BYU ENGINEERING
Civil & Construction Engineering

CAPSTONE

CENTRAL UTAH WATER CONSERVANCY DISTRICT
WATER DEVELOPMENT PROJECT
PROJECT ID: CEEN_CPST_019

by

Team 19
Brayden Allsop
Jaide Bosen
Olivia Neeley

A Capstone Project Final Report

Submitted to

Derek Bruton
Central Water Conservancy District

Department of Civil and Construction Engineering
Brigham Young University

April 11, 2022

Executive Summary

PROJECT TITLE: CENTRAL UTAH WATER CONSERVANCY DISTRICT WATER DEVELOPMENT PROJECT
PROJECT ID: CEEn_CPST_019
PROJECT SPONSOR: CUWCD
TEAM NAME: Team 19

Central Utah Water Conservation District (CUWCD) has developed a hydraulic model of the CUWCD Water Development Project (CWP). This water transmission system uses both treated surface water from a treatment plant and groundwater from deep wells. This model has not been calibrated. This project will use extensive Supervisory Control & Data Acquisition (SCADA) data to calibrate the hydraulic model. The necessary engineering specialties include hydraulics and water system modeling. The desired outcome is a calibrated hydraulic model of the water transmission system, including pipelines, pumps, storage tanks, pressure relief valves, and other similar features.

The overall objective of the project is to calibrate, run, and analyze the results of the existing CWP water transmission model. The tasks necessary to complete the project are to receive and organize SCADA data, interpolate the data into an EPANet acceptable format, and calibrate against the observed values. Two progress reports were written throughout the project's lifespan and the model was adjusted to better match previously recorded data. After determining the accuracy of the existing model against observed data, the team created realistic demand patterns representing the water flowing through the system. Using the pressures calculated by the EPANet model, the team could analyze what further steps needed to be made in the calibration process. The scheduled timeline for the project consisted of a start date of November 24, 2021, and a completion date of April 11, 2022. A more detailed schedule-timeline is provided in a later section of this document. The deliverables for the project are as follows: a report about the calibration status of the hydraulic model, a presentation stating the team's findings and recommendations, and a poster to present to the Capstone class. A more detailed deliverable description is also provided in a later section of this document.

Table of Contents

List of Figures

List of Tables

Introduction

Utah is the second fastest growing state in the United States, with an almost two percent growth according to the 2020 Census. In addition to the large population increase from 2020 to 2021, Utah is also one of the driest states and experiences severe to extreme drought conditions according to the U.S. drought monitor. Therefore, it is crucial that water demands are continually met as Utah grows. To accomplish this, existing pipeline networks must be analyzed precisely to understand their current capacity and achievable outputs. Modeling of the existing pipelines is required to simulate how current networks would function under higher demands and identify adjustments that may need to be made in the future. Accurate modeling allows water distribution to be more efficiently planned and would decrease excessive water storage. Understanding the exact demands required by current customers is essential to providing necessary water to clients in one of the fastest-growing and driest states in the US.

Central Utah Water Conservancy District (CUWCD) proposed the project of calibrating a previously designed pipeline network for the area of Saratoga Springs, Utah to Vineyard, Utah. The project is entitled Central Utah Water Conservancy District Water Development Project Water Transmission System, shortened to CWP. This system was recreated in a hydraulic model drawing from treated surface water via a treatment plant and groundwater from wells. The purpose of this project is to create a digital representation of the water transmission system to model existing conditions and be used to simulate future expansions. With growing populations in Utah Valley, water demand forecasting is essential for ensuring existing systems can provide necessary water to CUWCD clients.

Completion of this project included regular meetings with the sponsor and faculty advisor, extensive research on EPANet, interpolation of SCADA data, and calibration of the hydraulic model. The project timeline was from November 24, 2021, to April 11, 2022. In the schedule section of this report is a week-by-week plan made by the capstone team, in which understanding of the model is prioritized in the first half of the timeline and completing calibration in the second half. The second half of the schedule also included the team meeting two to three times a week regularly to calibrate the model, write the final report, and create the project's poster.

Regarding this project, it was assumed that the existing model was accurate to the pipelines, pumps, storage tanks, and pressure relief valves already in place. Elevations and tank levels were also assured to be correct in the model, allowing the team to focus on data interpolation instead of building the model. The assumption was made that calibration to an average water demand month, like May, would be the most effective way to calibrate the model. This is due to May not being one of the hottest or coldest months in the year, providing a reliable demand average. As mentioned in the recommendations section of this report, calibration to higher (June) and lower (February) demand months would create an even more accurate hydraulic model.

To begin the project, the team first organized the given data to identify monthly flow averages. Using data from May of 2020, water demand patterns were created to simulate what percentage of water would be flowing through each junction in the system. Average daily pressures were also included in the model for EPANet to calibrate against. The goal of calibrating in EPANet is for all flow demands to be met and use resulting pressures to compare to observed pressure previously inputted into the model. Graphs and statistics comparing computed pressure and the observed pressure are used throughout this report and can be found in Appendix D. The "correlation between means," or correlation coefficient is how the model's accuracy was measured. The plan was to perform future forecasting by increasing demands and identifying locations that would require pumps or pressure control vaults (PCV) within the pipe network if time allowed.

The initial expectations of the project included finding the current accuracy of the model, calibrating the model to given SCADA data, and analyzing the model with future forecasting data to provide CUWCD with recommendations on additional pumps or PCVs to meet increased demand. Due to the complexity of the model, the scope of the project changed to only include analyzing the model's accuracy as is and then tracking adjustments made in the calibration process for an average demand month. The team will include calibration recommendations so the model can be used in future forecasting but delivering those additional calibrated models was not in the adjusted scope.

There are three main deliverables of the project. The first deliverable was the calibrated CUWCD model. This includes the WaterCAD model initially given to the team, the EPANet model, and excel sheet calculations. A final report was also required that included the schedule, methods, design, analysis, and final recommendations for the model. The final report was then reformatted into a presentation for CUWCD. Finally, a poster was created expressing the project's objective, the calibration process, and the water transmission model's initial and current accuracy as the overall results.

Schedule

Week	Team Goals	Brayden	Jaide	Olivia
11/22	Meet with CUWCD	- Email CUWCD	-Propose a work and meeting schedule	-Clarify objectives
11/29	NA- Thanksgiving	-Finish facilities and performance	-Complete schedule	-Finish facilities and project budget
12/6	Submit SOW Begin Calibration	-Proofread SOW before submitting	-exchange data with Derek (SCADA and WaterCAD model)	-contact Dr. Williams about WaterCAD
12/13	NA- Finals week	-download WaterCAD	-download WaterCAD	-download WaterCAD
12/20	NA- Christmas Break	-	-	-
12/27	NA- Christmas Break	-	-	-
1/3	WaterCAD	-WaterCAD training videos	- WaterCAD training videos	-WaterCAD training videos
1/10	Calibration Process	-Meet with Dr. Williams about the calibration process	-Calculate monthly averages	-Practice calibration in WaterCAD
1/17	Data Entry	-Meet with Derek to interpret the data parameters	-Entering demands into model	-Interpreting demand data and with Derek
1/24	Calibration in WaterCAD	-Meet with Dr. Mitchel about contacting sponsors	-Meet with Dr. Mitchel about contacting sponsors	-Meet with Dr. Mitchel about contacting sponsors

		-Trial and error calibration	-Trial and error calibration	-Trial and error calibration
1/31	Switching to EPANet	-Meet with Dr. Sowby about EPANet -Creating demand patterns in EPANet	-Meet with Dr. Sowby about EPANet -Creating demand patterns in EPANet	-Meet with Dr. Sowby about EPANet -Creating demand patterns in EPANet
2/7	Demand patterns and model adjustments	-Assigning demand patterns to junctions	-Calculate demand multipliers for each junction	-Creating demand patterns
2/14	Pressure data and calibration	-Meet with Dr. Sowby about calibration graphs and model errors	-Create pressure calibration data to compare to	–EPANet research into demand dependent models
2/21	Begin drafting final reports	-Renaming nodes to match calibration data -Meet with Derek for naming convention	-Reworking schedule -Meet with Derek for naming convention	-Beginning introduction and adjusting deliverables
2/28	Calibration and report writing	-Adjusting "C" values to get observed pressures	-Tracking calibration statistics between observed and calculated pressures	-Introduction and Deliverables of project
3/7	Calibration and report writing	-Related Issues -Conclusion -Lesson Learned -Design Analysis & Results	-Recommendations -Appendix/formatting -Lesson Learned -Design Analysis & Results	-Introduction -Assumptions & Limitations -Lesson Learned -Design Analysis & Results

3/14	Calibration and report writing	-Adjusting nodes to be visible	-Creating new reservoirs	-Recording statistics
3/21	Calibration and report writing	-Adjusting well locations	-Calculating drawdown and head	- Recording statistics
3/28	Work on Poster	-Compile images	-Compile final data to be used in poster	-Work on converting paper to poster
4/4	Turn in Poster	-Proof read final report	-Work on Final PowerPoint	-Finalize Paper
4/11	Turn in Report			

Assumptions & Limitations

One of the main assumptions of the project was that the existing model is accurate to real-life conditions. Additionally, an assumption of the project was that the month of May could be used as the average data for any given month in the year, given its average temperatures. This created the limitation that the model would be calibrated to only one month's average, providing a slightly less accurate calibration. With direction from the sponsor, it was also assumed that a five percent error would provide an accurate enough calibration of the model.

Another assumption made before being assigned the scope of work is that the manning's roughness values (C values) are the exact same for every pipe at 130. After the teams own calibration, it was discovered that this was a safe assumption to keep. Although each pipe could slightly differ in C value considering variation in slight wear and tear on each pipe, the average remained 130. While this is an assumption, the fact that the C values need to stay right around 130 also acts as a limitation.

It was also initially assumed that the project would require the use of the program WaterCAD, but due to technical difficulties, the team started using EPANet. This decreased the amount of time allotted to calibrate the model. This decision limited the scope of work that could be done for the project. It was adjusted to reflect that only the calibration of the model would be required and forecasting data would be completed only if time allowed.

Considering the fact that the model of the pipeline is geographically representing reality, this introduces limitations that the team faced during calibration. Each junction has an invert elevation, and each pipe has a length, slope, and C value. These physical properties function as limitations as they should not be adjusted while calibrating the model. It also is not expected that the calibration should be perfect, knowing that all of these physical properties do not exactly match reality.

Another interesting limitation faced was in the raw data the team received. The only full year of data the team had to work with was 2020. As everyone knows, Spring of 2020 was the time when the Covid19 pandemic hit. While the average water demands in May 2020 do not seem to be too different from other spring seasons, there might be slight variation due to the unique situation that was experienced during the pandemic. The data received also did not give matching flow data and pressure data for each junction. These limitations were challenging to work around at times, but still enabled the team to reach a higher calibration of the model than when they started.

Design, Analysis & Results

The design process for this project included running the model, interpolating data, and adjusting the model to match observed data. The hydraulic model was provided to the capstone team in an as-built state, with existing elevations and locations of all major pipes, junctions, and reservoirs. For the team to effectively work with the model, the water transmission system was converted into EPANet. Figure 3 shows the model in EPANet without a background map. The choice to move from WaterCAD to EPANet was made because of available resources to EPANet expertise through a faculty mentor and a simpler interface for the one function of calibrating the model. After successfully running the water transmission model the team moved on to data interpolation.

The team was given daily and six-hour averages for parameters including pressure, flow, drawdown, and other variables. The team chose to isolate the daily averages of the month of May 2020. This data year was the only complete calendar year and may be the closest to an average year of water usage before the Coronavirus pandemic in 2020. The month of May was selected as an "average" month and promoted by the sponsor to calibrate to this time period due to the mild weather conditions. At each major junction, flow demands were averaged from each input and used to compute "multipliers" comparing daily flow to the monthly flow. These demand multipliers were used to create patterns to be used in the hydraulic model as shown in Figure 6. The demand patterns dictate the percentage of the daily average flow passed through the associated junction each day. EPANet uses those demand patterns to run the water transmission system and calculate the resulting pressures after meeting demands at each major junction. Loading the pressure data to compare the calculated pressures was done in a similar way to creating the demand patterns. As shown in Figure 7, calibration pressures were averaged and inputted into the model using text files. Graphs similar to Figure 8 were then produced to show the model's accuracy. The graphs compare the calculated values from the model to the observed pressures from SCADA data.

Analysis on the model was done using the previously mentioned graphs and calibration statistics. Initially, the model seemed very well calibrated with a correlation coefficient of 0.928. However, a closer look at the correlation plot revealed a wide range of pressure values computed by the model instead of more precise measurements. Using demand patterns in the model created more precise computed pressures as shown in Figure 9, but instead had a lower correlation coefficient, 0.806 (Table 1). The team consulted with Dr. Sowby to identify faults in the model and how to increase accuracy while maintaining precision. Dr. Sowby was able to assist the team in modeling variable speed pumps instead of single speed that was creating skewed data. The original arrangement of wells and reservoirs was preventing Well 13 from meeting expected demands. The team came to learn that the central reservoirs (QTAquiferA) was too far away from the wells and did not accurately depict the wells' function. To combat this issue, reservoirs were added for each well in the system that the team had data for.

The final well field depicted in Figure 1 resulted in the most accurate hydraulic model. The results presented in this report include a correlation coefficient of 0.922 and five of the twelve junctions analyzed with a percent error lower than 10%. The correlation plot below shows much more precise computed pressure than the "before" model and several junctions close to the 1:1 line on the plot. The junction that remained the farthest from calibrated still saw a nearly 14% increase in accuracy, decreasing from a mean error of 58 to 49. The team saw an overall increase in precision from the model and recommendations are provided later in the report to improve the model's accuracy.

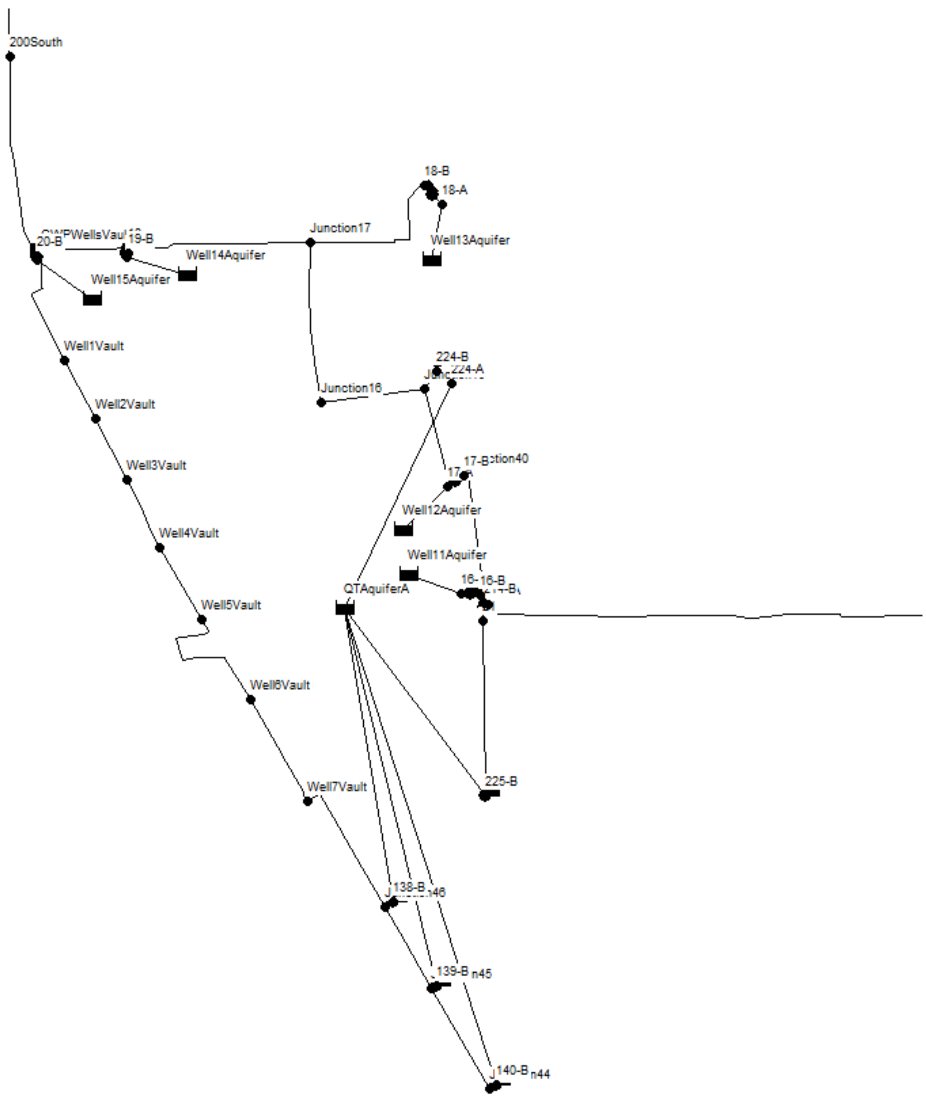

Figure 1. Final well field

Related Issues

The project has several implications to public health, safety, and community welfare. Water is essential to social, environmental, and economical aspects of life across the world. Although sounding very extreme, water projects like CWP are crucial to ensure peoples' water needs are met. It is crucial that any model of a current or future pipeline is accurate in forecasting flow capacity, pressure capacity, demand, and changes to be completed within the pipeline. The calibration of the CUWCD pipeline will have serious implications with the community it serves. The team was entrusted with the responsibility of producing an accurate representation of the CUWCD pipeline.

A calibrated model provides accurate and up to date data of the water transmission system, eliminating any miscalculations from using mathematical hand-predictions. The model can change with the growing demand of the population it serves and aid employees in forecasting possible areas of upgrading faster than before. This saves money, ensures public safety, creates a more efficient work environment, and helps to conserve water. Additionally, the work completed in this project could be used as a baseline of data for other similar pipelines, further innovation, and engineering.

Tax paying citizens trust the city engineers to spend an appropriate amount of time creating a safe and reliable water transmission system. The capstone team falls under these same responsibilities. The team was tasked to create an accurately calibrated model that will be used by CUWCD to provide a safe and reliable water transmission system. If the calibration of the model is not correct or can no longer be used by the city, CUWCD employees will have to go back and redo the work. It would result in tax-payer dollars being used to fix a problem that should have been completed by the team. The model can be used when demand forecasting and can help plan any changes and upgrades to the pipeline so that the most cost-efficient changes can be made in a timely manner. This would decrease the amount of work time spent on improving the pipeline and also help save tax-payer dollars. It is crucial that the team completes the project to the highest degree to keep an economical trust between CUWCD, Brigham Young University, and the people CUWCD serves.

The responsibility of managing water pressure in all pipes and at all junctions could have a direct impact on the safety of the public and workers who work in close proximity to these locations. The model shows the amount of flow and pressure that flows through the given pipeline. The team completed a calibrated model to show the accuracy of the initial model to real-world data. It is important for any maintenance crew working on a pipeline to know the flow and pressure of that pipeline to ensure the safety of every crew member. It is also essential that the calibration of the model is accurate because if the model shows the pipeline can support more flow than in reality a pipe could burst. A burst pipe would endanger any pedestrian in proximity and affect every community member the pipeline serves.

Every citizen who is served by this pipeline is entitled to the same access and quality of water. The water transmission model can be used to evaluate water distribution to each community the pipeline serves. It is the job of engineers to ensure equity is factored into every project. The calibrated model will aid CUWCD in providing reliable service of current water demands to their customers. The model can also be a resource for future water demands as well. As the Utah Valley's population increases, the water demand for the pipeline will also grow. CUWCD will be able to reference and run the calibrated model with varying data to ensure the best service is given to its customers. It will also be able to identify weak areas of the system that may need to be updated for the pipeline to grow with the increasing community, such as where more pumps are needed along the pipeline.

The ratios between observed and calculated data from the calibration data are used to show the model's accuracy and can act as a baseline for similar models. In addition, if future observed values are still within a 5% error to the calibrated model, then the model remains a good representation of reality. All changes made to calibrate the model can also be tracked to adjust models in the future to achieve similar results. This would give any company attempting to create a pipeline model, data to reference and compare. Potentially, the data from this model could be used as a basis for any similar project in or outside the United States. The work done with this calibration could provide the same safety, economic, environmental, and social benefits for any other Utah communities the pipeline serves.

Droughts are common in Utah. As of today, most of Utah is experiencing severe drought and 33.34% of Utah is experiencing extreme drought. It is crucial that every person and company work together to conserve as much water as possible. Droughts affect not only the residents in a community, but also nearby wildlife. It is important to ensure the local reservoirs stay as filled as possible. If water is over pumped into the pipe system, the natural water reserve will deplete, and the well system will overflow with water that could be used elsewhere. The model can help this issue by forecasting future water demand and ensuring the amount is not over-estimated. This will aid in conserving water and bettering Utah's beautiful natural environment.

Lessons Learned

During the time spent on the project, the team experienced a variety of challenges including choosing a calibration software, coordination with the sponsor and the individual team members, learning how to calibrate the model, and re-evaluating the planned scope of work.

Before receiving the hydraulic model, the team decided that WaterCAD would be the best calibration software to use because it was the software used to build the model and seemed to have a user-friendly interface. However, WaterCAD did not provide great resources on the calibration process, the teams advisor had limited knowledge on WaterCAD, and there were coordination issues with the sponsor. To overcome this challenge, the team changed the software to EPANet and found an expert, Dr. Sowby, to help navigate the program. The file format of EPANet fortunately works interchangeably with WaterCAD.

During the calibration phase of the project, there were many barriers to work through to complete calibration. The junctions needed to be labeled with identification numbers, multiple junction inputs needed to be combined/averaged, demand patterns needed to be created and assigned, etc. For the success of the project to prioritize understanding the data and organizing it into correct program inputs.

There were a variety of situations that occurred over the course of the project that made it difficult to meet with the sponsor. The solution for this was contacting Dr. Mitchell and the advisor, Dr. Williams to also reach out to the sponsor. Communication is key for any project to succeed. To help aid the communication of the team and sponsor; the team planned works session twice a week, regular check-ins with the sponsor and faculty advisor every two weeks, and established an effective system to relay urgent information to one another.

The team also learned the value of feedback and rough drafts. There were multiple times between the end of February and March that the team thought calibration was complete. Each time the model was presented to Derek, the team learned more and more about what else needed to be included and the next steps in calibration. Receiving this feedback with each draft only increased the team's knowledge of EPANet, the data, and an important lesson of patience. The team did not get discouraged with each return to the lab, but rather became more curious and thoughtful of the model. This repeated method allowed the team to complete the model to the best of their ability and within the mean error desired by Derek.

Overall, the team learned the value of consistency, communication, and overall teamwork. The ability to bounce ideas off each other during difficult times or when making plans was immensely helpful. The team learned that communication was not just important in an individual team, but also how to seek guidance from sponsors and facility.

Conclusions

The team has found that the existing model from CUWCD is nearly calibrated to real life conditions. The purpose of calibrating a digital water transmission system was to create an accurate model that could be used for forecasting future demands and appropriate adjustments. After completing calibration to the month of May 2020, the team found the model to have a high coefficient of correlation, equaling 0.922. After calibration, the model was producing much more precise values across the entire system, with 43% of the model having a percent error below 10%.

These conclusions were made after a lengthy calibration process of data interpolation and model manipulation. The team identified daily average flow data and created demand patterns for the EPANet model. After renaming major junctions to match the naming convention of the demand pattern data, the team could run the hydraulic model and start analyzing its results. The EPANet model computed resulting pressures from meeting the demand patterns the team input. The computed pressures were then compared to the observed pressures provided by CUWCD. The calibration statistics created by EPANet are provided in Appendix D.

The original objective of the project was to create a model with a 5% error or below. This objective was nearly achieved throughout the entire system with the correlation coefficient of 92%, just 3% short of the initial objective. The calibration statistics provided by EPANet helped the team track the model's accuracy and the included correlation plots showed the model's precision. Using a combination of correlation data, the team was able to conclude that the most precise and accurate state of the model was 92% accurate. All junctions saw at least a 14% growth in accuracy and the team is confident the model better represents realistic conditions.

Recommendations

After calibration, the capstone team found that the model was initially near accurate, but not very precise. Adjustments to produce a more precise model while maintaining accuracy have been documented for the CUWCD's reference.

During the calibration process, it was difficult to correlate the names of each pipe and junction with the raw data that was given. One major recommendation between data collection and modeling would be to coordinate naming conventions. With a uniform system of identifying nodes, there is less translation between collected data and the model.

The scope of the work included the calibration of one average month in one year, the team chose May 2020. Further calibration is recommended for high and low water usage months like July and February, respectively. Any additional calibration would increase the overall accuracy of the model, but the team recommends completing the average calibration to nearly a 100% correlation before attempting other periods. The low and high-water usage months would be the next step to further calibrate the model to fully capture the water demands through a calendar year.

For future capstone teams, the team recommends identifying experts in the modeling software early in the process. Determining the best lines of communication for questions and proper resources is essential to success. With any new software there is a large learning curve and understanding the workings of the model is crucial before any changes can be made. Identifying important data is another recommendation the team has to future capstone groups and mentors. Having clear communication of what data should be used and how would prevent roadblocks and backtracking in the future.

Appendix A: Team Resumes

BRAYDEN ALLSOP

bsam97@gmail.com

801.874.9188

linkedin.com/in/brayden-allsop

606 W 1720 N Provo, UT 84606

EDUCATION

Civil Engineering | Jun 2019 – Present

Brigham Young University
GPA: 3.3

Associate of Science | Jan 2018 – Apr 2019

Utah Valley University

EXPERIENCE

Civil Analyst | May 2021 – Aug 2021|Kimley-Horn

- Assisted in developing 8 different private commercial sites.
- Initiated professional email coordination with engineers, developers, architects, business owners, and land surveyors on a variety of site development projects.
- Worked in AutoCAD and Revu to produce entire site plans on a variety of developments including commercial and multi-family residential projects.

Inventory Manager & Sales Rep | Sep 2018 – Apr 2021|Runner's Corner

- Managed nutrition and select inventory. Created video gait analysis for people and taught them how to buy the correct running shoe.

Customer Service | Apr 2018 – Sep 2018|Cricut Design

- Telephone tech support for product hardware and software.
- Selected to assist in starting the first United States online chat team for customer tech support.

Shipping Tech | Jul 2015 – Sep 2015|Studies Weekly

- Maintained shipping boxes for school textbooks and supplies.

VOLUNTEER / LEADERSHIP EXPERIENCE

I served a two-year church service mission in Washington state, where I taught people about God, provided community service, learned Spanish, and served in a variety of leadership positions.

SKILLS

Experience with AutoCAD, Excel, Revu, ArcGIS Pro, Microsoft Office, and land surveying.

OTHER TALENTS

Building relationships, public speaking, Spanish speaking, collegiate athlete.

Jaide Bosen

(360) 953-7762 *jaidebosen@gmail.com *linkedin.com/in/jaide-bosen/ * hhttps://linktr.ee/jaidebosen

EDUCATION

BRIGHAM YOUNG UNIVERSITY Provo, UT
Bachelor's in Civil Engineering — *April 2022*

- **GPA:** 3.4
- **Scholarships and Awards:**
  - Simpson Strong-Tie Company Scholarship, BYU Weidman Center, Kiwanis Club of Palmer, AK, BYU (Full tuition, College of Engineering, Civil Engineering Department, and Alaska Alumni Scholarships)
- **Programs:**
  - CAD, Civil3D, Revit, VBA, Blue Beam, Arc GIS, RetainPro, and ENERCALC
- **Leadership:**
  - Hull design captain (ASCE concrete canoe), President Elect (Women in Civil Engineering), Global Leadership
- **Extracurricular Activities:**
  - Society of Women Engineers (SWE), Women in Engineering (WE), American Society of Civil Engineers (ASCE), BYU Phi Eta Sigma, American Railway Engineering and Maintenance Association (AREMA)

ENGINEERING EXPERIENCE

BRIGHAM YOUNG UNIVERSITY, Provo, UT
Teaching Assistant — *Aug 2021 – Dec 2021*

- Organizes and manages the Global Leadership course under Dr. Hotchkiss
- Assists and grades over 80 students on a weekly basis

JONES AND DEMILLE, Springville, UT
Structural Intern — *Aug 2020 – Nov 2021*

- Creating models and performing structural calculations for residential and municipal projects
- Completes deliverables within project timelines with 100% completion rate

RESEARCH ASSISTANT, Provo, UT
Research Assistant — *Sep 2019 – Jan 2021*

- Conducted MSE wall research with Dr. Kyle Rollins' and 6 of his graduate students
- Completed 1,500 hours of data analysis and research modeling for theses site design

ACUTE ENGINEERING, Orem, UT
Student Engineer — *Jan 2020 – Aug 2020*

- Completed structural calculations and construction plans for over 100 light framing production homes
- Maintained a maximum of 6-day turnaround time

KEN'S GARDEN CENTER and LAWN TECH, Wasilla, AK
Store Manager — *May 2014 – Aug 2019*

- Trained new employees, managed store front, and implemented work flow systems as the head of customer service

ENGINEERING PROJECTS

CONCRETE CANOE, Provo, UT
Prototype Designer — *Aug 2020 – June 2021*

- Researched, conceptualized, and designed a prototype to assist 400 women of Porcón, Peru
- Collaborated with Peruvians, food science faculty, and researchers to produce an effective quinoa washing product

GLOBAL OUTREACH, Provo, UT and Granja Porcón, Peru,
Prototype Designer — *Aug 2020 – June 2021*

- Researched, conceptualized, and designed a prototype to assist 400 women of Porcón, Peru
- Collaborated with Peruvians, food science faculty, and researchers to produce an effective quinoa washing product

INTERESTS

- Manufacturing, 3D printing/modeling, green infrastructure, tiny homes, kayaking, hiking, and running

Olivia Neeley

(724) 601-3478 • olivialneeley@gmail.com • www.linkedin.com/in/olivia-neeley

EDUCATION

Bachelor of Science, Civil and Environmental Engineering *Dec 2022*
Brigham Young University *Provo, UT*

- 3.59 GPA
- BYU Engineering Together Spotlight, BYU Alumni Scholarship Recipient, BYU Academic Scholarship Recipient, Kimley-Horn Outstanding Performance Award
- Clubs: ITE, WCE Network Chair, ASCE ISWS Chair, SWE, Concrete Canoe, EERI, Hip-Hop
- Relevant Coursework: Transportation Engineering, Concrete, Masonry, and Asphalt, Soil Mechanics, Advanced Application of GIS, Geometric Highway Design, Urban Transportation Planning

SKILLS

- AutoCAD, Civil 3D, Revit, ArcGIS, QGIS, Synchro, IHSDM
- Statistical analyses in R, Scientific writing, Experimental design, Advanced in Excel
- Languages: ASL, basic Spanish, HTML, VBA, Python

WORK EXPERIENCE

Transportation Planner: Active & Multimodal Transportation *Jan 2022-Present*
Utah Department of Transportation *Provo, UT*

- Create grant list for Utah First and Last Mile study with over 1000+ projects
- Develop routes for the 4 UDOT regional officials to experience in the Walk the Road program
- Research and aid in development of the first Healthy Places Index for the state of Utah

Civil Intern: Transportation Analyst *May 2021-Aug 2021*
Kimley-Horn: Planning & Design Engineering Consultants *Salt Lake City, UT*

- Data collection, analysis, and writing for 14 Traffic Impact Studies
- Completed modeling and safety analysis for 3 Intersection Control Evaluations
- Calculated trip generation, assignment, and distribution for 14 contracted projects
- Wrote and edited 6 letters of support, 3 grants, 2 public forum presentations
- Experienced traffic counting in the field

Research Assistant *Sep 2021-Present*
Transportation Lab – Scooter Project *Provo, UT*

- Plan out scooter riding routes, where pavement-smoothness data is collected
- Research and decide program fit to make a street network to analyze collected data
- Analyze 5 plus literature articles on the topic and write a literature review
- Collaborate with 3 other students to balance research, data analysis, and riding

Teaching Assistant *Aug 2021-Present*
Geographic Information Systems Course *Provo, UT*

- Lead lab sections of 40 students twice a week to teach geotechnical, surveying, and ArcGIS Pro skills
- Construct 14 lab activities that teach the fundamentals of geographic information systems
- Aid in teaching 80 students in lecture 3 times a week answering conceptual questions and guiding math problems

INTERESTS

- Basketball, Soccer, Dance, Gymnastics, Outdoor Sports, BYU Track and Field Heptathlete

Appendix B: Stages of the Model

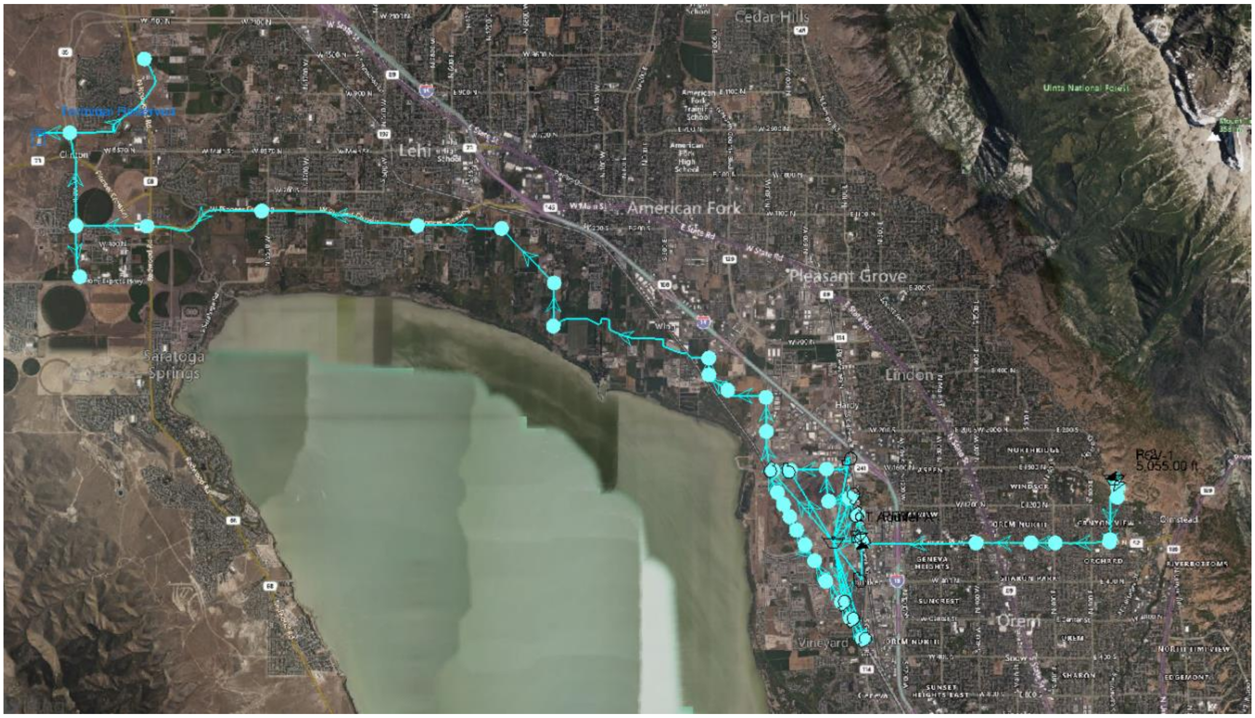

Figure 2. Original WaterCAD Model created by CUWCD

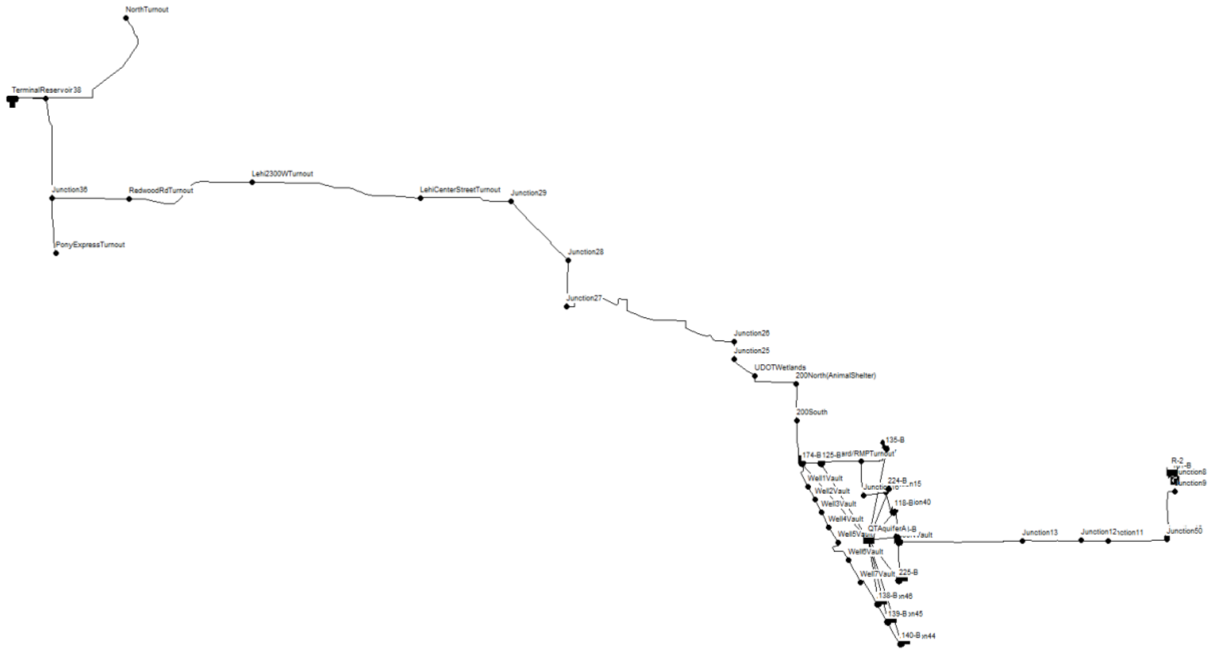

Figure 3. Original model loaded into EPANet

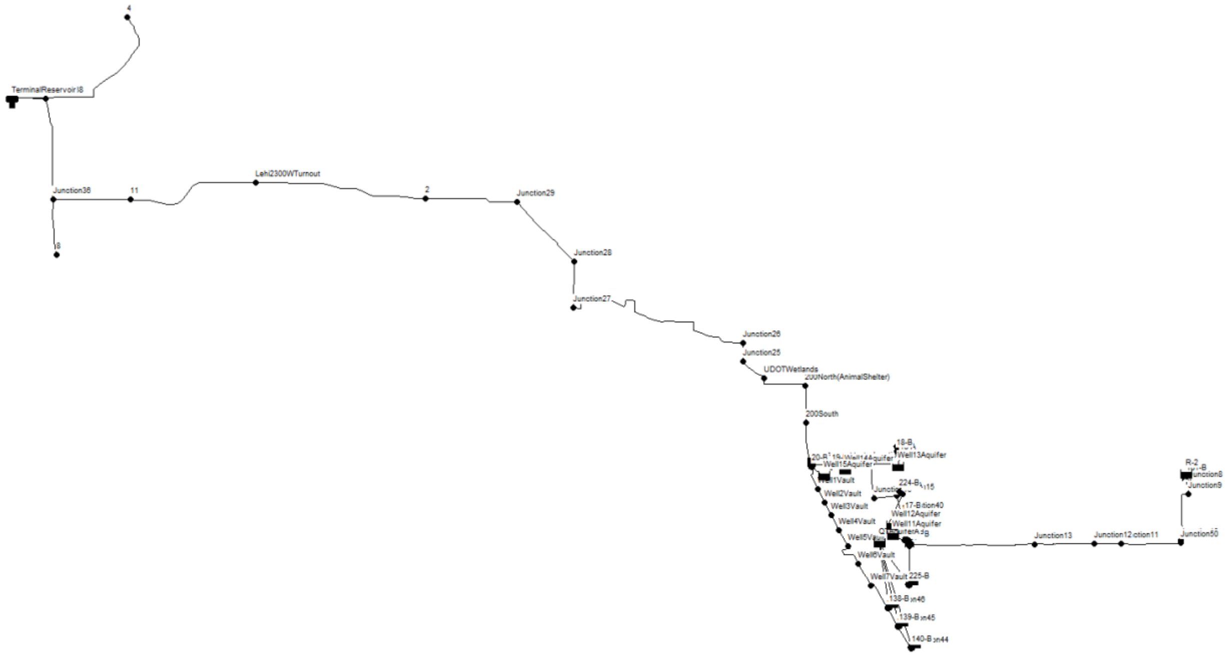

Figure 4. Final EPANet model

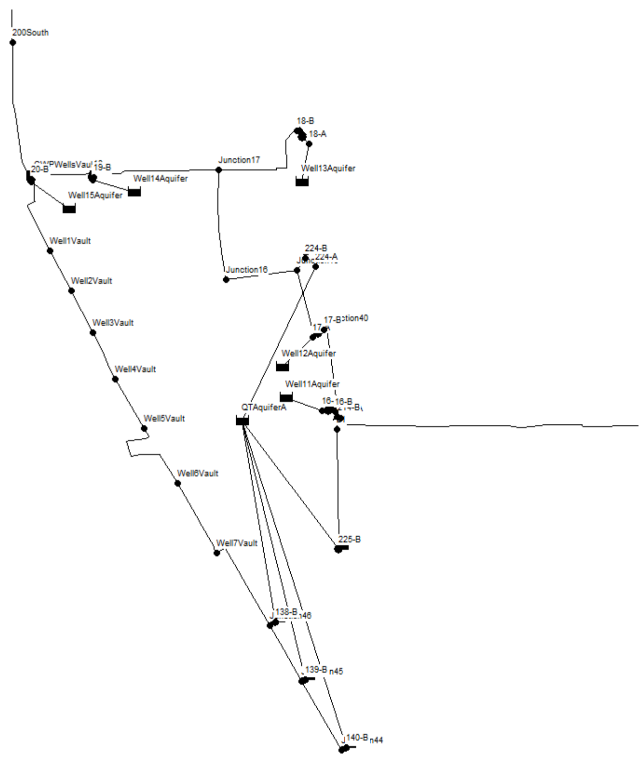

Figure 5. Enlarged view of the final well field

Appendix C: Data

Table 1. Raw SCADA flow data. (May 2020)

data_tag	Time Stamp	Value	Location	Parameter	Units
CWP.LCLEHIFLOW.F_CV	5/10/2020 12:00:00 AM	1397.46707	Lehi Center	Flow	gpm
CWP.NTJVFLOW.F_CV	5/10/2020 12:00:00 AM	5670.821462	North Turnout	JVWCD Flow	gpm
CWP.NTLEHIFLOW.F_CV	5/10/2020 12:00:00 AM	398.2199772	North Turnout	Lehi Flow	gpm
CWP.NTSARAFLOW.F_CV	5/10/2020 12:00:00 AM	850.5479446	North Turnout	Saratoga Springs Flow	gpm
CWP.PXEAGLEFLOW.F_CV	5/10/2020 12:00:00 AM	3785.3412	PX Turnout	Eagle Mt. Flow	gpm
CWP.PXPFLOW.F_CV	5/10/2020 12:00:00 AM	3801.118504	Pony Express Pump Station	Eagle Mt. Flow	gpm
CWP.PXSARAFLOW.F_CV	5/10/2020 12:00:00 AM	0	PX Turnout	Saratoga Springs Flow	gpm
CWP.RMP_12FLOW.F_CV	5/10/2020 12:00:00 AM	1228.008015	RMP Vault	Pacificorp Flow	gpm
CWP.RMP_6FLOW.F_CV	5/10/2020 12:00:00 AM	0.047049367	RMP Vault	Vineyard Flow	gpm
CWP.RWFLOW.F_CV	5/10/2020 12:00:00 AM	0	RR Turnout	Saratoga Springs Flow	gpm
CWP.TRFLOWEFFLUENT.F_CV	5/10/2020 12:00:00 AM	15.3605556	North Shore Terminal Reservoi	Outflow	gpm
CWP.TRINFFLOW.F_CV	5/10/2020 12:00:00 AM	6989.215623	North Shore Terminal Reservoi	Inflow	gpm
CWP.UV4PIPEFLOW.F_CV	5/10/2020 12:00:00 AM	30.96131172	Interconnect Vault	800 N Aq. Flow	CFS
CWP.VV_12FLOW.F_CV	5/10/2020 12:00:00 AM	0	Vineyard/Flow Control Vault	Vineyard 12" Flow	gpm
CWP.VV_6FLOW.F_CV	5/10/2020 12:00:00 AM	557.2955097	Vineyard/Flow Control Vault	Vineyard 6" Flow	gpm
CWP.W11FLOW.F_CV	5/10/2020 12:00:00 AM	0.217285599	Well #11	Flow	gpm
CWP.W12FLOW.F_CV	5/10/2020 12:00:00 AM	0.057778577	Well #12	Flow	gpm
CWP.W13FLOW.F_CV	5/10/2020 12:00:00 AM	0.087931615	Well #13	Flow	gpm
CWP.W14FLOW.F_CV	5/10/2020 12:00:00 AM	0.533692269	Well #14	Flow	gpm
CWP.W15FLOW.F_CV	5/10/2020 12:00:00 AM	-0.158145253	Well #15	Flow	gpm
CWP.WMFLOW.F_CV	5/10/2020 12:00:00 AM	27.12185934	Wells Vault	Flow	CFS

Table 2. Calculations to find the daily flow demand multipliers with multiple inputs

	North Turnout		Inputs				
Time	Multiplier	ID	JVWCD Flow	Lehi Flow	Saratoga Springs Flow	Sum	Units
1	0.9960	2	5668.20699	403.9675397	852.7776294	6924.952	gpm
2	0.9965	2	5668.728597	404.0151612	856.0581775	6928.802	gpm
3	0.9960	2	5670.838677	400.8514789	853.4374691	6925.128	gpm
4	0.9954	2	5672.321682	394.8115856	853.8230795	6920.956	gpm
5	0.9951	2	5669.358046	397.157615	852.2324653	6918.748	gpm
6	0.9949	2	5667.441114	396.8634684	852.9587699	6917.263	gpm
7	0.9956	2	5669.86352	397.9699638	854.3455823	6922.179	gpm
8	0.9957	2	5668.055986	403.3199005	851.6972421	6923.073	gpm
9	0.9954	2	5668.358791	399.9921008	852.7615319	6921.112	gpm
10	0.9952	2	5670.821462	398.2199772	850.5479446	6919.589	gpm
11	0.9947	2	5670.632842	394.8020891	850.633879	6916.069	gpm
12	0.9972	2	5670.435208	404.0852217	858.7726458	6933.293	gpm
13	0.9956	2	5669.844702	397.9229358	854.7601931	6922.528	gpm
14	0.9962	2	5668.347933	405.1481774	853.3592132	6926.855	gpm
15	0.9970	2	5676.049353	401.8903641	854.4818445	6932.422	gpm
16	0.9975	2	5680.121644	401.0026511	854.4992761	6935.624	gpm
17	0.9968	2	5683.418276	393.5586985	853.4028292	6930.38	gpm
18	0.9983	2	5680.729905	405.3160765	855.4324958	6941.478	gpm
19	0.9978	2	5682.567388	400.4896432	854.3904584	6937.447	gpm
20	0.9979	2	5684.149466	398.4439544	855.9448352	6938.538	gpm
21	0.9977	2	5680.773626	402.2717808	853.6548078	6936.7	gpm
22	0.9970	2	5682.65056	395.6784907	853.9791481	6932.308	gpm
23	0.9981	2	5682.475442	402.2200431	854.8946748	6939.59	gpm
24	0.9965	2	5682.535587	396.7057288	849.3365983	6928.578	gpm
25	0.9969	2	5681.503725	397.9121805	851.9267086	6931.343	gpm
26	0.9981	2	5682.144576	399.74105	858.174446	6940.06	gpm
27	0.9971	2	5682.421404	398.067988	852.4191327	6932.909	gpm
28	1.0141	2	5681.106624	516.2856194	853.2571086	7050.649	gpm
29	1.0271	2	5684.81016	601.7115192	855.0385796	7141.56	gpm
30	1.0266	2	5681.079604	599.9709215	857.1653806	7138.216	gpm
31	1.0259	2	5681.866919	597.5456698	853.8030516	7133.216	gpm
						6952.954	

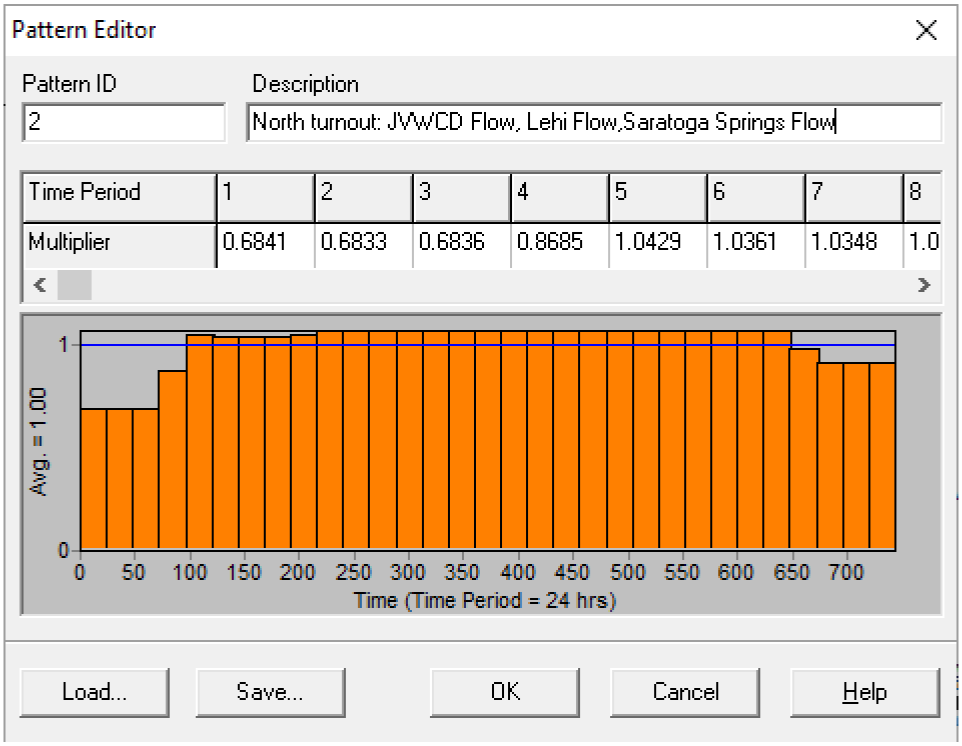

Figure 6. Demand patterns loaded into EPANet

```
;	Lehi Center U/S Pressure
;	Location	Time	Value
;-------------------------------
	2	24	120.6456214
		48	120.7290825
		72	120.9956528
		96	120.9437919
		120	120.5852163
		144	120.3876993
		168	120.3618178
		192	120.6424113
		216	121.2799512
		240	121.4833339
		264	121.091054
		288	120.8769534
		312	121.3843131
		336	121.5973768
		360	121.8435007
		384	121.9526999
		408	121.9545588
		432	121.0860582
		456	120.044852
		480	120.1823671
		504	120.2845929
		528	120.0833713
		552	119.9510606
		576	119.742374
		600	119.6267438
		624	119.9867879
		648	120.7762159
		672	120.3096278
		696	120.216249
		720	120.6206459
		744	120.9035352
```

Figure 7. Pressure data for an individual junction in EPANet for calibration

Appendix D: Calibration Statistics

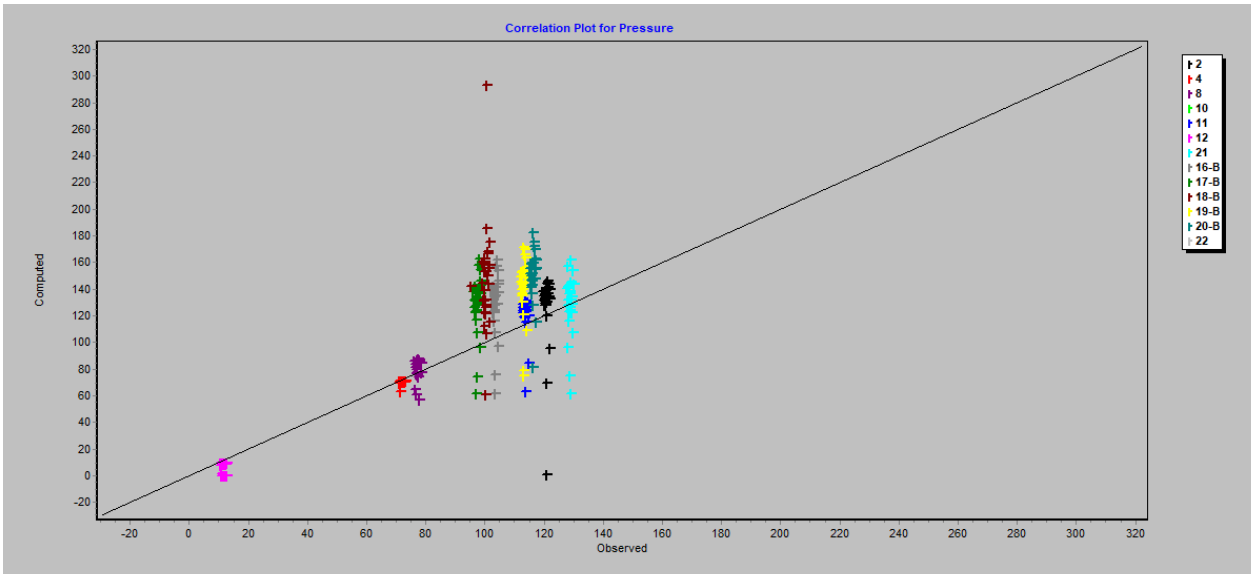

Figure 8. Pressure correlation Plot (PCP) for the initial model

Table 3. Calibration Statistic for pressure of the initial model

Calibration Statistics for Pressure

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
2	30	120.72	126.83	19.330	28.283
4	23	71.92	70.32	1.613	2.216
8	27	77.14	79.63	6.677	8.256
11	29	113.59	121.09	13.061	15.789
12	30	11.56	6.82	4.744	6.229
21	30	128.72	129.01	14.605	21.137
16-B	30	103.35	129.32	31.135	33.463
17-B	30	97.28	129.22	35.985	38.333
18-B	30	100.20	146.65	49.092	58.912
19-B	30	112.97	141.63	33.880	36.019
20-B	30	116.14	147.97	36.627	38.822
Network	319	96.42	112.86	23.066	31.358

Correlation Between Means: 0.928

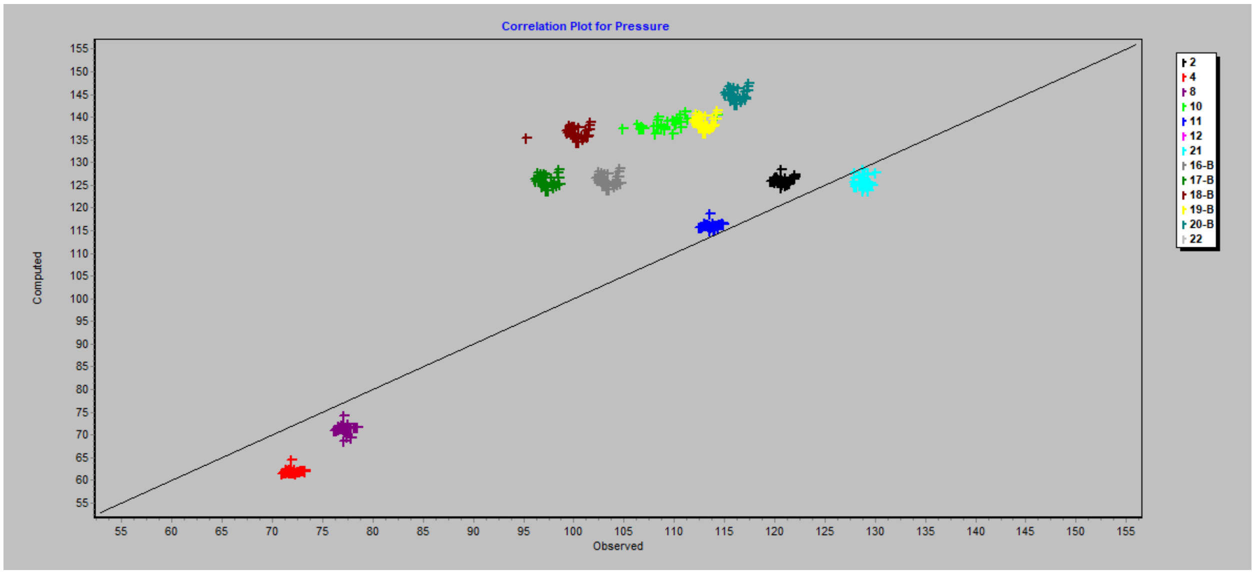

Figure 9. PCP for the model with observed demand patterns

Table 4. Calibration Statistic for pressure of the model with observed demand patterns

Calibration Statistics for Pressure

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
2	30	120.72	126.05	5.326	5.407
4	30	71.94	61.98	9.961	9.990
8	30	77.19	71.31	5.884	6.000
10	30	109.21	138.54	29.330	29.372
11	30	113.59	116.10	2.506	2.644
21	30	128.72	125.83	2.887	3.161
16-B	30	103.35	126.04	22.684	22.727
17-B	30	97.28	125.87	28.589	28.623
18-B	30	100.20	136.47	36.270	36.301
19-B	30	112.97	138.76	25.796	25.832
20-B	30	116.14	144.91	28.769	28.800
Network	330	104.66	119.26	18.000	21.732

Correlation Between Means: 0.806

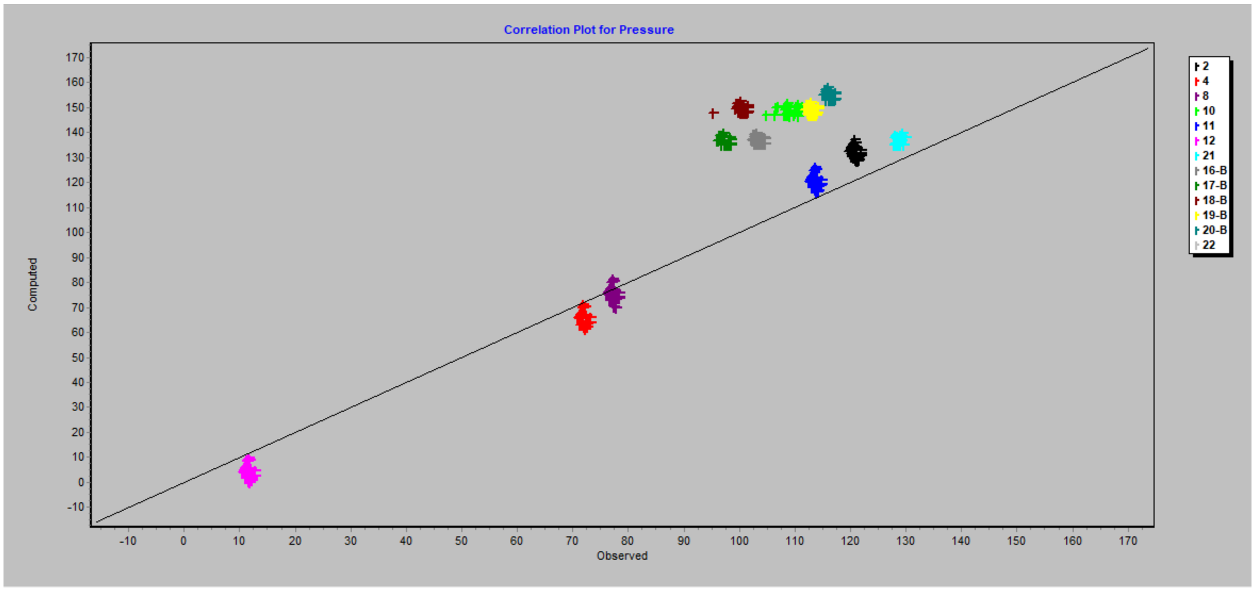

Figure 10. Calibrated PCP

Table 5. Final calibration statistics for pressure

Calibration Statistics for Pressure

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
2	30	120.72	132.59	11.867	12.193
4	30	71.94	66.21	5.733	6.601
8	30	77.19	75.82	3.069	3.758
10	30	109.21	148.74	39.533	39.595
11	30	113.59	121.01	7.414	8.071
12	30	11.56	4.78	6.783	7.523
21	30	128.72	136.74	8.017	8.132
16-B	30	103.35	137.04	33.690	33.741
17-B	30	97.28	136.81	39.530	39.574
18-B	30	100.20	149.58	49.383	49.420
19-B	30	112.97	149.00	36.035	36.091
20-B	30	116.14	154.91	38.774	38.827
Network	360	96.91	117.77	23.319	28.750

Correlation Between Means: 0.922