Appendix F

Generation Capability Assessment Report: Volume V – Merwin Project

FINAL DRAFT

GENERATION CAPABILITY ASSESSMENT REPORT
LEWIS RIVER HYDROELECTRIC PROJECTS
FERC Project Nos. 2111, 2213, 2071 and 935

VOLUME V

Merwin Project

FERC Project No. 935

Prepared by:

Northrop, Devine & Tarbell, Inc.

Prepared for:

PacifiCorp
Portland, OR
and
Cowlitz PUD
Longview, WA

January 1997

VOLUME V - MERWIN

CONTENTS

1.0 GENERAL OPERATING CONDITIONS

1.1 Headwater Level

Merwin Lake is operated in coordination with the Swift and Yale reservoirs to provide flood regulation in the Lewis River basin; to maintain downstream river flows; to accommodate recreation; and to schedule generation to match PacifiCorp's system requirements. Storage in Merwin Lake is also used to augment inflows when Merwin is delivering minimum Lewis River flows downstream of the project. The normal maximum and minimum Lake Merwin elevations are shown in Table 1.1-1.

Table 1.1-1. Normal Lake Merwin operating levels.

Description	Reservoir Elevation (ft)
Normal maximum	239.6
Normal minimum (summer)	235
Normal minimum	232

1.2 Tailwater Level

The Merwin powerhouse discharges directly into the Lewis River channel. The tailwater level is a function of the total powerplant and spillway discharges. Tailwater elevations are shown in Table 1.2-1.

Table 1.2-1. Estimated Merwin tailwater elevations versus total (turbine and spillway) discharge.

Total Discharge (cfs)	Tailwater Elevation (ft)
650	46.75
1,900	48.00
3,025	49.00
4,200	50.00
5,575	51.00
6,500	51.50
7,650	52.00
9,000	52.50
11,500	53.45

Note that the tailwater rating data provided in Table 1.2-1 is based on the flows through Merwin units no. 1, no. 2, and the house unit with the spillway gates closed (chart dated February 4, 1950). Study engineers assume that the tailwater level is more directly related to the total discharge than whether flows are discharged from the powerhouse or the spillway. The Merwin tailwater, for example, would be approximately at elevation 52.50 when the total discharge from the plant is 9,000 cfs regardless of whether the flow is passed through the turbines, over the spillway, or both.

1.3 Head Loss

Water is delivered from the Merwin dam to the powerhouse via three penstocks, one for each of the units. The Merwin penstock head loss coefficients as determined during 1989 index tests and reported in the 1990 Lewis River Upgrade Study Report are shown in Table 1.3-1.

Table 1.3-1. Merwin head loss coefficients.

Description	Head Loss Coefficient, K[1] (ft)
Unit No. 1	4.825 E-7
Unit No. 2	5.18 E-7
Unit No. 3	4.47 E-7
1. Total head loss = K * (unit flow in cfs)^2	

1.4 Maximum Net Head

The maximum net heads seen by the Merwin turbines under one, two, and three-unit operation are shown in Table 1.4-1. The maximum net head is based on an estimated turbine hydraulic capacity of 3,690 cfs for each of units no. 1 and no. 2, and 3,790 for unit no. 3.

Table 1.4-1. Maximum net head for one, two, and three-unit operation at Merwin

Description	One Unit Operation	Two Unit Operation	Three Unit Operation
Maximum headwater elevation (ft)	239.6	239.6	239.6
Total plant flow (cfs)	3,790	7,570	11,460
Minimum tailwater elevation (ft)	49.6	52.0	53.4
Estimated typical head loss[1] (ft)	7.4	7.4	7.4
Maximum net head (ft)	182.6	180.2	178.8
1. Estimated from the Unit No. 2 head loss coefficient.			

All of the turbine-generator performance and capability data presented in Section 2 and Section 3 are based on the approximate maximum net head under three unit operation.

2.0 EXISTING CAPABILITY

2.1 Water Delivery System

The capabilities of the features comprising the Merwin water delivery system are described in the following sections.

2.1.1 Intake

Water is delivered to the three existing Merwin penstocks via separate intakes. The Merwin intakes can be classified as a relatively deep, high-head intakes with design velocities ranging between 10 and 20 feet per second. Based on the penstock inlet diameters (15.5 ft each) and the minimum water surface elevation in Lake Merwin, the intake is capable of passing more than 150 percent of the existing plant hydraulic capacity without forming vortices according to industry standard criteria (e.g.; Gordon's criteria). The reasonable limit to the intake would ultimately depend on the acceptable head losses and penstock pressure rise limits. To date, the Merwin intakes have operated satisfactorily without vortex formation or excessive head loss. As a result, study engineers estimate the existing overload capability at 120 percent of the existing capacity. The existing and acceptable overload capabilities are summarized in Table 2.1-1.

Table 2.1-1. Merwin intake capability.

Description		Capability		
		Flow (cfs)	Velocity[2] (ft/sec)	Output (each intake) (kW)
Unit No. 1 and No. 2	Existing capability[1]	3,790	20.1	49,410
	Acceptable overload	4,540	24.1	59,290
Unit No. 3	Existing capability[1]	3,890	20.6	48,340
	Acceptable overload	4,670	24.7	58,000

1. Based on the existing maximum powerplant flow (see Section 2.2)
2. At each penstock inlet.

2.1.2 Penstocks

Each of the Merwin penstocks is 15.5 feet in diameter. At the existing maximum plant flow, penstock velocities are as high as 20.6 feet per second. However, all of the Merwin penstocks have operated satisfactorily since their installation. As a result, study engineers estimate their acceptable overload capability at 120 percent of the existing capacity. The penstock capabilities are summarized in Table 2.1-2.

Table 2.1-2. Merwin intake capabilities.

Description		Capability		
		Flow (cfs)	Velocity[2] (ft/sec)	Output (each intake) (kW)
Unit No. 1 and No. 2	Existing capability[1]	3,790	20.1	49,410
	Acceptable overload	4,540	24.1	59,290
Unit No. 3	Existing capability[1]	3,890	20.6	48,340
	Acceptable overload	4,670	24.7	58,000

1. Based on the existing maximum powerplant flow (see Section 2.2)

Note that an increase in the maximum penstock flow would result in increased penstock pressures during load rejections. The increase in pressure loading would be generally proportional to the square of the velocity, assuming that no changes are made in wicket gate timing or turbine hydraulic characteristics (note that replacement turbine runners will likely have different runaway discharge and choking flow characteristics). Study engineers have not completed a transient analysis to estimate the maximum instantaneous penstock pressure rise during a load rejection. However, the penstocks at this project are very short; study engineers expect that any unacceptable increase in penstock pressure rise could be addressed with modifications in the replacement turbine runner design or by changing the wicket gate closing times.

2.2 Turbine-Generators

2.2.1 Turbine-Generator Performance

Efficiency tests using the Gibson Method were conducted on Merwin Unit No. 1 following its installation in 1931. The original turbine runner was replaced with a new runner (of apparently similar design) in 1972. Additional performance tests were not completed following the runner replacement. In 1989, Unit No. 1 generator output versus servomotor stroke tests were completed as part of the 1990 Lewis River Upgrade Study. The results of these tests showed that, in general, the unit generated more power in 1989 (with the new runner) than it did in 1931 (with the original runner) at the same servomotor stroke. Summary results of the 1989 output versus servomotor stroke tests are shown in Table 2.2-1.

Table 2.2-1. Merwin Unit No. 1 output vs. servomotor stroke test summary (1989 power-gate tests).

Servomotor Stroke (in)	Gross Head (ft)	Generator Output (kW)
8.07	182.21	20,540
10.89	182.16	31,870
12.80	182.06	38,920
14.41	181.93	43,050
17.05	181.74	47,070
18.03	181.71	48,260

Index tests were not completed on Merwin Unit No. 2 or Unit No. 3 following their installation in 1940 and 1958, respectively. Index tests were performed in 1989 as part of the 1990 Lewis River Upgrade Study. Summary index test data are presented in Tables 2.2-2 and 2.2-3.

Table 2.2-2. Merwin Unit No. 2 index test summary (1989 test).

Servomotor Stroke (in)	Winter-Kennedy Differential	Gross Head (ft)	Generator Output (kW)
7.68	2.2255	182.37	19,900
9.65	3.3650	182.38	27,920
10.91	4.7670	182.37	33,180
12.32	6.2240	182.55	37,960
14.06	7.8230	182.58	42,180
18.03	11.2870	182.34	47,800

Table 2.2-3. Merwin Unit No. 3 index test summary (1989 test).

Servomotor Stroke (in)	Winter-Kennedy Differential	Gross Head (ft)	Generator Output (kW)
5.59	2.1330	181.99	19,950
7.44	3.9910	181.62	29,500
9.17	5.9120	181.38	36,950
10.87	7.7580	181.12	41,940
13.35	10.1720	181.13	45,710
15.35	11.7110	180.90	46,460

Merwin Unit No. 3 was installed 18 years after Unit No. 2 and 27 years after Unit No. 1. As a result, the hydraulic design of Unit No. 3 is slightly different from the hydraulic design of units no. 1 and no. 2 (which are essentially identical, despite the Unit 1 runner replacement in 1972). Unit No. 3, for example, has the same runner discharge diameter as the other two units, but a smaller wicket gate pin circle diameter (188 inches for Unit No. 3 compared to 190 inches on each of units no. 1 and no. 2) and a larger wicket gate pad height (37.5 inches on Unit 3 compared to 32.72 inches on each of units no. 1 and no. 2). The performance of Unit No. 3 is different from units no. 1 and no. 2 due to its different physical dimensions and hydraulic design.

2.2.1.1 Unit No. 1 and Unit No. 2 Performance

Note again that units no. 1 and no. 2 are essentially identical in their hydraulic design. In 1989, generator output versus servomotor stroke tests were conducted on Unit No. 1; index tests were conducted on Unit No. 2. The Unit No. 1 turbine performance is estimated from the Unit No. 2 index test data (since the runners are reportedly identical).

Assuming the peak efficiency measured on Unit No. 2 during the 1989 index tests is equal to the design peak efficiency, it is possible to convert the relative performance data into actual performance. Using this method, the peak turbine efficiency is between 92 and 93 percent. As described in Section 2.2 of the Swift No. 2 report, however, it is possible that the measured peak efficiency is less than expected but that the hydraulic capacity is greater than the design capacity. It is important to consider this possibility since this type of a difference in performance potentially impacts the Merwin flows (which were back-calculated in part from generation records) and the baseline against which upgrades are measured.

The upper efficiency curve shown in Figure 2.2-1 and the first set of performance data in Table 2.2-4 are based on the 1989 index test results (assuming the measured peak efficiency equals the original design peak efficiency) and is considered the maximum probable existing performance of units no. 1 and no. 2. The lower curve and the second set of performance data are developed by assuming that the peak measured efficiency is a nominal three percent below the design peak efficiency. This difference in peak efficiency results in a different Winter-Kennedy calibration coefficient. It is important to note that lower performance is based on the 1989 index test data but assumes either that the units' original performance was different than expected, that the performance has degraded over time, or both. While this lower curve may not represent the lowest probable performance of the existing units, it provides another reasonable estimate of the existing performance based on the test data available. The data shown do not reflect any adjustments to account for additional changes that may have occurred in the performance since 1989.

Table 2.2-4. Merwin units no. 1 and no. 2 turbine-generator performance at 179 feet net head.

Expected Performance[1]			Alternative Performance[2]		
Turbine Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency (%)	Turbine Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency (%)
1,655	19,660	78.4%	1,710	19,650	75.9%
2,039	27,730	89.8%	2,110	27,710	86.9%
2,431	33,120	89.9%	2,510	33,080	87.1%
2,784	38,140	90.5%	2,870	38,090	87.5%
3,128	42,630	90.0%	3,230	42,550	87.1%
3,786	49,410	86.2%	3,900	49,230	83.3%

1. Current performance estimated from the 1989 index test data assuming the actual peak efficiency is the design peak efficiency (Winter-Kennedy calibration coefficient = 1114.3).
2. Current performance estimated from the 1989 index test data assuming the actual peak efficiency is three percent below the design peak efficiency (Winter-Kennedy calibration coefficient = 1150.4).

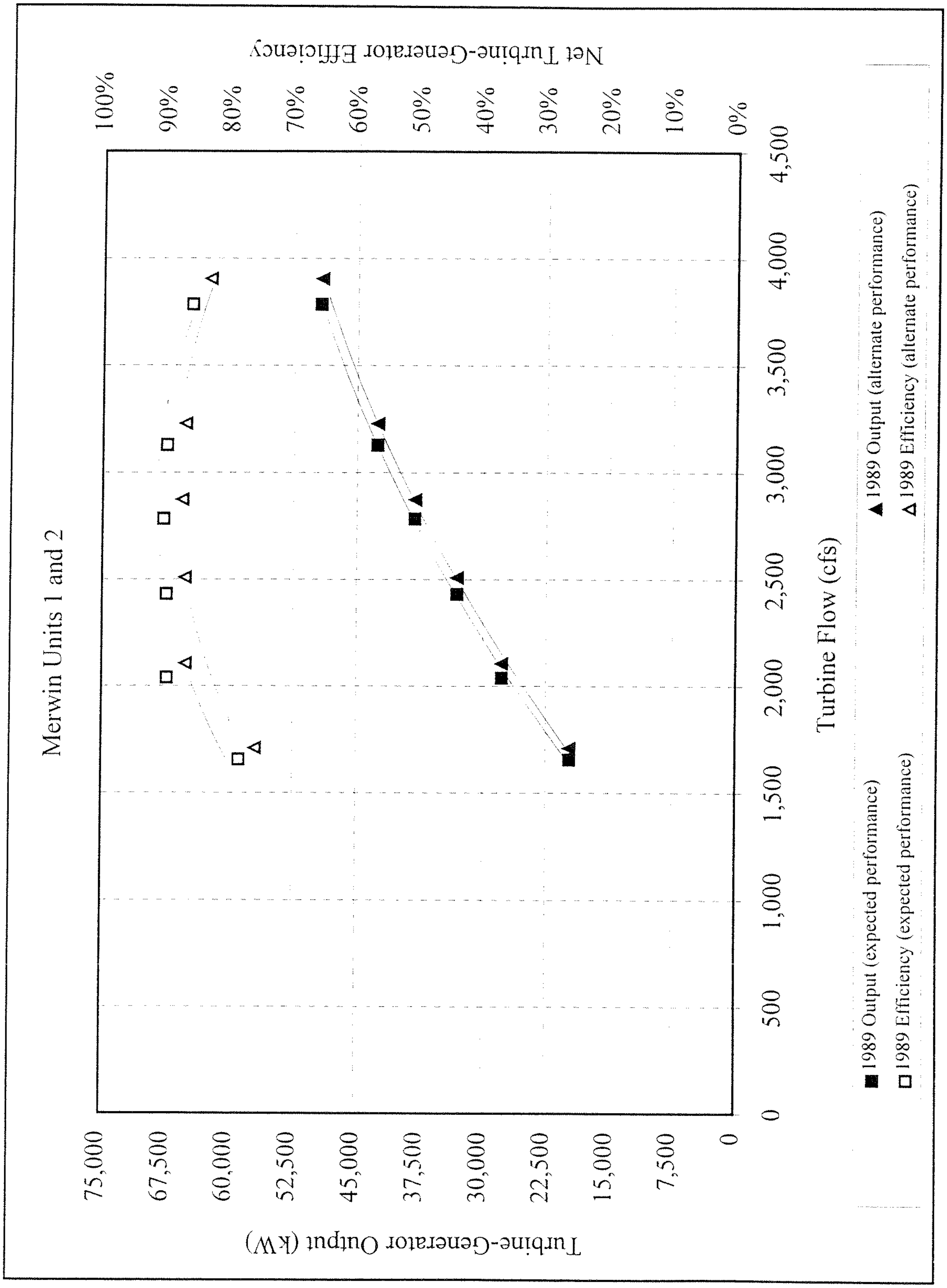

Figure 2.2-1. Merwin Units 1 and 2 turbine-generator performance.

2.2.1.2 Unit No. 3 Performance

Unit No. 3 turbine performance is shown in Table 2.2-5 and Figure 2.2-2. Two sets of performance data are shown. The first (more efficient) data set is based on the assumption that the peak efficiency measured in 1989 was equal to the design peak efficiency. The second data set assumes that the peak efficiency measured in 1989 is approximately three percent below the design peak efficiency.

Table 2.2-5. Merwin Unit No. 3 turbine-generator performance at 179 feet net head.

Expected Performance[1]			Alternative Performance[2]		
Turbine Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency (%)	Turbine Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency (%)
1,630	19,690	79.8%	1,680	19,680	77.2%
2,242	29,580	87.1%	2,310	29,550	84.3%
2,742	37,600	90.6%	2,830	37,540	87.6%
3,147	42,900	90.0%	3,250	42,820	87.1%
3,610	47,040	86.0%	3,720	46,920	83.2%
3,888	48,340	82.1%	4,010	48,200	79.4%

1. Current performance estimated from the 1989 index test data assuming the actual peak efficiency is the design peak efficiency (Winter-Kennedy calibration coefficient = 1121.1).
2. Current performance estimated from the 1989 index test data assuming the actual peak efficiency is three percent below the design peak efficiency (Winter-Kennedy calibration coefficient = 1157.5).

2.2.2 Existing Turbine Capability

The Merwin turbine capabilities are taken as the generator outputs when the turbines are operating at 100 percent gate; turbine capabilities are summarized in Table 2.2-6. Note that the generator efficiencies are necessarily included in the turbine capabilities. The turbine efficiencies (independent of the generator) are shown at best gate and full gate for comparison with the performance of potential upgrades (see Section 3) Also note that the turbine capability shown is based on the conventional approach to evaluating index test data (assuming the measured peak efficiency equals the design peak efficiency).

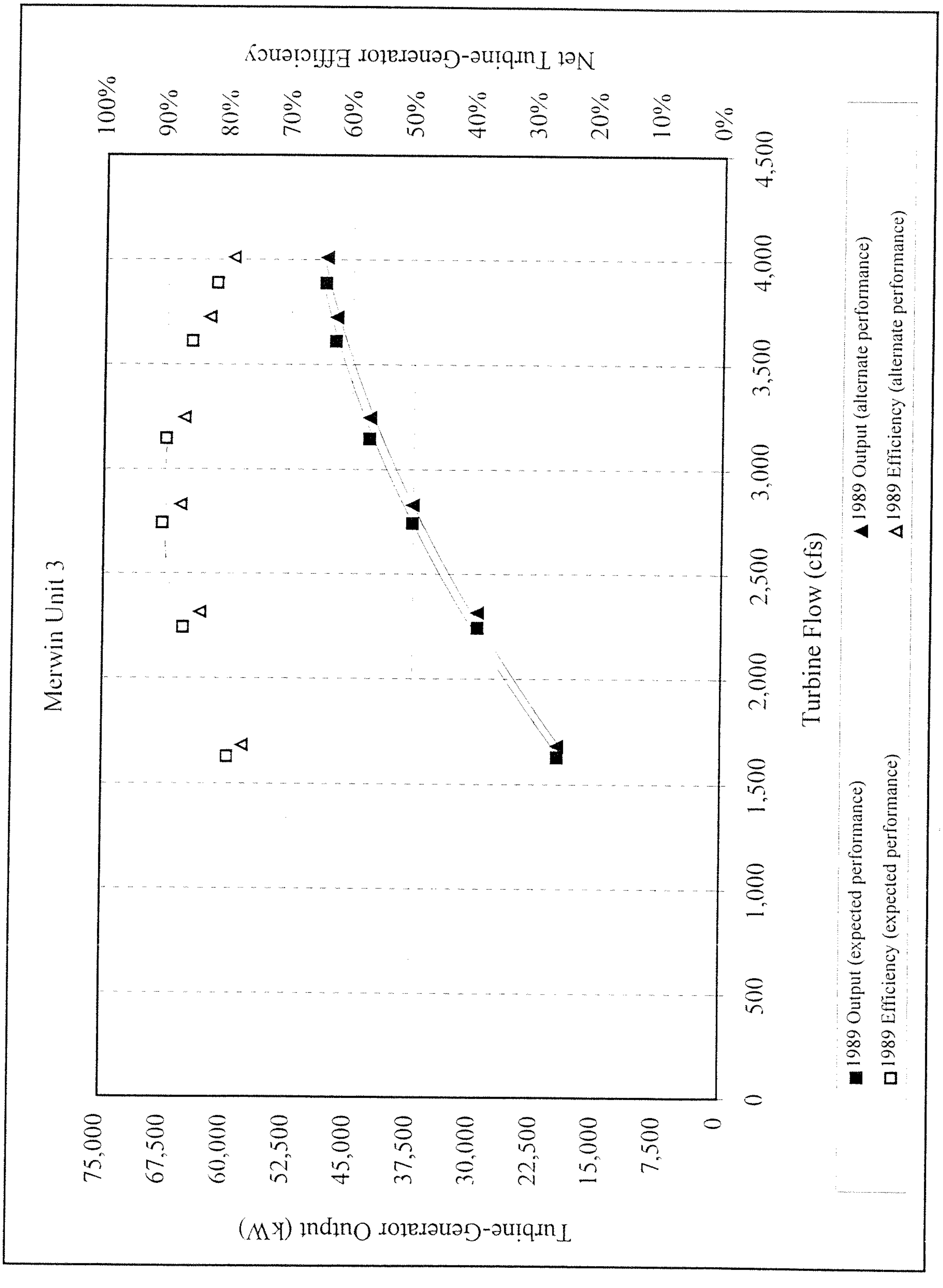

Figure 2.2-2. Merwin Unit 3 turbine-generator performance.

Study engineers completed an additional, independent analysis aimed at identifying potential changes and/or errors in the existing efficiency data. This analysis was based on the Lewis River flows measured at the USGS gage below Merwin. By comparing these measured flows with the turbine and spill discharges stored in PacifiCorp's KWH accounting system (which were determined from the existing performance data), engineers can locate potential errors/inaccuracies in the performance data. This analysis did not reveal any apparent errors in the assumed performance of the existing Merwin units. Further, assuming the highest probable existing performance results in the minimum upgrade benefits and is consequently considered the conservative assumption. The possibility of lower performance, however, will be considered in evaluating the Merwin upgrade potential. Note that the turbine capability (maximum power in kW) is very nearly the same regardless of whether the test data is analyzed using the conventional method or the alternative method described in Section 2.2.1. The hydraulic capacity and efficiencies, however, are different depending on the method chosen.

Table 2.2-6. Merwin turbine-generator performance summary at 179 feet net head.

Description		Turbine Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency	Generator Efficiency[1]	Turbine Efficiency
Unit 1 1	Best Gate	2,780	38,140	90.5%	97.5%	92.8%
	Full Gate	3,790	49,410	86.2%	97.5%	88.4%
Unit 1 2	Best Gate	2,780	38,140	90.5%	97.5%	92.8%
	Full Gate	3,790	49,410	86.2%	97.5%	88.4%
Unit 1 3	Best Gate	2,740	37,600	90.6%	97.5%	92.9%
	Full Gate	3,890	48,340	82.1%	97.5%	84.2%
Plant Capacity		11,460	147,160	NA	NA	NA
1. Estimated						

2.3 Generator

Merwin generators no. 1, no. 2 and no. 3 were installed in 1931, 1949, and 1958 respectively. Unit No. 1 was rewound in 1972. Original and existing nameplate ratings are shown in Table 2.3-1.

Table 2.3-1. Merwin generator nameplate ratings.

Unit	Original Nameplate Data					Existing Nameplate Data				
	Rating			Insulation Class	Temp. Rise[1] (°C)	Rating			Insulation Class	Temp. Rise[1] (°C)
	(kVA)	P.F.	(V)			(kVA)	P.F.	(V)		
No.1	56,250	0.8	13,800	B	50	57,000	0.8	13,800	B	50
No.2	56,250	0.8	13,800	B	50	NA				
No.3	56,250	0.8	13,800	B	50	NA				

1. Over a 40°C ambient temperature.

Heat rise tests were not conducted on the Merwin generators as part of the Lewis River GCA. Operating logs include daily generator cooling air temperature observations, but do not include generator stator temperature data (which is recorded on paper via an electronic device and stored off-site). The acceptable generator overload capabilities provided in Table 2.3-2 were confirmed by PacifiCorp staff, and are based on a nominal seven percent overload.

Table 2.3-2. Merwin generator capability.

Unit	Capability at Unity Power Factor (kW, each unit)	
	Nameplate Capability	Acceptable Overload[1]
Unit No. 1	57,000	61,000
Unit No. 2	56,250	60,200
Unit No. 3	56,250	60,200

1. Based on seven percent overload.

Note that overload operation of the generators will reduce the remaining life and reduce the time until a rewind or replacement is required.

2.4 Generator Switchgear and Bus

Power from the Merwin generators is transmitted at generator voltage via insulated rigid bus to an overhead rigid bus located on the transformer deck above the tailrace. From the overhead bus, rigid bus drops convey the generator output to the single-phase step-up transformers. Power is transmitted from the step-up transformers to the switchyard via overhead lines at 115 kV where two circuit breakers are provided for each generating unit in a configuration which allows transmission of project energy on the Battleground, Yale Lakes, or Longview 115 kV transmission lines. No generator switchgear exists in the system at generator voltage (13.2 kV).

In addition to the insulated rigid bus, disconnect links are provided in each unit's 13.2 kV bus for maintaining power to the step up transformers during generators maintenance. Also, manual disconnect switches are located on the 115 kV side of each transformer to isolate the transformer from the switchyard bus during transformer maintenance.

Study staff did not locate any nameplates or rating data during their site visit for the rigid bus or maintenance links for the Merwin generating units. Project drawings indicate that the generator bus and maintenance link capacities are 3000 amps at 13.2 kV. The 115 kV manual disconnects and the circuit breakers have amperage ratings ranging from 600 to 1200 amps. As no capacity ratings were identified for the maintenance links either in the site visit or drawing review, study staff assumed that these links carry the same amperage rating as the adjoining bus. Based on the data taken from the project drawings and the above assumptions, the equivalent power ratings for the generator bus, bus links, disconnect switches and circuit breakers are shown in Table 2.4-1.

Table 2.4-1. Merwin generator bus and bus link ratings.

Unit	Description	Nameplate Rating[1]		
		(A)	(kV)	(kVA)
Units No. 1, No. 2 and No. 3	Bus duct	3,000	13.2	68,500[2]
Units No. 1, No. 2 and No. 3	Disconnect switch	600	115	119,000[2]
Units No. 1 and No. 2	Circuit breakers	800	115	159,000[2]
Unit No. 3	Circuit breakers	1,200	115	239,000

1. Based on review of project drawings.
2. Each unit.

Based on the available data, study engineers are not able to identify any acceptable overload of the generator bus.

2.5 Transformer

The Merwin transformer data is summarized in Table 2.5-1.

Table 2.5-1. Merwin transformer data.

Unit	Manufacturer	Rating (kVA)	Temp. Rise (°C)	Cooling Type/ Class
No. 1	General Electric	16,667/22,222	55/65	OA/FA
	General Electric	16,667/22,222	55/65	OA/FA
	General Electric	16,667/22,222	55/65	OA/FA
No. 2	General Electric	16,667/22,222	55/65	OA/FA
	General Electric	18,750	55	OW
	General Electric	18,750	55	OW
No. 3	General Electric	20,000	55	OW
	General Electric	20,000	55	OW
	General Electric	20,000	55	OW

Transformer oil and winding temperatures are not recorded on the Merwin operating logs. Transformer overload capabilities identified by PacifiCorp staff are summarized in Table 2.5-2.

Table 2.5-2. Merwin 1 transformer capabilities.

Unit	Nameplate Rating[1] (kVA)	Acceptable Overload (kVA)
No. 1	16,667	22,000[2]
	16,667	22,000[2]
	16,667	22,000[2]
No. 2	16,667	22,000[2]
	18,750	19,690
	18,750	19,690
No. 3	20,000	21,000
	20,000	21,000
	20,000	21,000

1. Based on 55°C temperature rise.
2. Based on 65°C temperature rise.

2.6 Project Capability

The existing generating capability of Merwin units no. 1, no. 2, and no. 3 are shown in Figures 2.6-1, 2.6-2, and 2.6-3, respectively.

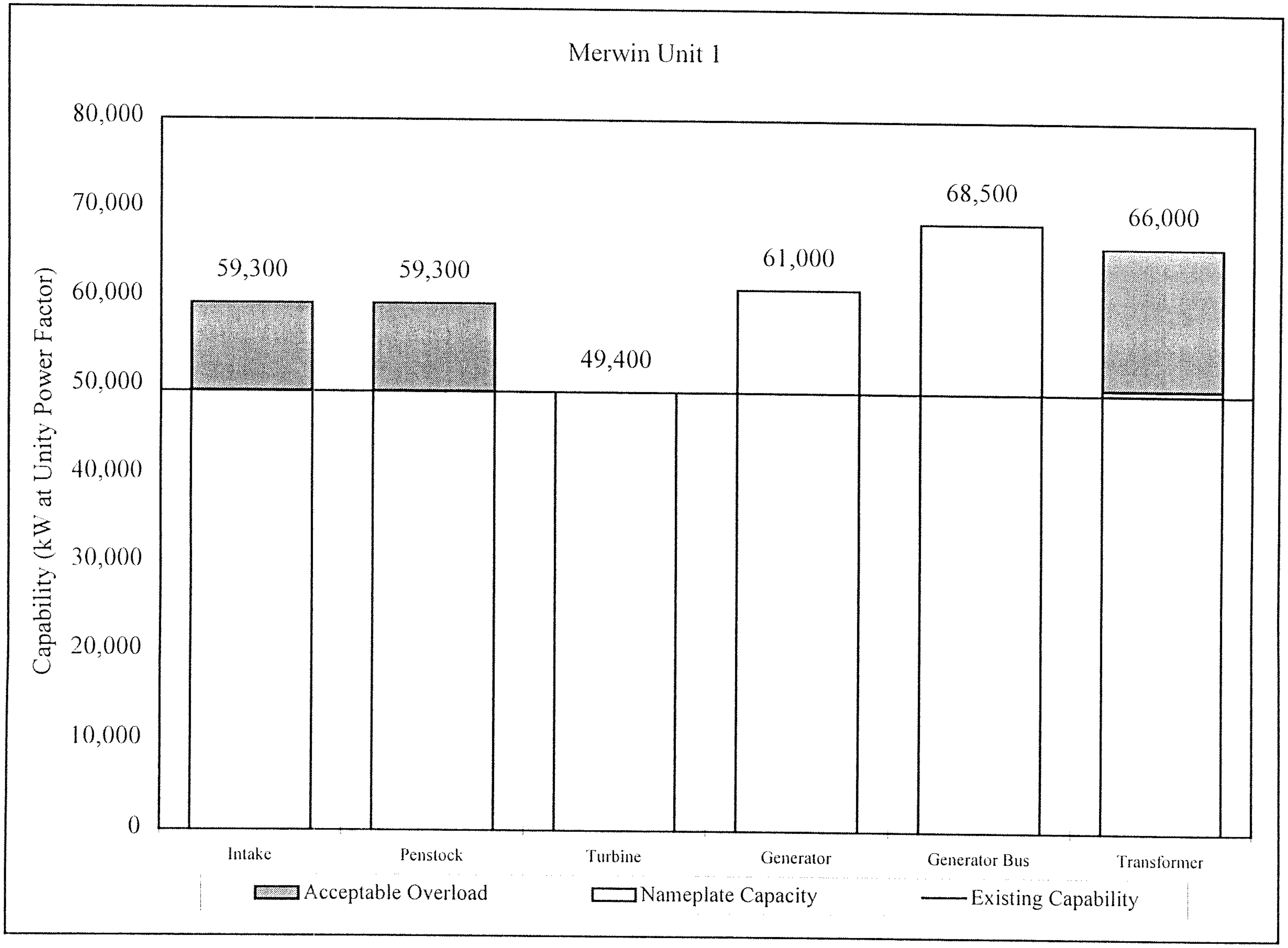

Figure 2.6-1. Existing Merwin Unit 1 generation capability.

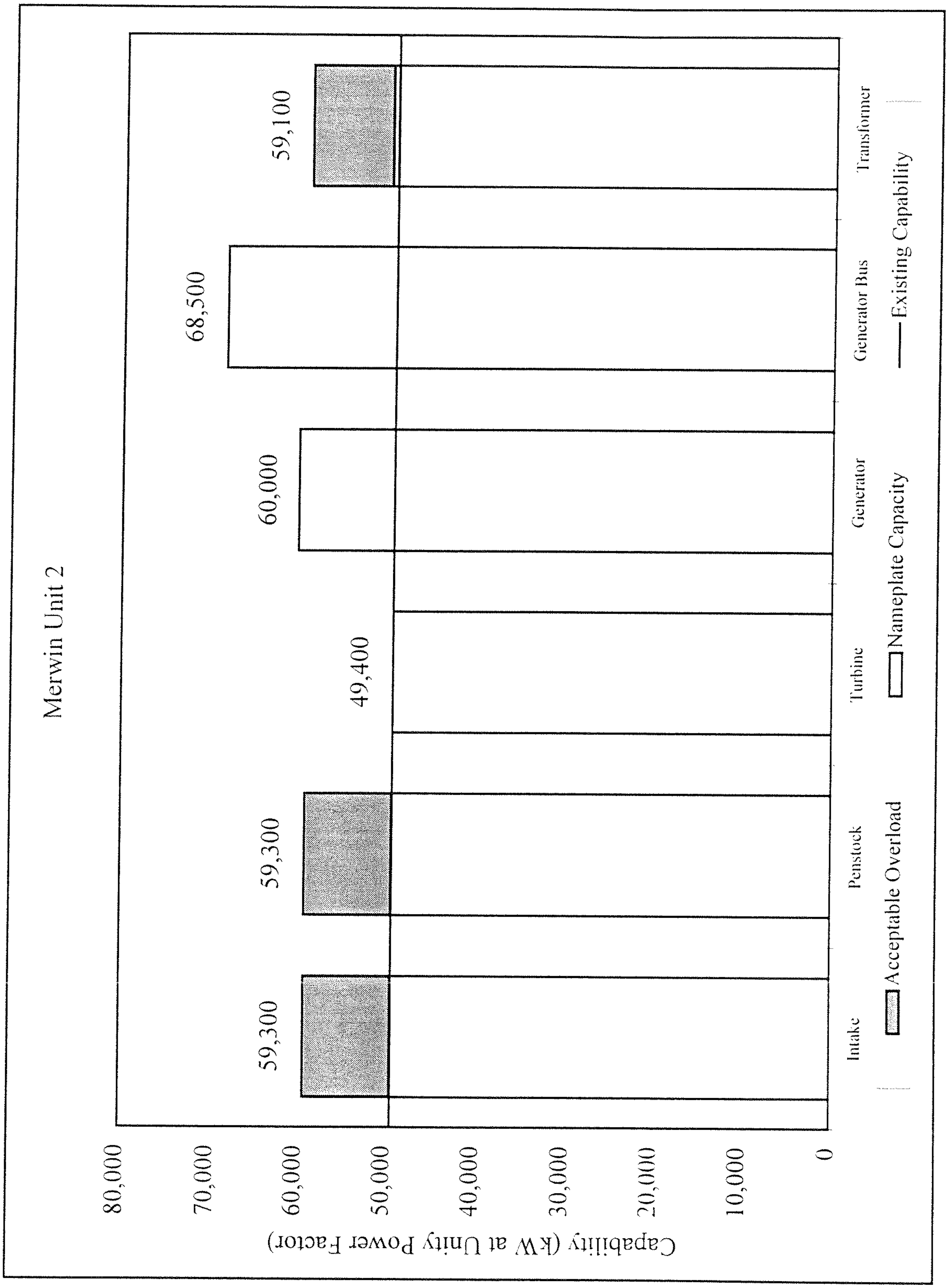

Figure 2.6-2. Existing Merwin Unit 2 generation capability.

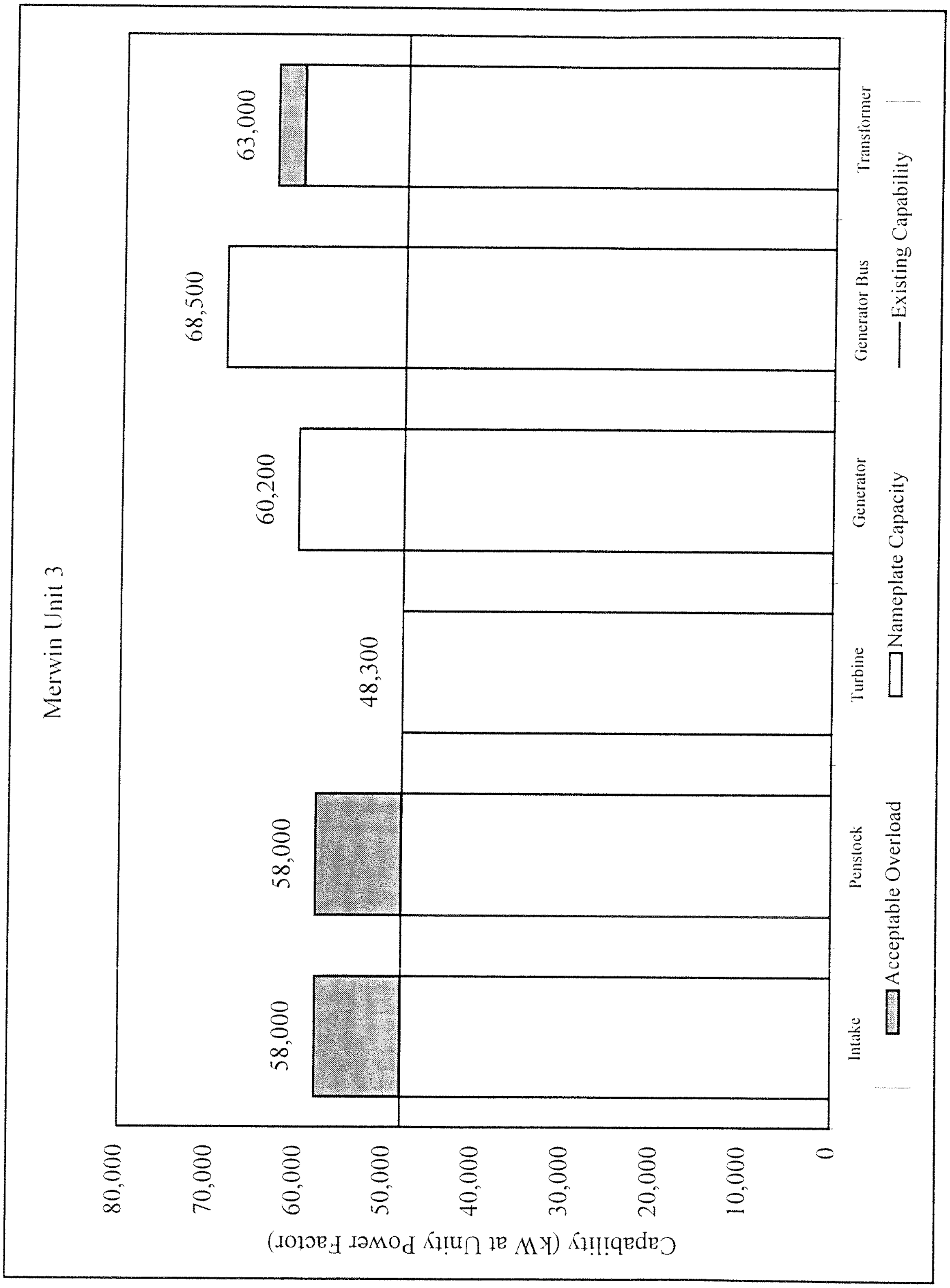

Figure 2.6-3. Existing Merwin Unit 3 generation capability.

3.0 UPGRADE ALTERNATIVES

3.1 Operational Alternatives

Merwin Lake is fluctuated on a seasonal basis to help regulate seasonal inflows to the Lewis River. In addition, Merwin Lake is fluctuated to a much smaller extent to allow peaking operation of Swift No. 1, Swift No. 2 plants, and particularly the Yale plant. Under some conditions, daily and weekly inflows from upstream peaking plants are stored in the reservoir and released during the off-peak period to provide more uniform downstream flows. At other times, Merwin operates as a peaking plant.

The changes in peak energy associated alternative allowable daily level fluctuations in the Merwin Lake are shown in Figure 3.1-1. The changes in peak energy shown reflect the net total change to the Lewis River system. Note that allowable daily level fluctuations in Merwin Lake less than 1 foot reduce the Lewis River projects' peak period energy.

The upgrade evaluations described in the following sections are based on the historical flows for water year 1991 (the median year). As a result, the actual seasonal drawdown and refill of Merwin Lake (as well as the Swift and Yale Reservoirs) during 1991 are automatically accounted for in the upgrade evaluations. This upgrade study does not consider new seasonal operating policies for any of the Lewis River reservoirs.

3.2 Water Delivery System Upgrades

The existing intake and penstock capabilities at Merwin are more than adequate to accommodate all of the turbine and electrical equipment upgrades considered. As a result, water delivery system upgrades were not developed.

3.3 Turbine-Generator Upgrades

3.3.1 Rationale

In order to determine the manner in which PacifiCorp has historically operated the Lewis River system (and presumably will continue to operate), study engineers examined

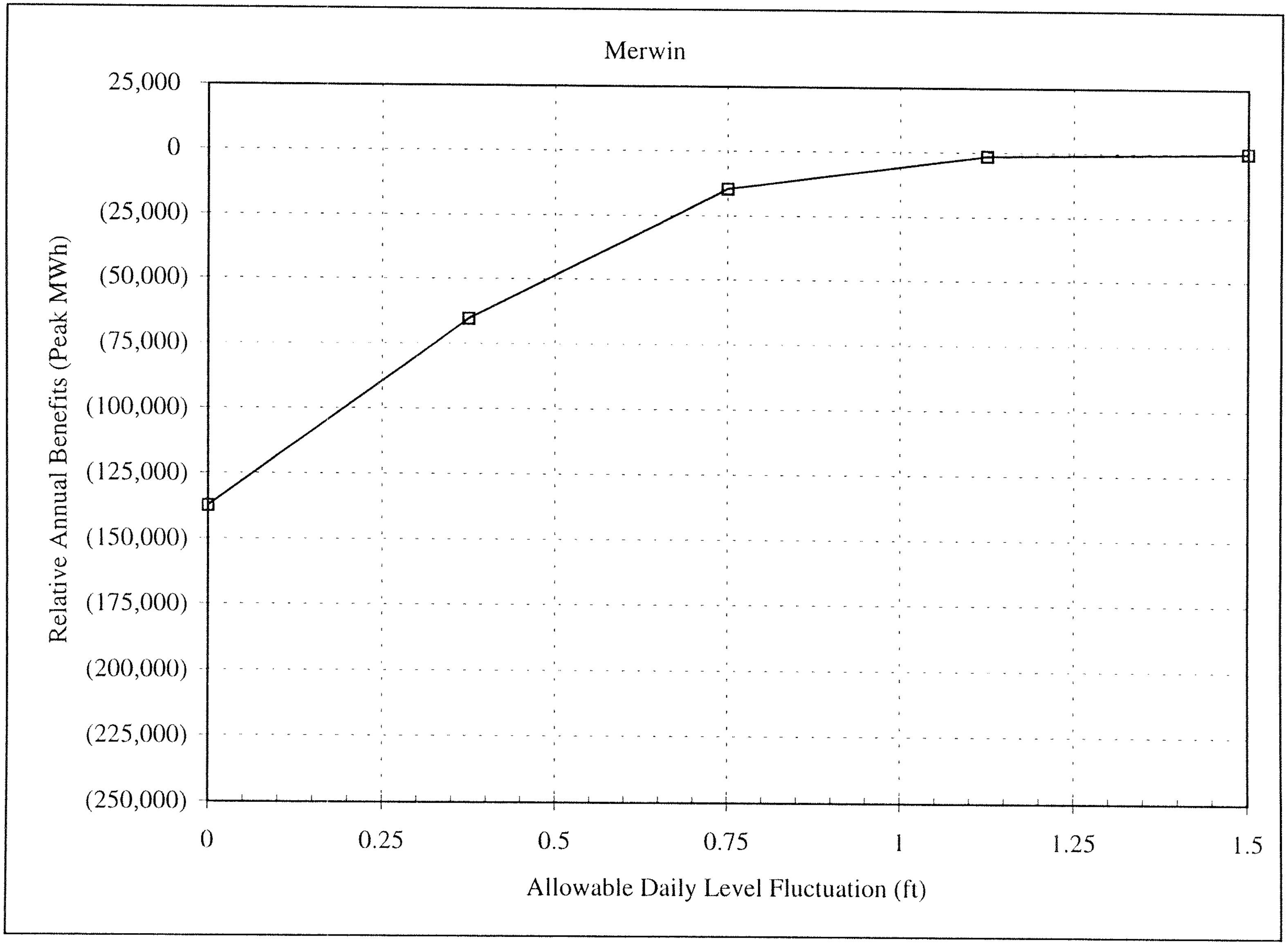

Figure 3.1-1. Peak energy impacts of alternative allowable daily level fluctuations in Lake Merwin.

historical operating records from approximately 1980 through 1995. This period is generally drier than normal for the Lewis River basin. As a result, study engineers concentrated on the median year (water year 1991) data.

The Lewis River projects very rarely spill (less than five percent of the time during the overall period examined, including the median year). Available storage in the Swift Reservoir, Yale Lake, and Lake Merwin is apparently sufficient to regulate typical short-term storm events and seasonal high runoff. Merwin operates at times as a peaking plant, and at other times as a reregulating plant to control changes in the Lewis River flows downstream of the projects. The goal for the Merwin upgrade alternatives is to evaluate the benefits of increased generating efficiency (especially during periods when Merwin is delivering only the required downstream minimum flows) and the benefits of increased capacity.

3.3.2 Turbine Upgrade Alternatives

Study engineers identified two turbine upgrade alternatives for Merwin. Alternative 1 is intended to increase the generating efficiency during periods when Merwin is delivering only the required minimum downstream releases. The historical operating records indicate that Merwin operates in this manner 15 to 20 percent of the time. Although increased-low flow efficiency might benefit Merwin during certain times of the year, a reduction in the Merwin plant hydraulic capacity might restrict PacifiCorp's flexibility in regulating seasonal runoff. Alternative 2 alone is intended to increase the overall Merwin capacity. The desired increase in hydraulic capacity for Alternative 2 is intended to minimize the change in the Merwin plant capacity when two units are upgraded (a runner similar to Alternative 1 on a unit, a runner similar to Alternative 2 another unit). The desired performance characteristics for these alternatives are as follows:

Alternative 1. Hydraulic Capacity of 2,000 cfs, peak efficiency as close to 1,500 cfs as possible.
Alternative 2. Maximum Possible Hydraulic Capacity

3.3.2.1 Turbine Upgrade Performance

Performance data provided by American Hydro for the turbine upgrade alternatives are summarized in Table 3.3-1. Performance data are shown graphically in Figure 3.3-1. Note that the Merwin Unit 1 and Unit 2 turbines' hydraulic designs are identical and, as a result, the upgrade performance characteristics are independent of the unit under consideration. The hydraulic design of Merwin Unit 3 is slightly different than the other units. Turbine upgrades specifically for Unit 3 are not included in this analysis.

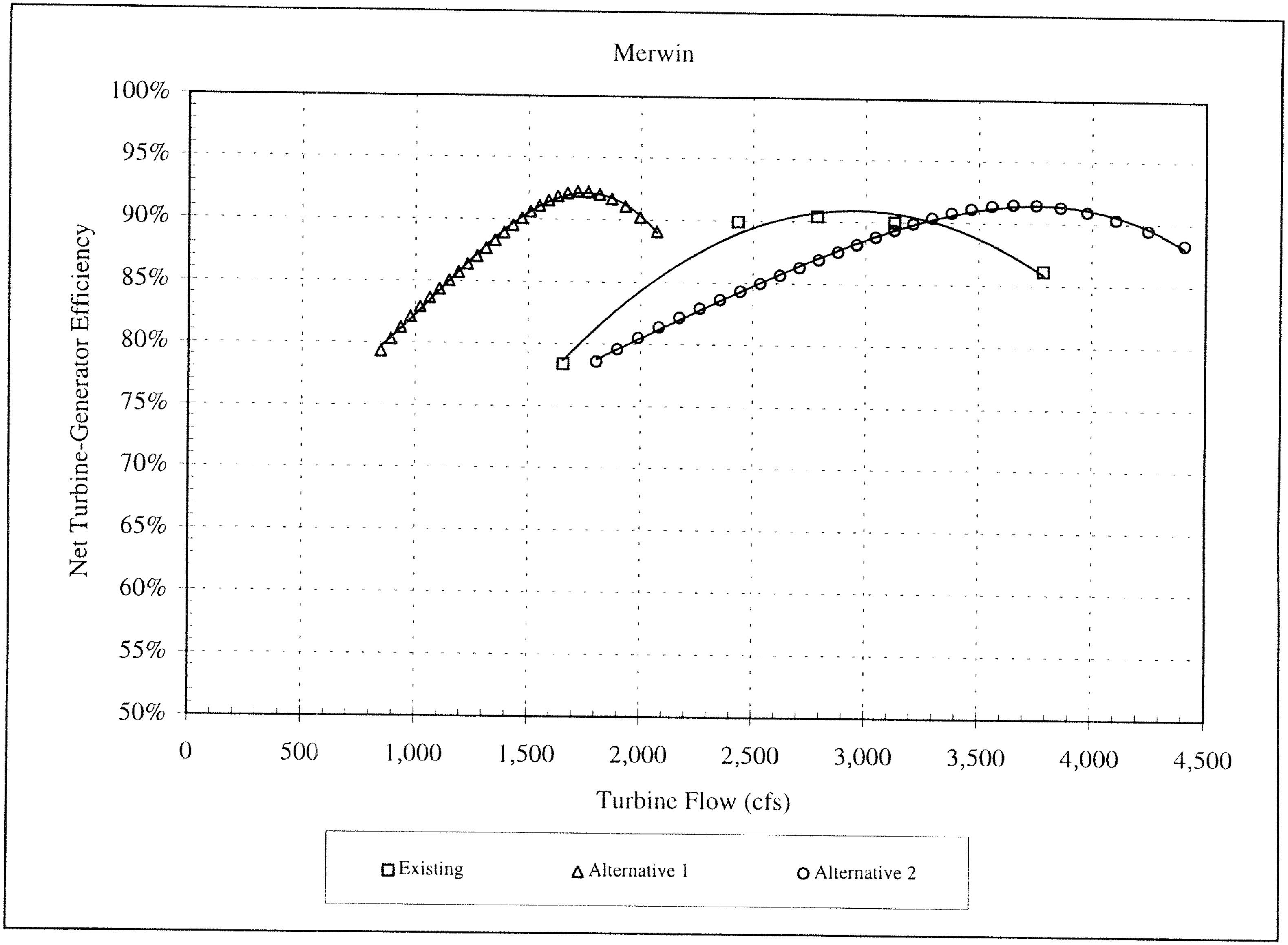

Figure 3.3-1. Performance data for the Merwin turbine upgrade alternatives at 179 feet net head.

Table 3.3-1. Expected performance data for the Merwin turbine upgrade alternatives at 179 feet net head.

Alternative 1 "Low Flow"			Alternative 2 "High Flow"		
Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency	Flow (cfs)	Generator Output (kW)	Net Turbine-Generator Efficiency
847	10,180	79.3%	1,805	21,500	78.6%
891	10,850	80.3%	1,898	22,890	79.6%
934	11,500	81.2%	1,990	24,280	80.5%
977	12,160	82.1%	2,082	25,680	81.4%
1,020	12,820	82.9%	2,173	27,060	82.2%
1,063	13,480	83.6%	2,264	28,450	82.9%
1,105	14,130	84.4%	2,354	29,830	83.6%
1,148	14,800	85.0%	2,444	31,230	84.3%
1,189	15,450	85.7%	2,533	32,620	85.0%
1,230	16,100	86.4%	2,620	34,010	85.6%
1,271	16,760	87.0%	2,707	35,400	86.3%
1,311	17,420	87.7%	2,792	36,780	86.9%
1,351	18,080	88.3%	2,877	38,180	87.6%
1,391	18,740	88.9%	2,961	39,570	88.2%
1,430	19,400	89.5%	3,044	40,960	88.8%
1,469	20,060	90.1%	3,127	42,350	89.3%
1,508	20,710	90.6%	3,210	43,730	89.9%
1,548	21,380	91.1%	3,294	45,120	90.4%
1,588	22,030	91.5%	3,380	46,520	90.8%
1,629	22,690	91.9%	3,467	47,890	91.1%
1,672	23,350	92.1%	3,558	49,290	91.4%
1,717	24,010	92.3%	3,653	50,670	91.5%
1,764	24,670	92.3%	3,754	52,060	91.5%
1,815	25,330	92.1%	3,862	53,460	91.3%
1,869	25,970	91.7%	3,979	54,850	90.9%
1,930	26,640	91.1%	4,107	56,230	90.3%
1,996	27,290	90.2%	4,249	57,620	89.5%
2,071	27,960	89.1%	4,408	59,010	88.3%

3.3.1.1 Turbine Upgrade Costs

Turbine manufacturers did not inspect the Merwin units; the condition of existing runners is unknown. Turbine manufacturers recommend replacing the original runners with new runners of modern design and materials to optimize plant output. Coincident with the runner replacement, the wearing components such as the stationary wear rings, gate linkage bushings and pins, gate stem bushings, shaft packing and facing plates should be thoroughly cleaned, inspected and replaced as necessary. The following embedded and removable component rehabilitations are also recommended:

- Sandblast, clean, test, and paint the spiral case, stay vanes and draft tube liner.
- Sandblast, clean, test and paint the headcover, discharge ring and draft tube.
- Line bore and fit the headcover and bottom ring gate stem holes with new bronze or self-lubricating bearings.
- Fit and machine the wear rings and facing plates.
- Clean and test the wicket gates. Remachine the gate ends, seals, and bearing area. Sandblast, repair any surface damage on, and paint the gate leafs. As an alternative, the gates may be replaced at a cost comparable to their rehabilitation. Note that the existing gates have a modern profile. Consequently, new gates will not enhance the units' performance.
- Clean and test the turbine shaft. If cracks in the shaft are discovered through nondestructive testing, the shaft should be replaced. If cracks are not revealed through testing, the bearing and packing areas should be true cut or sleeved as required.

The turbine costs are provided in Table 3.3-2. Note that the upgrade costs are the same, regardless of the alternative selected. Replacing instead of rehabilitating the gates (if necessary) should not significantly impact the total estimated upgrade cost.

Table 3.3-2. Turbine upgrade costs.

Description	Cost[1] ($)
New turbine runner	950,000
Disassembly and reassembly (field work)	265,000
Refurbish/replace turbine components	375,000
Discharge ring modifications	125,000 (Alternative 2 only)
Total estimated cost	1,590,000 (Alternative 1) 1,715,000 (Alternative 2)

1. The costs shown are estimated by turbine manufacturers and do not include any contingencies. Study staff have requested Yale upgrade costs from PacifiCorp staff to help refine the upgrade costs estimates for Merwin.

3.3.2 Generator Upgrade Alternatives

The existing Merwin generators have more than sufficient overload capabilities for the turbine alternatives investigated. As a result, study staff did not estimate the characteristics or cost of any generator upgrade options at Merwin.

3.4 Generator Bus Upgrades

The existing generator buses at the Merwin project have overload capabilities which exceed the capability of the maximum turbine output investigated. PacifiCorp staff report that bus connections in the switchyard reach high operating temperatures when the existing generators operate at full load. Upgrades of these bus terminations should be completed in conjunction with any turbine capacity-increasing upgrades at Merwin.

3.5 Transformer Upgrades

Each of the Merwin turbine-generators has three single phase transformers for step up from generator voltage to 115 kV. A variety of replacements and upgrades to these transformers has taken place since original commissioning of the project, to the extent that each unit's transformer bank has a different power capability. Acceptable overload ratings for each transformer bank are shown in Section 2 of this report.

In all cases, the transformer banks' overload capabilities exceed the capacity of the high flow (Alternative 2) turbine alternative. Therefore, study staff did not complete any evaluations for transformer upgrades at Merwin.

4.0 UPGRADE EVALUATIONS

4.1 Upgrade Options

Potential changes in the Merwin generation capability associated with turbine upgrades are shown in Figure 4.1-1. Note that the upgrade evaluations at Merwin did not consider the "house unit." The range of options investigated are described below.

Existing (Nameplate) Capability: This is the existing capability of the existing features and equipment at Merwin. The existing development capability is limited by the existing three unit full-gate turbine-generator output .

Option 1: This option consists of replacing the existing Unit No. 2 runner with a new low flow (Alternative 1) runner. The capability of Merwin under these conditions is limited by the new three unit full-gate turbine-generator output.

Option 2: This option includes replacing the existing Unit No. 2 runner with a new low flow (Alternative 1) runner and replacing the Unit No. 1 runner with a new high flow (Alternative 2) runner. Under these conditions, the Unit No. 1 intake and penstock operate above their existing maximum flow (but within the acceptable overload). This option is specifically intended to investigate the benefits of increasing the generating efficiencies when Merwin is delivering only the minimum downstream flows, while minimizing the reduction in the plant hydraulic capacity.

Option 3: This option includes only replacing the existing Unit No. 1 runner with a new high flow (Alternative 2) runner. The plant capability following this upgrade would be limited to the new three unit maximum turbine-generator output.

Option 4: Option 4 consists of replacing both the existing Unit No. 1 and Unit No. 2 runners with new high flow (Alternative 2) runners.

Option 5: Option 5 consists of adding a new fourth unit in the open powerhouse bay. This unit would be sized to efficiently release the seasonal minimum flows while overlapping the efficient operating range of the three existing units.

4.2 Upgrade Evaluations

The matrix of upgrade options investigated at Merwin is shown in Table 4.2-1. Upgrade cost summaries are provided in Table 4.2-2. Note that the energy benefits of the upgrade options are shown relative to the existing condition. The energy benefits shown reflect the net total benefits to the entire Lewis River system.

4.3 Economic Comparison of Upgrades

Based on the upgrade evaluations shown in Table 4.2-1, there are no turbine upgrade alternatives or new unit additions at Merwin whose energy benefits alone are sufficient to justify the costs. It appears difficult, if not impossible, to simultaneously increase Merwin's generating efficiency when its delivering only the minimum downstream flows; maintain the existing plant hydraulic capacity; and maintain efficient operations over the full range of Merwin flows only with upgrades of the existing units.

At PacifiCorp's request, study engineers estimated the benefits of the fourth unit addition at Merwin. This option provides the highest total energy benefits of any of the Lewis River upgrades investigated in the study. However, costs associated with achieved in these benefits are quite high. This option simultaneously increases the low-flow efficiency and increases the plant hydraulic capacity. If future economic conditions change, and a fourth unit at Merwin is considered, the new unit should be sized such that it operated satisfactorily at the lowest minimum river flow and has a maximum flow that overlaps the minimum load on any of the other three units. The fourth unit investigated in this study has a capacity of 28 MW with a minimum operating flow of approximately 850 cfs, a peak efficiency flow of approximately 1,725 cfs and a hydraulic capacity of 2,070 cfs. These benefits are shown as the New Unit Option in Table 4.2-1. The costs of this option were estimated at $27 million.

4.4 Upgraded Project Capability

No turbine upgrades at Merwin appear attractive. Upgraded capability diagrams are consequently not provided.

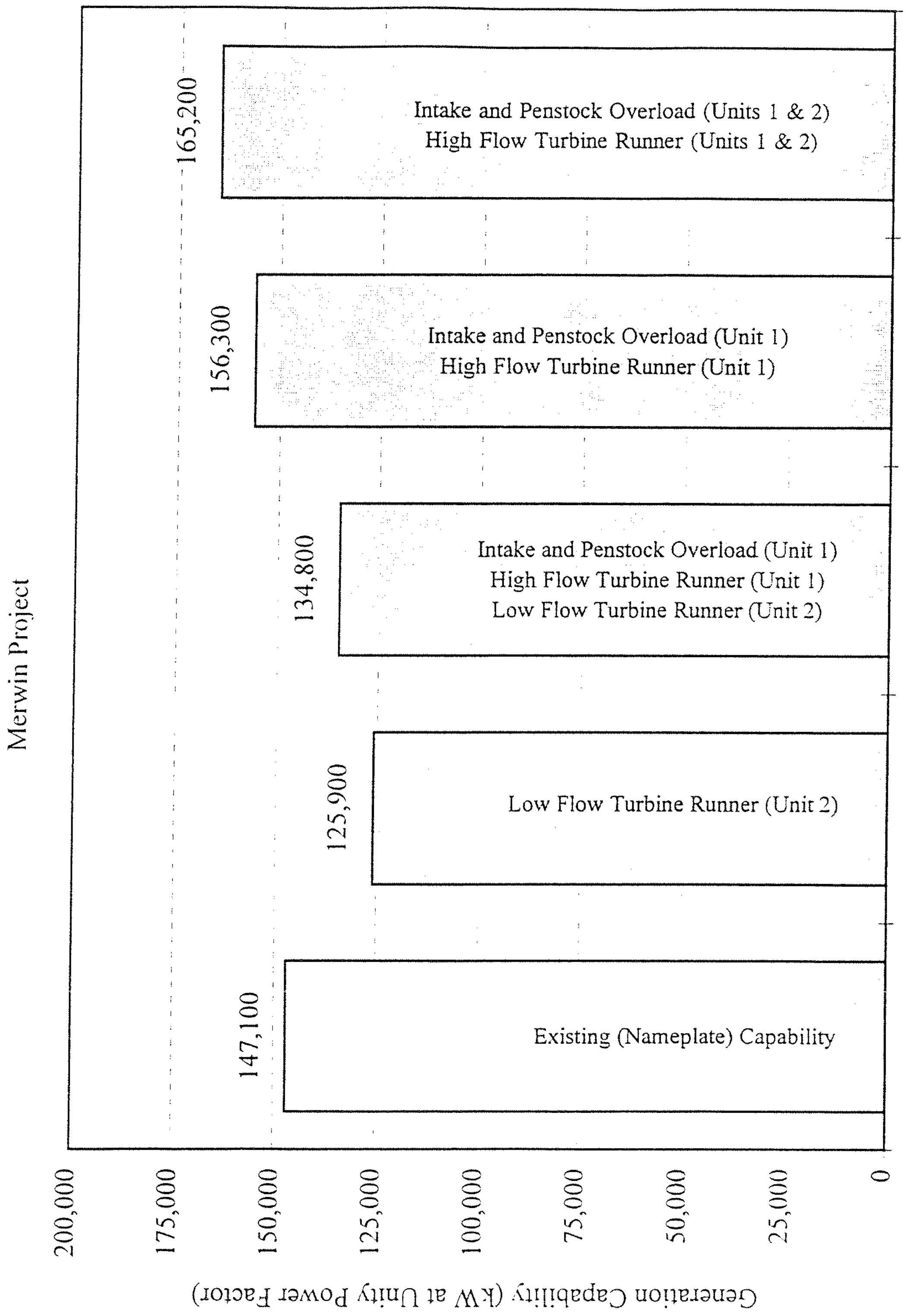

Figure 4.1-1. Potential increases in the Merwin generation capability.

Table 4.2-1. Merwin upgrade options.

	Merwin Unit 1						**Merwin Unit 2**						**Merwin Unit 3**						**Merwin Capability**		**Costs**	**Relative Annual Benefits (MWh)**		
Option	Merwin Unit 1 Existing Runner	Merwin Unit 1 Alt. 1 Runner	Merwin Unit 1 Alt. 2 Runner	Merwin Unit 1 Generator Rewind	Merwin Unit 1 Bus Upgrade	Merwin Unit 1 Transformer Upgrade	Merwin Unit 2 Existing Runner	Merwin Unit 2 Alt. 1 Runner	Merwin Unit 2 Alt. 2 Runner	Merwin Unit 2 Generator Rewind	Merwin Unit 2 Bus Upgrade	Merwin Unit 2 Transformer Upgrade	Merwin Unit 3 Existing Runner	Merwin Unit 3 Alt. 1 Runner	Swift Alt. 2 Runner	Merwin Unit 3 Generator Rewind	Merwin Unit 3 Bus Upgrade	Merwin Unit 3 Transformer Upgrade	Hydraulic Capacity (cfs)	Capability (kW)	Total Upgrade Costs ($)[1]	Peak	Off-Peak	Total
Existing Condition	X						X						X						11,470	147,100	0	0	0	0
Option 1	X							X					X						9,750	125,600	1,590,000	(8,200)	(5,100)	(13,300)
Option 2			X					X					X						10,300	134,600	3,305,000	(6,200)	(4,000)	(10,200)
Option 3			X				X						X						12,020	156,100	1,715,000	1,800	1,000	2,800
Option 4			X						X				X						12,570	165,100	3,430,000	1,000	600	1,600
Fourth Unit Addition	No upgrades to existing units - fourth unit addition only																		13,530	175,400	27,000,000	10,000	11,600	21,600

Table 4.2-2. Merwin upgrade cost details.

	Merwin Unit 1				**Merwin Unit 2**				**Merwin Unit 3**				
Option	Unit 1 Turbine Costs ($)	Unit 1 Generator Upgrde Cost ($)	Unit 1 Bus Upgrade Cost ($)	Unit 1 Transformer Upgrade Cost ($)	Unit 2 Turbine Costs ($)	Unit 2 Generator Upgrade Cost ($)	Unit 2 Bus Upgrade Cost ($)	Unit 2 Transformer Upgrade Cost ($)	Unit 3 Turbine Costs ($)	Unit 3 Generator Upgrade Cost ($)	Unit 3 Bus Upgrade Cost ($)	Unit 3 Transformer Upgrade Cost ($)	**Total Upgrade Cost ($)**
Existing Condition													0
Option 1					1,590,000								1,590,000
Option 2	1,715,000				1,590,000								3,305,000
Option 3	1,715,000												1,715,000
Option 4	1,715,000				1,715,000								3,430,000