Flow Rating Analysis for Pump Station CWPB2

M Canal/City of West Palm Beach

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Executive Summary

A rating analysis of CWPB2 pump station was carried out using the conventional case 8 model. Two rating equations were developed since there are two distinct pump units at this station. Both equations yield discharge rates that are within 1.8% of the discharges derived from the pump station rating curve under the expected range of static heads.

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Introduction

Pump station CWPB2 is a water supply station to the City of West Palm Beach. It pumps water from the L8 Canal to the M Canal. There are two pump units at this station, one electric and one diesel. The electric pump has a design capacity of 65,000 gpm at a TDH of 11.3 ft. The design engine speed is 1778 rpm while the impeller speed is 323 rpm. The diesel pump has a design capacity of 65,000 gpm at a TDH of 10 ft. The diesel engine is rated at a design speed of 1500 rpm while the corresponding impeller speed is 300 rpm.

Objectives and Scope

The primary purpose of the rating analyses conducted in this study is to enable flows through CWPB2 to be estimated using measured head water elevations, tail water elevations and pump motor speeds. The hydraulic rating equations are based on pump performance characteristics, hydraulic properties of the pump station, and sound engineering principles. As a check, flows computed with the rating equations were compared to a limited number of stream flow measurements. However, these measurements were not previously reviewed in accordance with SFWMD protocol. Hence, they could not be used to calibrate the rating equation.

Station Design

Pump performance curves for the electric and diesel pumps are shown in Figure 1 and 2, respectively. These depict the relationship between flow rate and TSH. Plan and cross sectional views of the pump station design are shown in figure 3, 4 and 5. As shown in Figure 4 and 5, these two pumps don't have any traditional discharge pipes. The flow enters the intake of the pump and overflows out of the top of the pump case immediately after the impeller. Pumped discharges exit the station directly into the downstream canal.

Considering the special design of this pump station, the discharge centerline elevation for these pumps will be set as the pump top rim elevation plus the velocity head at the design point of the pump. The top rim elevation for the electric pump is 21 ft. The velocity head at the design point of the pump is 1 ft. Therefore, the invert elevation for the electric pump is taken to be 22 ft. Similarly, the rim elevation of the diesel pump casing is 13 ft. The velocity head at the design point is 1 ft. Therefore, the discharge centerline elevation for the diesel pump is set to 14 ft.

Rating Analysis

The model rating equation applied to CWPB2 is the standard case 8 model (Imru and Wang, 2004):

$$Q = A\left(\frac{N}{N_0}\right) + BH^C\left(\frac{N_0}{N}\right)^{2C-1} \quad \text{..... (1)}$$

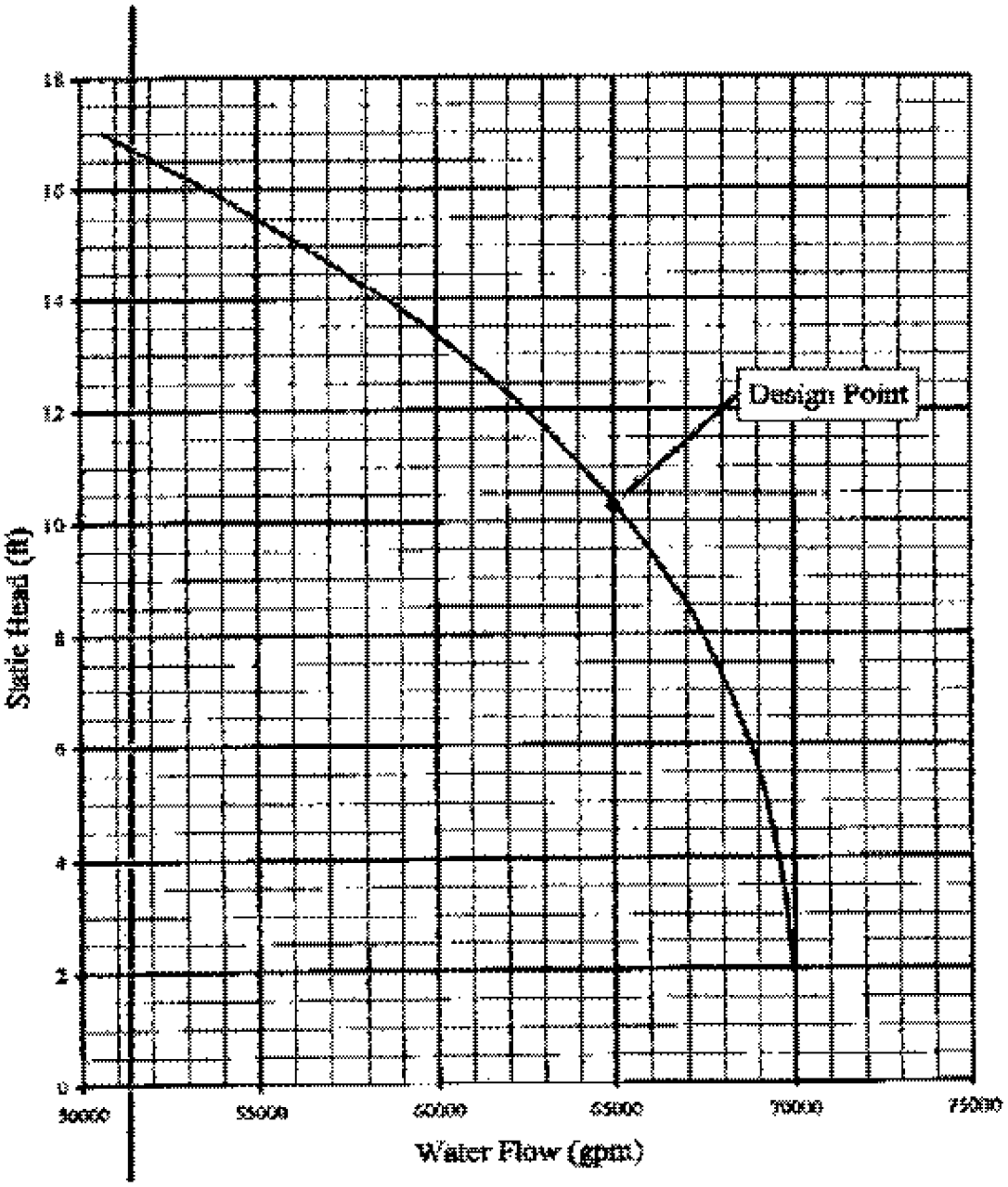

Figure 1. Pump performance curve of the electric pump.

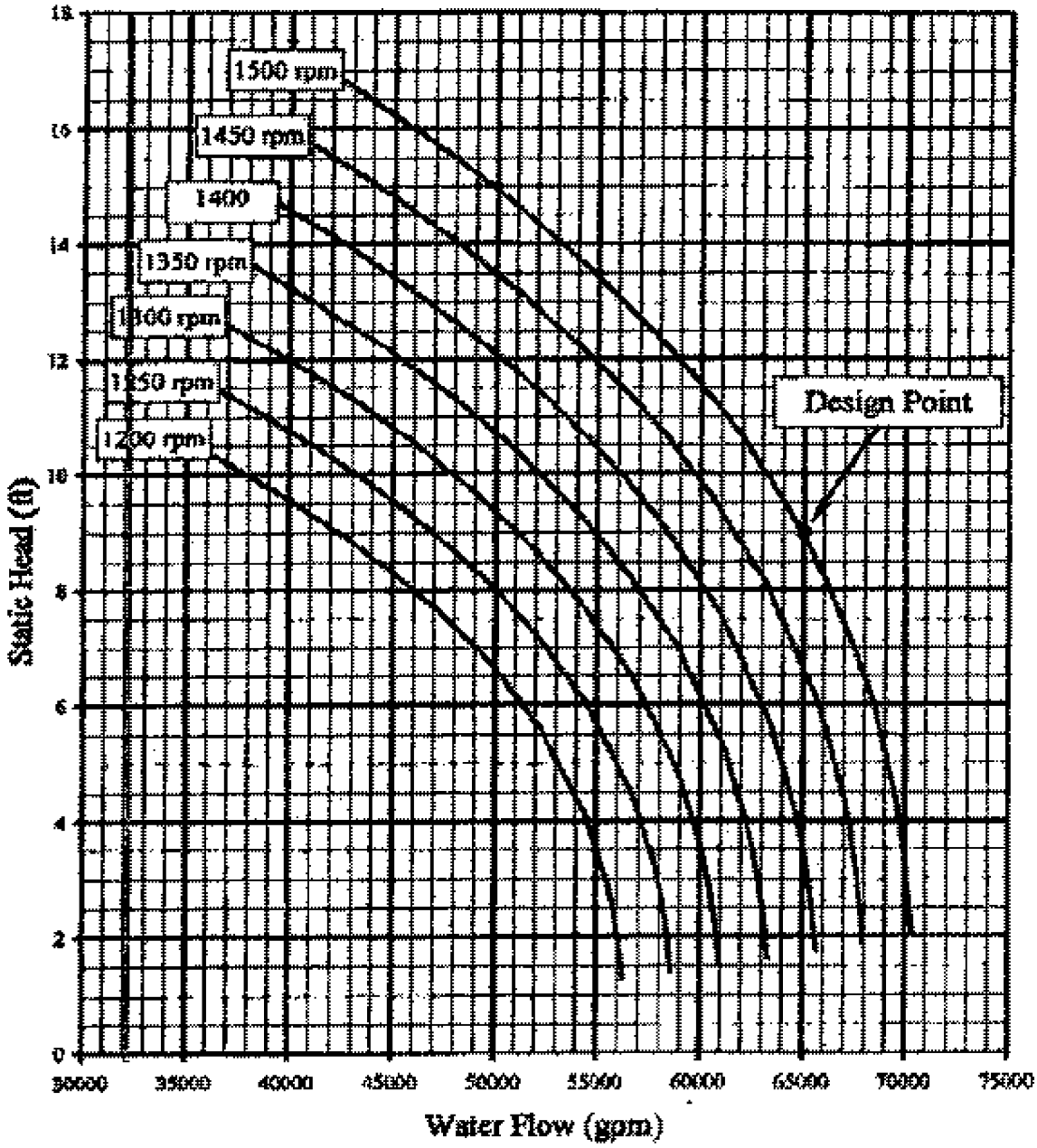

Figure 2. Pump performance curve of the diesel pump.

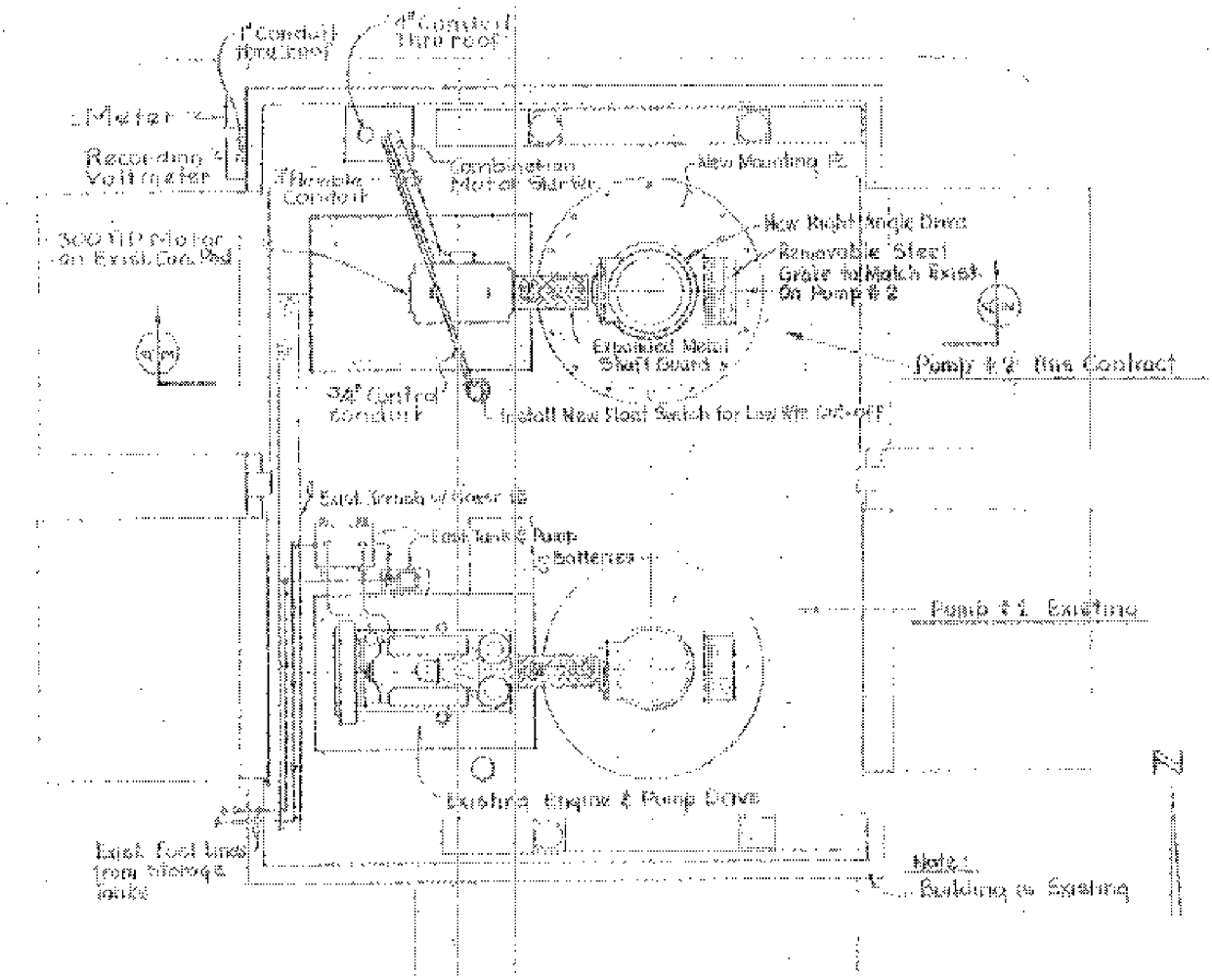

Figure 3. Plan view of the pump station design.

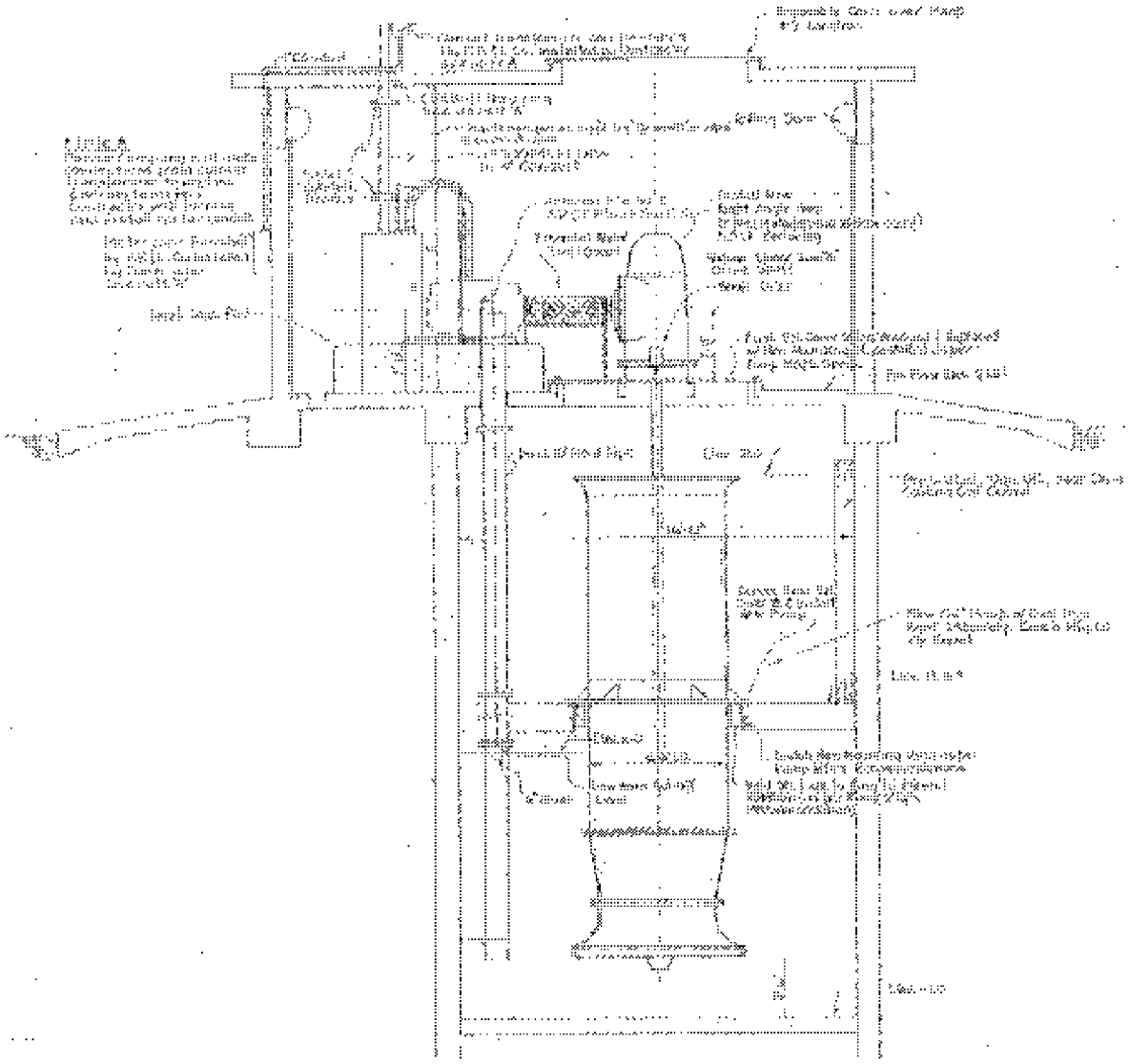

Figure 4. Section view of the electric pump unit.

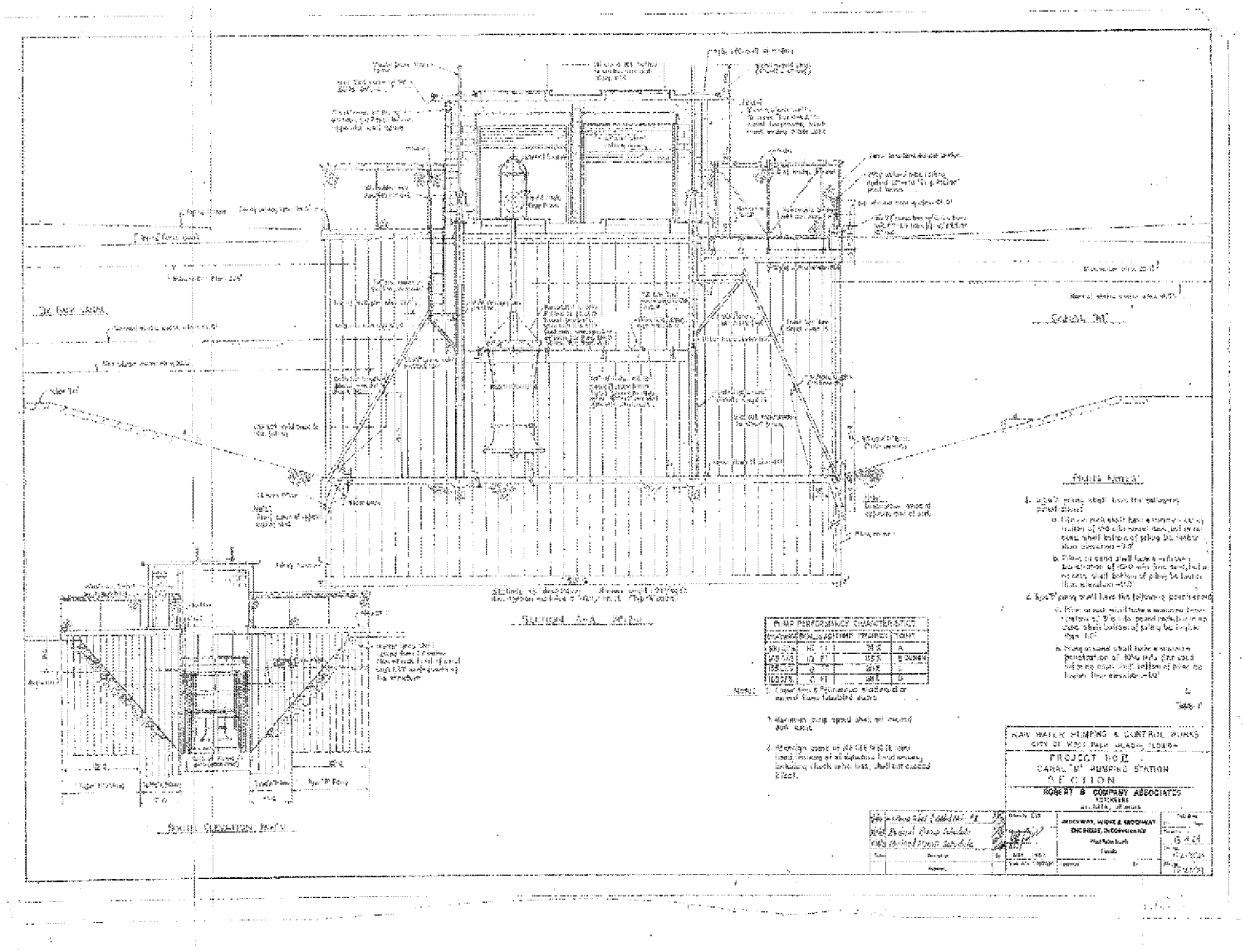

Figure 5. Section view of the diesel pump unit.

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 constants to be determined through regression. The form of this expression was determined through dimensional analysis and is based on the pump affinity laws. For constant speed pumps, $N_O = N$ so the ratios involving these parameters are eliminated.

Figure 6 depicts the TSH vs. flow relationship depicted in the pump performance curve for the electric pump (Figure 1). Equation (1) was fit to the TSH vs. Q curve shown in figure 6. The resulting values of A, B and C are provided in table 1. Table 2 provides a comparison of the rating equation with its respective pump station performance curve.

Similarly, Figure 7 depicts the TSH vs. flow relationship depicted in the pump performance curve for the diesel pump (Figure 2). Equation (1) was fit to the TSH vs. Q curve shown in figure 7. The resulting values of A, B and C are provided in table 1. Table 3 provides a comparison of the rating equation with its respective pump station performance curve.

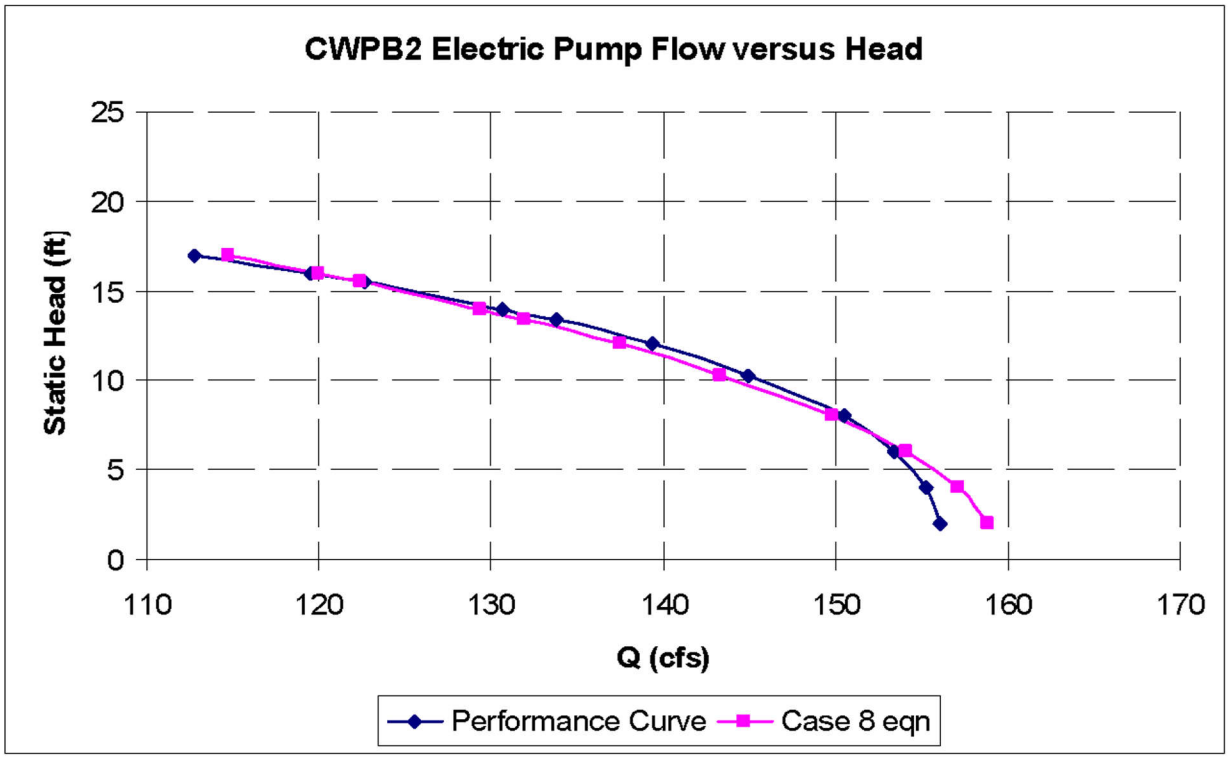

Figure 6. TSH vs. flow relationship for the electric pump unit.

Table 1. Values of A, B and C in equation 1

Regression Parameter	Pump	
	Diesel	Electric
A	158.3	159.432
B	-0.071	-0.141
C	2.394	2.032

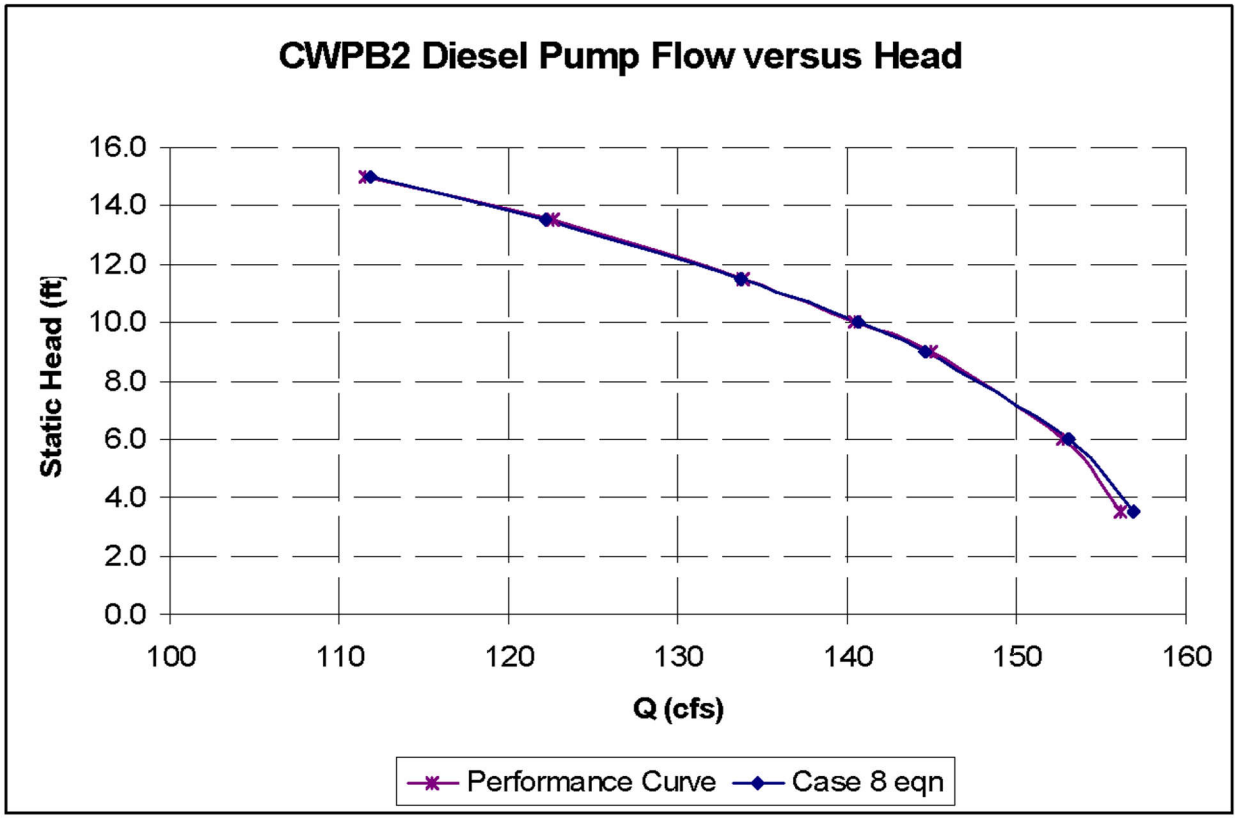

Figure 7. TSH vs. flow relationship for the diesel pump unit.

Table 2. Comparison of the regression equation and pump station performance curve for the electric pump.

TSH	Q (p.s. Perf. Curve, cfs)	Q (Regression, cfs)	Relative error (%)
17	113	114.8	1.8
16	120	120.0	0.4
15.5	123	122.5	-0.2
14.0	131	129.4	-1.0
13.4	134	131.9	-1.4
12.0	139	137.4	-1.4
10.3	145	143.3	-1.1
8.0	151	149.8	-0.5
6.0	153	154.1	0.4
4.0	155	157.1	1.2
2.0	156	158.9	1.8

Table 3. Comparison of the regression equation and pump station performance curve for the diesel pump.

TSH	Q (p.s. Perf. Curve, cfs)	Q (Regression, cfs)	relative error (%)
3.5	156.1	156.9	0.5
6.0	152.8	153.1	0.2
9.0	145.0	144.6	-0.2
10.0	140.5	140.7	0.2
11.5	133.8	133.7	-0.1
13.5	122.7	122.2	-0.4
15.0	111.5	111.9	0.3

Five flow measurements are available for the diesel pump and one measurement for the electric pump. However, as mentioned previously, these measurements were not formally reviewed by District staff. Furthermore, they only cover a small portion of the head range on the pump performance curve and are not adequate to calibrate a rating equation. For verification purposes, the available measurements were compared to flows computed by the rating equations for the two pumps. The results are shown in table 4. It is apparent that, for the diesel pump, the prediction for four out of five measurements is within 5 percent. The discrepancy is 10.75 percent for the remaining one. The reasons for this are not clear. Measurement error is always a possibility. For the electric pump, there is only one measurement available and the prediction is within 1.9 percent.

Table 4. Comparison of the regression equations and available stream flow measurements.

Pump	Q measured	H	N	Q computed	Error (%)
Diesel	96.33	3.94	1000	96.74	0.43
	114.8	4.05	1100	109.54	-4.58
	127.1	4.18	1200	121.56	-4.35
	149.33	4.26	1300	133.27	-10.75
	159.4	4.4	1500	155.84	-2.23
Electric	153.3	4.66	1778	156.20	1.9

Stream-Gauging Needs

The stream-gauging data needs for pump station CWPB2 are summarized in Table 5. Indicated are the targeted number of flow measurements under each of the operating conditions.

Table 5. Stream-gauging needs for Station S390.

Electric Pump	*TSH*	*RPM = 1778*		
	3.77	*5*		
	7.53	*5*		
	11.30	*5*		
Diesel Pump	*TSH*	*RPM*		
		1000	1250	1500
	3.33	*5*	*5*	*5*
	6.67	*5*	*5*	*5*
	10.00	*5*	*5*	*5*

Summary and Conclusions

A rating analysis of CWPB2 pump station was carried out using the conventional case 8 model. Two rating equations were developed since there are two distinct pump units at this station. Both equations yield discharge rates that are within 1.8% of the discharges derived from the pump station rating curve under the expected range of static heads (Table 2 and 3).

Given the uncertainties inherent to the pump performance curves obtained from laboratory pump tests, it is recommended that the rating equations be recalibrated with measured flows.

References

Imru, M. and Y. Wang. 2004. Flow Rating Development for New Pump Stations. Technical Publication EMA # 419, South Florida Water Management District, West Palm Beach, Florida, 44 pp.