International Journal of Smart Home
Vol. 10, No. 5 (2016), pp. 207-216
http://dx.doi.org/10.14257/ijsh.2016.10.5.19

Analysis and Design of Gravitational Sub-Pumping Station

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Abstract

Philippines archipelago experience scattered rain showers and most people are caught unprepared. Despite these changes in patterns especially in low elevated areas, road is totally impassable to the most type of vehicles due to flood. There were flood control programs implemented by the government and new flood equipment was used but seems not effective enough to solve the problems. This paper presents an analysis in the design of gravitational sub-pumping station in riverside road to assist the existing pumping station in that locality. Such a design can serve as a model that can be implemented to the other sections of the city. The design of this pumping station involved investigating the existing sub-pumping station in terms of its structure, financial resources, and the effect in the health of end-users, its maintenance including the traffic, operations and reduction of flood water. A conventional gravitational sub-pumping station was designed based on the conclusion that for the city of Taguig, a uniform, consistent, simple pumping station would be the most

***Keywords**: flood control, flooding, pump, pumping station, sewage system*

1. Introduction

Pumping station is one of the oldest known device structures in controlling flood problems and diverting waters to the more elevated areas for farm use and others. The existence and the developmental progress of pumping station contributes a both in both agricultural and modernization of city life

In agriculture, ancient people used traditional device in conveying water to irrigate the farms. The old civilization of Egypt used “sakieh”. The ancient wooden device raises water from a canal and deposits in a through set enough to sluice the water into irrigation ditches. Typically, a buffalo was hitched to the uppermost arms to drive the horizontal cogged wheel, which in turn powered the vertical lifting wheel. The same revolutionized farming when it was introduced in Egypt by the Ptolemy’s in the third century B.C. bringing in six fold increase in the amount of land that one farmer could irrigate in a day. The modern agriculture nowadays uses modern power pump to irrigate their farms.

In the modern city life, the most common purpose of the pumping station is either in flood control or water reserve for tall building and subdivision. Pumps are powered by electricity of fuel to operate; some of the commonly used are industrial turbine pump with cast iron discharge lead and vertical solid shaft motor. barrel pump with intake on barrel at elevations lower than discharge and deep well turbine pump with 55 gallon tank are all for lubricant supply [1].

In [2], they found that designing pumping station is a complex task that involves input from a wide range of engineering disciplines. Successful design of new station requires an integrated approach that takes into account such diverse factors as project definition and delivery, integrated system design, station lay out and control optimization. The challenges faced by designers are compounded by the requirement to deliver the

ISSN: 1975-4094 IJSH

improvements within strict financial constraints for project design and for the whole life costing of the delivered station.

2. Problem Statement

Flood was a common problem within Metro Manila. The existing pumping station is now less efficient as it was constructed forty years ago. City boarders extended. Many relocations and recreational areas were made on the coast line and there is an ecological imbalance that causes to penetrate low land areas.

It is necessary to update the waste in controlling flood as time changes the condition of a certain place. Pasig River water level reaches the worst 2 meters peak during high tide penetrating most estuaries, the drainage up to the surface of the road. Adding to the fact that squatters occupied some portion of esteros exhibiting improper waste disposal and sanitary malpractice causes the delay of estuary disposal of waste water.

In Figure 1, the recent condition of the existing Intramuros pumping station pave the way of the researcher in designing a unique sub-pumping station to alter the existing old pumping station for the same purpose of controlling flood problems in the said locality. The researcher aims to improve the waste of flood control by designing the gravitational sub-pumping station and further acceptance and implementation would surely ease the controversial flood problems.

Figure 1. Existing Pumping Station in Manila

With the use of GPS strategically that is well-designed and positioned can give a big deal in minimizing and in the long run, totally eliminate the flood problems along the riverside road.

The GPS focuses on the pumping of the floods water by means of a unique power source. The weight of the passing vehicle causes the pressing of the rubber paddle positioned across the road thus producing to open exhaust valve and releasing floods water from the catch basin into Pasig River.

Manila, being naturally located in the tropical zone suffers monsoon rains every year which result to flood and as well as known as elevation of most area within the Manila are noticeably low. By means of the new design pumping station, it can be ease the flood problems in the locality of Manila.

Further modification of this design can lead to a total zero floods not only in Manila but also to other part of the country with the same problem

3. Research Methodology

The researcher employed a descriptive method of research in the study. The focus of concern of the research is to analyze the design of gravitational sub-pumping station in riverside road of Manila to assist the existing pumping station in that locality. Every year, its' residents and public is affected by floods and the problem is causing a big concern among them. Accidental sampling under the category of non-probability sampling was adapted. The researcher went through the area within the subject and conducted a survey to those who gave them a chance. Eighty respondents who are making a living nearby the location of the subject and also the everyday passers-by were selected and employed in the study. The population consists of twenty five males and twenty five females. They belonged to almost all walks of life including vendors, teachers, workers, students, ordinary housewives and businessman. A structured interview was conducted among the fifty respondents guided by a specifically prepare questionnaires.

4. Results and Discussions

4.1. Adequacy of Structure

Table 1 implies that respondents viewed structure as very adequate. This is because the structure design and principles are very simple and practical. This is effective enough to comply with the expected results.

Table 1. Frequency Distribution of Adequacy in Structure

	Very adequate	Adequate	Less adequate	Inadequate	Total
Monitoring and supervision	77	2	1	0	80
Response of the implementation of the project	74	6	0	0	80

4.2. Financial Resources

Table 2 implies that respondents viewed financial structure as adequate. This is because the costs of the structures are cheaper than the existing pumping station.

4.3. Technical

Table 3 implies that respondents viewed technical expertise as adequate because this structure does not yet exist in the Philippines. However, respondents viewed technical assistance as inadequate since there is lack of knowledge in technical aspects.

Table 2. Frequency Distribution of Adequacy in Financial Resources

	Very adequate	Adequate	Less adequate	Inadequate	Total
Sufficient of Financial Resources	75	5	0	0	80
Availability of fund for the implementation of the projects	77	8	0	0	80

Table 3. Frequency Distribution of Adequacy in Technical

	Very adequate	Adequate	Less adequate	Inadequate	Total
Technical Expertise	0	1	23	56	80
Technical Assistance	4	61	15	0	80

4.4. Maintenance and Operation

Table 4 implies that respondents viewed repair and rehabilitation as adequate. This is because the materials used in building this structure are locally made. The operation is cheaper because the structure will not consume fuel during the entire operation

Table 4. Frequency Distribution of Adequacy in Maintenance and Operation

	Very adequate	Adequate	Less adequate	Inadequate	Total
Equipments	35	40	5	0	80
Pumps	25	55	0	0	80
Electric motors	24	39	17	0	80

4.5. Reduction of Floodwater

Table 5 implies that respondents viewed that the gravitational sub-pumping station will reduce the volume of floods water as very adequate

Table 5. Frequency Distribution of Adequacy in Reduction of Floodwater

	Very adequate	Adequate	Less adequate	Inadequate	Total
Sufficient final resources	45	53	0	0	80
Removed of sediments	39	41	0	0	80

4.5. Health

Table 5 implies that respondents viewed that health is adequate. This is because most of the respondents feel that eliminating the floods water will also eliminate the water borne disease, and odor that cause epidemic within the community.

Table 5. Frequency Distribution of Adequacy in Health

	Very adequate	Adequate	Less adequate	Inadequate	Total
Reduce epidemic infection	45	35	0	0	80
Raise level of awareness in sanitation	44	36	0	0	80

4.6. Traffic

Table 6 implies that respondents viewed that traffic is adequate because the humplike design of the structure will regulate the traffic flow, and at the same time will eliminate flood within the road

Table 5. Frequency Distribution of Adequacy in Health

	Very adequate	Adequate	Less adequate	Inadequate	Total
Traffic congestion	1	34	2	43	80
Public convenience safety	36	43	1	0	80
Driver safety	35	44	1	0	80

5. Pump Station Design

The Hydraulic Institute Standards (HIS) for Pump Intake Design was developed for use by manufacturers, design engineers and end users, to assist them in the development and selection of appropriate design criteria for a given operating condition. The Hydraulic Institute (HI) was formed under the American National Standards Institute and consisted of approximately twenty committee members representing manufacturers, researchers and end users [3,4]. The adopted standards were reviewed by approximately fifty organizations prior to approval. It is of the consensus of the HI that unfavorable hydraulic operating conditions can have an adverse affect on pump performance.

5.1. Hydraulic Institute Design Guidelines

HI design guidelines for DCWW's for solid-bearing liquids follow the same baseline criteria as for clear liquids, with the pumps centered in the wet well as shown in Figure 2. Selection of governing parameters needs to be made on pump type. In the case of submersible pumps, D_b refers to the volute diameter and in vertical pumps, the bell diameter [5]. However, the term D, without any suffixes, always refers to the bell diameter, regardless of pump type. Setting the design criteria based on the pump bell and volute assures that the wet well will be properly sized regardless of pump selection.

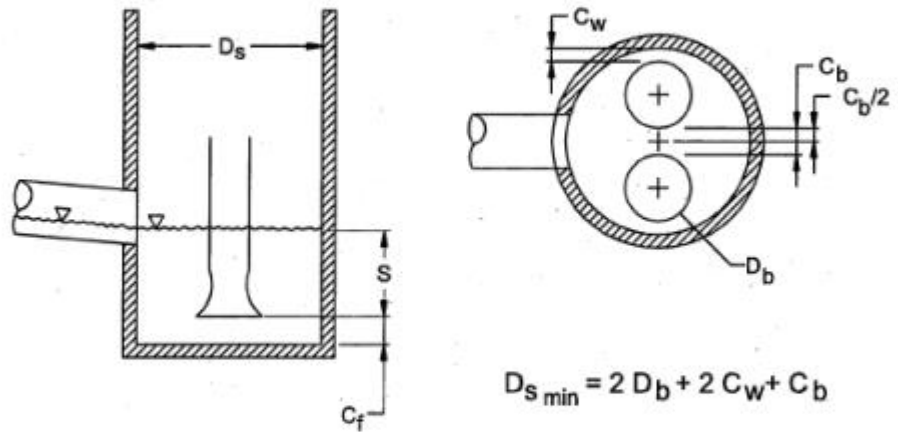

Figure 2. Wet Well Design Guidelines for Clear Liquid Application

Pump bell shape and size are determined by each manufacturer, resulting in a range of diameters for the same flow capacity. Each manufacturer may also offer various bell configurations depending on the pump type and application. Realizing this, the HI created the graph shown on Figure 3, which contains recommendations for bell diameter, as based on a corresponding bell velocity (in ft/s) for a given flow. Recommended pump bell velocities range from 2 ft/s to 9 ft/s [6.7].

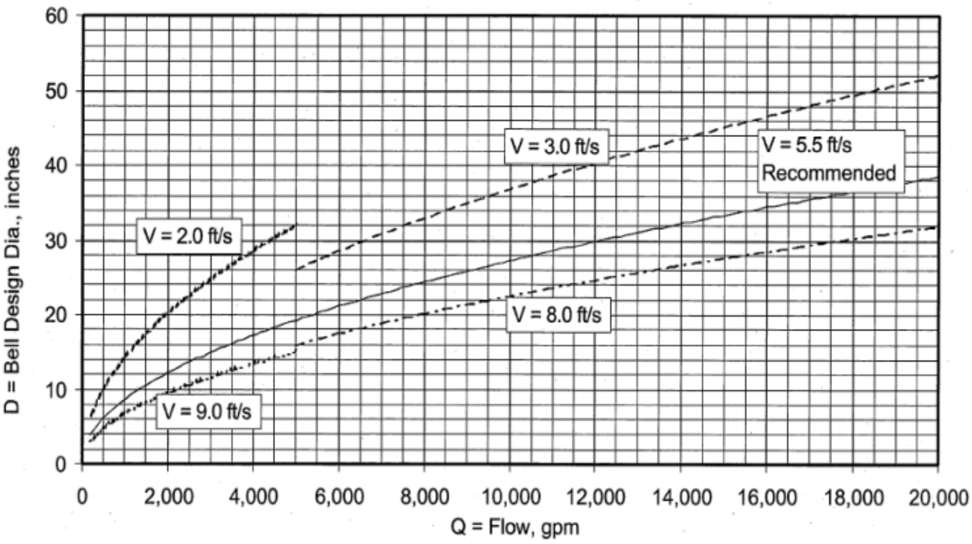

Figure 3. Recommended Pump Bell Diameter

The recommended minimum submergence can be determined using the following equation: $S = D + 0.574Q/D^{1.5}$ where S = inches, Q = flow (gpm), and D = bell diameter (inches) where S = inches, Q = flow (gpm), and D = bell diameter (inches) [8,9]. Since the pump bell selection is related to velocity, the HI also created graph shown on Figure 4, which contains recommendations for submergence as based on a corresponding bell diameter and velocity for a given flow. It should be noted that the recommended minimum submergence is based on uniform flow approaching the pump, which circular wet wells may not possess without the installation of flow-straightening devices. Consequently, the actual required minimum submergence may differ.

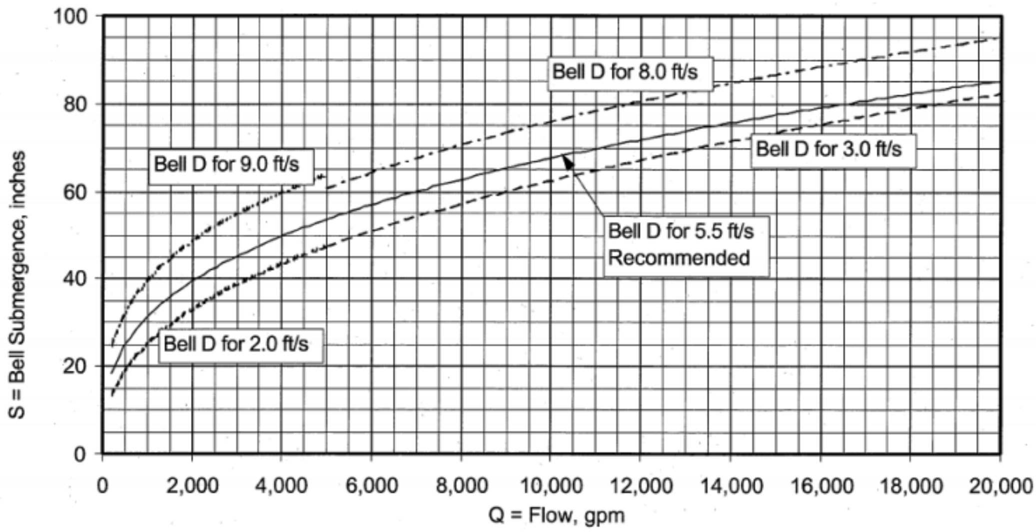

Figure 4. Recommended Pump Submergence

Only general recommendations are made for the position and orientation of the inflow pipe. The pipe shall have no bends, valves or fittings within five pipe-diameters directly upstream of the wet well. The pipe is not to be positioned higher than shown in Figure 2. However, as this is only a graphical representation, it is unclear as to the precise location. It stands to reason that the higher the pipe, the greater the amounts of air impingement, due to the free-discharge impinging on the water surface at lower water elevations. There is no recommendation for the slope of the pipe. It is recommended that the placement of the pipe is radial to the tank and perpendicular (normal) to the centerline of the pumps to reduce rotational flow patterns. However, it is unknown as to whether or not an inline (coplanar) orientation would perform better than a normal orientation.

There are no specific recommendations for the angle of the side slope within the guideline section covering DCWW's. However, within the general discussion on Intake Structures for Solid-Bearing Liquids, a minimum angle of 60 degrees is recommended for vertical transitions of concrete surfaces and 45 degrees for smooth surfaces such as plastic and coated concrete [10]. It is currently unknown if one slope angle is advantageous over another.

5.2. Hydraulic Influence on Pump Performance

Solid handling pumps transport particles ranging in size from silts to gravel and therefore, are fairly robust in design. However, unsatisfactory hydraulic conditions such as asymmetrical flow, swirling flow, vortexing, air entrainment and turbulence can cause non-uniform loading, reduce the efficiency of a pump and lead to excessive wear on the impellers, bearings and motors, resulting in high maintenance costs. Ideally, flow will enter the pump bell uniformly from the entire perimeter, with no axial angular component of the flow. Realistically, this would only occur under ideal conditions when the flow is perfectly radial to the bell. As evident from the layout shown on Figure 2, this will most likely not be the case with DCWWs. Swirling flow is extremely problematic in DCWWs, as the circular wet well design promotes rotational flow around the pump(s).

This can lead to the formation of both free-surface and 11 subsurface vortices, which in turn can cause vibration, cavitations on the impeller and premature wear. Additionally, excessive swirl can reduce the overall efficiency of the pump by causing a shift in the performance curve. If the swirl direction is opposite of the impeller rotation, the pump will need to work harder to produce the required flow.

On the other hand, if the swirl is the same as the pump, it could result in excessive run-out and motor damage. It is the consensus of the HI that limiting the pump suction swirl angle to a maximum of 5 degrees will result in a negligible impact on the pump performance.

A vortex is a circulating flow phenomenon upon which the elements rotate about a central point, forming a closed curve and which strength can range from a weak surface swirl to a strong air core, as experienced when a bathtub drains.

Although vortices can be described, the prediction of vortices within a wet well is difficult at best and estimating the strength of a vortex is virtually impossible, even with the use of numerical modeling techniques such as computational fluid dynamics (CFD). This is because vortices tend to be unsteady and intermittent due to unpredictable fluctuations in the flow field caused by turbulence. It is necessary to know the precise boundary conditions and effects of included geometries on turbulence within the domain, in order to predict the tendency for a vortex to form. For this reason, it is recommended that vortices be studied with the use of a physical model. Air entrainment within wet wells is problematic when the air enters the pumps, as this causes a loss of pumping capacity and efficiency due to the reduced liquid volume, as well as possible excessive wear on the pump due to uneven loading and vibration on the impeller. Another major issue of air entrainment with regard to wastewater facilities is the release of odorous gases to the atmosphere, as well as the possible production of sulfuric acid, which corrodes the metal and concrete surfaces.

6. Conclusions and Recommendations

It is important to find the causes that trigger the flood problems which include natural causes and manmade causes, having a tropical weather conditions. The Philippines suffer a lot monsoon rains and storms that trigger the flood. The squatter living along the esteros and other bodies of water plus the proper imposed of garbage aggravate the flood problems. There is a tendency to take floods for granted to think that is something natural and inevitable, that there is no hope for feasible solution.

There is a need to acknowledge that social problem and issue of flooding would inevitably lead to the large issue of population and poverty, and their convergence into the problem of squatting. This issue of population and poverty proves to be the highest problem in the maintenance and operation of the pumping station.

This project design of gravitational sub-pumping station is believe that it will not be prone to population and poverty problems. The GSPS is strategically positioned to achieve its out most efficiency, elevation and distance to the outlet of floods water discharge is considered.

In keeping the pace with the explosive increase in the population, an increase number of the people have suffered from the flood during rainy seasons, which occur almost every year. This project has been organized as part of the infrastructure development project aim on attacking problems confronting Intramuros, Manila and its early implementation is being sought.

The people benefiting from the project are mainly residents living in the low lying areas are commuters from neighboring cities and municipalities. This project is very significance since it’s is expected to reduce flood damage afflicting the people contribute to the improvement. The MMDA shall provide personal maintenance of this project. For the benefit to the populace, adequate preparation shall be done with the proper implementation of the project.

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