The Preconstruction of a Foundation for a Greenhouse

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This project outlines the preconstruction process for building a concrete base for a prefabricated greenhouse unit. This project was initiated by the Cal Poly Garden Club so they could plan for the installation of a greenhouse at the Student Experimental Farm on Cal Poly's campus. The members of the club currently share a greenhouse with another Cal Poly Club which restricts their ability to use the greenhouse freely. The initial goal of the project was to request a permit, however, that will be postponed until the specific location is determined. This project still provides the necessary elements for requesting a permit through Cal Poly's facilities department, including the design of a concrete base with proper drainage for a greenhouse unit to be bolted to. Additionally, a prefabricated greenhouse unit was selected that met all the needs of the Cal Poly Garden Club. A comprehensive cost estimate was created to determine the materials and costs for the project, including the materials needed for formwork, reinforcement, concrete, and drainage. A preliminary schedule and construction plan are also included to determine the overall project duration. These deliverables can be used by future students to find funding and eventually request a permit for construction.

Keywords: Greenhouse, Concrete Foundation, Construction Project, Construction Management, Cost Estimate

Introduction

The Cal Poly Garden Club is an on-campus organization at Cal Poly, San Luis Obispo, founded by students in 2017 who were passionate about plants. This club grew tremendously in the last four years and now runs a Student Experimental Farm which has offered students of every major the opportunity to learn and undertake projects that interest them. This project started because one of the club's main goals this year was to get a greenhouse for the Student Experimental Farm. Although there are many steps to be taken, preconstruction and planning for the installation of a greenhouse is the necessary first step. The goal of this paper is to outline the preconstruction process of building a foundation for a prefabricated greenhouse unit. This includes outlining the scope of the project, designing a 3-dimensional model, creating a materials estimateand a construction schedule, and generating a construction plan.

When the project first started, the full project scope had not yet been determined. The Cal Poly Garden Club was debating between the installation of a new greenhouse or repairing and retrofitting the existing greenhouse that sits at the student experimental farm. However, after investigating the use and ownership of the existing greenhouse, which was owned by the Polyponics Club (a club that is centered around hydroponics), it was determined to proceed with the design of a new greenhouse. Although the initial goal of this project was to request a building permit from Cal Poly Facilities Management and Development, the Garden Club decided to postpone the request for the permit until they decided they were ready to start the process. As of the date of this paper, the final site location is still under debate since the club has many pending projects in the works. The club is currently deciding on the best use of the land available to them, and they have also proposed a vineyard for the project site. Until the exact location is decided, the site cannot be surveyed, and that part of the project will have to go unfinished.

Design

The Cal Poly Garden Club had several specific requirements for a greenhouse, including good air circulation, proper ventilation, integrated irrigation, proper drainage, temperature control, and a size between 200 and 300 square feet. To fulfill their requirements, the greenhouse will be a prefabricated unit secured to a concrete slab and foundation system. The greenhouse will be fastened to the concrete using bolts.

The choice for the prefabricated unit relied on the requirements given by the Garden Club members. There were many different units to choose from based on size and use, including educational, recreational, hobbyist, or compact greenhouses. Since this greenhouse will be used by students to learn and experiment, an educational greenhouse was chosen at a size of 288 square feet. These other option choices were excluded because their materials would not receive the necessary care needed to last well over an extended period of time. This educational greenhouse requires little to no maintenance and is very user-friendly for students who are still learning about greenhouses and plant care. As shown on the website, "Riverstone Industries (RSI) Whitney Premium Educational Greenhouse 12ft x 24ft" (2021) the RSI Whitney Educational Greenhouse shown in Figure 1, includes:

- Two (2) 24-inch motorized shutters for air circulation
- One (1) 18-inch Quietaire industrial exhaust fan
- Two (2) 3-ft. deep 24-ft. long commercial workbenches
- One (1) two-stage commercial thermostat to control fan & shutters
- One (1) 240-volt electric heater with a built-in thermostat
- One (1) 22ft x 26ft (63%) shade cloth with tie-down rope
- One (1) automatic and programmable watering system with timer

Figure 1: Prefabricated Greenhouse Unit. (Riverstone Industries (RSI) Whitney Premium Educational Greenhouse 12ft x 24ft, 2021)

An additional requirement to be fulfilled is proper drainage within the greenhouse unit. It is important for a greenhouse to have proper drainage for multiple reasons; it can get muddy and slippery, excess moisture can affect the concrete, and water puddles on the ground promoting algae growth and insect breeding grounds (Peterson, 2021). The base was designed with two slabs that have a two percent slope toward the center of the greenhouse where water can drain into a trench drain and be taken out of the greenhouse (see Figure 2). Due to the slope of the slabs, it was necessary to add a stem wall around the perimeter of the slab for the greenhouse to sit on a level surface. This stem wall will sit on top of a footing, which is below grade. However, the stem wall is slightly above grade, meaning, a ramp is necessary for this greenhouse to be accessible to all students (See Figure 3). All parts of this concrete base will be reinforced with No. 4 rebar spaced 16 inches on-center due to the expansive soil on campus and the weight this base is expected to carry.

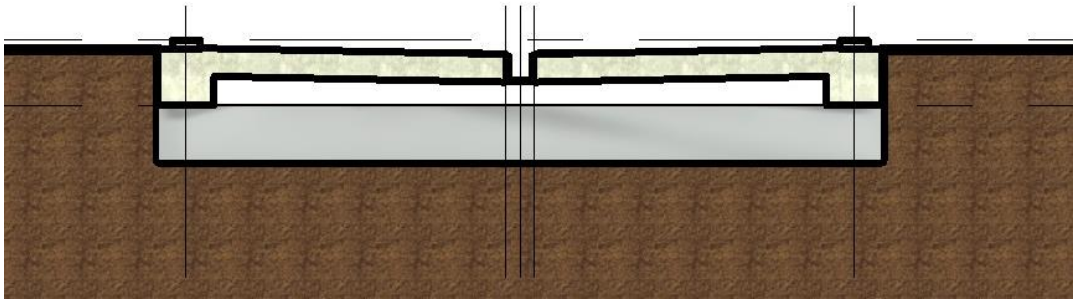

Figure 2: Section Cut of Concrete Base

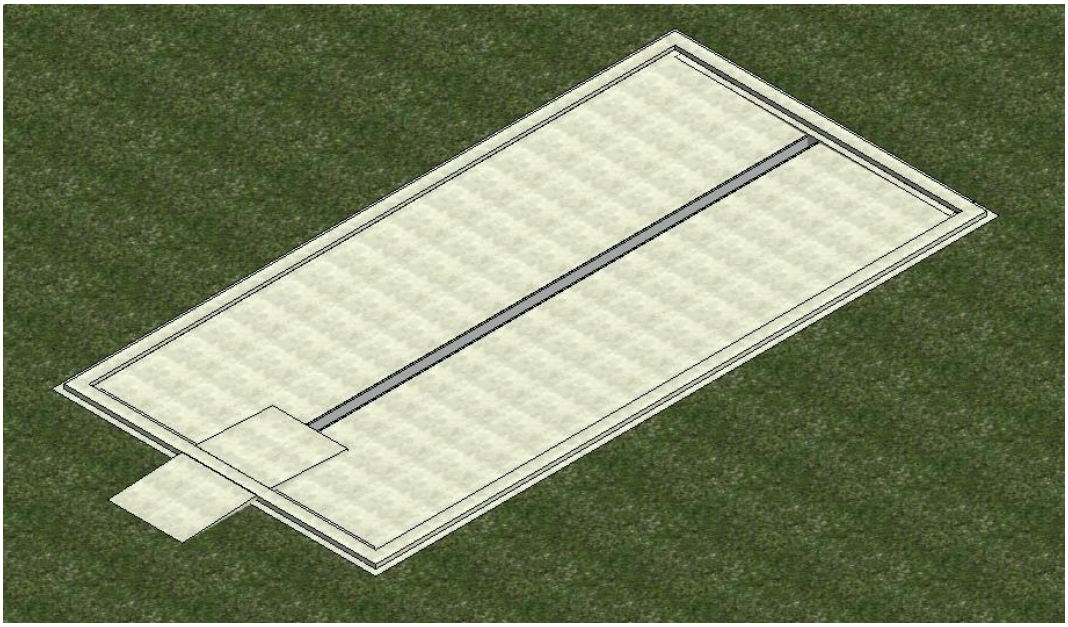

Figure 3: Three-Dimensional View of Concrete Base

Estimate

A cost estimate was created for the project to determine the necessary funding to complete the project (see Figure 4). This estimate excludes the cost of excavation and grading since the greenhouse's final location is pending. The estimate is divided into two sections to separate the costs based on materials. The concrete footing is twelve inches deep and will be dirt-formed because it is below grade. The formwork for the stem wall was determined with the help of the Revit model. 2x3 lumber was used because the height of the stem wall was only designed to be 2 inches in height. The formwork for the slabs used 2x8 lumber because the slabs are 6 inches thick. However, the formwork for the slabs were only two pieces of lumber that spread across the 24-ft length of the concrete base. This is because the grade and the footing would give the slabs form and the lumber is there just to take the place of the trench drain that will later be installed in the center of the concrete base.

The volume of concrete was calculated using Revit and included all concrete for the complete concrete base system. This volume was multiplied by the cost per cubic yard which yielded the cost of concrete. Underneath the concrete slabs, there is a two-inch layer of gravel (crushed stone) that was accounted for as well as a 10-mil vapor retarder to help keep moisture out of the slabs. The cost of rebar and rebar ties was also calculated so the footing, slabs, and stem wall could be reinforced. The #4 rebar is going to be sixteen inches on center going vertically through the footing and stem wall and there would be horizontal #4 rebar at the top and bottom of the footing. The slabs would also be reinforced with rebar at 16 inches on center forming a grid within the slabs. Rebar ties were also accounted for because those would be used when setting up the rebar before pouring the concrete.

Next, the costs of the prefabricated greenhouse unit and the trench drain were calculated. The sellers of the greenhouse unit provided a quote for the RSI Whitney Educational Greenhouse. The cost was based on factors like wind load, location, and state codes that needed to be followed. This is because

the wind load and location determine the type of anchors the greenhouse needs to stay on the ground which in turn affects the cost of the unit as it is sold altogether. The cost of a trench drain was somewhat expensive; A less expensive option was presented but, it was not made of a material that could withstand the weight of humans for an extended period of time. Since this trench drain goes through the middle of the greenhouse and will see the weight of humans, it was decided to utilize the more expensive option instead of replacing the drain every time it breaks.

The last cost accounted for was labor. The Cal Poly Garden Club offered to provide volunteer labor for as much as possible to lower the costs of this project. This means that everything but the excavation, grading, pouring of concrete, and assembly of the greenhouse can be done with volunteers. The assembly of the greenhouse needs to be done by a professional, as stated on the seller's website. A local contractor has to be contacted for the assembly of this greenhouse.

Overall, the project will cost about $38,700. This includes all materials, paid labor, volunteer labor, overhead, and contingency. The majority of the cost is associated with the greenhouse and channel drain which are about $31,500. The formwork cost the least and was short of $100 while the concrete and rebar were both slightly more than $1000 each. Figure 4 shows the estimated costs for this project.

Greenhouse Materials Estimate					Estimator:	Alla Hashim	
Item Name	**Estimated Quantity**	**Unit**	**Price per Unit**	**Labor**	**Total Per Unit**	**Total Price**	**Overall Total**
Concrete Formwork							$ 93.02
2x3 Formwork	143	LF	$ 0.36	$ -	$ 0.36	$ 51.48	
2x8 Formwork	46	LF	$ 0.76	$ -	$ 0.76	$ 34.96	
Nails	1	Box	$ 6.58	$ -	$ 6.58	$ 6.58	
Concrete							$ 1,461.55
Concrete	7.51	CY	$ 120.00	$ 31.67	$ 151.67	$ 1,138.87	
Gravel (crushed stone)	2.39	CY	$ 51.66	$ -	$ 51.66	$ 123.68	
Vapor Barier	1	Roll	$ 199.00	$ -	$ 199.00	$ 199.00	
Greenhouse							$ 31,509.00
Greenhouse	1	Unit	$ 30,000.00	$ 200.00	$ 30,200.00	$ 30,200.00	
Channel Drain	1	Unit	$ 1,309.00	$ -	$ 1,309.00	$ 1,309.00	
Rebar and Hardware							$ 1,057.26
#4 Rebar	1321.5	LF	$ 0.44	$ -	$ 0.44	$ 581.46	
rebar ties	244	Tie	$ 1.95	$ -	$ 1.95	$ 475.80	
TOTAL							**$ 34,120.83**
Administrative							$ 5,800.54
Contingency	10%					$ 3,412.08	
Overhead	7%					$ 2,388.46	
OVERALL TOTAL							**$ 38,771.09**

Figure 4: Cost Estimate

Schedule and Construction Plan

A preliminary schedule was developed for planning purposes. This schedule is meant to yield a practical timeline for the project from start to finish. It starts with the preconstruction phase, then follows with the excavation and grading. After that, formwork, rebar, and concrete pours will start. The first phase is mainly about the setup. The gravel for the slabs will be placed with the 10-mil vapor retarder right above it. Then the rebar for the slabs and the footing will be laid out and tied together with rebar ties. After that, the formwork for the stem wall and slabs will be put together and placed so

phase two can start. In phase two, the concrete will be poured to form the footing first and then the stem wall and the slabs. After the concrete for the footing, stem wall, and slabs have cured, the trench drain will be placed in the center of the concrete base, and assembly of the greenhouse will begin. After the greenhouse unit is assembled and anchored to the concrete base, closeout will start, and the project will be finished.

The overall project is estimated to take about 113 days. It is split between preconstruction which is estimated to take about 86 days and construction which is estimated to take about 29 days. Preconstruction typically will take longer due to the permitting process and documentation and planning involved. For a more detailed view of the schedule, please view Appendix A.

Lessons Learned

Throughout this project, there have been many learning opportunities. Having a club as a client rather than a single person was difficult to manage because meetings had to have every person present and coordinating schedules proved challenging and it was hard to get things done quickly. Another lesson learned was that it is hard to get things done on campus because Cal Poly Facilities is very strict with the selection of projects to be carried out, which, I now understand after going through the preconstruction phase of a project. The preconstruction process needs to be very well thought out and organized because the more you plan, the fewer complications will arise after starting the project. It's important to be meticulous and understand the full scope of the project in order to get all the preconstruction done. Planning is the most important part of the project.

Conclusion

The Cal Poly Garden Club is an organization founded by students who are passionate about agriculture and plant care. They run a student experimental farm where they currently share a greenhouse with another cub on campus, but they do not have the ability to use it freely for anything they want. This project started the process of installing a new greenhouse at the student experimental farm for them.

Although this project had many setbacks, the Cal Poly Garden Club is now closer to the point of requesting a permit than they were previously. A design for a concrete base was created for a prefabricated greenhouse unit. The concrete base includes a footing, a stem wall, and two slabs with a two percent slope toward the center of the base. The cost estimate includes a list of materials along with their costs and the cost of labor which is partly outsourced and partly voluntary. The estimate is necessary for finding the funding to complete the project and provides a detailed view of the tasks required to complete the project and the overall project duration. The construction plan outlines the order of the tasks and the methods used to complete the project.

The initial goal of this project was to complete the preconstruction phase for a greenhouse project on Cal Poly's campus. Although this project is not ready for permit request, future students can continue this project and take it through the permitting and construction phase. Future students will need to decide on a location with the Cal Poly Garden Club and survey the site. Then they will need to determine the quantity and cost of excavation as well as the cost of grading. A site plan will need to be created to show water and electrical lines as the greenhouse require those two things to function properly. Future students will also need to find funding to get this project up and running. Requesting

a permit requires all costs, plans and specs, funding, and schedule to be completed and ready for evaluation.

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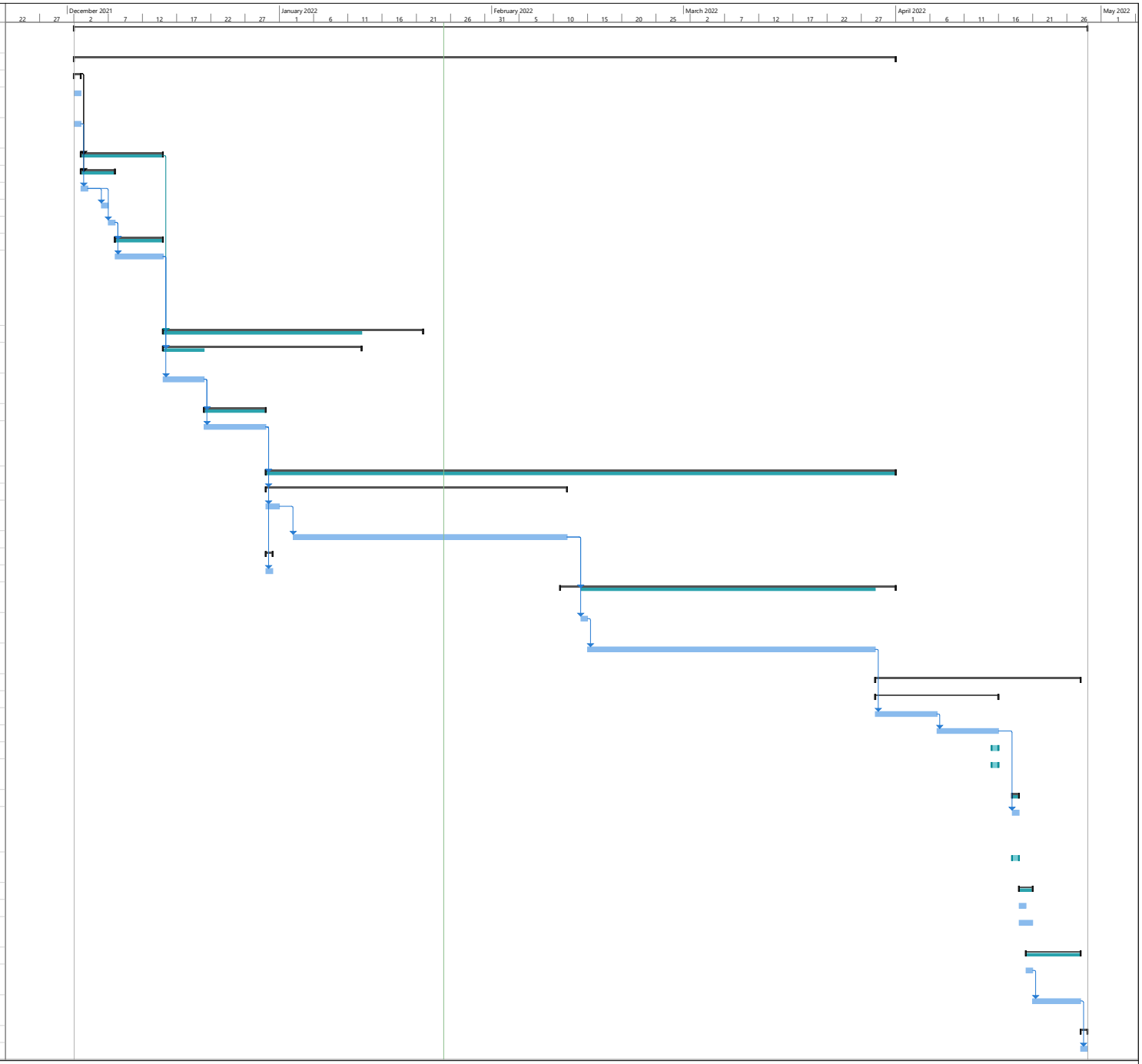
"Appendix A"

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Greenhouse and Foundation Project**	**106 days**	**Thu 12/2/21**	**Thu 4/28/22**	
2		**Preconstruction**	**86 days**	**Thu 12/2/21**	**Thu 3/31/22**	
3		**Planning**	**1 day**	**Thu 12/2/21**	**Thu 12/2/21**	
4		Meeting with the Garden Club	1 day	Thu 12/2/21	Thu 12/2/21	
5		Determining Location	1 day	Thu 12/2/21	Thu 12/2/21	
6		**Site Planning**	**8 days**	**Fri 12/3/21**	**Tue 12/14/2**	3
7		**Surveying**	**3 days**	**Fri 12/3/21**	**Tue 12/7/21**	3
8		Survey the s	1 day	Fri 12/3/21	Fri 12/3/21	5
9		Designing a l	1 day	Mon 12/6/21	Mon 12/6/21	8
10		Excavation P	1 day	Tue 12/7/21	Tue 12/7/21	8
11		**Site Plan**	**5 days**	**Wed 12/8/21**	**Tue 12/14/2**	10
12		Determining Location of Water and Electrical Lines on a plan	5 days	Wed 12/8/21	Tue 12/14/21	10
13		**Design**	**28 days**	**Wed 12/15/2**	**Fri 1/21/22**	6
14		**Concrete Foundation**	**21 days**	**Wed 12/15/21**	**Wed 1/12/22**	12
15		Design of a Concrete Base	4 days	Wed 12/15/21	Mon 12/20/21	12
16		**Greenhouse**	**7 days**	**Tue 12/21/2**	**Wed 12/29/2**	15
17		Pick a Prefabricate Greenhouse	7 days	Tue 12/21/21	Wed 12/29/21	15
18		**Permitting**	**66 days**	**Thu 12/30/2**	**Thu 3/31/22**	17
19		**Cost**	**32 days**	**Thu 12/30/2**	**Fri 2/11/22**	17
20		Create and Estimate	2 days	Thu 12/30/21	Fri 12/31/21	17
21		Find Funding	30 days	Mon 1/3/22	Fri 2/11/22	20
22		**Scheduling**	**1 day**	**Thu 12/30/2**	**Thu 12/30/2**	
23		Creating a Pr	1 day	Thu 12/30/21	Thu 12/30/2	17
24		**Proposal and Permit Request**	**35 days**	**Fri 2/11/22**	**Thu 3/31/22**	21
25		Submit a Proposal	1 day	Mon 2/14/22	Mon 2/14/22	21
26		Request a Permit	30 days	Tue 2/15/22	Mon 3/28/22	25
27		**Construction**	**22 days**	**Tue 3/29/22**	**Wed 4/27/2**	
28		**Site Prep**	**14 days**	**Tue 3/29/22**	**Fri 4/15/22**	
29		Excavation	7 days	Tue 3/29/22	Wed 4/6/22	26
30		Grading	7 days	Thu 4/7/22	Fri 4/15/22	29
31		Placing Gravel	1 day	Fri 4/15/22	Fri 4/15/22	
32		Placing Vapor Retarder	1 day	Fri 4/15/22	Fri 4/15/22	
33		**Formwork**	**1 day**	**Mon 4/18/22**	**Mon 4/18/2**	
34		Laying Rebar for Footing and Stem Wall	1 day	Mon 4/18/22	Mon 4/18/22	30
35		Laying Rebar for Slabs	1 day	Mon 4/18/22	Mon 4/18/22	
36		**Concrete**	**2 days**	**Tue 4/19/22**	**Wed 4/20/2**	
37		Pouring Concre	1 day	Tue 4/19/22	Tue 4/19/22	
38		Letting Concrete Cure	2 days	Tue 4/19/22	Wed 4/20/22	
39		**Greenhouse**	**6 days**	**Wed 4/20/22**	**Wed 4/27/2**	
40		Placing Trench Drain	1 day	Wed 4/20/22	Wed 4/20/22	
41		Assembling Greenhouse	5 days	Thu 4/21/22	Wed 4/27/22	40
42		**Closeout**	**1 day**	**Thu 4/28/22**	**Thu 4/28/22**	
43		Inspection	1 day	Thu 4/28/22	Thu 4/28/22	41



Project: SP Schedule
Date: Tue 1/25/22

Task | Milestone | Project Summary | Inactive Milestone | Manual Task | Manual Summary Rollup | Start-only | External Tasks | Deadline | Manual Progress
Split | Summary | Inactive Task | Inactive Summary | Duration-only | Manual Summary | Finish-only | External Milestone | Progress