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RATING ANALYSIS FOR PUMP STATION S2

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Executive Summary

A rating analysis of the S2 pump station was carried out using the conventional case 8 model along with the existing pump station performance curve. A rating equation was developed for each of four identical pump units configured the same way. The equation yields discharge rates that are within 2 % of the discharges derived from the pump station performance curve under the expected range of static heads.

It is recommended that the new rating be implemented into DBHydro with a new effective date starting June 2007. According to the impact analysis, no reload is needed for the historical data records prior to June 2007. Furthermore, it is recommended that the rating equation be recalibrated with additional measured flows of acceptable quality.

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Introduction

The S2 structure is a four-unit pumping plant located in the alignment of Lake Okeechobee's south shore levee at the intersection of the Hillsboro and the North New River Canals with Lake Okeechobee. The purpose of the structure is to pump surplus water into Lake Okeechobee via the Hillsboro and North New River Canals from the agricultural area south and east of the structure. It is equipped with four Fairbanks Morse 144-inch diameter vertical lift pumps, each rated for 900 cfs at 7.2 feet of static head. Each pump unit is driven by a Fairbanks Morse Model 1160 horsepower diesel engine connected to the pump through a right angle type gear transmission manufactured by Farrel-Birmingham Company. Priming of the main pumps is normally accomplished by an electric motor-driven Nash Model vacuum pump. Power for the station is supplied by two Cummins Model 6CTA 9.3-G2 150 KW AC generators.

Available Flow Measurements

There are 17 flow measurements for this station as shown in Table 1. These measurements were obtained using either a Price AA meter or an ADCP. Measurements obtained with a Price AA meter were all dated prior to 1992. Compared to modern stream gauging equipment such as ADCP, Price AA meters provide data of lower quality. The three corresponding measurements, although tagged to be excellent, are deemed inconsistent with the remaining measurements obtained from ADCP. Therefore, they will only be used for comparison purposes. Another 12 flow measurements obtained with an ADCP include six measurements that were not subject to any formal QA/QC process and another six obtained when the headwater elevation was higher than the tailwater elevation. Although they can be used for comparison purposes, these measurements should not be directly used in a rating analysis. Consequently, there remain only two measurements that are of adequate quality for a flow rating analysis. This is clearly insufficient.

Objective and Scope

The objective of this report is to present a new hydraulic rating analysis for the pumps at S2 and convert the case 2 rating equation to a case 8 equation. The current analysis is based on the pump performance curve, hydraulic properties of the station and the case 8 model. In addition, the stream gauging needs will be identified for this station so that the current rating can be calibrated in the future.

Station Design and Methodology

The manufacturer's pump performance curves depicting TDH vs. discharge are not available. However, the TSH versus flow curve for all four pumps is available and shown in Figure 1. Cross sectional and plan views of the pump station design are shown in figure 2. This figure contains one of the record drawings completed just after the pump

station was constructed. As shown in Figure 2, the discharge tunnel is split throughout its length by a vertical concrete splitter.

Since the TSH vs. flow curve for the pump station is available, it is not necessary to calculate the system head losses. The TSH curve will be directly used in the rating analysis.

Table 1. Flow measurements available at pump station S2.

STATION	MEAS_DATE	HW_AVG	TW_AVG	DISCHARGE	STATUS	TAG	DESCRIPTION
S2_P	6/28/92 12:15 PM	12.15	14.25	2254.00	Q	E	Price AA data
S2_P	6/29/92 1:05 PM	11.90	15.18	2064.00	Q	E	
S2_P	6/30/92 12:05 PM	12.20	15.32	2158.00	Q	E	
S2_P	8/25/95 2:00 PM	10.96	16.62	3462.00	F	N	ADCP, no QA/QC
S2_P	10/10/99 4:51 PM	11.33	17.54	2635.00	F	N	
S2_P	10/18/99 4:20 PM	11.34	17.53	2481.00	F	N	
S2_P	10/18/99 5:49 PM	11.25	17.58	2560.00	F	N	
S2_P	10/18/99 6:00 PM	11.19	17.58	2696.00	F	N	
S2_P	9/7/04 12:41 PM	10.55	14.56	1961.28	F	N	
S2_P	3/31/01 9:04 AM	10.68	10.30	1275.00	Q	G	ADCP, Headwater higher than tailwater
S2_P	6/2/01 7:40 AM	10.51	9.88	1014.00	Q	E	
S2_P	6/8/01 10:28 AM	10.74	9.86	1098.00	Q	G	
S2_P	6/9/01 8:55 AM	10.59	9.85	1009.00	Q	G	
S2_P	6/10/01 9:24 AM	10.48	9.85	1022.00	Q	G	
S2_P	6/12/01 9:07 AM	10.62	9.12	1066.00	Q	P	
S2_P	9/7/04 3:07 PM	10.62	14.54	2006.00	F	G	Data that can be used
S2_P	9/23/04 10:45 AM	10.69	15.96	1084.40	Q	E	

Rating Analysis

The model rating equation applied to S2 is the standard case 8 model (Imru and Wang, 2004):

$$Q = A\left(\frac{N}{N_O}\right) + BH^C\left(\frac{N_O}{N}\right)^{2C-1} \quad \text{..... (1)}$$

Where Q is the discharge at N RPM, H is the TSH, N_O is the design engine or pump speed, and A, B and C are coefficients to be determined through regression. The form of this expression was determined through dimensional analysis and is based on the pump affinity laws.

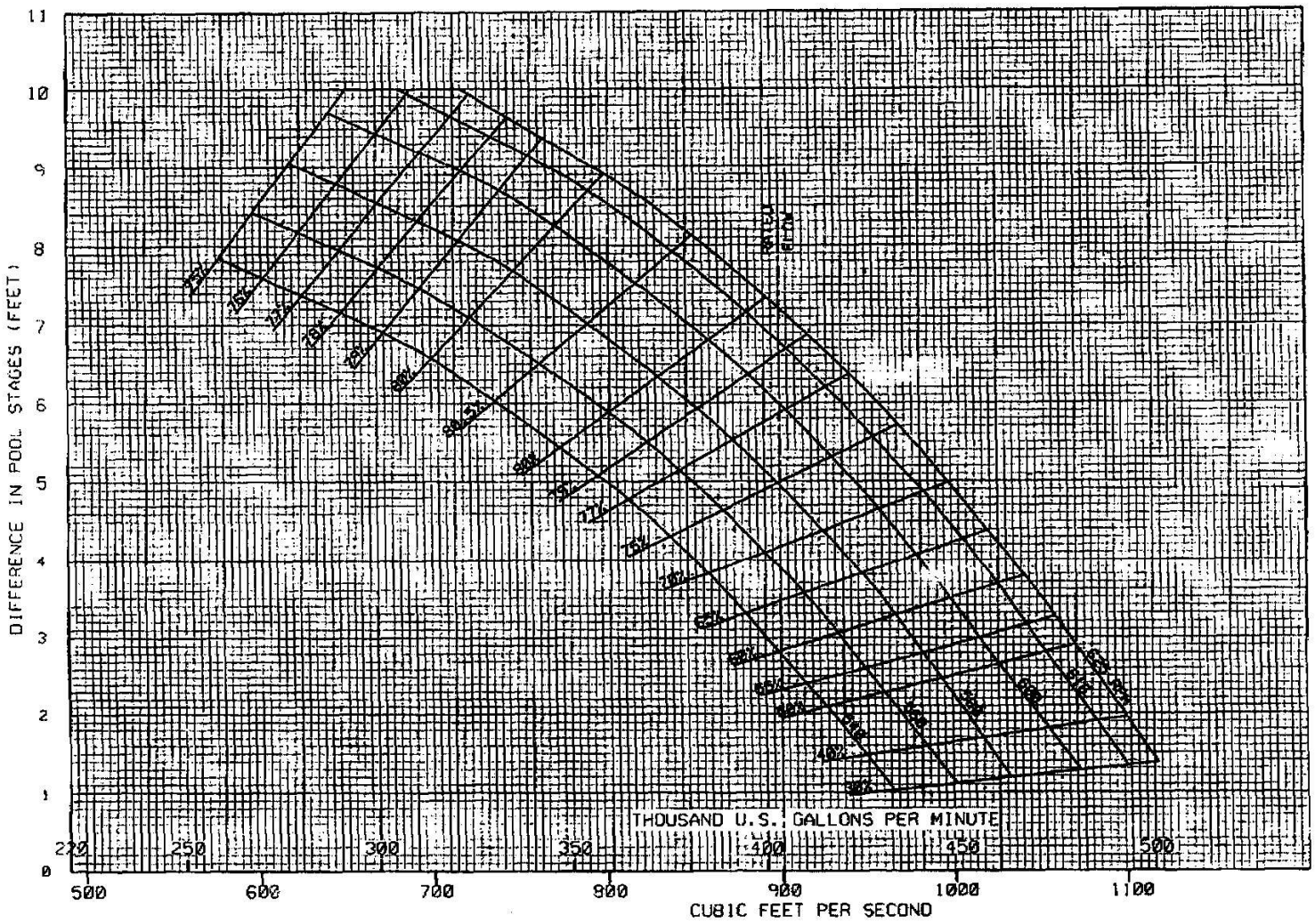

Figure 1. Pump performance curve for station S2.

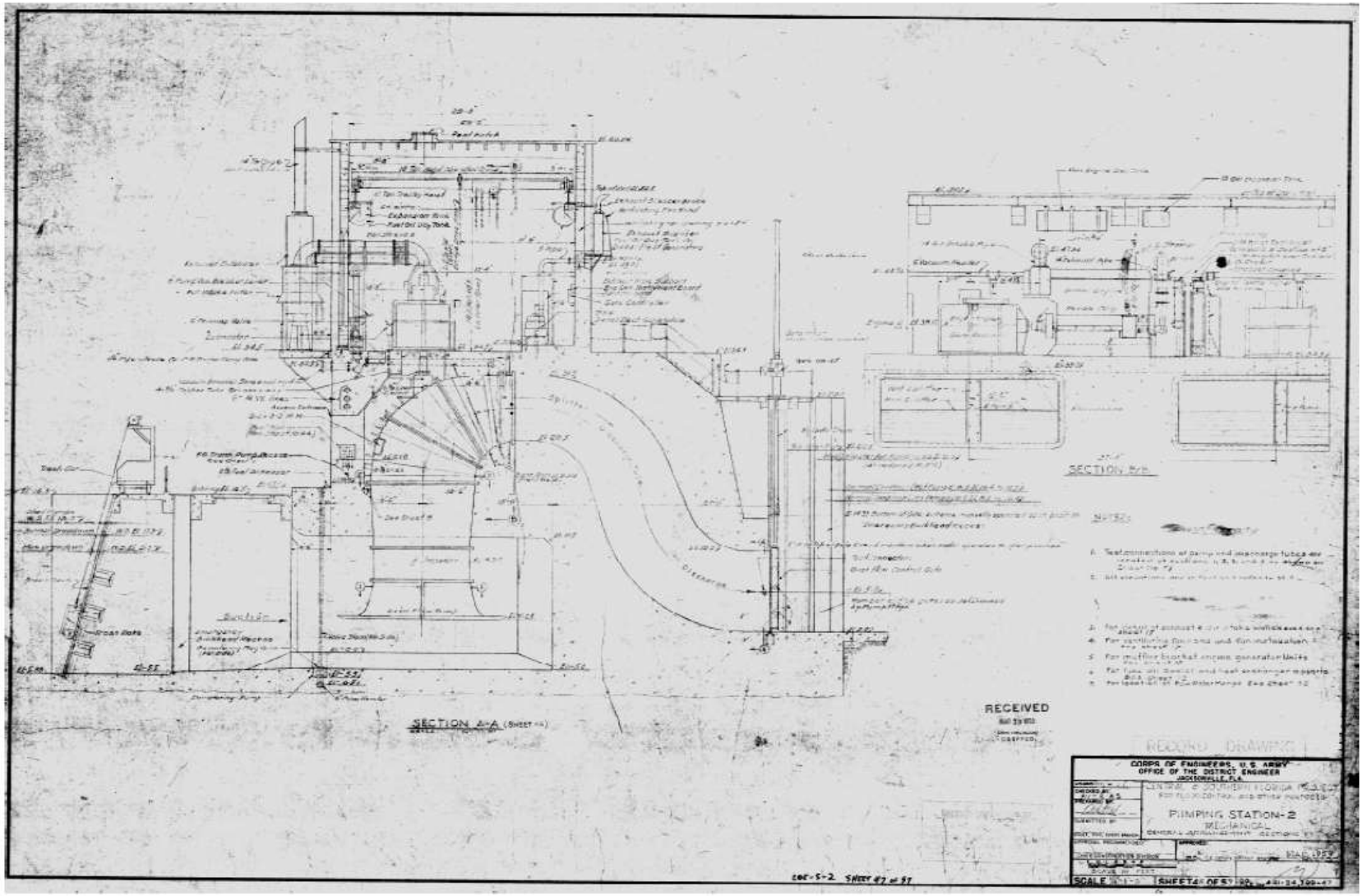

Figure 2. Section views of S2.

Figure 3 depicts the manufacturer's TSH vs. flow curve at the speed indicated, the rating curves for various engine speeds, and all available flow measurements. The computed rating curves were obtained by fitting Equation (1) to the manufacturer's TSH vs. Q curve at the design speed. The resultant values of A, B and C are provided in table 2. Table 4 provides a comparison of the rating equation with the pump station performance curve at a design engine speed of 625 rpm. Figure 4 provides a comparison of the measured and computed flows. Where the TSH < 0, its absolute value is used in equation 1 while the sign of B is reversed.

Table 2. Regression parameters of the S-2 rating.

Regression Parameter for Equation (1)	A	B	C
Approximate lower 95% C.I.	1106.40	-10.0025	1.5720
Estimate	1116.00	-7.8355	1.6868
Approximate upper 95% C.I.	1125.60	-5.6685	1.8016

Impact Analysis

An impact analysis was carried out over the entire period over which there are flow data. It was found that from 1985 to the present, mean daily flows computed using the current and existing equations agree within 5 percent most of the time (Table 3). For those years where the average difference is greater than 5 percent, the magnitudes daily flow values are small compared to the design capacity of the station. Therefore, it may not be worthwhile to reload the computed flows for those years.

Table 3. An impact analysis on the historical mean daily flows.

Year	Average Diff (%)	Avg Flow (cfs)	Station Capacity (cfs)		Year	Average Diff (%)	Avg Flow (cfs)	Station Capacity (cfs)
1985	-1.9				1997	-9.7	136.8	2700
1986	-4				1998	-3.4		
1987	-2.6				1999	-1.7		
1988	-4.7				2000	-3.6		
1989	-2.4				2001	-3.8		
1990	-2.7				2002	-19.5	17.2	2700
1991	-2.4				2003	-28	5.7	2700
1992	-2.6				2004	-3.4		
1993	-0.8				2005	-4.5		
1994	-0.8				2006	-4.4		
1995	-1.1				2007	-9.9	18.5	2700
1996	-12.4	87.7	2700					

Stream-Gauging Needs

As indicated previously, there are only two measurements that are suitable for a flow rating analysis. It is recommended that those measurements not previously subjected to any QA/QC processes be formally reviewed so that they can be utilized if possible. More

data are needed to calibrate the proposed flow rating equation to measured discharges. The stream gauging data needs for pump station S2 are summarized in Table 5. Indicated for each of the operating conditions is the desired number of flow measurements.

Table 4. Comparison of the regression equation and pump station performance curve.

RPM	TSH	Q (manfct. perf. curve)	Q (regression)	%Error
625	1.43	1111.52	1101.68	-0.89
625	2.03	1093.49	1090.13	-0.31
625	2.46	1080.29	1080.23	-0.01
625	2.86	1067.98	1069.88	0.18
625	3.26	1055.23	1058.49	0.31
625	3.56	1045.55	1049.28	0.36
625	3.86	1035.00	1039.52	0.44
625	4.27	1020.49	1025.33	0.47
625	4.58	1009.06	1013.95	0.48
625	5.00	994.11	997.67	0.36
625	5.40	979.59	981.27	0.17
625	5.83	962.44	962.68	0.02
625	6.11	951.01	950.06	-0.10
625	6.48	934.74	932.76	-0.21
625	6.99	910.99	907.78	-0.35
625	7.48	887.25	882.57	-0.53
625	7.92	863.50	858.94	-0.53
625	8.28	844.59	838.92	-0.67
625	8.74	818.21	812.47	-0.70
625	9.11	794.46	790.48	-0.50
625	9.59	759.72	761.02	0.17
625	10.06	717.51	731.19	1.91

Table 5. Stream gauging needs for S2.

	No. of Measurements Needed	Engine Speed (rpm)		
S2 Diesel Pump Unit 1,2,3,4	TSH (ft)	350--442	442--533	533--625
	0--2.1	*5*	*5*	*5*
	2.1--4.1	*5*	*5*	*4*
	4.1--6.2	*5*	*5*	*4*

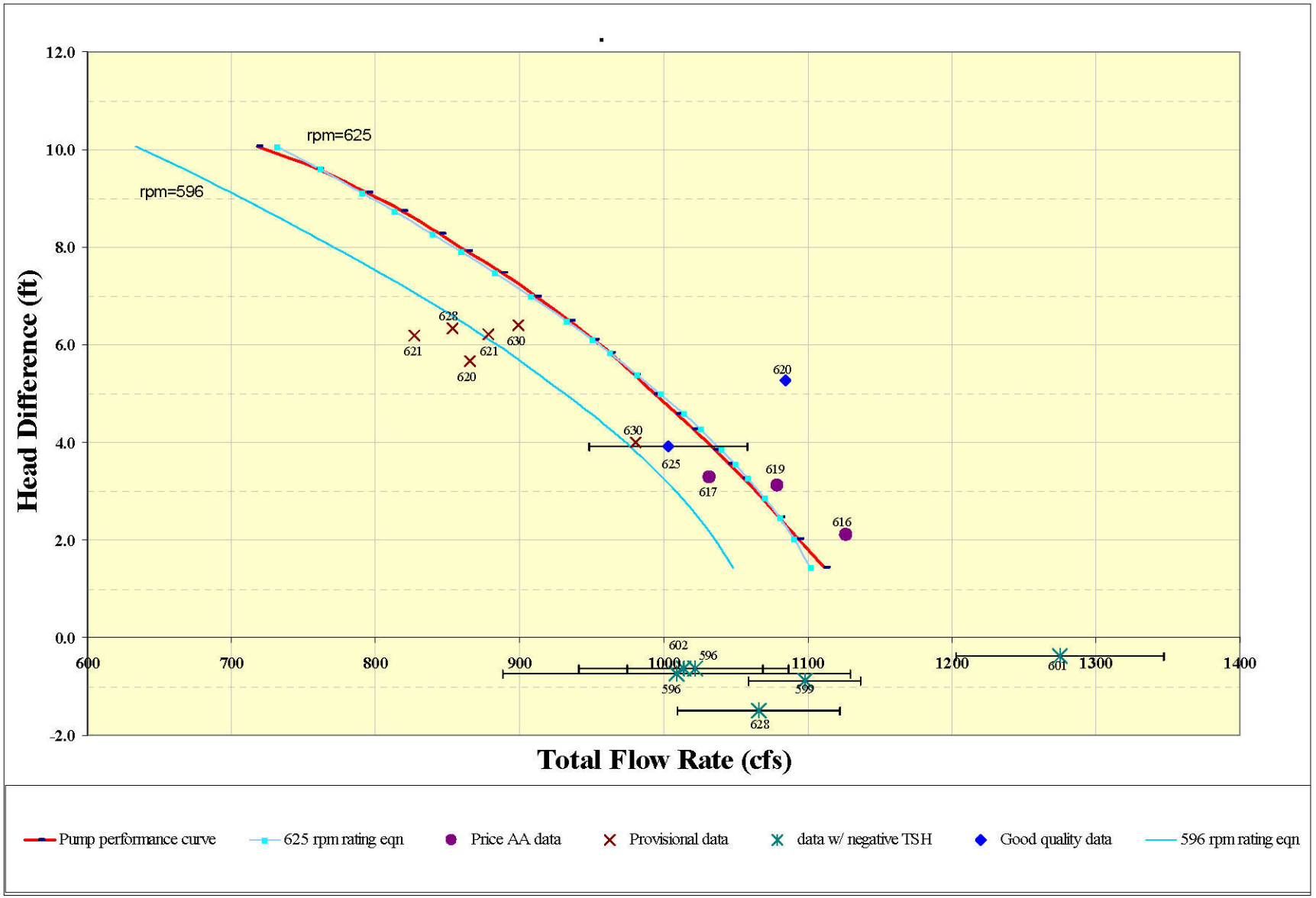

Figure 3. TSH Pump curve, rating curves and flow measurements at pump station S2

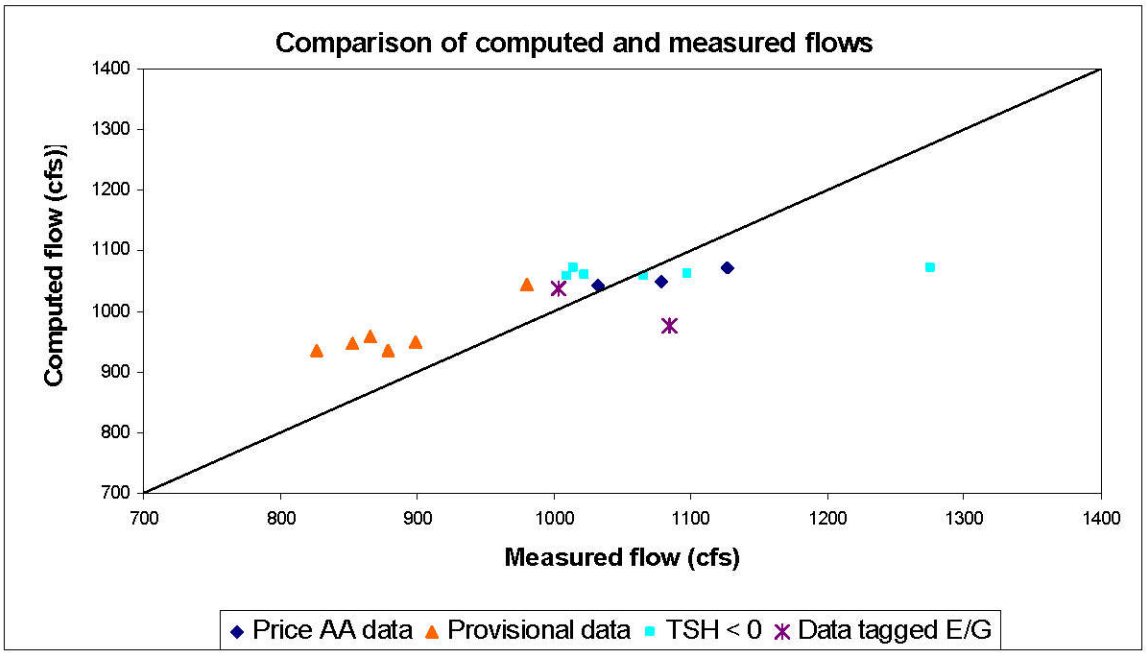

Figure 4. Comparison of computed and measured flows.

Summary and Conclusions

A rating analysis of the S2 pump station was carried out using the conventional case 8 model along with the existing pump station performance curve. A rating equation was developed for each of four identical pump units configured the same way. The equation yields discharge rates that are within 2 % of the discharges derived from the pump station performance curve under the expected range of static heads.

It is recommended that the new rating be implemented into DBHydro with a new effective date starting June 2007. According to the impact analysis, no reload is needed for the historical data records prior to June 2007. Furthermore, it is recommended that the rating equation be recalibrated with additional measured flows of acceptable quality.

References

Imru, M., and Y., Wang, 2004, Flow Rating Analysis for Pump Station S2, Technical Publication EMA #416, Hydrology and Hydraulics Division, South Florida Water Management District, West Palm Beach, Florida.