International Water Development

Student Design Guides

These design guides cover a variety of topics and are made by students, both for future students and the course as well as those involved in the NGO Engineers Without Borders at UC Berkeley and beyond. Find the guides compiled below and feel free to reach out if you have questions

Instructor: Tyler Waterman

tswater@berkeley.edu / tyswater@gmail.com

Table of Contents

Network Survey Manager and EPAnet Tutorial

Maggie Chen

Abstract

This guide covers how to run a pressure analysis of a gravity fed water distribution system using Network Survey Manager and EPAnet. General basics regarding manual inputting of data into both NSM and EPAnet will be explained followed by how to set up all relevant parameters needed to analyze the system and visualize results. The tutorial will follow an example network based off of a single branch of Panama's India network.

Table of Contents

I. Introduction

EPAnet is a computer program developed by the Environmental Protection Agency to simulate hydraulic behavior within pressurized pipe networks. Models can be built with components including pipes, nodes, pumps, valves, storage tanks, and continuous reservoirs. The program performs calculations for pressure at each node and tank and is also able to follow concentrations of chemicals such as chlorine residuals during a given time simulation. While EPAnet is a great tool available for easy student usage due to its free availability, the program has not been updated since 2008 and the user interface is not the friendliest for inputting large amounts of data.

For this reason, I recommend using an Excel program called Network Survey Manager (NSM) to help with inputting data. NSM is built with Visual Basic for Application code to help check data and quickly visualize the network which can then be exported into multiple file formats, including the input file read by EPAnet. Data can be imported directly into NSM from GIS, GPS, or EPAnet, or can be inputted manually. The following tutorial will only cover manual inputting of data in NSM, as this is the most basic and what is often most available. The EPAnet portion of the tutorial will provide information on how to draw a simple network and input data, as well as how to run and visualize a pressure simulation for a gravity distribution system. Pumps and continuous reservoirs will not be covered, but help on these topics can be found in the EPAnet manual and workbook. In order to run the most accurate EPAnet simulations, a complete data set of GPS coordinates and elevations for all tapstands, tanks, valves, and turns in the distribution network is necessary. Without this information, approximate guesses can be made, but will significantly reduce the reliability of pressure readings and I would recommend obtaining better data before proceeding. Population density and water demand data is also incredibly useful to have on hand, but safe assumptions can be made if this data is not available.

Download links for EPAnet and NSM will be available in an appendix, along with the user manuals for both programs and an EPAnet workbook that has more comprehensive exercises to practice specific aspects of EPAnet. Unfortunately, these programs are currently only compatible with Windows. A downloadable Mac version exists and you are able to draw a network and input data into it. However, you will be unable to run the actual analysis. Lastly, data for the sample network used in the tutorial will also be provided in the appendix.

II. Network Survey Manager Tutorial

1. Setting up the Project

Download NSM from the provided link in the appendix. Open the file and make sure to enable all contents otherwise many of the functions in the program will not work. The “Main” worksheet in NSM is where basic project information can be inputted, provides a check and summary of data inputted, and provides access to many tools. As this tutorial will not cover pumps, navigate to the “Curves” worksheet in NSM and delete any data that may be there. Failing to do so will lead to errors in running your system in EPAnet.

2. Project Basics

Have the data for the example network found in the appendix readily available as it will be referenced for the remainder of the tutorials. At the top of the “Main” worksheet, input a project name. Find the maximum and minimum GPS coordinates of the system. In order to be compatible with EPAnet, all GPS coordinates must first be converted into UTM. NSM has an easy tool to convert coordinates, but it doesn't work in this section. A Google search can be done to find an online converter, or navigate to the "Junction" worksheet in NSM and input your coordinates there. Locate the "Project Setup" toolbar at the bottom of the "Main" worksheet. Fill in two temporary Junction IDs and the lat/long coordinates of your maximum and minimum. Return to "Main" and press 'Coordinates' > 'Projection' > 'Convert Lat Lng to UTM'. Ensure latitudes are in the x-coordinate location and longitudes are in the y-coordinate location, then press 'yes'. The coordinates should now be in UTM and you can copy and paste them back into the max/min cells in the project setup area.

Input maximum and minimum elevations and ensure 'WGS_1984' is selected under 'Datum'. Then, using one of your GPS points, find the UTM zone the project is located in. This can easily be done with a simple Google search. Input this into the respective cell. Your project should now look like this.

Name of the project :		X Coord (E/W)	Y Coord (N/S)	Elevation	Datum	WGS_1984	
India Network	Max	658,557.40	1,001,201	50	UTM Zone	17	P
	Min	658,492	1,001,149	25			
	Decimals	1	1	2			

Figure 1: NSM Project Background

3. Inputting Junctions and Tanks

Under the "Tank" worksheet, fill in columns J-R with the given information. Hovering the cursor over columns M-S in row 2 will provide a description of the information requested.

	J	K	L	M	N	O	P	Q	R	S	T
1	Base data										
2	Tank ID	X-Coord	Y-Coord	Elevation	InitLevel	MinLevel	MaxLevel	Diameter	MinVol	VolCurve	Description
3	Tank1	658'557.3	1'001'200.6	50.00	1.98	0	1.98	2.2	0		

Figure 2: NSM Tank Data

Complete the "Junctions" worksheet with the remainder of the data. Fill in columns J-M. Other information such as demand and time patterns will be completed in EPAnet later. Once all data points have been entered, convert the GPS points to UTM as in step 2. Your tank coordinates will also be converted. Your "Junctions" worksheet should now look like this.

1	Base data							
2	Junction ID	X-Coord	Y-Coord	Find Elev	Demand	Pattern	Emitter	Description
3	V1	658,551.9	1,001,191.5	45.73				
4	V2	658,548.9	1,001,191.9	39.78				
5	Tap1	658,548.7	1,001,195.8	39.78				
6	V3	658,538.3	1,001,196.0	37.62				
7	V4	658,531.4	1,001,194.0	34.01				
8	V5	658,514.5	1,001,189.9	32.57				
9	Tap2	658,501.8	1,001,187.6	30.89				
10	V6	658,500.3	1,001,186.1	30.17				
11	V7	658,501.0	1,001,186.1	29.93				
12	V8	658,496.5	1,001,182.1	29.45				
13	V9	658,491.6	1,001,171.8	25.68				
14	V10	658,501.5	1,001,163.9	32.43				
15	V11	658,497.1	1,001,154.9	35.96				
16	Tap3	658,505.6	1,001,149.3	40.81				

Figure 3: NSM Junctions Data

4. Linking Pipes

Navigate to the “Pipe” worksheet and begin linking junction nodes together. It is important to pay careful attention to the direction junctions are linked. If they are linked in the wrong direction, EPAnet will direct the flow of water in the wrong direction and incorrect pressures would result during analysis. Complete columns H-M and column O. After inputting data for columns H-J, simply pressing ‘Find’ in column K will automatically calculate pipe lengths while taking into account elevation changes. For column M, PVC pipe corresponds to a roughness coefficient of 140 in the Hazen-Williams equation, which will be used in EPAnet to calculate pressures. All pipes should be initially set to open in column O. You should now have the following:

1	Base data								
2	Pipe ID	Node 1	Node 2	Find Length	Diameter	Roughness	Find MinorLoss	Status	Description
3	P1	Tank1	V1	15	50	140		Open	
4	P2	V1	V2	9	50	140		Open	
5	P3	V2	Tap1	4	50	140		Open	
6	P4	V2	V3	14	50	140		Open	
7	P5	V3	V4	11	50	140		Open	
8	P6	V4	V5	19	50	140		Open	
9	P7	V5	Tap2	14	50	140		Open	
10	P8	Tap2	V6	17	50	140		Open	
11	P9	V6	V7	1	50	140		Open	
12	P10	V7	V8	7	50	140		Open	
13	P11	V8	V9	15	50	140		Open	
14	P12	V9	V10	20	50	140		Open	
15	P13	V10	V11	14	50	140		Open	
16	P14	V11	Tap3	16	50	140		Open	

Figure 4: NSM Pipe Data

5. Visualizing the System

A handy tool in NSM is the "Chart" worksheet. This worksheet shows a geographical map of the tanks, junctions, and pipes that you have inputted and can easily be used to help determine if there are any errors such as missing pipe connections. Or, if you are familiar with what your system should look like and the chart worksheet shows something completely different, you will know to check all data. With this tutorial, the map should look like this:

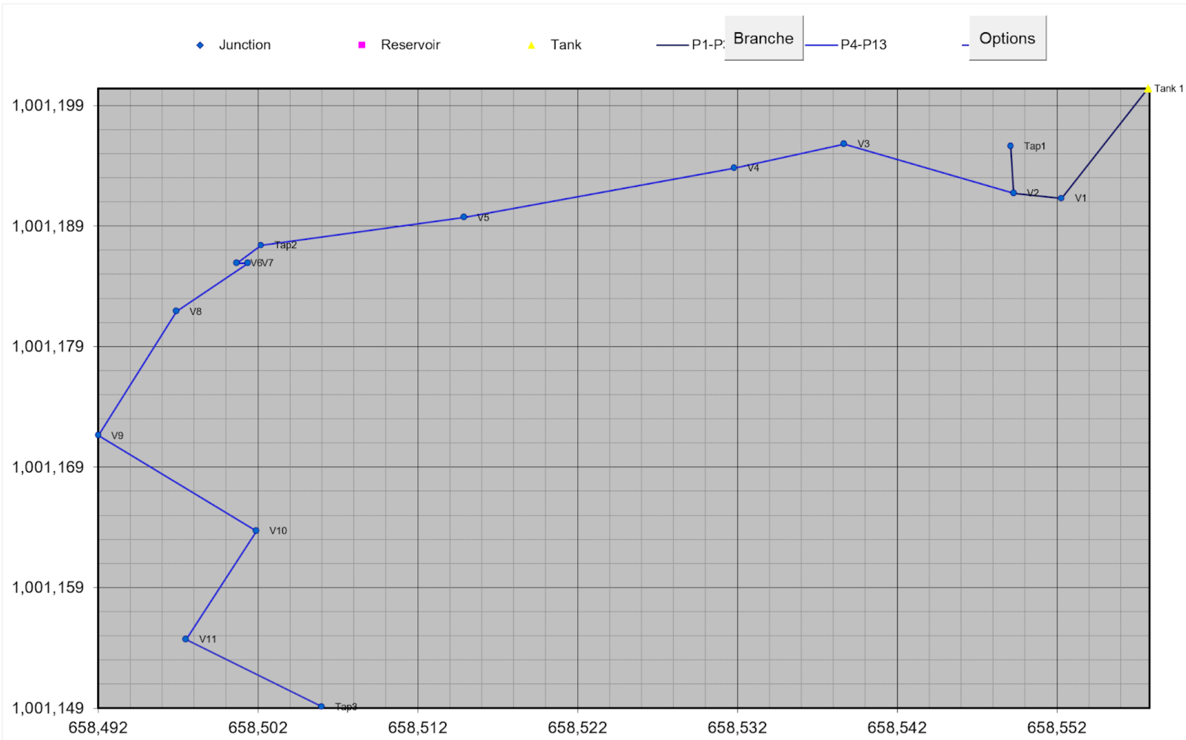


Figure 5: NSM Chart of System

6. Exporting to EPAnet

Make sure to first save this file, then return to the "Main" worksheet and perform the following commands: 'Design and Export' > 'Export File'. It will prompt you for a file name, enter "India Network Tutorial". Make sure 'EPAnet' is chosen under 'Save as type' and save. We are now ready to open the network in EPAnet.

III. EPAnet Tutorial

1. Importing to EPAnet and Setting up the Project

Download and open EPAnet. Follow 'File' > 'Import' > 'Network' and choose "India Network Tutorial" which you saved previously. Then, choose 'Projects' > 'Defaults' > 'Hydraulics'. Under 'Flow Units', choose 'LPS' (Liters per second) and under 'Headloss Formula' choose 'H-W' (Hazen-Williams). Select 'OK'. At this point, the imported network map should look like the following:

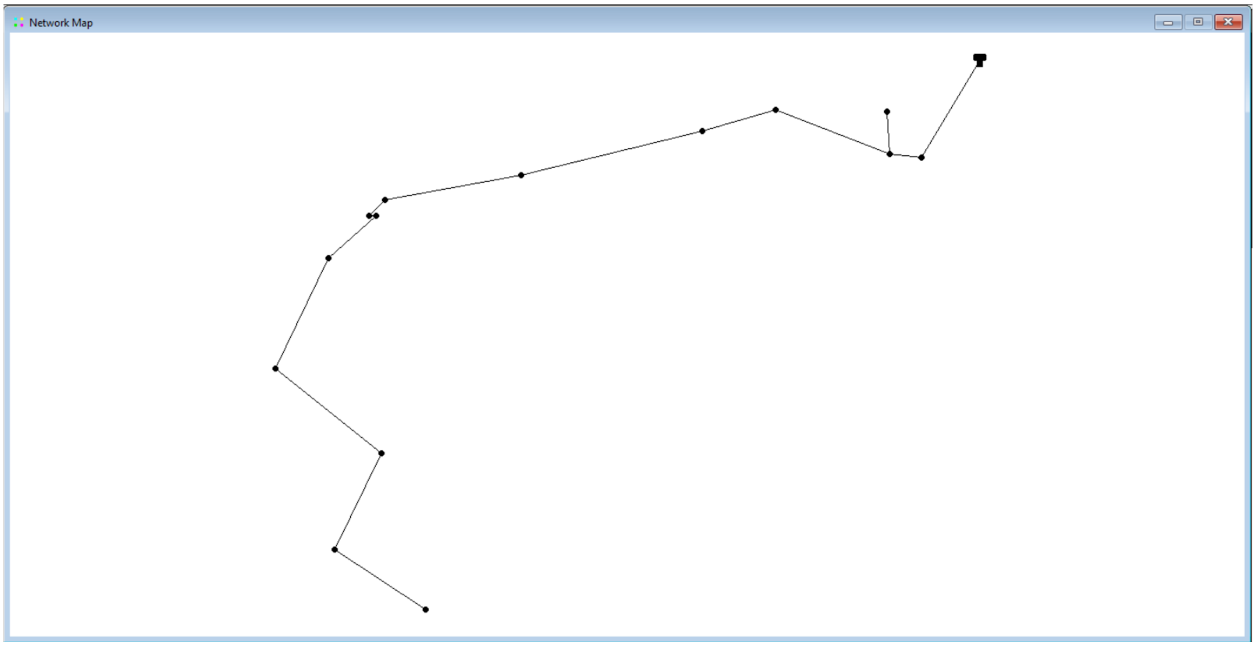


Figure 6: EPAnet Initial Network Map

At the top toolbar, you will see the following tools. Unfortunately keyboard commands do not work on EPAnet, so you will have to constantly switch back and forth between the “select object” cursor, the “pan” tool, and the zoom in/out tools as you work. The second half of the toolbar in the figure below are the drawing tools used to manually draw nodes, tanks, reservoirs, pipes, etc. directly into the network map. Use of these tool won’t be covered here, but they are relatively simple to use and help can be found in the first few exercises of the EPAnet workbook. It is also important to note that EPAnet does not have an “undo” button, so make any changes carefully.

Figure 7: EPAnet Toolbar

2. Minor Losses from Fittings

We now wish to input additional parameters of the system such as minor head losses from fittings and valves and a water demand pattern. These can also be inputted easily in NSM, but we will do this in EPAnet for practice.

EPAnet considers ball valves to be fittings so it does not require drawing a valve onto the system and instead, minor loss coefficients can simply be inputted for the pipes on which they are located. Larger valves such as pressure reducing and pressure sustaining valves would need to be drawn on as separate components. A chart of common loss coefficients is provided in the appendix.

From the example data, ball valves are located at the tank site and by each tap stand. Double click pipe P1 exiting the tank site. Doing so will open a menu showing all the properties of this pipe. Under loss coefficient, input 0.05. Do the same for pipes P3, P7, and P14 which are connected to the tapstands. Follow a similar procedure for the pipes on which tees and elbows are connected. Tees will require inputting two different loss coefficients on two separate pipes-- a branch flow loss of 2.0 on the pipe branching away from the main line and a line flow loss of 0.9 on the pipe following the given junction where it is connected. We see that pipe P3 has minor losses from both a ball valve and the branch flow from the tee at junction V2. Simply add the minor losses: 0.05 + 2.0 = 2.05. Similarly add loss coefficients for pipe P14 which includes losses from an elbow fitting and a ball valve.

3. Water Demand and Distribution Pattern

At this point the entire network has been drawn and all physical parameters have been inputted. It is now time to load the model, which means determining the water demand and distributing it along the network at the tapstands.

First, we must calculate the base demand at each tapstand. The example data gives that this network is serving 200 people at 40 liters per day. Base demand is required in liters per second so the following calculation should be performed: 200 people * 40 liters/day * 1 day/86400 seconds = 0.09 L/s over the entire community. We have 3 tapstands and will assume that the population is distributed evenly amongst the tapstands. Therefore, each tapstand will have a base demand of 0.09/3 = .03 L/s. Double click on each tapstand in the network and input .03 under 'Base Demand'.

As water consumption varies throughout the day, we wish to establish a pattern of consumption. If accurate water usage data is available for the community being modeled, use that data to calculate the consumption pattern and hourly multipliers. An in-depth tutorial on how to calculate multipliers is given in exercise 16 of the EPAnet workbook. For this tutorial, we will assume that consumption peaks once in the morning at 50-60% of water usage and then again in the late afternoon at 25-35% of the water usage. From this, we obtain the consumption pattern provided in the appendix. This is a safe consumption model for water usage in developing countries.

To input this consumption pattern into the model, locate the 'Browser' panel in EPAnet, usually located to the right of the network map. Follow 'Data' > 'Patterns' > 'Add'. In the pattern editor that opens, input '1' under Pattern ID and 'Daily Consumption' as the description. Fill in the multipliers in the corresponding cells and click ok. Select each tapstand junction and input '1' under 'Demand Pattern'.

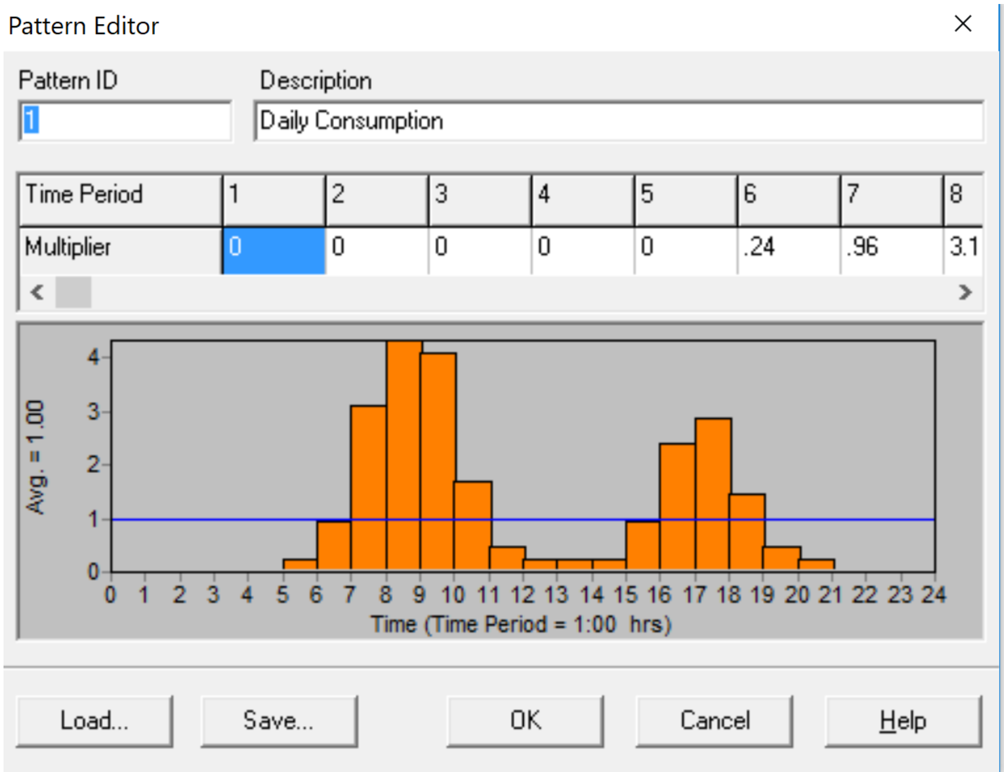


Figure 8: EPAnet Consumption Pattern

4. Running an Analysis and Visualizing Results

Before running the analysis, we want to set up the map to best visualize our results over time. At the 'Browser' panel, navigate to the 'Map' tab. Then, choose 'Pressure' under 'Nodes'. A 'Node Legend' will appear at the top left hand corner of the network map. Click on this to change the colors and values. For this system, we wish to make our minimum pressure 3 m. As the tank is at an elevation of 50 m, this will be our maximum. Choose intermediate values to your liking, something similar to the following:

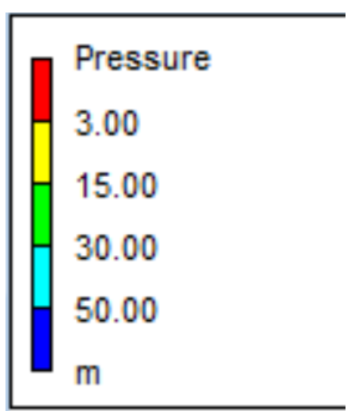


Figure 9: EPAnet Pressure Nodes

Return to the 'Data' tab of the 'Browser' panel. Choose 'Options' > 'Times' and set 'Total Duration' to 24:00. This will allow us to run an analysis of the network over a full day. Check that the remainder of the time options match the following.

Times Options

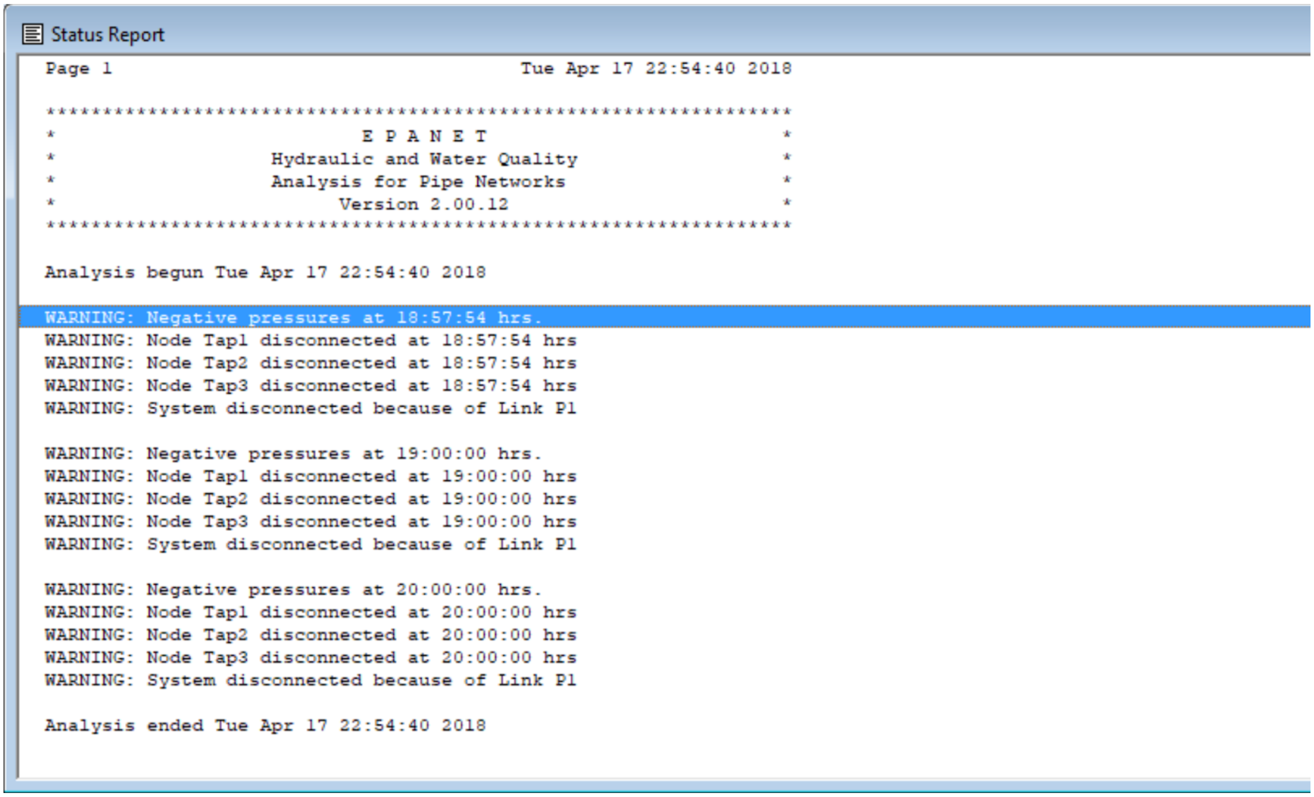
Property	Hrs:Min
Total Duration	24:00
Hydraulic Time Step	1:00
Quality Time Step	0:05
Pattern Time Step	1:00
Pattern Start Time	0:00
Reporting Time Step	1:00
Report Start Time	0:00
Clock Start Time	12 am
Statistic	None

Figure 10: EPAnet Analysis Time Parameters

At the main toolbar, choose the lightning bolt icon to run the analysis. A Run Status message will appear stating that warning messages were generated. Press 'OK'. Minimize the status report window for now, we will return to this later. Return to the 'Map' tab of the 'Browser' panel and press the play button. EPAnet should now show the junctions changing colors corresponding to the pressure legend as the pressure varies throughout the day. Hovering your cursor at any junction or opening the properties panel by double clicking any junction will give the exact pressure at that time.

We see that the pressure is at acceptable levels until 19:00. Return to the status report. The first warning message states that negative pressures exist at 18:57:54 hours. Following this, each tap is disconnected followed by the full system. If we look at the tank properties at 18:00 hours, we see that the net inflow is -0.13 and the pressure is 0.12. From this, it is clear that within the hour, the tank becomes completely empty, explaining why the system disconnects.

If we now change the initial and maximum level of the tank to 2.5 and re-run the analysis, the run is successful and we can see that .45 m of water remains in the tank at 24:00 hours and all nodes receive sufficient water pressure to fulfill demand during the day.



```
Status Report
Page 1                                   Tue Apr 17 22:54:40 2018

******************************************************************
*                           E P A N E T                          *
*                   Hydraulic and Water Quality                  *
*                   Analysis for Pipe Networks                   *
*                         Version 2.00.12                        *
******************************************************************

Analysis begun Tue Apr 17 22:54:40 2018

WARNING: Negative pressures at 18:57:54 hrs.
WARNING: Node Tap1 disconnected at 18:57:54 hrs
WARNING: Node Tap2 disconnected at 18:57:54 hrs
WARNING: Node Tap3 disconnected at 18:57:54 hrs
WARNING: System disconnected because of Link P1

WARNING: Negative pressures at 19:00:00 hrs.
WARNING: Node Tap1 disconnected at 19:00:00 hrs
WARNING: Node Tap2 disconnected at 19:00:00 hrs
WARNING: Node Tap3 disconnected at 19:00:00 hrs
WARNING: System disconnected because of Link P1

WARNING: Negative pressures at 20:00:00 hrs.
WARNING: Node Tap1 disconnected at 20:00:00 hrs
WARNING: Node Tap2 disconnected at 20:00:00 hrs
WARNING: Node Tap3 disconnected at 20:00:00 hrs
WARNING: System disconnected because of Link P1

Analysis ended Tue Apr 17 22:54:40 2018
```

Figure 11: EPAnet Status Report

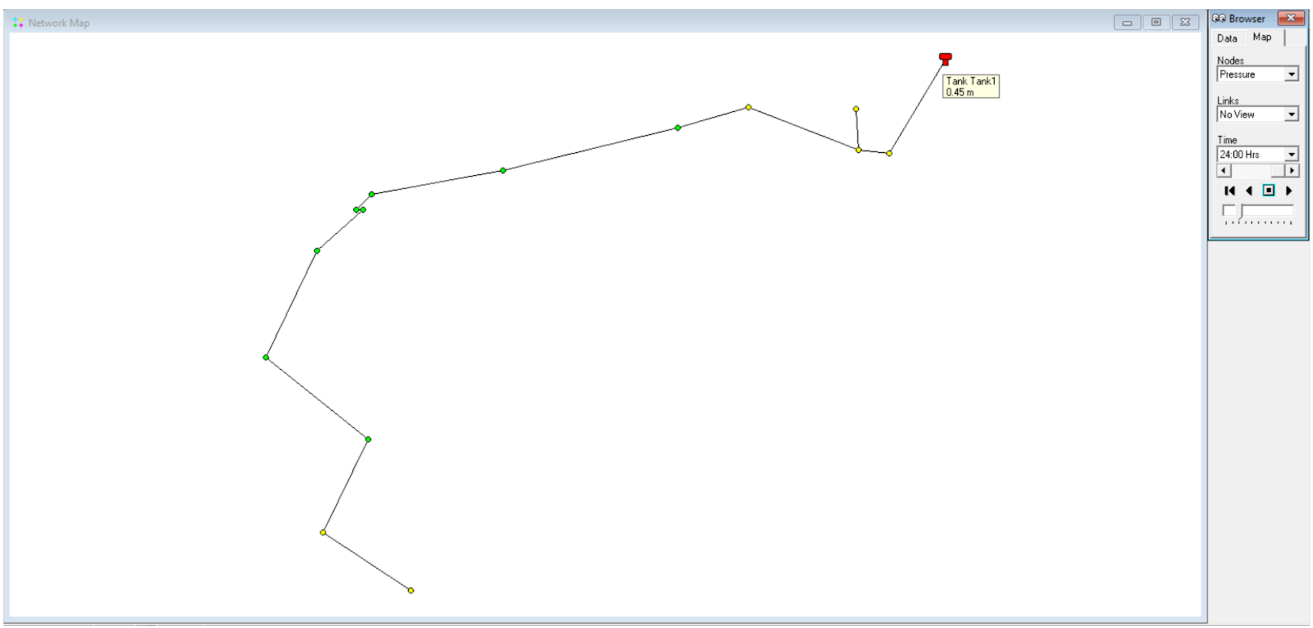


Figure 12: EPAnet Network Map after Analysis

5. Other Ways to Visualize Results

EPAnet also has the capability to tabulate and graph results. At the main toolbar, locate the 'Graph' icon. Select 'Time Series' as the Graph Type, 'Nodes' as the Object Type, and 'Pressure' as the Parameter. At the 'Browser' panel, choose 'Tanks' > 'Tank1', then click ‘Add’ on the Graph Selection window and click ok. We obtain the following graph showing the pressure of the tank throughout the day. This corresponds to the elevation of the water in the tank. We can similarly visualize results for all other junctions. Next to the ‘Graph’ icon is a tool to tabulate results. You can choose what parameters to show and which nodes to include. An example is shown below.

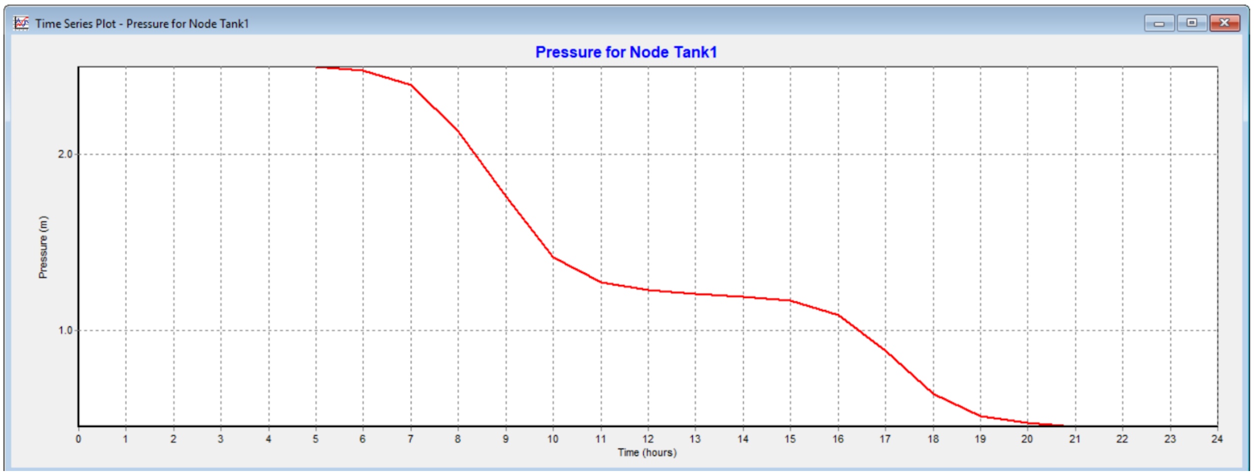


Figure 13: EPAnet Graph of Tank Pressure vs. Time

Network Table - Nodes at 12:00 Hrs

Node ID	Elevation m	Head m	Pressure m
Junc V1	45.73	51.23	5.50
Junc V2	39.77990723	51.23	11.45
Junc Tap1	39.77991	51.23	11.45
Junc V3	37.61694336	51.23	13.61
Junc V4	34.01208496	51.23	17.22
Junc V5	32.57019043	51.23	18.66
Junc Tap2	30.88793945	51.23	20.34
Junc V6	30.16687012	51.23	21.06
Junc V7	29.92651367	51.23	21.30
Junc V8	29.44592285	51.23	21.79
Junc V9	25.68	51.23	25.55
Junc V10	32.43	51.23	18.80
Junc V11	35.96	51.23	15.27
Junc Tap3	40.81	51.23	10.42
Tank Tank1	50	51.23	1.23

Figure 14: EPAnet Table of Junction Results at 12:00

IV. EPAnet Flaws and Common Mistakes

1. Intermittent Flow:

   EPAnet was not developed for usage in intermittent flow networks. However, in many developing countries, it is often the case that the flow of the system is determined by when water is available in the first place, leading to such irregular flows. The main problem with this is that EPAnet assumes a constantly pressurized system. Although full research on how this affects water quality and hydraulic modeling is unknown, it has been previously observed that the roughness coefficient for the pipes decreases due to air pockets in the pipe that develop when water is not flowing, resulting in higher head losses. Additional errors can result if demand multipliers are heavily averaged over long periods of time (i.e. If tanks are filled every 8 days and water is obtained only the first day and then stored in people's homes, demand should not be averaged over the 8 days).

2. Units:

   Before starting any EPAnet project, it is imperative that you check the project defaults and ensure that all units you are using are consistent with the head loss equation you have chosen. In this tutorial, we have chosen to use the Hazen-Williams equation as it is the most commonly used in the United States and has been empirically determined. Chezy-Manning is often used for open channel flows and Darcy-Weisbach is the most theoretically accurate. To give a sense of problems that could occur if you are not careful, the roughness coefficient for PVC for Hazen-Williams is given as a unitless 140, for Darcy-Weisbach it is 0.005 millifeet, and for Chezy-Manning's equation it is 0.011.

3. Internal vs. External Pipe Diameters

   PVC pipe is generally named by its external diameter. However, pressure calculations are performed using internal diameters (external diameter minus thickness of the pipe wall). Thus, when inputting pipe diameters in EPAnet, make sure to use the internal diameter. Although the difference is likely just a few millimeters, doing so will greatly improve the accuracy of the analysis.

4. Negative Pressures:

   One main problem with EPAnet is that it allows for negative pressures. Even though it will generate a warning message when negative pressures are encountered, the analysis will continue to run and use these negative values. Thus, any values obtained at a node after a negative pressure is first encountered will be incorrect and must be carefully scrutinized. In addition, as explained in a previous section, EPAnet will direct flow in the direction you link pipes while connecting nodes. It is very easy to accidentally link a pipe in the wrong direction and obtain negative pressures without realizing why. Be sure to always check this if bizarre values are being obtained.

5. Error Codes:

Most of the error codes you may encounter while using EPAnet have to do with improper formatting of data, syntax errors, or general errors in the input file. If you obtain an error code, first follow the documentation link provided in the appendix to determine what the error is. If you do so and cannot fix the error, or if it is a problem with the input data, I recommend exporting the EPAnet project and opening it as a text file. From here you should be able to more concisely see all of your data and determine if anything looks out of place.

Note, working in a EPAnet exported text file is also the easiest way to input data without using NSM. NSM is handy in that it will calculate lengths and convert GPS coordinates for you, but if this is not a concern, inputting directly into an EPAnet command file is not difficult, though it may take more time. Example formatting for all objects is found in Appendix C of the EPAnet Manual. However, you do want to avoid manually drawing all points directly in the Network Map screen of EPAnet as this will take an excruciating amount of time and will likely not be accurate/to scale.

V. Appendix and References

A. References and Download Links

NSM:
Software: http://designwss.weebly.com/3-nsm.html
Manual: http://designwss.weebly.com/uploads/2/4/5/3/24534121/nsm_3-8_manual_draft_01-05-14.pdf

EPANET:
Software: http://epanet.de/
Manual: https://www.innovyze.com/products/epanet/download/P1007WWU.pdf
Error Codes: http://epanet.de/documentation/errorcodes.html.en

Rahimi Thesis:
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.471.2922&rep=rep1&type=pdf

Rahimi, Navid. “Modeling and Mapping of MaeLa Refugee Camp Water Supply.” Massachusetts Institute of Technology, Massachusetts Institute of Technology, 2008.

Rahimi modeled a very large water distribution system in EPAnet and his thesis covers in pretty substantial detail his process in inputting data into EPAnet as well as all the parameters and assumptions he makes. I have found it to be a useful source when I encounter problems or need easier to understand explanations than what is given in the EPAnet user manual.

B. Example Network Data

Name	Latitude	Longitude	Elevation	Details	Water Consumption Multipliers	
Tank 1	9.05458	-79.55737	50.00	Ball Valve	Time	Multiplier
V1	9.054498	-79.55742	45.73		1:00	0
V2	9.054502	-79.55745	39.78		2:00	0
Tap 1	9.054537	-79.55745	39.78	V2 Branches to Tap 1, Ball Valve	3:00	0
V3	9.054539	-79.55754	37.62	Branched Tee	4:00	0
V4	9.054521	-79.55761	34.01		5:00	0
V5	9.054485	-79.55776	32.57		6:00	0.24
Tap 2	9.054464	-79.55788	30.89	Ball Valve	7:00	0.96
V6	9.054451	-79.55789	30.17	90°Elbow	8:00	3.12
V7	9.054451	-79.55788	29.93		9:00	4.32
V8	9.054415	-79.55792	29.45		10:00	4.08
V9	9.054322	-79.55797	25.68	90° Elbow	11:00	1.68
V10	9.05425	-79.55788	32.43	90° Elbow	12:00	0.48
V11	9.054169	-79.55792	35.96	90° Elbow	13:00	0.24
Tap 3	9.054118	-79.55784	40.81	Ball Valve	14:00	0.24
					15:00	0.24
Tank			**Population and Water Demand:**		16:00	0.96
Initial Level (m)	1.98		200 people		17:00	2.4
Minimum Level (m)	0		40 L/person/day		18:00	2.88
Maximum Level (m)	1.98				19:00	1.44
Diameter (m)	2.2				20:00	0.48
Minimum Volume (m)	0				21:00	0.24
					22:00	0
					23:00	0
					24:00	0

Figure 15: Example Network Input Data

C. Table of Minor Loss Coefficients

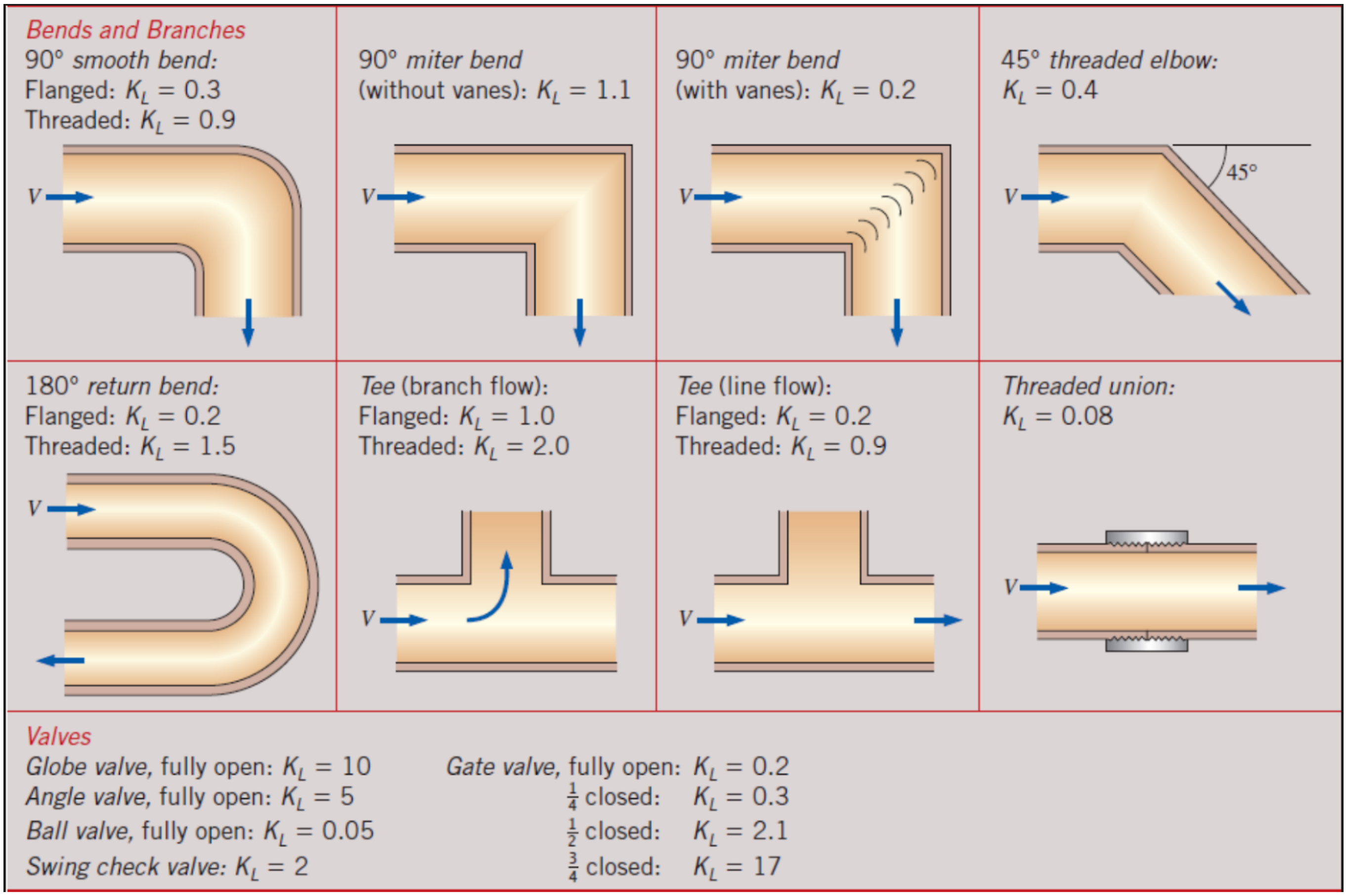


Figure 16: Minor Loss Coefficients

EWB - UC Berkeley Surveying Guide

A comprehensive guide to writing and giving community surveys including data collection and analysis.

Prepared by: Cayla Anderson

April 25th, 2018

Why do we survey?

Any EWB project is only as good as its ability to understand the community we aim to serve. While we often have contacts in the community, these are usually the community leaders or NGO contacts and do not represent the myriad of needs and concerns of the community members we work with. Thus, the creation and implementation of good surveys is vital to our ability to fully understand the community and ensure our projects are attuned to community needs and wants. Furthermore, in the long run, survey data that shows the success of the project can be used to secure funding (something we often struggle with). While this should never be the primary goal, it is a useful byproduct of securing enough survey data to be presented easily in graphics and visuals.

I. How to survey: The Questions

I.I Introduction

This section goes over the basics for what types of questions to include in a survey. When initially constructing the surveys, keep in mind you will want the data to be utilized over the course of the project - in other words make sure it will apply to all phases of the project(assessment, implementation, closing). Additionally, it is important to note that the survey data must be quantized in a way that can be presented graphically. When writing the survey, be sure to have some type of foresight as to how you would like the results to be presented. In the appendix there are links to surveys done by other research groups. In this section I will walk through the types of survey questions written for the Panama team's project in El Valle de San Francisco, Panama.

I.II Demographics

Demographic data is used to contextualize the community. Each survey should begin with basic questions regarding age, sex, number of people in the household etc. When taking this data, be sure to be mindful of people's privacy. While demographic data will not be as sensitive as health and hygiene, if you feel uncomfortable asking or the community member feels uncomfortable answering, skip or change the question!

Example(from Panama Baseline Survey 2017):

Household Demographics				
1	Number of total people living full time within this compound:	Open ended number	household size to equate per person values	#
2	Number of children living within the compound (10 yo or less):	Open ended number	Income potential in family	#
3	Occupation of adults within the household	Check all that apply: o Subsistence farming o Cash crop farming o Casual laborer o Trade/ skilled labor o Monthly salaried job o Government position	Income of household	1-5 scale (mark the highest level) 1. Subsistence farming 2. Cash crop farming 3. Casual laborer 4. Trade/ skilled labor 5. Monthly salaried job or Government position
4	Use or observe the following materials of the household:	Check all that apply: o Exposed brick housing o Concrete floors o Plastered walls o Smart phones o Electricity directly from service provider o SNECC Water hook up o Flush toilets o Vehicle	We use consumption as a proxy for economic status (Deaton, 1997). This question lets us know what their disposable income is for durable goods. We can use material possession to equate economic ladder advancement	1-5 scale (mark the highest level) 1. Exposed brick housing 2. Concrete floors or Plastered walls 3. Smart phones, Electricity directly from service provider 4. SNECC Water hook up 5. Flush toilets, Vehicles

*I would like to point out that these surveys are used to survey households, not the individual. It is up to your discretion to decide if you would like the include the age, gender and income of the person you are interviewing.
** This example comes from a survey conducted mid project. If your survey is at the start of the project, consider including more demographic related questions (see appendix for examples)

As can be seen in the example, we use a mix of open ended and multiple choice questions. When possible, try to use more open ended questions than multiple choice. This way the community member can most accurately convey their experience.

You may also wish to record the family name in demographic information. However, this could become a breach in privacy. Be sure to ask your in country contacts how to approach this. If you do choose to include family name, ask permission of the family first and be honest in how you will be using this information.

General demographic information can often be found online. Be sure to consult government and UN resources to see what information is available there first before including similar questions in your survey.

I.III Health/Hygiene

Most EWB projects are geared towards improving some form of public health. Therefore, the survey should have an assessment of this. Furthermore, because improvement in the health of the community is the ultimate goal, this data is vital to showing the success or areas of improvement needed for the project. However, this data is some of the hardest to quantize. I have included a few examples of the types of health/hygiene questions that could be asked. Especially with these questions, keep in mind the types of graphics you will want this data to produce. Because an improvement in overall health is the end goal, you will want data that can easily show a change over time.

Example 1 (From Panama Implementation Trip #3 survey):

(a) Have any of your children been sick in the past 6 months? If yes, how many children have gotten sick? (if no, answer N/A)
What kind of illness? What do you think made him/her sick?
What do you think are the most common sources of illness among children in the community/ household?

Example 2 (From Panama Baseline Survey 2016):

Q16 (a) Have any of your children been sick in the last week? (b) If any, what kind of illness? (c) What do you think made him/her sick?

Q17 What are the most common sources of illness among children in the community/ household?

These surveys are almost identical however the first one asks if any children have been sick in the past 6 months and the second, in the past week. Other surveys we have conducted have been more vague, asking if any children have been recently sick. The purpose of this question is to initially assess the overall health of the community, and then to hopefully show a decrease in this number over time. The biggest issue with the Panama survey data over the course of the project is that this question has changed, therefore there is no consistent data to actually show a decrease in the number of sick children. When designing your survey, decide at the onset which health question to ask and try not to change it. 6 months is very different than past week. I would recommend using the internet first to see if there is any reported data for your area or of one similar to it. To see what other researchers used to ask similar questions could help when writing yours.

Furthermore, the first example asks how many of these children have gotten sick. This question is very important as it allows us to calculate the per capita illness in our community, something the questions in example 2 do not account for.

Also, note all of these questions are open ended. This allows for the freedom of the community member to tell you what is actually going on. You could choose to use multiple choice for what kind of illness, however be sure to include a fill in option.

I.IV Project Specific

Because I am using examples from the Panama project's survey, these questions will all be water storage and usage based. While some of these questions are applicable to other projects, before building this part of your survey, be sure you have decided what is important information to know for your project. If the project is dealing with water filtration, it will be vital to take data for water demand and source of water. However, who gets the water and time spent getting water might be less important than for the distribution project using these examples.

Example (From Panama Baseline Template 2017) :

5	How do you obtain water for daily use?	a. Piped into household/compound b. tanker truck c. Collected from local catchment d. Makeshift connection e. Other:______________	Divide by those who collect water and those who pay for piped in supply	1 yes containers 2. no containers
	Who collects the water?	a. Adult Male b. Adult felame c. Daughter d. Son e. Elderly	Determine who to gear educational material towards	
6	Distance to water source? If collecting, time for one way trip.	a. Piped into house/compound c. Less than 10 min walk to source d. less than 30 min walk to source e. more than 30 min walk to source	Understand time spent collecting water	1-4 scale
7	How often is this water available throughout the week?	a. Always available c. Intermittent, available 6 days/week d. Intermittent, available 5 days/week e. Intermittent, available 4 days/week f. Intermittent, available 3 days/week g. Intermittent, available 2 days/week h. Intermittent and inconsistent. f. Other: _______________	Reliability of source	1-6 scale 1 Depends on season 2 Not dependent on season
8	How much water does your household use per day (L/day)? If collecting, have them present all buckets used to fetch water and ask how often they collect in a day/week.	a. Less than 100 L/day b. Between 100-150 L/day c. Between 150- 200 L/day d. Between 200-250 L/day e. More than 250 L/day	Water ussage	1-5 scale
9	Cost to your household for water? $/month	open ended		#
	What is the water used for?	Check all that apply: o Drinking o Cooking o Cleaning o Shaving o Bathing o Laundry o Brushing teeth o Washing hands o Other __________	Determine possible changes in usage trends with increased access	?
	How is water being retrieved from the storage unit?	a. Dipping Cup b. Valve c. Pouring d. Other _________	Determine potential for contamination at the storage point and education materials for behavioral changes.	1 Yes sealed container 2 No sealed container
	Location of container in the household	open ended answer based on surveyer's observation	Determine potential for contamination at the storage point and education materials for behavioral changes.	

Because these types of questions are so project specific it is difficult to give a general outline. What I would like to emphasise is to make the questions as non-technical as possible. Even asking water use in L/day is difficult to answer(could you answer this question?). For this I would recommend asking in buckets/day and then figuring the exact volume of this yourself .

12	What is your satisfaction level with your current water source?	1. Extremely dissatisfied 2. Dissatsified 3. Neither dissatisfied nor satisfied 4. Satisfied 5. Extremley satisfied	Satisfaction in water access	1-5 scale
13	What is your biggest issue with your curent water source?	1. time spent for collection 2. unsafe 3. intermitent supply 4. cost 5. difficult to obtain 6. lines at collection taps 7. Other ____________	Reason for satisfaction	1-5 scale
14	Why is this a problem? What does this cause?	open ended		

These questions are also from the same source as the last example however they deal with satisfaction level and closing questions. It has been found that ranking satisfaction by scale is a very western concept. Keep in mind that the people you will be surveying may not be familiar with this system. Other options could be a simple yes/no question or an open ended question asking how the community member feels, eliminating completely the multiple choice component. The last question is important as it gives space for the community member to share an anecdote. This is often the best way to get to know the community even if it cannot be quantized into a graphic.

II. How to Survey: Giving the Survey

II.I Mindset

When giving the survey there are a couple things to keep in mind:

1) This is a living document. Do not feel constricted to ask only what is written. If the person you are surveying is confused or uncomfortable by a question do not hesitate to change it. While yes, you are collecting data, you are also engaging in conversation with the person you are surveying so treat the interaction as such. Make any changes you feel are necessary as you go, just make sure to write down what these changes are!
2) Be friendly! You are in country to build the project but you are also there to get to know the community! Surveying is a great opportunity to learn more about the community members but also a way for them to get to know you. You are here to build a relationship and an engineering project.
3) Practice the language. You will more likely than not be conducting the survey in a language other than English. Be familiar with the language before giving the survey.
4) You may need to explain what the questions mean. If you were not the one who wrote the survey, make sure you speak with the person who did to ensure you fully understand the questions and will be able to elaborate on them if the community member is confused.

II.II Step - by - step

Alright, now you have your survey, your mindset, you have arrived in country and now the day to give the survey you have both mentally and physically been preparing yourself for is here. Let's walk through the process!

Step 1: Choose the area

- If this is a sector the team has not previously surveyed, ask if your in country contacts could go with you the first time or at least provide an introduction. This will help build trust from the onset.
- Always survey in groups of **two.** At least one should be able to speak the language. The other team member will be performing water quality tests.

Step 2: Introduction

- Walk up to the first home - be sure you have GPS location/house number recorded
- If children are out front ask if their parents are home
- Introduce yourself and the project. Be sure to emphasise that you are students and make sure they know what the project is.
- Ask, "May we ask you some questions about your water use". If yes then proceed. If they decline politely leave. Do not force the survey on people!!!
- Ask if it would be ok if we took a sample of their water. If yes, take the sample.

Step 3: Give the survey

- This is done using an offline survey app. Practice with this app before using it in the community

- Keep track of time. The surveys are designed to take ~10 minutes. Do not rush through but also don't spend too much time on one house.

Step 4: Exit

- Thank the community members for their time
- Ask them what questions they may have regarding the project.

Congrats you have just given a survey! Save all the data and move on the the next house. You have many many more to go!

II.III Frequently asked Questions by the Community:

1) Time frame of project, when will it be completed?
2) Defining more technical syntax.
3) What does satisfaction mean?

When answering these questions, be sure to give them all the information you have but nothing more. DO NOT make promises you aren't 110% on. Keep in mind you are the one coming in and changing their community. They will and should have concerns. It is up to you to be as transparent as possible with the people you are aiming to serve.

III. Analyzing the Data

III.I Importing

The raw survey data should be imported into a spreadsheet. From here, the raw data should be recorded in a data log by question and each answer given a code(see example below). All per capita and percentage calculations should be done in this stage.

Example ([Panama Data Log](#)):

Q16 If yes, what illness?

1 = DIAHRREA | 2 = VOMITING | 3 = FEVER | 4 = STOMACH PAIN | 5 = OTHER

Overall

Code	Value	Frequency	Percentage
1	DIAHRREA		
2	VOMITING		
3	FEVER		
4	STOMACH PAIN		
5	OTHER		
	Total		

Assesment Trip 3 - 20 Individual Responses

Code	Value	Frequency	Percentage
1	DIAHRREA	0	0
2	VOMITING	1	14.28571429
3	FEVER	0	0
4	STOMACH PAIN	2	28.57142857
5	OTHER	4	57.14285714
	Total	7	100

Implementation Trip 1 - 18 Individual Responses

Code	Value	Frequency	Percentage
1	DIAHRREA	5	71.42857143
2	VOMITING	1	14.28571429
3	FEVER	0	0
4	STOMACH PAIN	1	14.28571429
5	OTHER	0	0
	Total	7	100

Q17 What are the most common sources of illness among children in the household?

1 = DIAHRREA | 2 = VOMITING | 3 = FEVER | 4 = STOMACH PAIN | 5 = SKIN DISEASE | 6 = OTHER

Overall

Code	Value	Frequency	Percentage
1	DIAHRREA		
2	VOMITING		
3	FEVER		
4	STOMACH PAIN		
5	SKIN DISEASE		
6	OTHER		
	Total		

Assesment Trip 3 - 20 Individual Responses

Code	Value	Frequency	Percentage
1	DIAHRREA	11	55
2	VOMITING	3	15
3	FEVER	1	5
4	STOMACH PAIN	0	0
5	SKIN DISEASE	0	0
6	OTHER	5	25
	Total	20	100

Implementation Trip 1 - 18 Individual Responses

Code	Value	Frequency	Percentage
1	DIAHRREA	13	61.9047619
2	VOMITING	0	0
3	FEVER	5	23.80952381
4	STOMACH PAIN	0	0
5	SKIN DISEASE	3	14.28571429
6	OTHER	0	0
	Total	21	100

Q18 What is your satisfaction level with your current water source?

*See appendix for other resources on ways to record and analyze survey data

III.II Graphics

This has historically created larger debates than necessary. Pie and bar graphs have been found to be the best representations of data however what graphs chosen is usually open to the interpretation of the data analyst. I've included examples of the graphics used in the Panama team's Winter 2018 Health Assessment Report.

Example 1([Winter 2018 Health Assessment Report](#)):
* Pie graphs are good ways to show percent distributions

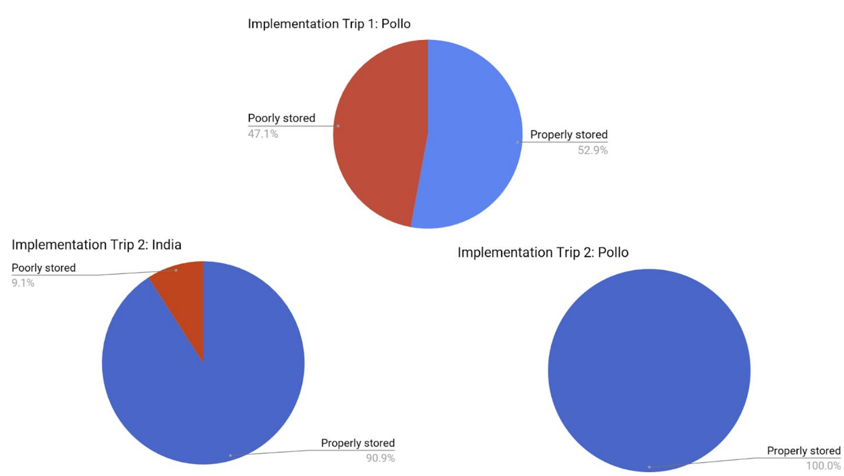


Figure 1: Percentage of households storing water in a covered container with a secured lid across two trips

Example 2(Winter 2018 Health Assessment Report):
*Charts and tables can also be utilized

	Pollo (Post Implementation)	India (Pre implementation)	Implementation 1 (Pre Implementation)
# of surveys	8	11	16
# households w/ sickness	1	2	6
% households with sickness	12.5	18.2	37.5

Table 2: Sickness in households before and after implementation

III.III Ethics of Data Presentation
Given the time frames, sample sizes and structures of the surveys we have given in the past, the data collected would not hold up under peer review. While this is somewhat acceptable given the nature of our projects, keep in mind that each new survey should be an improvement on the last. In other words, the goal should be to create a survey with results that can honestly describe the community. The data and graphics in the examples are based off inconsistent sample sizes with more variables than are dictated by a scientific process. These ethical and statistical issues can be significantly eliminated by ensuring the data is well recorded from the beginning.

IV. Final Remarks

Surveying is an incredibly complicated science as there are many variables and room for error present. The purpose of this guide, and the surveys we as EWB produce, is to minimize this statistical error as much as possible while still being able to gain a holistic understanding of the community we are working with. This is their project as much as it is ours and the survey is one of the best ways to explore this relationship. Survey data should not be taken lightly as the results from one trip are used to assess what is needed in the subsequent. Furthermore, I cannot overstate the importance of using positive analysis of the data to secure funding. Grants and corporate partners want to see the success of their investments. This data is one of our only ways of showing this. With that, good luck with your project and do some good!

Appendix

A.I Further Readings

[Multidimensional Poverty Assessment Tool] **-** From Khalid Kadir(Lecturer in GPP, Developing Economics and College of Engineering)

Water Sanitation Survey Example - can be found under Survey Guide in Panama sustainability drive

A.II Past Surveys

Panama Implementation Trip #3 Survey

Baseline Survey Template - Panama 2017

Baseline Survey - Panama 2016

A.III Reports

Panama Team Winter 2018 Health Report

A.IV Other Resources

Mira Chaplin - Best Sustainability Lead ever

Andrew Chow
Engineers Without Borders: UC Berkeley

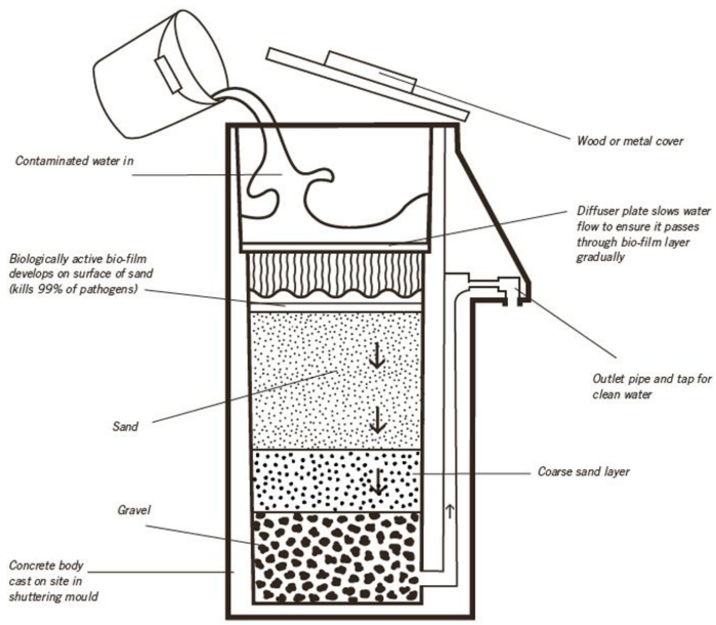
Abstract

Slow sand filtration has been an effective solution to treating water and producing a potable product for over the last 150 years. The slow sand filter is unique in design in that it utilizes both mechanical and biological filtration using different sized substrates and a naturally grown biofilm. This guide contains an overview of the process, structure, health benefits, and pros and cons of slow sand filtration.

Table of Contents

Filtration Process

The process of treating water through a slow sand filter is quite simple and yet effective. Contaminated water is poured into the top of the filter and is cleaned as gravity pulls it through a biofilm and several different layers of sand. When the water flows through the biological layer, predatory bacteria feed off of waterborne microbes and effectively clean the water of pathogens. The water then flows through substrate (sand), mechanically removing sediment and other large contaminants. Finally, the water collects at the bottom of the tank and can be retrieved through a spout or pipe at this location.



Structure

The structure of a slow sand filter is quite simple and low technology. A tank or box with a cover is required as a filter chamber which holds the substrate and the naturally grown biofilm. The substrate (sand and gravel) layers are ordered with coarse grains at the bottom and fine grains at the top. In addition, a diffuser plate often sits on top of the filter to prevent the disruption of the sand from the force of the water being poured into the chamber. Finally, pipes are used to access the filtered water from the bottom of the chamber and may be also used to pump water into the top of the system.

Examples of Slow Sand Filters in rural environments

<u>Design Considerations</u>

Design considerations for a slow sand filter include:

1. The flow of water must be maintained at a rate between 0.1–0.3 meters per hour
2. Every two months, all the valves must be opened and closed to keep them from becoming stuck, and any leaks in the system must be repaired immediately
3. It is best to utilize gravity in this filter and let water flow through the filter as opposed to forcing it through with a pump or other device
4. The filter should ideally sit on a flat and stable foundation of concrete or packed dirt

A flat and stable foundation for a Slow Sand Filter

General Advantages vs Disadvantages

Advantages

1. Very effective removal of bacteria, viruses, protozoa, turbidity and heavy metals in contaminated fresh water
2. Simple design and high self-help potential since construction, operation, and maintenance only require basic skills and minimal effort
3. If constructed with gravity flow only then no (electrical) pumps are required
4. Local materials can be used for construction
5. Reliable and able to withstand fluctuations in water quality
6. No need for additional chemicals
7. Easy to install in rural, semi-urban and remote areas
8. Long lifespan (estimated >10 years)

Disadvantages

1. Minimal quality and constant flow of fresh water required: turbidity and low algae contamination.
2. Cold temperatures lower the efficiency of the process due to a decrease in biological activity
3. Loss of productivity during the filter skimming and ripening periods
4. Very regular maintenance essential; some basic equipment or ready-made test kits required to monitor some physical and chemical parameters
5. Possible need for changes in cultural attitude due to disbelief that water that flows through a green and slimy filter is safe to drink without chemicals
6. Miniscule natural organic matter not removed
7. May require electricity
8. Need large land area, large quantities of filter media, and manual labor for cleaning
9. Low filtration rate

Health Benefits

Slow sand filtration is an extremely efficient method for removing microbial contamination. Lab effectiveness studies with a mature biolayer have shown 99.98% protozoan, 90-99% bacterial, and variable viral reduction occurs during the filtration process. Field effectiveness studies have also documented E. coli removal rates of 80-98%. In addition, two health impact studies reported a 44-47% reduction of diarrheal disease incidence in users.

In short, slow sand filtration is highly effective for removing:

1. Bacteria
2. Protozoa
3. Viruses
4. Turbidity

5. Heavy metals (Zn, Cu, Cd, Pb)

References

- CDC: Safe Water Systems: <https://www.cdc.gov/safewater/sand-filtration.html>
- SSWM University Course: Slow Sand Filtration: <https://www.sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/slow-sand-filtration>
- Oasis Design: Slow Sand Filtration: <http://oasisdesign.net/water/treatment/slowsandfilter.htm>
- WHO: Slow Sand Filtration: WHO Slow Sand Filtration.pdf

An Overview of Various Latrines Suitable for Rural Communities

Engineers Without Borders
University of California, Berkeley
Emily Colón

Table of Contents

1. **Abstract**

This guide is designed to provide a general overview of different latrine types, in order to compare and contrast their potential uses. This is intended as a starting point for sanitation projects hoping to get a general idea of the functionality of various latrines. The three latrines outlined here are the Simple Pit Latrine, the Ventilated Improved Pit Latrine, and the Pour Flush Ventilated Pit Latrine.

2. **Introduction**

   A. Significance of Latrines & Sanitation

   Sanitation is an underestimated public health concern in society, especially with regards to the proper disposal of fecal matter. This is the reason that effective latrines are necessary in all societies—besides greatly improving the quality of life, the lack of latrines greatly increases the risk of disease transmission in a community. Specifically, it reduces the spread of fecal-oral pathogens that cause diarrhea, intestinal worm infections, etc. The presence of good latrines in a community also generally encourages good hygiene awareness, fostering a safer, healthier community.

   B. Wet vs. Dry Systems

   A dry latrine is one that does not use water, and usually consists of a toilet with some containment system where the excrement can be disposed of or separated for reuse. A wet system is what is traditionally understood to be a toilet, in which water is flushes the excrement down the toilet. The dry toilet is the more basic latrine type, very common/easily installed in comparison to the wet toilet. The wet toilet requires a continuous water supply and a more complex design. The wet toilet is associated with a higher quality of life, and culturally tend to be looked at more highly than a dry toilet as a sign of affluence.

   C. Latrine Design Considerations

      i. Location

      The location of the latrine must be chosen in order to minimize the possible health concerns for the community in terms of feces exposure, to maximize the lifetime of the latrine, and to be practical for the daily lives of the community members. The latrines should be built away from bodies of water and from the flood plains of any surface water bodies to limit both groundwater contamination and any flooding that could spread the feces. The latrine design should also include drainage to limit the effects of flooding as well. The locations and patterns of the nearby bodies of water need to be analyzed as well, to ensure any possible run off does not affect the latrine. Similarly, the soil in the region should be analyzed in order to choose a location that is stable and relatively unaffected by conditions such as erosion. The latrines should also be built 50 meters from residences, in order to limit human exposure to the feces as well as to the possible odors and flies that could arise from the latrines. The latrines should be built away from trees in order to prevent obstruction of ventilation pipes (if present). These choices become more complex for wet latrines and might require the opinion of an expert depending on the complexity of the system. Many more, fairly logical considerations exist, such as ensuring the latrine does not prevent vehicle access to the area, and logistical conditions that are dependent on the daily life of the locals.

ii. Sizing.
Extensive community surveys need to be taken in order to adequately estimate the scale of the latrines project. This will depend heavily on the cultural and social preferences of the community, as well as technical specifications based on the terrain of the region. The questions should gage the population size, as well as general questions about their lives and the community. The latrine needs to be designed with a feces containment system that is large enough to meet the needs of the community without needing to empty the pit too regularly. The team also needs to evaluate how many latrines the system needs and how much viable land space is available to construct the latrines on.

iii. Maintenance
The maintenance needs for each latrine need to be considered during the latrine design to ensure that the necessary regular maintenance can be done easily with as little technical expertise as is necessary. Latrines need to be cleaned regularly and should not be cleaned with any harsh chemical cleaning supplies as they can kill the microorganisms that allow the excrement to decompose. The latrine needs to be designed so that it can be easily, thoroughly cleaned. The plan for handling the waste when the pit is full also needs to be taken into account for the pit design. If the plan is to move the latrine and start a new pit when full, then the latrine needs to be very easy for the community to move themselves. If the excrement is to be composted or disposed of then the latrine needs to be designed with a system of desludging the pit, either manually or with some sort of machine, while minimizing the risk of disease spread due to human exposure to the excrement. These decisions depend heavily on the amount and type of land available to the community, as well as the community preferences.

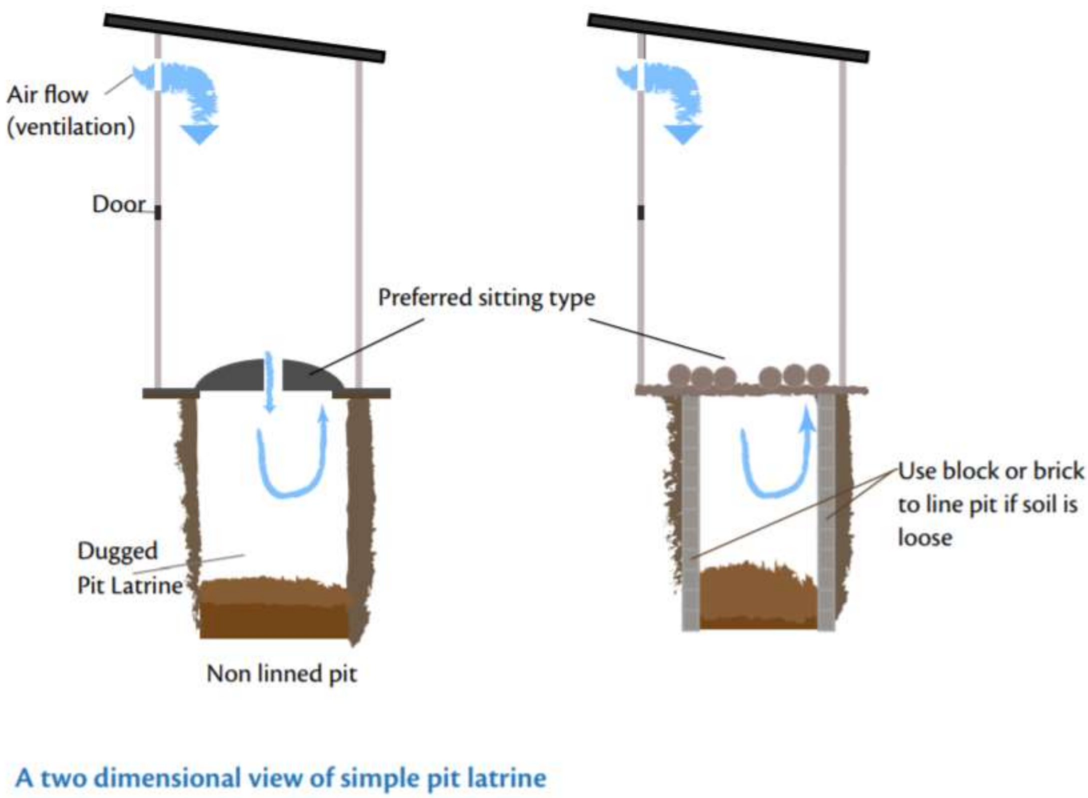
3. Simple Pit Latrine

A. Basics
The simple pit latrine is the most basic form of latrine, consisting of a pit that is used to collect and store excrement. This pit is usually covered by a slab with a hole, which serves as the toilet—a seat of some variety can be installed on top of this hole to make a proper toilet. The latrine is generally built with a structure surrounding it,

allowing for privacy to protect the user in poor weather conditions.
The excrement in the pit decomposes eventually into a sludge. When the pit is full, the sludge can be removed manually and composted or otherwise disposed of. If the latrine is designed to be mobile, the latrine can be moved to a new location, filling in the old put with soil and/or even planting a tree in the spot.

B. Pros and Cons

Figure A. *Simple Pit Latrine:*



Pros	Cons
• Low water usage • Low capital costs • Easy to operate • Low maintenance	• Bad odors/poor ventilation • Simplistic design is known to collapse in poor conditions • Attracts bugs • Risk of groundwater pollution • Disposal of excrement when pit is full can be difficult

C. Applicability
Simple Pit Latrines are generally used in rural areas and should be considered for

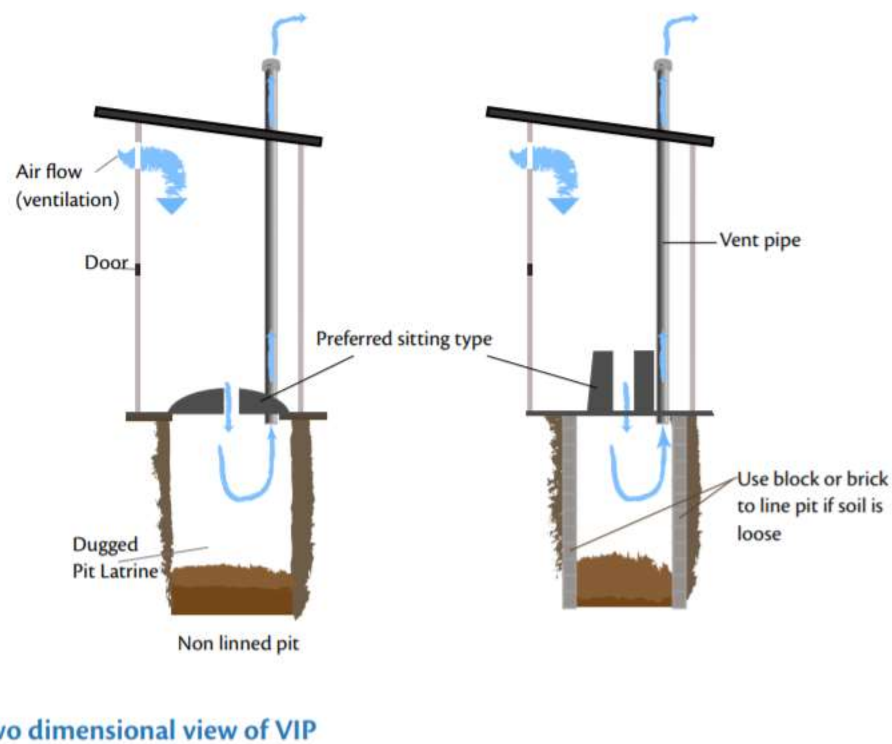
areas with natural characteristics that lead to easy implementation. For example, communities with a large amount of land available, with soil that can be easily dug, regions without flooding, etc. The resources available to the community also need to be considered as well, such as the materials locally available for construction and their applicability. This can be gauged by visiting local stores during assessment trips to see the materials that are accessible easily and affordable. Materials to look for can include various types of wood, concrete, and various metals. The choice of materials depends heavily on the plan for disposal of the excrement, because if the plan is to continually move the latrine then the materials that are chosen need to be lightweight. The materials chosen for the latrine building structure need to be designed to withstand the natural weather patterns of the region as well.

4. Ventilated Improved Pit Latrine

A. Basics

The Ventilated Improved Pit (VIP) Latrine is an improvement on the simple pit latrine. This latrine is very similar except for the addition of a ventilation system. This consists of a ventilation pipe that travels from the pit directly to outside the latrine, and the structure can also include vents to allow air flow within the latrine area that the user is in. The ventilation pipe usually also has a fly screen at the top to trap any flies that may have been bred in the excrement pit. All other aspects of the latrine are the same as Simple Pit Latrines.

***Figure B**. Ventilated Improved Pit Latrine:*



B. Pros and Cons

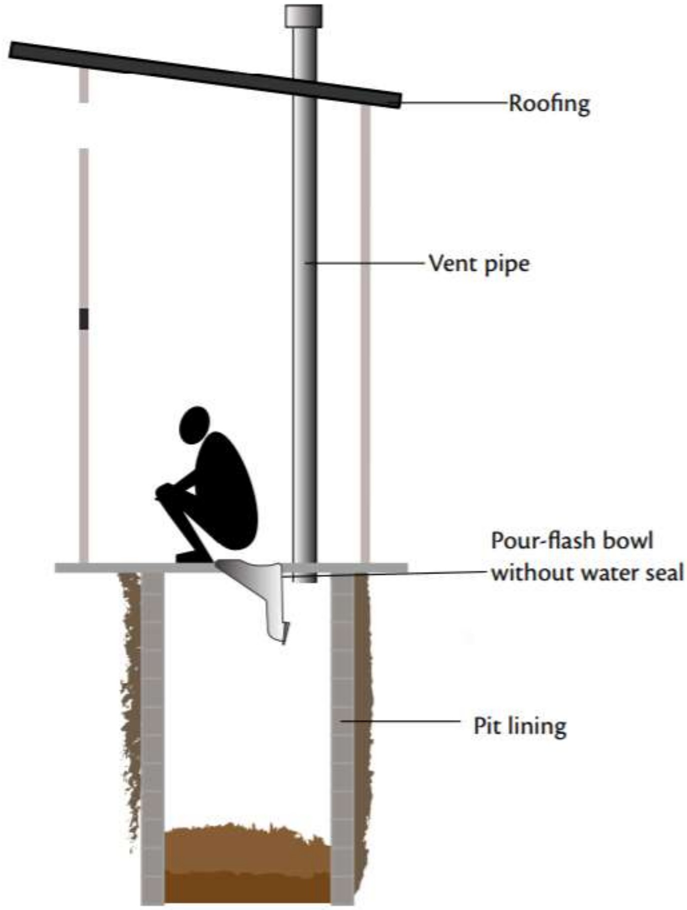
Pros	Cons
• Low capital costs • Reduced bad odors • Health risks associated with flies/insects reduced	• Slightly more complex design • More difficult to make a mobile latrine • Disposal of excrement when pit is full can be difficult • Possible groundwater contamination

C. Applicability
This is suitable for the same types of communities as the Simple Pit Latrine. The same considerations for materials apply, but in addition PVC piping is needed for the ventilation pipe.

5. Pour Flush Pit Latrine

A. Basics
The Pour Flush Pit Latrine is an IVP Latrine upgraded to be a wet system. Pour flush toilets consist of a water seal (such as the common U-trap) that is used to keep excrement, odors, and flies from returning up the pipe into the latrine space. These toilets require the user to pour water directly into the latrine.

Figure C*. Pour Flush Pit Latrine:*



A two dimensional view of Pour-Flush Toilet without Water-Seal, Installed On Direct Pit (Ventilated Pit)

B. Pros and Cons

Pros	Cons
• Usually only requires 2-3 L per flush • High social acceptance/dignity • Very few odor issues • Very few insect issues	• Requires water • Possible groundwater contamination • Requires separate container and disposal methods for solid anal cleansing materials

C. Applicability

The Pour Flush Pit Latrine is suitable for regions with significant water sources, but not so much water that there is a risk of flooding. Similar materials are required as for the other latrines.

6. References

(1) Nyarko, K.; Buamah, R.; Nunoo, F.; Appiah-Effah, E.; Afful, K.; Samwini, N.; Owusu-Boakye, A. Latrine Technology Manual https://www.unicef.org/ghana/Latrine_technology_option_manual_final__a4_size.pdf (accessed Apr 5, 2018).

(2) Information on Improved Latrine Options http://www.wsp.org/sites/wsp.org/files/publications/improved_latrine_options.pdf (accessed Apr 5, 2018).

(3) Hygiene and Environmental Health Module: 20. Latrine Construction: View as single page http://www.open.edu/openlearncreate/mod/oucontent/view.php?id=207&printable=1 (accessed Apr 5, 2018).

(4) Types of Toilet and Their Suitability http://repo.floodalliance.net/jspui/bitstream/44111/1778/1/4f7ceecd-e1a0-4b9a-a491-05dd1661b3dc%20(1).pdf (accessed Apr 5, 2018).

(5) Study Session 5 Latrine Technology Options for Urban Areas: View as single page http://www.open.edu/openlearncreate/mod/oucontent/view.php?id=80510&printable=1 (accessed Apr 5, 2018).

(6) Akter, T.; Ali, A.; Dey, N. Transition Overtime In Household Latrine Use In Rural Bangladesh: A Longitudinal Cohort Study. *BMC Public Health* 2014, *14*.

How to Mix Concrete (Pre-packed)

Abstract:

In this guide, I hope to have provided clear and concise instructions for mixing concrete. Within this guide, you will find general information about the verbiage used when talking about concrete, different types of concrete, and step by step instructions on how to mix concrete.

Table of Contents:

Vocab:

Coarse aggregate: any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter.

Fine aggregate: generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve.

Resource: Reader from CE 60 on Aggregates

Cement: a powdery substance made with calcined lime and clay. It is mixed with water to form mortar or mixed with sand, gravel, and water to make concrete.

Resources: Lecture on Portland Cement from CE 60
Reader on Hydraulic Cements from CE 60

PSI: pounds per square inch; measurement of how many pounds per square inch concrete can withstand; used to quantify strength of concrete.

Materials Necessary:

1. Concrete mix
2. Container for mixing (bucket, pan, wheelbarrow--ideal)
3. Shovel
4. Clean water
5. Measuring instruments

Mixing Ratios:

	Water-cement ratio, by weight	
Compressive strength at 28 days (psi)[a]	Non-air-entrained concrete	Air-entrained concrete
6000	0.41	---
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

	Volume of dry-rodded coarse aggregate[a] per unit volume of concrete for different fineness moduli of sand			
Maximum size of aggregate (in.)	2.40	2.60	2.80	3.00
⅜	0.50	0.48	0.46	0.44
½	0.59	0.57	0.55	0.53
¾	0.66	0.64	0.62	0.60
1	0.71	0.69	0.67	0.65
1½	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.80	0.78	0.76
6	0.87	0.85	0.83	0.81

Absolute volume of materials, ft3 per cubic yard of concrete:	
air	1.5%x27=0.405
water	300/62.4=4.807
cement	625/196=3.189
coarse aggregate	1853/168=11.029
TOTAL	19.429
By difference-fine aggregate	27-19.429=7.59
Fine Aggregate Content, lb/yd3	7.59x167=1264

Resources:

[Reader from CE 60 on Mixture Proportions]

[Lecture from CE 60 on Mixture Proportions]

Steps:

1. Measure amount needed:
    a. Calculate volume of concrete necessary for job
        i. Take measurements of the space (length*width*depth)
    b. Divide the volume by the package yield (given on package of concrete)
2. Determine type of concrete needed:
    a. 3000 PSI: gravel, sand, and Portland cement. Generic type of concrete, widely used, inexpensive, good for repairs and setting poles.
    b. 4000 PSI: used for sidewalks, driveways, etc. and has higher durability than 3000 PSI, used for repairs on structures
    c. 5000 PSI: quick-setting concrete and highest strength of three options
    d. Sand mix: no coarse aggregate, used for smooth surface like grouting or topping
    e. **Resources:**
        i. Lecture from CE 60 on Strength
        ii. Reader from CE 60 on Strength
3. Gather materials:
    a. Concrete mix
    b. Container for mixing (bucket, pan, wheelbarrow--ideal)
    c. Shovel
    d. Clean water
    e. Measuring instruments
4. Pour concrete mix into container for mixing. Careful with this step and pour slowly to avoid losing cement powder into the air.

5. Create a crater in the middle of the concrete mix and pour water into crater slowly and in small increments so it does not spill out of the crater. Mix concrete. Repeat this step (make crater, add more water, mix) until all water is mixed in.
    a. Water necessary determined by volume of cement in bag, *not* the weight of the bag. Generally 1 gallon per 80 lb bag.
    b. When mixing with shovel, scoop the bottom and sides of the mixture and make a chopping motion through the center to evenly mix the concrete and create a uniform moistness throughout

6. Once all components have been mixed and concrete appears uniform, pour concrete into the space needed to fill. Smooth concrete's surface with a shovel or smoothing tool to make the surface as flat and smooth as possible. Once smoothened, "rod off" concrete with a straight edge by doing a scraping motion over the top of the concrete to ensure the surface is as flat and uniform as possible.

7. Protect the area from pedestrians as the concrete will take time to dry.
    a. Resource: CE 60 Lecture on Fresh Concrete

References:

Pictures from WikiHow: https://www.wikihow.com/Use-Prepackaged-Concrete-Mix

Resources throughout: CE 60 lecture slides and reader from Fall 2017, taught by Paulo Monteiro

Other Resources from CE 60 Lab:
CE 60 Lab Presentation
CE 60 Lab Manual

Total Coliform Testing: A Reference Guide

Abstract

Contamination of water systems by fecal matter is a health risk due to the presence of pathogenic organisms. One way to detect such contamination is to test for an indicator bacterium like total coliform. This guide will provide information about when to perform a coliform test, the benefits of doing so, and will include a comprehensive section on performing the test. The test requires the Total Coliform Indicator Bacteria Test Kit from LaMotte. Possible results, site of contamination, and further steps necessary to eliminate coliform bacteria from a water source are also included.

Table of Contents

I. What is coliform bacteria?

Coliform are bacteria that are present in the digestive tracts of humans and animals and are found in their waste. Coliform bacteria itself is not harmful, but their presence in water indicates the presence of pathogens.

Total Coliform	▪ Found naturally in the environment ▪ Found in water that has been influenced by human or animal waste
Fecal Coliform	▪ Present in the gut and feces of warm-blooded animals ▪ More accurate indicator of animal or human waste than total coliform
Escherichia Coli (E. Coli)	▪ Best indicator of fecal pollution and presence of possible pathogens ▪ Can cause serious illness

II. Why should I perform a coliform test?

- While most coliform bacteria do not cause illnesses, they are a good indicator of disease causing organisms and potability of water. If coliform is present, it is likely that other pathogens are also present.
- Changes can occur to water sources without change in taste, odor, and color. It is best to test to make sure coliform bacteria is not present in a water source.
- Coliform testing can be done anywhere! Kits are available online and are equipped with all materials and instructions. It is a fast, easy, and effective method for determining the presence of coliform bacteria.

III. When should I perform a coliform test?

- Testing should be done on water distribution systems at least annually, even if systems seem to be functioning properly.
- Late spring or early summer is a good time to test for coliform as the wet environment is when coliform is most likely to be present.
- If changes to your water source have been made, it is best to test the potability of the water.
- If there is any indication of contamination, it is important to test the water source as changes may not be apparent.

IV. Performing a Coliform Test

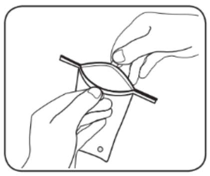
- Although this guide will indicate presence of total coliform, other tests are available.
- Testing will focus on the absence/presence of coliform bacteria since the EPA considers above zero concentrations of total coliforms in a water source to be above the maximum contaminant level goal (MCGL). The EPA also considers the Maximum Contaminant Level (MCL) to be 5% in water systems.
- This test requires the Total Coliform Indicator Bacteria Test Kit from LaMotte

List of Materials

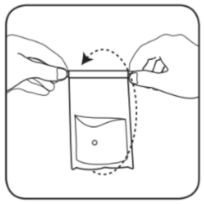
- 5 glass tubes, marked at 10 mL
- Coliform tablet (in tubes)
- Sterile water sampling bag with dechlorinating tablet
- Cotton ball or gauze
- Household alcohol

Steps for Sampling

1. Soak the cotton ball or gauze with household alcohol and wipe the area of the water outlet
2. Allow water to run for about 2-3 minutes
3. Allow rate of water flow to be slow enough that water does not splash when filling the sampling bag
4. Tear off the top of the bag at the scored line and pull tabs outward. Be careful not to touch the bag opening or inner surface



5. Fill the bag to the 4 oz. line and pull the wire ends to close
6. Whirl the bag for three complete revolutions. Be sure to shake the bag so that the tablet dissolves
7. Remove all tubes from the display package and remove caps
8. Unwhirl the bag, pull the tabs out to open the bad, and fold one tape wire to form a spout



9. Carefully fill each tube to the 10 mL line with the water and recap tubes. Be sure not to disturb or shake the tubes

10. Place tubes back in the carton in the vertical position, making sure that the tablet is at the bottom of each tube
11. Store the tubes at room temperature and out of sunlight for approximately 44-48 hours.

V. Results

- Positive test
  - Gas bubbles are present
  - Gel rises to the surface
  - Liquid is cloudy
  - Indicator turns yellow
- Negative test
  - Liquid above gel is clear
  - Indicator remains red or turns yellow
  - No gas bubbles present
  - Gel remains at the bottom of the tube.
- If there are coliform bacteria present in your water source, the risk of pathogens in the water is increased. It is possible the water source is polluted and steps should be taken to treat the water.

Possible Areas of Contamination and Treatment Plans

- Pipes: Holes or cracks in the piping could be the source of contamination. Fix the crack or hole and then shock chlorinate the water. Perform another coliform test before using the water.
- Recent construction on water system: It is possible that work done on the system had not been disinfected. Shock chlorination can be used to treat water and another test should be performed after treatment is complete.
- Faucet: Bacteria could be growing at the swivel point, and if this is the case replace faucet with a new one and retest.
- Shallow well: Surface water could be contaminating the system. Multiple treatments can be used such as chlorination, UV, or ozone water treatment. It is also possible to dig the well deeper
- Until steps have been taken to treat water, boiling water can be used temporarily. This should not be a long-term solution.

VI. References

- Online Sources:
  - United States Environmental Protection Agency: Drinking Water Requirements for States and Public Water Systems - https://www.epa.gov/dwreginfo/revised-total-coliform-rule-and-total-coliform-rule
  - United States Environmental Protection Agency: National Primary Drinking Water Regulations - https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations
  - Nielson Research Corporation: Interpreting Coliform Bacteria Test Results - http://nrclabs.com/interpreting/
  - LaMotte: Total Coliform Test Kit for Drinking Water http://www.lamotte.com/en/education/bacteria-studies/4-3616.html

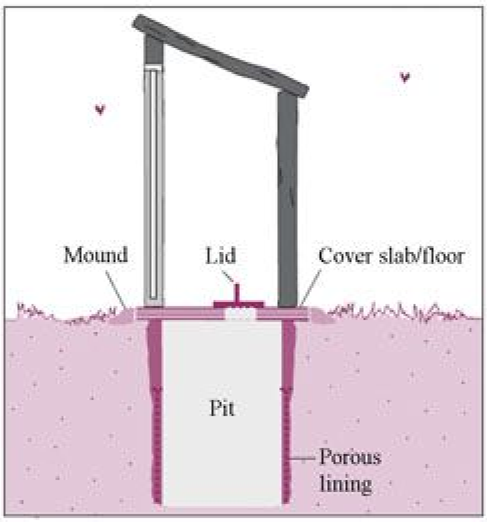
Comparative Study of Types of Latrines

Sallie Johnson
April 2018
Engineers without Borders

This study will be comparing four different types of latrines with the purpose of finding the most realistic and effective solutions for future EWB projects. The types of latrines being studied are the open pit latrines with slabs, pour-flush latrines, ventilated improved pit (VIP) latrines, and ecological sanitation (composting) latrines. Each of these types of latrines have various advantages and disadvantages that will be discussed, and fall within the capabilities of EWB teams.

1. Open Pit Latrines with Slabs

This type of the latrine is the simplest form of dry latrine, made up of a pit dug into the ground and some sort of slab or other mechanism for covering it. Typically they are constructed on a slight mound in order for liquid at surface to flow away from the pit, and so that the surrounding ground is lower. While the sides of the pit can be lined, the bottom must remain open in order for liquids to drain into the soil. The slab must be cleanable (and existent) in order for this system to be considered an improved sanitation system. To use them, one simply moves any covering or lid over the hole in the slab and excretes into the pit. A lid over the hole is generally preferred to help control odors and flies.



Source: WHO and IRC, 2003, *Linking technology choice with operation and maintenance in the context of community water supply and sanitation: A reference document for planners and project staff*)

Advantages:

- Do not require water so good with there is no adequate water supply
- Avoid contamination of surface water and topsoil if properly installed and maintained
- Very inexpensive, can be constructed using local material and local skills
- Properly constructed slabs allow for easy cleaning

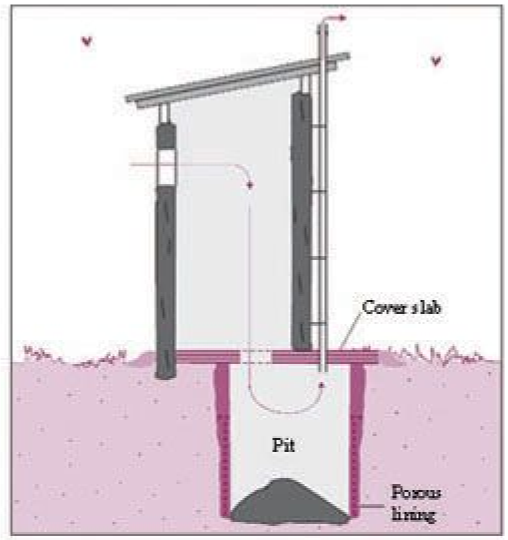
Disadvantages:

- Bad odors, attracts flies and mosquitos
- New pit needs to be dug every time one is filled
- Vulnerable to flooding and failure in areas with heavy rain

2. Ventilated Improved Pit latrines

VIP latrines are fairly similar to simple open pit latrines, but employ slightly more sophisticated technology for controlling flies and odors. The VIP latrine utilizes a ventilation pipe installed in the pit. This exhausts odors and controls flies by taking advantage of the continuous stream of air that initially enters the superstructure of the system and goes into the pit through the hole in the slab. This fresh, cold air displaces the hot, odor-carrying air within the pit and pushes it up through the pipe.

This system also helps to control flies because newborn flies will be attracted to the sunlight that enters through the pipe, so they will move up the pipe. By attaching a mesh filter to the top of the pipe, one can ensure the flies do not escape the pipe to get back outside of the latrine.



Source: same as previous photo

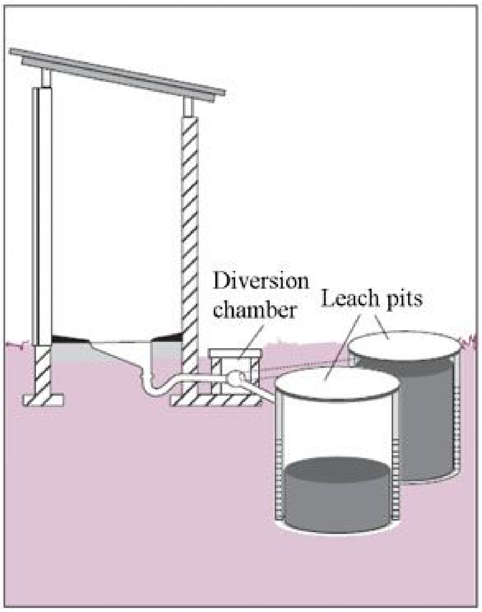
Advantages:

- Flies and odors are significantly reduced
- Do not require water so helpful with there is no adequate water supply
- Avoids contamination of surface water and topsoil if properly installed and maintained
- Very inexpensive, can be constructed using local material and local skills
- Properly constructed slabs allow for easy cleaning

Disadvantages:

- New pit needs to be dug every time one is filled (not sustainable)
- Still potential health risks from flies
- Vulnerable to flooding and failure in areas with heavy rain
- No specific reuse of faeces and urine
- Leachate and other potential contaminants can seep into groundwater
- Required manual removal of humus
- Higher capital cost than simple pit systems

3. Pour-Flush Latrines



Source: same as previous photos

Pour-flush latrines are usually made of ceramic materials reminiscent of western toilets. They are reminiscent of western cistern-flush toilets, but without the plumbing needs. To operate, about 2-3 liters of water are poured manually into the toilet bowl from a bucket to flush down the excreta. The water must also be poured in with enough force to properly flush the excreta. The wastewater is disposed of in a septic tank or seepage pit. Thus, these pits will contain the excreta, cleansing water, and flush water. This is a more sophisticated model than the pit latrine and the VIP latrine.

Advantages:

- Water seal prevents odors from coming back up
- Before the next person arrives, the excreta of the previous user has been flushed away
- Safer and more comfortable for the user
- More sanitary than pit latrines
- Uses less water than a flush toilet

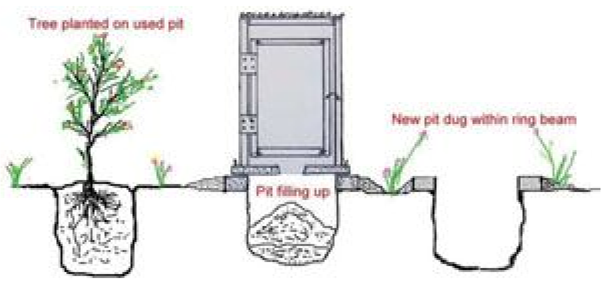
Disadvantages

- Potential for groundwater contamination through faecal organisms leaching into the soil
- Prone to clogging since less water is used in a pour-flush model than a traditional flush toilet.
- Much more expensive to install than a pit model
- Materials and skills for construction are not universally available
- Requires a constant source of water, so not suitable for dryer environments
- Might be outside the capacities of EWB
- More maintenance required than a simple pit system
- No specific reuse of faeces and urine

4. Ecological Sanitation (Compostable) Latrines

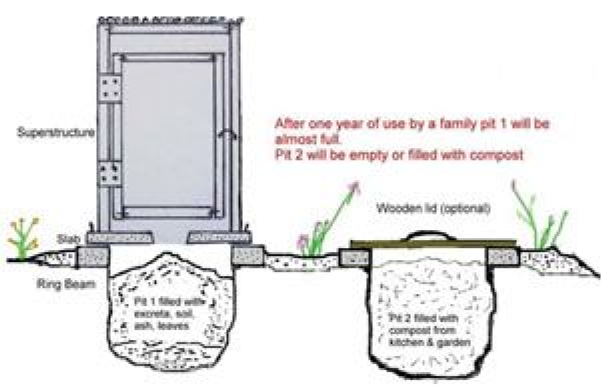
Compostable latrines are an incorporation of a method of reuse of the excreta accumulating in the pit latrines. In this method, it is transformed into a product that can be used as a soil enhancer or a fertilizer. Note that it takes roughly 6-12 months for material to compost.

There are two different types of Compostable Latrines that will be evaluated. The first is a single pit method (*Arborloo)* which consists of one shallow, unlined pit that consists of a superstructure, a slab, and a portable circular support. In addition, leaves, soil, and wood ash are added into the pit to help make a suitable compost system. Once the pit is full, it is again covered with leaves and soil. Once the latrine system has been moved to another pit, a tree is planted on top of the full pit.



Source: same as previous photos

The second type of compostable latrine is a double pit method (*Fossa Alterna)* that is very similar to the single pit method, except two slight shallower pits are used instead of one pit. The maximum depth of this type of pit system is typically 1.5 meters. The pit in use is similarly filled with leaves, soil, wood ash, and biodegradable food waste; however, for this system a small amount of this mixture should also be added after each defecation. This will add organisms such as worms that help with the composting process, as well as necessary nutrients to combine with human waste. When the first pit fills, it should be covered and allowed to fully compost while the second pit starts to be used for excretion. The compost material in the first pit can be manually taken out after it has fully broken down and used as a fertilizer for soil.



Source: same as previous photos

Advantages:

- Provides clear reuse of excretory materials
- Do not require water so helpful with there is no adequate water supply

- Avoids contamination of surface water and topsoil if properly installed and maintained
- Very inexpensive, can be constructed using local material and local skills
- Properly constructed slabs allow for easy cleaning
- *Single pit method:* no manual handling of the excretory matter is required
- Decreases environmental contamination caused by human excretion
- Prevents faeco-orally transmitted diseases
- Amount of artificial fertilizer used in agricultural fields is decreased, which saves money and prevents eutrophication in nearby bodies of water
- Minimal

Disadvantages:

- Require more land than other pit systems
- *Double Pit Method-* Decomposed waste must be manually removed from the pits
- Potential community rejection- some people may not want to eat crops grown from this composted soil because of excretory matter

Conclusion:

When deciding which type of latrine would be the best for our teams to adopt, it is important to consider each through the parameters of affordability, sustainability, benefit to community, and team capability. After doing so, it seems as if the ecological sanitation latrine is the best method. It is cheap and easy to build (community members can and should dig the pits), can be sourced from local material, does not require constant water, is easy to maintain, and has the added benefit of providing useful fertilizer and soil for the community. While it is important to consider the community's reaction to using their excretions to grow food, through education and building relationships with the community this problem can be resolved.

If some external factors prevent the possibility of a compostable latrine, a VIP latrine is a good alternative solution, since it is still a sophisticated model and an improvement from the simple pit latrine. Like with the ecological sanitation latrine, the community can contribute a significant amount of the labor and materials can be sourced locally. The major reason why this is less ideal than the ecological sanitation latrine is because there is no additional benefit to the community from the system.

If considering between the simple pit latrine and a pour flush toilet, the most important factors to consider are environmental capacity and team budget. A pit latrine is evidently significantly cheaper, and does not require a constant water source like the pour flush toilet, but the pour flush toilet is more sanitary and pleasant for the user.

Sources

Eawag. “Single Ventilated Improved Pit (VIP).” SSWM, Seecon, www.sswm.info/node/8291.

Eawag, et al. “Pour Flush Toilet.” SSWM, Seecon, www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/user-interface/pour-flush-toilet.

“Hygiene and Environmental Health Module: 20. Latrine Construction.” Open Learn Create, The Open University, www.open.edu/openlearncreate/mod/oucontent/view.php?id=207.

Morgan, Peter. *Toilets that make Compost.* Stockholm, Stockholm Environment Institute, 2007.

EPANET Tutorial

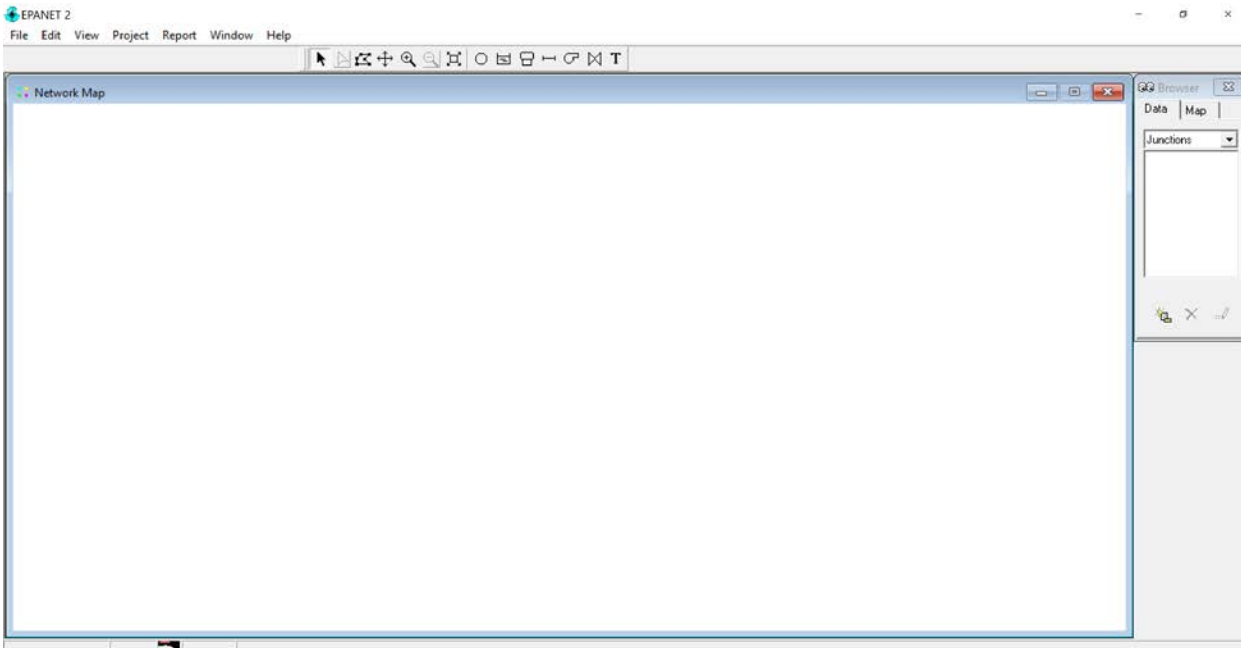
Claire Liu

Abstract:

This EPANET tutorial will cover the basics in drawing network diagrams with pipes, nodes, and water sources such as a spring. The user should be able to model network systems and have an understanding of what EPANET is modeling for them. The guide will end with a practice problem and a potential answer so that the user can test their skills. The final page includes a reference sheet with units and ways to change the background of the EPANET screen.

Table of Contents:

EPANET Tutorial by Claire Liu



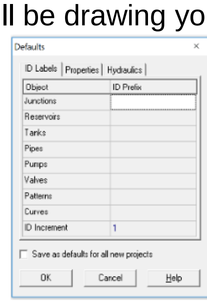
EPANET is used to model drinking water distribution systems. We can draw a system sketch and test things such as water pressure and head loss, based on variables such as water demand, speed pumps, and valves.

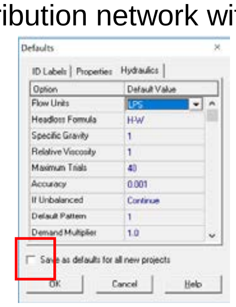
Basic Tutorial: Drawing a Network Diagram

*Note: the tutorial included in the EPANET software only works up until Windows 8.1, later versions of Windows do not support this feature.

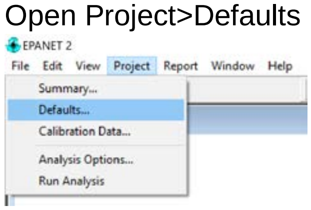
**The Help button also is not supported

1. Always **Configure Units First**, otherwise you will be drawing your distribution network with the wrong measurements.





- Open Project>Defaults



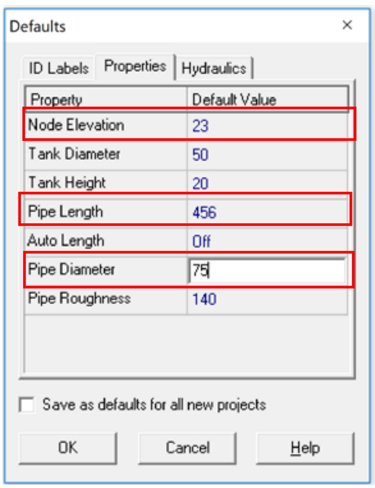
- Change Hydraulics to LPS
    - Upon changing to LPS assure that the units are meters, millimeters, liters and seconds.
- Make sure headloss (friction) formula is H-W
- Set default values for different properties in the Properties' tab. For example, if you are mainly working with a certain size pipe, making the diameter value of 100 mm will make any new pipe you draw 100 mm.
- Check red box and press OK

Repeat this procedure for each new Project

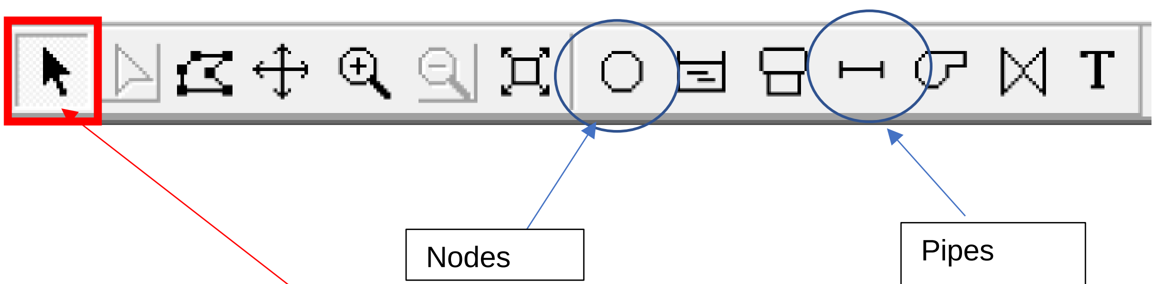
2. We are going to **Draw a water distribution network** whose pipes measures 456 m length, 75 mm in diameter, and have nodes with an elevation of 23 m. This is a simple model for water flow through connected pipes.

For this exercise, all of the pipes, and nodes we draw will have the same length, diameter and elevation. If your network has several pipe lengths that are the same, it is a good idea to preconfigure the lengths and then modify the few that are different.

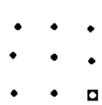
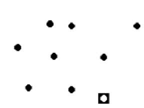
- Open Defaults again and click "Properties."



Changing the default values will make every pipe and node(junction point for pipes) you draw in this project have these properties.

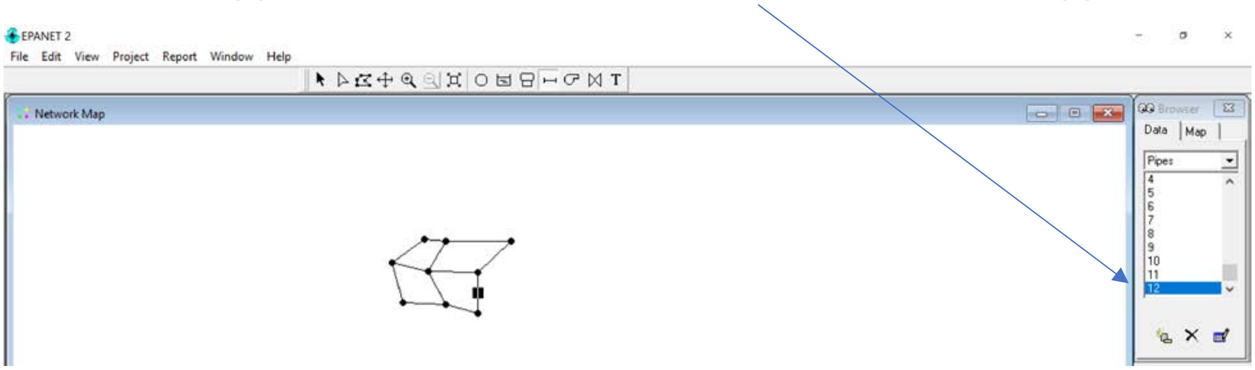


- Click the nodes button and make 9 dots on the screen. The nodes will appear wherever you click the screen. It doesn't matter where you put them.

This:  is the same as  because EPANET is a model, not to scale.

- To stop drawing nodes when you click, click the mouse button to deselect the node button, or any of the drawing buttons.
- To **delete** a node, or any object, click the mouse button, and click the object. Make sure the object you want to delete has a flashing black square that is highlighting it. Then, press the delete button on your keyboard.

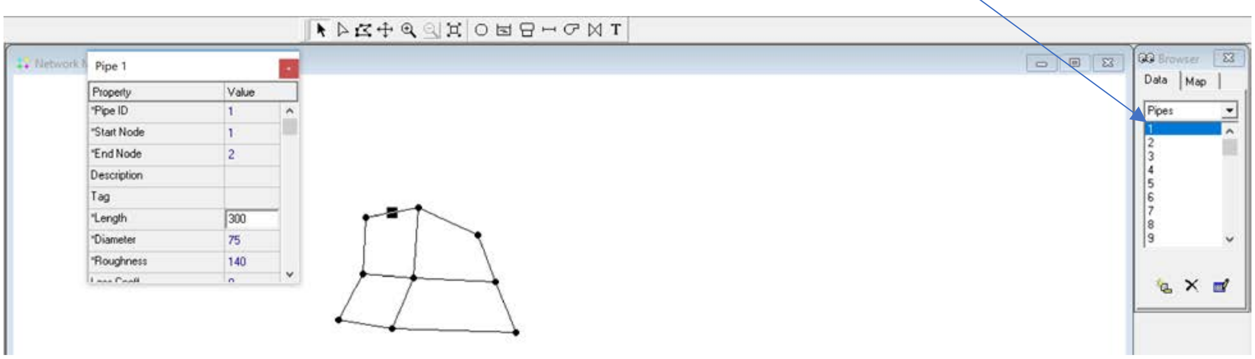
- Now, click the pipes button and draw the pipes in by clicking the node you want the pipe to start at and then clicking the node you want the pipe to end at. Draw the horizontal pipes first, then the vertical ones. There should be a total of 12 pipes



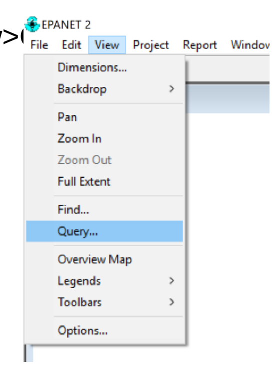
Remember, we want pipes with a diameter of 75mm. Let's double check.

- If you double click the pipe, its own property tab will appear and you can see that the length is 456m and the diameter is 75mm. However, as you can see below, we can also change the lengths individually. If you need to change individual pipe or node properties, double clicking the specific object will allow you to modify its properties.
- Another way to open the individual properties is to click the exact pipe number on the right side. Clicking pipe 1 will open the same properties tab below. To check the nodes (or junctions) this way, click the drop-down menu where it says "Pipes" and change it to Junctions, and you will see a list of the 9 junction points.

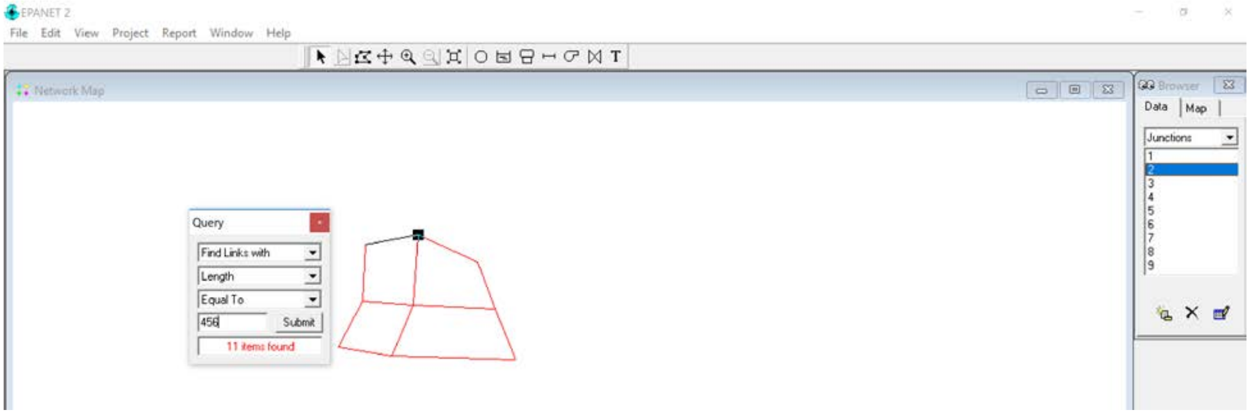
(I know the picture is different because I accidentally exited the app while creating this tutorial, but this just further drives the point that the pictures look different but are still THE SAME NETWORK.)



- To check the values of all your objects, go to View>



and a menu like this should appear:

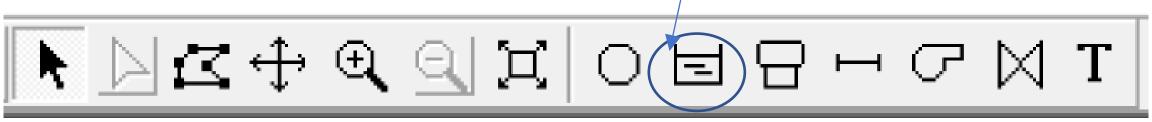


- Using the drop-down menus construct the sentence “Find Links with Length Equal to 456” and press submit. You should see that all the pipes that are default 456 are highlighted and the one we changed to 300m is not highlighted.

Testing Water Pressure

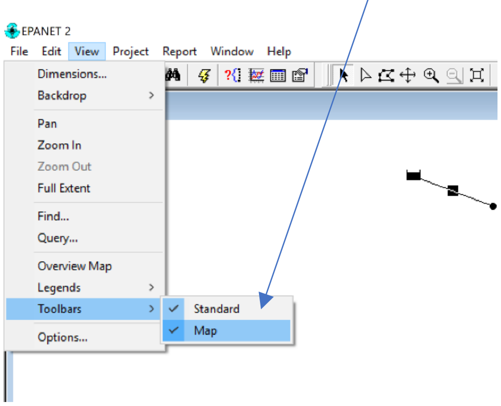
Sometimes, we don’t know what length or diameter pipes we need for a certain system. Luckily, EPANET will tell us.

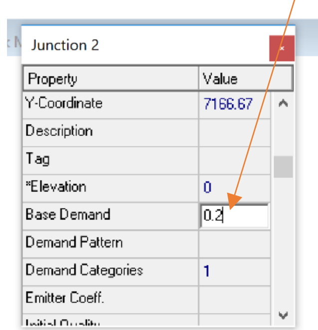
Let’s try to figure out what diameter of pipe you would need so that a water system supplies water with 1 bar (10 meters of water column). The reservoir is at 20 m and the elevation of the node is 0 m. The demand at this point is 0.2 l/s, the equivalent of a normal tap.

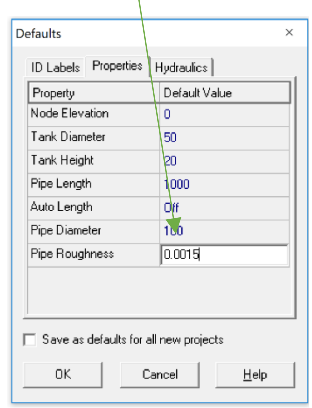


- Place a reservoir and a node on the screen and connect the 2 with a pipe.
- Then, make sure the given values are set in the Defaults tab, and change the roughness (friction coefficient) for the plastic pipe to its typical value of 0.0015.
- Double click the node and change the base demand to 0.2 L/s.

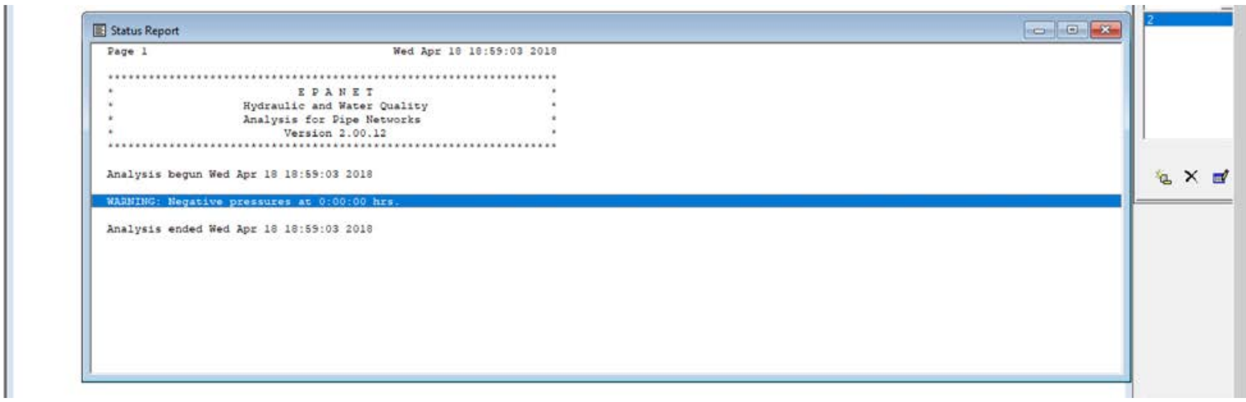
**Make sure your standard and map toolbar are both in your window



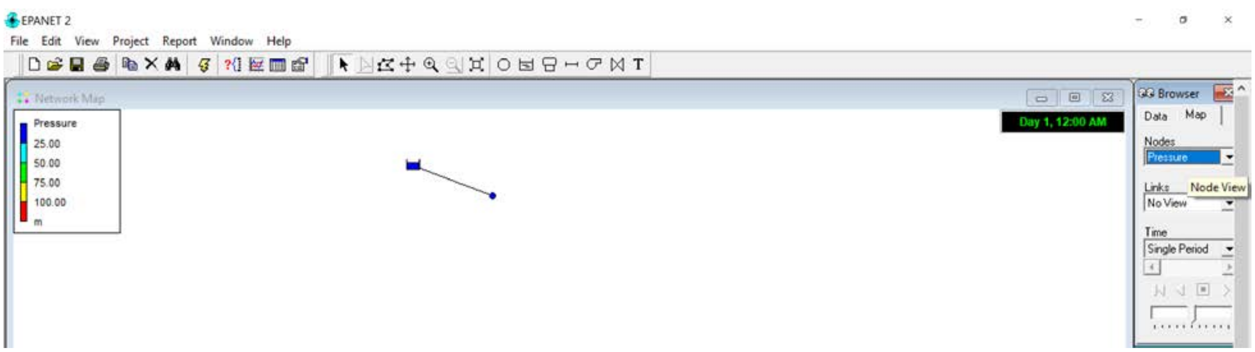




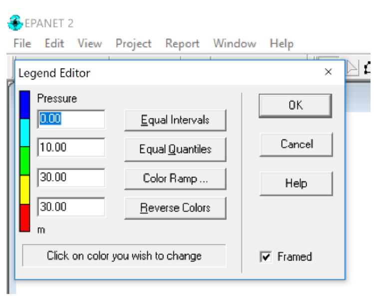
A warning message will appear. Don't panic, press okay, this is what EPANET is for.



- Basically, negative pressure= no water supply. This is not what we want. However, we can fix this by changing the diameter and length of the pipe!
- First, so we can see the pressure changing lets go to Maps > Nodes? Pressure.
- Double click the pipe and keep increasing the diameter, and you'll notice pressure begins to become positive around 1.25 m (enter 1220, it is in mm). Yay! Water is delivered.

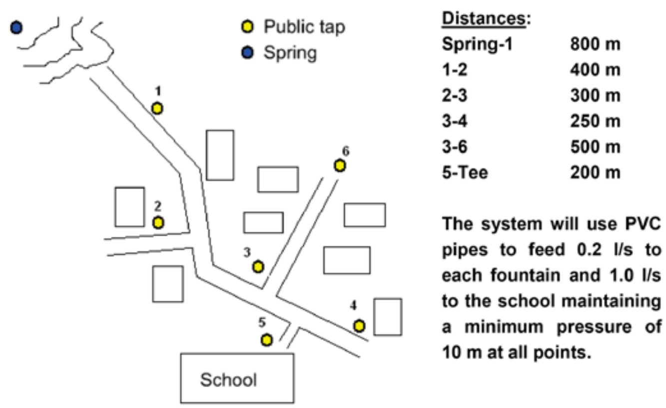


To change the pressure scale, simply right click the pressure legend and you can change the numbers:



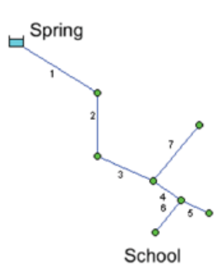
Practice Problem:

The small town of Massawa was in need of a water supply system for some time. Traditionally the water was transported by donkey from a stream 6 km away, but funds are now available to use spring in the hill at an elevation of 36 m. The flow is estimated at 3 l/s. A system is planned to supply 6 public fountains, all of them at 17 m of elevation, except number 6 (22 m) and number 1 (25 m) in accordance with this sketch.



1. Configure the defaults so that you make the least changes – 4/6 of the nodes have an elevation of 17m, for example.
2. Draw out the 6 nodes, you can label your diagram using the "T" (textbook) in the toolbar. Type in your text and press enter when you have finished typing the label. The spring is a reservoir.
3. Note you will need to place an additional node in between 3 and 4 as to create a T shaped system to connect all the nodes.
4. PVC Roughness ranges from 140-150
5. Remember, your first system will likely work when the lightning bolt is pressed, however we want to conserve material. Try to balance maintaining the pressure above 10m and using the smallest diameter pipes possible.
6. Use practical diameter numbers. You can't buy a 237mm pipe, but there are 250mm ones.

Below is a possible answer, but there are many ways to optimize this system.



Link ID	Length m	Diameter mm
Pipe 1	800	100
Pipe 2	400	75
Pipe 3	300	75
Pipe 4	150	50
Pipe 5	100	18
Pipe 6	200	50
Pipe 7	500	50

EPANET Reference Sheet

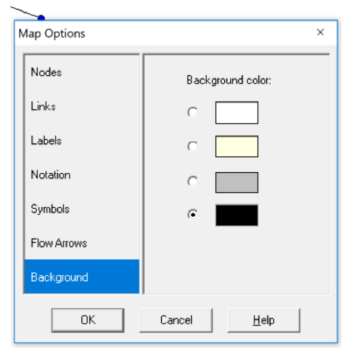
Units:

• Flow: liters/second.
• Pressure: column meters of water, being 10 meters to 1 bar or kg/cm2.
• Diameter: millimeters.
• Length: meters.
• Elevation: meters.
• Dimensions: meters.

- In metal pipes the diameter that is specified corresponds with the internal diameter
- the plastic pipes (PVC and HDPE) are named by their external diameter. The internal diameter is the external one minus the thickness of the wall. At the moment of modeling them you should use this internal diameter.

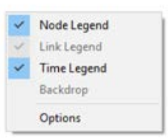
You can use this table for an approximate correspondence between the nominal diameters (ND) or how pipe are commercially named and internal diameters (ID):

ND	25	32	40	50	63	75	90	110	125	140	160	180	200	250	315	400	450	500
ID HDPE	20	26	35	44	55	66	79	97	110	123	141	159	176	220	277	353	397	462
ID PVC	21	29	36	45	57	68	81	102	115	129	148	159	185	231	291	369	--	462



Change background:

- Right Click anywhere on the map screen and select Options.



- Press Background on the left hand tabs side and click the color you want and press OK

References

[Arnalich Water and Habitat]: [Epanet and Development: A progressive 44 exercise workbook]
[EPANET Workbook]

A Guide on Community Education for EWB

Engineers Without Borders University of California, Berkeley
Sydney Osugi

Abstract

This guide will introduce the concept of community education and will mainly focus on the importance of community education for EWB. This is intended as a starting point and will cover various topics to keep in mind, as well as suggestions while creating an educational plan.

Table of Contents:

Definition

Community education promotes learning and development about a specific topic. A defining feature is that most educational plans encompass activities and dialogue with the community members.

Importance

Projects need community involvement/investment/knowledge of how to use the system so it is maintained and the water doesn't get recontaminated.

a. Specifically, the community needs to be able to sustain the system and be able to use it after EWB leaves.

Audience

First and foremost, know your audience. Effective teachers are those that are able to engage their students and create a welcoming environment.

Be aware of any possible language/educational barriers.

a. It is often difficult to learn a new concept. Adopt the teaching style of complementing one's efforts and giving constructive feedback works to encourage learning when a topic is tough.

Lessons/workshops need be engaging and able to engage a range of ages.

b. Kids' attention spans are low (you can't teach them like you would adults)

Arts/crafts/skits/coloring/drawing are all recommended.

c. Activities that are more hands-on are recommended since they are more universal activities and easier to convey a message without dialogue.

(See section 7 for a few educational plans.)

Lessons taught need durability.

d. The focus is for the community to retain knowledge after EWB leaves.

There needs to be flexibility in lesson plans.

e. Kids may be uninterested in the original lesson, there may be an unexpected amount of attendance, or there may be less time available than scheduled. Unexpected issues arise all the time and EWB must be able to accomodate for these problems.

Topics of education

Every lesson should have a learning goal. After each lesson, reflect on how it went and take notes on its effectiveness of conveying the learning goal or any issues that arose to be able to adjust the lesson plans for next time.

a. Clean water/importance of clean water.
    i. Many of those in the community may be content with the way they collect water. Repeat this throughout the lesson since repetition aids memory.
b. Water sources/good water sources/bad water sources.
    i. Everyone should know where they get their water.
c. Common pathogens and how to identify them.

        i. Be aware that different communities will have different common problems and you should those your community.
        ii. Transmission of illnesses, such as, ingestion/consumption, dermal contact, and inhalation.
            1. Bacteria → e.coli/typhoid fever/cholera
            2. Viruses → norovirus/hepatitis
    d. Storage
        i. All members of the community should know how to properly store water.
            1. If just one person in the community knows how to maintain the system and he or she leaves or dies, then the system will fail.
        ii. Focus should be on the prevention of contamination and the remediation of water.
    e. Create a manual on how operate and maintain the water system.
        i. This should be easy to follow.

Build confidence/trust with community

Many community members may not trust the new system and not want to use it, as EWB are strangers entering into their community. However, in order for the project to be successful and for the system to be utilized to its full potential, it needs to be used.

a. Review all lesson plans with community leaders to get their input.
    i. This conveys respect and their input may be important since the community may have sacred areas and places meaningful to the community that EWB wouldn't know about.

Difficulties of Community Education	Overcoming Difficulties
Lack of trust/won't maintain the system	Build trust with the community
Difficult to Implement the Project	Consult community leaders with any issues
Community Educational Barriers	Tailor education to the community
EWB lack of knowledge/experience	Educate all EWB members before arriving

Lesson plan ideas

Hygiene

Materials: Water, soap, ashes, commercial toothbrush, stick toothbrush, nail cutter, comb, toothpaste, salt foam from plants, flashcards, slips of paper/cards, pens/chalk, beans/seeds
Activity: Singing and Miming

1. Prepare a song for young children that allows them to mime specific habits of personal hygiene

    a. “This is the way we wash our face… wash our face… this is the way we wash our face… early in the morning.” to the tune to london bridges
2. Encourage open discussion of the children’s personal hygiene habits
3. Encourage the children to come up with examples of good hygiene and when it is the most important

Safe Water
Materials: Paper/pencils, paint/markers, slates/chalk, paper/ scissors, glue/ modeling clay, drinking cups, glass bottles for solar disinfections, utensils to boil, saree/materials to filter water
Activity:
1. Ask children where they get their drinking water
2. Have each child draw/model/cut/paste their drinking water source
3. Let them display their drawings and create discussion about what else occurs at these sources besides collection of water (swimming, bathe…)
4. Open a discussion about cleanliness and waterborne diseases

References

Khamal, S, Mendoza, R, Phiri, C, Rop, R, Snel, M and van Wijk, C (2003). The global joy of learning. Participatory education activities for children and educators (PEACE) on water, sanitation and hygiene. Delft, the Netherlands, IRC International Water and Sanitation Centre. (E-book series X). ...p. Includes a bibliography and Y illustrations

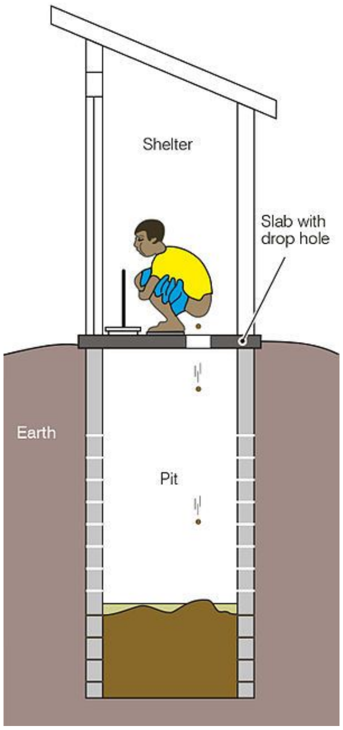
Ventilated Improved Pit Latrines

Abstract

This guide will cover the overview of Ventilated Improved Pit Latrines, followed by design considerations when first planning to build one, advantages of the double versus single pit, and implementation. The ventilation pipe will be elaborated on and emptying the pit will be covered within the implementation section.

Table of Contents

Overview



Ventilated improved pit latrines are extremely viable options for sanitary waste management at a relatively low cost. The general components for a standard pit latrine are a hole in the ground around 10 inches in diameter, a slab to cover it when not in use, and a pit around 3 meters deep and 1 meter wide along with a shelter to cover everything. Faecal matter, dry cleansing materials, urine etc. enter through the hole into the pit which is sometimes lined with some stone or brick to prevent collapsing. The bottom is generally kept unlined in order allow for filtration of urine into the surrounding soil. While this liquid permanence is key for the pit to not fill as quickly, it also offers a potential problem of leaking into groundwater sources. Thus, the pit should be built a good distance away from water sources to avoid this. When the pit is filled, manual extraction and pumping is required so it can be reused again.

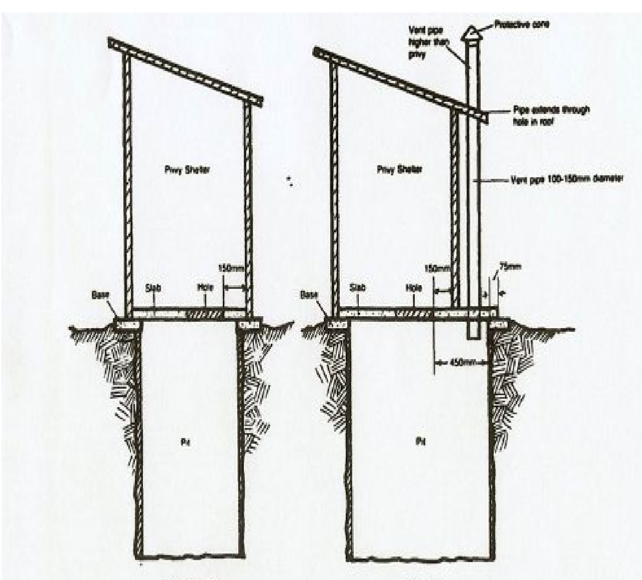
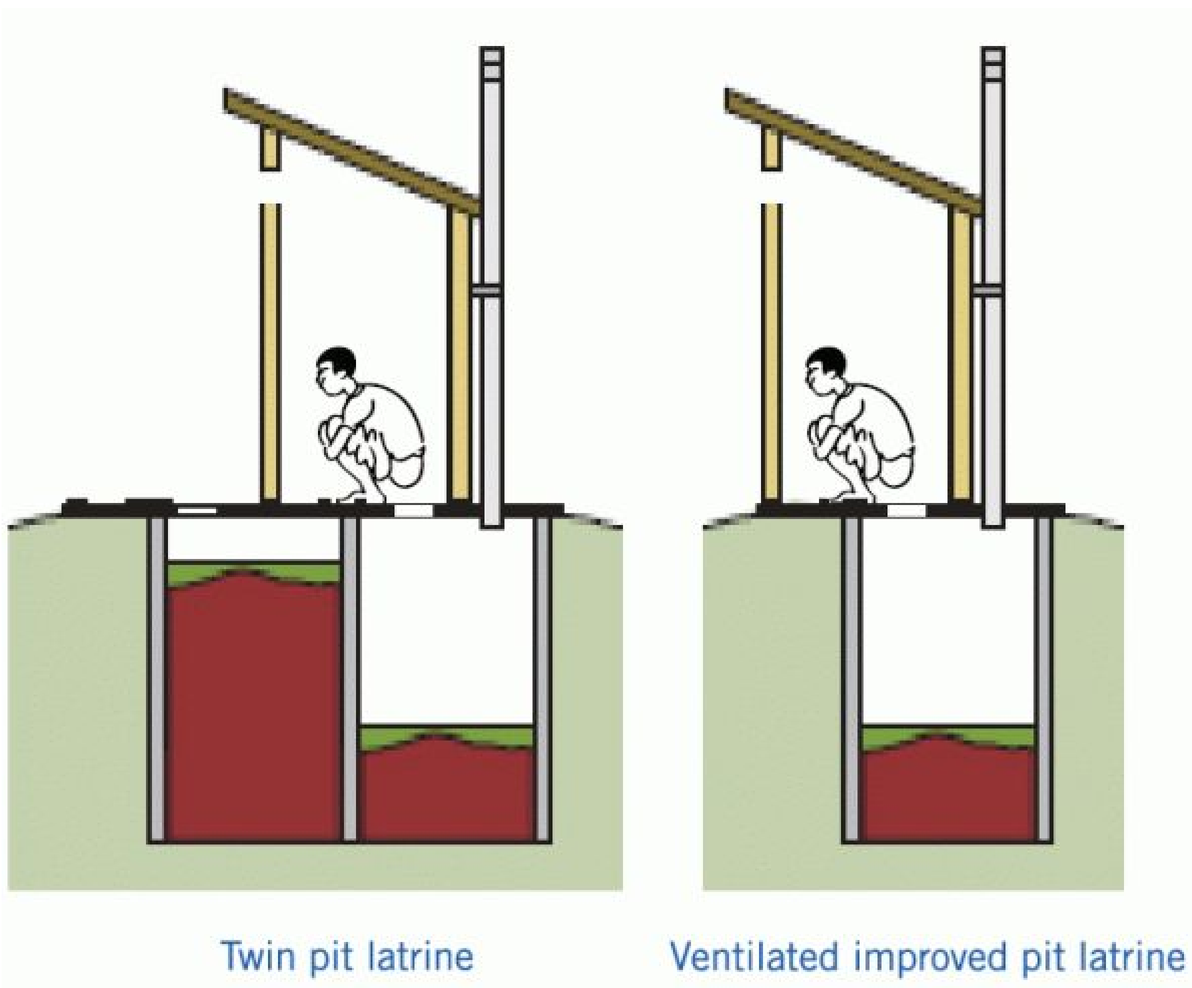


Figure 4. Comparison of Privies with and without Vent

Source: USAID

The advantage of the ventilated pit latrine is the addition of a ventilation pipe which filters out the smell. It also attracts flies to the light where they get caught in a mesh trap. While slightly more expensive, this greatly reduces the risk of disease from flies and allows for a more pleasant experience overall. Regular cleaning and maintenance are recommended to ensure the ventilation pipe is clear and mesh cleaned.

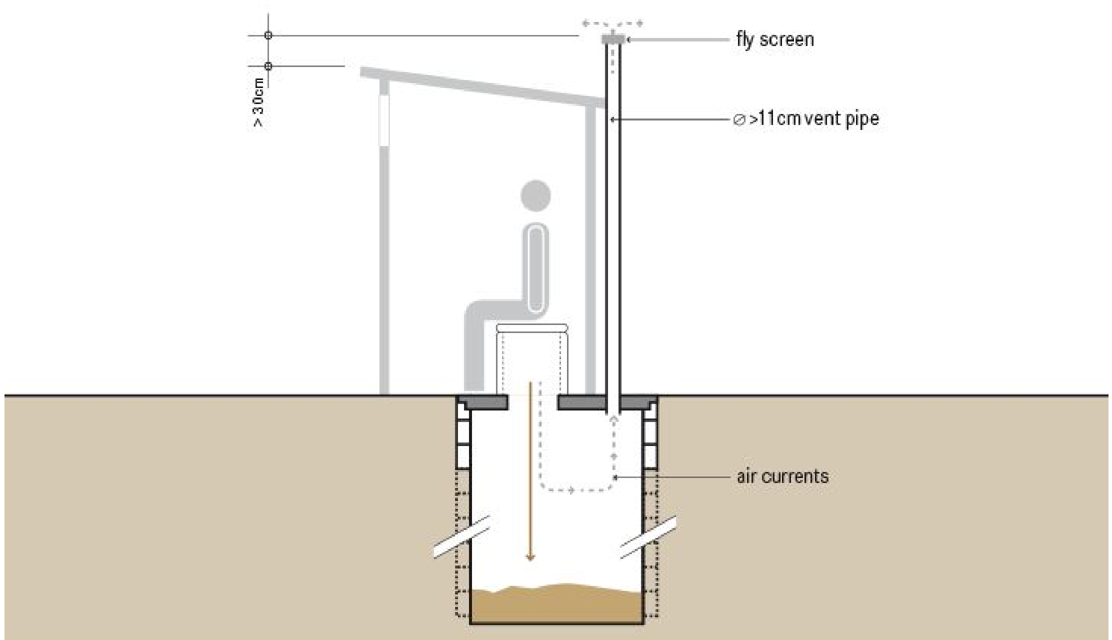
The difference between the double and single ventilated pit designs is, as the name implies, the addition of another pit for the double design. This way, after one pit is used, you can cover the first pit and use the second one while the material in the first pit degrades and drains. When done correctly, the double pit design allows for a much more efficient latrine design.



The double pit is generally preferred since it doesn’t require moving the entire structure to a new location as often, and requires minimal extra effort or cost to implement. The area must be analyzed to make sure there’s suitable space and soil for a double pit design.

Implementation

Since on average solids accumulate in the pit at a rate of 40 to 60 L/year per person or 90 if dry cleaning materials are used, pits should be dug roughly 3 meters deep and 1 wide, not exceeding 1.5 diameter to prevent collapsing. To ensure groundwater contamination doesn't occur, the pits should have at least a 2 meter gap above the source. Once the pit is dug and the superstructure is constructed, line the pit with stone, brick etc. to ensure it will not collapse. The bottom must remain unlined to allow for exfiltration of liquids.



The vent pipe should have a diameter of roughly 110 mm, and reach more than 300 mm above the highest point of the superstructure. PVC, bricks or iron are recommended to construct the pipe. The mesh placed at the top of the pipe should be made from aluminum and be large enough to allow air circulation and prevent clogging.

To empty the pit, use a pump that's either motoried or human powered. The pump will go into the pit and drained this way whenever matter has reached within 0.5 meters of the top of the pit.

References

Single Ventilated Improved Pit

Sustainable Sanitation and Management

https://www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/site-storage-and-treatments/single-ventilated-improved-pit-(vip)

https://www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/site-storage-and-treatments/double-ventilated-improved-pit-(vip)

Ventilated Improved Pit

Unicef

https://www.unicef.org/ghana/latrine_options_flyers.pdf

Disinfection Via Chlorination

By: Emily Paszkiewicz

Abstract:

Disinfection is of the utmost importance to prevent the spreading of bacteria, viruses and other microorganisms. These can lead to gastrointestinal diseases. The most widespread means of disinfection is to use free chlorine to kill bacteria before it causes harm to consumers. This guide outlines how to properly disinfect pipelines, reservoirs, wells and pumps in order to promote general public health.

Table of Contents

General Notes for Chlorination

- For disinfection purposes, it is best to use free chlorine over combined chlorine.
- Do not release highly chlorinated water to the surrounding area since it can be harmful to the environment, particularly in large volumes.
- The best way to test chlorine residuals abroad is to use a pool kit and to follow the instructions in the kit because pool kits tend to be inexpensive and portable. Be sure not to use an old kit or else the readings may not be accurate.
- Disinfection must be performed before using any water distribution system.
- The WHO standard for chlorine residual in drinking water is between 0.2 – 5 mg/L, however it is recommended to keep the residual below 2 mg/L for taste purposes.

Guide for Disinfecting Pipelines:

Pipelines must be disinfected not more than 3 days before use to ensure recontamination will not occur. Typical disinfection is done via chlorine in the following steps:

1. Flush out the pipes with water to remove any large debris in the pipes. Use a hydrant or blow-off.
    a. Minimum flushing velocity: 0.8 m/s (2.5 fps)
    b. Use this chart to determine the optimal water flow (lps) given the pipe size:

Table 8.1: Required Flow for Flushing Pipelines (lps)

Pipe Diameter (mm)	Flow Requirement To Produce 0.80 m/s
100 (4")	6.3
150 (6")	12.6
200 (8")	25.2
250 (10")	37.8
300 (12")	56.8
400 (16")	100.9
Hydrant Discharge to Atmosphere @ 28 m Residual Pressure	
63.5 mm (2½")	63.1
114.3 mm (4½")	157.7

2. Pump a solution of not more than 50 mg/L of free chlorine into the pipe system.
    a. Start at one end and wait until the pipes are full of the chlorinated solution.
    b. Ensure that all valves and fixtures are also being disinfected with the chlorinated solution.
    c. Leave the chlorine solution in contact with the pipes for 24 hours.
3. After 24 hours, release the chlorine solution, ensuring that the chlorine does not enter the potable water stores.

4. Test for chlorine residual all along the length of the pipe. Chlorine residual must be greater than 25 mg/L or else treatment must be repeated.
5. Use clean water to flush the disinfected pipeline. The chlorine residual must be between 0.2 and 2 mg/L.

Guide for Disinfecting a Reservoir:

After reservoirs have been fully tested for leakages, they must be disinfected before being filled with potable water.

For safety reasons, all people working to disinfect the reservoir must wear fully protective clothing including closed toed shoes, long sleeves, long pants and a breathing mask. They also must completely shower/bathe to wash off chlorine.

1. Clean reservoir well before chlorinating.
2. A strong free chlorine solution: 200 mg/L should be sprayed on the interior surfaces of the reservoir
    a. Purpose: to kill bacteria on contact
3. Prevent the strong chlorine solution from contaminating the distribution line.
4. Fill the reservoir bottom with chlorine solution 50mg/L to a depth of 30 cm.
    a. Let this solution sit for 24 hours before draining.
5. After 24 hours, drain, and ensure that the solution now has a concentration of less than 25 mg/L of chlorine.
6. Then fill the reservoir with clean water and test the chlorine residual to ensure that the residual is between 1 and 2 mg/L

Guide for Disinfecting a Well and Pump:

1. Pour a free chlorine solution (50 mg/L) into a well and pump.
2. Allow the well to stand for 24 hours.
3. Pump the water to waste until the odor of chlorine disappears. Then test for chlorine residual and ensure that it is between 0.2 and 2 mg/L.

References:

RWS vol. 2 Chapter 8

Environmental Health at US Aid: Chlorine Residual Testing Fact Sheet.
http://www.ehproject.org/PDF/ehkm/cdc-chlorineresidual-updated.pdf

CE 98 Final Project
By Ethan Sun

Rainwater Catchment Technology Guide

Abstract:

This paper is a technological guide of implementing rainwater catchment as a water supply for households. It mainly discusses why rainwater catchment is an important source of water, the techniques and applications involved, and also its advantages and disadvantages.

Table of Contents:

Introduction

Securing a clean and sufficient water supply for populations has been a struggle for many developing nations, even in the modern era – the 21st century. Water scarcity is currently affecting every continent on our planet, with an estimated 844 million people lacking access to clean drinking water, and a further 2.3 billion people using poorly sanitized water.[1] In clearer words, 1 in 9 people lack access to safe water, while 1 in 3 lack access to a toilet, and "more people have a mobile phone than a toilet".[2]

Besides physical water scarcity, where there is simply limited fresh water to supply, there is also economic water scarcity, where local governments cannot support the funding of basic infrastructure to filter and deliver water, even when there are many fresh water sources in the region. Local residents may go to rivers and lakes to fetch water daily, for either domestic or agricultural uses. This potentially results in the spreading of many waterborne diseases (such as cholera) if the water source is polluted. Other contaminants in water also lead to major health concerns.

While urging local governments to put in greater considerations for water safety, we can also

[1] https://water.org/our-impact/water-crisis/ accessed 20180417

[2] Same as above

persuade communities to use alternative water sources, which are inexpensive and simple to harvest. One such example is rainwater harvesting.

The usage of rainwater catchment by our ancestors can be dated back to ancient history. Archaeological evidence documents rainwater catchment being implemented in Baluchistan (nowadays Pakistan) as far back as three millennium BC.[3] "It is one of the oldest means of collecting water for domestic purposes." People in the Mediterranean, in the Middle East, in the Saharan desserts, in China, and even on small islands in the Pacific Ocean, have been known to collecting rainwater, storing them in tanks, above- or underground, ranging from 200 to 2000 cubic meters. Storage is increased in wet seasons and utilized in dry seasons. Many tanks are still operational today. In Europe, the Americas and Australia, rainwater is continued to be used as an important water source for many isolated homesteads and farms.[4]

Nowadays, we don't recognize rainwater catchment as a major water source anymore as urbanization has provided us with a stable municipal water supply. However, this is becoming an issue, because the increasing size of cities have put pressure on such water systems, and there are already many parts of the world with municipal supply under stress.

Relatively, rainwater catchment has remained a small scale domestic activity. The owners of the system are usually the ones who control and maintain it, and the ones who consume the water supply. They are usually domestic residents, and there's limited commercial use, especially in cities. However, this situation is beginning to change. The Shanghai Tower, the tallest structure in Shanghai, China, has implemented a state-of-the-art rainwater catchment system, which provides water for various purposes such as central-heating and toilet flushing. It is targeted to reduce water consumption by 40%.

Techniques and Applications[5]

An overall consideration of the water quality of rainwater

Relatively, untreated rainwater is a cleaner source than many other sources of water, such as groundwater and surface water, which may be contaminated by various pollutants. Many times, it is difficult and costly to locate such pollutants, which makes rainwater a superior source. Naturally, it has better chemical and physical properties.

However, it is also important to emphasize the two main possible contaminations of harvested rainwater. Firstly, there are contaminations due to the equipment used. For example, roofs, piping and tanks that are involved in the catchment process may contain toxic materials that may pollute the water. Then there are also external contaminations, including

---

[3] https://www.ukessays.com/essays/environmental-sciences/rain-water-harvesting-as-water-scarcity-solution-environmental-sciences-essay.php accessed 20180417

[4] Same as above

[5] This section has many references from the *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean,* by UNEP - International Environmental Technology Centre url < http://www.oas.org/dsd/publications/Unit/oea59e/ch10.htm >

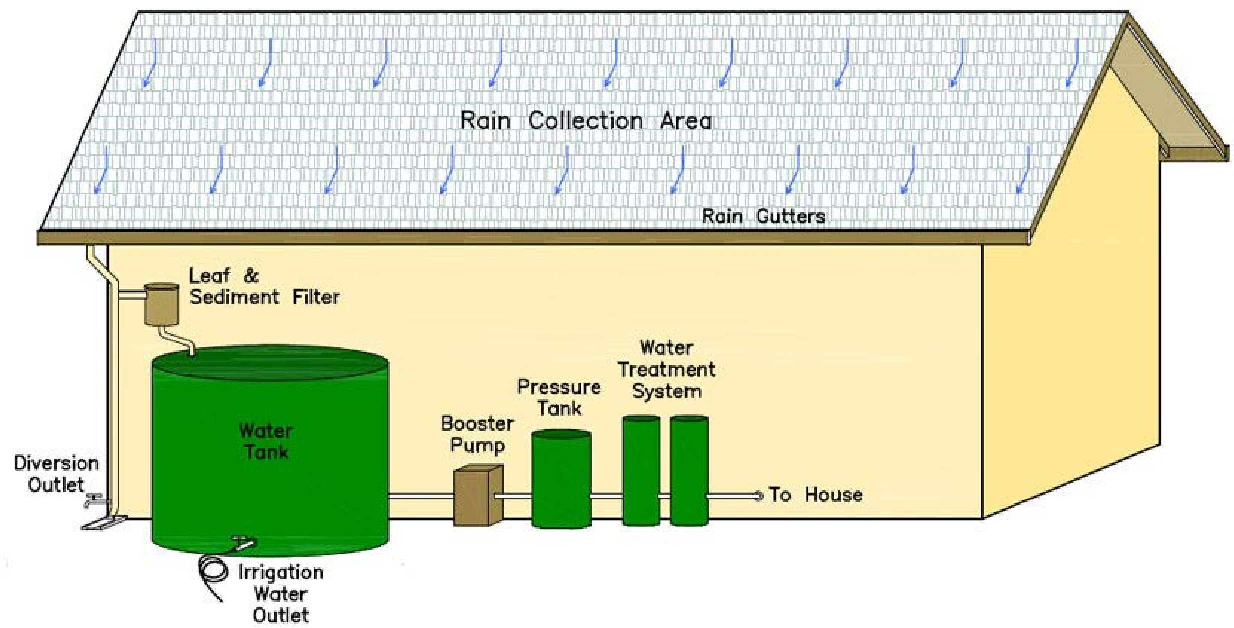
substances in the air (consider whether acid rain is known to the region), bird and animal droppings, and insects. Further techniques to isolate these contaminations will be discussed further in the paper.

Pre-construction: Evaluation and Planning

Typically, rainwater catchment is feasible in areas where there is significant rainfall but lacks centralized water supply by the government, or areas where a clean source of groundwater or surface water is unavailable. Although rainwater harvesting can be a cheap and convenient source of water supply, many aspects should still be considered whether to implement such a system.

Here are some listed on an internet source:

1. Is there a real need for an improved water supply?
2. Are present water supplies either distant or contaminated, or both?
3. Do suitable roofs and/or other catchment surfaces exist in the community?
4. Does rainfall exceed 400 mm per year?
5. Does an improved water supply figure prominently in the community's list of development priorities?



[6]

---

[6] Diagram of rainwater catchment system from internet. Link http://www.hurvitzenvironmental.com/rainwater.html accessed 20180424

When the overall evaluation confirms the proposal to build a rainwater catchment system, the planning of the construction can begin. Generally, there are three elements in a rainwater catchment system: a collection area, a conveyance system, and storage facilities. The collection area can simply be roofs of domestic residences, but the specific design of the roof can affect efficiency and water quality. If an existing rooftop is being used as a collection area, it should be inspected so there are no potential contaminants. Possible contaminants are rust on a metal surface, paint, vegetation etc.

The conveyance system is the piping that delivers water collected to long term storage. Some kind of measurements should be taken to prevent animals and insects from entering the pipes. It should also be designed so that clogging (e.g. by leaves) would not occur or can be easily removed. Future operability of cleaning and maintenance of the system should also be considered.

Finally, water will be stored in a tank or cistern, which can be designed as a part of the building, or can be separated from the building, depending on how the water will be used and by whom. There are also some specific requirements for the design of the tank:

1. A solid secure cover
2. A coarse inlet filter
3. An overflow pipe
4. A manhole, sump, and drain to facilitate cleaning
5. An extraction system that does not contaminate the water; e.g., a tap or pump
6. A soakaway to prevent spilled water from forming puddles near the tank
7. A device to indicate the amount of water in the tank
8. A sediment trap, tipping bucket, or other "foul flush" mechanism

It is **crucial** that all three elements of the catchment system should be constructed by chemically inert materials that do not corrode in a wet environment. Some good materials are plastic, fiberglass, stainless steel, aluminum and reinforced concrete.

Rooftop paint should be avoided if possible. If inevitable, then only non-toxic paint should be used.

Post-Construction: Operation and Maintenance

Overall, operation and maintenance of a rainwater catchment system is not a skillful or stressful job, and little supervision is needed. After some basic training, the whole community can familiarize the standard procedures.

Water provided by rainwater catchment can be used for different purposes. Hence, different standards apply when it comes to various purposes.

Basic standards, for non-drinking and non-cooking, limited to laundry, house-cleaning, plumbing, agricultural, etc.

Most of the major contaminations can be eliminated through careful planning and construction. As long as proper construction materials are used, many toxic contaminants that require sophisticated water processing wouldn't exist in the rainwater collected. (In contrast, arsenic, lead, iron, manganese, nitrates and other pollutants that exist in many groundwater and surface water sources.)

1. "Foul flush" should be eliminated. "The first part of each rainfall should be diverted from the storage tank since this is most likely to contain undesirable materials which have accumulated on the roof and other surfaces between rainfalls." Precisely, during the first 10 minutes of rainfall, no rainwater should enter storage.
2. Storage tanks should be checked and cleaned periodically, using a chlorine solution to clean the walls and bottom. It should be thoroughly rinsed before entering service again.
3. Gutters and downpipes should also be periodically inspected and cleaned. The same goes to any water distribution system connected to the tank if there is one.
4. Storage tanks should be shielded well to prevent frogs, lizards and mosquitos from nesting in the water. The should be taken as a precautionary step rather than a corrective step as the water supplied would be contaminated if there are pests in the tank.
5. Community systems require the creation of a community organization to maintain them effectively. Similarly, households must establish a maintenance routine that will be carried out by family members.
6. Community members should acquire healthy water usage habits. Kids shouldn't play or tamper with any rainwater harvesting equipment. People should keep the storage area clean. If there is a malfunction, someone who is capable of fixing it should be called, instead of blindly trying to fix it and worsening the issue. If the system wasn't designed for drinking water purposes, don't just drink the water.

Drinking water standards, e.g. drinking, cooking, bathing, domestic animals

Additional steps should be conducted before using the stored rainwater for drinking purposes. It's important to understand that if the construction of the system didn't allow for drinking purposes (such as a previous rooftop was used for collection and it has oil-based bitumen shingles), the drinking water standard cannot be met.

- Although bacterial contamination can be minimized by keeping the equipment clean, it cannot be totally eliminated. The water should still be disinfected. There are many means of doing this, such as using a filtration (e.g. in-line charcoal filter) system, chlorinating the water in the tanks, or boiling the water before used for drinking.

Advantages

- Rainwater catchment can provide water precisely at the place it is needed – this means domestic residences and buildings, even in rural areas.
- The construction of a rooftop rainwater catchment system is cheap, simple and convenient, which doesn't require a huge investment.
- Post-construction running costs are also low.
- Basically, anyone can be easily trained to construct and maintain such a system, and the processes are not labor-intensive.
- Such an affordable and convenient system means that many people are able to own and manage the system by themselves, achieving self-sufficiency of water.
- Naturally, the chemical and physical properties of the water collected by rainwater catchment are superior than other water sources such as groundwater and surface water.
- Also, such a system can be quickly built and implemented in case of an emergency water shortage.
- Urbanization also is bringing together large number of people within smaller areas to live (such as flats, apartments, residential complexes) where rainwater harvesting is becoming a community-based approach. The costs and the benefits can be shared within the members of the communities.[7]


[8]

[7] https://www.ukessays.com/essays/environmental-sciences/rain-water-harvesting-as-water-scarcity-solution-environmental-sciences-essay.php accessed 20180424

[8] Photo of a large cistern. Link: https://www.forkauaionline.com/harvesting-rainwater-for-a-more-sustainable-kauai/

Disadvantages

- The system has great dependency on local climate and rainfall. It cannot provide water in seasons of dry weather and drought. This might impose some risks on local communities since if the dry weather last for longer than expected then they might run out of stored water and risk a shortage.
- For situations where rainfall is not consistent throughout the year, large storage tanks need to be built to increase storage during wet seasons. These would increase the costs and reduce the economic feasibility of rainwater catchment systems.
- The above two reasons are mainly why rainwater catchment are not used frequently in larger communities, where a constant municipal water supply would be more stable and efficient.
- Including a cistern in the initial design of the house may increase complexity and hence raise costs. Homeowners may not be willing to do so, especially if there’s already an existing water supply in the community.
- Water quality may be affected during long-term storage if the cistern is poorly managed. Animals and insects may enter the cistern and result in contamination. Also, the cistern tank itself is a risk for small children.

Conclusions

Rainwater catchment is a technology with a long-standing history and it has also been improved over the years to be suited in a modern environment. New materials and healthier water consumption habits have made long-term usage of rainwater as a drinking water source much more feasible than before. It is a crucial technology in helping to solve the ongoing physical and economical water shortage in many parts of the world. With its many advantages, and by solving its disadvantages through better planning and management, rainwater catchment is preferable alternative and backup of many important water sources, and it has the potential of becoming the main water supply in many regions in the world. Rainwater is a great component of freshwater on Earth. Utilizing this valuable resource would definitely make our world greener and more sustainable.

Matthew Takara

25 April 2018

Tap Stand Construction - Draft

Based on Panama Team Design

Table of Contents

Abstract

The tap stand is meant to give easy access to clean and safe water to residents of a rural community transporting water from a water tank that is some distance away. This guide will cover the materials required to build a simple tap stand and how to build it. It will also discuss the education that is required after building to make sure it can be maintained by the community after EWB has left.

Materials Needed

- Pipe (GI or PVC), various sizes and pieces
    - GI fares well both above and below ground, but it is more susceptible to corrosion and causes more head loss due to friction.
    - PVC is corrosion resistant, lighter, and cheaper, and it does not create as much head loss. However, it requires proper bedding and can deform if not properly maintained when kept above ground.

PVC Pipe

GI Pipe

GI Pipe that has been corroded

    - Straight pipe, elbows, T-connectors, etc.
- Gravel
- Cement
- Sand
- Water (fresh)

*sizes and amounts of material vary with each tap stand. Refer to the figure on page 4 for an example.

Preparing the Site

- Make sure that there will be good drainage at the site beforehand
- Be aware of the surrounding area
    - You don't want a tap stand near livestock, a landfill or other waste storage areas, for example
    - You also don't want the tap stand right near a slope where there is the potential of runoff contaminating the tap stand in any way

1) Dig a pit roughly 15 inches deep in the site where you want the vertical pipe of the tap stand to be built.
    a) The pipe will bend perpendicular to the vertical from and run underground and connect to a valve controlling the water.
2) Fill this pit with gravel to about three inches above the bottom covering the horizontal pipe.
3) Choose a location that is most convenient for the greatest number of users possible.
    a) Consult several members of the community; don't only ask one or a few because they may be biased towards directing you to a location that benefits them, but it is not necessarily most beneficial to the community as a whole.

Construction

1) After laying the underground pipe connected to the valve, assemble the vertical portion of the tap stand along with the faucet pieces from where the water will exit
    a) You want to do this all before beginning the mixing of the concrete. If you do it after, the concrete may settle before you are ready to place it.
    b) You may also want to reduce the number of faucet heads on the tap (e.i. instead of 4 exits for the water, just have 2). This will help deal with the potential issue of not enough head and keep water pressure at a high enough level.

2) After you have done this, then you can start mixing the concrete and laying it over the pipe and around the base filling in the rest of the pit.

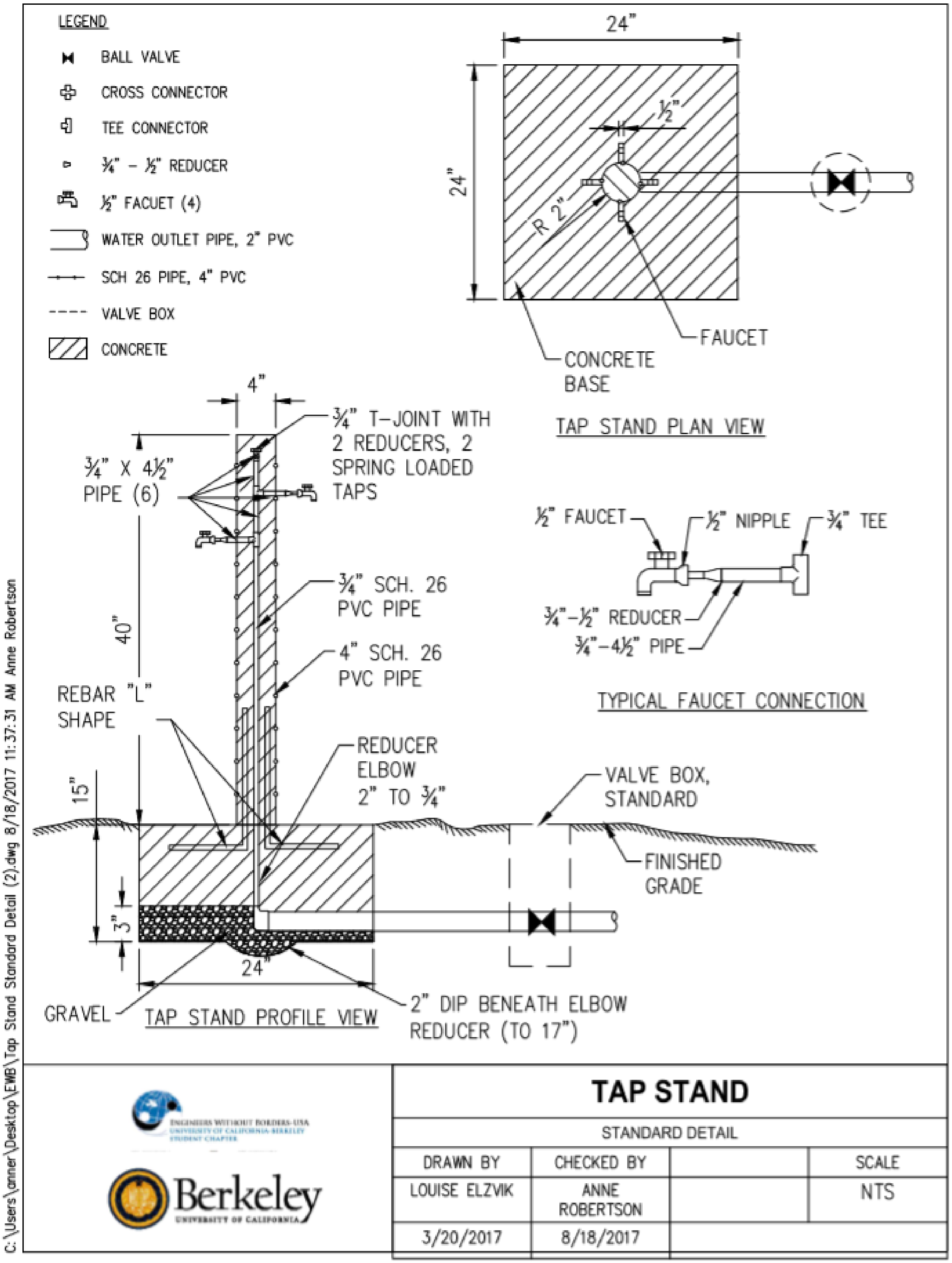


Figure: Drawing for the design of tap stand by and used for the Panama team project.

Education

- The design of the tap stand should remain fairly simple and easy to use so that you can effectively teach community members how to operate and maintain it after you have already left.
- During the construction process, make sure the workers are educated on appropriate concrete mixing techniques.
    - Workers often tend to add excessive amounts of water to their mix to increase workability.
    - While this is true and it makes it much easier to pour and mix the concrete, this adversely affects the long-term strength of the concrete.
- Other usage considerations for the community members:
    - Turn off the tap stand when not in use
    - Do not let livestock or other animals near the tap stand or the water will be much more susceptible to contamination

Conclusion:

It is important to have both proper tap stand design and construction as well as proper education of community members. This will help ensure that your tap stand is sustainable in the sense that it can be maintained and used properly and safely after EWB has left the site.

Sources

"The Design, Construction, and Maintenance of a Gravity-Fed Water System in the Dominican Republic" Matthew A. Niskanen

https://www.mtu.edu/peacecorps/programs/civil/pdfs/matt-niskanen-thesis-final.pdf

Tap Stand Construction, Mambo Village – Ernest Liu and Crystal Wong

http://www.mambosteunpunt.org/Downloads/Tap%20Stand%20Construction.pdf

Public Standpipe design and maintenance for rural South Africa

http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-20192009000100002

Maggie Chen (in person, during Decal 4/11/2018)

Tap stand designs from EWB Panama project folder

CE98: FINAL PROJECT DESIGNING A CONSTRUCTION SCHEDULE

Primary Investigator: Karen Tapia

Primary Investigator: Karen Tapia

Guide Abstract

This guide serves as a tool to help future EWB members create construction schedules to ensure success in their projects. The guide will inform the members about how to brain storm different tasks and the order that the tasks should be placed. The guide will introduce technical terms that will ease the process of choosing completion dates for each task. Finally the guide will provide examples of construction schedules so that EWB members can have a template of real construction schedules and can model theirs after the examples.

Primary Investigator: Karen Tapia
Final Project designing a construction schedule

Date Submitted: April 18, 2018

Table of Contents

Primary Investigator: Karen Tapia

Guide

Introduction

Construction schedules are essential to the success of a future project because it allows everyone on the construction team to be on the same page. A construction schedule allows for there to be a timeline where different tasks get completed to make sure that the final project can be completed within a certain deadline. By having a guideline to follow this ensures that the project will be completed not just in time but successfully. There are three main parts to a project schedule, the components such as the specific tasks that need to be completed, the expected deadlines, and the final deadlines of when certain things must be completed. There are many templates online to accommodate the different components that a person would want to add. Overall designing a construction schedule is the brain of building a project because it creates a timeline that allows the project to be finished in time.

Creation of tasks

The first part of creating the construction schedule is brainstorming different tasks that would be important to the creation of the project. How you decide on the tasks depends on the project that you're creating. [1] Based on different templates online some of the main tasks are preconstruction, project procurement, construction, inspection, and close off. Under pre-construction there could be sub-tasks such as preparing the contract drawings, making sure the foundation is ready, getting permits for the building, and setting up the site. Under project procurement the subtasks could be making sure that a subcontractor is hired and making sure the materials are ready. Under construction there could be different sub tasks such as the main parts that need to be constructed. For example, creating a well the different tasks that could be created under construction would be drill dewatering well, excavation, installing pipes, and ect. Under inspection and close-out the tasks would be created to make sure that the site works well and check that all the parts are working. Making sure that the sites is cleaned and that EWB can leave and if anything were to happen to people from the area can fix the situation.

ID	Task Name	Duration	Start
1	**Pre Construction**	**215 days**	**Mon 1/24/11**
2	Prepare Contract Drawings	93 days	Mon 1/24/11
3	Permit (Foundation-G4 Level)	1 day	Fri 3/18/11
4	Permit (Full Building)	1 day	Mon 10/3/11
5	Site Utility Relocation	190 days	Mon 2/28/11
6	**Project Procurment**	**359 days**	**Mon 1/17/11**
7	Subcontractor Bid & Interview Period	19 days	Tue 2/22/11
8	Recommendation and Approval of Subcontracts	20 days	Mon 3/21/11
9	Sheeting & Shoring Procurment	32 days	Mon 1/17/11
10	Other Material Procurement	294 days	Mon 4/18/11
11	**Construction - West (Column Lines 1-11)**	**458 days**	**Mon 4/18/11**
12	Notice to Proceed	0 days	Mon 4/18/11

Figure 1 shows an example of different tasks and it's divided into a main task and the smaller tasks to make each task doable.

Link types to decide order of tasks

Deciding how to place certain tasks is called link types because all the tasks are linked together and if one doesn't get completed then the ones after won't get done either. There are four main types of link types that decide the order of the tasks and helps create the construction schedule. [2] The first is finishing to start (FS) which means that the dependent task B can't be completed until the task it depends on A is completed. The next is starting to start (SS) which means that dependent task B cannot begin until the task that it depends on A begins. The next is finishing to finish (FF) which means that dependent task B cannot be completed until the task that it depends on A is completed. The last link type is starting to finish (SF) which means that the dependent task B cannot be completed until the task that it depends on A begins. These link types are important when deciding where to place tasks and the order they should be placed in.

Choosing Dates

What accompanies the tasks are the dates that belong to the different tasks. The first thing to do is determine when the project will start and decide an end date. Afterwards one can connect the smaller tasks to fit in within the time frame of the whole project. Many templates have a duration column which states how many days a specific task is planned to take. The other columns are start and finish dates of the expected project. Some templates have a due date for the specific task but one can also add an extra column where the end date is a flexible end date and another one were the task must be done.

TASK NAME	TOTAL HRS	START	FINISH
CONCEPT DEVELOPMENT	18 HRS	TUE 1/9	FRI 1/12
CONCEPT	4 HRS		
SKETCH	6 HRS		
MODEL	4 HRS		
POSSIBLE MATERIAL SELECTION	2 HRS		
STRUCTURE?	2 HRS		
GREEN STRATEGIES	18 HRS	FRI 1/12	MON 1/29
RESEARCH	4 HRS		
CUT SHEETS	2 HRS		
PERFORMANCE CHARTS	4 HRS		
DIAGRAMS	8 HRS		
CODE ANALYSIS	29 HRS	FRI 1/19	MON 1/29
RESEARCH	6 HRS		
ZONING	1 HRS		
F.A.R	2 HRS		
OSHPD	20 HRS		

Figure 2 shows an efficient example from an architecture schedule, of how to design the dates for each task.

Constraints on Dates

There are also constraints that affect the construction schedule. The constraints allow the person who's creating the schedule to control when the project starts and when it ends. The three main type of constraints are flexible constraints, semi-flexible constraints, and inflexible constraints. The flexible constraint doesn't have a set date associated with them and allows you to set them early or later in the project schedule. The semi-flexible constraint requires an associated date which means that it controls the earliest and latest date that a task will get completed. The last inflexible constraint is the inflexible constraint which requires an associated date that will determine the specific date of when the task must be completed.

Timeline

The last component that belongs to a construction schedule is a complete timeline with the specific tasks highlighted. This provides a concise timeline of all the tasks and makes it easier to read the construction schedule.

Conclusion

Creating a construction schedule can be overwhelming since it takes a lot of planning and brainstorming from various people to make sure that all tasks are included. Luckily there are numerous templates available online to help create a construction schedule. An example I looked for reference was a technical assignment by Jonathan Fisher. In page 15 there is a great example of a construction schedule that includes the different tasks, how they decided on the specific dates, and the overall timeline of the schedule. [3] Another example I referenced was a schedule from an architectural class that my brother who's a senior in an architectural program made. This file will be included with the file for this guide just because it's an excel file. By referencing these different templates, it will make it easier to create your preferred construction schedule.

References

[1] Fisher, Jonathan A. "Technical Assignment 2." *Architectural Engineering 2012 Senior Thesis*, 12 Oct. 2012, www.engr.psu.edu/ae/thesis/portfolios/2013/jaf5277/tech2final.pdf+.

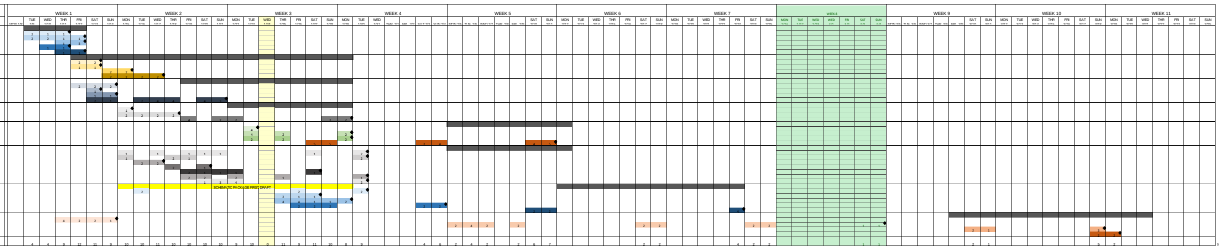
[2] "How Project Schedules Tasks: Behind the Scenes." *Project*, support.office.com/enus/article/how-project-schedules-tasks-behind-the-scenes-df3431ab-8d8a-4047-afc6a87b547dbac0.

[3] Tapia, Nilo S. *AR502 SCHEDULE*. *AR502 SCHEDULE*, mail.google.com/mail/u/1/#search/nilo/1628fc50e07455af?projector=1&messagePartId=0.3.

File to excel sheet will be included with file of guide

AR502 SCHEDULE

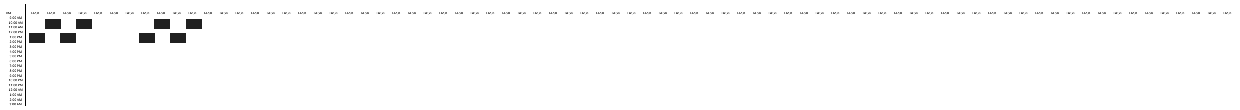
TASK NAME	TOTAL HRS	START	FINISH
CONCEPT DEVELOPMENT	18 HRS	TUE 1/9	FRI 1/12
CONCEPT	4 HRS		
SKETCH	6 HRS		
MODEL	4 HRS		
POSSIBLE MATERIAL SELECTION	2 HRS		
STRUCTURE?	2 HRS		
GREEN STRATEGIES	18 HRS	FRI 1/12	MON 1/29
RESEARCH	4 HRS		
CUT SHEETS	2 HRS		
PERFORMANCE CHARTS	4 HRS		
DIAGRAMS	8 HRS		
CODE ANALYSIS	29 HRS	FRI 1/19	MON 1/29
RESEARCH	6 HRS		
ZONING	1 HRS		
F.A.R	2 HRS		
OSHPD	20 HRS		
MASTER PLAN	21 HRS	MON 1/22	MON 1/29
SKETCH	1 HRS		
DRAFT CURRENT MASTER PLAN	8 HRS		
DETAILED MASTER PLAN	12 HRS		
SITE DEVELOPMENT	43 HRS	MON 2/5	MON 2/12
SKETCH	4 HRS		
SITE PLAN	8 HRS		
LANDSCAPING	6 HRS		
SITE MODEL (SCALE TBD)	25 HRS		
BUILDING DEVELOPMENT	44 HRS	MON 2/5	MON 2/12
STRUCTURE	8 HRS		
FLOOR PLAN (LOBBY)	5 HRS		
FLOOR PLAN (URGENT CARE)	4 HRS		
FLOOR PLAN (RECOVERY)	3 HRS		
FLOOR PLAN (O.R)	6 HRS		
FLOOR PLAN (SUPPORT AREAS)	8 HRS		
MASSING MODEL	10 HRS		
SCHEMATIC PACKAGE	40 HRS	FRI 2/12	FRI 2/23
ELEVATIONS	6 HRS		
FLOOR PLAN (2)	4 HRS		
SECTIONS (2)	12 HRS		
BUILDING SYSTEMS	10 HRS		
RENDER(S)	8 HRS		
THESIS DOCUMENT	39 HRS	TUE 3/9	WED 3/21
501 CORRECTIONS	7 HRS		
PLACE RESEARCH IN INDESIGN	22 HRS		
CHECK LAYOUT	6 HRS		
CITATIONS	4 HRS		
TOTAL HOURS	258 HRS	TUE 1/9	WED 3/21



LEGEND

PROJECT TIMELINE (OFFICIAL DATE OF PROJECT ASSIGNED & DUE DATE)	
PROPOSED DEADLINE BY STUDENT (CORRECTIONS CAN COME AFTER THIS DEADLINE OR BEFORE)	◆

BASED ON 18HR DAYS (TIME AWAKE)



Field GPS Data Collection Guide

Abstract

This report focuses on the proper use of electronic GPS devices in order to collect field data for geospatial analysis, network pressure analysis, and the construction of accurate maps. The topics of device selection, pre-field preparation, proper mapping procedure, and data extraction are covered in depth.

Prepared By:

Caleb Wright

EWB - University of California, Berkeley Chapter

Table Of Contents

Data Collection Tools/ Devices

The data a travel team collects can only be as accurate as the device they are using, thus it is important that the right tools are used when taking GPS and elevation data. The ideal devices for the work done in EWB projects are those used in land surveying, however, these devices are often very expensive (upwards of $2,000) and require proper training to operate correctly. For the purposes of water distribution projects such as the EWB-UC Berkeley Panama Project, a less expensive GPS device, such as those sold by Garmin for hiking, is adequate. These devices typically have a lateral error of within 15 feet and a larger elevation error that can be as high as 30 or 40 feet. We will discuss ways to reduce this error in a later section.

Dedicated Handheld GPS vs. Cell Phone GPS

The two most common options for GPS devices of mid-tier accuracy are dedicated handheld GPS devices such as those sold by Garmin for the purpose of hiking, or the GPS technology built into many modern smartphones. Testing of these two devices shows that many new phones can provide equal GPS and elevation accuracy to handheld devices, however there are a few things to keep in mind when considering a smart phone GPS over a Garmin style handheld. For EWB projects, it is beneficial to have a standard device that is owned by the team as opposed to using a team member's phone because a standard procedure can be established based on that device in terms of data collection and retrieval. Also, phone GPS is contingent on the owner's phone coverage plan and may lead to problems when traveling abroad. For the sake of an EWB project, it is generally more efficient and practical to use a dedicated GPS device, however a phone GPS may be used if the aforementioned arguments are taken into close consideration.

Preparation

Mapping Team Roles

Before beginning to collect any data, it is necessary to assign roles to team members who will be mapping and ensure the team has the right materials and tools. There are four main roles that need to be filled by team members: **mapper, sketcher, photographer, and scribe.**

The **mapper** is responsible for carrying the GPS device and taking data points. A data point is simply a information unit that is recorded by the GPS device containing longitude,latitude, elevation, and a data point name. This person should have prior experience using the GPS device and be comfortable taking data points.

The **sketcher** will replicate the route taken by the mapper on a piece of paper or site map printed from Google Earth. It is crucial that the sketcher records every data point on their sketch and labels it the same as the label the mapper inputs into the GPS device so that connecting data points on the computer is simple later. If the travel team is mapping a community for the first time, the sketcher should include important community landmarks for reference.

The **photographer** is responsible for taking pictures at every data point and labeling the pictures in a way that links it to the corresponding data point and location on the sketch.

The **scribe** will document different features of the area surrounding important GPS points and write them down in a way that the observations are easily connected to the corresponding data point and picture. If mapping a built water system for the purpose of pressure analysis or as built drawings, the scribe would record the type of joint (90,45,22.5) at a data point or record the name of the tapstand if the point referred to a tapstand. Similarly, the scribe could record qualitative observations about houses if the mapping team is recording house locations, or even create a numeric rating system to rank house qualities.

Example of sketch to be done by sketcher and scribe

Multiple roles may be done by a single person, but at least 2 people should be present at all times when mapping to ensure quality of data collected and safety of the mapping team.

Materials

Travel teams should arrive in country and on site everyday with printed overhead maps of the community from Google Maps, as-builts of existing networks, and any sketches or data from previous days' mapping. These will give the mapping team a frame of reference in unfamiliar areas of the community and allow for notes and sketches to be drawn directly onto a map for later reference. Clipboards with multiple compartments are a great way to store all of the mapping materials in the field.

GPS Device Initial Calibration

It is crucial that the GPS device is properly calculated using known GPS coordinates before any data is taken in the field. GPS coordinates of the in country airport are always a great place to take an initial reference point once arriving in country because the real GPS coordinates of airports are almost always correct on Google Earth. Take a reference point at the airport exit and then compare it to Google Earth's GPS and elevation data for the corresponding point to ensure you are taking data correctly and the device is accurate. This should be repeated at other known points in country such as a bank or the hotel you are staying in if the GPS and elevation data is known. If the device is giving incorrect data, consult the user manual for the device and make sure all the correct device settings are being used.

Mapping Procedure

Mapping a New Area

Before attempting to map a new area, it is important to become familiar with the area. Walking through the area with a community member and having them point out important features of the community before mapping is a great way to ensure the mapping team records relevant data points that are also important to the community. A good activity is to have community members draw a map of the community which will reveal which parts of the community are important to the community.

When beginning to actually map the community, make sure each map team member has their role clearly defined and knows what they are responsible for. The mapper has the option to either use the live tracking feature available on most GPS devices or record individual points manually.

The live tracking feature will take points at a specified time interval or change in distance based on the specific device. This feature is useful because it gives an abundance of points that would take a very long time to take individually. However, if you walk the wrong direction or go backwards while using the live tracking feature, points will be taken that are off the intended route and will make analyzing these points much more complicated in the future.

Taking individual points is also a good option, as it allows the mapper to mark every specific turn and landmark. It is crucial that enough points are taken by the mapper if using this option, otherwise turns and key geographical features will be cut off when connecting points during data analysis.

Either of these methods are good options when mapping a large area, however the mapper should be aware of the strengths and weaknesses of each method and choose accordingly.

Mapping a Distribution Network

Accuracy is crucial when mapping a built or proposed water distribution network for as-built drawings or pressure analysis. It is import to mark every intricacy of the network to ensure that all details of the network are accounted for. Because of this, the mapper should take individual points manually and *not* use the live tracking feature. The mapper should mark a data point at every joint, valve, tapstand, branch, and other part of the network that will contribute to headloss (pressure loss) or is important to the system. When taking points manually, make sure to label them in a way that is easy to remember and makes logical sense when connecting. Ensuring that the sketcher and scribe draw a model of how to connect the points and what the overall network looks like will make data analysis much easier in the future.

Establishing Reference Points for Elevation

At the beginning of the trip, the mapping team needs to *assign two or more reference points* that will be used to compare and adjust recorded data to for the remainder of the trip. A point at the travel team's base camp, a community landmark, or a tank site are great examples of potential reference points in the field. Every day of the trip, even when not mapping, the mapper should:

- Record a data point at the beginning and end of the day at each reference point to create a clear picture of the GPS device error and develop a standard for the calibration of future data points. At the end of the trip, the average elevation and location of these reference points can be calculated in order to adjust other data points to the correct elevation.

- On days that the team *is* mapping, reference point data needs to be taken every 3-4 hours to account for weather conditions and satellite movement that will cause the device to become uncalibrated from the reference points.
- Make sure to record the *time* at which these reference points are taken if the device does not already do so. This is especially important when trying to record accurate elevation data for pressure analysis, because most handheld GPS devices use a barometric altimeter that measures air pressure to determine elevation. Consequently, changes in weather throughout the day can cause the device to become inconsistent with points taken earlier in the day, so taking periodic reference point data throughout the day is necessary.

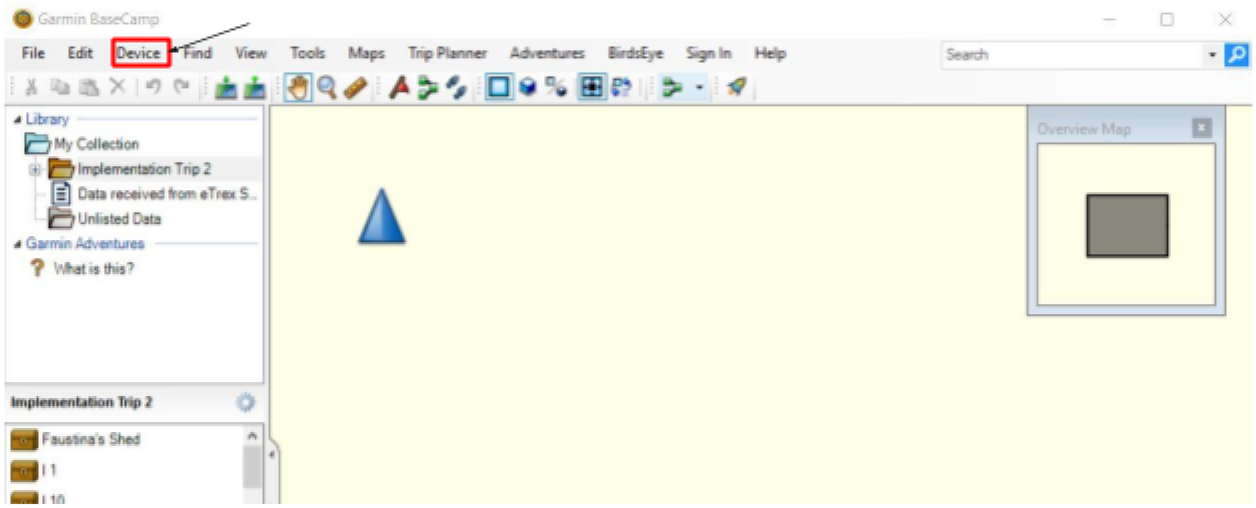
After the trip, elevation data from each day can be adjusted according to the average reference point elevation that was determined. An example from a rural water distribution project in Thailand is given here:

"For example, suppose a benchmark for the reference value was decided to be 175 meters or the average value throughout the site visit [entire travel trip]. On one particular day suppose we measured elevations of 185 meters at noon and 195 meters at 4PM. Between noon and 4PM we made measurements at other points. Suppose we measured an elevation of 250 meters at 2PM. Based on our prior and subsequent measurements of the reference point, we would interpolate the reference value to be 190 meters at 2PM. Since this is 15 meters higher than the benchmark elevation of 175 m, we would subtract 15 meters from the elevation measured at 2PM to arrive at a corrected elevation of 250 – 15 = 235 meters." (Harding 29)

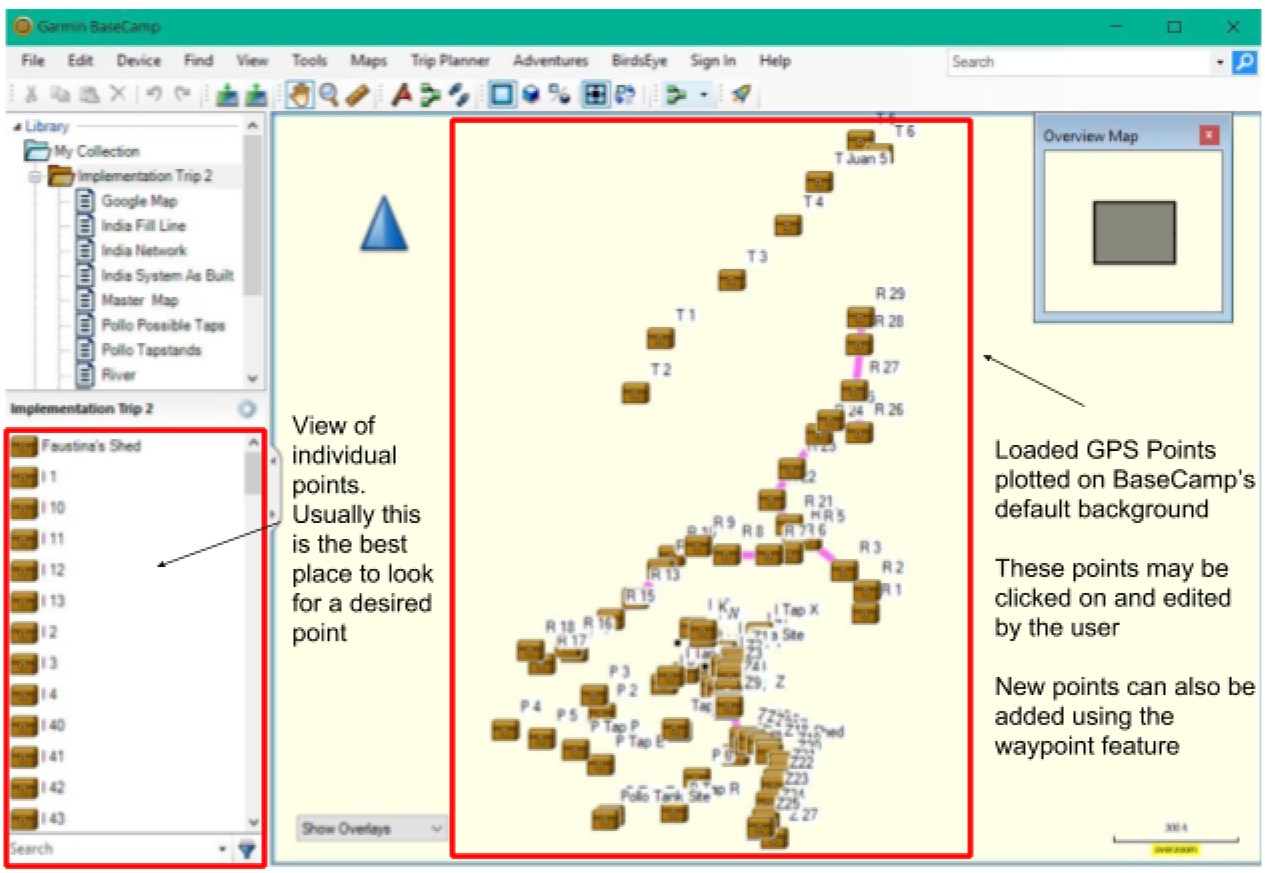
Loading and Exporting Data on the Computer

Garmin offers free downloadable software on its website called *BaseCamp* to export and edit data collected on their devices (the link to download is attached in the references). This data can then be exported to other formats and file types to be used by programs such as Excel and EPANET. This section will outline how to load and connect data from the Garmin GPS device to the computer and then export that data into other usable formats. The topic of modeling data in GIS, Excel, and EPANET is not covered in this guide.

Loading Data Into BaseCamp

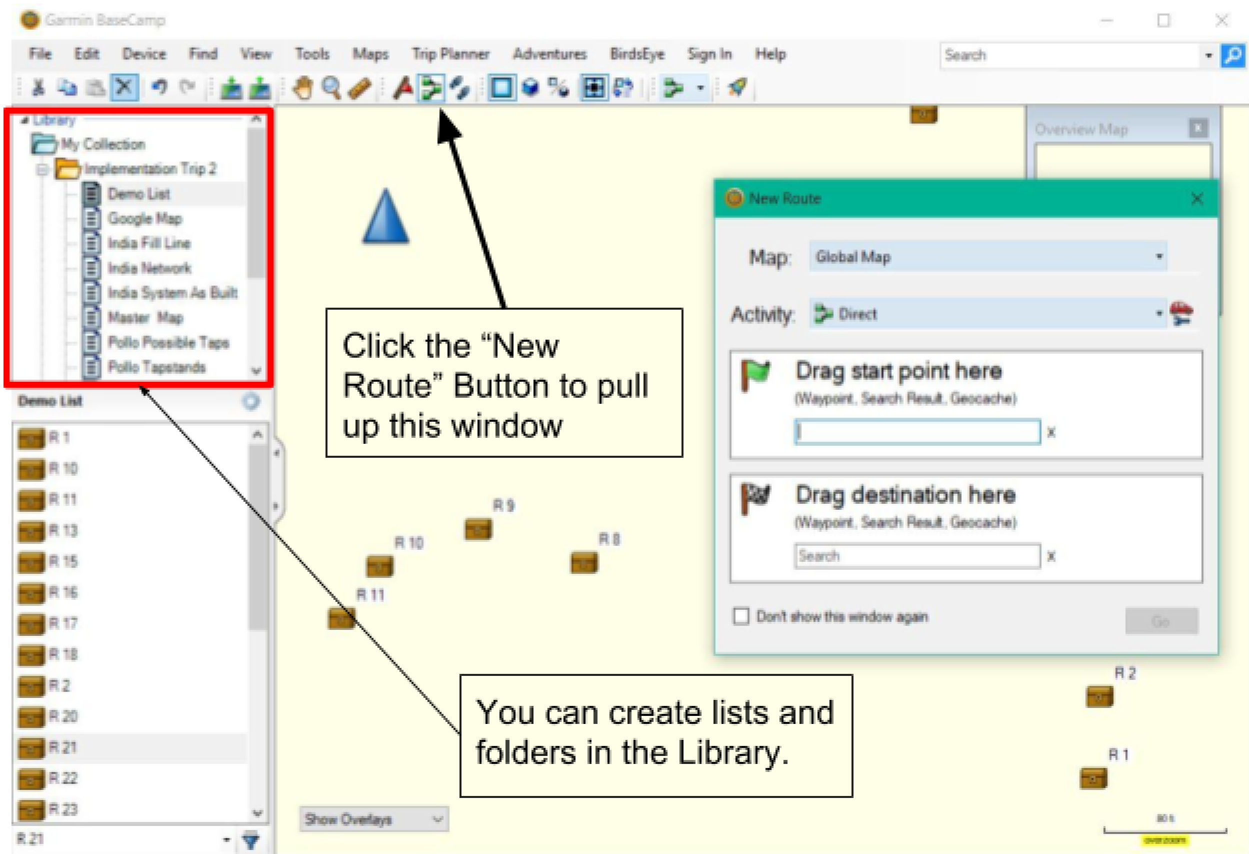


Start off by connecting your Garmin device to the computer with a USB or appropriate cable. Then click on the "Device" tab and then select "Receive From Device". To load all the data that has been collected on the GPS.



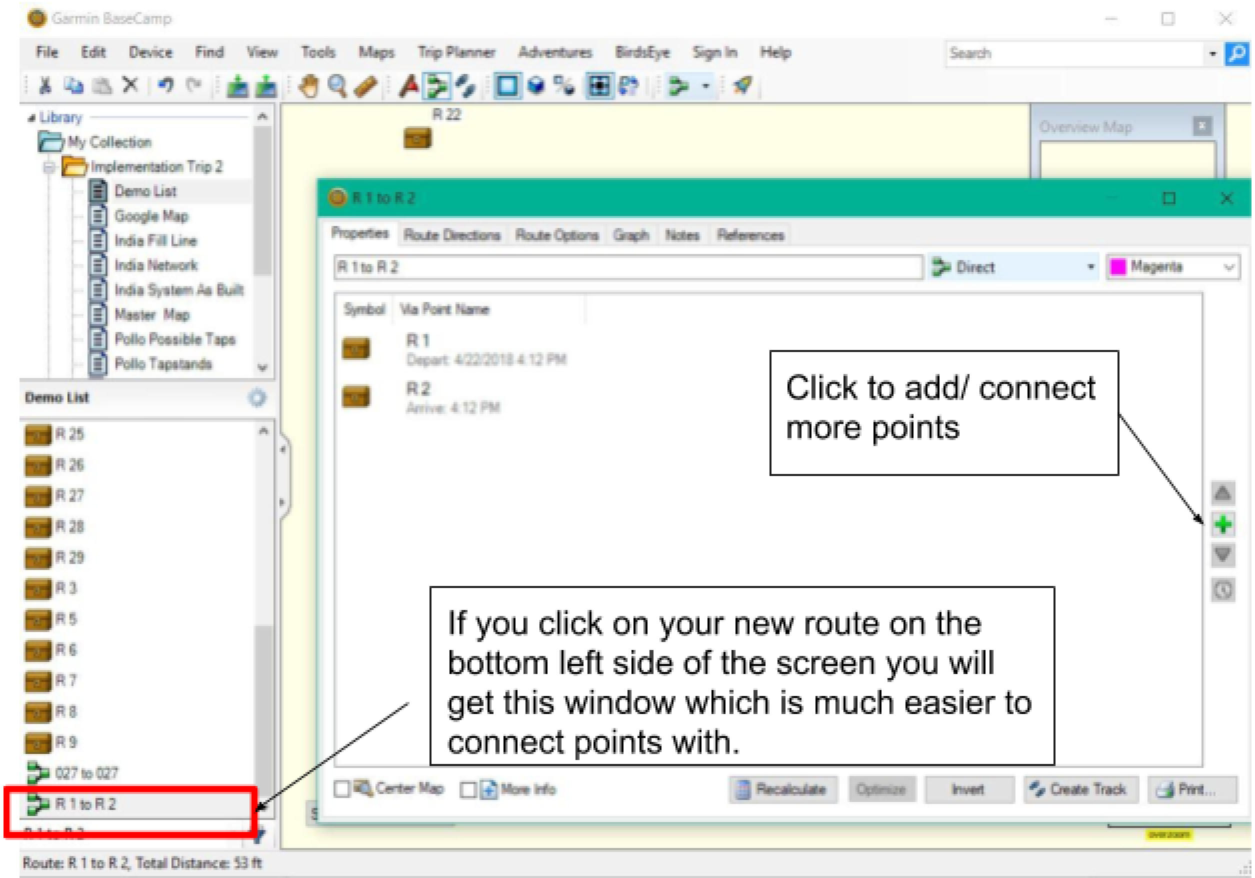
After loading the data, you should get a window that displays all of the points taken on the device like this. Do not worry if the points are not already connected, we will do this next.

Connecting Data Points and Making Routes

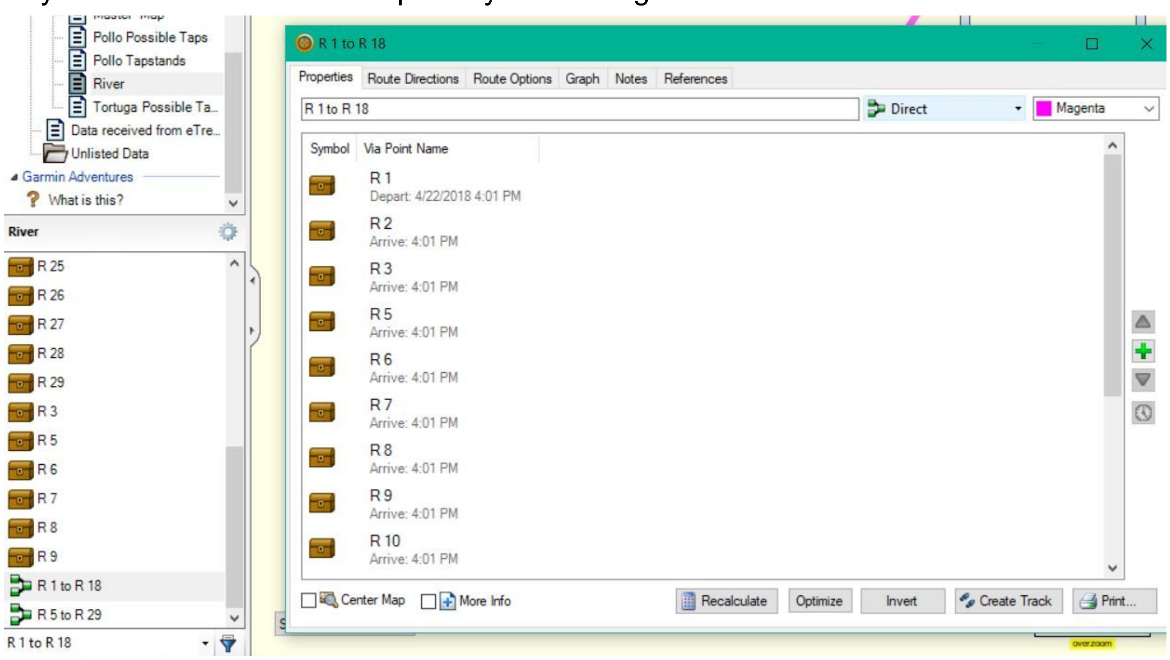


First, create a list by right clicking on the "Library" window (Upper left corner of screen) and selecting "New List". A list will allow you to drag GPS points from the entire device collection or other lists into a place that will only contain the desired points. Similarly, you can create folders that contain multiple lists. As you can see, I have created a folder called "Implementation Trip 2" and will be working on a list called "Demo List" within that folder.

Use the “New Route” feature to connect data points in the order that they are meant to be connected. You can drag your two initial points into the boxes above.



Once you have connected all the points you should get a window that looks like the one below:



Exporting Your Routes and Points to Other Formats

Now that you know how to load and connect points in BaseCamp, you can take your data and routes and export them to different file types to be used in other softwares. In the upper tab, click on **“File”** → **“Export”** → **“Export [list name]”**.

Available Export File Types:

- .**gpx** - Default GPS data file that can be used in BaseCamp and possibly other GPS software
- **.gdb** - Garmin Database file. Old version of the .gpx file that has less capabilities. It is better to export as a .gpx when choosing between the two.
- **.csv** - File that is readable by Excel. Very handy for data analysis and input into EPANET
- **.kml** - Default file type of Google Earth Pro. This is useful for doing low level GIS work on Google Earth Pro and makes visualizing route very easy. I would recommend viewing the data you collect in Google Earth before starting any analysis of specific points.
- **.tcx** - Training Center XML file. File type used by Garmin but is not very useful for any other softwares. Can be ignored for the most part.
- **.txt** - Creates a text file containing information about all of the exported points. This may be useful in certain situations, but a .csv will be easier to input into Excel.

Conclusion

GPS mapping is essential to the success of any EWB project, and thus it is important that travel teams are practiced and educated on proper procedure when mapping. The mapping team also needs to understand that community members should be consulted before mapping unknown areas in order to establish safety and determine which areas are of highest interest to the main stakeholders of the project. If done correctly, mapping can be an efficient and fun process that allows the travel team to explore different parts of the community they work in.

References

Online: EWB-USA: *Technical Paper 101: Field Mapping ~ A How-To on Mapping in a Developing Country*

Online: Mary Pierce Harding**:** *GIS Representation and Assessment of Water Distribution System for Mae La Temporary Shelter, Thailand*
http://web.mit.edu/watsan/Docs/Student%20Theses/Thailand/Harding%20MEng%20Thesis%202008.pdf

Online: EWB-USA: *Mapping for Water Supply Improvements in Developing Countries*
https://www.youtube.com/watch?v=1AAIAOxphLs

Useful Information

- Online tool to help use EPANET with BaseCamp:
  https://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html

- BaseCamp Download Link:
  https://www.garmin.com/en-US/shop/downloads/basecamp