Arizona Water Jacks:

Oak Creek Low Water Crossing

Devin Kelley

Hilary Sizemore

Fawaz Alotaibi

Bruce Connolly

December 6, 2013

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Ms. Beth Ann Dzierson
Crossing Chairman
Rancho Mission Shangri-La

Re: Arizona Water Jacks: Oak Creek Low Water Crossing Capstone Team
Devin Kelley – Team Manager
Fawaz Alotaibi, Bruce Connolly, Hilary Sizemore
Final Proposal

Dear Ms. Dzierson,

As per the requirements of the Low Water Crossing in Oak Creek project description, the assembled team has made the proper advancements to gather the necessary information to begin the design and analysis portion of the capstone project.

You will find enclosed the data the group has collected thus far, excluding the surveying data. The team is diligently working on gathering all pertinent information so that all local, state, and federal regulations will be taken into consideration for the design. Enclosed you will find a "Cost" portion of the final report. This portion is not an actual cost estimate and there is no need to monetarily compensate the group. This section is purely for the capstone class.

We appreciate your time spent reviewing the enclosed documents. Please feel free to contact Devin Kelley, Team Manager, with any questions or concerns regarding the Low Water Crossing.

Sincerely,

Devin Kelley
(949)228-6602
Dek62@nau.edu

For Arizona Water Jacks

Table of Contents

1.0 Project Understanding

1.1 Purpose of Project

The residents of the Rancho Mission Shangri-La Subdivision, located in Oak Creek Canyon, have only one road access connecting their subdivision to highway 89-A. The road to the homes crosses Oak Creek via a low water earth and concrete crossing built over culverts that allow the creek to pass under the crossing the majority of the year.

In times of flooding, however, Oak Creek rises above the crossing to a point where passage is dangerous or impossible. During these times of flooding, the residents are either confined to their homes or locked outside until the water reaches levels conducive to crossing.

The residents are worried about the long-term structural integrity of the crossing. They have requested the current crossing be protected to prevent erosion of the existing foundation. The residents have requested a new crossing design on hand in the event that the existing crossing is compromised out.

1.2 Background Information

During a large flood in 1993, the low water crossing used by the residents of the Mission Rancho/ Rancho Shangri-La subdivision to cross Oak Creek was washed out. The flood reached a historical peak of 23,200 cubic feet per second (cfs) at the downstream gaging station in Sedona on February 19, 1993. After the floodwaters abated, a temporary crossing was devised using fill dirt compacted over a few small culverts. This allowed residents to drive to their residence until a more permanent solution could be constructed. The existing structure was built near the end of the 1993 and is the sole means of vehicular transportation to and from the subdivision.

1.3 Key Stakeholders

The members of the Shangri-La subdivision are the key stakeholders of the project. Members of the subdivision use the crossing daily as it the only egress in and out of their neighborhood. The access across the creek is vital for services such as the filling of propane, trash pick-up, delivery of materials, and access for fire protection as well.

Beth Ann Dzierson is the head of the neighborhood POA and is our main liaison to communicate any concerns of the POA during our study and research on this project.

1.4 Existing Conditions

The existing crossing is approximately 40 feet long and 14 ½ feet wide. During flows below overtopping depth, the creek flows through four 48" concrete culverts. The elevation of the roadway is approximately four feet above the water line at base flow. The existing crossing has a weight limit of 30 tons.

The residents of the subdivision are concerned with erosion. They are afraid that it could lead to the failure of the crossing during a large flood. Of most concern is the erosion that is occurring under the downstream apron and the western downstream retaining wall. Erosion extends up to three feet under the downstream apron and up to seven feet under the downstream retaining wall used to support the roadway across the creek.

The site is located on the Oak Creek Fault. Due to fault slip, the soil consists of pulverized aggregate and stream deposits. No bedrock was found during a fifteen foot excavation conducted at the site and it has been assumed that the fault has eliminated any chance of anchoring to solid bedrock.

2.0 Scope and Tasks

Arizona Water Jack's involvement with the crossing will entail mostly hydrological and hydraulic data in order to design a new crossing and to protect the current crossing. The new crossing should incorporate box culverts in order to accommodate a higher flow. The project will incorporate regulations and preliminary data collected from varying State and Federal agencies (i.e. ADEQ, EPA, Army Corps, etc.). The data collected from the agencies will help establish certain parameters that will be used to model the project site in order to design the safest and most economical crossing while preserving the integrity of Oak Creek.

The scope, Table 2-1, outlines what deliverables will be generated from the research and modeling.

Scope Description

Task A: Research

Research that will be completed pertains to government agencies' regulations per construction, safety, design requirements, and performance requirements. Adequate research ensures the optimal design potential.

A.1 Army Corps:

The Army Corps of Engineers is a governing agency that deals with the hydrological and hydraulic nature of projects. Their manuals will be referenced for the following areas of interest:

- Flood protection procedures
- Sustainability and protection of the creek (i.e. Oak Creek)
- Ecological protection of the area

A.2 ADEQ:

The Arizona Department of Quality (ADEQ) has declared Oak Creek a Unique Water Status. ADEQ regulations will need to be addressed in order for the agency to issue a permit. This is to insure the water quality of Oak Creek will be unharmed during and after any construction and or armoring of the existing structure. Their manuals will be referenced for the following:

- Ecological protection procedures for Oak Creek
- Construction procedures while working along creek
- Methods for digging within Oak Creek
- Construction permits
- Any possible earthwork (cut and fill) that will be required to improve or hinder flow
- SWPPP (Stormwater Pollution Prevention Plan)
- Watershed description

Clean Water Act, Sections 404 and 401 will need to be addressed in order show that discharge of dredged and or fill material will be kept to acceptable levels.

A.3 ADOT:

Due to the project site's close proximity to US-89A, certain procedures will have to be taken in order to ensure the safety of the construction crew. ADOT will be referenced for the following:

- Construction phasing
- Right-of-Way
- Permits for construction vehicles to access crossing

ADOT will be used for traffic purposes that include the permission for construction vehicles to access the narrow crossing road, possible rerouting for traffic, right-of-way, and encroachment.

A.4 EPA:

The EPA has numerous regulations in terms of the protection of streams and rivers within the US. 40 CFR part 232.1-232.3 will be referenced to discuss the moving of heavy materials in the creek. The following will be referenced through

the EPA:

- Construction permits
- Water maintenance
- Any possible vegetation disturbance
- CFRs (Code of Federal Regulations) relating to the project

A.5 Forest Service:

The Forest Service will be considered for the protection of the surrounding flora and fauna. Certain manuals that will be needed will address the following:

- Construction procedures
- Possible endangered species affected by construction
- Prevent any unwanted interaction between construction and the surrounding environment
- Maximum noise levels at certain times of the day
- Allowable lightning for construction

A.6 Arizona Game and Fish:

The team will focus in the fishing regulations that affect the project. The types of fish present near the project site will need to be protected to an extent. The following topics will be addressed by Arizona Game and Fish manuals:

- Protection of fauna
- Allowed discharges in creek
- Construction procedures over the creek
- Endangered species present in area

A.7 Safety:

Safety is the main concern for the project. Many precautions will be taken to ensure the safety of workers. The following procedures will be some of the precautions implemented:

- Traffic barriers
- Guardrails
- Little to no exposure to any toxic chemicals
- PPE for workers

Future safety protocols will be developed as the research process continues and other factors must be taken into consideration.

Task B: Modeling

All software that will develop an understanding for the low water crossing and surrounding environment are categorized as modeling. The multiple software that will be used are to develop certainty in design alternatives.

B. 1 HEC-HMS:

HEC-HMS will be used to determine the amount of precipitation the project site may encounter within the foreseeable future. HEC-HMS will provide the following data:

- Annual amount of precipitation received at crossing
- The amount of runoff the crossing may encounter in a given year for a given storm-year
- When floods are most common and the numerical data of said floods

- The effects of snowmelt and evapotranspiration at the crossing

HEC-HMS will help establish the needed data in order to run Culvert Master to estimate an appropriate size for the culverts.

B.2 HEC-RAS:

The hydrologic Engineering Centers River Analysis System (HEC-RAS) is a modeling software that will perform the following procedures:

- One-dimensional steady flow calculations
- Unsteady flow calculations
- Sediment transport
- Water temperature modeling.

This modeling software was developed by the Army Corps of Engineers to manage natural water channels. This system will be used to manage the up-stream channel reach of the low water crossing as well as the effect of stream changes due to maintenance and excavation. This modeling relies on the completion of the channel reach surveying. All surveying data will be used to create the cross sections of the stream reach.

B.3 USGS Data:

The U.S. Geological Survey (USGS) data will be used to estimate the stream flow. The data from USGS will give the team the following:

- Maximum and minimum daily discharge
- Stream gage measurements to analyze the stream flow
- How stream flow fluctuates throughout the year
- What influence each year-storm has on the discharge

The USGS data is necessary to estimate flood magnitude and to expect the time of the flood. The team will use the stream flow data to determine possible overtopping caused by a flood. The USGS data will also help determine certain physical feature of the area, such as the fault line that coincides with Oak Creek.

B.4 Land Survey:

The land surrounding the project site and the creek will be surveyed to document the change in elevation within the creek and around the crossing. This data will help with the following:

- Elevation changes of area
- Cross-sectional area of the creek
- Creek's slopes

Task C: Impacts

Impacts of the project are taken into consideration for the benefit of the client and surrounding community to evaluate. The social and political impacts of the low water crossing are developed based on contractor interpretation.

C.1 Political:

Many political factors have to be accounted for within the project. The project itself is situated over an extremely important water channel that cannot be hampered with extensively. The community is adamant about having as few conflicts within the creek, so the community's wishes must be taken into consideration. Much animosity has been shown by the community when large

projects are proposed in the area. This animosity should not be met with the size of the team's project.

C.2 Social:

The protection of the creek is one of the highest social impacts. Much of the tourism and economy is based off of Oak Creek. Thus, it must not be affected extensively where it will be permanently disrupted. Oak Creek plays a vital role for many of the businesses and State Parks in the area.

Task D: Analysis and Design

Analysis of software and calculation is critical for the design process. Once modeling is complete, analysis including other software will be used to develop a full understanding of the low water crossing parameters. The design process incorporates all learned parameters from modeling and analysis to develop design alternative for the low water crossing's enhancements. The client's needs and suggestions will be considered in the design direction and alternatives.

D.1 AutoCAD:

AutoCAD will be used to help establish the project site and certain parameters of the project site. The watershed that affects the project area will be delineated. This delineation will be used in HEC-HMS to estimate flooding values and state what times of the year seem to have the most trouble with flooding. AutoCAD will not be used for any other design reasons besides the deliverable listed above.

D.2 Culvert Master:

Culvert Master will be used to help model how the creek would interact with the current crossing and what culverts should be used for the designed crossing. For Culvert Master to be used properly, data will need to be compiled on the creek to help with the parameters of the analysis. Culvert Master will generate multiple scenarios for different sizes of culverts. The program will provide the following data:

- Amount of flow through different sized culverts
- Speed of flow through the culverts
- Height of water in the culverts

Culvert Master will have different storms-years to give an estimate on what size culverts should be considered for the design. These storm-years' data will be generated from HEC-HMS.

D.3 HydraFlow Express:

AutoCAD is a typical engineering tool that allows 2D and 3D modeling. Within the AutoCAD software is a function called Hydra Flow. The Hydra Flow function will be used to model the effects of a culvert of different characteristics to determine best theoretical fits for this specific situation. The software will allow for box and round culverts along with material differences and sizes. Based on these results the team can provide significant knowledge of the water discharge conditions that would overtop or hinder the crossing.

D.4 Bentley WaterGEMS:

Bentley WaterGEMS is a modeling application that is compatible with other programs such as AutoCAD. WaterGEMS is used to model the piping of distribution systems. In this case, WaterGEMS will produce the following:

• Profile of the low water crossing with calculated water flow • When the creek will overtop the crossing • Culvert behavior as discharge increases with different year-storms This is important to determine because potential pressurized pipe flow could deteriorate the stream armoring set in place with maintenance. This modeling system will help determine the discharges that are at most risk for pressurized flow.
D.5 Armoring Existing Crossing: Currently there is minimal armoring up and down stream of the low water crossing. It is the job of the engineers to determine the appropriate additional armoring needed to protect the low water crossing from damage brought upon by heavy discharge. Based upon modeling data, the appropriate armoring needed for the stream will be based on velocities of the stream, Reynolds' Roughness Coefficient, and the available materials. Stream armoring is usually associated with rocks and boulders that will prevent erosion along the stream bed or obstructions that are used to slow the velocities up-stream to prevent erosion and scouring. Stream armoring will be initial construction with the new crossing design, but will also have a heavy emphasis in maintenance of the crossing.
Task E: Exclusions The following tasks are excluded due to outside contracting. These tasks are needed for the overall project's life span, but will not be completed in this contract.
E.1 Geotechnical Engineering: Geotechnical engineering services will not be provided by the team due to time constraints. Geotechnical tasks will be performed by an outside engineering firm in the future.
E.2 Traffic Control: Traffic control will not be planned out by the team because of time constraints. This task will be done by an outside firm.
E.3 Structure: The technical structural components of the crossing will not be calculated by the team due to lack of time available and professional expertise. However, many things will be taken into consideration while designing the new crossing: • The self-weight of the crossing • The estimated dead load of the crossing • The anticipated live load applied to the crossing

Table 2-1: Scope Table

3.0 Schedule

This schedule outlines major milestones and tasks necessary for a successful outcome for both the client and Arizona Water Jacks. Arizona Water Jacks has utilized a Gantt chart system for this purpose.

All tasks and duties of the team are clearly displayed on the schedule thus providing a critical path of the required functions ensuring an efficient use of time and resources. The schedule for the team is provided in Appendix B.

3.1 Website

A major component of our deliverables is the construction and maintenance of the Arizona Water Jacks' website. The website will be fully functional by December 6, 2013. The website will continue to be updated and refined as information is collected and design decisions are made.

3.2 Research

Research will be conducted in order to gain any information that is necessary to ensure a compliant design of the low water crossing in Oak Creek Canyon. The research will provide any engineering parameters as well as guidelines and requirements by various agencies. Research is planned to be completed by January 17, 2014. The research will be ongoing throughout the project as needed.

3.3 Modeling

Modeling is scheduled to occur after two milestones have been completed, land surveying and research. Modeling of the site survey as well as computer modeling of water flows will be conducted to accurately evaluate the environment. Hydrologic modeling and survey data will be required for a complete analysis of site parameters. Modeling will be completed on February 12th.

3.4 Impacts

The impacts of a low water crossing with respect to political and social concerns will be explored. The impact review will consist of items that may arise concerning the construction of a low water crossing as well any other impacts the crossing may have on the local community. These impacts will also be taken into account during the analysis of collected information. Impacts will be completed by February 13th.

3.5 Analysis

Once all available information has been collected and explored, a critical analysis of the data will be conducted. Analysis of all available information will be completed by February 21st.

3.6 Final Design

Design alternatives will be explored after analysis of the local environment has been completed. During this time, all design alternatives will be evaluated and a final design will be chosen. The final design is scheduled to be completed by March 31st to allow for any final report and presentation concerns to be addressed.

3.7 Reports and Presentation

The final job for our team will be the preparation of reports and presentation of our final design to the client. The culmination of work will be represented in the final report and presentation. Our final report will be delivered on May 1st and our presentation will be delivered on April 25th.

3.8 Critical Path

The critical path is indicated on the schedule with the dark orange tasks. These tasks have been deemed essential because the team needs to finish each stage's critical tasks before proceeding to the next stage of the project. Research and surveying must be completed before modeling begins. HEC-HMS and HEC-RAS must be completed in modeling before analysis can begin. AutoCAD and Culvert Master must be completed in the analysis stage before the design can

begin. The completion of the design will lead to the final presentation and the completion of the capstone project.

4.0 Cost

The cost of engineering services provided by Arizona Water Jacks includes compensation for a Senior Engineer, Engineer, Intern, and Administrative Help roles. All compensation is based upon estimated hours worked per team role. A fully expanded table including the Estimated Hours per Task is located in Appendix A. The following table includes the total cost and comparison for the engineering services.

Cost Estimate For Engineering Services					
1.0 Personnel					
Tasks	Senior Engineer	Engineer	Intern	Administrative	Total Per Task (hrs)
Research (hrs)	10.5	28	35	3.5	77
Modeling (hrs)	14	41	41	0	96
Impact (hrs)	1	1	4	6	12
Analysis (hrs)	22	48	48	10.5	128.5
Design (hrs)	10	32	32	2	76
Total Per Role (hrs)	57.5	150	160	22	389.5
Pay Scale Per Role	*$ 170.00*	*$ 90.00*	*$ 30.00*	*$ 45.00*	
Cost	$ 9,775.00	$ 13,500.00	$ 4,800.00	$ 990.00	$ 29,065.00
Total Personnel Cost	**$ 29,000.00**				
2.0 Reinbursment					
Not to exceed	**$ 1,000.00**				
3.0 Subcontracts					
Geotechnical Analysis	**$30,000**				
4.0 Total Service Cost	**$ 60,000.00**				
5.0 Comparison	Clients Budget				
	80000	>	$ 60,000.00		
Remaining Budget	**$ 20,000.00**				

Table 4-1: Total Cost Estimate

The first section of Table 4-1 reports the totaled hours per task and per team role. This was included to give the client a comprehensive view of the time acquired in engineering services. The furthest right column totals the hours per task, and below each individual task, the hours are totaled per team role. Each role's pay scale is multiplied by the estimated hours worked. The pay scale per role is calculated based on a dedicated 60% day's work compensation. The total personnel compensation is estimated to be approximately $29,000. Travel costs and other necessary services

will not exceed $1,000 in reimbursements. It is determined all geotechnical analysis will be excluded from this project scope and subcontracted out for $30,000.

The total estimated cost of the engineering services will be $60,000. The budget estimated by the client was approximately $80,000. Using Arizona Water Jacks' engineering services, the client is able to use $20,000 towards future construction costs.

5.0 Conclusion

The project site at Oak Creek is frequented with floods which has overtopped the crossing at times. The current crossing has taken some damage due to the erosional forces of Oak Creek and plans for a new crossing are needed in case the current crossing is washed out again.

Due to the fragile nature of the project site and the amount of regulation on Oak Creek, all factors must be considered carefully. The designs of the new crossing and the armoring of the current crossing must strictly follow local, state, and federal laws pertaining to the preservation of Oak Creek. No physical changes to the creek can be made. Arizona Water Jacks will review all possible design alternatives and choose which alternative best fits the needs of the community without affecting Oak Creek.

6.0 Appendix

See attached appendices sections

6.0 Appendix A

Complete Estimated Hours per Task per Role				
	Senior Engineer	Engineer	Intern	Administrative
Research				
Army Corps	1.5	4	5	0.5
AZDEQ	1.5	4	5	0.5
ADOT	1.5	4	5	0.5
EPA	1.5	4	5	0.5
Forest Service	1.5	4	5	0.5
Game & Fish	1.5	4	5	0.5
Safety	1.5	4	5	0.5
Total	**10.5**	**28**	**35**	**3.5**
Modeling				
HEC-HMS	2	7	7	0
HEC-RAS	2	7	7	0
USGS DATA	2	7	7	0
Land Survey	8	20	20	0
Total	**14**	**41**	**41**	**0**
Impact				
Political	0.5	0.5	2	3
Social	0.5	0.5	2	3
Total	**1**	**1**	**4**	**6**
Analysis				
AutoCAD 3D	4	8	8	0.5
Geomorphology	4	8	8	0.5
Culvert Master	4	8	8	0.5
Hydraflow Express	4	8	8	0.5
Bentley W. Gems	4	8	8	0.5
Documentation	2	8	8	8
Total	**22**	**48**	**48**	**10.5**
Design				
Structure	4	11	11	0
Armoring Exist.	4	11	11	0
Documentation	2	10	10	2
Total	**10**	**32**	**32**	**2**

Table A-1: Expanded Hour's Log

Tasks	Senior Engineer	Engineer	Intern	Administrative	Allocated days per Schedule
Research (hrs)	10.5	28	35	3.5	60
Modeling (hrs)	14	41	41	0	20
Impact (hrs)	1	1	4	6	5
Analysis (hrs)	22	48	48	10.5	30
Design (hrs)	10	32	32	2	15
Total Per Role (hrs)	**57.5**	**150**	**160**	**22**	**130**

Table A-2: Total Hours per Task

6.1 Appendix B

	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		WEBSITE	112 days	Fri 10/18/13	Mon 3/24/14		
2		**Research**	**51 days**	**Mon 11/11/13**	**Mon 1/20/14**		
3		Army Corps	50 days	Mon 11/11/13	Fri 1/17/14		
4		AZ DEQ	50 days	Mon 11/11/13	Fri 1/17/14	3SS	
5		ADOT	50 days	Mon 11/11/13	Fri 1/17/14	4SS	
6		EPA	50 days	Mon 11/11/13	Fri 1/17/14	5SS	
7		Forest Service	50 days	Mon 11/11/13	Fri 1/17/14	6SS	
8		Game & Fish	50 days	Mon 11/11/13	Fri 1/17/14	7SS	
9		Safety	50 days	Mon 11/11/13	Fri 1/17/14	8SS	
10		Research Complete	50 days	Mon 11/11/13	Fri 1/17/14	9SS	
11		**MODELING**	**63 days**	**Sat 11/16/13**	**Wed 2/12/14**		
12		Project Survey	23 days	Sat 11/16/13	Wed 1/29/14		
13		USGS Data	10 days	Thu 1/30/14	Wed 2/12/14	10	
14		HEC-HMS	10 days	Thu 1/30/14	Wed 2/12/14	10,12	
15		HEC-RAS	10 days	Thu 1/30/14	Wed 2/12/14	10,12	
16		Modeling Complete	0 days	Wed 2/12/14	Wed 2/12/14		
17		**IMPACTS**	**15 days**	**Fri 1/24/14**	**Thu 2/13/14**		
18		Political	15 days	Fri 1/24/14	Thu 2/13/14		
19		Social	15 days	Fri 1/24/14	Thu 2/13/14		
20		**ANALYSIS**	**16 days**	**Sat 2/15/14**	**Fri 3/7/14**		
21		Geomorph	16 days	Sat 2/15/14	Fri 3/7/14	10	
22		AutoCAD	15 days	Mon 2/17/14	Fri 3/7/14	10	
23		Hydraflow Express	16 days	Sat 2/15/14	Fri 3/7/14	10	
24		Bently W. Gems	16 days	Sat 2/15/14	Fri 3/7/14	10	
25		Culvert Master	16 days	Sat 2/15/14	Fri 3/7/14	10	
26		Analysis Complete	0 days	Fri 3/7/14	Fri 3/7/14		
27		**DESIGN**	**16 days**	**Sat 3/8/14**	**Fri 3/28/14**		
28		Structure	16 days	Sat 3/8/14	Fri 3/28/14	10,16,26	
29		Armor Existing Stucture	16 days	Sat 3/8/14	Fri 3/28/14	10,16,26	
30		Design Complete	0 days	Sat 3/8/14	Sat 3/8/14		
31		**REPORTS & PRESENTATION**	**54 days**	**Mon 2/17/14**	**Thu 5/1/14**		
32		50% Design Report	19 days	Mon 2/17/14	Thu 3/13/14		
33		Interim Presentation	19 days	Mon 2/17/14	Thu 3/13/14		
34		Final Presentation	20 days	Mon 3/31/14	Fri 4/25/14	1,30,10,16,26	
35		UGRADS Presentation	0 days	Fri 4/25/14	Fri 4/25/14		
36		Final Report	24 days	Mon 3/31/14	Thu 5/1/14	1,30,10,16,26	
37		Project Complete	0 days	Thu 5/1/14	Thu 5/1/14		

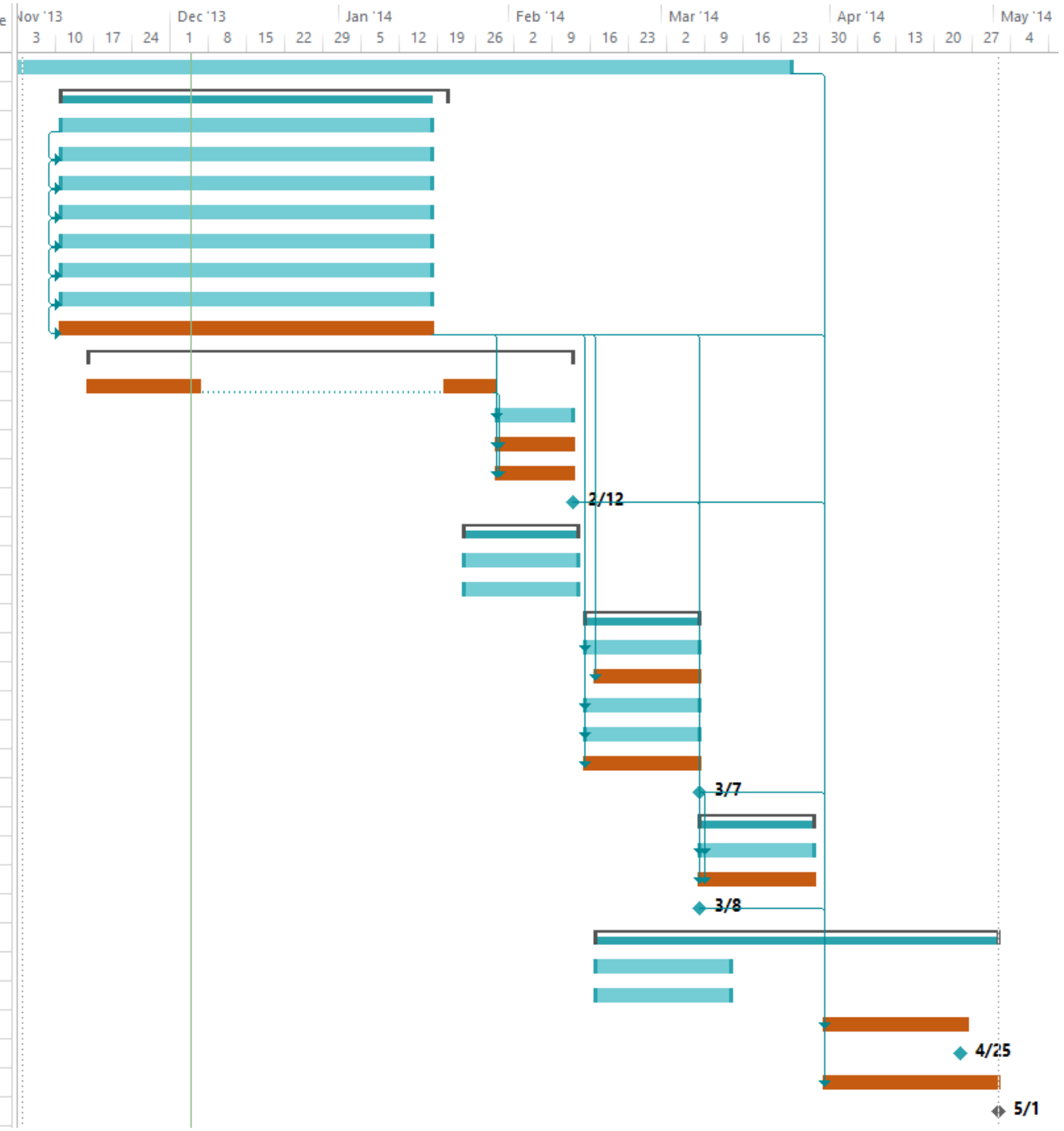

Figure B-1: Schedule with Critical Path marked in dark orange