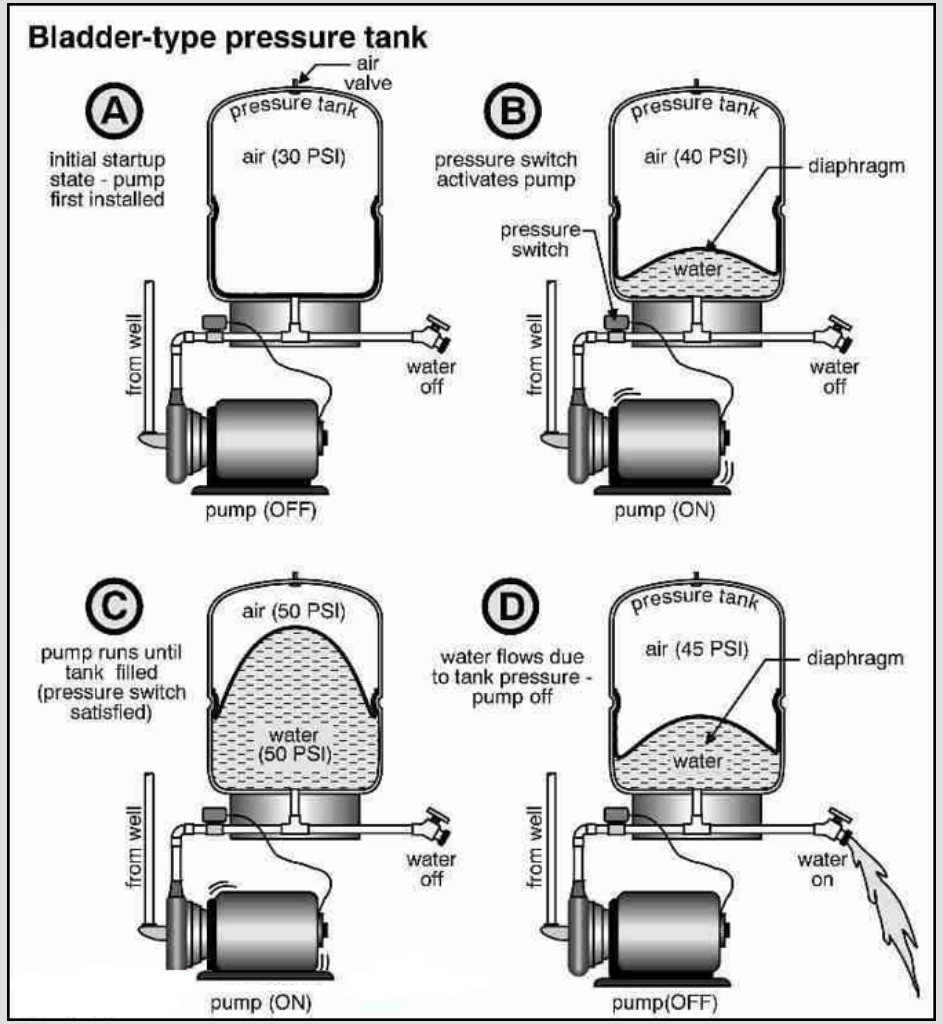

Figure 13: Pressure Tank Schematic [11]

PUMP SELECTION

Equation 4: Energy Equation [13]

$$z_1 + \frac{p_1}{\gamma} + \frac{{v_1}^2}{2g} + h_p = z_2 + \frac{p_2}{\gamma} + \frac{{v_2}^2}{2g} + \cancel{h_t}^{\,0} + h_{lf} + h_{lm}$$

Equation 5: Headloss Due to Friction Loss [13]

$$h_{lf} = f\,\frac{L}{d}\,\frac{v^2}{2g}$$

$f = friction\ factor \quad g = gravity\left(\frac{ft.}{s^2}\right) \quad L = pipe\ length\ (ft.)$

$d = pipe\ diameter\ (ft.) \qquad v = velocity\left(\frac{ft.}{s}\right)$

Equation 6: Headloss Due to Minor Loss [13]

$$h_{lm} = \Sigma\left(\xi\,\frac{v^2}{2g}\right)$$

$\xi = pipe\ fitting\ loss\ coefficient$

Table 6: Energy Equation Results

Variable	Symbol	Units	Value
Cistern Elevation	z_1	feet	5871.5
Cistern Pressure	P_1	psi	11.2
Cistern Velocity	v_1	ft./s	0
Head of Pump	h_p	**ft.**	**112**
Tank Elevation	z_2	feet	5887.5
Tank Pressure	P_2	psi	50.0
Toilet Velocity	v_2	ft./s	0
Friction Loss	h_{lf}	feet	2.31
Minor Losses	h_{lm}	feet	4.18

✓ Results provide pump selection requirements

PUMP SELECTION

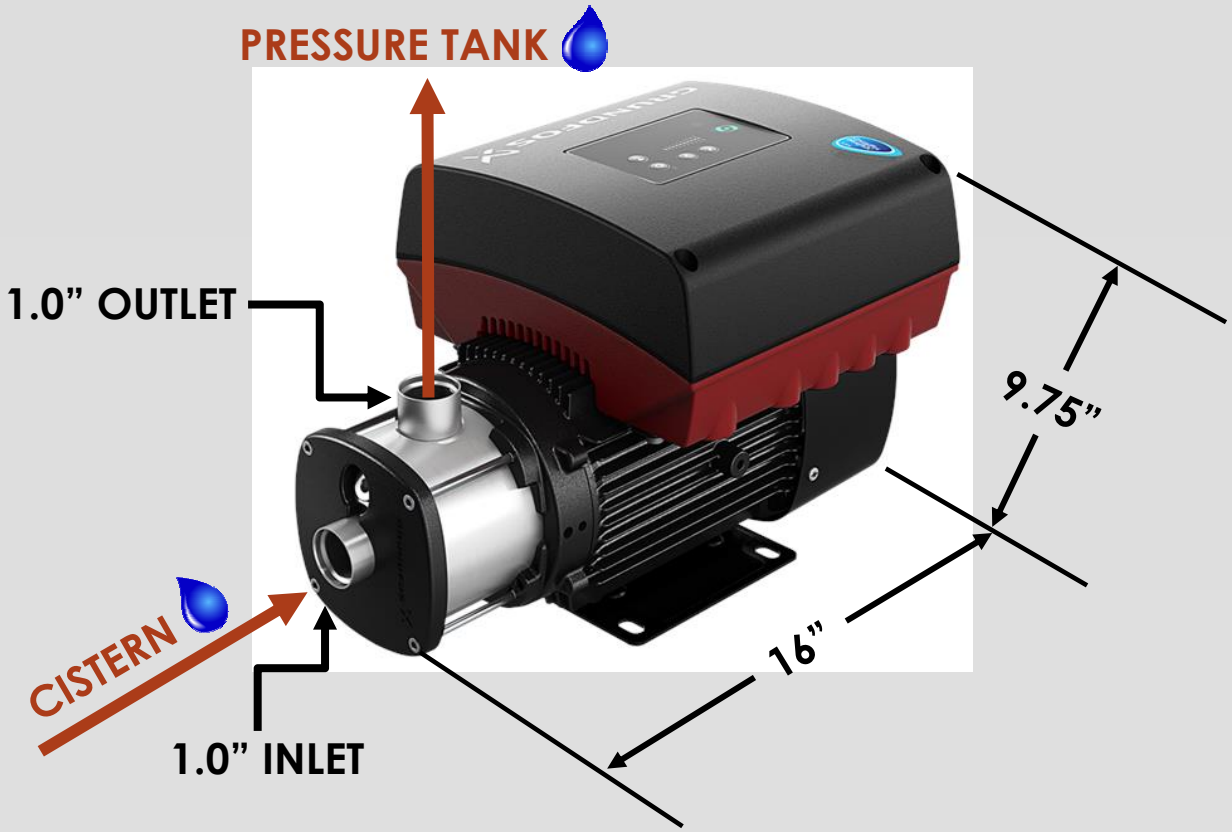

Figure 14: Selected Pump Schematics [12]

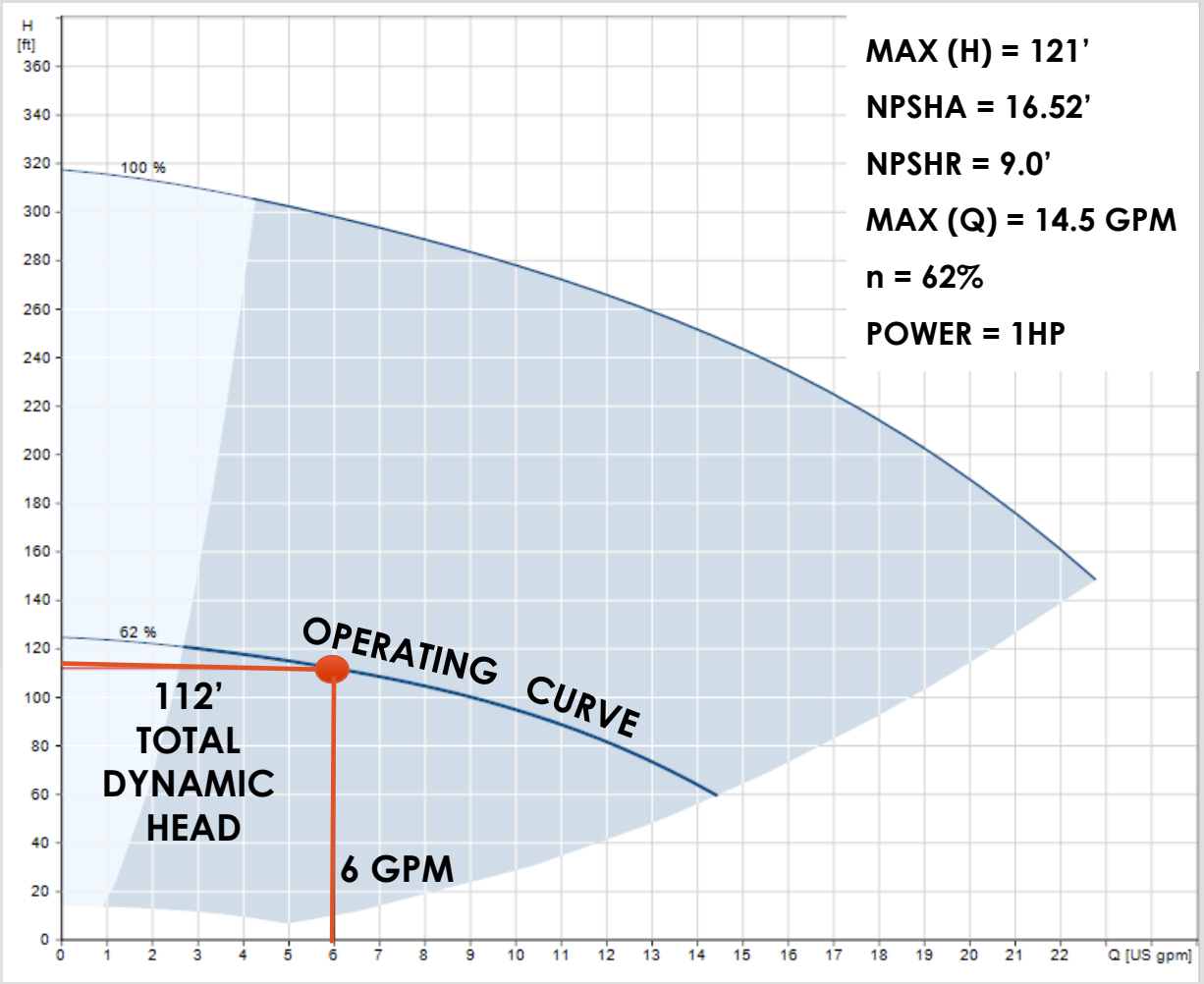

Figure 15: Pump Curve [12]

PRESSURE TANK SPECIFICATIONS

Equation 7: Energy Equation [13]

$$z_1 + \frac{p_1}{\gamma} + \frac{{v_1}^2}{2g} + \cancel{h_p}^{\,0} = z_2 + \frac{p_2}{\gamma} + \frac{{v_2}^2}{2g} + \cancel{h_t}^{\,0} + h_{lf} + h_{lm}$$

- Located in client's indoor utility closet
- Operating pressure = 30-50psi
- Distribution source for both bathroom locations and irrigation.

Figure 15: Selected Pressure Tank [14]

Table 7: Energy Equation Results

Variable	Symbol	Units	Value
Tank Elevation	z_1	feet	6883.5
Tank Pressure	P_1	psi	30.0
Tank Velocity	v_1	ft./s	0
Toilet Elevation	z_2	feet	6883
Toilet Pressure	$\boldsymbol{P_2}$	***psi***	***27.8***
Toilet Velocity	v_2	ft./s	0
Friction Loss	h_{lf}	feet	2.11
Minor Losses	h_{lm}	feet	3.44

✓ Results verify minimum code requirements, and provide pressure tank specifications are met

ECONOMIC ANALYSIS

Table 8: Aluminum Gutter Costs [15]

Parameter (units)	Quantity	Cost/Unit ($)	Cost ($)
Heat Tape (160 ft. Section)	2	112	224
Outside Corner Piece	10	84	84
Inside Corner Piece	6	8	50
Downspout	4	22	87
10' Section	15	10	141
5" End Cap	4	3	10
Mounting Brackets	146	0.98	143
Downspout Filter	4	8	32
TOTAL			***771***

Table 9: Project Component Costs [15]

Parameter (units)	Quantity	Cost/Unit ($)	Cost ($)
Gutter Components (LS)	1	771	771
CME3-7 Pump (LS)	1	2,000	2,000
Concrete Cistern (LS)	1	5,550	5,550
PEX Piping (LF)	110	0.45	50
PVC Piping (LF)	282	2	494
Pressure Tank (LS)	1	324	324
TOTAL			***9,188***

This analysis does **NOT include excavation and construction costs*

PROJECT STAFFING HOURS

Table 10: Proposed Cost of Engineering Services

Classification	Hours	Billing Rate, $/hr	Cost, ($)
SENG	13	170.00	2,210
ENG II	117	100.00	11,700
ENG I	265	65.00	17,225
GTECH	13	22.00	286
AA	45	30.00	1,350
TOTAL	***453***		***32,771***

Table 11: Actual Cost of Engineering Services

Classification	Hours	Billing Rate, $/hr	Cost, ($)
SENG	26	170.00	4,420
ENG II	105.5	100.00	10,550
ENG I	210.5	65.00	13,683
GTECH	20	22.00	440
AA	49.5	30.00	1,485
TOTAL	***411.5***		***30,578***

PROJECT IMPACTS

ENVIROMENTAL IMPACTS

- Mitigates stormwater runoff to treatment facilities
- Controls drainage
- Reduces soil erosion

ECONOMIC IMPACTS

- Lowers residential water utility cost

SOCIAL IMPACTS

- Educates consumers

REFERENCES

[1] “Kachina Village.” 35°06’37.55” N 111°42’27.60”W. Google Earth. 2016.
[2] *Source:* “Kachina Village and the City of Flagstaff.” Map. Google Maps. Google, 27 April 2016. Web 27 April 2016
[3] B. Hightower, Rainwater Harvesting Schematic, Flagstaff, 2016.
[4] Kiesow, Erica H. *REVIT*. Vers. 2017. N.p.: Autodesk, 2017. Computer software.
[5] "4-in X 120-in K Style Gutter." *Shop Amerimax 4-in X 120-in K Style Gutter at Lowes.com*. Lowe's, 2016. Web. 29 Nov. 2016.
[6] "Chromalox SRF-RG Roof & Gutter Heating Cable." *Chromalox SRF-RG Roof & Gutter Heating Cable*. Heaters Plus, 2015. Web. 29 Nov. 2016.
[7] Data, US Climate. "Climate Flagstaff - Arizona." *U.S. Climate Data*. World Climate, 2016. Web. 29 Nov. 2016.
[8] "Graf Basket Filter - Pedestrian." *Rainwater Collection and Stormwater Management*. Rainwater Harvest Systems, 2016. Web. 29 Nov. 2016.
[9] Hightower, Brett. *AutoCAD*. Vers. 2017. N.p.: Autodesk, 2017. Computer software.
[10] Jensen Precast. "Stormwater Interceptor." *Jensen Precast - Stormwater*. Jensen Precast, 2017. Web. 29 Nov. 2016.
[11] “Presure Tank Diagram.” Inspectapedia.com. N.p., n.d. Web. 26 Nov. 2016.
[12] “CME3-7 A-S-I-E-AVBE.” Grundfos.com. N.p., n.d. Web. 11 Sept. 2016.
[13] Chin, David A. *Water-resources Engineering*. 3rd ed. Upper Saddle River, NJ: Pearson Education, 2014. Print.
[14] “32 Gal Pressurized Well Tank.” HomeDepot.com. N.p., n.d. Web. 6 Oct. 2016.
[15] “Aluminum Gutter Fittings.” HomeDepot.com. N.p., n.d. Web. 4 Oct. 2016.

QUESTIONS

Acknowledgements:

Lar Reiboldt, Client, Capstone Instructor

Dr. Jeffrey Heiderscheidt, Technical Advisor