THE UNIVERSITY OF IOWA
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

Pocket Neighborhoods
Project Design & Management

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In partnership with
East Central Intergovernmental Association

ECIA

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Executive Summary
This report contains AJ & Grants' official written submission for the preliminary design of a pocket neighborhood in Preston, IA. . This report was submitted to the Instructors of the Senior Design Capstone Course in Civil and Environmental Engineering at The University of Iowa. The report has been promoted on behalf of the East Central Intergovernmental Association (ECIA) who has overseen the final design of the project.

In Preston, the 3.25 acre site is located on the southwest edge of town on the borderline between developed community and farmland. It is located just south of West St. Joseph Street. Work tasks included the design of a pocket neighborhood: a planned community consisting of small single-family homes (<1,000 sq. ft.), structures, foundations, roadways, edible landscaping, and on-site storm water management. The construction of the neighborhood will not be done on this site, but was chosen as a blueprint for other potential pocket neighborhoods. Thus, the following report will include design objectives of the neighborhood, preliminary designs, final design details, and a cost estimation for a typical pocket neighborhood project. The team utilized a variety of design manuals and modeling software such as *Revit*, *Civil 3D*, and *ArcGIS* to illustrate each aspect of the project.

Modifications to the preliminary designs are warranted to fit the needs and wants of the community. The site plan was chosen from a group of 3 alternatives and modified to fit the wants of the ECIA. The site design includes a house design, foundation of the houses, a one-way road around the site, drainage, and a detention basin. The house is constructed of No. 2 Douglas Fir and a typical exterior consists of 2x6 studs with 24" O.C. spacing and rest on top of a 2x6 treated sill board. The roof uses a truss system which is spaced 24" O.C. A shallow foundation with a spread footing is used. The base of the foundation is calculated to be 5 ft. wide and 2 ft. deep under all the exterior walls of the house. The road is an 18 ft. wide one-way street that has an 8-inch base and 4 inches of asphalt overlay that surrounds the site so residents can access their homes from the street. On street parking is available for all residents, providing an additional 27 parking spots.

The team evaluated the water quality volume runoff and for a duration of 6 and 24 hours, and a frequency of 2, 5, 10, 25, 50, and 100 years. The water quality volume was found to be 0.0186 acre-ft or 809.21 ft^3. The required diameter of the storm sewer pipes are 7.48 in., so standard 8-inch concrete piping is used. There will be two dry detention basins on the west end of the site including a safety bench. Each basin will have a length and width of 46.65 ft. and 26 ft., respectively.

All of these designs are necessary for the overall completion of a pocket neighborhood. The total estimated cost is $2,067,000. Each home costs $163,000, the site work costs $423,000, and the landscaping costs $9,000.

Contents

<u>Section I</u>: Project Overview

1. Introduction

AJ & Grants has designed a pocket neighborhood and written this report for the East Central Intergovernmental Association (ECIA) who is the client for the project. The purpose of the design of the pocket neighborhood is to provide a new type of community-driven affordable housing that aims to rejuvenate the connection between neighbors. The neighborhood was designed for a 3.25 acre site located in Preston, Iowa. The site is located on the southwest edge of town on the borderline between developed community and farmland. It is located just south of West St. Joseph Street shown below in Figure 1.

Figure 1. Site location in Preston, IA.

The complete construction of the neighborhood will not be done on this site, but was chosen as a blueprint for other potential pocket neighborhoods. Thus, the following sections will include design objectives of the neighborhood, preliminary designs, selection of the final design, final design details, and a cost estimation for a typical pocket neighborhood project.

2. Design Objectives

A pocket neighborhood is to be designed to provide a new type of community-driven affordable housing that aims to rejuvenate the connection between neighbors. In some instances, it is critical to conserve land while providing new residential development, and one way to do this is to have smaller houses all sharing one plot of land; this way families can still enjoy the privacy of their own home while sharing land with other neighbors. Therefore, work tasks for the team included the design of a pocket neighborhood: a planned community consisting of small single-family homes (<1,000 sq. ft.), structures, foundations, roadways, edible landscaping, and on-site storm water management.

3. Approaches

The team utilized a variety of modeling software such as *Revit*, *Civil 3D*, and *ArcGIS* to illustrate each aspect of the project. This includes storm water drainage, trails and sidewalks, a garden and grilling area, foundations, horizontal alignment, vertical alignment, cross-section, traffic flow, and the overall home design. Drainage calculations were completed in compliance with the Iowa Storm Water Management Manual. Each structure on site was designed according to the International Building Code and ASCE 7. Road design calculations were completed in compliance with the Iowa SUDAS (Statewide Urban Design and Specifications) and APAI (Asphalt Paving Association of Iowa) design manuals. A reference list can be found in Appendix A.

4. Constraints

This section will evaluate the constraints associated with this project. Constraints will be denoted as “hard” or “soft,” with hard constraints being mandatory and soft constraints will be adhered to wherever possible, but have flexibility. Hard constraints include cost, space available, time for completion, design building requirements, and adequate space for emergency vehicle access. The cost required to complete the pocket neighborhood may not be exceeded. Consequently, this placed a limit on available alternatives for the project as the budget may not allow for elements such as a full community building. The neighborhood is assumed to be built on 3.25 acres of land and this area may not be exceeded. This limits the number of houses and community features that were built on the site. It is also essential that emergency vehicles have proper access to the completed neighborhood. Therefore, the site designs have accounted for roads wide enough for a fire truck to pass through. Soft constraints include aesthetics and the project schedule. Aesthetics of the neighborhood are limited to cost. This includes things like green features, a larger garage, or a finished basement. The project schedule was also a soft constraint. The team has mapped out approximately how much time is needed to complete each task. However, if more or less time was needed, the team adjusted accordingly.

5. Challenges

A major challenge in implementing any affordable housing neighborhood is to get the surrounding communities to buy into the neighborhood. AJ & Grants believes this designed pocket neighborhood will increase the popularity of the area and should increase the property values around the area.

6. Societal Impacts

Building a pocket neighborhood will provide a welcome option for anyone seeking a tight-knit community. The common space in the center of the neighborhood, uninterrupted by cars or traffic, will give residents the opportunity for care, oversight, and enjoyment of a shared area. AJ & Grants is confident this will provide residents with a sense of safety and identity as they become acquainted with their neighbors. This project may also encourage more people to move into the expanding and surrounding neighborhoods, giving more growth to the chosen community.

<u>Section II</u>: Preliminary Development

The team additionally developed three feasible design alternatives:

Alternative #1

The first design alternative encompasses our most traditional approach to the pocket neighborhood design. As you enter the pocket neighborhood you are greeted by a large rain garden filled with wild flowers and other local flora. Wooden bridges will span either side providing access to the sidewalks. The closely spaced individual homes provide a strong sense of community while the open green space still allows ample room for family activities. Key design features will include the classic shotgun style as well as high windows in the bedrooms for maximum privacy. Each home will include a large front porch along with a small picket fenced-in front yard that ends at the sidewalk. This space will allow each home to have its own unique style suited to the homeowners and provide a variety of landscaping for all to enjoy.

A patio sits on the far side of the neighborhood. This common space will include a large seating area atop stone pavers and include raised walls surrounding the patio. The southern end will feature a small pavilion and grilling area to provide cooking facilities for frequent community gatherings. To the North of the patio lie several raised gardens in which to grow fruits and vegetables. This will be the perfect setting for a lesson in sustainability with the kids and to snag the freshest produce around. On the eastern most point in the neighborhood sits an area for guest parking so friends and family can join in the festivities.

This first design encompasses the perfect balance of privacy and community living. Every homeowner will bring a unique style to the space making this a truly special community. Whether you're sitting on the front porch watching the kids play or enjoying time with friends by the grill, the neighborhood will feel like home. Included below are several concept images for the raised gardens, rain garden bridges, and patio respectively.

Figure 2. Possible rain garden design.

Figure 3. Possible bridge design.

Figure 4. Possible patio design.

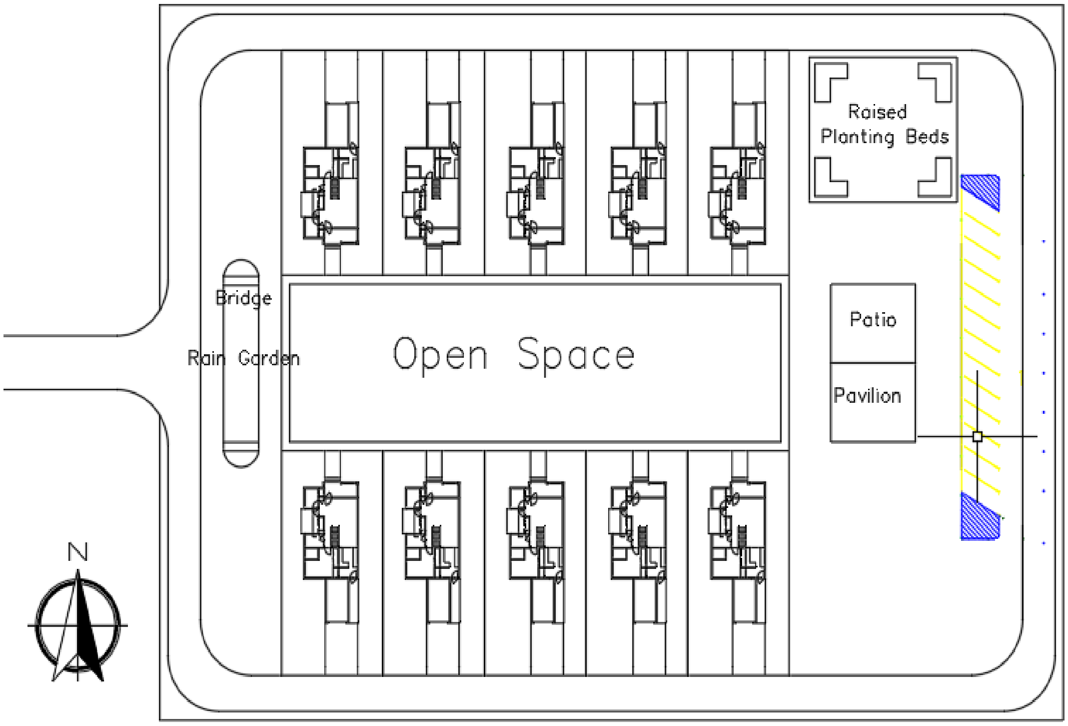


Figure 5. Preston site design alternative #1.

<u>Alternative #2</u>

The second design alternative brings duplex housing into the neighborhood. The duplex has the same floor layout as the single family house so residents won't have to compromise for any less space. This site design has three duplex houses and four single family houses keeping the total number of dwellings at a consistent ten.

This site design creates a copious amount green space throughout the neighborhood, giving it a natural feel. A sidewalk down the center of the site creates easy access from the street on the west side. As you stroll through the neighborhood, you can drift onto the winding path to enjoy a nature walk; seeing and smelling all the beautiful gardens, plants, and yard games like horseshoe. This path strategically leaves the site at the northeast side in anticipation of a connecting sidewalk to the high school. On the far east side of the map there is a gazebo. This is different than the pavilion in Alternative #1, this gazebo has the capability to be enclosed, which could be used to keep insects out. A shared community shed is hidden behind the gazebo for neighbors to keep tools like lawn mowers, shovels, rakes, etc.

This alternative does not include a parking lot, it only has on-street parking. In doing this, no extra space is needed on the roads because the road will be a one-way going counter-clockwise. This also frees up more open/green space for future use or to leave and let the kids play there. Included below are a few concept images for a gazebo and the site design, respectively.

Figure 6. Possible gazebo design.

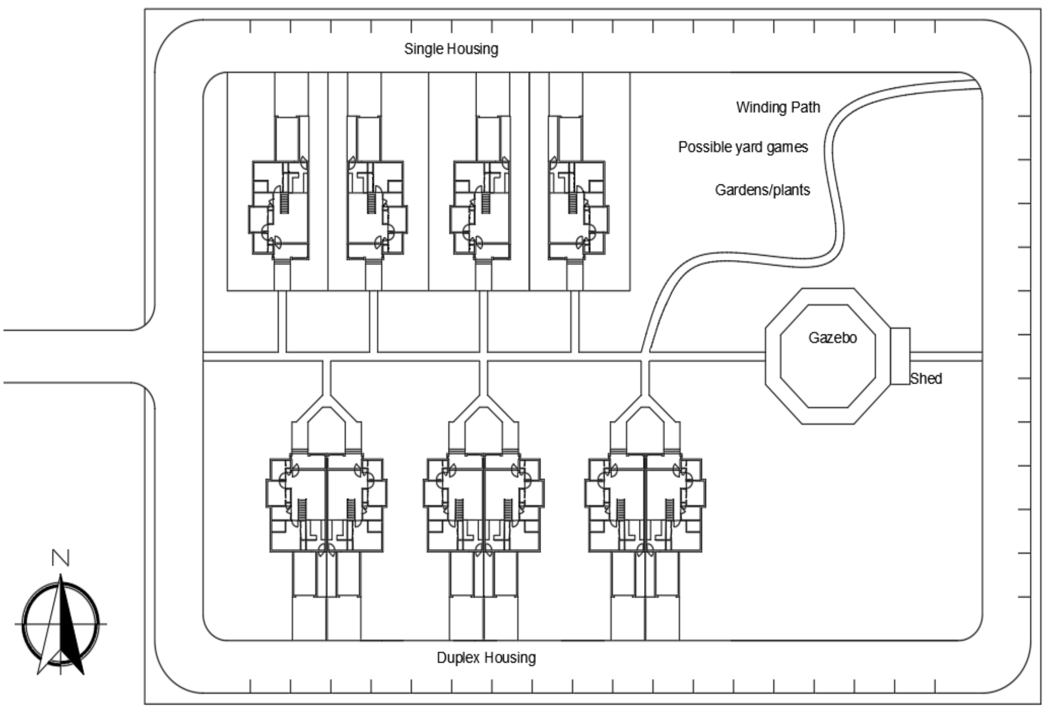


Figure 7. Preston site design alternative #2.

<u>Alternative #3</u>

The third design alternative has the same housing layout as alternative #1, but the rain garden is located in the center of the green space. The rain garden allows rainwater runoff from roofs, concrete surfaces, and lawn areas the opportunity to be absorbed directly into the ground because it is a depression that acts as a pool for water to collect. The rain garden also will be a beautiful focal point for the residences of the pocket neighborhood to look at while on their porch or walking around the community.

The sidewalk around the rain garden would be a perfect spot to put benches for seating. There are sidewalks connecting each house to the main sidewalk that runs through the middle. These allow easy access to other houses in the community during winter months when there is snow on the ground. On the east side of the neighborhood, there is a paved patio area for gatherings and will have the capability to have grilling equipment and seating for cookouts. Just north of the patio is a greenhouse that allows community members to grow their own plants and have fresh produce even during cold months. Attached to the greenhouse is a shed that can store lawnmowers, tools, snow removal equipment, etc. Just south of the patio is an open green space for kids to play in. Similar to Alternative #2, this alternative does not include a parking lot, but has extra parking spots on the one-way road that travels around the houses. Included below are a few concept images for a rain garden and the site design, respectively.

Figure 8. Typical rain garden design.

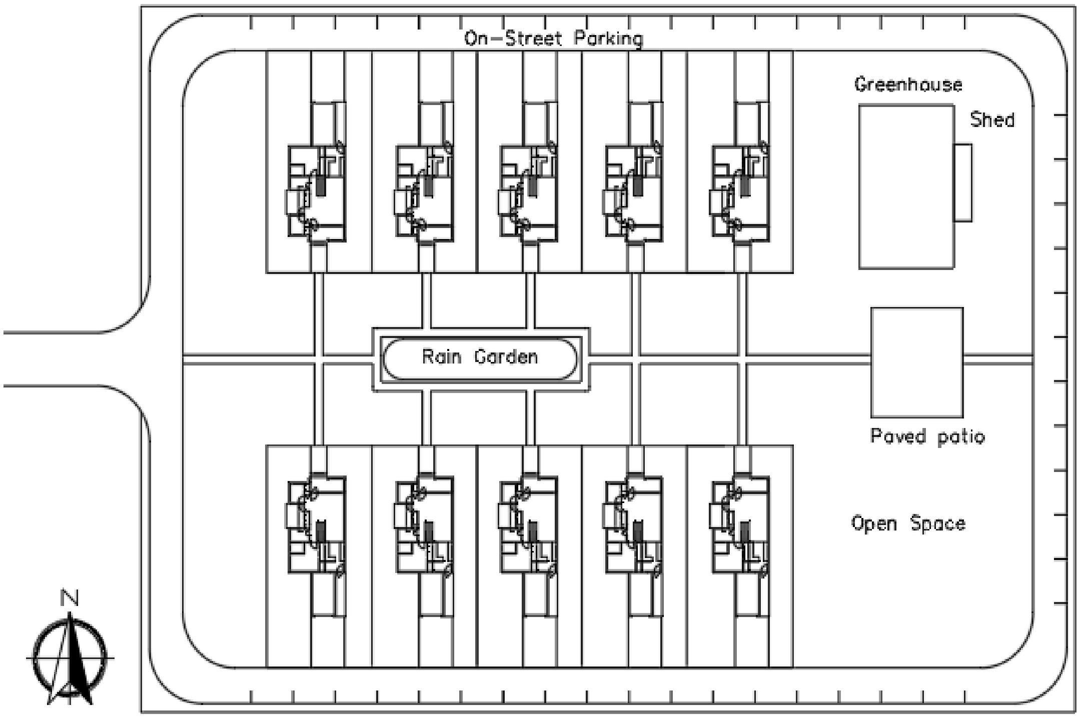


Figure 9. Preston site design alternative #3.

Below in Figure 10, the basic design for the floor layout is shown. This home includes a single car garage with the ability to be a two car garage. The main floor has a kitchen, family room, bathroom, two large bedrooms, and a smaller room as a possible office or third bedroom. At the front of the house there is a porch, which is great to view the entire pocket neighborhood from and connect with others as you enjoy the scenery. Lastly, the house will have a basement that can be designed for residents as they please. All the houses in the above alternatives have this layout including the duplexes. Additional figures below depict the exterior of the homes.

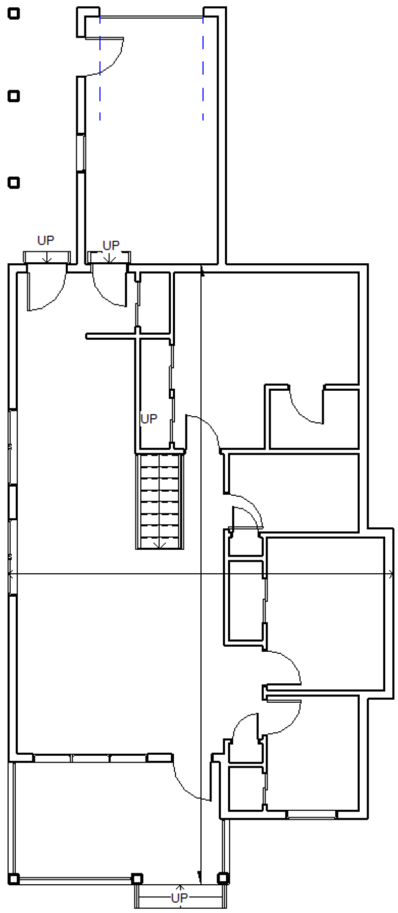


Figure 10. Basic floor layout design.

Figure 11. Elevation view of the front side of a home design.

Figure 12. Elevation view of the back side of the home design.

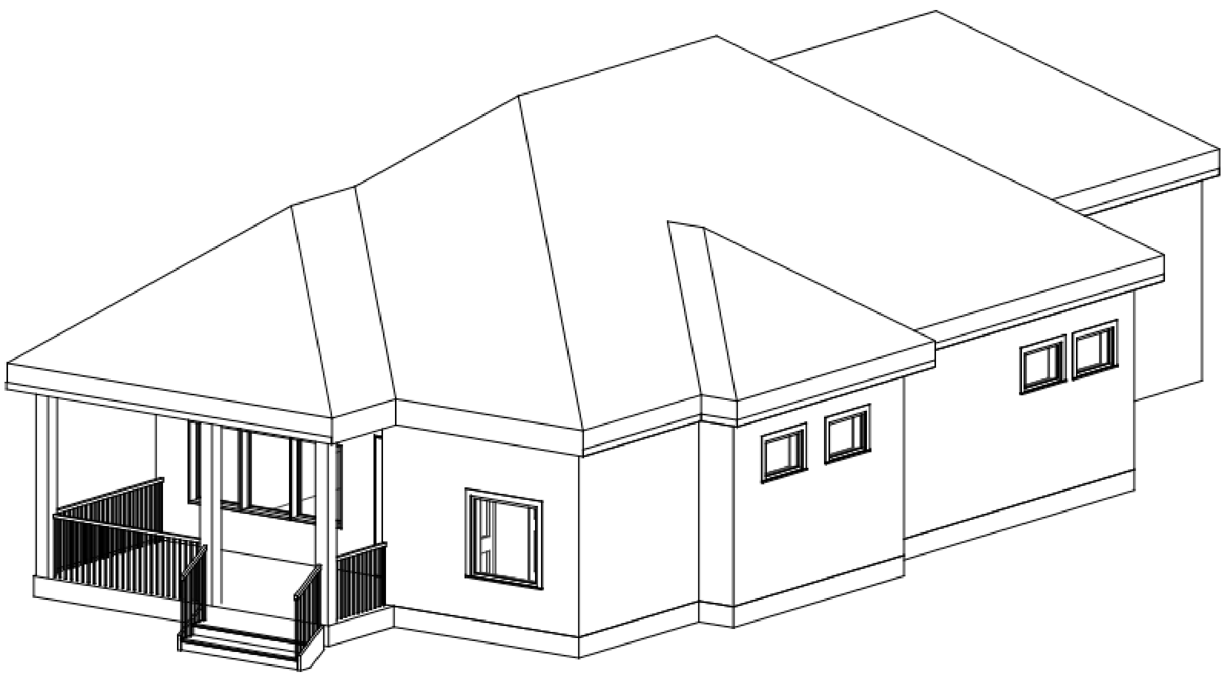


Figure 13. 3D rendering of the home design.

Section III: Design Selection and Modification Process

The selections process was a combination of planning meetings and weekly phone calls between the team, the proposed clients in Preston and the ECIA. The initial planning meeting took place at Preston city hall with several stakeholders and ECIA project managers. From this meeting alternatives 1, 2 and 3 were developed. The revision period was a collaborative effort, balancing the needs of the clientele with designs that could be integrated in a variety of locations.

The primary proposal was issued for review on February 3, 2017. Weekly planning meetings were established to review the proposal and assess what features were most desirable. Conference calls were held individually, both with the clients and with the overseeing planning organization. After several weeks of collaboration we narrowed the design to alternative #1.

Using specific site features and other consulting from local Preston stakeholders the plan was essentially finalized for design. A rain garden was added at the East end of the property along with a bridge walkway. The open space was kept with sidewalks in front of the homes; however no fences on the individual properties were included. The initial proposed space for rain gardens on the west end of the site was converted to detention basins to accommodate storm water.

Section IV: Final Design

Using the three preliminary alternatives and the input received from the ECIA and Preston City Council members, the final site layout is designed as shown in Figure 14 below.

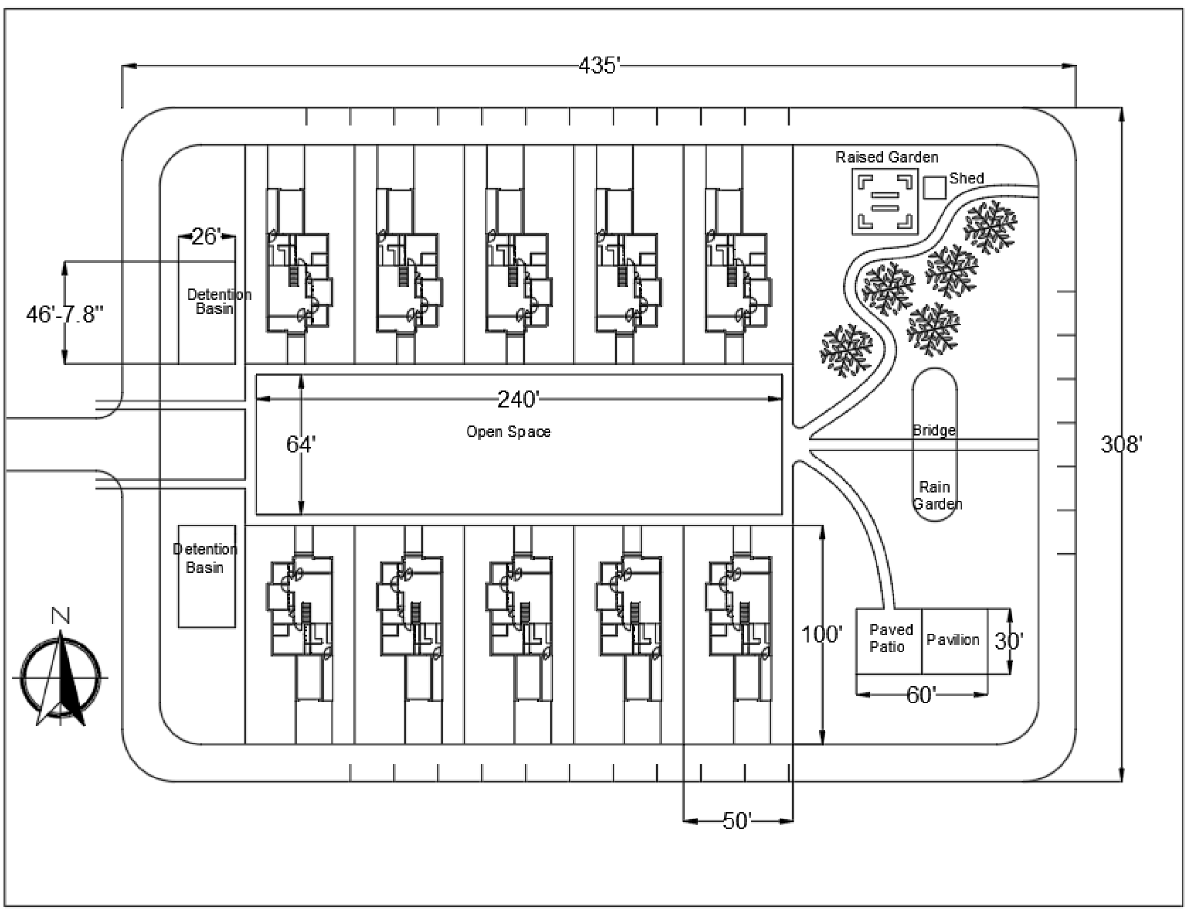


Figure 14. Final design site layout

The site maximizes the open green space in the middle, where community members can join to chat and play. There are 10 houses that have each have 0.11 acres of land where a typical plot of land in a neighborhood would be about 0.25 acres. The west side of the site has two dry detention basins that can hold a 25-year 24 hour storm. On the east side of the open space, three features offer additional community oriented activities. The northeast area of the site has the raised gardens where members can plant fresh fruit and vegetables. East of the garden is a large shed intended to give community members extra storage for extra tools. The winding path is designed to give community members a pleasant stroll through trees, bushes, and flowers that leads to the high school. A rain garden acts as another on site storm water management tool and will alleviate potential flooding during intense rainfall. The southeast side of the site has a paved patio and pavilion combination where residents can cookout, enjoy a bonfire, or take shade from the sun.

1. On-site Storm Water Management

All drainage calculations were made in compliance with the Iowa Storm Water Management Manual and based off of the site characteristics in Preston. The storm water design will satisfy the water quantity and water quality requirements for the site.

Runoff Calculations and Water Quality Volume

Based on the sizes of the residential, paved, and park areas of the site, pre- and post-development discharge quantities were calculated using the rational method. Data for intensity, duration, and frequency of storms was pulled from the Iowa Storm Water Management Manual for 2016. The team evaluated the runoff for a duration of 6 and 24 hours, and a frequency of 2, 5, 10, 25, 50, and 100 years. The site's water quality volume was then calculated, which is the first 1.25 inches of storm water runoff required to be collected and treated to remove the majority of storm water pollutants. The water quality volume was found to be 0.0186 acre-ft or 809.21 ft^3. Detailed calculations can be found in Appendix B.

Storm Sewers

The storm drains were designed to collect water from the roadways and run primarily east to west along the street. The natural slope of the site will be implemented here to run the water down to the detention basin on the west end of the site. The slope was found to be 3.77% from an elevation map that can be found in Appendix C. The pipes on the east end of the site running north to south will slope down and outward from the manhole to be collected by the pipes running the length of the site. The required diameter of the pipes was found to be 7.48 in using the rational method. Thus, standard 8-inch piping will be used. Detailed calculations can be found in Appendix D. Figure 15 below depicts the storm sewer pipe lines, manholes, and direction of flow.

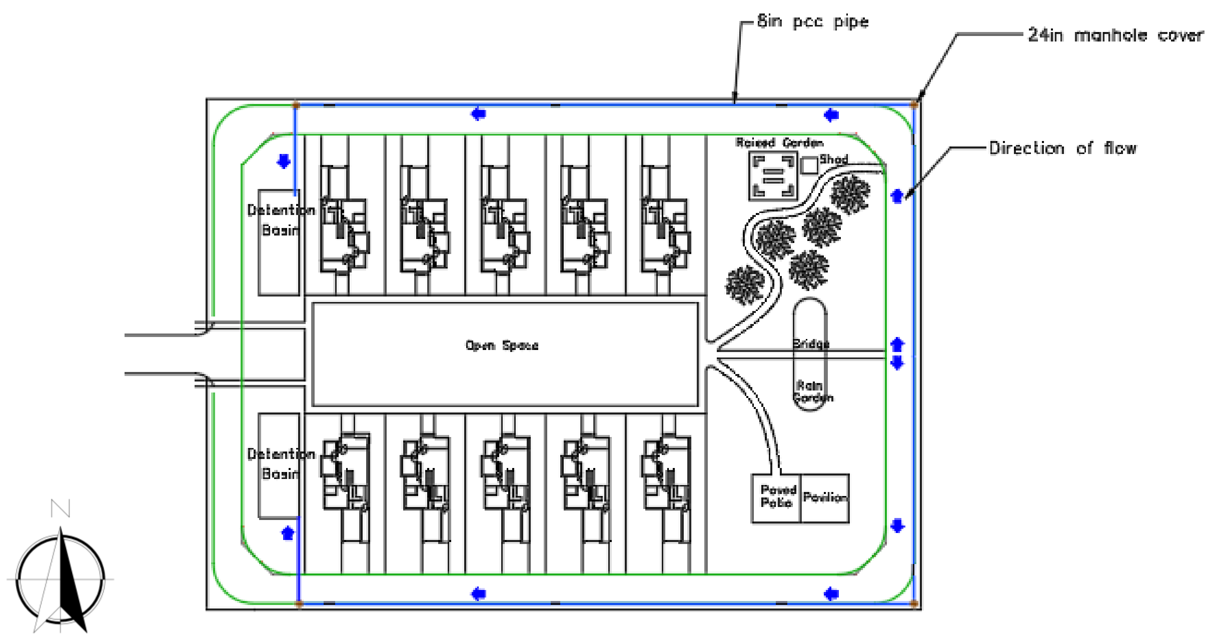


Figure 15. Storm sewer pipe lines

Detention Basin

The team designed two dry detention basins, as dry basins are typically a cheaper alternative and require less maintenance than a wet detention basin. The team considered designing a wet detention basin or an extended dry detention basin, however, the Iowa Storm Water Management Manual does not recommend designing either of those for a site under 10 acres. This is because smaller flow rates that come with sites of smaller areas are prone to more clogging of the basin's outlet structure.

The two basins are located at the west end of the site and is designed for both water quality control and flood control. The required flood control volume was evaluated based on the peak discharge of the 25 year, 24 hour storm event of the pre and post-developed site. It was found to be 0.00856 acre-ft or 373 ft^3. The water quality volume of 809.21 ft^3 was increased by 20% to account for sediment accumulation, giving a final required volume of 970.21 ft^3. The average depth of the detention basin was designed to be 2 ft. As all wet ponds are a drowning hazard, a 6-inch depth and 5 ft wide safety bench was included. Vegetation may be planted here, which will act as a deterrent from entering the pond. The final design has a length and width of 46.65 ft and 26 ft, respectively. A schematic of each basin and a cross section are shown below in Figure 16. Detailed calculations can be found in Appendix E.

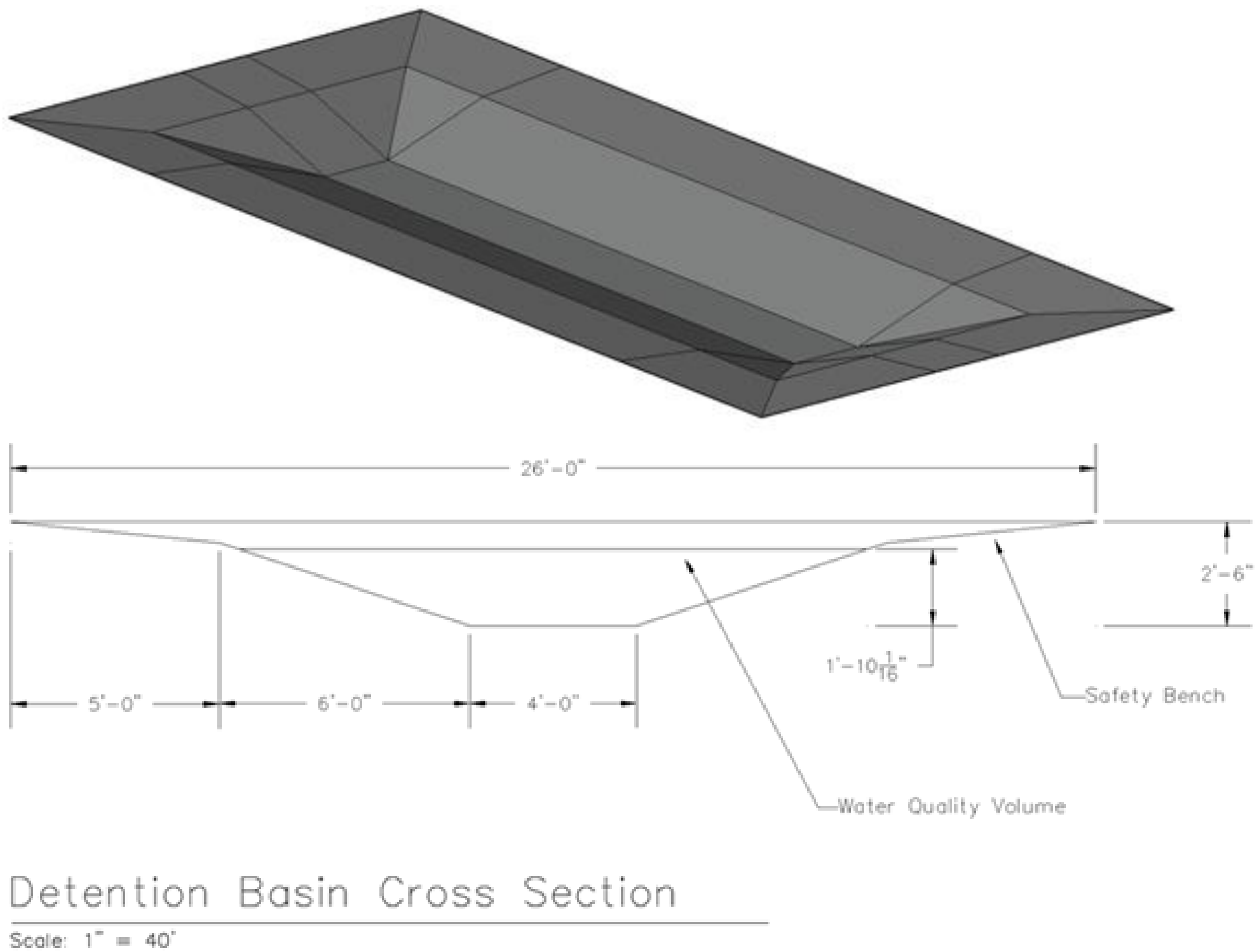


Figure 16. A schematic and cross section of each basin

2. Road Design

Cross Section

Below in Figure 17 is the cross section of the one-way road that wraps itself around the pocket neighborhood. When designing the road thickness, APAI Design Manual was used. This road is considered to be a Class II road, which is typical of residential roads in Iowa. According the table 4-1.B, the road requires an 8 in aggregate base and 4 inches of asphalt overlay. AASHTO's standard 6 inch curb will be used on the outside of the road.The width of the road is 18 ft wide. This was determined using the Iowa SUDAS manual 5C-1.02. A typical length width for a residential is 10 ft and on street parking requires another 7.5 ft, summing to 17.5 ft. A half-foot buffer is added to give 18 ft for the total width of the one way road. The slope from the inside of the road to the outside is -2.00%. This aids in moving rain off the road and into the storm sewer system.

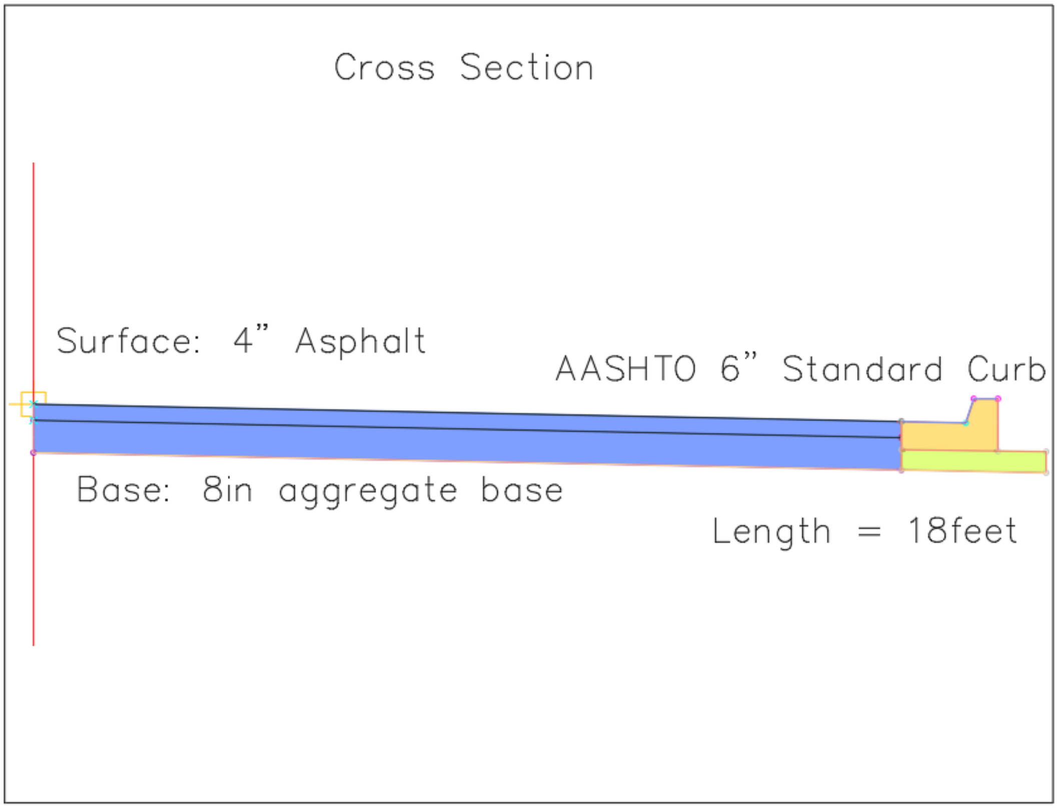


Figure 17. Road cross section

Horizontal Alignment

Below is a picture of our horizontal alignment of the site's road. The first station of the road is located in the northwest corner of the site, just south of the turn. The last station is located just north of Station 0+00 because the stations move counterclockwise around the site. The road can be seen on this picture in pink. In order to make sure a fire truck or other emergency vehicles could get around the site, AutoCad's vehicle tracking technology was utilized to place a large school bus on the road and it traced its path on the site in red. Notice that the red lines are the vehicle's wheels, which stay on the road at all times, including when it makes the turns in the corners. It also leaves room for on-street parking for cars. A school bus was used as the design vehicle to accommodate for all large vehicles like fire trucks and garbage trucks.

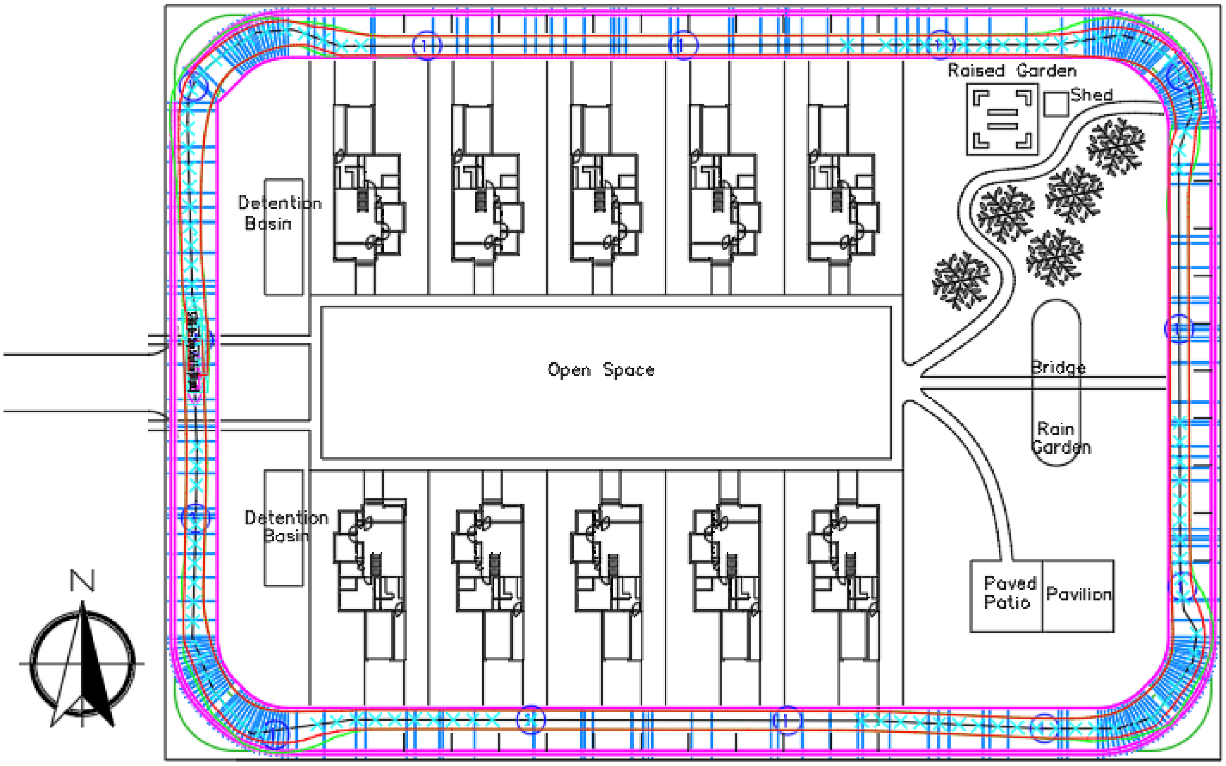


Figure 18. Horizontal Alignment of the site

Vertical Alignment

Below is a picture of the vertical alignment of the road. The red line on the graph shows the existing ground elevation for our site. The blue line on the graph represents the selected vertical alignment. It is important that the first station and the last station have the same elevation because that is where the road will meet. The peak in the graph represents the far east side of the site where the elevation is about 13 feet higher than the west side. The maximum slope on the road is -3.09 % which gives the driver a smooth path. Another reason for this vertical alignment is to keep as much as the existing elevation as possible. A total cut of 509.57 yd^3 will be needed and 2169.61 $yd^3$of fill material, leaving only 1660 yd^3 of material to fill the rest of the land.

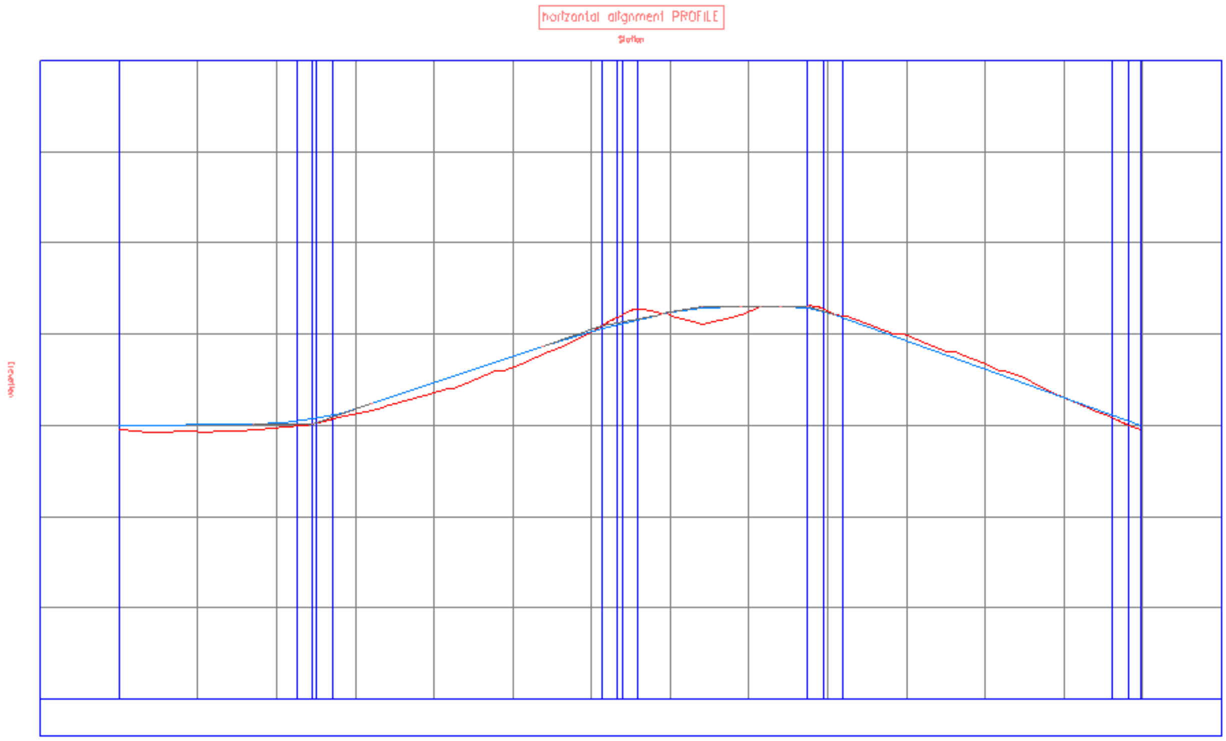


Figure 19. Vertical alignment of the site

3. Home Design

All residential structure designs were completed in accordance with Jackson County, Iowa code. Preliminary design calculations referenced ASCE 7-10, Minimum Design Loads for Buildings and Other Structures, for the site specific loading on location in Preston. Based on the minimum design values, the structure was split into four categories. These included the foundation, floor system, wall system, and roof system. The designs introduced in the following subsection meet the safety standards described by Jackson County and Iowa State code. The house design is shown in Figure 20 below.

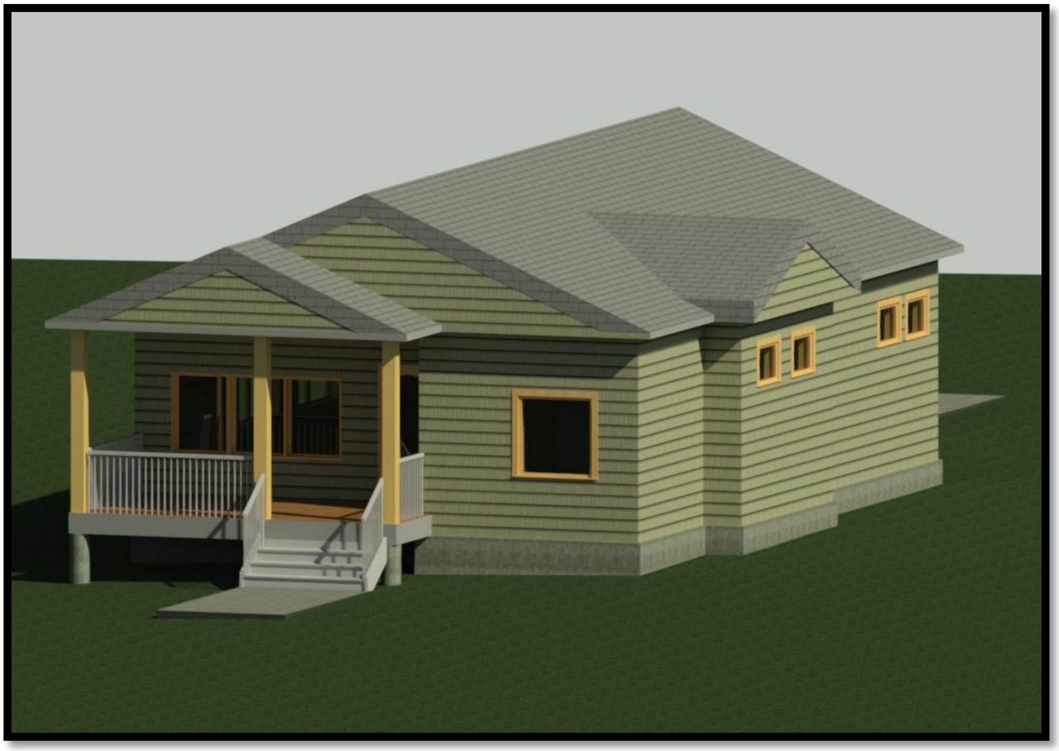


Figure 20. House design

Subgrade

The entirety of the subgrade structure is concrete foundation. All calculations utilized the *Principles of Foundation Engineering* textbook by B.M. Das. The basement is 8 ft deep with a 6 in concrete slab sitting on top of a shallow foundation that has a spread footing under each of the exterior walls of the house. The base of the foundation is 3 ft wide and 1 ft deep.

Above Grade

The entirety of the above grade structure is wood frame construction. All calculations utilize ASD load combinations, typical of wood frame members. All wood members are designed No. 2 Douglas Fir unless otherwise specified.

Below in Figure 21 is the floor plan layout for the residential homes. Floor system design began with an assumption of the occupancy requirements. The structure is intended to function as a single family, residential home. Based on these characteristics a live load of 40 PSF was selected. From there, preliminary materials for floor covering, insulation, and mechanical equipment are selected to determine the dead load by performing a gravity load take down. Only dead (gravity) and live loads act on the floor system. Based on the loading, the joists, beams and columns can all be sized. This process is completed by using tributary width analysis and spacing the joists. Based on calculated loads, TJI Joists by Weyerhaeuser, type TJI 210 were selected. Using the same analysis model, built up wooden beams were selected to carry the joist loading. Beams are configured to span between bearing walls running in the East - West orientation. Concrete core, steel columns are placed at the center of beam spans to transfer the remainder of the loading into the foundation. Use supplier Dean Column Co. Inc, 4" Column, 11 Guage, 8'-0" Section or comparable specification selected by contractor.

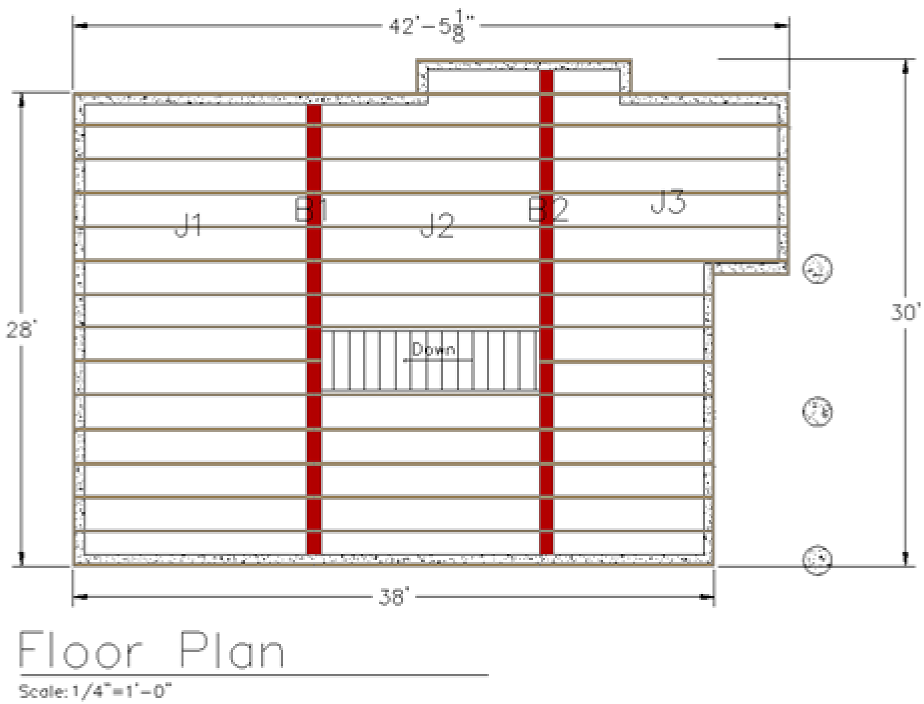


Figure 21. Residential home floor plan

The wall system must support dead and live load of the roof, snow load and lateral wind loading. Forces generated by earthquakes can be neglected based on ASCE risk category figures. The wall system acts as the lateral force resisting system against all wind loading. The finished space of the home totals 1042 square feet with a slender “shotgun” design. This allows placement of load bearing walls only on the exterior of the building. A typical exterior wall consists of a 2x6 stud wall, 24” O.C., attached atop a 2x6 treated sill board. Exterior walls are filled with batt insulation and receive an outside cover of ZIP plywood sheathing to act as a water barrier. The exterior of the homes are vinyl siding to simplify construction, maintenance and repair. A variety of colors can be selected based on client's specification. Headers for windows and doors are typical construction type with detailed dimensioning on bid documentation. A typical cross section of the exterior walls can be seen in Figure 22.

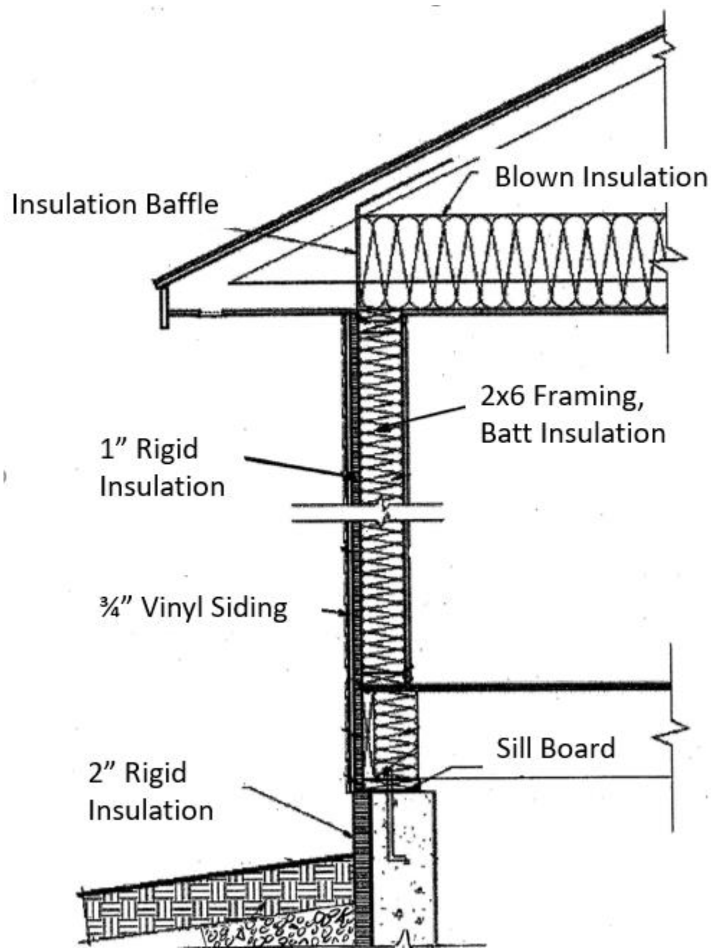


Figure 22. Bearing wall design

The roof system is designed to act as a water barrier and withstand wind, snow and live loads and is shown in Figure 23 below. Typical roof truss design is used to ease construction and provide support for the necessary span. Three different designs are detailed in the bid documentation for construction at discretion of the contractor or owner. The truss framing is uniform throughout each of the designs with 24" O.C. spacing. Panels are again ZIP plywood sheathing for added water protection and batt insulation is added between trusses. The roof finish is common shingles with several color options. Detailed calculations for the floor design, trusses, and wind loadings can be found in Appendix F, G, and H, respectively.

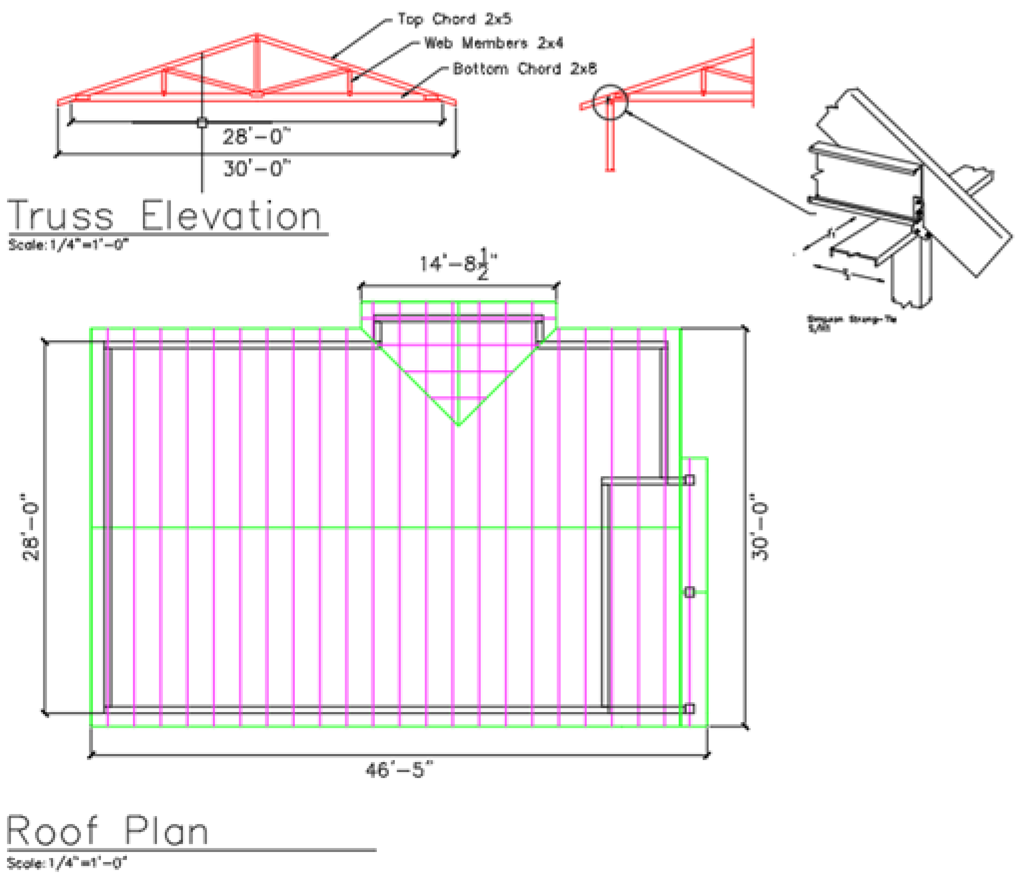


Figure 23. Roof design

<u>Section V</u>: Design Services Cost Proposal

1. Implementation: Work Plan

This section outlines AJ & Grants estimated construction schedule for the project. Each task and duration is outlined in Figure 24 below.

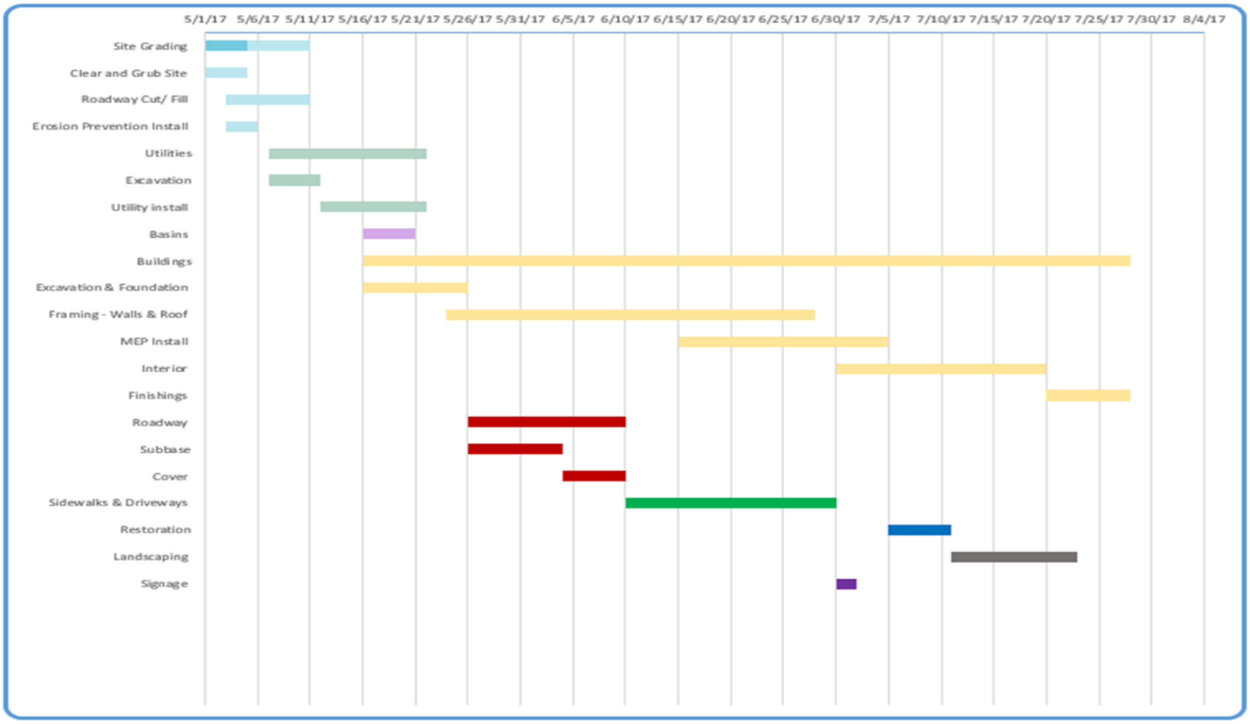


Figure 24. Gantt chart illustrating the estimated construction schedule.

2. Cost Analysis

This section provides a cost estimate of construction services to be provided by a contactor specified by the client. Table 1 estimates cost based on materials, labor and equipment cost broken down by category. The categories are defined based on construction phase and type. This estimate is for client informational purposes and does not reflect any actual bid cost or timeline. These estimates are to be used for client reference only in any future phases of the project.

Table 1. Total cost estimate for the project based work phase and type.

House Estimate Average				
Subtotal Direct Building Costs	Materials	Labor	Equipment	Total
Estimate 1	63756	72441	5321	141518
Estimate 2	79371	66716	2730	148817
Estimate 3	77061	47189	1566	125816
Average	73396	62115	3206	138717
Subtotal Indirect Building Costs	Materials	Labor	Equipment	Total
Estimate 1	9326	1090	0	10416
Estimate 2	8364	743	0	9107
Estimate 3	9478	567	0	10045
Average	9056	800	0	9856
Contractor Markup (10%)	14857			14857
House Average Total Costs	$97,309.30	$62,915.33	$3,205.67	$163,430.30

Site Work Estimate	$423,302.18
Landscape & Finishing Estimate	$9,018.30
Project Estimated Grand Total	$2,066,623.48
Cost/ Home	$206,662.35

Section VI: Conclusions

This final design report includes the official written summary for the design of a pocket neighborhood. The city of Preston, IA was used as a sample site location for the neighborhood. However, the overall design has the capability to be used in many different site locations with some slight modifications to account for the drainage, road, and specific characteristics of each location. The purpose of a pocket neighborhood is to bring together community members by switching around the flow of a typical neighborhood. Therefore, there are ten houses on site that face inward towards a common open green space that allows for more interaction between neighborhood members. The team created three design alternatives that each had different aspects to fit the needs of the community. One final design of the site was then chosen that includes two detention basins, raised gardens, and a paved patio area. AJ & Grants believes that this site design can be implemented into any city and positively change the way neighborhoods are designed.

Section VII: Proposal Attachments

Appendix A – References

American Wood Council

- Manual
- National Design Specifications
- Span Tables for joists and rafters

APA

- Panel Design Specification
- Load span tables

ASCE 7-10

- Minimum Design Loads for Buildings and Other Structures

TJI

- Truss joist load tables

Iowa Storm Water Management Manual

- IDF data for Jackson County, Iowa
- Sizing storm drains and detention basin

Principles of Foundation Engineering 8th Ed, B.M. Das

Water Resources Engineering 3rd Ed, David A. Chin

Appendix B – Runoff Calculations and Water Quality Volume

Pre-development:

Cover Type	Cover Area (ft2)	Cover Area (acres)	% Coverage	C Value
Pre-development	141570	3.25	100.00	0.35

Flow Calculations	*Rational Method,* Q=CiA (ft3/sec)	Duration (hours)	Frequency (years)	I, intensity (in/hr)	Total Rainfall (in)	Runoff (acre-ft)
Pre-development	0.44	6	2	0.38	2.30	0.002
	0.55	6	5	0.48	2.89	0.002
	0.66	6	10	0.58	3.45	0.002
	0.82	6	25	0.72	4.30	0.003
	0.96	6	50	0.84	5.02	0.004
	1.11	6	100	0.97	5.80	0.004
	0.14	24	2	0.13	3.01	0.001
	0.18	24	5	0.16	3.75	0.001
	0.21	24	10	0.18	4.42	0.001
	0.26	24	25	0.23	5.44	0.001
	0.30	24	50	0.26	6.29	0.001
	0.35	24	100	0.30	7.22	0.001

Post-development:

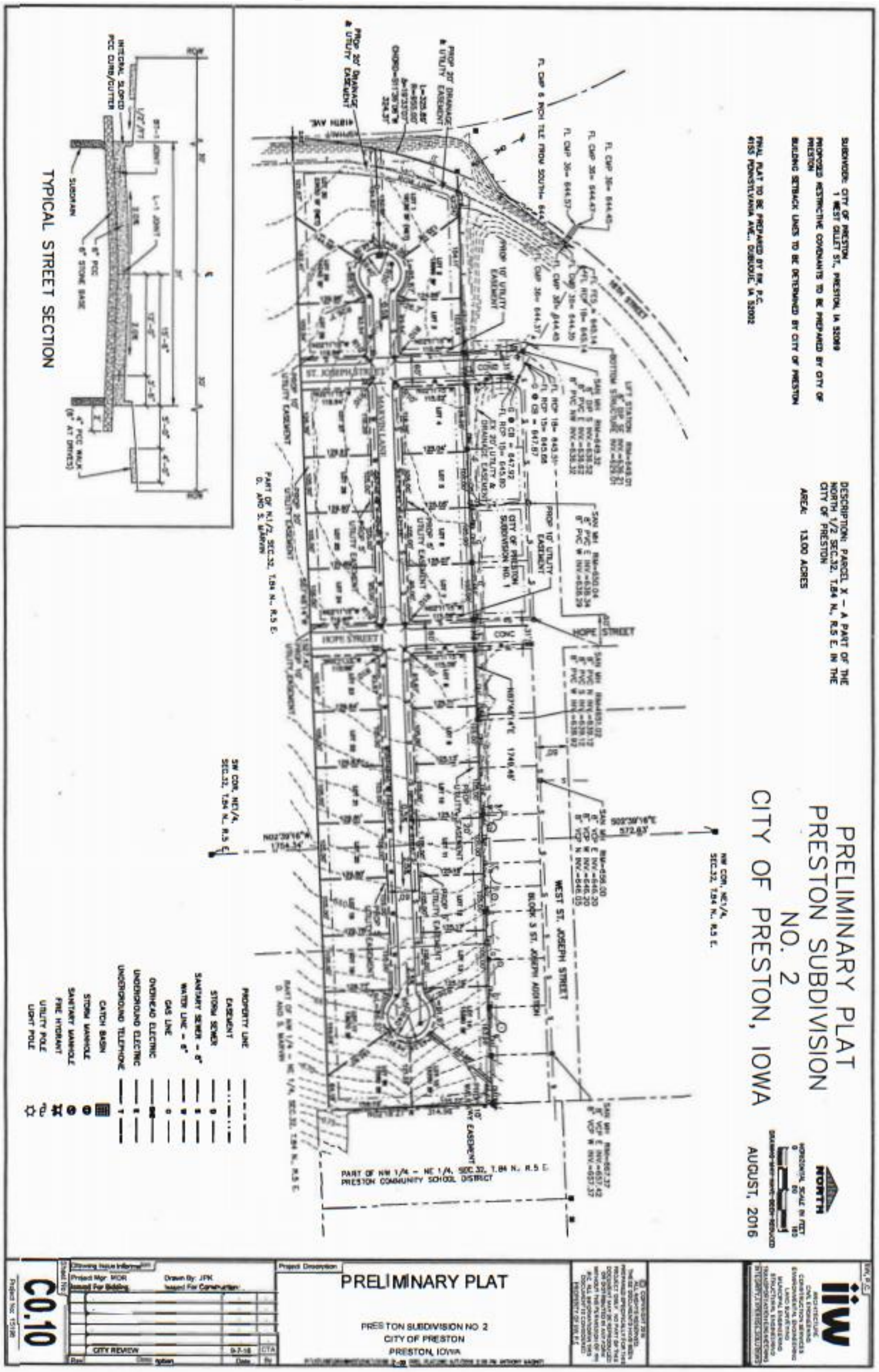
Cover Type	Cover Area (ft2)	Cover Area (acres)	% Coverage	C Value
Residential	38114	0.87	26.92	0.75
Driveways/Streets	12600	0.29	8.90	0.95
Lawns/Parks	90856	2.09	64.18	0.35
Total Area:	**141570**	**3.25**		

Flow Calculations	*Rational Method,* Q=CiA (ft3/sec)	Duration (hours)	Frequency (years)	I, intensity (in/hr)	Total Rainfall (in)	Rv	Runoff (acre-ft)
Residential	0.25	6	2	0.38	2.30	0.052	0.010
	0.32	6	5	0.48	2.89		0.013
	0.38	6	10	0.58	3.45		0.015
	0.47	6	25	0.72	4.30		0.019
	0.55	6	50	0.84	5.02		0.022
	0.64	6	100	0.97	5.80		0.025
	0.08	24	2	0.13	3.01		0.013
	0.10	24	5	0.16	3.75		0.016
	0.12	24	10	0.18	4.42		0.019
	0.15	24	25	0.23	5.44		0.024
	0.17	24	50	0.26	6.29		0.027
	0.20	24	100	0.30	7.22		0.031
Driveways/ Streets	0.11	6	2	0.38	2.30	0.056	0.0054
	0.13	6	5	0.48	2.89		0.0067
	0.16	6	10	0.58	3.45		0.0081
	0.20	6	25	0.72	4.30		0.0100
	0.23	6	50	0.84	5.02		0.0117
	0.27	6	100	0.97	5.80		0.0135
	0.03	24	2	0.13	3.01		0.0070
	0.04	24	5	0.16	3.75		0.0088
	0.05	24	10	0.18	4.42		0.0103
	0.06	24	25	0.23	5.44		0.0127
	0.07	24	50	0.26	6.29		0.0147
	0.08	24	100	0.30	7.22		0.0168
Lawns/Parks	0.28	6	2	0.38	2.30	0.056	0.019
	0.35	6	5	0.48	2.89		0.024
	0.42	6	10	0.58	3.45		0.028
	0.53	6	25	0.72	4.30		0.035
	0.62	6	50	0.84	5.02		0.041
	0.71	6	100	0.97	5.80		0.047
	0.09	24	2	0.13	3.01		0.025
	0.12	24	5	0.16	3.75		0.031
	0.14	24	10	0.18	4.42		0.036
	0.17	24	25	0.23	5.44		0.044
	0.19	24	50	0.26	6.29		0.051
	0.22	24	100	0.30	7.22		0.059

Water quality volume:

Cover Type	WQv (acre-ft)	WQv (ft3)
Residential	0.0048	208.13
Driveways/Streets	0.0017	73.21
Lawns/Parks	0.0121	527.87
Total:	**0.0186**	**809.21**

Appendix C – Elevation Map



Appendix D – Storm Sewer Calculations

Raw data summary is as follows:

Surface	C	L (ft)	L (m)	n	So	Area (acre)	Area (m2)
PER	0.2	748	228	0.2	0.0377	2.09	8458
IMP	0.9	1076	328	0.1	0.0377	1.16	4694

t_c and i_c were calculated using Wolfram Alpha and the following equations:

$$ic = C * (\frac{8000}{tc + 40})$$

$$tc = \left(\frac{6.99}{ie^{\frac{2}{5}}}\right) * \left(\frac{nL}{sqrt(So)}\right)^{3/5}$$

The results are summarized as follows:

Surface	tc (min)	ic (mm/hr)	ic (m/s)	C	Q=CiA (m3/s)	D (m)	D (in)
PER	3.36	36.9	1.03E-05	0.25	2.17E-02	0.19	7.48
IMP	0.57	177.46	4.93E-05	0.25	**5.78E-02**		

The weighted runoff coefficient is the sum of runoff coefficients multiplied by the section's area, divided by the total area:

$$\frac{.2(.36 * 8458) + .9(.64 * 4694)}{8458 + 4694} = 0.25$$

The impervious surface flow rate was found to be the limiting factor, so the flow rate of 0.057 m^3/s was used to calculate the required pipe diameter.

D was calculated using the following equation:

$$D = \left(\frac{3.21Qn}{sqrt(So)}\right)^{3/8}$$

Where Manning's coefficient *n* was assumed to be 0.013.

Appendix E – Detention Basin Calculations

Flood control: Designing for 25 year, 24 hour storm event

Time of concentration, T_c:

$$Tc = \left(\frac{0.007(nL)^{0.8}}{(Tr)^{0.5}(S)^{0.4}}\right)$$

where: Manning's coefficient *n* was assumed to be 0.013
L = 374 ft
Tr = Total rainfall of 25 year, 24 hour storm event = 5.44 in
S = 3.77%

$$Tc = 0.863\ hr$$

Required Volume, V:

$$V = 0.08264Tc * (Qa - Qb)$$

where: Qa = Flow rate post-development = 0.38 ft^3

Qb = Flow rate pre-development = 0.26 ft^3

$$V = 0.00856\ acre - ft = 373\ ft3$$

Accounting for 20% above WQv of 809.21 ft^3 for sediment accumulation, the required holding volume is 970.21 ft^3 plus the flood control volume for a **total volume of 1343 ft^3**. As there are two detention basins on site, each one will be designed to hold half of that volume, or 671.5 ft^3.

Preliminary design:

The team chose an average depth for the basins of 2 ft. This was chosen based on the area available on the Preston site for the detention basins. The side slopes of the basins will be 3:1, adding a length and width of 6 ft on each side of the basin. The very bottom of the basin will be 4ft in width, plus an extra 10 feet for a safety bench of 5 ft on each side. The length will be 46.65 ft, also with the safety bench included. These dimensions were also chosen based on the area available on the Preston site for the detention basins. This gives a length to width ratio of about 2:1.

Safety bench:

The safety bench will be 5 ft wide and 6 inches deep.

Appendix F – Floor Design Calculations

Floor System Load

		Dead Load (psf)
Floor Finish:		
general (hardwood flooring)		4
bathroom (Linoleum or asphalt tile, 1/4in.)		1
3/4" OSB		2.5
6.25" fiberglass batt insulation	6.25 * 0.04 =	0.25
*Structural Framing (I Joist 16" O.C.)		2.8 PLF
MEP		4
Gypsum Board	4 * 0.55 =	2.2
	Total:	

*use larger floor finish value for design calculation

Live Load: Assume 40 psf

Panel Loading:
D = 4 PSF
L = 40 PSF

Panel Design

APA Panel Design Specification Table 2B
OSB Structural 1 Sheathing
40/20 Span Rating Spec.

L/360 = 98 PSF ≥ 80 PSF	Live Loading
L/240 = 146 PSF ≥ 84 PSF	Total Loading
Bending = 156 PSF ≥ 84 PSF	Total Loading
Shear = 182 PSF ≥ 84 PSF	Total Loading

Design Thickness = 3/4"
Suited for 24" O.C. Joist Spacing

Joist Design

Constriants:

- Spaced 24" O.C. $TA := 2$

Joist Loading
D= 13 PSF
L = 40 PSF

Layout:

J1: $JL1 := 13\ ft - 7.125\ in$

J2: $JL2 := 13\ ft - 4\ in$

J3: Design for worst case
$JL3 := 14\ ft - 2\ in$

Total Load:

$D := 13$
$L := 40$

$w_D := TA \cdot D = 26$ PLF

$w_L := TA \cdot L = 80$ PLF

$w := w_D + w_L = 106$ PLF

Select Section: TJI 210 11 7/8" J3

Dimensions
b = 2 1/16
d = 11 7/8

Weight = 2.8 PLF
Moment = 3,795 ft-lb
E = 315 * 10^6 in2 lb
Shear = 1,655 lb

See Truss Joist TJI Joists by Weyerhaeuser

Beam Design

Constriants:

- Column at each end
- depth, dmax = 8" or d(joist) + 4"
- span, L ≥ 16' requires interior column [treat as continuous beam]

Layout:

$BL11 := 12.33$ $BL12 := 14.33$ $BL21 := 14.33$ $BL22 := 14.33$
$A1 := 168.62$ $A2 := 171.05$ $A3 := 176.25$ $A4 := 140.4$ ft2

Loading: $D := 13$ $L := 40$ $T1 := 1.4 \cdot D = 18.2$
$T2 := 1.2 \cdot D + 1.6 \cdot L = 79.6$ PSF

$TAB1 := 13.67$

$Load11 := (A1) \cdot T2 + (6 \cdot TAB1) \cdot 2.8 = 1.365 \cdot 10^4$ lb

$BLoad11 := \frac{Load11}{BL11} = 1.107 \cdot 10^3$ PLF

$Load12 := (A2) \cdot T2 + (6.5 \cdot TAB1) \cdot 2.8 = 1.386 \cdot 10^4$

$BLoad12 := \frac{Load12}{BL12} = 967.507$

$TAB2 := 11.58$

$Load21 := (A3) \cdot T2 + (6 \cdot TAB1) \cdot 2.8 = 1.426 \cdot 10^4$ lb

$BLoad21 := \frac{Load21}{BL21} = 995.056$ PLF

$Load22 := (A4) \cdot T2 + (6.5 \cdot TAB2) \cdot 2.8 = 1.139 \cdot 10^4$ lb

$BLoad22 := \frac{Load22}{BL22} = 794.598$ PLF

Service Moments & Working Stresses [Ftool]

Beam 1 (L=12.33)

$Mp1 := 20.9 \cdot 12000$ lb-in

$V1 := 6.8 \cdot 1000 = 6.8 \cdot 10^3$

Beam 2 (L=12.33)

$Mp2 := 25.7 \cdot 12000$ lb-in

$V2 := 7.2 \cdot 1000 = 7.2 \cdot 10^3$

Beam Size [Built up]:

$b := 1.5$ $d := 11.25$

$b_{nom} := 2$ $d_{nom} := 12$

No.2 Douglas Fir-Larch Properties (psi):

$Fb := 900$ $Fc := 1350$

$Ft := 575$ $E := 1600000$

$Fv := 180$ $E_{min} := 580000$

$Fc_{perp} := 625$ $SG := 0.5$

$\#members := 7$

$Ao := b \cdot d = 16.875$

$A := (b \cdot d) \cdot \#members = 118.125$ in^2

$ba := 1.5 \cdot \#members = 10.5$

$Sx := \#members \cdot 31.64 = 221.48$ in^3

$I := \#members \cdot 290.8 = 2.036 \cdot 10^3$

[input beam dimenions]

$fbp1 := \frac{Mp1}{Sx} = 1.132 \cdot 10^3$ psi

$fbp2 := \frac{Mp2}{Sx} = 1.392 \cdot 10^3$ psi

Appendix G – Truss Calculations

Loading

Truss

Hem-Fir Construction Grade

$Fb := 975$ $Fc := 1550$
$Ft := 600$ $E := 1300000$
$Fv := 150$ $Emin := 470000$
$Fcp := 405$ $SG := 0.43$

$\rho := SG \cdot 62.4 = 26.832$
$v := 0.3$
$\alpha := 2.1 \cdot 10^{-6}$

Lumber weight lb/ft

2x4	2x6
$w1 := 0.978$	$w2 := 1.537$

Use Howe (K) Truss
24' to 36' span
TYP Span for Calculation = 30'

Assume a truss spacing of 24" OC

Dead		Load (psf)
'Truss Self weight:		Robot
Standing Seam Copper Roof		1
Self-adhering Waterproofing Membrane		0.72
Roof Sheathing		1.7
'Blown in cellulose insulation (20in)	$0.14 \cdot 20 = 2.8$	2.8
'5/8" gypsum board		2.75
'MEP		6

$Dtop := 1 + 0.72 + 1.7 = 3.42$ psf $Dtop := Dtop \cdot \frac{24}{12} = 6.84$ lb/ft
$Dbot := 2.8 + 2.75 + 6 = 11.55$ psf
Dbot will include truss self weight added in robot $Dbot := Dbot \cdot \frac{24}{12} = 23.1$ lb/ft

Live

$Ltop := 20$ psf $Ltop := 40$ lb/ft
$Lbot := 20$ psf $Lbot := 40$ lb/ft

Wind

$Risk\_Category := 2$
$V := 115$
$S := 18.435$
Exposure C
$\lambda := 1.21$
$Kzt := 1$

Simplified Wind Pressures Ps30 (psf)

Horizontal	Vertical
$A := 28.155$	$E := -25.2$
$B := -8.013$	$F := -17.187$
$C := 18.805$	$G := -17.5$
$D := -4.450$	$H := -13.081$
$EOH := -35.3$	$GOH := -27.6$

Ps (psf)

$A' := 1.21 \cdot A = 34.068$	$E' := 1.21 \cdot E = -30.492$
$B' := 1.21 \cdot B = -9.696$	$F' := 1.21 \cdot F = -20.796$
$C' := 1.21 \cdot C = 22.754$	$G' := 1.21 \cdot G = -21.175$
$D' := 1.21 \cdot D = -5.385$	$H' := 1.21 \cdot H = -15.828$
$EOH' := 1.21 \cdot EOH = -42.713$	$GOH' := 1.21 \cdot GOH = -33.396$

Ps Factored (lb/ft)

$Af := 0.6 \cdot 2 \cdot A' = 40.881$

$Bf := 0.6 \cdot 2 \cdot B' = -11.635$

$Cf := 0.6 \cdot 2 \cdot C' = 27.305$

$Df := 0.6 \cdot 2 \cdot D' = -6.461$

$EOHf := 0.6 \cdot 2 \cdot EOH' = -51.256$

$Ef := 0.6 \cdot 2 \cdot E' = -36.59$

$Ff := 0.6 \cdot 2 \cdot F' = -24.956$

$Gf := 0.6 \cdot 2 \cdot G' = -25.41$

$Hf := 0.6 \cdot 2 \cdot H' = -18.994$

$GOHf := 0.6 \cdot 2 \cdot GOH' = -40.075$

Snow

Case	Applied Snow Load	Width of pressure (ft)	
Balanced	$ps := 11.06$ psf $ps := 22.12$ lb/ft	33 ft	Entire roof
Unbalanced Case 1	Is * pg = 20 psf $pun := 40$ lb/ft	16.5 ft	Leeward side

Load Combinations (lb/ft)

Dead	Live	Liveroof	Snow	Wind
$Dtop := 8.377$	$Lbtm := 40$	$Ltop := 40$	$Ps := 22.12$	$Bf := -11.635$
$Dbtm := 25.91$			$Pun := 40$	$Ef := -36.59$
				$Ff := -24.956$
				$EOHf := -51.256$

	Load		
Top Chord			
Left Roof Overhang:	3	$-Dtop - Ltop = -48.377$	lb/ft
Left Roof:	3	$-Dtop - Ltop = -48.377$	lb/ft
Left Roof Horizontal:	5	$0 + Bf = -11.635$	lb/ft
Right Roof Overhang:	3	$-Dtop - Pun = -48.377$	lb/ft
Right Roof:	3	$-Dtop - Pun = -48.377$	lb/ft
Bottom Chord	2	$-Dbtm - Lbtm = -65.91$	lb/ft

1. D
2. D + L
3. D + (Lr or S or R)
4. D + 0.75L + 0.75(Lr or S or R)
5. D + (0.6W or 0.7E)
6a. D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)
7. 0.6D + 0.6W

Example Load Calc for worst case

$-Dtop = -8.377$

$-Dtop - 0 = -8.377$

$-Dtop - Ps - Pun = -70.497$

$-Dtop + 0 - 0.75 \cdot (Ps + Pun) = -54.967$

$-Dtop - 0 = -8.377$

$-Dtop + 0 - 0.75 \cdot 0 - 0.75 \cdot (Ps + Pun) = -54.967$

$-0.6 \cdot Dtop - 0 = -5.026$

Design Forces

Top Chord

$Tt := 4130.20$ lb (compression)

$Mt := 0.33509$ kip-ft

$Mt := Mt \cdot 12000 = 4.021 \cdot 10^3$ lb-in

Bottom Chord

$Tb := 3732.91$ lb (Tension)

$Mb := 0.43296$ kip-ft

$Mb := Mb \cdot 12000 = 5.196 \cdot 10^3$ lb-in

Web Members

$Tw1 := 1321.19$ lb (compression) $lw1 := 7.29$

$Tw2 := 1297.93$ lb (tension) $lw2 := 4.54$

Truss

Assume 2x6 initial member

Hem-Fir Construction Grade

$Fb := 975$ $Fcp := 405$ $Emin := 470000$

$Ft := 600$ $Fc := 1550$ $SG := 0.43$

$Fv := 150$ $E := 1300000$

Bottom Chord Design Final Design iteration use 2x8

$Ab := 10.88$ $Sxb := 13.14$

$bb := 1.5$ $db := 7.25$

$ft := \frac{Tb}{Ab} = 343.098$ psi

$fb := \frac{Mb}{Sxb} = 395.397$ psi

Tension

$CD := 1.0$ $Cfu := 1.0$

$CM := 1.0$ $Ci := 1.0$

$Ct := 1.0$ $Cr := 1.0$

$CF := 1.0$

Bending

$lb := 7.25$ ft

$\frac{lb \cdot 12}{db} = 12$ > 14.3 So $le := 1.84 \cdot (lb \cdot 12) = 160.08$ in

$RB := \left(\frac{le \cdot db}{bb^2}\right)^{0.5} = 22.712$

$Fbe := \frac{1.2 \cdot Emin}{RB^2} = 1.093 \cdot 10^3$

$Fb' := Fb \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci \cdot Cr = 975$ psi

$$CL := \frac{1+\left(\frac{Fbe}{Fb'}\right)}{1.9} - \sqrt{\left(\frac{1+\left(\frac{Fbe}{Fb'}\right)}{1.9}\right)^2 - \frac{\left(\frac{Fbe}{Fb'}\right)}{0.95}} = 0.859$$

$Fb'' := Fb \cdot CD \cdot CM \cdot Ct \cdot CL \cdot CF \cdot Cfu \cdot Ci \cdot Cr = 837.749$ psi

$Ft' := Ft \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci = 600$ psi

$ft = 343.098$ < $Ft' = 600$ OK

$fb = 395.397$ < $Fb'' = 837.749$ OK

$\frac{ft}{Ft'} + \frac{fb}{Fb''} = 1.044$ OK

Top Chord Design **Final Design iteration use 2x5**

$At := 6.75$ $Sxt := 5.06$

$bt := 1.5$ $dt := 4.5$

$fc1 := \frac{Tt}{At} = 611.881$ $fc2 := \frac{Tt}{Sxt} = 816.245$

Buckling Crushing

$CD := 1.0$ $Cfu := 1.0$ $lt := 7.64$ ft

$CM := 1.0$ $Ci := 1.0$ $c := 0.8$

$Ct := 1.0$ $Cr := 1.0$

$CF := 1.0$

$\frac{lt \cdot 12}{dt} = 20.373$ < 50 OK

$$FCE := \frac{0.822 \cdot Emin}{\left(\frac{lt \cdot 12}{dt}\right)^2} = 930.777$$

$$CP := \frac{1+\left(\frac{FCE}{Fc}\right)}{2 \cdot c} - \sqrt{\left(\frac{1+\left(\frac{FCE}{Fc}\right)}{2 \cdot c}\right)^2 - \frac{\left(\frac{FCE}{Fc}\right)}{c}} = 0.5$$

$Fc' := Fc \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci \cdot CP = 775.485$

$fc1 = 611.881$ < $Fc' = 775.485$ OK

$DCR := \frac{fc1}{Fc'} = 0.789$ Use 2x5

*Closest DCR factor obtainable

Check 2x5 chord for crushing
*exclude CP

$$Fc' := Fc \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci = 1.55 \cdot 10^3$$

$fc2 = 816.245$ < $Fc' = 1.55 \cdot 10^3$ OK

Web Member Design

Final Design iteration use 2x4

$Aw := 5.25$ $Sxw := 3.06$
$bw := 1.5$ $dw := 3.5$

$$fc := \frac{Tw1}{Aw} = 251.655 \qquad ft := \frac{Tw2}{Aw} = 247.225$$

Buckling

Tension

$CD := 1.0$ $Cfu := 1.0$
$CM := 1.0$ $Ci := 1.0$
$Ct := 1.0$ $Cr := 1.0$
$CF := 1.0$ $c := 0.8$

Web Members $lw1 := 7.29$
$lw2 := 4.54$

$Tw1 := 1321.19$ lb (compression)
$Tw2 := 1297.93$ lb (tension)

$$FCE := \frac{0.822 \cdot Emin}{\left(\frac{lw1 \cdot 12}{dw}\right)^2} = 618.427$$

$$\frac{lw1 \cdot 12}{dw} = 24.994$$ < 50 OK

$$CP := \frac{1 + \left(\frac{FCE}{Fc}\right)}{2 \cdot c} - \sqrt{\left(\frac{1 + \left(\frac{FCE}{Fc}\right)}{2 \cdot c}\right)^2 - \frac{\left(\frac{FCE}{Fc}\right)}{c}} = 0.359$$

$$Fc' := Fc \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci \cdot CP = 556.176$$

$fc = 251.655$ < $Fc' = 556.176$ OK

$Ft' := Ft \cdot CD \cdot CM \cdot Ct \cdot CF \cdot Ci = 600$ psi

$ft = 247.225$ < $Ft' = 600$ OK

Tie Down Connector

Worst Case Loading

Dead

$Dtop := 8.377$

Wind

$Bf := -11.635$

$Ef := -36.59$

$Ff := -24.956$

$EOHf := -51.256$

#7 0.6D+0.6W

$L7 := -(0.6 \cdot Dtop \cdot 33) - (EOHf \cdot 2 + Ef \cdot 14.5 + Ff \cdot 14.5) = 829.064$ lb

$\frac{L7}{2} = 414.532$ lb

Select H1 Connector in Seismic & Hurricane Ties

Allowable Load = 585 lb OK

Appendix H – Wind Loading Calculations

Design Project 3 Calculations

1. Wind Loading

Simplified Wind Pressures Ps30 (psf)

$Risk\_Category := 2$
$V := 115$ mph
$S := 18.423$
Exposure C
$\lambda := 1.21$
$Kzt := 1$

Horizontal
$A := 28.155$
$B := -8.013$
$C := 18.805$
$D := -4.450$
$EOH := -35.3$

Vertical
$E := -25.2$
$F := -17.187$
$G := -17.5$
$H := -13.081$
$GOH := -27.6$

Ps (psf)

$A' := 1.21 \cdot A = 34.068$ $E' := 1.21 \cdot E = -30.492$
$B' := 1.21 \cdot B = -9.696$ $F' := 1.21 \cdot F = -20.796$
$C' := 1.21 \cdot C = 22.754$ $G' := 1.21 \cdot G = -21.175$
$D' := 1.21 \cdot D = -5.385$ $H' := 1.21 \cdot H = -15.828$
$EOH' := 1.21 \cdot EOH = -42.713$ $GOH' := 1.21 \cdot GOH = -33.396$

Ps Factored (lb/ft)

$Af := 0.6 \cdot 2 \cdot A' = 40.881$ $Ef := 0.6 \cdot 2 \cdot E' = -36.59$
$Bf := 0.6 \cdot 2 \cdot B' = -11.635$ $Ff := 0.6 \cdot 2 \cdot F' = -24.956$
$Cf := 0.6 \cdot 2 \cdot C' = 27.305$ $Gf := 0.6 \cdot 2 \cdot G' = -25.41$
$Df := 0.6 \cdot 2 \cdot D' = -6.461$ $Hf := 0.6 \cdot 2 \cdot H' = -18.994$
$EOHf := 0.6 \cdot 2 \cdot EOH' = -51.256$ $GOHf := 0.6 \cdot 2 \cdot GOH' = -40.075$

Roof Load Inclination factor
$Cs := 0.79$