FLOW RATING ANALYSIS FOR PUMP UNIT 2 AT PUMP STATION G388

By
Sheng Yue & Emile Damisse

February 2012

SFWMD-HIST-019

Hydro Data Management Section
Operation & Infrastructure Bureau
South Florida Water Management District

TABLE OF CONTENTS

TABLE OF CONTENTS ..... **I**

LIST OF FIGURES ..... **II**

LIST OF TABLES ..... **II**

DEFINITIONS ..... **III**

EXECUTIVE SUMMARY **1**

1.0 INTRODUCTION **2**

1.1 BACKGROUND 2
1.2 OBJECTIVES AND SCOPE 2

2.0 RATING ANALYSIS **3**

2.1 CURRENT RATING EQUATION 3
2.2 NEW RATING EQUATION FOR PUMP #2 4

3.0 STREAMGAUGING NEEDS **6**

4.0 CONCLUDING REMARKS **7**

REFERENCES **8**

LIST OF FIGURES

FIGURE 1. LOCATION MAP FOR STA-3/4 AND PUMP STATION G388 2
FIGURE 2. CURRENT RATING CURVE FOR PUMP #1 & #2 4
FIGURE 3. NEW FLOW RATING CURVE FOR PUMP #2 WITH PUMP SPEED OF 224 RPM 6

LIST OF TABLES

TABLE 1. RATING COEFFICIENTS FOR CURRENT RATING EQUATION 3
TABLE 2. COMPARISON BETWEEN MEASURED AND COMPUTED FLOWS BASED ON CURRENT RATING 4
TABLE 3. FLOW CONVERTED FROM PUMP SPEED OF 350 RPM TO 224 RPM 5
TABLE 4. RATING COEFFICIENTS FOR PUMP #2 WITH PUMP SPEED OF 224 RPM 5
TABLE 5. COMPARISON BETWEEN MEASURED AND COMPUTED FLOWS BY NEW RATING 6
TABLE 6. STREAM GAUGING NEEDS FOR PUMPS AT PUMP STATION G388 7

DEFINITIONS

Acronyms

TSH	Total static head
SFWMD	South Florida Water Management District
STA	Stormwater treatment area

EXECUTIVE SUMMARY

SFMWD changed pump speed of Pump Unit 2 (Pump #2) at Pump Station G388 from 350 rpm to 224 rpm on August 11, 2011. This results in the decrease in the flow capacity of Pump #2. The current rating equation developed based on pump speed of 350 rpm cannot be used to compute flow through Pump #2. This report summarizes the revision of the flow rating equation for Pump #2 at Pump Station G388 based on the speed of 224 rpm. The updated rating equation will be used to compute flow through Pump #2.

1.0 INTRODUCTION

1.1 Background

Pump Station G388 is the outflow pump station for the PSTA Demonstration Project, located at Stormwater Treatment Area 3/4 (STA 3/4), as shown in **Figure 1**. The station consists of two 42-inch, electric motor-driven, axial flow pumps with pump speed of 350 rpm (revolution per minute). Each pump is originally designed to have a capacity of 100 cfs at a total dynamic head of 9.0 ft. However, the pump speed of Pump Unit 2 (Pump #2) was modified from 350 rpm to 224 rpm on August 11, 2011, and hence the flow capacity of the pump was decreased. Flow computed through Pump #2 after August 11, 2011 was overestimated by the current rating equation since the rating had been developed based on the speed of 350 rpm. The flow rating equation for Pump #2 should be updated to reflect the decrease in its speed and capacity.

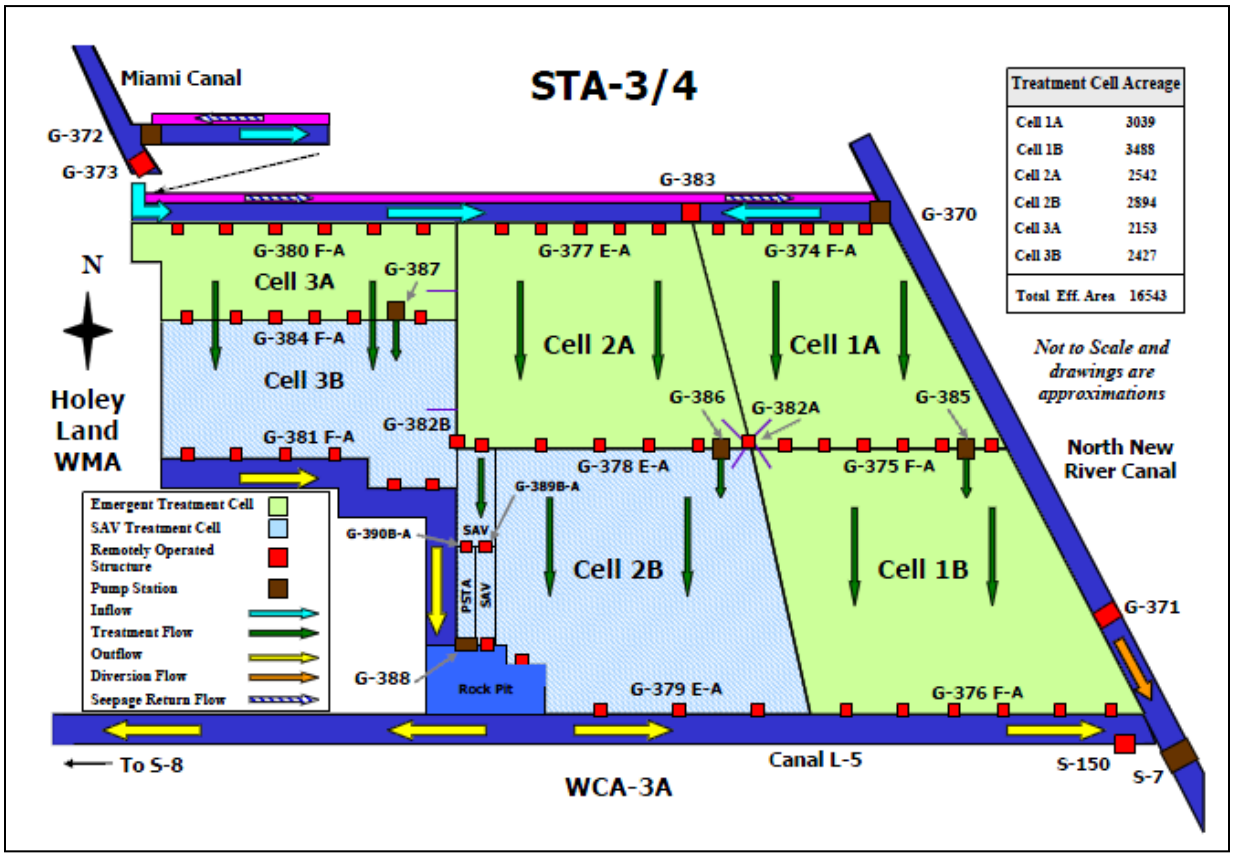

Figure 1. Location map for STA-3/4 and Pump Station G388

1.2 Objectives and Scope

We will conduct a rating analysis to update a flow rating equation for Pump #2 at Pump Station G388 to reflect its speed decrease.

2.0 RATING ANALYSIS

2.1 Current Rating Equation

BFA (2011) developed the current rating equation for the two pumps at Pump Station G388 based on factory pump performance curve using conventional Case 8 model. Case 8 rating equation is developed using dimensional analysis and the pump affinity laws. This conventional rating equation represents all the possible cases, as documented in Damisse (2001) and Imru and Wang (2003). Equation below shows the Case 8 flow rating equation.

$$Q = A\left(\frac{N}{No}\right) + BH^{C}\left(\frac{No}{N}\right)^{2C-1} \quad (1)$$

$$H = \max\{CL, TW\} - HW \quad (2)$$

Where

Q:	Discharge in cfs;
H:	Total static head or head differential (TSH) in ft;
N:	Pump engine speed in rpm;
No:	Design pump engine speed in rpm (= 350 rpm);
A, *B* and *C*:	Regression coefficients determined through regression analysis (A > 0, B < 0, and C > 1.0).
CL:	Discharge pipe outlet centerline elevation;
TW:	Tailwater elevation;
HW:	Headwater elevation.

For electric pumps with constant speed, $N = N_o$, and Equation (1) becomes

$$Q = A + BH^{C} \quad (3)$$

Table 1 presents the coefficients of the above rating equation developed by BFA in January 2011. **Figure 2** illustrate the rating curve of the pump station along with the measured flows. **Table 2** provides the absolute relative errors between computed and measured flows. The average absolute relative error (AARE) is 8.8%, and the rating is rated as "Good" based on the current criteria for assessing the quality of flow rating. However, the existing five flow measurements have a narrow range of head differential. We need more good flow measurements distributed along a wide range of head differential to further calibrate and potentially improve the rating.

Table 1. Rating Coefficients for Current Rating Equation

Pump Unit	Rating Coefficient	Estimate	Approximate lower 95% C.I.	Approximate upper 95% C.I.
Pump #1 and #2	A	103.3	103.2	103.5
	B	-0.525	-0.5736	-0.4762
	C	1.6745	1.6358	1.7312

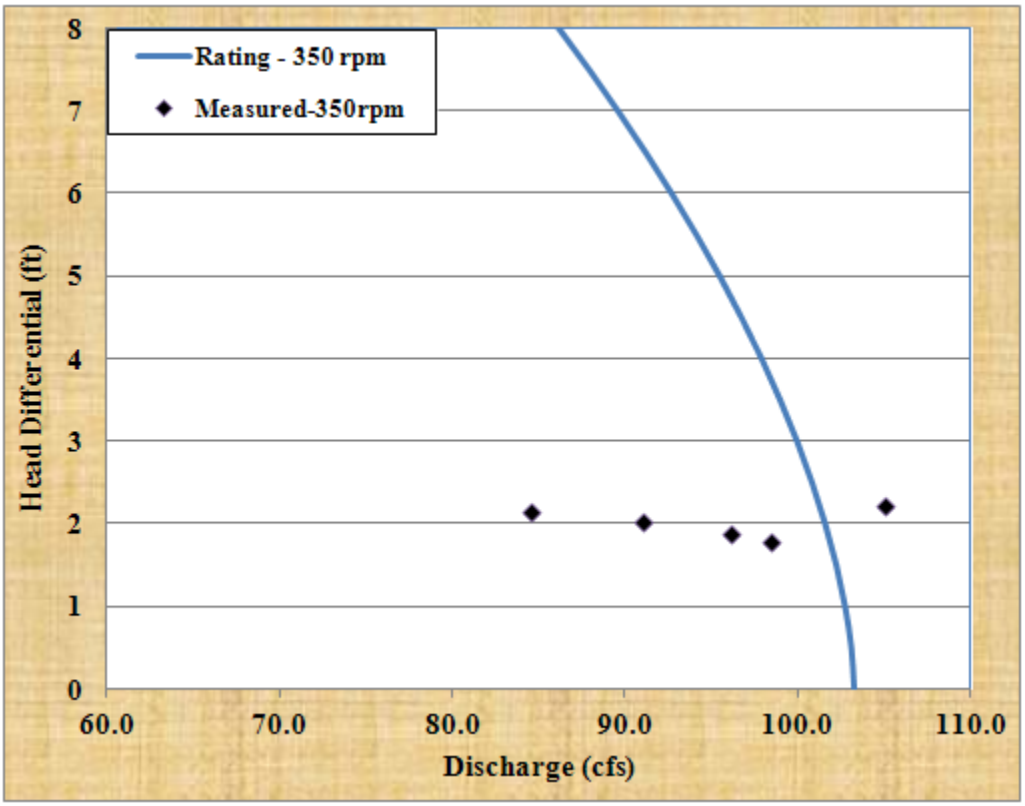

Figure 2. Current rating curve for Pump #1 &#2

Table 2. Comparison between Computed and Measured Flows by Current Rating

Streamgauging Date	HW (ft, NGVD)	TW (ft, NGVD)	Discharge CL EL (ft, NGVD)	Head Differential (ft)	Measured flow (cfs)	Flow Measurement QA TAG	Computed Flow (cfs)	Absolute Relative Error (%)
5/5/2010	10.03	10.12	12.25	2.22	105.07	Good	101.30	3.6
11/10/2010	10.46	11.09	12.25	1.79	98.52	Good	101.91	3.4
11/10/2010	10.37	11.09	12.25	1.88	96.18	Good	101.79	5.8
11/10/2010	10.23	11.08	12.25	2.02	91.10	Good	101.60	11.5
8/31/2011	10.10	10.36	12.25	2.15	84.63	Fair	101.41	19.8
Average								**8.8**

2.2 New Rating Equation for Pump #2

SFWMD revised the speed of Pump #2 from 350 rpm to 224 rpm on August 11, 2011. The flow capacity of Pump #2 was reduced due to the decrease in pump speed. In order to correctly compute flow through Pump #2, the current rating equation needs to be revised to reflect the decrease in pump capacity. We can use Equation (1) to convert flows from pump speed of 350 rpm to 224 rpm at a given head differential

since the change was only applied to pump speed and pump characteristics were not altered. **Table 3** presents the converted discharges using Equation (1).

Table 3. Flow Converted from Pump Speed of 350 rpm to 224 rpm

Head Differential (ft)	Discharge - 350 rpm (cfs)	Discharge - 224 rpm (cfs)
0.0	103.3	66.1
0.5	103.1	65.6
1.0	102.8	64.6
1.5	102.3	63.2
2.0	101.6	61.3
2.5	100.9	59.2
3.0	100.0	56.7
3.5	99.0	53.9
4.0	98.0	50.9
4.5	96.8	47.5
5.0	95.5	43.9
5.5	94.2	40.1
6.0	92.8	36.0
6.5	91.2	31.7
7.0	89.6	27.2
7.5	88.0	22.4
8.0	86.2	17.4
8.5	84.4	12.2

We then conduct non-liner regression analysis using SAS NLIN function on head differential vs. converted discharge to derive the rating coefficients for the new rating equation with pump speed of 224 rpm. **Table 4** presents the rating coefficients for Pump #2 with pump speed of 224 rpm. **Figure 3** illustrates and compares the converted discharges vs. the rating curve based on the new rating. The rating curve well fits the converted discharges. **Table 5** gives the absolute relative errors between measured and computed flows by the new rating. The average absolute relative error (AARE) is 6.5%, and the rating is rated as "Good" based on the current criteria for evaluating the quality of rating. For comparison, the three measured flows are also plotted on **Figure 3**, which are reasonably close to the curve. However, we need more good flow measurements that distribute along wide range of head differentials to further calibrate and to develop a more accurate rating equation to compute flow through Pump #2.

Table 4. Rating Coefficients for Pump #2 with Pump Speed of 224 rpm

Pump Unit	Rating Coefficient	Estimate	Approximate lower 95% C.I.	Approximate upper 95% C.I.
#2	A	66.1032	66.0640	66.1424
	B	-1.4956	-1.5059	-1.4853
	C	1.6750	1.6721	1.6779

Table 5. Comparison between Measured and Computed Flows by New Rating

Streamgauging Date	HW (ft, NGVD)	TW (ft, NGVD)	Discharge CL EL (ft, NGVD)	Head Differential (ft)	Measured Flow (cfs)	Flow Measurement QA TAG	Computed Flow (cfs)	Absolute Relative Error (%)
8/31/2011	10.35	10.34	12.25	1.9	56.1	Good	61.7	10.0
8/31/2011	9.86	10.35	12.25	2.39	56.6	Fair	59.7	5.5
8/31/2011	10.07	10.37	12.25	2.18	58.2	Good	60.6	4.1
Average								**6.5**

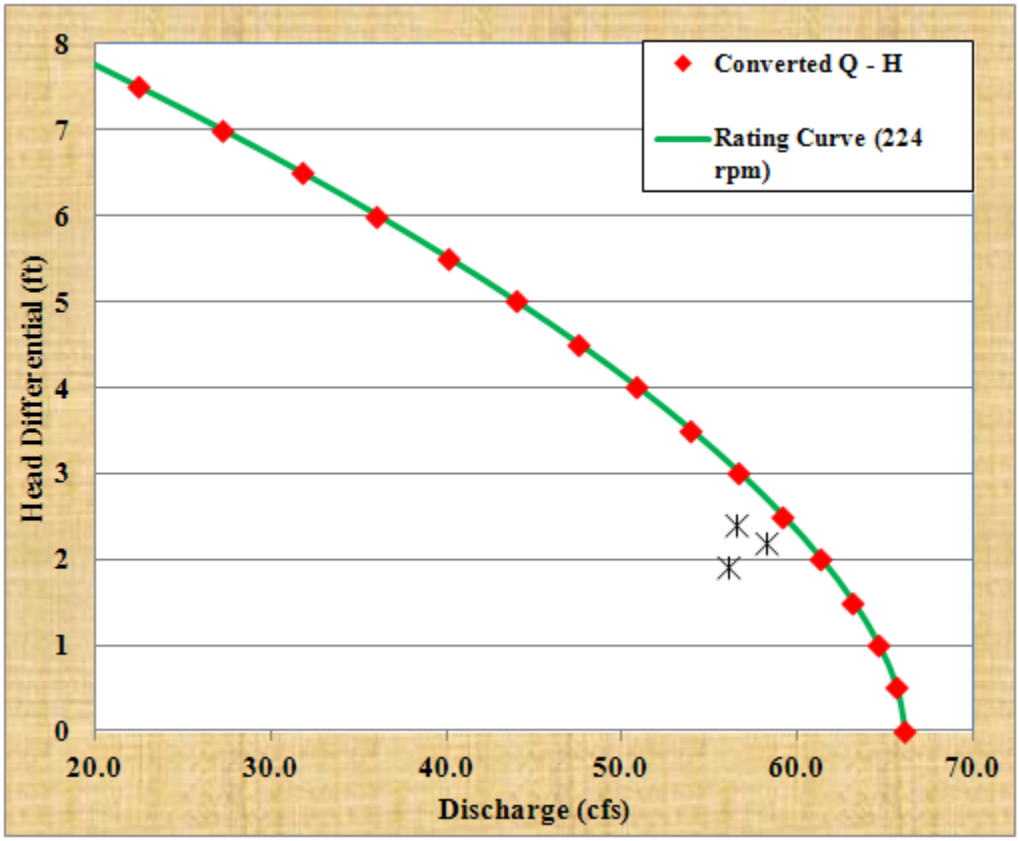

Figure 3. New flow rating curve for Pump #2 with pump speed of 224 rpm

3.0 STREAMGAUGING NEEDS

The previous section indicates that we need more good flow measurements distributed along a wide range of head differential to potentially improve the rating for both pumps. **Table 6** summarizes the desired number of flow measurements.

Table 6. Stream Gauging Needs for Both Pumps at Pump Station G388

Head differential (ft)	# of Flow Measurements Required
0 - 1.5	5
>2.5	5

4.0 CONCLUDING REMARKS

We conducted updated flow rating analysis for Pump #2 at Pump Station G388 due to the change in its pump speed. **Table 4** presents the coefficients of its flow rating equation after reflecting the decrease in its pump speed. The rating can be used to compute flow through Pump #2 for now. More flow measurements are needed to calibrate, and to potentially improve the rating.

REFERENCES

BFA (Barns, Ferland and Associates, Inc), 2011. Flow Rating Analysis for Pump Station G388 PSTA Project Storm Treatment Area ¾. Rating Developemnt Report, Contract No. ST060586-WO-02R2, South Florida Water Management District, West Palm Beach, Florida.

Damisse, E. 2001. Flow rating development for G335 Pump Station in STA-2. Hydrologic Data Management Division, South Florida Water Management District, West Palm Beach, Florida.

Imru, M. and Y. Wang. 2003. Flow Rating Analysis Procedures for Pumps. Technical Publication EMA # 413, South Florida Water Management District, West Palm Beach, Florida.