Hydraulic Transport in Biological Systems- LAB 3310

Below I have included my favorite lab from this course, the Hydrostatic Pressure lab. I chose this lab as I feel this was the lab where I exhibited my best writing, as well as the best overall understanding of the lab objectives. The lab portion of this class overall challenged my abilities as a writer, and pushed me to improve me scientific writing- specifically my ability to explain concepts and conclusions solely on paper. The semester I took this course was affected by COVID-19, so many things changed with how the labs could be performed. Thus, it added an extra challenge as some of the labs for this course could not be performed by us as students, but this lab I have included below was one of the ones I did get to complete face-to-face with a group.

In Lab 3 below, I had a good grasp on the objectives, as it was a lab with a dual purpose. The lab was meant to familiarize students with a hydrostatic pressure system and calculate the resultant force exerted on the surface at different water depths, but also it was an excellent way to show how theoretical and actual values can compare. By comparing the obtained values with theoretical calculations, it gave me a better understanding of why for some equations a “correctional factor” will be added into an equation. I also learned that when there is a discrepancy between theoretical calculations and obtained values, the percent error calculated can be an indicator of the source of error. For instance, in Lab 3 below, the relative percent error is plotted in Figure 5 and Figure 10 versus the actual height of the water obtained in the lab. In both instances the relative percent error was small, and followed no distinct pattern, leading to the conclusion that the source of error was human error. Had the error percent been larger, or increased with the height of water, it could have been concluded that there was an error with the system used, or that weights had not correctly been measured.

As I go into future courses, I will take these writing skills and learned objectives with me, but I do admit I could still stand to work on my graph presentations. As seen in Figure 6 and 7, my graphs are the same size as my other figures, but the portion containing data is small and lies in one corner of the graph. I could do to spend more time in excel perfecting my graphing so that it is more visually appealing and easily interpreted by the reader.

BSEN 3310: Hydrostatic Pressure Lab 3

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ABSTRACT *Confirming the validity of theoretical equations is important for students because it can help give a better understanding of concepts. It is also important because it shows students how theoretical values are not always equal to the values achieved in the lab during practical application. An Edibon Hydrostatics Pressure System was used to obtain the values of the height of water at different attached masses. It was found that for the partially submerged data, the theoretical height of water was higher than the actual water height by a factor of 1.039. For fully submerged trials, the theoretical height of water was higher than the actual water height by a factor of 1.0582. The most likely source of error for this experiment was found to be human error.*

INTRODUCTION Hydrostatic pressure is the pressure exerted by a fluid at equilibrium, due to gravitational acceleration, at a point within the fluid (Cengel and Cimbala, 2006). Hydrostatic pressure is an important concept for engineers to understand. Many engineering systems, such as liquid storage tanks and dams, require engineers to determine the hydrostatic pressure. Hydrostatic pressure at a known depth is calculated by the density of the liquid multiplied by the acceleration of gravity and the height of the liquid (Cengel and Cimbala, 2006). Hydrostatic pressure increases in proportion to the height of the fluid, because as the height increases, there is more fluid exerting the downward force of its weight. The hydrostatic pressure also increases with an increase in density, as a larger density in a controlled volume indicates an increased mass, which means a larger weight of the fluid that can be exerted on an object. It is important to note that this holds true only for a static system. Hydrostatic pressure is an important concept for any engineers working with plants, as xylem water potential and local water potential can both change the hydrostatic pressure inside a plant (Thorpe et al, 2005). Additionally, hydrostatic pressure is needed to measure sap pressure in plants that produce sap (Scholander et al, 1965). High hydrostatic pressure is seeing an increased use in food processing, as it does not change the nutritional value of the food product, nor does it heat any food product (San Martin, Barbosa-Canovas, & Swanson, 2010).

OBJECTIVES The objectives for this lab were to measure the effect of depth of water (that is at rest) on the magnitude and location of resultant force exerted on a partially and fully submerged vertical rectangular surface. Also, to confirm the validity of the theoretical equations used to estimate magnitude and location of resultant force exerted on a partially and fully submerged vertical rectangular surface.

METHODS AND MATERIALS The materials for this lab were an Edibon Hydrostatics Pressure System, weights, and water from the laboratory faucet. To test the first objective, a weight tray was attached and the counterweight was moved until the balance bridge arm was horizontal. Water was added to the tank until the free surface of the water touched the lowest edge of the quadrant. A combination of water addition and the drain were used to achieve this. A known mass was placed on the tray. The balance bridge arm was displaced, and water was slowly added until the arm became horizontal again. The value of the mass added and the height of water at this point were recorded. The previous two steps were repeated for at least six equally spaced readings, until a height of 100 mm was obtained. To test the second objective, the entire process was repeated, except water was added to the tank until the free surface of the water touched the upper edge of the vertical surface of the quadrant, and the combination of the weights resulted in the same number of readings, but from 105mm to 160 mm.

RESULTS AND DISCUSSION

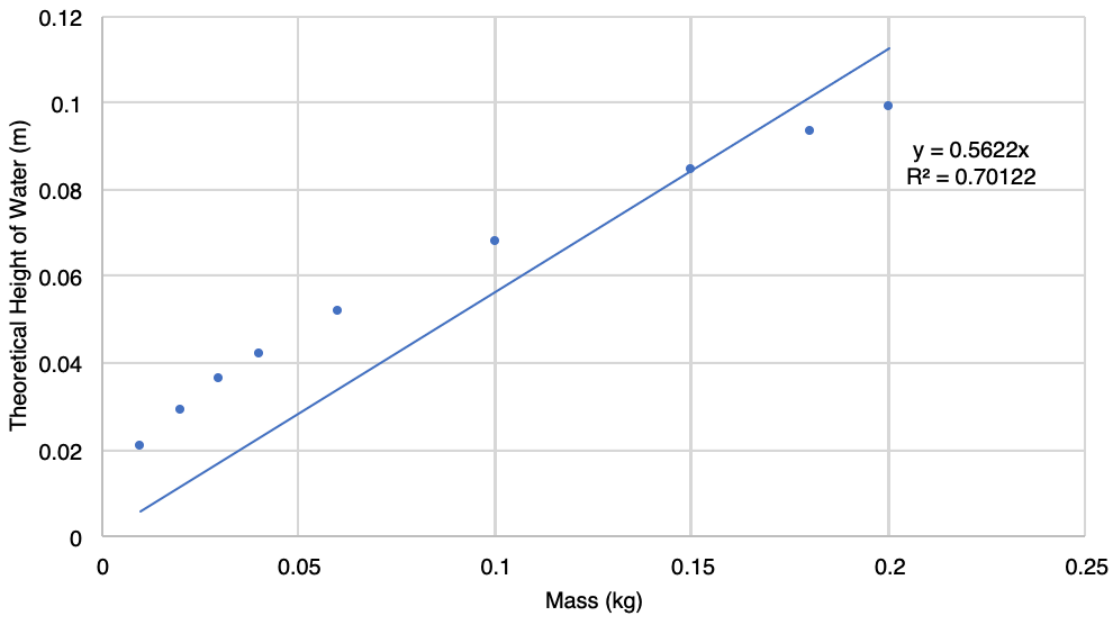

Figure 1. Mass of the Weight versus the Theoretical Height of the Water, for Partially Submerged Trials.

$$(Equation\ 1) \quad m = \frac{\rho b}{2L}\left(a + d - \frac{y}{3}\right) y^2$$

The collected data for the mass of the weights were put into Excel Solver, and the theoretical height of the water was obtained. This was done using the equation 1 to solve for y. Figure 1 shows the plot of the calculated theoretical height of water and the mass of the weights used. This plot proves that the relationship between the mass and the theoretical height of water is not linear, as the linear trend line is a poor fit, since the R^2 value is 0.7. This makes sense because the equation 1 that was used to calculate the theoretical water height is a cubic equation, so the plotted values should not fit a linear trend line well.

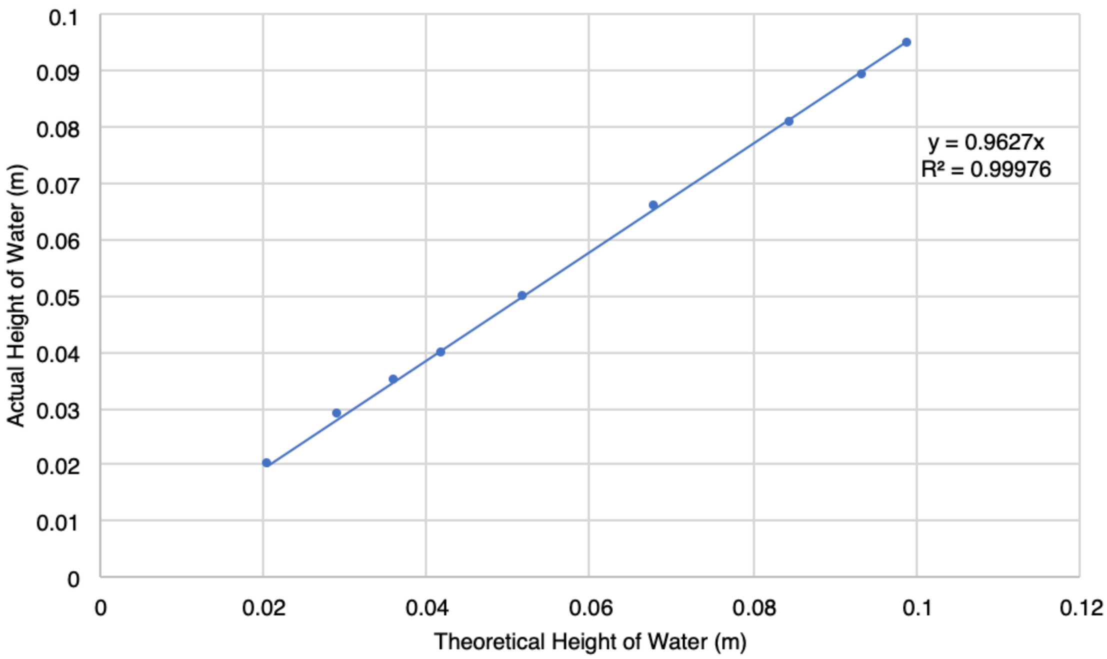

Figure 2. Theoretical Height of Water versus Actual Height of Water, for Partially Submerged Trials.

Figure 2 shows the relationship between the calculated height of water and the actual height of water. The linear trend line displays a good fit, with an R^2 value of 0.999, meaning that the values have a direct relationship, and that each calculated value of the height differs from the actual value of the height by approximately the same constant value, which can be found from the equation as 0.9627. This means that overall, the theoretical height of water was slightly higher than that which was recorded in the lab. Using the trend line equation, it is found that the theoretical height of water is higher than the recorded water height by a factor of 1.039.

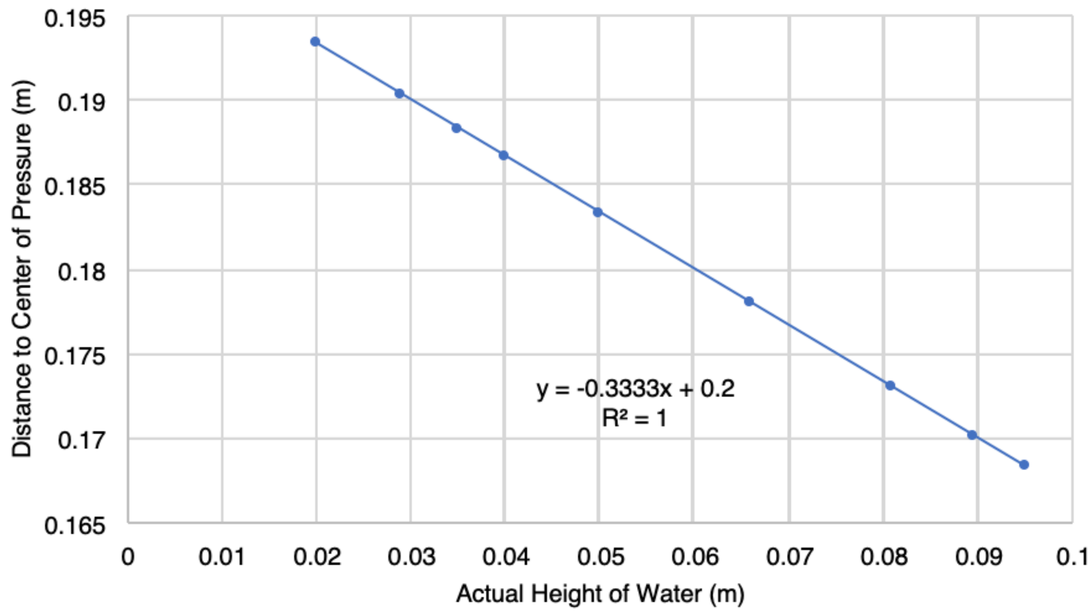

Figure 3. Actual Height of Water versus Distance to Center of Pressure, for Partially Submerged Trials.

As shown in Figure 3, the distance to the center of pressure decreased as the height of the water increased. The distance to the center of pressure describes how far the resultant hydrostatic force is from the balance beam arm of the Edibon Hydrostatics Pressure System. This means that as the water height increases, as mass increases, the resultant hydrostatic force acts closer and closer to the balance beam arm.

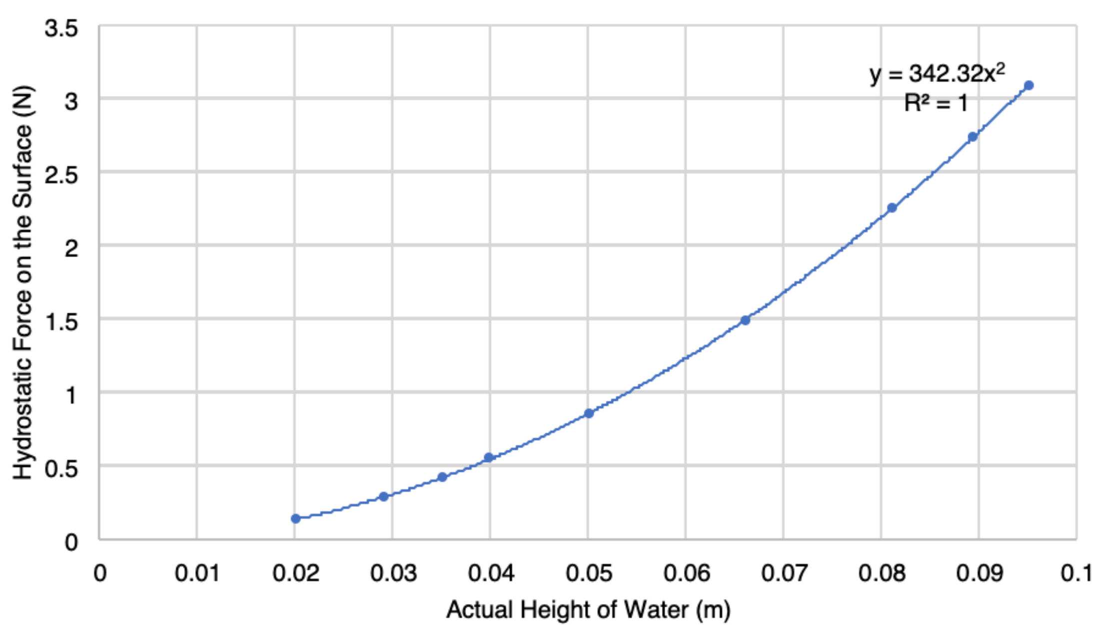

Figure 4. Actual Height of Water versus Hydrostatic Force on the Surface, for Partially Submerged Trials.

Figure 4 shows that the actual height of water and the hydrostatic force on the surface have a polynomial relationship. The resultant hydrostatic force that acts on the surface increases as more mass is added and the water height rises, and as the force itself acts closer to the balance beam arm. This makes sense because as you add more mass there is a greater amount that gravity can act.

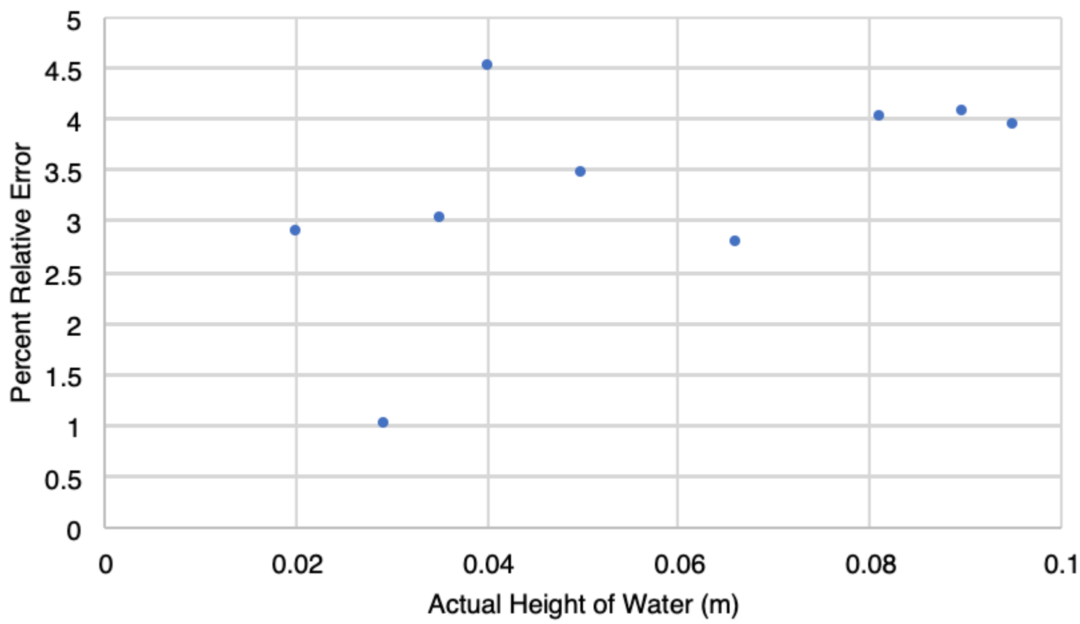

Figure 5. Actual Height of Water versus Percent Relative Error, for Partially Submerged Trials.

The Figure 5 displays no distinct trend in the data. This means that the relative error was likely related to human error, as if it had been the result of a specific problem with the hydrostatic system, the error would have been constant as the water height increased. An error with the system could have also been shown in a different way, such as an increase in error for the larger water height values if there had been an error with mislabeled or inaccurate weights for the higher values. Since the error is random and not following a trend, the conclusion is that it is most likely due to human error, because a human would not be able to read off the height of the water at the same error level for each increment of weight.

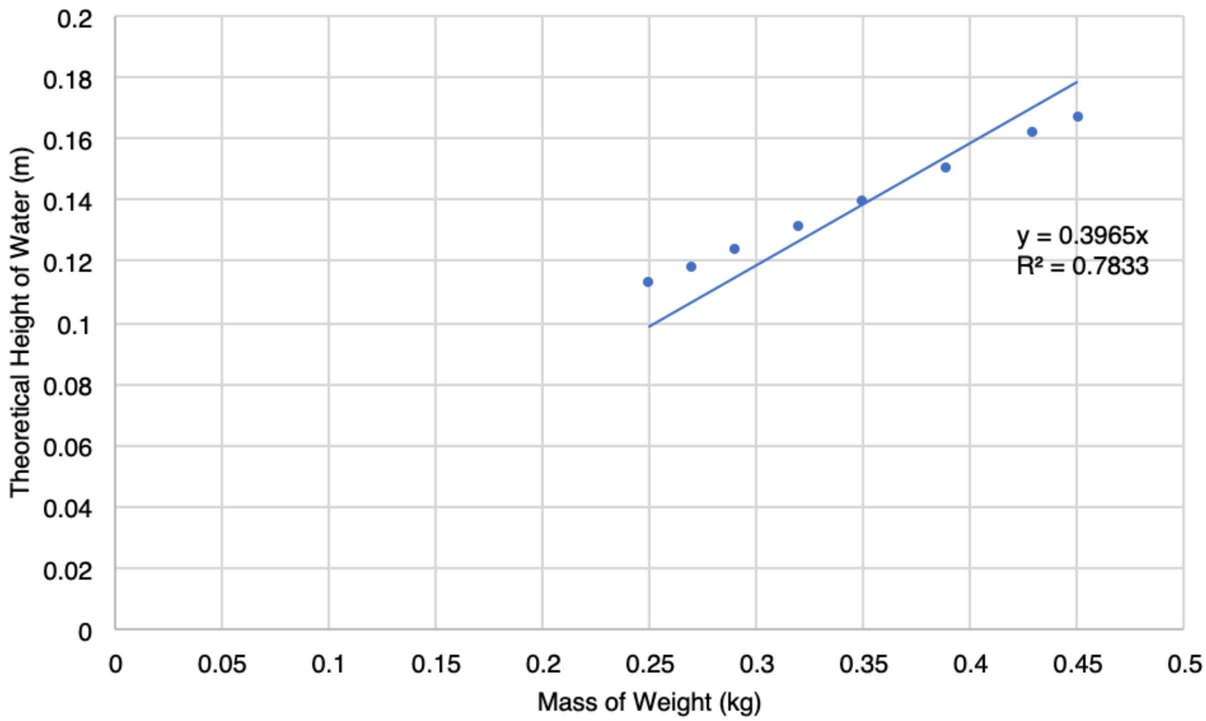

Figure 6. Mass of Weight versus Theoretical Height of Water, for the Fully Submerged Trials.

Different equations were used for the fully submerged trials when the data was put in to Excel. Just as it was seen in the partially submerged trials, in Figure 6 the mass and theoretical height of water do not seem to fit a linear trend very well, as the R^2 value is 0.7833. The theoretical height of the water does increase with mass, as is expected due to the equation used involving mass in a direct relationship to the theoretical height. This also makes sense because practically as mass is added, the water height is expected to increase because there is more mass to be displaced.

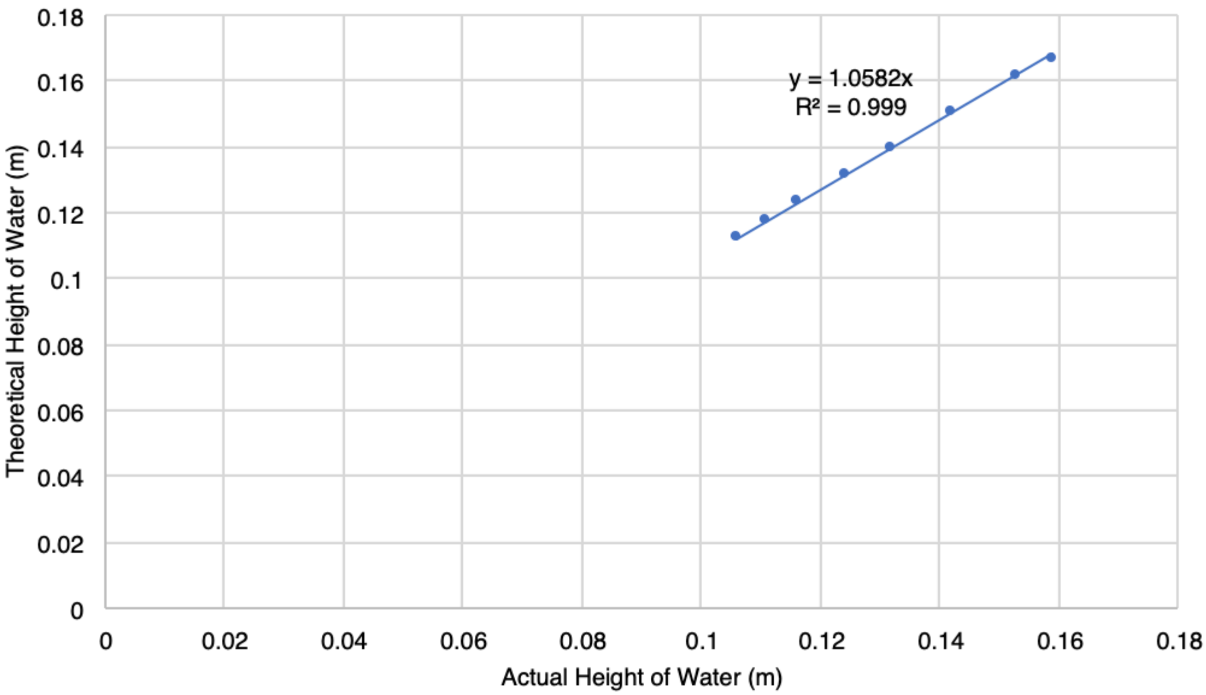

Figure 7. Actual Height of Water versus Theoretical Height of Water, for the Fully Submerged Trials.

Figure 7 shows that the actual and calculated height of water have a linear, direct relationship. This data fits the linear trend line very well, with an R^2 value of 0.999. Overall, the theoretical height of water is consistently higher than the actual height of water, and is higher than the measured height by a factor of about 1.0582.

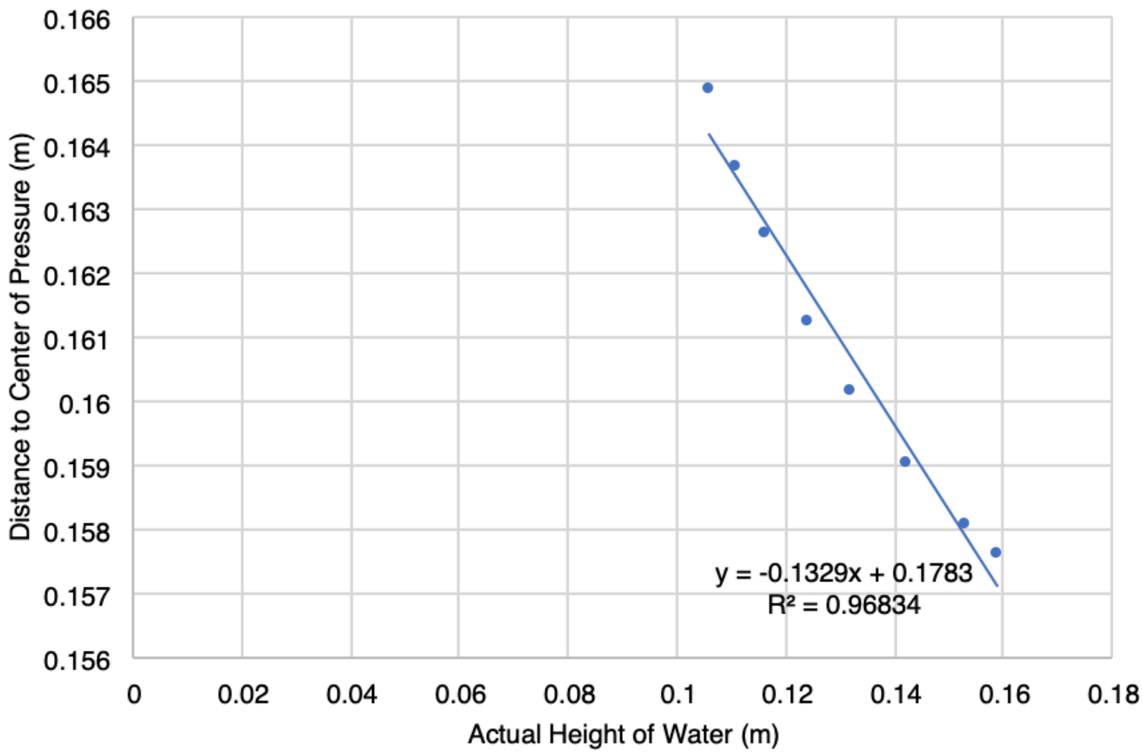

Figure 8. Actual Height of Water versus Distance to Center of Pressure, for Fully Submerged Trials.

Shown in Figure 8, as the actual height of the water increases, the distance to center of pressure decreases, following a linear path. This is expected because the distance from center of pressure is how far the resultant force acts from the balance beam arm. This distance would be expected to change because the area the force acts over increases as the amount of water that has to be added to balance the arm in the system increases.

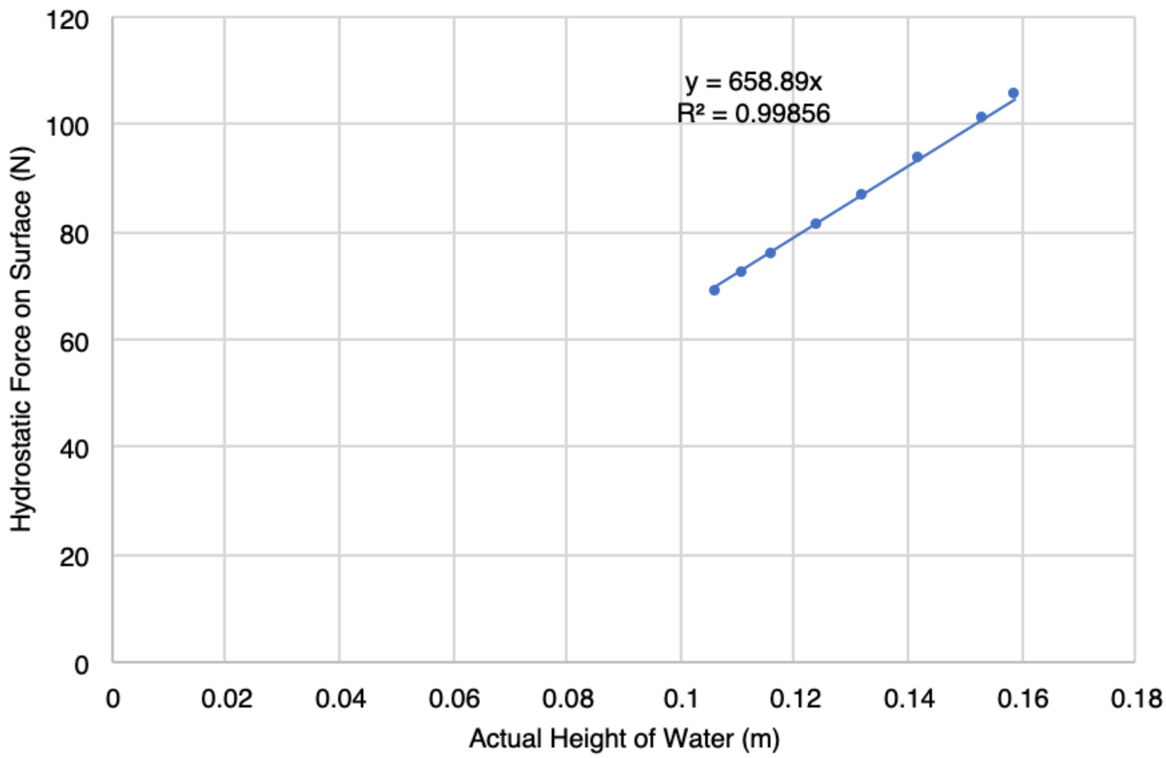

Figure 9. Actual Height of Water versus Hydrostatic Force on Surface, for Fully Submerged Trials.

Figure 9 shows that the actual height of water and the hydrostatic force on the surface have a direct, linear relationship. This data fits the linear trend well with an R^2 value of 0.99856. As water is added to the system to balance the arm, area increases for the force to act over. But mass is also being added to the system, so in addition to the distance the resultant force acts decreasing with increased area, the force is expected to increase.

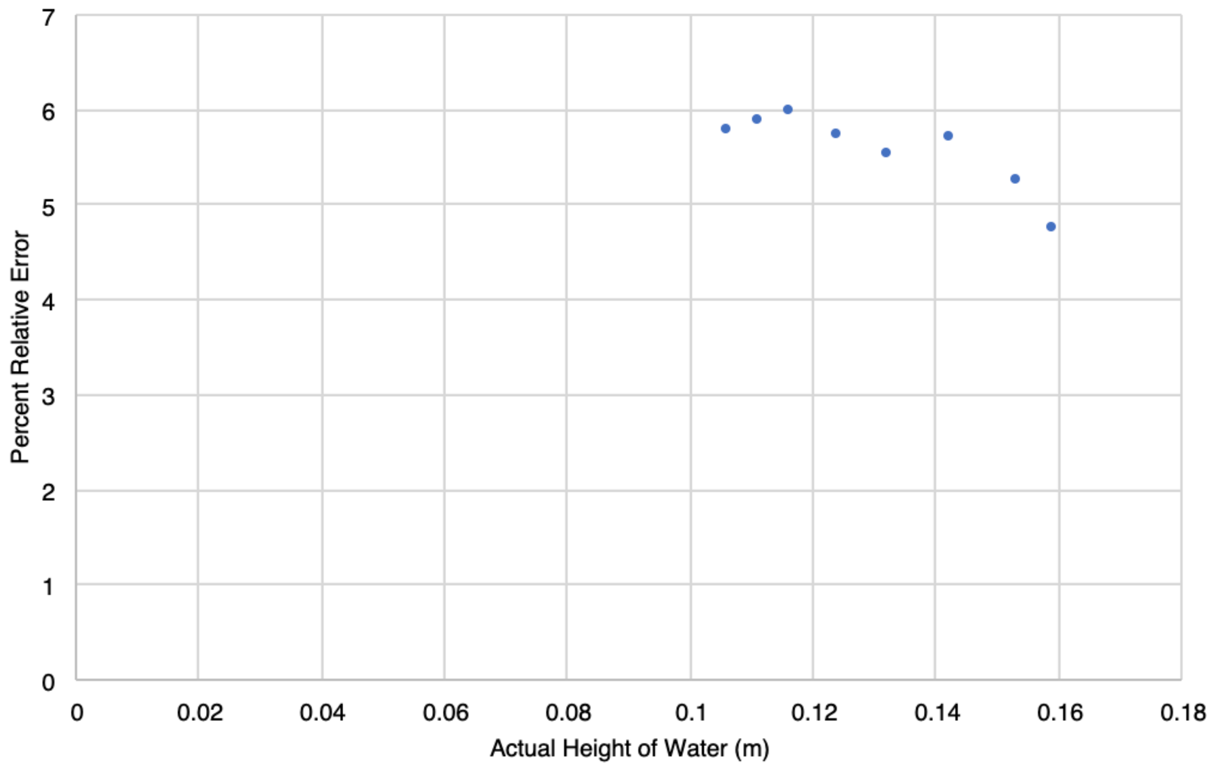

Figure 10. Actual Height of Water versus Percent Relative Error, for Fully Submerged Trials.

Figure 10 shows a slight downward trend in the percent relative error. This downward trend does not appear to be prominent enough to justify an error in the system, such as a leak in the system or weights being inaccurate. Much like the partially submerged trials, it appears the only justifiable error is human error, as human error is inconsistent and does not follow a trend.

CONCLUSIONS The theoretical equations for the Hydrostatic Pressure System were found to be accurate, with the only source of error being most likely human error, as it was inconsistent as height of water varied. For both the partially submerged and fully submerged trials, it was found that the theoretical height of water calculated was higher than the actual measured height of water. For both the partially submerged and fully submerged trials, the resultant hydrostatic force was found to increase with the increase of water height, and come closer to the balance arm as the height of water increased.

REFERENCES

Cengel, Y.A., & Cimbala, J. M. (2006) *Fluid Mechanics Fundamentals and Applications* (2nd Edition., pp. 50-54) New York, NY: McGraw-Hill.

Scholander, P.F., Bradstreet, E.D., Hemmingsen, E. A., Hammel, H. T. (1965) Sap Pressure in Vascular Plants. *Science.* (Vol. 148, pp 339-346)

San Martin, M.F., Barbosa-Canovas, G.V., & Swanson, B.G. (2010) Food Processing by High Hydrostatic Pressure. *Reviews in Food Science and Nutrition.* (Vol. 42, pp 627-645)

Thorpe, M., Minchin, P., Gould, N., McQueen, J. (2005) *Physiological Ecology: Vascular Transport in Plants* (pp 201-220) Academic Press.