Department of Civil Engineering
Wentworth Institute of Technology
Boston, MA 02115

Technical Memorandum

Date:	July 9, 2019
To:	Dr. Gautham P. Das, Elder Endowed Professor
From:	Jake Berry , Amanda P. Siciliano , Brad Walden
Subject:	Design Report for Grayson Water Distribution System

Dear Dr. Das,

Attached please find SWB Engineer's preliminary design for the proposed water distribution system throughout the town of Grayson, Georgia.

This design is based on the information provided to SWB through the project contract documents distributed to all consulting engineering companies. Please note that any revisions to the existing conditions in Grayson could result in a change in the proposed design.

This design assumes that all involved parties will work together to develop a sustainable and constructable water network. Please note that all engineering assumptions and justifications are clearly noted in the proposal.

Thank you for providing SWB this opportunity. The company looks forward to hearing from Grayson.

Sincerely,

SWB Engineers

Executive Summary

The town of Grayson is bidding a redesign of their water distribution system. The community needs advising on a new water system that will meet the demands of the current and future operations. Currently, the issue in consideration is that Grayson anticipates a growth in population and business, which the preexisting system cannot handle. SWB is investigating the existing issues in order to provide a feasible engineering solution. Through a variety of hydraulic engineering techniques, SWB is able to approach this redesign. The methods involved in executing this project requires an understanding of the town layout, population growth, water demands, needed fire flow, pipe sizing, and pump selection. This method determined that the town of Grayson required a water distribution system with a H24XHC pump. This pump is able to deliver 12.9 million gallons per day throughout the town's underground Schedule 40 Steel network. This principle finding comes as a time and cost effective solution in designing a water distribution system for the community.

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Introduction

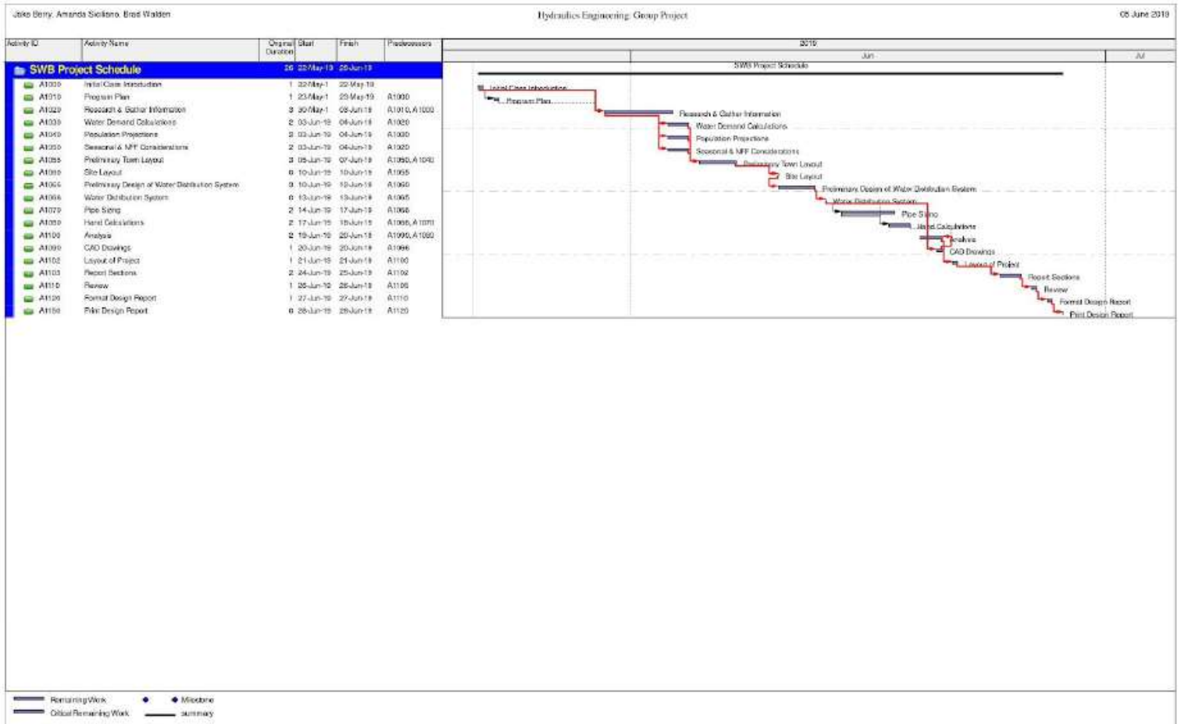
Project Overview

The town of Grayson, GA consulted SWB Engineers to create a preliminary design for a water distribution system. This design, with a fifty year life span, considered the varying components located within Grayson in order to meet the needs of the town. When analyzing the existing water supply layout, SWB learned that it was both inefficient and outdated, requiring new innovative solutions to help the growing needs of Grayson. Appropriate distribution systems are fundamental in maintaining the health and wellbeing of a community. Because of the recent population growth within the town and advancements in the managing of natural resources, the town of Grayson will profit from the installment of an effective and individualized water distribution system. This updated system ensures the proper quality, quantity, and pressure of delivered water.

In this report, SWB Engineers explains the justification of the engineering solutions and assumptions made throughout this project. Within this engineering report, please find a plethora of information that covers the problem statement, description of layout & method of computation, discussion & analysis of design results, CAD drawings, conclusion, and appendix.

Company Background

Established in 1963, SWB Engineers offers a variety of consulting engineering services related to fluid-dynamics, hydraulics, and coastal engineering. Lead engineers work with clients to create effective design systems, budgets, schedules, and work plans suited for any type of water-related project. SWB utilizes Wentworth Institute of Technology graduates, ground-breaking software, and professional experience to deliver engineering solutions of the highest caliber. This family business strives to provide feasible projects that are both time and cost effective.



Put the schedule on this page - act as place holder for printing

Meeting Minutes

Date: 22 May 2019
Time: 2 - 330 PM
Location: Library - Study Room 06
Attendance: Amanda, Brad, Jake

Meeting Agenda

- Collect information on water demands
  - Looking at different types of establishments
  - Will also need to consider time frames
- Set up schedule
  - Used Primavera P6 to aid schedule
  - Discussed durations and sequencing
- Outline of map
  - Discussed wanting a + system for water pipes instead of arrows off of corners
  - Residential areas
    - How to handle the number of homes
    - Apartment complexes
    - Divide into 2 or 4 neighborhoods
- Population
  - Estimations
    - P = P0 x e ^ (rt)
    - (50 years = t, 0.03 = r, p0 = 12,000)
    - (look into more of values - considering adding last 5 years and doing an average? - US census Data)
    - @7% 397,385 people
    - Average of the differences
  - Summer swelled population
    - Motels = 3,600 rooms @ 2 = 7,200 people
    - Tents = 132 @ 2 people = 264 people
    - Difference = 1,536 people
      - Assume renting Air BNB's, commuting, or staying with family/friends in the area
  - Design for peak demand and 50 years from now
    - 18,000 max demand in 50 years assuming 3% growth
    - Das used 3% but should we?

        - Design for 40-50 years?
- Questions
    - How do we include time for water demands?
        - Using 8 hour day and then using smaller demand for shorter work days?
    - Population growth
        - We used formula for 7% and got way too high of a number for this town
        - Should we design for 360,000 people?
    - + joints vs Y joints
        - Wanting to more effectively design the town so that there's either 2 or 4 pipes running to a business/neighborhood

- Need more information on
    - Needed fire flow
        - 2 biggest things
    - Pumps
    - Grid systems
    - Design?

Date: 29 May 2019
Time: 2 - 330 PM
Location: Library - Study Room 06
Attendance: Amanda, Brad, Jake

Meeting Agenda

- Schedule
  - Fixed schedule in Primavera P6
  - Needed to edit start and deadlines (original schedule went until July 28th, not June)
  - Included time off for memorial day weekend and Das' wife / him being out of class
- Water demands
  - Decided to add in movie theatre and offices to make town more realistic
  - Was able to find all of info in different areas of information
  - Only for public areas (grocery stores, etc)
  - Still to calculate for residential, tents areas
- CAD drawing of preliminary town layout
  - Working on basic cad drawing from information discussed in class and in previous meeting that was written on whiteboard
- Population estimations
- Technical memo format
- Residential Estimations = 3,000 people
  - Single family complexes (2.5 people / per)
    - **900 households** @ 2.5 people / per = 2,250 people
      - https://datausa.io/profile/geo/grayson-ga/
    - Population increase after 40 years = + 270 households
      - Adds in another 675 people
    - Should we include 1,170 households?
  - Apartment complexes (1.75 people / per)
    - Wanted to make the apartments smaller (figure more people in larger families buy houses)
    - **430 apartments** @ 1.75 people = 753 people
    - Population increase after 40 years = +129 apartments
      - Adds in another 226 people

        - Should we include 559 apartments?
    - Town Center (150 acres @ 30 persons / acre)
        - Possibly add motels in here?
        - Assume population density can come from people working
    - Rest of town (??? acres @ 3 people / acre)
- Summer swelled population = 9,000
    - Motels = 3,600 rooms @ 2 people / room = 7,200 people
    - Tents = 132 @ 2 people = 264 people
    - 9,000 - (motels + tents) = 1,536 people
        - Assume renting Air BNB's
        - Commuting
        - Staying with family/friends in the area
- Population
    - Population year round = 3,000 people
        - Population 9960 people after 40 years, 3% growth
        - Population 22,167 people after 40 years, 5% growth
    - Population = 12,000 people (9,000 summer)
        - Original of 9,000 Population 29,880 people after 40 years, 3% growth
        - Original of 9,000 Population 66,501 people after 40 years,
    - Decided to use 3% growth, as we discussed and felt that 5% growth over 40 years would lead to such a large population increase that Grayson's entire infrastructure would have to be rebuilt
        - For the purposes of this small scale project, wanted to keep certain limitations such as buildings being no more than 3 stories
        - Wouldn't be feasible to support more than 50,000 people with this sized town
    - Estimations
        - P = P0 x e ^ (rt)
        - (40 years = t, 0.03 = r, p0 = 12,000)
    - Information came from:
        - http://worldpopulationreview.com/us-cities/grayson-ga-population/
        - https://datausa.io/profile/geo/grayson-ga/

    - Questions
        - When taking into account the population growth, how should we model the population swell?
            - Should the population year round vs the summer population remain the same, despite the 3% growth over 40 years?

        - Should we design the residential areas to stay as 3,000 people or should we consider the construction and water demand requirements of the new houses to situate the 10,000 people it would grow to after 40 years?
    - As the population grows will there be new construction?

SWB

Date: 11 June 2019
Time: 3 - 415 PM
Location: Library - Study Room 07
Attendance: Amanda, Brad, Jake

Meeting Agenda

- Finalize water demands
  - Also found the value for residential areas
  - Organized by highest to lowest demands
  - Motels, residential, and factories are the highest water demands
- Finalize layout of Grayson
  - Residential / school - 312,260
  - Motel / Tents - 365,280
  - Factories - 93,750
  - Town Center - 60,000
  - Pumps - supplying all water
- CAD Drawings
  - Can't really move things around until we have more info about how to set up the pipe system
- Finalize schedule
  - Keeping as is
  - Could be good to finish early with original deadline
- Question
  - What is the Hardy Cross Method?
    - Do we assume the pipe breakdown is 100% or will water be used/lost along the way?
    - Need to include head loss/friction
  - Should we set up our town so that the flow is the same or use different pipe sizes?

Use 1.2% growth per year --

Date: 19 June 2019
Time: 4 - 530 PM
Location: Library - Study Room 06
Attendance: Amanda, Brad, Jake

Meeting Agenda

- Review needed fire flow
  - Used Guide for determining needed fire flow to estimate values for 2 largest (restaurant, school)
  - Calculated areas based on additional resources
  - Found that total NFF = 11.87 million gallons per day (school ~8.9, restaurant ~2.9)
  - Might want to check with Das - values seem a little high
- Edit the schedule
  - Wants to include dates
  - Fixed to show the dates
- Schematic - town layout
  - Loop 1: 2 seasonal restaurants, 1 bar, offices, movie theatre, barber shop = 14,456
  - Loop 2: 2 seasonal restaurants, 1 grocery store, 2 gas stations = 14,769
  - Loop 3: 1 seasonal restaurant, 1 regular restaurant, 2 bars, 1 grocery store, beauty salon = 14,291
  - Loop 4: 2 seasonal, 3 bars = 15,870
- Next:
  - Pumps + Pipe Sizing
    - Will have to use Appendix E (emailed to us earlier)
    - Table - Friction Loss in Smooth Pipe - E-12/13
  - Hardy Cross

SWB

Date: 26 June 2019
Time: 2 - 330 PM
Location: Library - Study Room 03
Attendance: Amanda, Brad, Jake

Meeting Agenda

- Updating CAD Schematic
  - Decided to label each ones with letters so makes it easier to read
- Pumps + Pipe Sizing
    - Will have to use Appendix E (emailed to us earlier)
    - Table - Friction Loss in Smooth Pipe - E-12/13
- Setting up the Hardy Cross Excel
- Working on the executive summary
- Fixing Population
  - Population year round = 3,000 people
    - Population 5446 people after 50 years, 1.2% growth
  - Population = 12,000 people (9,000 summer)
    - Assume the seasonal populations remains the same (9,000 people) over 50 years
  - Decided to use 1.2% growth, as we discussed and felt that 5% growth over 40 years would lead to such a large population increase that Grayson's entire infrastructure would have to be rebuilt
    - For the purposes of this small scale project, wanted to keep certain limitations such as buildings being no more than 3 stories
    - Wouldn't be feasible to support more than 50,000 people with this sized town
  - Estimations
    - P = P0 x e ^ (rt)
    - (50 years = t, 0.012 = r, p0 = 3,000)
  - Information came from:
    - http://worldpopulationreview.com/us-cities/grayson-ga-population/
    - https://datausa.io/profile/geo/grayson-ga/
- Questions
  - Is the project due next Tuesday?
  - What do we need hand calculations for?
    - We used excel for water demands, needed fire flow

Date: 01 July 2019
Time: 2 - 330 PM
Location: Library
Attendance: Amanda, Jake

Meeting Agenda

- Review missed work from class
- Plan for individual assignments
  - Introduction - Amanda
  - Problem Statement - Amanda
    - Executive Summary
    - Description of town
    - Population Growth
  - Description of Layout & Method of Computation
    - Water Demand Table - Amanda
      - Want to include endnotes for references
      - Talk about splitting fire flow up evenly through the output
    - Needed Fire Flow - Brad
      - Explanation
      - Sample equations
      - Hand Calc
    - Head Loss / Energy Equation - Amanda
      - Explanation
      - Hand Calcs
    - Pipe Sizing - Jake
      - State Assumptions
      - Drawing
      - Include Explanation
      - Using E
    - Hardy Cross - Brad
      - Explanation / Description
      - Hand Calcs
      - Drawing (Jake)
    - Pumps - Jake
      - explanation
      - Hand calcs

- Find online pump tables
- Drawing?

- Discussion & Analysis of Design Results - Jake
- CAD Drawings - Jake
  - Description
- Conclusion - Amanda
- Appendix
  - Hand calcs go in here

Date: 02 July 2019
Time: 830 - 12 PM
Location: Class, Library
Attendance: Amanda, Jake

Meeting Agenda

- Spoke with Das to answer questions
  - Pumps
    - Will need to use a really big pump
    - Q = 10,758 gallons / minute
    - National Pump Company
    - Exit pipe can be just a straight pipe - up to Jake's choice
    - Will have 16 x 18 - ??
  - Pipe Sizing
    - Did this correctly
    - Used E-16 to help size, Headloss / 100 for x axis, converted Q for Y axis
    - Okay to have some bigger than textbook - online resource was good
  - Initial Hardy Cross
    - Correct in splitting the fire flow between the 5 different outlets
    - Don't put these values into Q - do values from the Hardy Cross
  - CAD Drawing
    - Include north arrow on schematic
    - Include where each item goes on the pipes for schematic
    - Will put the Q values on from the end of the hardy cross
  - Binder
    - Make sure to include table of contents
    - Discussion will be explaining why we did everything
      - Why pipe size?
      - Why splitting fire flow?
      - Pump performance curves
  - Appendix
    - Include sample basic hand calcs here
    - Put any tables (NFF)

Problem Statement

Project Objectives

Upon hire as the consulting engineers for the town of Grayson, Georgia, SWB Engineers set about to re-design the layout of the community. Relevant factors, such as town layout, anticipated population growth, business water demands and needed fire flow, have all been considered when creating this preliminary design. The use of a grid system to align the inner town center creates a more favorable layout, where water is supplied from a reservoir through a pump system and distributed throughout the town. Beyond creating an updated town grid to serve the community in a more effective water distribution system, SWB focused on the additional objectives of reviewing pipe sizing, incorporating efficient pumps, using the Hardy Cross technique, analyzing sufficient municipal water supplies, and preparing the necessary drawings, figures, and tables to deliver to the town of Grayson. By presenting the method of computation and a discussion of the design results, SWB aims to advise the community through profitable engineering solutions.

Description of Layout & Method of Computation

Town Layout

A grid network system was used to split up the town center, where different businesses were divided into four quadrants. The different businesses were reviewed for water demands and placed to balance out the system requirements. Additional town businesses, beyond just those currently located in the town, were considered so as to improve the variety of establishments located within Grayson. Four different quadrants compose the inner town center. The northwestern (D) quadrant contains 2 seasonal restaurants, 1 bar, 1 office building, 1 movie theatre, and 1 barber shop. The northeastern (E) quadrant holds 2 seasonal restaurants, 1 grocery store, and 2 gas stations. The southwestern (G) quadrant has 2 seasonal restaurants and 3 bars. The southeastern (H) quadrant of the town center includes 1 seasonal restaurant, 1 year-round restaurant, 2 bars, 1 grocery store, and 1 beauty salon.

The outskirts of the town host the population, education, industry, and water sources. The northwest (A) and northeast (C) corners of the town include the suburbs, where townhouses and apartment complexes house the residents of Grayson. Located nearby, the local school resides in the northern (B) portion of the town. The eastern (F) portion of the town contains the industrial park, where a paper mill and furniture manufacturing facility are located. The southwestern (I) corner addresses the hiking and tenting demand, where a national park and tenting campground are located. For the additional tourists that travel to Grayson, motels are adjacent to the campgrounds. Grayson is supplied with water from the streams and lakes that feed from a reservoir positioned in the southeastern (J) corner of the town, 80 feet below the town.

Population Growth

Another reason the water distribution system needed updating was due to the drastic changes within the population of Grayson. Because of the popular hiking and tenting grounds, the population during the summer months is much larger than that of the year-round population. While there are 3,000 people in the town year round, the popular hiking and tenting grounds cause a population swell of an average 9,000 during the summer months. It is important to evaluate the cyclic patterns of population growth over the span of the fifty year life cycle of the distribution system. In order to consider the changes to the town, a "worst-case" scenario evaluation was considered, as it is important to have a water distribution system that can account for a larger demand than necessary. To evaluate these changes, the following formula was used:

$$P = P_0 e^{rt}$$

Water Demand

To ensure an updated water distribution system, it was important to first consider the water demands throughout the town at maximum usage. The different recreational, education, residential, and commercial establishments located throughout Grayson were evaluated for peak performance across the system lifespan. To evaluate the demands of these establishments, local building codes, business requirements, and building occupancy were reviewed in order to have accurate parameters. These values were recorded based on the maximum population that would occur at the end of the 50 year life span of the updated water distribution system. By estimating the daily water demand for the different businesses for the year 2069, it allows the system to prepare for the maximum daily usage for the varying units.

Needed Fire Flow

In the event of a fire within the community, there must be a sufficient supply of water to extinguish the flame. To determine the needed fire flow for a certain building, the following equation is used:

$$NFF = (C_i) * (O_i) * (1 + (X + P)_i)$$

In this equation, needed fire flow, or NFF, is represented in gallons per minute. X represents the factor related to exposure of the building and P represents the factor related to communication between buildings. The construction factor, Ci, is based off of the construction type and area nearby, found through the equation:

$$C_i = 18 * F * A_i^{0.5}$$

In this equation, occupancy factor, or F, represents the primary usage for the building, while Ai represents the effective area of the evaluated building. In order to calculate the needed fire flow within the water distribution system, two of the buildings with the largest water demands were experimentally "set on fire" to calculate the amount of water required to stop the flames. Due to their large water demands, the school and restaurant were chosen as the two buildings to be evaluated. In case of a serious emergency within the town center, there must be sufficient flow to compensate for the water being used to put out the fire. By knowing the design and construction of each of these buildings, suggested water demand values can be obtained. Values for estimated needed fire flow were assumed to be larger than necessary, as it is better to have a larger factor of safety with an excess amount of water.

Pipe Sizing

The proposed distribution system will feature all Schedule 40 commercial steel pipes. Generally, a Schedule 80 pipe would be used in applications where the pipe would be exposed, whereas a Schedule 40 would be for cases where extra protection is not required (Prabhat 2011). Because of the assumption that this distribution system will be underground, Schedule 40 steel pipes will suffice. In order to correctly size the pipes for the Grayson water distribution system, an initial estimate was needed for the flow rate through each pipe. These flow rates were calculated through the first step of the Hardy-Cross method. Flow rates were estimated to ensure that both the individual junctions and the overall system had equal input and output flows.

When calculating these initial flows, water demand values were rounded up slightly to simplify the pipe sizing process. By using larger water demand values than necessary, population growth, excess water, and needed fire flow values were also accounted for. Next, head loss was calculated using the following energy equation:

$$\frac{p1}{\gamma} + \frac{v1^2}{2g} + z1 - HL = \frac{p1}{\gamma} + \frac{v2^2}{2g} + z2 \ ,$$

Since all of the pipes were assumed to be at the same elevation and velocity, the energy equations can be rewritten as the following equation:

$$HL = \frac{p1 - p2}{\gamma}$$

Once a preliminary flow value was assigned to each pipe in the system and head losses were calculated, Figure E103.3(6) was utilized to determine corresponding pipe diameters (VBS 2006). Other information required to determine pipe size include friction loss per 100 feet of needed pipe, which was calculated through the head loss equation. To determine the pipe size on the graph, the flow rate was projected horizontally until it crossed the vertical projection of the friction loss. It was assumed that if an intersection for the pipe landed between two pipe sizes, the larger pipe would be chosen (VBS 2006). For those pipes that required larger diameters than those listed in Appendix E, an online calculator was used (TLV 2019).

Hardy Cross

When designing a water distribution system, the Hardy Cross is an iterative method that determines the flow in pipes through a network system. In order for the Hardy Cross method to work, some assumptions must first be made. Some of these assumptions include initial flow values and directions, while other factors such as the diameter, length, and roughness of the pipes are known. This method also assumes that there is a relationship between the head loss in the pipes and flow rate.

To start the Hardy Cross, a series of equations are generated to determine initial flow rates. Once the predicted flow rates are calculated, the dimensions of the pipes can be determined for Schedule 40 steel pipes (VBS 2006). Once the area, diameter, size, and length of the pipes are all known, the k values can be calculated in terms of f using the equation:

$$k = \frac{L}{D} * \frac{1}{2*g*A^2} * f$$

In this equation, L is the length of the pipe, D is the inside diameter of the pipe, g is gravity, A is the inside area of the pipe, and k is the resistance to flow.

The relative roughness of the pipes can then be calculated by the equation $\frac{D}{\varepsilon}$. Found in Table 8.2, Pipe roughness, ε, is $1.5 * 10^{-4} ft$ is since all the pipes are Scheduele 40 Steel (Mott and Untener 2015).

To calculate the Reynolds Number for each pipe the following equation is used:

$$N_R = \frac{Q*D}{A*\upsilon}$$

In this equation, Q is the flow rate, measured in cubic feet per second, D is the inside diameter of the pipe, measured in feet, A is the area of the pipe, measured in square feet, and υ is the kinematic viscosity of the water, measured in square feet per second. For this distribution system the water was assumed to be at 50 degrees Fahrenheit, having a kinematic viscosity of $1.4 * 10^{-5} \frac{ft^2}{s}$ .Once all the values are obtained the Hardy Cross method can be applied to achieve the actual flow rates throughout the system.

Pump Selection

In order to compensate for the 80 foot elevation difference from the town of Grayson to the reservoir, a pump is required. The total water demand for the town is needed before determining the proper pump size. This water demand value came from the Hardy Cross method, where flow rates through individual pipe sections were determined. The net pressure suction head is also needed to properly size the town's pump and can be determined through the following equation: .

$$NPSHa = Hsp \pm Hs - Hf - Hvp$$

In this equation, available net pressure suction head, or $NPSHa$, represents the pressure at the suction port of the pump. Other involved factors are the static pressure head above the reservoir, or Hsp, elevation difference, or Hs, head loss in suction piping due to friction and minor losses, or Hf, and vapor pressure head of the water at the pumping temperature, or Hvp. To determine Hsp, the following equation can be used:

$$Hsp = \frac{\text{static pressure above reservoir}}{\gamma}$$

To determine Hf, the following equation can be used:

$$Hf = f(\frac{L}{D})(\frac{v^2}{2g}) + 2(ft)(\frac{Le}{D})(\frac{v^2}{2g})$$

To determine Hvp , the following equation can be used:

$$Hvp = \frac{\text{vapor pressure head of liquid}}{\gamma}$$

Once the NPSHa is calculated, the net positive suction head required, NPSHr, is determined to understand the minimum pressure at the suction port of the pump using the following equation:

$$NPSHr = \frac{NPSHa}{1.1}$$

These NPSH and flow rate values allow for the correct pump sizing. These calculations were crucial in determining a pump that has sufficient power and efficiency. By using engineering solutions, a pump was selected that avoids cavitation, a phenomenon where bubbles form throughout the water in areas of low pressure surrounding an impeller. These bubbles can damage a pump by causing the velocity surrounding the impellers to drastically increase. SWB Engineers considered the cost-effective solution of having a properly designed pipe, in order to supply the town of Grayson with a functioning water distribution system for the anticipated lifespan.

Discussion & Analysis of Design Results

Population Growth

When analyzing the population changes, a 5% annual population growth was originally suggested. However, it was believed that this growth would require a new town infrastructure to account for the drastic increase. After reviewing the changes to the population over the last nine years, it was noticed that the most significant increases occurred in the past four years (WPR 2019). As a result, it was estimated that the town of Grayson would experience a 1.2% population growth over the suggested 50 years. This population growth was assessed for both the year-round population of 3,000, and seasonal population of 9,000. Using the previously stated formula, the calculations indicate that the year-round population will grow from 3,000 to 5,467 while the seasonal population will grow from 9,000 to 16,399. These calculations are projected to be the population amount by 2069.

Water Demand

A variety of sources were used to evaluate the total water demands throughout the establishments in Grayson, as shown through *Table 1.0 Water Demands for Grayson, GA Establishments*. This table assesses the different establishments located within Grayson, and includes the quantity of units and description in order to produce a daily and total water demand.

Table 1.0 Water Demands for Grayson, GA Establishments

Establishment	Quantity (units)	Description	Water Demand (per day)	Total Water Demand (GPD)
Motel	8	$450\ \frac{rooms}{unit}$	$100\ \frac{gal}{room}$	360,000
Residential Townhouses	900	$2.5\ \frac{people}{unit}$	$260\ \frac{gal}{unit}$	234,000
Residential Apartment Complexes	430	$1.75\ \frac{people}{unit}$	$182\ \frac{gal}{unit}$	78,260
Paper Mill	1	Production	$50{,}000\ \frac{gal}{unit}$	50,000
Paper Mill	1	$950\ \frac{employees}{unit}$	$30\ \frac{gal}{employee}$	28,500

Furniture Manufacturing Facility	1	Production	10,000 $\frac{gal}{unit}$	10,000
Furniture Manufacturing Facility	1	175 $\frac{employees}{unit}$	30 $\frac{gal}{employee}$	5,250
Seasonal Restaurants	7	265.3 $\frac{patrons}{unit}$	24 $\frac{gal}{patron}$	44,568
School	1	400 $\frac{students}{unit}$	20 $\frac{gal}{student}$	8,000
School	1	25 $\frac{teachers}{unit}$	15 $\frac{gal}{teacher}$	375
Bars	6	43.83 $\frac{patrons}{unit}$	24 $\frac{gal}{patron}$	6,312
Tents	132	1 $\frac{camper}{unit}$	40 $\frac{gal}{unit}$	5,280
Restaurant	1	120 $\frac{patrons}{unit}$	24 $\frac{gal}{patron}$	2,880
Grocery Stores	2	10,000 $\frac{ft^2}{unit}$	0.16 $\frac{gal}{ft^2}$	3,200
Beauty Salon	1	5 $\frac{chairs}{unit}$	270 $\frac{gal}{chair}$	1,350
Office Complex	1	25 $\frac{employees}{unit}$	20 $\frac{gal}{employee}$	500
Gas Stations	2	3.5 $\frac{pumps}{unit}$	65 $\frac{gal}{pump}$	455
Barber Shop	1	2 $\frac{chairs}{unit}$	55 $\frac{gal}{chair}$	110
Movie Theatre	1	40 $\frac{patrons}{unit}$	2 $\frac{gal}{patron}$	80
Total				**839,120**

One of the largest water demands came from the motel, where 8 units of 450 rooms each required a total water demand of 360,000 gallons per day (GPD). The residential areas required a 234,000 GPD and 78,260 GPD for the townhouses and apartment complexes respectively (Emrath 2017). The paper mill totaled 50,000 GPD for production and 28,500 GPD for employees, while the furniture manufacturing facility required 10,000 GPD for production and

5,250 GPD for employees (USGS 2019). The 7 seasonal restaurants included to address summer population swell used 44,568 GPD, while the 6 bars totaled 6,312 GPD and the year-round restaurant used 2,880 GPD (Flusberg 2016). The school required 8,000 GPD for the 400 students and 375 GPD for the 25 teachers (SFRPC 2006). To account for the large hiking industry, 5,280 GPD were used by the 132 tents (Snodgrass 2007). The included businesses within Grayson, such as grocery stores, beauty salon, and barber shop used 3,200 GPD, 1,350 GPD, and 110 GPD respectively (Action MFG 2019).

Some establishments that were included in anticipation of the growing population of Grayson include an office complex and movie theatre, which totaled water demands of 500 GPD and 80 GPD respectively (Action MFG 2019). The 2 gas stations, with a total of 7 pumps, required 455 GPD (Broward County Florida 2012). While many of the water demands for these establishments were based on the number of students, patrons, or employees per unit, the demand for the grocery stores was based on the square footage of the building. It is projected that the 50 year life span of this water distribution system will have a total water demand of 839,120 GPD.

Needed Fire Flow

In order to determine the needed fire flow for each building, the area and construction class must first be evaluated. The construction of both the school and restaurant fell under Class I, or wood framing. The school was set to hold 400 students and 25 teachers. In order to size the school correctly, data was found that showed each student requires 181 square feet and each teacher requires about 272 square feet (School Planning and Management 2015). This gives an effective area of 79,200 square feet for the school. The restaurant was sized to hold 120 patrons, where each patron requiring 20 square feet and a kitchen requiring about 40% of the building (Total Food Service 2013). Calculations determine that the restaurant has an area of 3500 square feet, a significantly smaller value than that of the school. After evaluating and calculating the Ci factor, rounded to the nearest 250 gallons per minute, it was determined that the construction factor for the school was 6750 gallons per minute and 1750 gallons per minute for the restaurant.

After determining the construction factor, it is important to evaluate the building occupancy factor. Since there are limited concentrations of combustible material in schools for young children, joisted masonry, or C-2, was chosen for the occupancy factor. The restaurant contains furniture and supplies that are moderately combustible, giving a classification of noncombustible, or C-3.

The last two steps involve finding the factor related to the exposure of buildings, X, and the factor related to the communication between buildings, P. Since the school is generally far away from other surrounding buildings, the distance to the closest exposed building was evaluated at 61-100 feet. Also, since buildings within the town of Grayson tend to be shorter than three stories, the length to height ratio used was 1-100. This produced an X value of 0.08. Because of the restaurant's city center location, the distance used to the next exposed building was 11-30 feet and the length to height ratio was 1-100. This produced an X value of 0.17. Lastly, to establish the factor related to communication between buildings, Table 330.B was used (ISO 2008). It was decided that the school would have Class A double door at the end of each passageway, giving a P value of 0. The restaurant was said to have a Class B double door at the end of a single passageway, giving a P value of 0.

After plugging the different evaluated factors into the needed fire flow equation for each building, results indicated that the school would need 8.9 million gallons per day and the restaurant would need 2.9 million gallons per day should either building ever experience a fire.

Pipe Sizing

Since it was known that none of the pipes in the system would be exposed, it was assumed that all of the pipes in the system would be Schedule 40 Steel pipe. To properly find the pipe sizing, it was necessary to calculate the head loss through out the system, which was found to be 127 feet. This value could then be converted to 1.27 per 100 feet of head loss, which is a number needed when using Figure E103.3(6) to find pipe diameters (VBS 2006). This value of 1.27 was constant for all pipes in this system since they were all the same type. Knowing that the pipes would all be schedule 40, the pipes could be sized properly using the assumed flow rates. *Table 1.1 Pipe Sizings* below displays the final selected sizes of pipes used throughout the Grayson's distribution system.

Table 1.1 Pipe Sizings

Pipe Number	Schedule 40 Steel Pipe Size (inches)
1	NPS 20
2	NPS 16
3	NPS 20
4	NPS 10
5	NPS 8
6	NPS 6
7	NPS 8
8	NPS 12
9	NPS 10
10	NPS 10
11	NPS 6
12	NPS 6

Please note that the “NPS” listed represents an empirical unit associated with Schedule 40 Steel pipe sizing. As listed in Table XXX, a wide range of pipe sizes was required in order to make this distribution system run effectively. This system has pipe sizes ranging in diameter from 6 inches to 20 inches. It can be noted that an increase in pipe size usually comes with an increased water demand.

Hardy Cross

After using the Hardy Cross Method, the flow rates in the pipes varied from the initial estimate. The purpose of this method is to achieve a small change in flow rate, or delta Q. After thirteen trials, the change in flow rate produced favorable results, as shown by Table XXX. The first loop achieved a change in flow of $2.09 * 10^{-14} \frac{ft^3}{s}$, the second loop had a value of $-5.30 * 10^{-8} \frac{ft^3}{s}$, the third loop experienced $-1.93 * 10^{-7} \frac{ft^3}{s}$, and the fourth loop had a value of $-5.95 * 10^{-5} \frac{ft^3}{s}$. *Table 1.2 Initial & Final Flow Values* also compares and contrasts the initial and final flow rates, measured in both million gallons per day (MGD) and cubic feet per second ($\frac{ft^3}{s}$).

Table 1.2 Initial & Final Flow Values

Pipe	***Predicted Flow Rate (MGD)***	***Predicted Flow Rate ($\frac{ft^3}{s}$)***	***Actual Flow Rate (MGD)***	***Actual Flow Rate ($\frac{ft^3}{s}$)***
1	6.4	11.89	6.35	11.80
2	4	7.43	4.09	7.60
3	6.5	12.08	6.57	12.20
4	2.4	4.46	2.49	4.62
5	1.2	2.23	1.29	2.40
6	0.6	1.11	0.66	1.22
7	0.8	1.49	0.65	1.21
8	3.4	6.32	3.26	6.05

9	2.2	4.09	2.06	3.82
10	2	3.72	2.22	4.12
11	0.8	1.49	0.66	1.22
12	0.6	1.11	0.38	.71

Pump Selection

From the Hardy Cross calculations, it was determined that the total water flow for the town of Grayson was 12.9 million gallons per day, or 10,758 gallons per minute. In the original contract documents, it was specified that there was an 80 foot difference in elevation between the reservoir and the town. So when calculating NPSHa, Hs was set to a value of 80 feet. It should be noted that this value is negative, since the pump was placed above the reservoir, drawing water upwards. A value of 0.4109 feet was assigned for Hvp, which is a constant number for water at 50 degrees Fahrenheit found in Table 13.2 (Mott and Untener 2015). Hf was calculated to equal 1.29 feet, which was the summation of head losses due to friction loss in the 24" Schedule 40 Steel pipe and the (2) 45 degree standard bends in the pump system. Hsp is the quotient of the static pressure above the reservoir and the specific weight of water, which worked out to be 33.92 feet. All of these values were then added together to get NPSHa, which was -47.78. Please note that the absolute value of this number was used when sizing the pump. The net positive suction head available was then divided by 1.1 to find the NPSHr, which equaled 43.44. Using the NPSHr and total flow rate, it was determined that a H24XHC pump would be required to deliver the necessary amount of water to Grayson, GA (NPC 2017).

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CAD DRAWING PAGE 1

CAD DRAWING PAGE 2

Conclusion

The objective of SWB Engineers' consultation services was to advise the community of Grayson, Georgia on how to create an effective water distribution system, suitable for a 50 year lifespan. To accomplish this goal, the principal engineers reviewed and redesigned the town layout, creating an optimal grid system that would account for population and business growth. Optimal water demands were determined, based on preliminary research, that allowed for the understanding of total water demands and needed fire flow. Using the iterative method of the Hardy Cross, preliminary flow rates were calculated and initial pipe sizing was completed. It was determined that a demand of 12.9 million gallons per day was sufficient to supply water to the town of Grayson. A variety of underground Schedule 40 Steel pipes were used, ranging in diameter from 6 to 20 inches. After completing several variations of the Hardy Cross to increase the efficiency and accuracy of the flow calculations, pumps were reviewed and researched. Due to the large flow required to serve the community, it was determined that an H24XHC pump would be best suited for this water distribution system.

It should be noted that this project serves as a preliminary design report in advising the community of Grayson for the best steps needed to design a water distribution system. It is indeed possible that some of the water demand calculations may contain errors, due to the estimated nature of the anticipated demands required for the various establishments. Since pipe sizing is dependent on water flow, it is possible that these selected sizes may also vary from the actual demand. This report serves as a means of delivering SWB Engineers' solutions and recommendations to improve the water distribution system throughout the town of Grayson.

Appendix

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