

Plant Cost Calculator

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Abstract

AguaClara designs low-cost water treatment facilities and desired a tool to estimate and present the capital and operational costs of an AguaClara plant. The goal of the Plant Cost Calculator team is to create such a tool to provide an accurate estimate of the costs associated with constructing and operating an AguaClara water treatment plant. The objective of the calculator is to allow users to easily obtain accurate design and operational cost estimates that can be compared to alternative water treatment options, and to make users better aware of the factors that contribute to the final plant cost. At the end of our first semester, the plant cost calculator team has completed the back-end for a working and easy-to-use calculator based in part on data from existing plants in Honduras. Future objectives will include developing a more attractive front-end interface, closer collaboration with WTTSG, and integrating India plant costs into the data used for prediction.

Introduction:

The plant cost calculator team's goal is to create a tool that provides an accurate estimate of the cost to build, train, transfer and operate an AguaClara water treatment plant. The main difficulties with this were finding accurate data, making appropriate estimates where necessary, and omitting costs that don't substantially contribute to the overall cost of the project. The plant cost calculator team is relatively new, and was formed with the goal to provide accurate cost information to those interested in potentially taking advantage of AguaClara technologies. Upon completion and integration of the plant cost calculator, potential AguaClara users will have access to an extremely valuable tool. With this calculator the user will be able to obtain an accurate estimate that could potentially influence their decision to build an AguaClara plant. Users could compare the price of an AguaClara system to a competitor's system to determine how to best provide clean drinking water at a more desirable cost to those in need.

Objectives:

- Find and verify reliable cost data from Honduras medium-flow treatment facilities
- Create a formula, that is easy to update and modify, to estimate cost using existing empirics and AguaClara's population-flow rate recommendation
- Develop a front-end interface that is easy to use and provides intuitive foundation for sharing estimated cost
- Develop our cost calculator in a modular and robust way such that our interface may be inserted into any AguaClara webpage and so we can analyze future plant design costs
- Upon completion of the medium-flow calculator, begin extending our program to encompass low-flow plants and various international cost discrepancies (e.g. differences in operator wages between Honduras and India).

Initial Data:

A substantial amount of information regarding various AguaClara is available. This information includes the flow rates for the Honduras plants. Detailed cost lists were also provided for Atima, Alauca, and San Nicolas. The cost lists includes material costs, skilled labor costs, transportation costs, operator wages, among other relevant information; however, this detailed cost information is not provided for the majority of plants. An estimate of 10,000USD/(L/s) as a total capital cost was suggested by Monroe. This estimate includes the costs to design, build, train, operate and transfer an AguaClara plant. One of our semester objectives was to improve upon this rough 10,000USD/(L/s) estimate.

Evaluating the Data:

One of our primary goals was to improve upon the total capital cost estimate. In order to achieve this we ran a regression on existing plant data (we regressed cost on flow rate). New AguaClara plants are being built with stacked rapid sand filtration systems, which were not present on older plants. The costs have therefore been corrected for the integration of these systems using the Tamara SRSF transition cost. A regression was performed on these corrected data points and a resulting best fit equation was obtained. A linear best-fit equation was chosen rather than a quadratic or exponential equation due to a dearth of data and potential outliers in the model. This linear equation was used to automate the estimation process for any given set of plant inputs in our calculator. As more information becomes available it can be added to the existing data points

and the regression can be modified. This will continue to improve upon the initial capital cost versus flow rate estimate and therefore the overall plant cost estimate.

Regression Results:

Based on our current findings, a weak negative correlation exists between capital cost per flow rate(USD/L/s) and flow rate(L/s). However, this correlation is the result of only six data points. A graph below is included to show this correlation along with a table of the various plants. Each of the points represents one plant that had sufficient data. The data for this, as well as our other calculations, was provided by those working with Aguaclara. With this information we will be able to improve upon the 10000USD/L/s total capital cost estimate. The current cost per flow rate equation (1) is shown below.

$$C = -95.893 * f + 10567 \quad (1)$$

Where C = cost per flow rate; f = flow rate

The data used is shown in the table below and a graph is shown in Figure 1.

Plant Name	Flow rate(L/s)	Cost / flow rate (USD/L/s)
Alauca	12	10713
Atima	16	7570
La Libertad El Faldon	32	7722
San Nicolas	32	7486
La Libertad Los Laurales	35	6867
Las Vegas Piedras Amarillas	44	6645

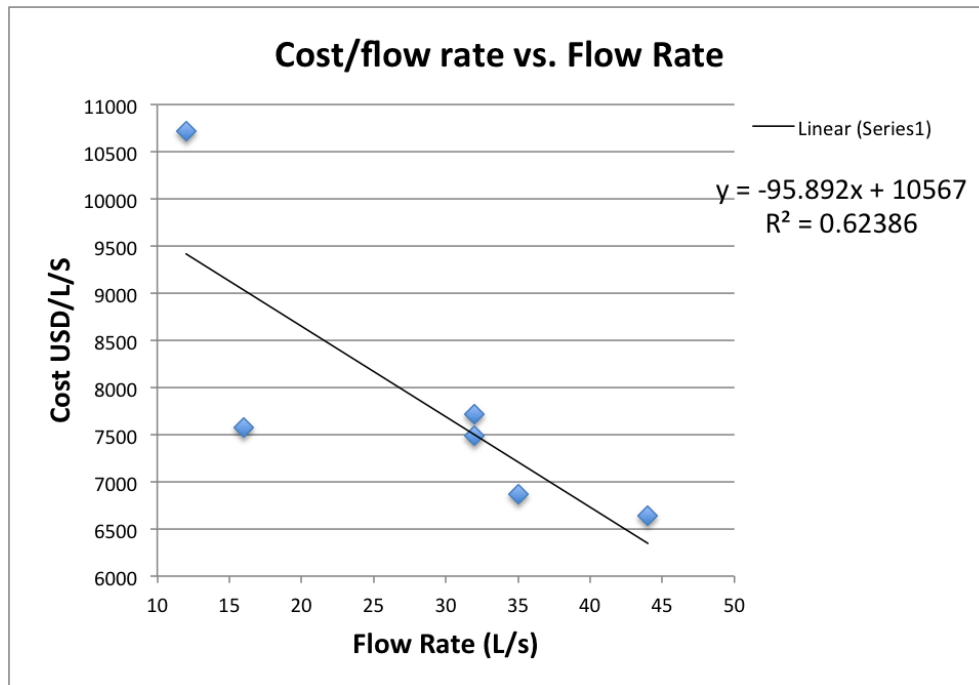


Figure 1: Cost per flow rate vs. flow rate

User Inputs:

The user inputs we have decided to require are listed below. (Note: The default values are shown; however, the user has the ability to specify alternative units and correct the values.)

1. per capita water demand; Default value: 150 (L/day/person)
2. population growth rate; Default value: 3 (percent increase per year)
3. initial population; Default value: 1000 (persons)
4. desired plant adequacy; Default value: 25 (years)
5. cost of coagulant; Default value: 1.1 (USD/kg)
6. cost of chlorine; Default value: 2.6 (USD/kg)
7. hourly wage; Default value: 2.5 (USD/hr)

The initial population, population growth rate, and desired plant adequacy are necessary inputs to determine the final population of the community. With

the final population of the community and the per capita water demand, the necessary capacity of the plant can be determined. The cost of chlorine and coagulant are used to determine the monthly per person cost of each. The hourly wage is used to determine the cost due to employees over the lifetime of the plant. These user inputs allow for a reasonably accurate estimate for plant cost. This choice of user inputs also provides a good balance between accuracy and feasibility . A user can reasonably be expected to know these inputs ensuring they can obtain an estimate. However, we have decided on default values for each of these inputs to allow the user to continue the calculation in the event that they do not know the inputs. The default inputs were decided based on available data and discussions with Monroe.

Cost Formulas:

Final population (2)

$$P_f = P_i * \left(\frac{1+n}{100}\right)^t \quad (2)$$

Where P = final population (persons); Pi = initial population (persons); n = annual population growth rate (percent); t = plant adequacy (years) Design cost (3)

$$D = \left(\frac{C * q * P_f}{86400}\right) \quad (3)$$

Where D = Design Cost (USD); C = capital cost estimate (USD); q = per capita water demand (L/day/person); Pf = final population (persons)

Total wages (4)

$$W = h * t * E * 8765.81 \quad (4)$$

Where W = total wage costs (USD); h = hourly wage (USD/hr); t = plant adequacy (years); E = employees (persons)

Monthly chlorine cost per person (5)

$$C_{chlorine} = D_{chlorine} * L_{chlorine} * q * .70 * 30.4 \quad (5)$$

Where C chlorine = cost chlorine/person/month (USD/person/month); D chlorine= dose of chlorine (kg/L); L chlorine = cost of chlorine/kg (USD/kg); q = per capita water demand (L/day/person)

Monthly coagulant cost per person (6)

$$C_{coagulant} = D_{coagulant} * L_{coagulant} * q * .70 * 30.4 \quad (6)$$

Where C coagulant = cost chlorine/person/month (USD/person/month); D coagulant = dose coagulant (kg/L); L coagulant = cost of coagulant/kg; q = per capita water demand (L/day/person)

Monthly wage cost per person (7)

$$C_{wage} = E * w * 730.48 / P_{initial} \quad (7)$$

Where C wage = monthly wage cost per person (USD/month/person); E = number of employees (persons); w = hourly wage (USD/hr); P initial = initial population

Design Considerations:

On the front-end a visual-edit template, such as Kompozer, was considered. We decided against this mainly due to the benefits resulting from the compatibility between PHP, HTML, and MySQL. A visual editor would also have a learning curve similar to that of PHP and HTML for a future member with some programming experience. A PHP and HTML base for the first implementation of the calculator was chosen. This combination was chosen because PHP and HTML are interchangeable within a page, and PHP has interactive features that are necessary for the calculator. PHP and HTML are also easy to use ensuring future teams are able to improve upon the calculator. Despite being text-based, PHP is relatively easy to learn, even for someone with little to no programming experience. Once familiarized, we expect a PHP to have long-term benefits as a design framework. .

Working Prototype:

Currently the working prototype outputs a cost estimate using the linear regression described above (1). This code is written in HTML and PHP. However, currently the AguaClara host does not support PHP code. An application called MAMP, which allows us to use a local server to run PHP code, is being used to test the code. The prototype has default values discussed above. Regardless of the initialized value, the user is able to provide a value manually and to select from an options of units for each input. For example when inputting the per capita demand, the user is able to choose between (L/day/person) or (G/day/person), and the code will perform the appropriate unit conversions. This will prevent the user from having to perform manual conversions and will ultimately provide a more pleasant user experience. The current prototype also allows the user to revert back to the default values. The goal of this feature is to allow the user to correct an error without having to re-enter data they had previously entered. The image below is a screenshot of the current prototype.

AguaClara Plant Cost Calculator

The cost plant calculator will estimate the cost of building a water treatment plant in the specified area. Enter in the following information to view the estimated cost.

Per Capita Demand	<input type="text" value="150"/>	<input type="text" value="litres/person/day"/>	<input type="button" value="restore to default"/>
Current Population	<input type="text" value="3000"/>	<input type="text" value="persons"/>	<input type="button" value="restore to default"/>
Population Growth Rate	<input type="text" value="3"/>	<input type="text" value="%"/>	<input type="button" value="restore to default"/>
Plant Adequacy Time	<input type="text" value="25"/>	<input type="text" value="years"/>	<input type="button" value="restore to default"/>
Chlorine Cost	<input type="text" value="2.6"/>	<input type="text" value="U.S. Dollars/kilogram"/>	<input type="button" value="restore to default"/>
Coagulant Cost	<input type="text" value="1.1"/>	<input type="text" value="U.S. Dollars/kilogram"/>	<input type="button" value="restore to default"/>
Hourly Wage	<input type="text" value="2.5"/>	<input type="text" value="U.S. Dollars"/>	<input type="button" value="restore to default"/>

Estimated final population: 6281.33378896...Estimated flow rate: 10.9050833836...

**Estimated Plant Design Cost: 103830.54
USD**

**Estimated Monthly Operating Cost: 4.94
USD per person**

Figure 2: Prototype Screenshot

Documentation:

Plant Data

Available plant data can be found in the AguaClara server. To access this data follow these steps.

1. open a new finder window
2. press "command + n"
3. press "command + k"
4. Follow the path: RESEARCH/Plant Cost Calculator and WTTSG/Spring 2014/PCC_data

Calculator Code

The current code is written in PHP and HTML. Documentation of this code can be found within the code itself.

Online Resources

These websites contain the necessary information to learn enough PHP and HTML to understand and improve upon the plant cost calculator.

1. <http://www.w3schools.com/html>
2. <http://www.w3schools.com/php>
3. <http://www.stackoverflow.com>
4. <http://www.php.net/manual>

Accessing Code

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MAMP

Currently the AguaClara server is not PHP enabled. In order to test the plant cost calculator code, an application such as MAMP must be used. PHP is a server-side language, which means you need access to a server – luckily MAMP provides this. MAMP is an application that provides access to a local PHP and MySQL server. MAMP can be downloaded for free at <http://www.mamp.info/en/downloads/>. After installation MAMP must be opened and an icon reading start server will appear. Click on this icon and a new webpage will open.

Running Code

In order to run the code follow these steps:

1. Save the code in htdocs following this path: Applications/MAMP/htdocs.htdocs.
2. Open MAMP and start the server
3. Enter <http://localhost:8888> followed by address containing desired code (e.g. http://localhost:8888/calculator_code/calculator_submit.php)

Edits and Integration with AguaClara Website

The code file `calculator_submit.php` is fully and clearly internally commented with a description of the file functions and operations - new team members are encouraged to contact old members with regards to any of the comments. To work toward integration into an AguaClara page, one will need to access the HTML code from the AguaClara website's header and footer, and to include these two items in the PHP "echo" statement in the `calculator_submit` file. An echo statement is where the PHP essentially writes (spits out) a page in HTML code. Currently this output includes the HTML code that displays the calculator title, form, output values, etc. A simple addition of AguaClara website header before the calculator HTML and footer after the calculator HTML will allow this output to provide a full and integrated page that can later be uploaded to the AguaClara server.

Challenges:

A major challenge faced initially was sorting through a plethora of cost data and deciding how to create a cost estimate formula. Initially the goal was to break plant costs into many categories such as materials, skilled labor, unskilled labor, transportation, education and training, and administrative costs. This would allow us to see which categories contributed significantly to the overall cost and provide a fairly accurate estimate. This proved too challenging due to insufficient or non-existent data for various plants. A simpler approach was necessary to make sufficient progress.

Another major challenge was finding accurate cost information on each plant to devise a method that improves the capital cost estimate of 10,000USD/(L/s). Currently the most feasible way to do this is to create a scatter plot of the provided information and perform a regression.

Another challenge was finding a reliable source of chlorine and coagulant costs, but we have decided to use a default cost of 2.6USD/Kg and 1.1USD/Kg respectively. These chlorine and coagulant costs were provided by Monroe, and were compared with existing plant data to ensure they were reasonable. Since these are not extremely accurate and the prices fluctuate, the user is allowed to correct them. Yet another major challenge is determining how to integrate regression software into our prototype. Our goal is to allow an AguaClara affiliate to simply append new plant cost information to some sort of database as it becomes available and have a program that adjusts the regression accordingly. This data has been moved from Stata modeling software to an Excel spreadsheet for accessibility across computers and users. The user must, for now, manually run a regression when new data is added and paste the equation into the PHP code under a clearly marked cost equation variable. In the future, we hope to host our information online and to automatically compute a regression

on whatever data has been supplied, allowing the calculator to automatically update equations that rely on the data. MySQL is one possibility for hosting the data, but it has proven to be more challenging and time consuming than anticipated. PHP supports a regression feature as do many other web-based options that may be integrated into a PHP format.

Finally, our initial calculator code included a file for a pre-submit page and a separate file for a post-submit page. At the end of the semester, we redesigned and streamlined our back-end code to integrate our entire calculator into one clear and condensed file such that the page displays correctly by using PHP to determine if the user has already input values into the calculator.

Future Work:

After a semester of work and the resulting prototype, it is clear there are improvements to be made. Currently an AguaClara team member updating the calculator must manually run a regression when new data is added and paste the equation into the PHP code under a clearly marked cost equation variable. In the future, we hope to host our information online and to automatically compute a regression on whatever data has been supplied, allowing the calculator to automatically update equations that rely on the data. PHP supports a regression feature as do many other web-based options that may be integrated into a PHP format.

We have developed an operational back-end for the calculator model but there are several notable areas for improvement in addition to automatically computing a regression on the existing data. The first area for improvement is the limited scope of our regression equation – note that too extreme a value will in fact result in a negative cost estimate! Recall equation (1) above has a negative coefficient on flow rate, so an area with an expected future population much larger than any current Honduras plant area could result in a negative estimate via a large required flow-rate. A quick fix could be to set a lower bound on cost per flow rate after a certain level (e.g. approx. 7,000USD/(L/s) after the plant reaches a large enough flow rate requirement). A second consideration is calculator precision – using population of the vicinity of a given AguaClara plant and using default values for the remaining fields, our calculator estimate is within about 20,000USD of actual design cost for most plants. A question for future work is whether this is too large a margin of error for estimated cost. One decision we reached from our discussions with Monroe was to compute maximum necessary flow-rate from how much water the final future population would demand if the plant were to run 24 hours per day; these estimates for maximum flow rate appear slightly below the actual flow rate of many Honduras plants so this estimation technique could be subject to modification. Future members may also want to consider backup options if the website we access using our webcrawler should ever fail to provide proper conversion rates.

A final area of future back end work is integrating and interpreting India data in an efficient way for the cost calculator. One initial suggestion is to use Honduras plant data for Honduras plant cost estimates and India data for India plants, respectively, although checking for potential design redundancies with AguaClara LLC could be fruitful to extract more information from the existing data. The front end of the calculator is currently not very communicative or visually refreshing. Stylistic changes need to be made to ensure the calculator aligns with the current AguaClara website and more importantly provides an intuitive and informative experience for the user. An important aspect of the calculator should be emphasizing certain costs as prominent displays. For example, displaying the monthly cost of chlorine per person to highlight low costs of an AguaClara plant. The goal is that a user will be able to see that the monthly cost of chlorine per person is miniscule, compared to the operating costs of a plant which requires electricity, and will dispel any uncertainties they may have regarding these costs. Gathering appropriate cost information of electric plants for reference will be essential so that comparison between the capital and operational costs of AguaClara plants can be easily compared to those of other technology options.

The plant cost calculator needs to be integrated with the water treatment selection guide. To do this the water treatment selection guide will need to require the inputs that the plant cost calculator relies on. The water treatment selection guide can then simply run the existing plant cost calculator code. The resulting code can then be incorporated into the AguaClara website. Note that although the current cost calculator is not displayed online, the calculator in its current form can be easily integrated into a webpage with only small modification. This has been discussed in our documentation.