Flow Rating Analysis for Pump Station G422

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Executive Summary

A rating analysis of G422 was carried out using the conventional case 8 model. The equation developed yields discharge rates that are within 0.37 percent of the discharges derived from the pump station performance curve under the expected range of static heads. Given the uncertainties inherent to the hydraulic head loss calculations, it is recommended that the rating equation be recalibrated with measured flows.

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Introduction

G422 is a pump station located on the C4 canal. It has seven identical electric motor-driven pumps. Each pump is rated at a capacity of 65 cfs at a static head of 9.9 ft. The electric motor is rated at 125 hp with a design engine speed of 1780 rpm. The reduction gear ratio is 6:1. The design pump speed is 297 rpm.

Objectives and Scope

The primary purpose of the rating analyses conducted in this study is to enable flows through G422 to be estimated using measured head water elevations, tail water elevations and pump/engine speeds. The hydraulic rating equations are based on pump performance characteristics, hydraulic properties of the pump station piping and appurtenances, and sound engineering principles. Since G422 became operational only recently, the rating equations could not be calibrated to stream flow measurements since none were available at the time this rating analysis was conducted.

Station Design

The pump performance curve for all seven pumps from the pump manufacturer is shown in Figure 1. Cross sectional and plan views of the pump station design are shown in figure 2. Table 1 contains the dimensions of the station piping while table 2 contains estimates of pipe roughness for STD steel pipes.

Rating Analysis

The model rating equation applied to G422 is the standard case 8 model (Imru and Wang, 2004):

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

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. For pumps driven by electric motors, N_O = N so the ratios involving these parameters are eliminated.

Figure 3 depicts the TSH vs. flow relationship obtained from the pump performance curve assuming minimum, average and maximum head losses. For comparative purposes, the TDH vs. flow relationship is also shown in the same figure. The associated head loss computations are provided in appendix A. In this case the frictional head loss is negligible. Equation (1) was fit to the average TSH vs. Q curve shown in figure 3. The resultant values of A, B and C are provided in table 3. Table 4 provides a comparison of

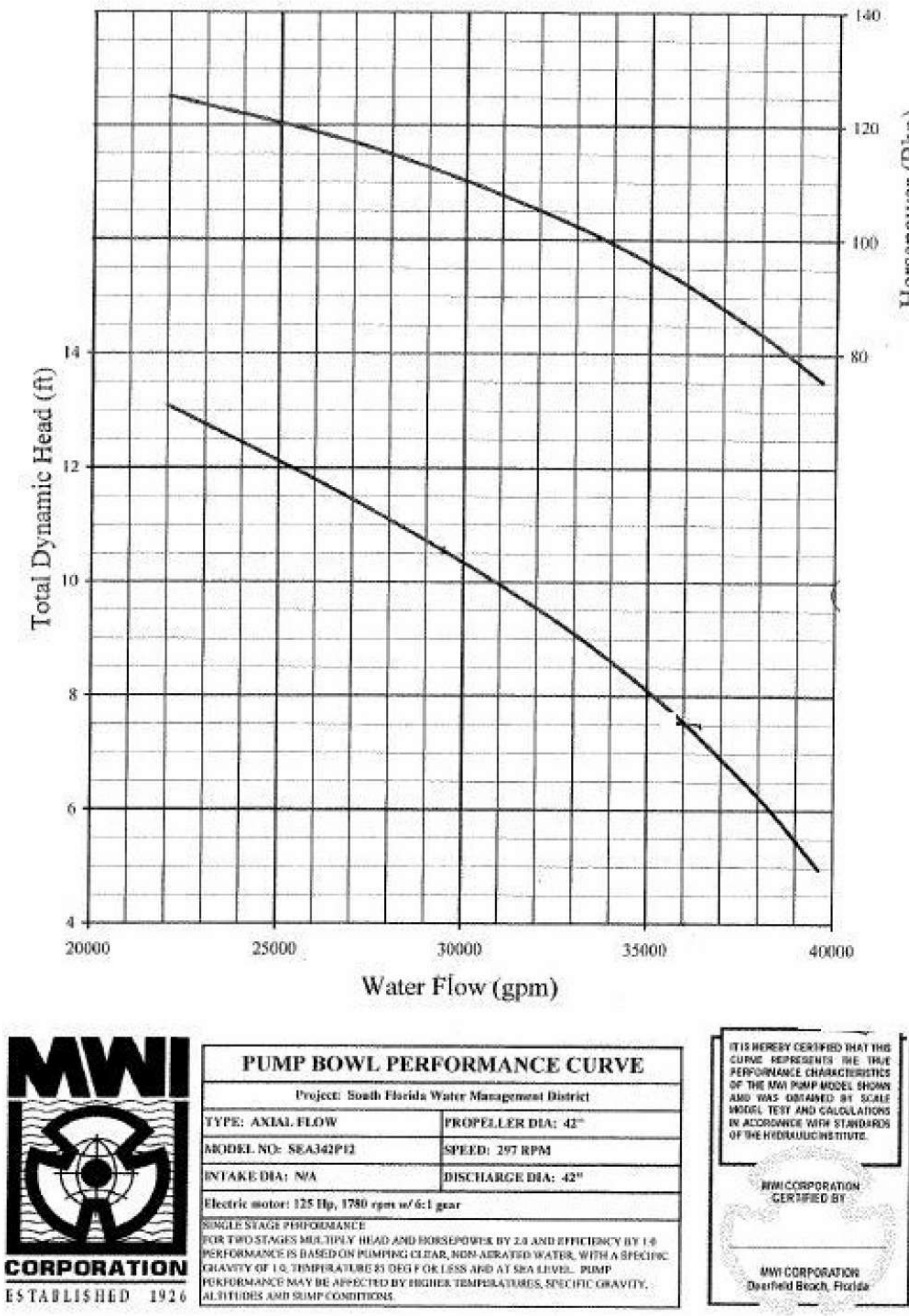

Figure 1. Pump performance curve for G422.

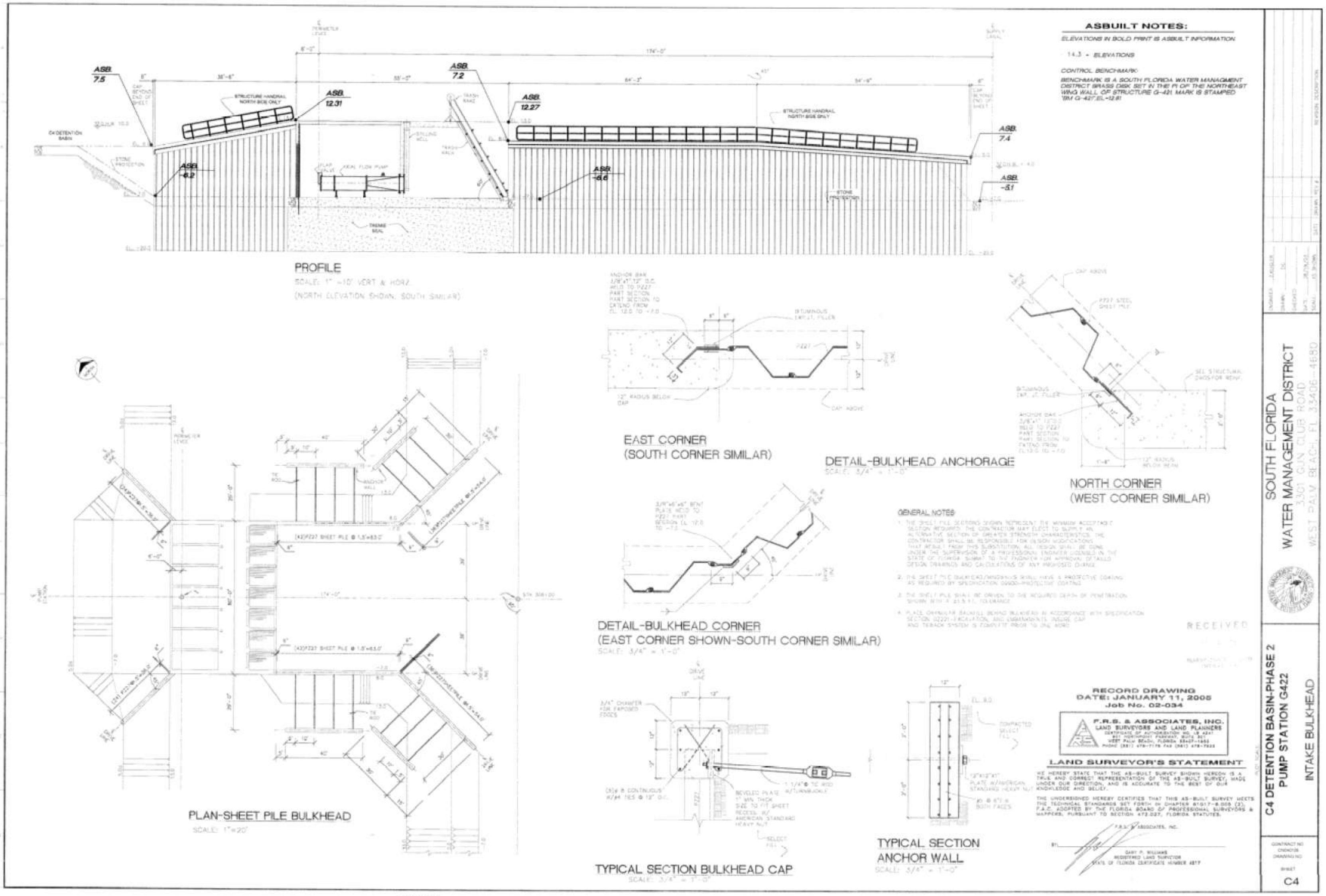

Figure 2. Plan and section views of pump station G422.

Table 1. Dimensions of station piping.

Steel Pipe Dimensions at G422			
Pipe OD =	42	in	*plans*
Wall Thickness =	0.375	in	*Jones (2006); proj specs*
Pipe ID =	41.3	in	
Pipe ID =	3.438	ft	
Pipe Length =	2.9	ft	*plans*
Area =	9.28	sq ft	

Table 2. Estimates of steel pipe roughness.

Pipe Head Losses				
ε =	0.00015	ft	*Hydraulic Inst. (1990)*	*new steel*
ε =	0.00133	ft	*Jones (2006)*	*old steel*

the rating equation with its pump station performance curve.

Impact Analysis

An impact analysis was carried out by evaluating the differences between flows computed using the existing and the new rating equations. On average, it was found that the existing rating equation under predicts flows by 5.1 percent relative to the existing rating equation. Given the fact that no measured flow data exist to support either rating, it is recommended that historical flows not be reloaded at this time. However the new rating equation should be used to compute future flows.

Stream-Gauging Needs

The stream-gauging data needs for pump station G422 are summarized in Table 5. Indicated is the desired number of flow measurements under each of the operating conditions.

Summary and Conclusions

A rating analysis of G422 pump station was carried out using the conventional case 8 model. A rating equation was developed for seven identical pump units configured the same way. The equation yields discharge rates that are within 0.37% of the discharges derived from the pump station performance curve under the expected range of static heads. Given the uncertainties inherent to the modified pump station curves discussed

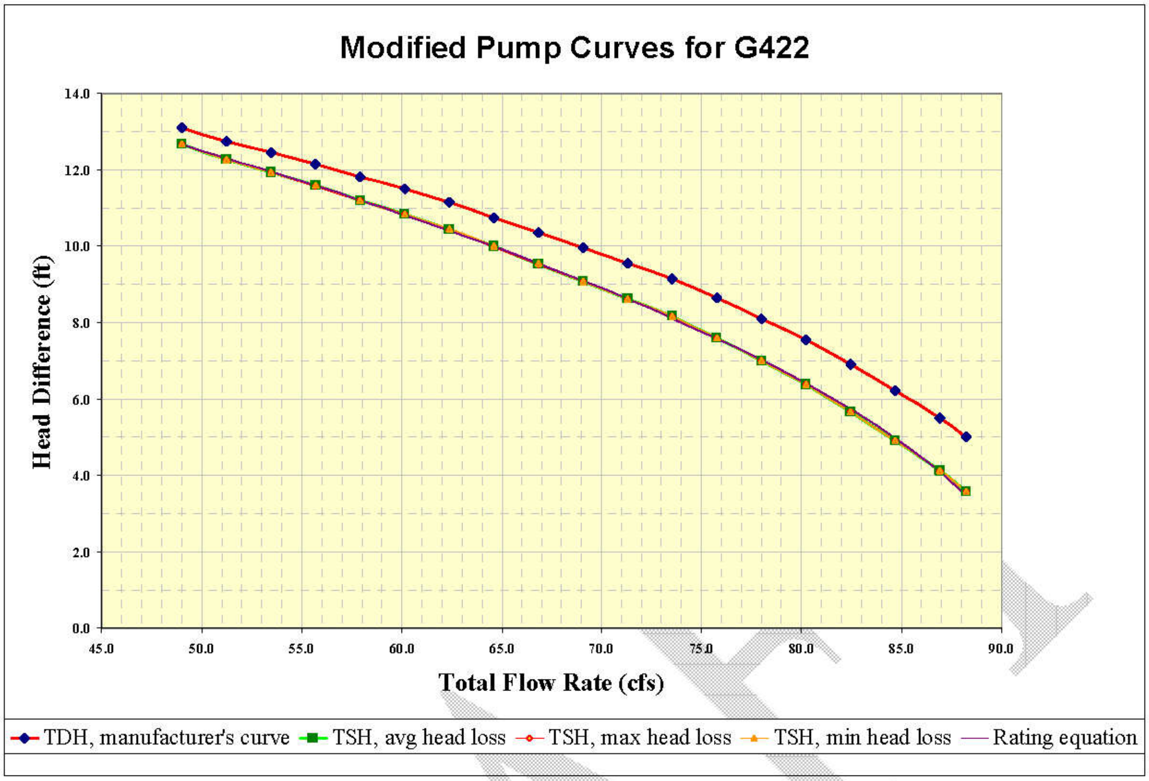

Figure 3. Modified curves for pump station G422.

Table 3. Regression parameters for G422.

Regression Parameter for Equation (1)	A	B	C
Approximate lower 95% C.I.	91.4522	-0.3694	1.8731
Estimate	91.8444	-0.3329	1.9140
Approximate upper 95% C.I.	92.2367	-0.2964	1.9548

above, it is recommended that the rating equation be calibrated with measured flows.

References

Hydraulic Institute (1990). Hydraulic Institute Engineering Data Book. Second Edition.

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.

Jones, G. M., et al. (2006). Pumping Station Design. Butterworth-Heinemman Publishers, Burlington, MA.

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

TSH	Q (p.s. perf. curve)	Q (regression)	%Error
12.63	49.02	48.94	-0.17
12.24	51.25	51.44	0.37
11.89	53.48	53.57	0.17
11.55	55.71	55.66	-0.09
11.15	57.94	57.99	0.09
10.80	60.17	59.98	-0.31
10.39	62.39	62.19	-0.33
9.94	64.62	64.60	-0.04
9.48	66.85	66.91	0.09
9.02	69.08	69.14	0.09
8.56	71.31	71.28	-0.04
8.10	73.54	73.32	-0.29
7.53	75.76	75.68	-0.11
6.92	77.99	78.08	0.11
6.30	80.22	80.30	0.10
5.58	82.45	82.66	0.25
4.83	84.68	84.84	0.19
4.03	86.91	86.83	-0.08
3.49	88.24	88.02	-0.25

Table 5. Stream-gauging needs for G422.

Pump	TSH (ft)	Number of Measurements needed (@RPM =1780)
Unit 1,2,3,4,5,6 and 7	0~3.3	5
	3.3~6.6	5
	6.6~9.9	5

Appendix A: Head Loss Calculations

Table A1. Minimum head loss calculations

Minimum head loss calculations

1780 RPM			Swamee & Jain(1976)							
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	N_R	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
13.1	22000	49.02	5.28	1815809	0.43	0.01182	0.00	0.43	0.44	12.66
12.75	23000	51.25	5.52	1898346	0.47	0.01177	0.00	0.47	0.48	12.27
12.45	24000	53.48	5.76	1980883	0.52	0.01173	0.01	0.52	0.52	11.93
12.15	25000	55.71	6.00	2063420	0.56	0.01169	0.01	0.56	0.57	11.58
11.8	26000	57.94	6.24	2145957	0.61	0.01165	0.01	0.61	0.61	11.19
11.5	27000	60.17	6.48	2228493	0.65	0.01161	0.01	0.65	0.66	10.84
11.15	28000	62.39	6.72	2311030	0.70	0.01158	0.01	0.70	0.71	10.44
10.75	29000	64.62	6.96	2393567	0.75	0.01155	0.01	0.75	0.76	9.99
10.35	30000	66.85	7.20	2476104	0.81	0.01151	0.01	0.81	0.81	9.54
9.95	31000	69.08	7.44	2558640	0.86	0.01149	0.01	0.86	0.87	9.08
9.55	32000	71.31	7.68	2641177	0.92	0.01146	0.01	0.92	0.93	8.62
9.15	33000	73.54	7.92	2723714	0.97	0.01143	0.01	0.97	0.98	8.17
8.65	34000	75.76	8.16	2806251	1.03	0.01141	0.01	1.03	1.04	7.61
8.1	35000	77.99	8.40	2888788	1.10	0.01138	0.01	1.10	1.11	6.99
7.55	36000	80.22	8.64	2971324	1.16	0.01136	0.01	1.16	1.17	6.38
6.9	37000	82.45	8.88	3053861	1.23	0.01134	0.01	1.23	1.24	5.66
6.22	38000	84.68	9.12	3136398	1.29	0.01132	0.01	1.29	1.31	4.91
5.5	39000	86.91	9.36	3218935	1.36	0.01130	0.01	1.36	1.37	4.13
5	39600	88.24	9.51	3268457	1.40	0.01129	0.01	1.40	1.42	3.58

Table A2. Average head loss calculations

Average head loss calculations

1780 RPM			$f_{av} = sqrt(f_{min} f_{max})$						
TDH(ft)	**Q (GPM)**	**Q(cfs)**	**V(ft/s)**	**$V^2/2g$ (ft)**	**f**	**$h_l = f(L/D)V^2/2g$**	**$h_m = \Sigma KV^2/2g$**	**Total Head Loss (ft)**	**Static Head (ft)**
13.1	22000	49.02	5.28	0.43	0.01384	0.01	0.43	0.44	12.66
12.75	23000	51.25	5.52	0.47	0.01380	0.01	0.47	0.48	12.27
12.45	24000	53.48	5.76	0.52	0.01377	0.01	0.52	0.52	11.93
12.15	25000	55.71	6.00	0.56	0.01374	0.01	0.56	0.57	11.58
11.8	26000	57.94	6.24	0.61	0.01371	0.01	0.61	0.61	11.19
11.5	27000	60.17	6.48	0.65	0.01369	0.01	0.65	0.66	10.84
11.15	28000	62.39	6.72	0.70	0.01366	0.01	0.70	0.71	10.44
10.75	29000	64.62	6.96	0.75	0.01364	0.01	0.75	0.76	9.99
10.35	30000	66.85	7.20	0.81	0.01362	0.01	0.81	0.81	9.54
9.95	31000	69.08	7.44	0.86	0.01359	0.01	0.86	0.87	9.08
9.55	32000	71.31	7.68	0.92	0.01357	0.01	0.92	0.93	8.62
9.15	33000	73.54	7.92	0.97	0.01356	0.01	0.97	0.99	8.16
8.65	34000	75.76	8.16	1.03	0.01354	0.01	1.03	1.05	7.60
8.1	35000	77.99	8.40	1.10	0.01352	0.01	1.10	1.11	6.99
7.55	36000	80.22	8.64	1.16	0.01350	0.01	1.16	1.17	6.38
6.9	37000	82.45	8.88	1.23	0.01349	0.01	1.23	1.24	5.66
6.22	38000	84.68	9.12	1.29	0.01347	0.01	1.29	1.31	4.91
5.5	39000	86.91	9.36	1.36	0.01346	0.02	1.36	1.38	4.12
5	39600	88.24	9.51	1.40	0.01345	0.02	1.40	1.42	3.58

Table A3. Maximum head loss calculations

Maximum head loss calculations

1780 RPM			Swamee & Jain(1976)							
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	N_R	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
13.1	22000	49.02	5.28	1815809	0.43	0.01620	0.01	0.43	0.44	12.66
12.75	23000	51.25	5.52	1898346	0.47	0.01618	0.01	0.47	0.48	12.27
12.45	24000	53.48	5.76	1980883	0.52	0.01617	0.01	0.52	0.52	11.93
12.15	25000	55.71	6.00	2063420	0.56	0.01616	0.01	0.56	0.57	11.58
11.8	26000	57.94	6.24	2145957	0.61	0.01614	0.01	0.61	0.61	11.19
11.5	27000	60.17	6.48	2228493	0.65	0.01613	0.01	0.65	0.66	10.84
11.15	28000	62.39	6.72	2311030	0.70	0.01612	0.01	0.70	0.71	10.44
10.75	29000	64.62	6.96	2393567	0.75	0.01611	0.01	0.75	0.76	9.99
10.35	30000	66.85	7.20	2476104	0.81	0.01610	0.01	0.81	0.82	9.53
9.95	31000	69.08	7.44	2558640	0.86	0.01609	0.01	0.86	0.87	9.08
9.55	32000	71.31	7.68	2641177	0.92	0.01608	0.01	0.92	0.93	8.62
9.15	33000	73.54	7.92	2723714	0.97	0.01607	0.01	0.97	0.99	8.16
8.65	34000	75.76	8.16	2806251	1.03	0.01607	0.01	1.03	1.05	7.60
8.1	35000	77.99	8.40	2888788	1.10	0.01606	0.01	1.10	1.11	6.99
7.55	36000	80.22	8.64	2971324	1.16	0.01605	0.02	1.16	1.18	6.37
6.9	37000	82.45	8.88	3053861	1.23	0.01605	0.02	1.23	1.24	5.66
6.22	38000	84.68	9.12	3136398	1.29	0.01604	0.02	1.29	1.31	4.91
5.5	39000	86.91	9.36	3218935	1.36	0.01603	0.02	1.36	1.38	4.12
5	39600	88.24	9.51	3268457	1.40	0.01603	0.02	1.40	1.42	3.58