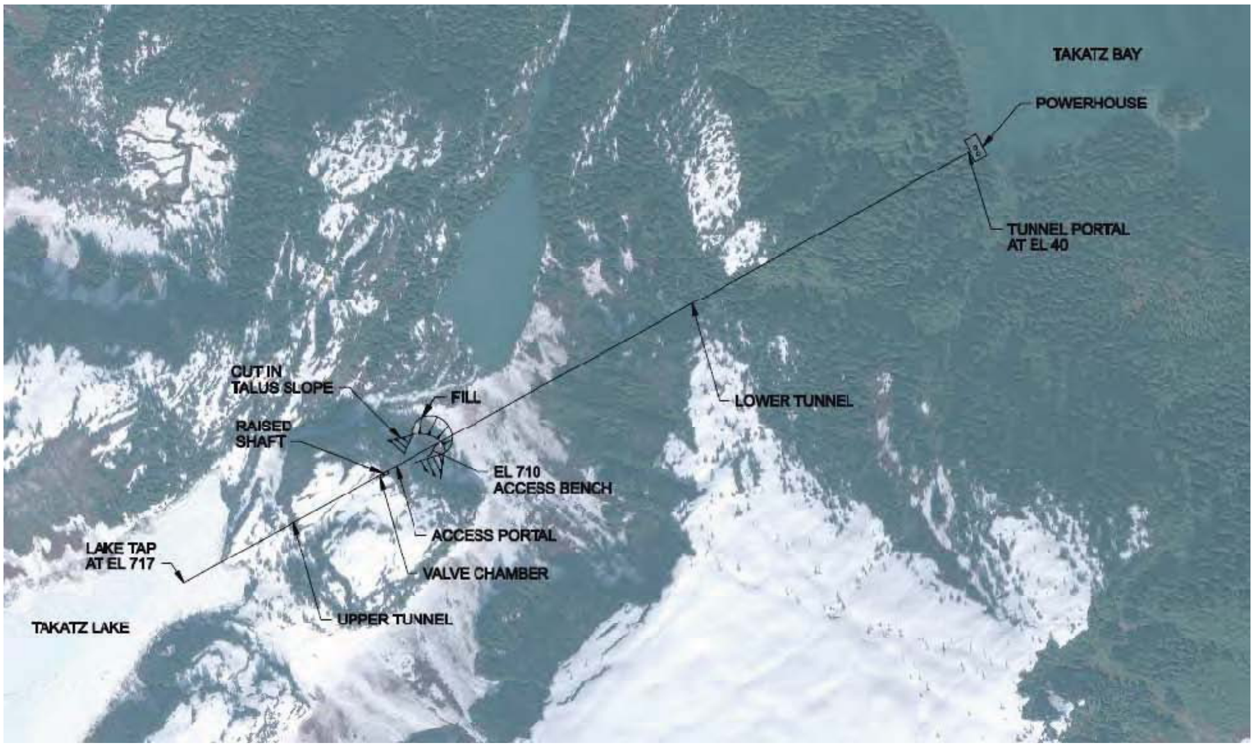
Takatz Lake Hydroelectric Development
Project Capacity Analysis
Study Report



Submitted to

City and Borough of Sitka
Sitka, Alaska

Submitted by

Currents Consulting
Seattle, Washington

March, 2011

Takatz Lake Hydroelectric Development
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Study Report

The engineering material and data contained in this Report were prepared under the supervision and direction of the undersigned, whose seal as a registered professional engineer is affixed below.

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April 1, 2011

(Date of Issue)

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SECTION 1 - SUMMARY

1.1 Background

The City and Borough of Sitka (the City) is pursuing development of the Takatz Lake Hydroelectric Project. The City is presently completing environmental studies in support of its FERC Preliminary Permit for the Project. This capacity analysis study was undertaken to confirm that the proposed Project arrangement, specifically the reservoir storage capacity and the powerhouse generating capacity, are both appropriate for the future needs of the City.

The project arrangement proposed by the U.S. Department of the Interior in 1968 was used as the baseline arrangement in our study effort. That report defined the optimum project arrangement as: two dams that would raise the Takatz Lake water level to el. 1040; a tunnel and penstock system extending to tidewater; and a two-unit 20 MW powerhouse on Takatz Bay. The 2011 project review included an analysis of what reservoir capacity is appropriate based on industry guidelines and the likely Takatz reservoir operating policy, if it were similar to the City's current operation of the Blue Lake and Green Lake projects.

The study program included a review and extension of hydrologic records for Takatz Creek and development of an operations model to simulate operation of the Takatz Project. Our study effort considered the appropriate generating capability at Takatz given Sitka's electric loads, other hydro generating resources in the system, and the cost and feasibility of varying capacities at Takatz Lake. No construction costs were developed in our work. The focus of this study was to confirm that the proposed project arrangement is appropriate for the City's future needs.

1.2 Hydrology Assessment

An extensive hydrologic assessment of the Takatz Lake site was carried out in 1968. Our study team reviewed that work and extended the hydrology data set from a 19 year record (water years 1946 to 1964) to a 23 year record (calendar years 1946 through 1968). The average outflow at Takatz Lake over this revised period of record was 171 cfs (a basin yield of 124,000 ac-ft per year). This revised inflow estimate was used in our estimates of reservoir capacity and in the operations model to estimate the Project's energy generation.

1.3 Reservoir Capacity Analysis

We completed a reservoir capacity analysis for the Blue Lake, Green Lake and Takatz Lake reservoirs. This analysis defines the lake storage volume, aka the "mass balance volume", needed to fully regulate average inflows and shape the outflows to match electric loads in the Sitka system. The analysis shows that the City's current reservoir operating policy at Green Lake and Blue Lake can be closely approximated by this approach. The active reservoir storage volumes actually developed at Green Lake and Blue Lake provide this "mass balance" volume for their respective basins plus a small reserve volume at each lake (a 7% reserve at Green Lake and a 14% reserve in the Blue Lake Expansion reservoir).

Based on our analysis we defined a mass balance reservoir volume for Takatz Lake of 48,359 ac-ft and determined that a suitable reservoir storage volume at Takatz would be 52,950 ac-ft (9% greater than the mass balance reservoir volume).

Our review of the 1968 proposed plan of development shows that the 82,400 ac-ft reservoir storage volume proposed in 1968 is considerably larger than what we anticipate is needed. The 1968 study suggested this large reservoir volume to maximize the Project's firm energy capacity and to minimize spill. We anticipate that regulation of the Takatz Lake inflows, comparable to how the City now operates Blue Lake and Green Lake, can be achieved with a total reservoir storage volume of 52,950 ac-ft.

1.4 Operations Modeling

We developed a project operations model, similar to the City's existing model for Green Lake and Blue Lake. The Takatz model is a stand-alone spreadsheet model, which operates the project to meet varying annual project energy goals, using the 23-year hydrologic record. The model was our primary tool for estimating the energy generation from four principal alternatives considered in this study.

1.5 Project Arrangement Alternatives

Four alternatives for development of the project were considered. These include:

1. **Phase 1**. A lake tap arrangement with tunnel and penstock system extending to a 25 MW powerhouse at tidewater. This phase would not include any dam, surge chamber, or access road to the lake area. The lake level operating range would be el. 747 to el. 905.
2. **Phase 2**. Following the Phase 1 development, construction of an access road to the dam and a single main dam at the lake outlet, raising the maximum lake level to el. 990. Project rated capacity would increase to 29.2 MW, due to the increase in head. The lake level operating range would be el. 747 to el. 990.
3. **Single-Stage Development**. A conventional development of the site, with a surface intake, single main dam, tunnel and penstock leading to a 25 MW powerhouse at tidewater. The lake level operating range would be el. 890 to el 990.
4. **1968 Plan of Development**. A Project plan with a lake level operating range as recommended in 1968. This includes a main dam and saddle dam at the lake, a tunnel and penstock system extending to a 25 MW powerhouse at tidewater. The lake level operating range would be el. 900 to el. 1040.

1.6 Evaluation of Alternatives

The annual energy predicted for each of the four alternatives is shown in Table 1-1. From our evaluation it appears that phased development of the Takatz Lake site has considerable merit, in that as much as 84% of the ultimate project energy benefits can be achieved without construction of a dam at the lake outlet. The Phase 2 dam addition would incrementally increase the Project's annual energy and would provide significant reserve storage for dry-year carry over and for major outages of the Blue Lake or Green Lake developments.

We determined that the 1968 plan of development likely represents a reservoir storage volume larger than that needed to effectively develop the site.

The Study team identified two major uncertainties with the Phase 1 lake tap arrangement. First, it is unclear whether there exists a suitable subsurface slope in the lake where a lake tap intake can be constructed. Second, the very large sediment delta in the westerly third of the lake poses an unknown risk of movement into the lake, leading to potential blockage of a lake-tap intake.

1.7 Future Engineering Studies

The study team recommends the following engineering studies be carried out in 2011 or 2012:

- A bathymetric survey of the lake, to characterize bottom surface conditions at the potential lake tap locations.
- A preliminary analysis of the sediment delta volume, its risk of movement, and risk of blockage at a group of alternative lake tap locations.

Following these early studies, more in-depth feasibility analyses of the phased development will be required. These studies should include confirmation of the project arrangements, site investigations, assessment of technical feasibility, and preliminary construction cost estimates.

Table 1-1 Summary of Recommended Project Capacities for Development of Takatz Lake

Phased Development of Takatz Lake								
Project Development	Reservoir Capacity			Powerhouse Capacity		Annual Generation		
	Storage, ac-ft	Maximum level, ft	Minimum level, ft	cfs	MW	MWh		Ave MW
						90% (1)	Ave	
Phase 1 (2)	52,950	905	747	450	25	75,000	86,140	9.8
Phase 2	99,300	990	747	474(3)	29.2(3)	88,900	90,644	10.3
Single Stage Development of Takatz Lake (4)								
Single-Stage	52,000	990	890	450	27.8	85,000	96,919	11.1
1968 Proposed Plan of Development for Takatz Lake (5)								
1968 Plan	82,400	1040	900	450	29.3	95,900	99,134	11.3

Notes:
1. Annual MWh possible with 90% confidence, based on providing this energy in 21 of 23 year period of record.
2. The Phase 1 arrangement could also be the final project development, if the Phase 2 dam addition proves uneconomic
3. Turbine hydraulic capacity and MW output increase due to increase in project head. Units are not changed as part of Phase 2 construction.
4. This is the recommended arrangement if the lake tap proves infeasible.
5. Estimated generation based on lake levels proposed in 1968 Plan of Development for Takatz Lake.

SECTION 2 – INTRODUCTION

2.1 Study Background and Scope

The City and Borough of Sitka, Alaska (Sitka or the City) holds a Federal Energy Regulatory Commission (FERC) preliminary permit for the study and development of the Takatz Lake hydroelectric site. A series of mapping, environmental, and engineering feasibility studies were undertaken in the 2009 to 2011 time frame to help define the impacts, feasibility, and cost of the Takatz Project. As part of these current studies the City sought to determine whether the arrangement of the Project's generating facilities, as proposed in past engineering studies, is still appropriate for the City's 21st century needs.

Historical studies of the hydroelectric potential at Takatz Lake date back almost 50 years to the mid-1960's. Those studies were completed in the context of a much smaller Sitka area population and electrical load. In the mid 1960's electric loads in the Sitka area were met by the existing Blue Lake hydro plant (7 MW capacity), diesel generators, and by generation by the Alaska Lumber and Pulp mill.

A major feasibility study of the Takatz Lake project was completed in 1968 by the US Department of Interior. That study recommended development of a 20 MW hydro project that would include two concrete arch dams, a tunnel, penstock, and two-unit powerhouse near tidewater.

In the 2013 to 2015 time frame Sitka's electric loads will be served by a fundamentally different set of generation resources compared to the 1960's electric system. The current generating resources include: the Green Lake hydro plant (16 MW capacity); an expanded Blue Lake hydro project (proposed 15.9 MW capacity in 2013); and back-up diesel generators owned by the City. The ALP pulp mill closed in 1993 and is no longer a source of generation for the City and Borough.

Consequently, in 2010 the City commissioned Currents Consulting to complete a review of the appropriate reservoir storage capacity, hydraulic capacity, installed megawatts, and number of generating units for the Takatz Lake development. The fundamental goal of this study is to determine what reservoir storage capacity and generating capability is most appropriate at Takatz to both develop its hydrologic resource and to augment the City's existing hydro generation resources. This study was authorized by City of Sitka Purchase Order 11-00224161, dated October 5, 2010. Paul Carson of Currents Consulting and Mike Frantz of MF Solutions comprised the study team identified in this report.

This study's scope of work includes development of a hydro operations computer model for the Takatz Project, which can accurately predict the Takatz generation under different reservoir inflow conditions. This model is similar to the existing Blue Lake – Green Lake hydro operations model that the City currently uses to predict seasonal generation capability and reserves. Also, the scope includes assessment of whether the Takatz Project might be developed in phases. The phased development concept considers whether a Phase 1 lake tap, without a dam, could be constructed at the site. Phase 2 would include construction of a dam (or dams) to increase reservoir storage and generating head.

It is important to note what this 2011 study effort does not include. One of the major cost, technical feasibility, and environmental feasibility issues for the Project is the transmission line between Takatz Lake and the City of Sitka. The routing, assessment, and cost estimating for the transmission line are the subject of other studies. The transmission line is not considered in this 2011 Capacity Analysis study.

This 2011 study does not attempt to determine the final technical feasibility of the project arrangements recommended herein. Frankly, this is a paper study. The study authors have not yet visited the Takatz Lake site. Our study work is based on the following resources: the 1968 Department of Interior Study report; USGS stream flow records for Takatz Creek; modern topographic maps developed from a 2009 LiDAR survey of the Takatz Lake area; and recent satellite photographs of the project area.

Confirming the technical feasibility of the project arrangements recommended in this study will require site investigations and further engineering feasibility studies. Specific recommendations for follow-on investigations and studies are included in Section 9 of this report.

Finally, this 2011 study effort makes no attempt to define the Takatz Project construction cost. Some comparative cost information is provided in Section 9 of this report to help identify the possible value of alternative development strategies for the project. However this discussion of costs is aimed at defining the fraction of total project costs that might be deferred by a phased development of the project, or saved by a single-stage development which is smaller in scope than that proposed in 1968.

2.2 Reference Documents and Prior Studies

The primary reference for this 2011 study work is the:"Plan of Development, Takatz Creek Project, Alaska". U.S. Department of the Interior, January 1968, which is referred to in this report as "the 1968 Study". That proposed project development and its supporting appendices were the result of a comprehensive investigation of the Takatz Creek site, undertaken in the 1965 to 1967 time frame. The study included field investigations of hydrology and geology at the site, preliminary design of the project facilities, and power studies which predicted firm and average annual energy from the Project.

The seminal 1947 report "Water Powers, Southeast Alaska" was used as a reference in estimating a suitable reservoir storage volume at Takatz. This historical study was also used as a benchmark for comparing the reservoir capacity and generating capability of other projects in the Southeast Alaska region.

Hydrology data for Takatz Creek is available from the USGS for water years 1951 to 1969. This currently available hydrology record was modified and extended by the USGS after completion of the 1968 study. The modified and updated record was used in our study effort. Details of the changes made by the USGS in the hydrology record and our calculated flows available for power generation are described in detail in Section 3 of this report.

Topographic maps were developed in 2010 for the Takatz Lake area. These maps were developed from a LiDAR aerial survey conducted on September 29, 2009 by Aero-Metric, Inc., Anchorage, AK under contract to the City of Sitka (Aero-Metric job no. 6090905). Satellite images used in development of the City's GIS database for the Takatz area were also used as reference documents in this study work.

2.3 Plan of Development Proposed in 1968

Takatz Lake is located on Baranof Island about 20 miles east of Sitka. The lake location relative to Sitka and the proposed transmission line route are shown in Figure 2-1. This figure represents the City's initial proposal for project development at the time of their Preliminary Application Document, filed in late 2009. The specific transmission route continues to be under review as part of the City's studies.

The overall plan of development proposed by the Department of Interior in 1968 is shown in Figure 2-2. In that plan the project would include a 205 ft high concrete arch dam at the outlet of Takatz Lake and a 63 ft high concrete arch "saddle dam" located in a swale to the south of the lake outlet. These two dams would combine to raise the natural lake level 135 feet from el. 905 ft to el. 1040 ft. Together, the dams would develop an active storage volume of 82,400 ac-ft between el. 1040 ft and el. 900. The 1968 plan included a concrete intake structure, tunnel and penstock system delivering water to a powerhouse at tidewater, Figure 2-3. The selected powerhouse arrangement is shown in Figure 2-4. The powerplant was proposed as a conventional indoor facility with two vertical-shaft 4-nozzle Pelton type turbines, a combined generating capacity of 20.0 MW, and a stated hydraulic capacity of 328 cfs at rated conditions.

This proposed development plan assumed construction of all the power facilities as a single program over a period of two to three years. The construction work would include construction of a dock facility in Takatz Bay, a road to the powerhouse site, and a road continuing from the powerhouse vicinity to the dam. The 82,400 ac-ft storage created with this plan represents a substantial volume, compared to the annual yield of the Takatz Lake basin. The goal with this large volume was to provide significant carry-over storage for the Sitka electric system during dry years.

Figure 2-5 shows the results of the 1968 power study analysis. That analysis, and the reservoir sizing it is based on, allows a large reservoir draw-down volume during the driest three year period in the hydrologic record. In turn, this storage volume provides a firm power capacity of 97,100 MWh (an average project generation output of 11.1 MW). Note that the secondary generation predicted in 1968 was only 9,800 MWh, or 9% of the total generation. This is an unusually small proportion of secondary energy, reflecting the large storage volume proposed. The 1968 power operations study regulated the lake inflows so completely that the lake filled fully and spilled in only 9 of the 19 years simulated.

Figure 2-6 shows the proposed reservoir area-capacity curve from the 1968 study. Note that the 1968 study effort included soundings of the lake down to el. 700 ft, in order to establish the dead storage in the lake. In the 1968 study report narrative the authors stated:

> "*Takatz Lake has a surface area of 403 acres at elevation 905 feet. The lake basin is deep and step walled, having an area of 243 acres at elevation 700 feet. Soundings of the lake bottom showed a minimum elevation of 435 feet (depth 470 feet below the existing water surface)"*.

This narrative on the lake soundings and maximum depth is the only mention of the sub-surface survey program carried out at the lake for the 1968 study. This narrative and the area-capacity curve developed from the survey do lend credence to the argument that the 1968 study engineers considered a lake-tap (no dam) alternative plan of development. The limited information gleaned from the 1968 Study report regarding the lake tap option is discussed in Section 8 of this 2011 report.

2.4 Alternative Project Arrangements Considered

The Study team considered three basic variations for development of the project:

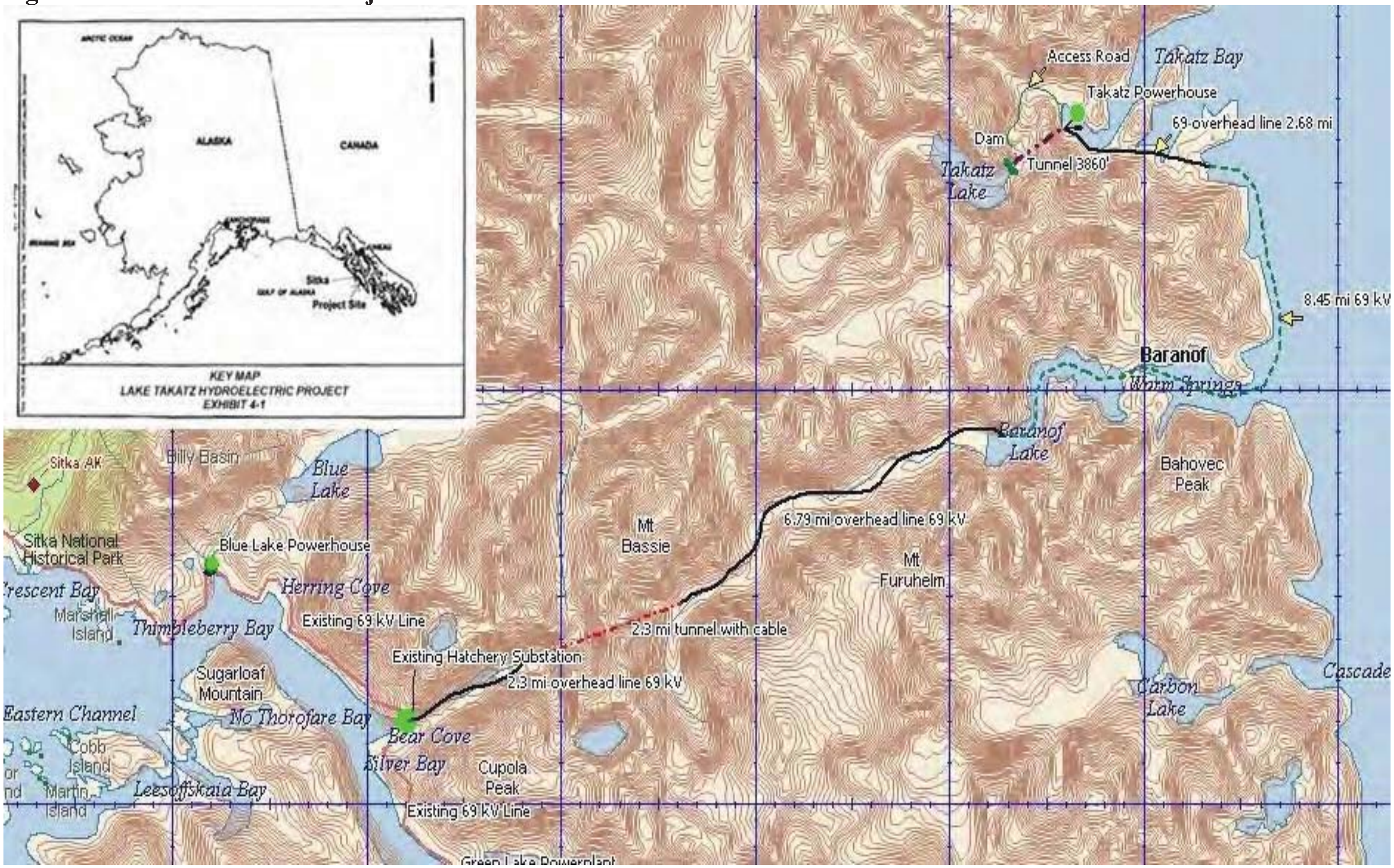
1. The development plan proposed in 1968
2. A single stage development similar to the 1968 plan, but with a lower height dam and less reservoir storage
3. Phased project development where Phase 1 would be a lake tap intake, tunnel and powerhouse, followed some years later by Phase 2 which would be construction of the dam(s).

In each case, no significant consideration was made for alternative powerhouse locations or large variations in the tunnel alignment. Also, no assessment was made of alternative dam locations as the 1968 study involved a comprehensive assessment of the optimum dam site location. The 1968 studies included site surveys, geotechnical mapping of the area, and a geotechnical exploratory drilling program at the dam sites. No information has been developed since 1968 that would allow us to improve on the dam siting analysis described in the 1968 study.

The 2011 study program involved the following steps:

1. Updating the available streamflow predictions to confirm the hydrologic resource available at Takatz Lake.
2. Assessment of the reservoir storage volume required to regulate lake inflows and provide a monthly project generation schedule suitable for loads in the Sitka electric system.
3. Estimating reservoir storage reserve capacities required to meet Sitka system needs.
4. Estimating the installed MW capacity required to effectively regulate power releases and to provide adequate generation and peak load reserves in the Sitka system.
5. Developing a proposed project arrangement for a single-stage development that meets the reservoir storage and installed capacity goals defined in steps 2 and 3.
6. Developing proposed project arrangements for phased project development, where the Phase 1 and Phase 2 arrangements reasonably meet the reservoir capacity and generating capacity goals defined for this 2011 study.

Figure 2-1 Takatz Lake Project Location



Source: City and Borough of Sitka Electric Department, FERC Preliminary Application Document, 2009

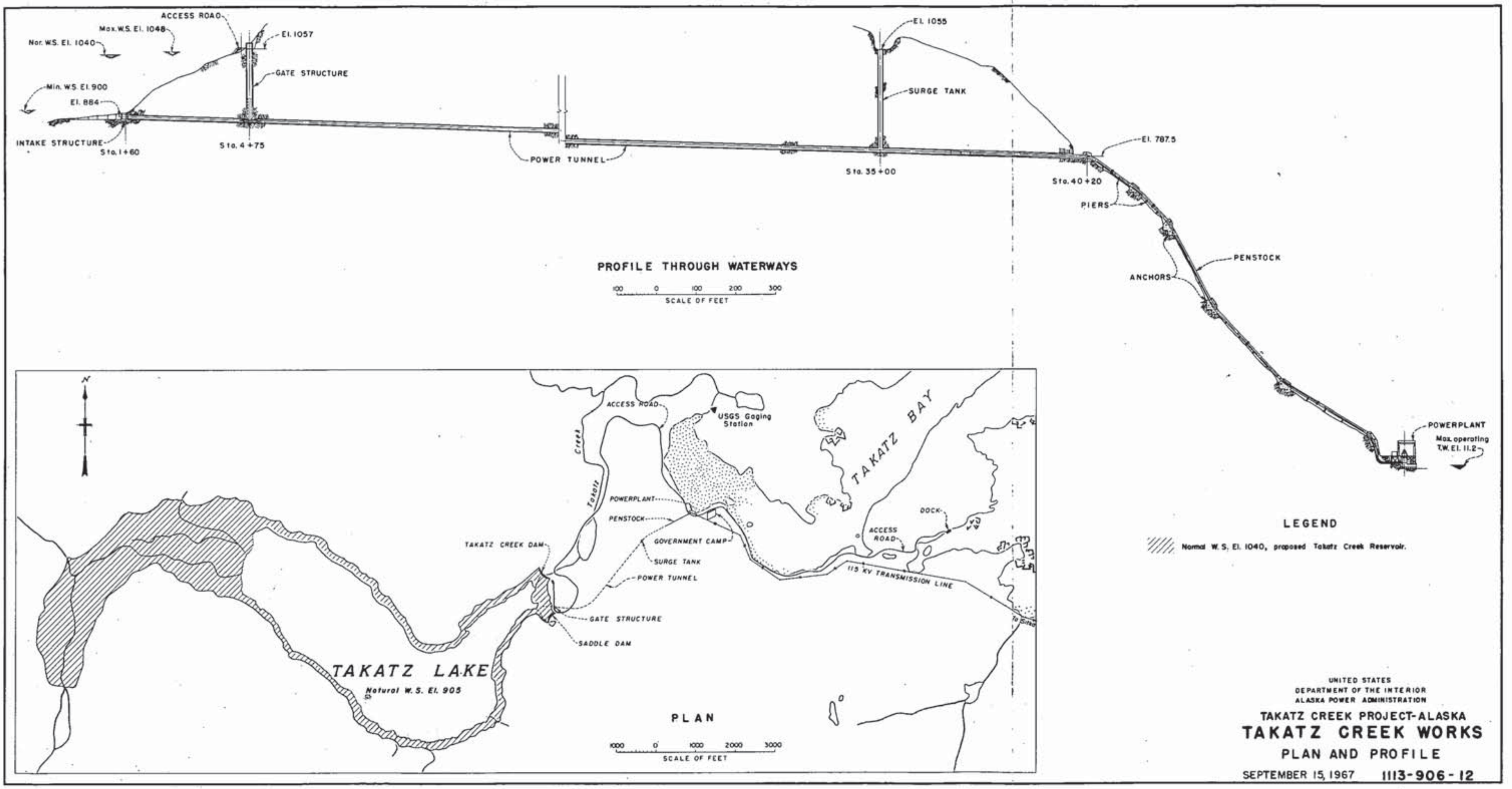


Figure 2-2 Takatz Project Plan and Profile, from 1968 Study

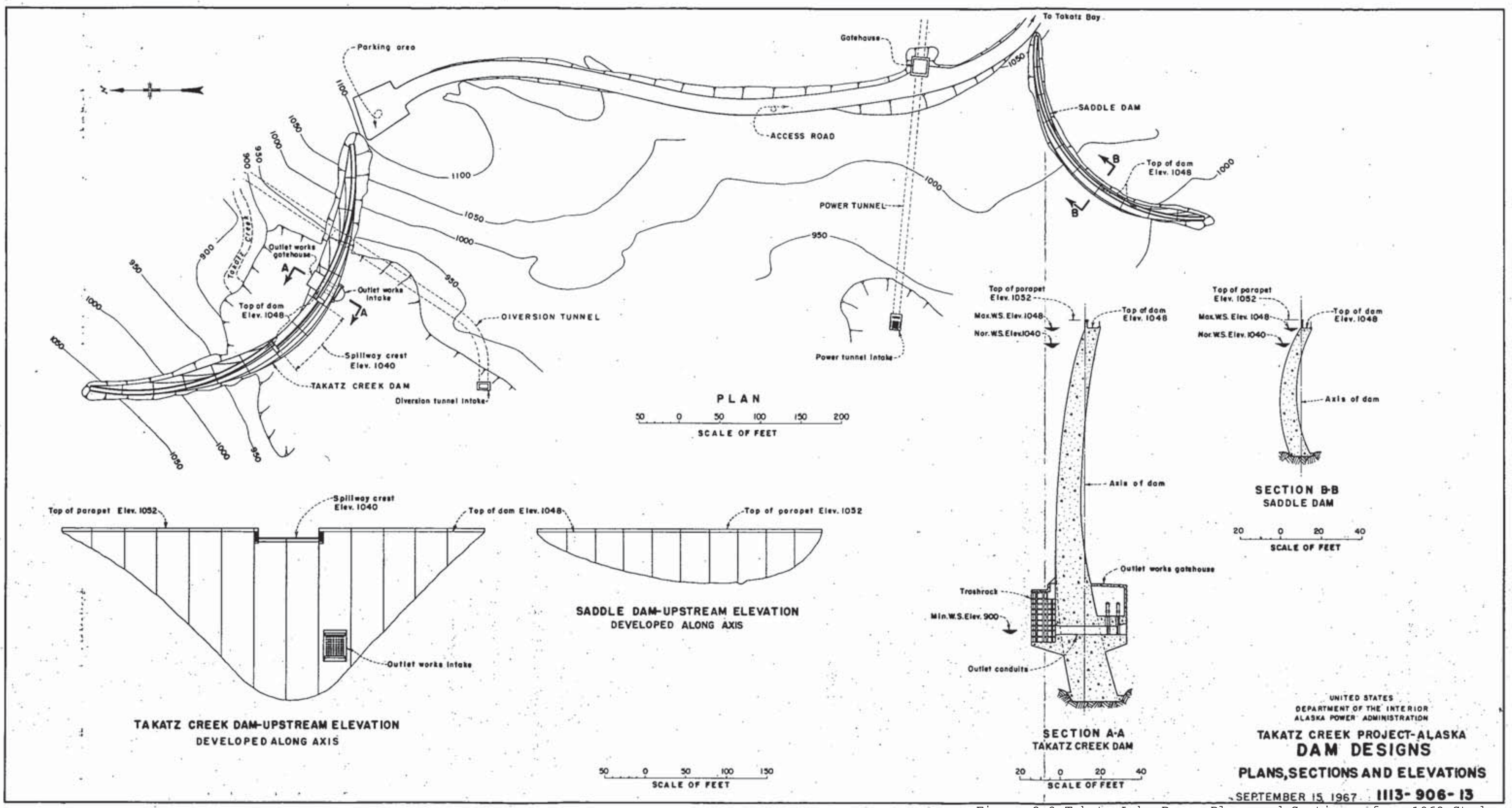


Figure 2-3 Takatz Lake Dams, Plans and Sections, from 1968 Study

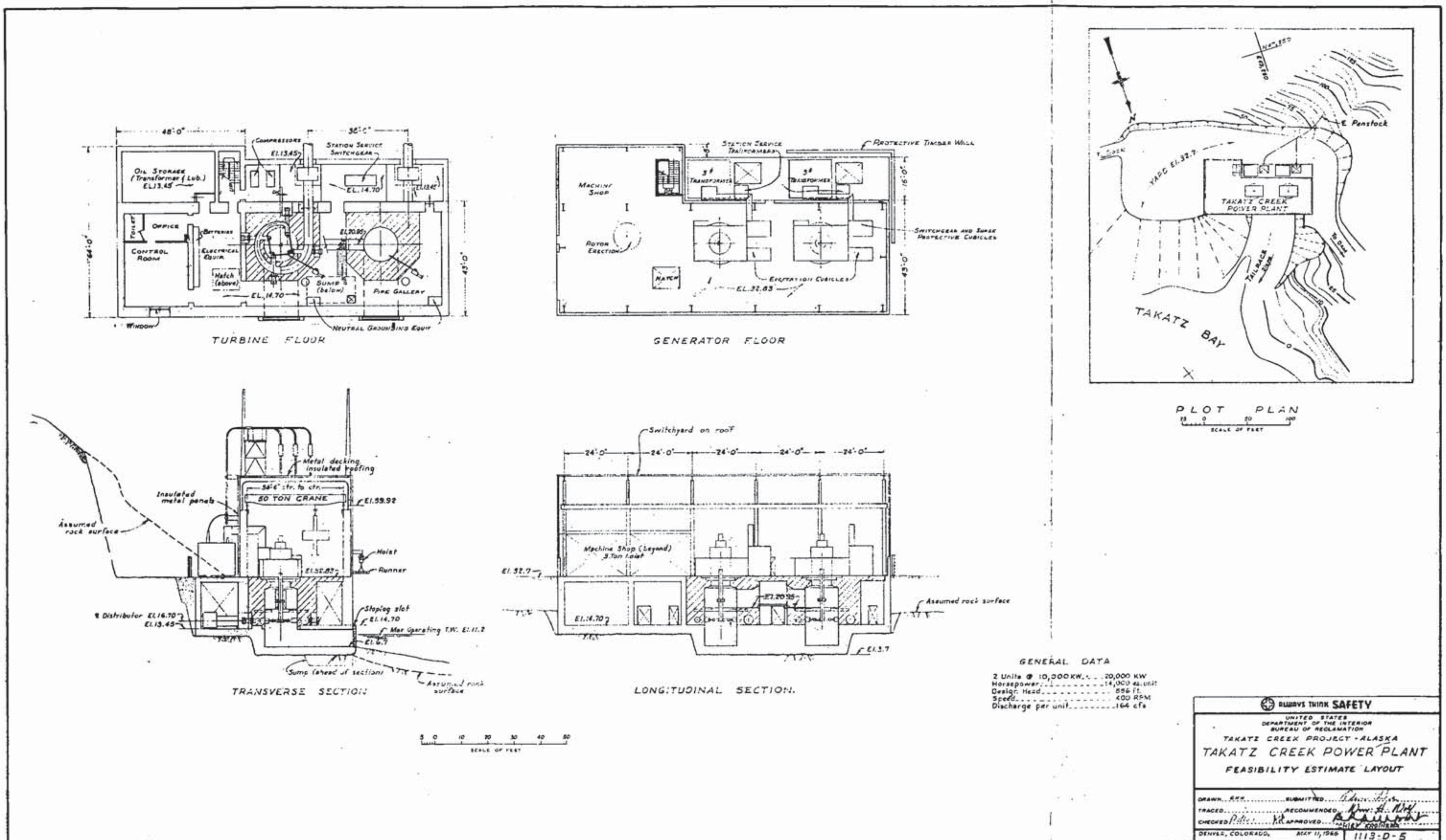


Figure 2-4 Takatz Lake Powerhouse, Plans and Sections, from 1968 Study

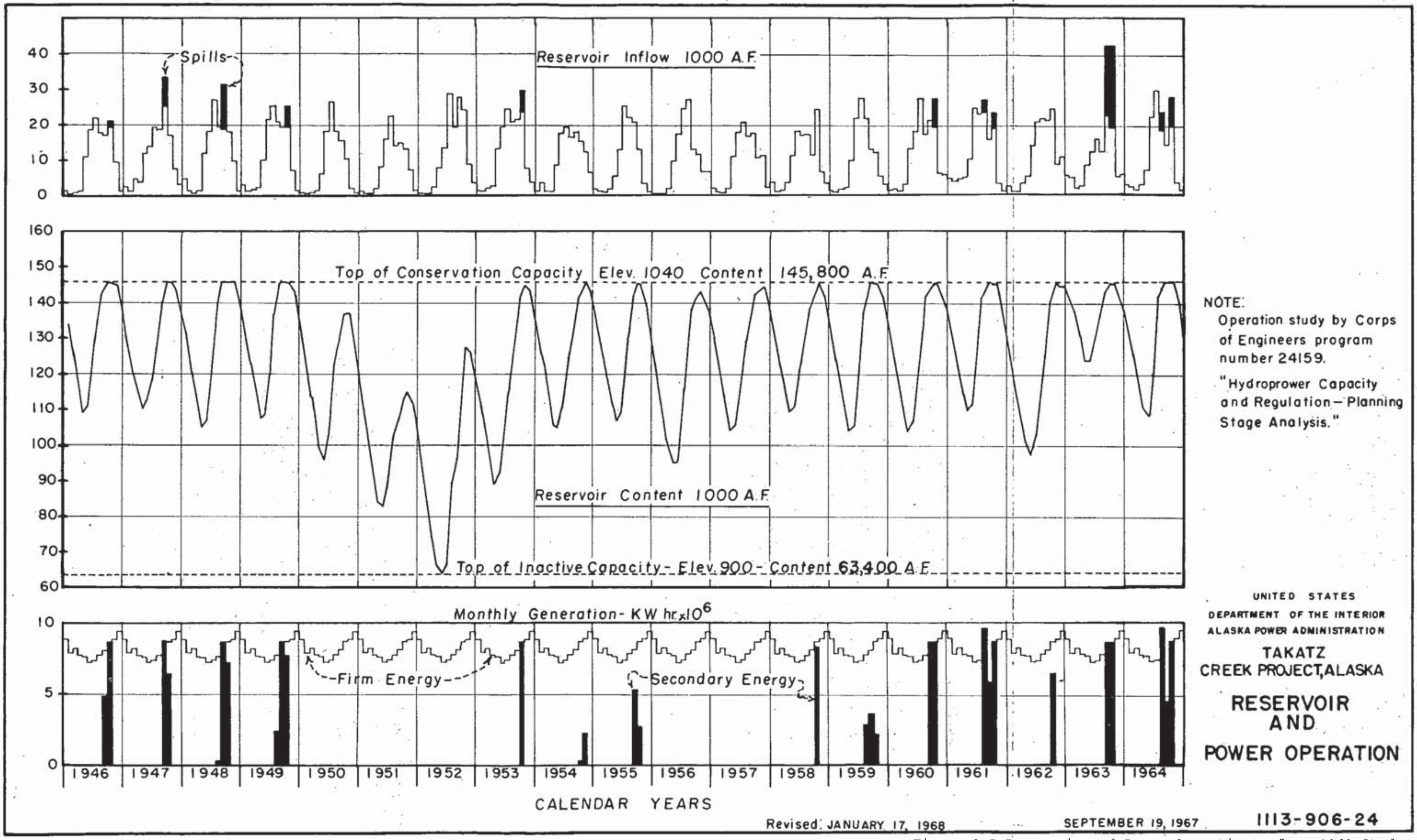
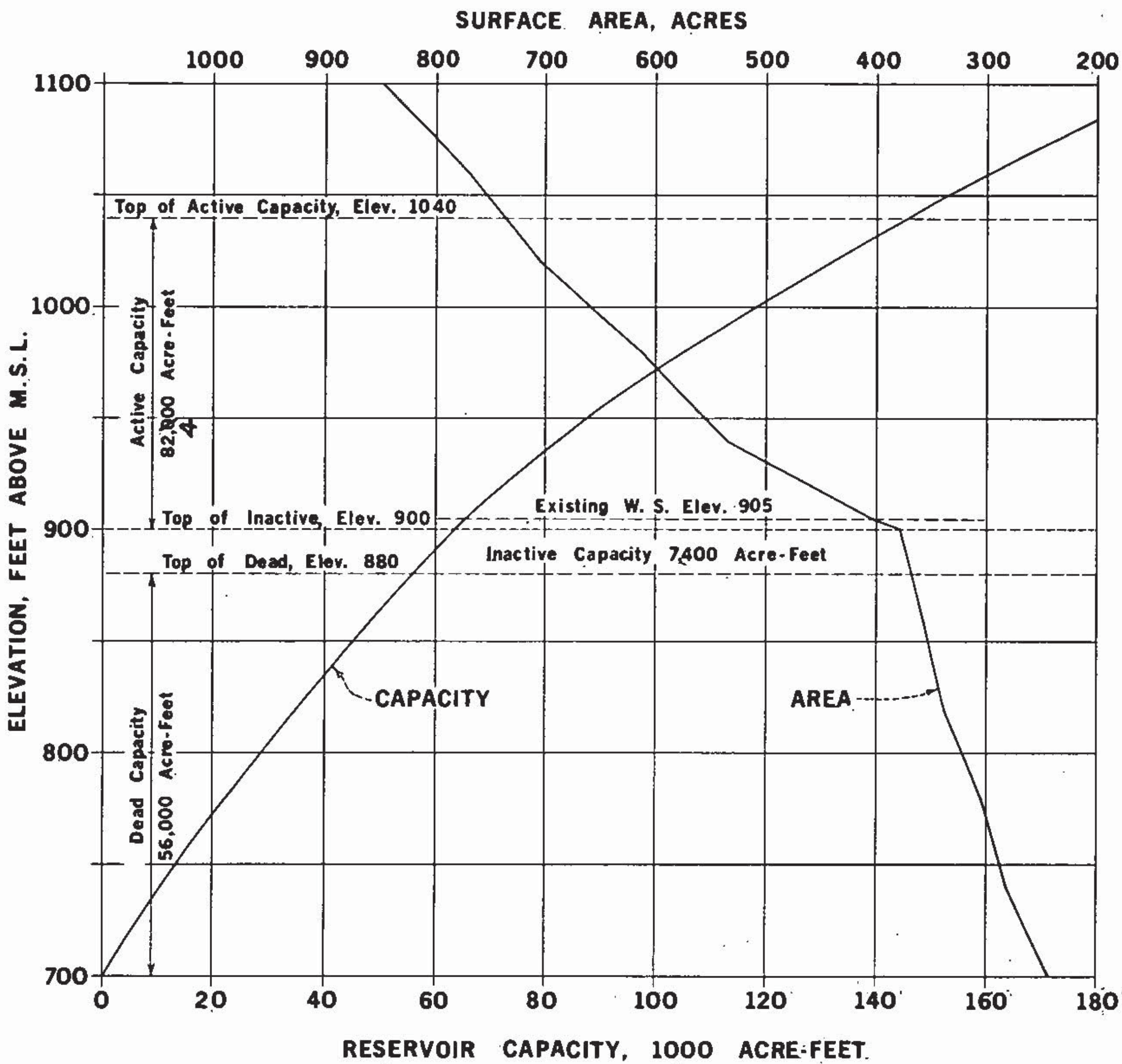


Figure 2-5 Reservoir and Power Operations, from 1968 Study



ELEV. (Feet)	AREA (Acres)	CAPACITY (Ac.-Ft.)
700	243	0
740	281	10,400
780	304	22,100
820	336	34,900
860	357	48,700
900	378	63,400
905	403	65,400
940	535	82,200
980	612	105,200
1020	703	131,400
1060	769	160,900
1100	848	193,200

NOTES:

1. Data source, U.S.G.S. Topography sheet Takatz Creek, Alaska, 1957.
2. Capacity below Elev. 700 not determined.

UNITED STATES
DEPARTMENT OF THE INTERIOR
ALASKA POWER ADMINISTRATION

TAKATZ CREEK PROJECT

AREA-CAPACITY DATA

September 15, 1967 1113-906-14

Figure 2-6 Area-Capacity Curve, from 1968 Study

SECTION 3 – HYDROLOGY

3.1 Streamflow Records on Takatz Creek

Streamflow data for the Takatz Creek outlet (near tidewater) and the outlet of Takatz Lake are quite limited. The outflow of Takatz Creek near tidewater (USGS gage No. 15100000) was gaged from July 1951 to September 1969. Over this 18 year period the average annual discharge from the basin was 256 cfs. The drainage area at this gage is 17.5 square miles, which is 62% larger than the 10.8 square mile drainage area at the outlet of Takatz Lake.

In October 2008 the USGS installed a stream gage at the outlet of Takatz Lake (USGS gage No. 15099900 – Takatz Creek at Takatz Lake Outlet near Baranof AK). Consequently only two years of direct streamflow data are available for the Takatz Lake outlet. This data was provisional at the time of our study effort, in part because the flow rating table for the gage site has not been fully developed by USGS staff. Because of this data's short record and provisional nature, it was not used in estimating flows from Takatz Lake.

The 1968 Study's hydrology work did include a detailed estimate of Takatz Lake outflows for the 1946 to 1964 period (a 19 year record). This record was developed from the 1951 to 1964 Takatz Creek gage record, using an areal adjustment for flows at the mouth of Takatz Creek vs. flows at the lake outlet, and from correlations to neighboring stream records for the years from 1946 to 1950. The estimating methodology was well documented in the 1968 Study report. As a result, the 2011 study team was able to extend the Takatz Lake outflows estimated in 1968 to include a longer record which is more suitable for the 2011 power operations studies.

3.2 Hydrology Studies in the 1968 Study

Appendix A of the 1968 Study document (pages A-1 to A-33) includes a discussion of the climate, typical hydrology and streamflow data available at the time of that study. The hydrological analysis included a comparison of precipitation and temperature records between the east and west sides of Baranof Island to help characterize the likely basin yield at Takatz Lake. The analysis compared the limited Takatz Creek streamflow record to other waterways on Baranof Island that had longer gage records, notably Sawmill Creek near Sitka and the Baranof River. The evaluation also compared the average runoff of 22 Southeast Alaska streams and rivers, based on the average elevation of each stream's drainage basin (Figure 3-1). That analysis established a unit runoff for Takatz Lake of 12,300 acre-ft of water per square mile per year, which equates to an average annual runoff at the lake outlet of 17 cfs per sq mile.

The 1968 Study compiled available monthly flow distribution data for the following streams: Takatz Creek; Baranof River; Sawmill Creek; Green Lake outlet; Maksoutof River, Deer Lake outlet; and Coal Creek. This data was used to develop an areal correlation between the expected Takatz Lake outflows vs. the recorded flows of Takatz Creek at gage no. 15100000. That correlation determined that the estimated annual Takatz Lake outflow is 65.3% of the measured outflow at the Takatz Creek gage (i.e., the higher elevations of the Takatz Creek basin above the lake, which comprise 60.6% of the basin area, account for 65.3% of the total basin flow). Note also that the 1968 analysis considered the basin area above Takatz Lake to be only 10.6 square miles. This reduction from 10.8 sq miles is due to the saddle dam proposed in the 1968 Study. The saddle dam actually cuts off 0.2 square miles of the natural drainage basin feeding the lake.

A seasonal adjustment factor was developed in the 1968 Study, which accounted for the high elevation of the Takatz Lake basin. Runoff from these high elevations is characterized by very low flows in the November to April months, when the basin is largely frozen. Runoff from the basin is concentrated in the July to October period when warmer conditions, snowmelt, and rain produce most of the basin's annual flow. That seasonal variation in flows was estimated as shown in Table 3-1.

Table 3-1 Seasonal Runoff Distribution for Takatz Lake (from 1968 Study)

	Runoff, percent of annual flow		
Season	Nov - Apr	May - June	July - Oct
Percent of annual flow	15.0	20.7	64.3

The 1968 hydrology development used the areal and seasonal runoff correlations described above to estimate the monthly flows at the Takatz Lake outlet, for the years from 1952 to 1964.

Annual flows at the Takatz Creek gage site, from 1946 to 1951 were estimated using a streamflow correlation between Sawmill Creek and Takatz Creek flows. The correlation equation and its error from actual gage records are shown in Figure 3-2. The estimated annual basin flows derived from this equation were then distributed on a monthly basis using the correlation equations shown in Table 3-2. The resulting estimated 1946 to 1951 Takatz Creek monthly flows were then further adjusted for the areal and seasonal correlations to estimate the 1946 to 1951 monthly inflows to Takatz Lake. The combined data set, of monthly Takatz Lake inflows for the 1946 to 1964 period is shown in Table 3-3.

Figure 3-1 Takatz Lake Estimated Runoff per sq. mile, from 1968 Study

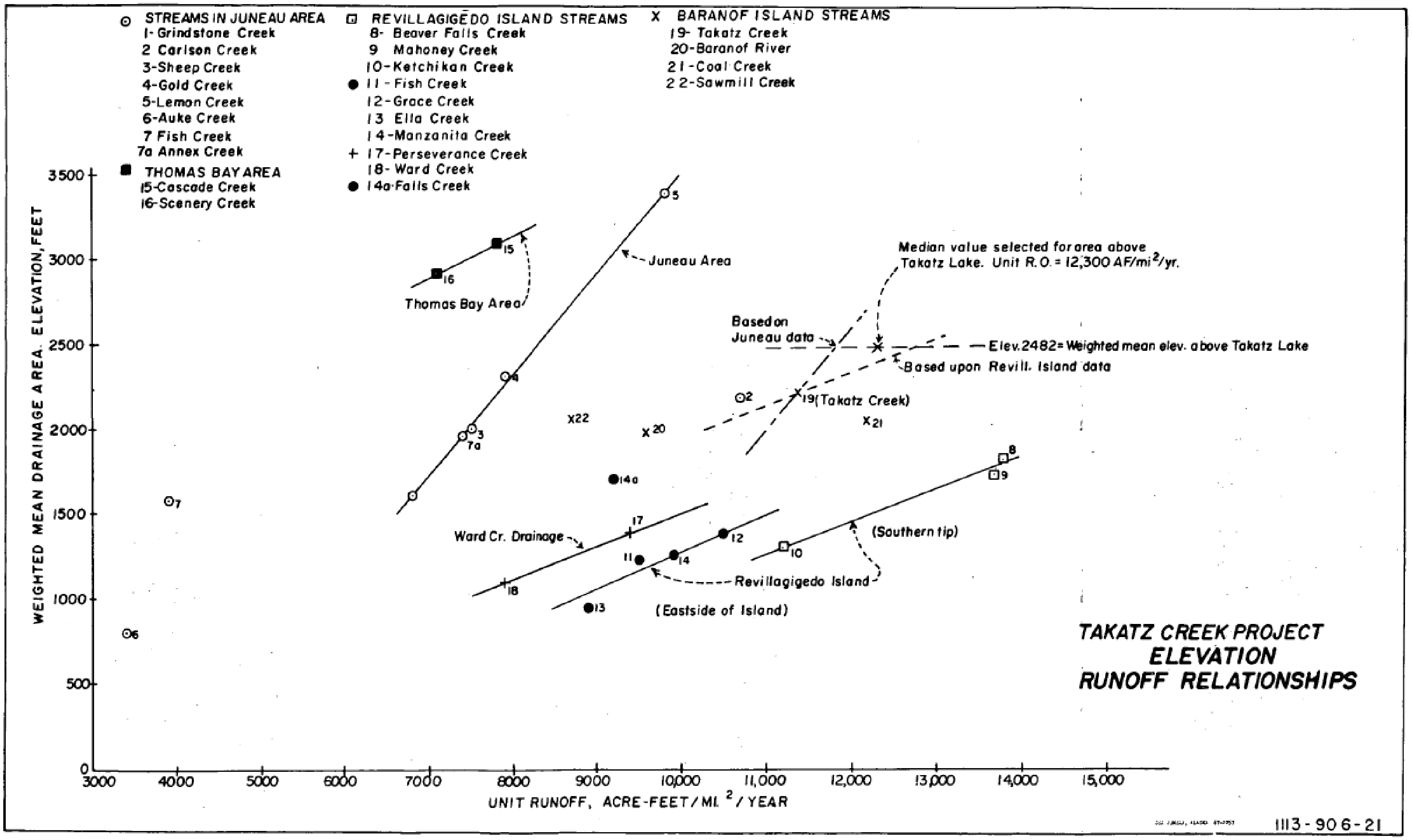


Figure 3-2 Flow Correlation between Takatz Creek and Sawmill Creek, from 1968 Study

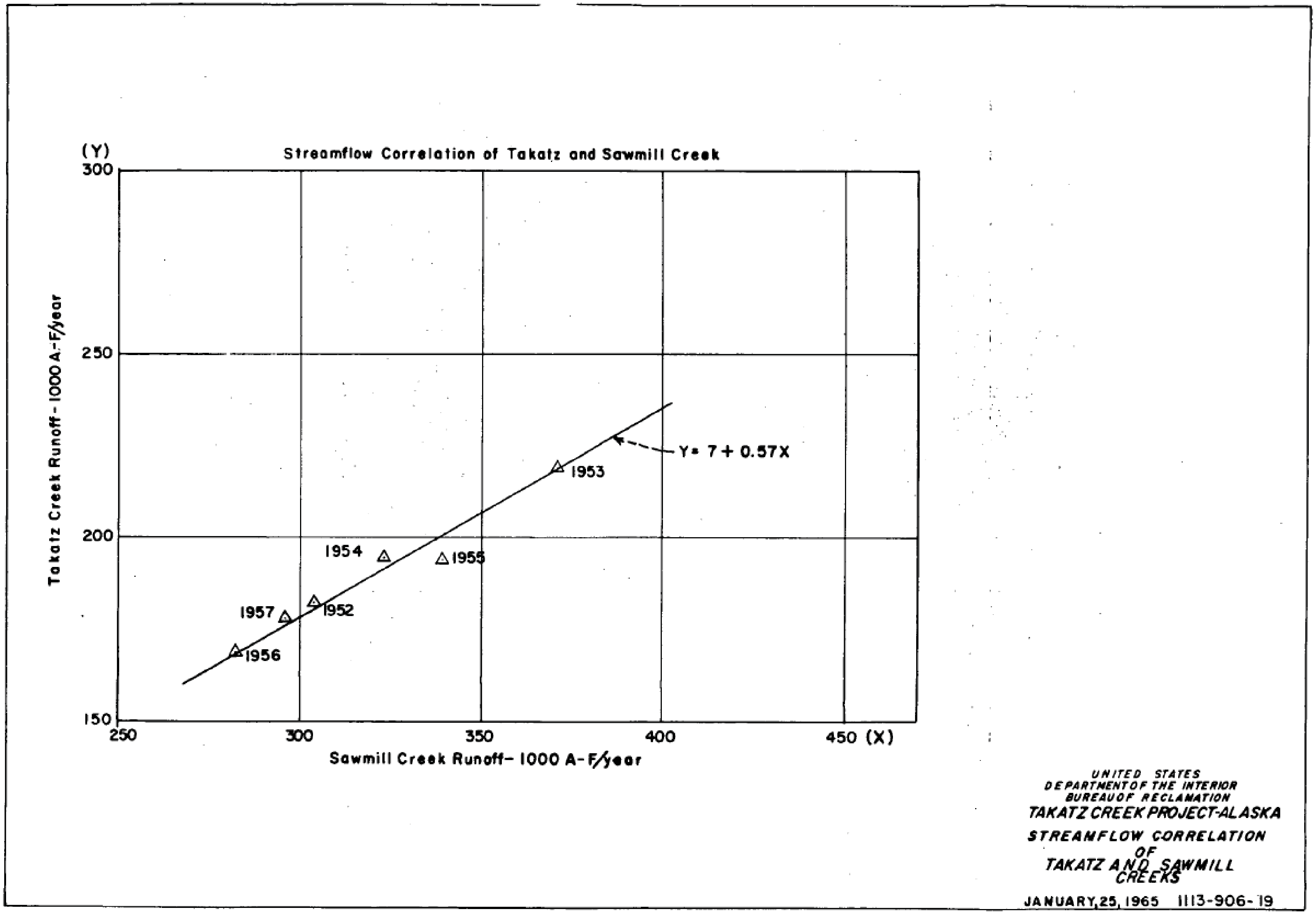


Table 3-2 Monthly Flow Correlation: Takatz Creek to Sawmill Creek, from 1968 Study

Table 10--Computations for Takatz Creek Flow, 1946-1951

A. Equations: (y) Takatz Flow; (x) Sawmill Creek Flow

Units: 1,000 Acre-Feet

Annual: $y = 7.0 + 0.57x$ Ave. Error 3%

Monthly Equations:		Ave. Error, Percent
November-April:	$y = 0.6 + 0.372x$	(Not Computed)
Sept. & October:	$y = 3.3 + 0.524x$	8.5
May:	$y = 0.485x$	16.9
June:	$y = 0.652x$	13.1
July:	$y = 9.8 + 0.535x$	5.6
August:	$y = 2.7 + 0.633x$	6.7

B. Sample Computations:

Month	Sawmill Recorded Flow (y)	Takatz Flow by Monthly Equation	Adjustment to Annual Value	Correlated Takatz Flow
(1946)				
October	67.1	38.5	-.6	37.9
November	18.2	7.4	-.1	7.3
December	7.9	3.5	-.1	3.4
January	6.9	3.2	-.1	3.1
February	3.0	1.7	-	1.7
March	4.5	2.3	-	2.3
April	5.8	2.8	-.1	2.7
May	39.6	19.2	-.3	18.9
June	49.1	32.0	-.5	31.5
July	37.6	29.9	-.5	29.4
August	34.4	24.5	-.4	24.1
September	39.6	24.1	-.4	23.7
Annual	313.7	189.1	-3.1	186.0 a/

a/ $y = 7.0 + 0.57\ (313.7) = 186.0$

Table 3-3 Computed Inflow to Takatz Lake 1946 to 1964 Water Years, from 1968 Study

(JUL 53)
BUREAU OF RECLAMATION

HYDROGRAPHIC DISCHARGE DATA

TABLE 14 --

Computed Inflow to Takatz Lake — Unit 1000 AF — Drainage Area 10.6 Sq. Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL	PERCENT MEAN
1946	27.8	3.6	1.7	1.5	0.8	1.1	1.3	11.0	18.3	21.6	17.7	17.4	123.8	
1947	21.4	9.3	1.4	2.3	1.3	4.6	3.8	12.2	13.8	19.3	18.7	33.6	141.7	
1948	17.0	7.4	2.9	4.5	1.1	0.9	1.0	11.9	18.0	26.5	19.7	31.1	142.0	
1949	17.9	9.8	1.6	3.1	1.2	1.8	2.2	10.0	20.9	24.9	20.2	18.8	132.4	
1950	24.8	6.6	1.6	0.9	0.7	0.8	1.1	6.1	18.1	26.0	17.5	15.3	119.5	
1951	10.4	1.9	0.8	1.0	0.6	0.7	1.9	8.0	15.8	22.0	14.0	14.7	91.8	
1952	13.1	7.2	1.6	0.6	0.6	0.5	2.4	7.5	13.7	28.3	19.0	27.6	122.1	
1953	24.0	8.7	3.5	1.7	1.6	2.1	2.7	13.3	19.2	24.0	20.7	21.3	142.8	
1954	29.5	7.2	3.9	1.5	3.5	1.1	1.0	8.5	17.5	19.3	16.2	17.9	127.1	
1955	15.5	12.3	6.7	1.9	1.3	1.2	1.6	5.2	12.9	24.9	22.0	20.4	125.9	
1956	12.8	3.0	1.1	0.7	0.7	0.7	1.9	9.8	17.4	24.5	27.2	13.1	112.9	
1957	11.9	6.6	6.4	2.0	1.1	1.0	1.9	10.8	17.8	20.5	16.5	17.7	114.2	
1958	10.6	11.3	2.2	4.0	1.2	1.5	3.5	11.4	18.1	17.1	17.4	11.8	110.1	
1959	24.1	6.5	3.4	1.4	1.2	1.9	2.3	9.9	21.6	27.4	21.2	13.1	134.0	
1960	12.2	5.5	3.3	1.5	1.8	1.4	2.8	13.3	17.9	26.9	17.3	21.0	124.9	
1961	27.6	6.1	6.0	2.6	2.0	2.6	3.2	10.2	24.4	22.7	26.6	15.7	149.7	
1962	23.3	3.6	1.4	2.3	1.2	1.1	3.6	5.6	14.1	20.6	21.8	21.3	119.9	
1963	24.4	8.7	10.6	6.0	5.4	2.1	2.6	8.7	12.5	15.9	12.7	42.5	152.1	
1964	42.4	5.5	6.6	3.1	2.5	1.5	2.7	6.9	22.0	29.1	23.2	14.0	159.5	
(f)	.735	.497	.497	.497	.497	.497	.497	.582	.582	.735	.735	.735		
TOTAL	390.7	130.8	66.7	42.6	29.8	28.6	43.5	180.3	334.0	441.5	369.6	388.3	2446.4	
MEAN	20.6	6.9	3.5	2.2+	1.6-	1.5	2.3	9.5	17.6	23.2	19.4+	20.5-	128.8	
PERCENT	16.0	5.4	2.7	1.7	1.2	1.2	1.8	7.4	13.6	18.0	15.1	15.9	100.0	

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3.3 Hydrology Developed for 2011 Study Work

For purposes of this 2011 study, we determined that the 1968 methodology was adequate to meet the goals of the capacity analyses. If a further refinement of this study is pursued in the future, the hydrology record could be improved by using actual streamflow data from the proposed project site. Essentially, the 2011 hydrology work amounted to replicating the 1968 methodology to verify it, and then using the series of calculations developed in 1968 to extend the record from 1946-1964 to 1946-1968. It should also be noted that while the 1968 study work focused on water years, hydrology in this study report is summarized on a calendar year basis. This shift from a water year basis to a calendar year was made to be consistent with Sitka's current hydro operations model.

3.3.1 Source Data

The primary data sources used to develop the Takatz Lake streamflow data were the USGS gages 15088000 Sawmill Creek Near Sitka, AK and 15100000 Takatz Creek Near Baranof, AK.

3.3.2 Study Methodology

As described in section 3.2, the 1968 report outlines the methodology for synthesizing an inflow record for Takatz Lake for water years 1946 through 1964. At the time of that study, the Takatz Creek data beyond 1964 was still provisional. For the current study we utilized the same methodology to extend the period of record to include 1965-1968 (incorporating the full record of the Takatz Creek gage data). The steps followed are summarized below:

1. Annual and seasonal correlations between Sawmill Creek flows and Takatz Creek flows are used to extend the Takatz Creek period of record. After this step the Takatz Creek flow record extends from 1946-1968. The 1946-1951 data is the synthesized record from Sawmill Creek (see Table 3-4).
2. Seasonal/Areal flow ratios were used to synthesize Takatz Lake inflows from the Takatz Creek gaged flows. Reflecting the higher elevation and reduction of total basin size, this step transforms the monthly Takatz Creek flows developed in Step 1 into Takatz Lake monthly inflows. (see Table 3-5). Note that Table 3-5 presents calculated flows for a Takatz Lake drainage area of 10.6 sq miles. This is the effective drainage area if a saddle dam is constructed as part of the project. The saddle dam would actually cut off 0.2 sq miles of drainage area, reducing the net inflow by a bit less than two percent.
3. For development options that do not include the saddle dam the areal inflow ratio was increased by 1.89%, effectivly increasing all estimated inflows to Takatz Lake by 1.89%. This adjustment reflects the difference between the lake's gross drainage area (10.8 square miles) vs. the net area with the saddle dam (10.6 sq miles). The resulting estimated Takatz Lake inflows with no saddle dam are shown in Table 3-6.

Table 3-4 Takatz Creek Monthly Average Flows

		Takatz Creek Monthly Average Flows (cfs) - 17.5 mi^2 Drainage Area												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Avg
Takatz Creek From Sawmill	1946	50.7	30.4	36.4	45.5	307.3	529.4	478.0	390.9	397.3	476.2	314.4	46.5	259.8
	1947	74.4	50.0	153.2	127.5	340.0	402.8	429.7	413.9	767.7	379.3	253.5	94.1	291.4
	1948	148.0	39.1	30.1	33.8	333.6	520.1	588.8	437.4	710.8	395.9	332.7	52.3	303.0
	1949	102.0	41.9	59.6	73.3	278.9	603.7	552.9	446.6	428.1	548.2	224.0	55.1	286.0
	1950	27.9	27.1	26.0	37.5	168.7	524.3	577.6	387.3	350.5	239.5	67.5	26.8	206.1
	1951	35.2	21.8	25.6	66.3	234.6	478.9	449.9	309.3	324.4	266.2	226.0	53.6	208.4
Takatz Creek from USGS Data	1952	20.0	20.0	17.0	80.1	209.8	395.0	586.9	420.0	482.0	463.1	283.8	115.0	259.1
	1953	56.5	58.6	68.8	90.4	372.5	547.3	523.3	441.5	456.6	519.3	226.3	128.8	292.3
	1954	49.7	125.5	35.7	33.5	237.7	502.8	427.8	357.2	364.6	284.3	401.0	205.4	252.3
	1955	62.8	47.3	39.1	54.1	144.0	370.9	544.0	466.1	426.6	282.3	100.4	36.9	215.7
	1956	22.8	24.0	25.0	63.9	274.8	466.8	541.6	541.2	299.3	251.5	222.6	197.7	245.9
	1957	66.2	40.3	33.4	65.6	300.8	512.0	447.6	363.5	348.3	233.9	302.7	73.1	233.0
	1958	130.3	45.4	50.0	118.2	318.5	523.3	378.6	385.3	268.5	454.3	205.5	110.7	250.4
	1959	47.4	44.9	62.6	77.4	277.3	607.7	580.3	438.4	294.9	269.3	186.8	108.3	250.8
	1960	49.5	64.4	47.8	95.2	371.8	515.7	590.1	382.5	409.0	521.0	202.3	195.8	288.7
	1961	85.0	72.1	86.7	106.9	286.2	585.9	492.1	467.0	355.4	411.6	121.2	45.2	260.8
	1962	74.9	44.5	37.3	120.1	155.7	404.9	455.3	459.3	448.7	442.0	295.3	280.2	269.5
	1963	175.9	195.9	70.0	88.4	242.2	362.0	352.4	281.1	779.5	673.8	184.3	213.8	301.9
	1964	102.5	86.7	49.4	90.1	192.1	627.6	606.5	493.5	320.8	453.3	194.4	149.7	281.8
	1965	128.8	50.0	59.1	85.6	144.2	412.7	489.5	334.9	278.5	587.8	116.5	80.6	232.3
	1966	22.9	31.2	58.7	86.8	245.5	482.5	507.8	412.3	548.0	351.9	136.8	47.5	245.3
	1967	53.5	45.6	22.5	37.0	250.4	520.1	468.5	441.0	685.9	309.5	280.3	63.3	265.3
	1968	38.3	87.7	142.0	73.7	303.5	542.7	420.7	364.5	580.4	284.5	188.2	54.9	257.2
Average		70.7	56.3	53.7	76.1	260.4	497.4	499.6	410.2	448.9	395.6	220.3	105.9	259.0
Maximum		175.9	195.9	153.2	127.5	372.5	627.6	606.5	541.2	779.5	673.8	401.0	280.2	303.0
Minimum		20.0	20.0	17.0	33.5	144.0	362.0	352.4	281.1	268.5	233.9	67.5	26.8	206.1
Median		56.5	45.4	47.8	77.4	274.8	515.7	492.1	413.9	409.0	395.9	222.6	80.6	259.1

Table 3-5 Takatz Lake Monthly Average Inflows (with Saddle Dam)

		Takatz Lake Monthly Average Flows (cfs) - with Saddle Dam 10.6 mi^2												
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann Avg**
Takatz Lake From Sawmill	1946	25.2	15.1	18.1	22.6	178.9	308.1	351.3	287.3	292.0	350.0	156.3	23.1	168.9
	1947	37.0	24.8	76.1	63.4	197.9	234.4	315.8	304.2	564.3	278.8	126.0	46.8	188.5
	1948	73.5	19.4	14.9	16.8	194.2	302.7	432.7	321.5	522.5	291.0	165.4	26.0	197.9
	1949	50.7	20.8	29.6	36.4	162.3	351.4	406.4	328.3	314.7	402.9	111.3	27.4	187.0
	1950	13.9	13.5	12.9	18.6	98.2	305.1	424.6	284.7	257.6	176.0	33.5	13.3	137.6
	1951	17.5	10.8	12.7	33.0	136.5	278.7	330.7	227.3	238.4	195.7	112.3	26.7	134.8
Takatz Lake from USGS Data	1952	9.9	9.9	8.4	39.8	122.1	229.9	431.4	308.7	354.2	340.4	141.1	57.1	171.0
	1953	28.1	29.1	34.2	44.9	216.8	318.5	384.6	324.5	335.6	381.7	112.5	64.0	189.2
	1954	24.7	62.4	17.7	16.6	138.3	292.6	314.4	262.6	268.0	208.9	199.3	102.1	158.8
	1955	31.2	23.5	19.4	26.9	83.8	215.9	399.9	342.6	313.5	207.5	49.9	18.4	144.4
	1956	11.3	11.9	12.4	31.7	159.9	271.7	398.1	397.8	220.0	184.9	110.6	98.3	158.8
	1957	32.9	20.0	16.6	32.6	175.1	298.0	329.0	267.1	256.0	171.9	150.4	36.3	148.5
	1958	64.8	22.6	24.9	58.7	185.4	304.5	278.3	283.2	197.3	333.9	102.1	55.0	159.2
	1959	23.5	22.3	31.1	38.5	161.4	353.7	426.5	322.2	216.7	197.9	92.8	53.8	161.5
	1960	24.6	32.0	23.8	47.3	216.4	300.1	433.7	281.1	300.6	382.9	100.5	97.3	186.1
	1961	42.2	35.8	43.1	53.1	166.6	341.0	361.7	343.2	261.2	302.5	60.2	22.5	169.4
	1962	37.2	22.1	18.5	59.7	90.6	235.7	334.6	337.6	329.8	324.9	146.7	139.3	173.4
	1963	87.4	97.4	34.8	43.9	141.0	210.7	259.0	206.6	573.0	495.2	91.6	106.3	195.3
	1964	51.0	43.1	24.5	44.8	111.8	365.3	445.8	362.8	235.8	333.2	96.6	74.4	182.8
	1965	64.0	24.9	29.4	42.5	83.9	240.2	359.7	246.2	204.7	432.0	57.9	40.1	152.6
	1966	11.4	15.5	29.2	43.1	142.9	280.8	373.2	303.0	402.8	258.6	68.0	23.6	162.4
	1967	26.6	22.7	11.2	18.4	145.7	302.7	344.4	324.2	504.1	227.5	139.3	31.4	174.5
	1968	19.0	43.6	70.6	36.6	176.6	315.9	309.2	267.9	426.6	209.1	93.5	27.3	165.9
Average		35.1	28.0	26.7	37.8	151.6	289.5	367.2	301.5	330.0	290.8	109.5	52.6	168.2
Maximum		87.4	97.4	76.1	63.4	216.8	365.3	445.8	397.8	573.0	495.2	199.3	139.3	197.9
Minimum		9.9	9.9	8.4	16.6	83.8	210.7	259.0	206.6	197.3	171.9	33.5	13.3	134.8
Median		28.1	22.6	23.8	38.5	159.9	300.1	361.7	304.2	300.6	291.0	110.6	40.1	168.9

Table 3-6 Takatz Lake Monthly Average Inflows (without Saddle Dam)

		Takatz Lake Monthly Average Flows (cfs) - No Saddle Dam 10.8 mi^2												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Avg
Takatz Lake From Sawmill	1946	25.7	15.4	18.4	23.0	182.2	313.8	357.7	292.6	297.4	356.4	159.1	23.5	172.0
	1947	37.7	25.3	77.5	64.5	201.5	238.7	321.7	309.8	574.6	283.9	128.3	47.7	192.0
	1948	74.9	19.8	15.2	17.1	197.7	308.2	440.7	327.4	532.1	296.4	168.4	26.5	201.5
	1949	51.6	21.2	30.2	37.1	165.3	357.8	413.9	334.3	320.5	410.3	113.4	27.9	190.4
	1950	14.1	13.7	13.2	19.0	100.0	310.7	432.4	289.9	262.3	179.3	34.1	13.6	140.1
	1951	17.8	11.0	12.9	33.6	139.0	283.8	336.8	231.5	242.8	199.3	114.4	27.2	137.3
Takatz Lake from USGS Data	1952	10.1	10.1	8.6	40.5	124.4	234.1	439.3	314.4	360.8	346.6	143.7	58.2	174.2
	1953	28.6	29.7	34.8	45.7	220.8	324.4	391.7	330.5	341.8	388.7	114.6	65.2	192.6
	1954	25.1	63.5	18.1	17.0	140.9	298.0	320.2	267.4	272.9	212.8	203.0	104.0	161.8
	1955	31.8	23.9	19.8	27.4	85.3	219.9	407.2	348.9	319.3	211.3	50.8	18.7	147.0
	1956	11.5	12.1	12.7	32.3	162.9	276.7	405.4	405.1	224.0	188.3	112.7	100.1	161.7
	1957	33.5	20.4	16.9	33.2	178.3	303.4	335.0	272.0	260.7	175.1	153.2	37.0	151.2
	1958	66.0	23.0	25.3	59.8	188.8	310.1	283.4	288.4	201.0	340.0	104.0	56.0	162.2
	1959	24.0	22.7	31.7	39.2	164.3	360.2	434.4	328.2	220.7	201.6	94.5	54.8	164.5
	1960	25.0	32.6	24.2	48.2	220.3	305.6	441.7	286.3	306.1	389.9	102.4	99.1	189.6
	1961	43.0	36.5	43.9	54.1	169.6	347.3	368.4	349.5	266.0	308.1	61.3	22.9	172.6
	1962	37.9	22.5	18.9	60.8	92.3	240.0	340.8	343.8	335.8	330.8	149.4	141.8	176.6
	1963	89.0	99.1	35.4	44.7	143.6	214.6	263.8	210.4	583.5	504.3	93.3	108.2	198.9
	1964	51.9	43.9	25.0	45.6	113.9	372.0	454.0	369.4	240.1	339.3	98.4	75.8	186.2
	1965	65.2	25.3	29.9	43.3	85.5	244.6	366.4	250.7	208.5	440.0	58.9	40.8	155.4
	1966	11.6	15.8	29.7	43.9	145.5	286.0	380.1	308.6	410.2	263.4	69.2	24.1	165.4
	1967	27.1	23.1	11.4	18.7	148.4	308.2	350.7	330.1	513.4	231.7	141.9	32.0	177.7
	1968	19.4	44.4	71.9	37.3	179.9	321.7	314.9	272.8	434.5	212.9	95.2	27.8	168.9
Average		35.8	28.5	27.2	38.5	154.4	294.8	373.9	307.0	336.0	296.1	111.5	53.6	171.3
Maximum		89.0	99.1	77.5	64.5	220.8	372.0	454.0	405.1	583.5	504.3	203.0	141.8	201.5
Minimum		10.1	10.1	8.6	17.0	85.3	214.6	263.8	210.4	201.0	175.1	34.1	13.6	137.3
Median		28.6	23.0	24.2	39.2	162.9	305.6	368.4	309.8	306.1	296.4	112.7	40.8	172.0

The flows in Table 3-5 are used in the operations modeling work to determine potential project output, for project arrangements that include the saddle dam and the reduced net drainage area of the Takatz Lake basin. The flows in Table 3-6 are used in the modeling work to determine potential project output for any project arrangement that does not include the saddle dam.

As mentioned previously, there are some issues with the limited flow record, as well as the reliance on statistical correlations to synthesize the record. For those reasons, if more detailed study of the project is performed in the future, improving the hydrologic record is recommended. Actual streamflow data would be desirable.

It should also be noted that while the current hydrology analysis followed the same methodology as the 1968 study, some discrepancies were found. The Takatz Creek USGS gage data for 1951 to 1964 utilized in the 1968 report is different than the currently published USGS record for the Takatz Creek gage for the same time period, 1951 to 1964. The differences appear to be clustered around months with days of relatively high flows (greater than 800 cfs, or so). It is likely that at some point after the 1968 study was completed the Takatz Creek gage rating curve was revised by the USGS, with the majority of the adjustment occurring at the higher flow readings.

Without the daily flows used in the report it is impossible to ascertain exact source of the differences, but study engineers believe the differences to be minor in the overall study scope. However, it does heighten the importance of gathering actual streamflow data at the project site.

The net effect of the changes made by the USGS was to reduce the USGS-documented average flow at the Takatz Creek gage from 269.9 cfs to255.1 cfs for the period from 1951 to 1964. This is a 5.5 percent reduction in average yield for the Takatz Creek basin during that 14 year period. The average flow reported by USGS for the 1965 to 1969 water years was 252.8 cfs. Combining this data for the last four years of the gage record with the revised USGS 1951 to 1964 data results in an average flow at the Takatz Creek gage of 254.5 cfs for the full 19 year USGS gage record.

Using the correlation functions developed in the 1968 study work and the updated USGS 1951 to 1968 flow records for Takatz Creek gives an estimated average Takatz Lake inflow of 169.2 cfs (for a 10.6 sq mile drainage area). This is 5 percent less than the 177.9 cfs average inflow documented in the 1968 study.

3.3.3 Hydrology Summary

The primary goal of the hydrology analysis is to create an inflow record for Takatz Lake to support the project capacity analyses. The following flow duration/exceedance charts summarize the hydrology data set developed in 2011 for inflows to Takatz Lake. These charts are based on calendar year flows from January 1, 1946 to December 31, 1968, a 23 year period of record.

Figure 3-3 Takatz Lake Flow Exceedance Curve

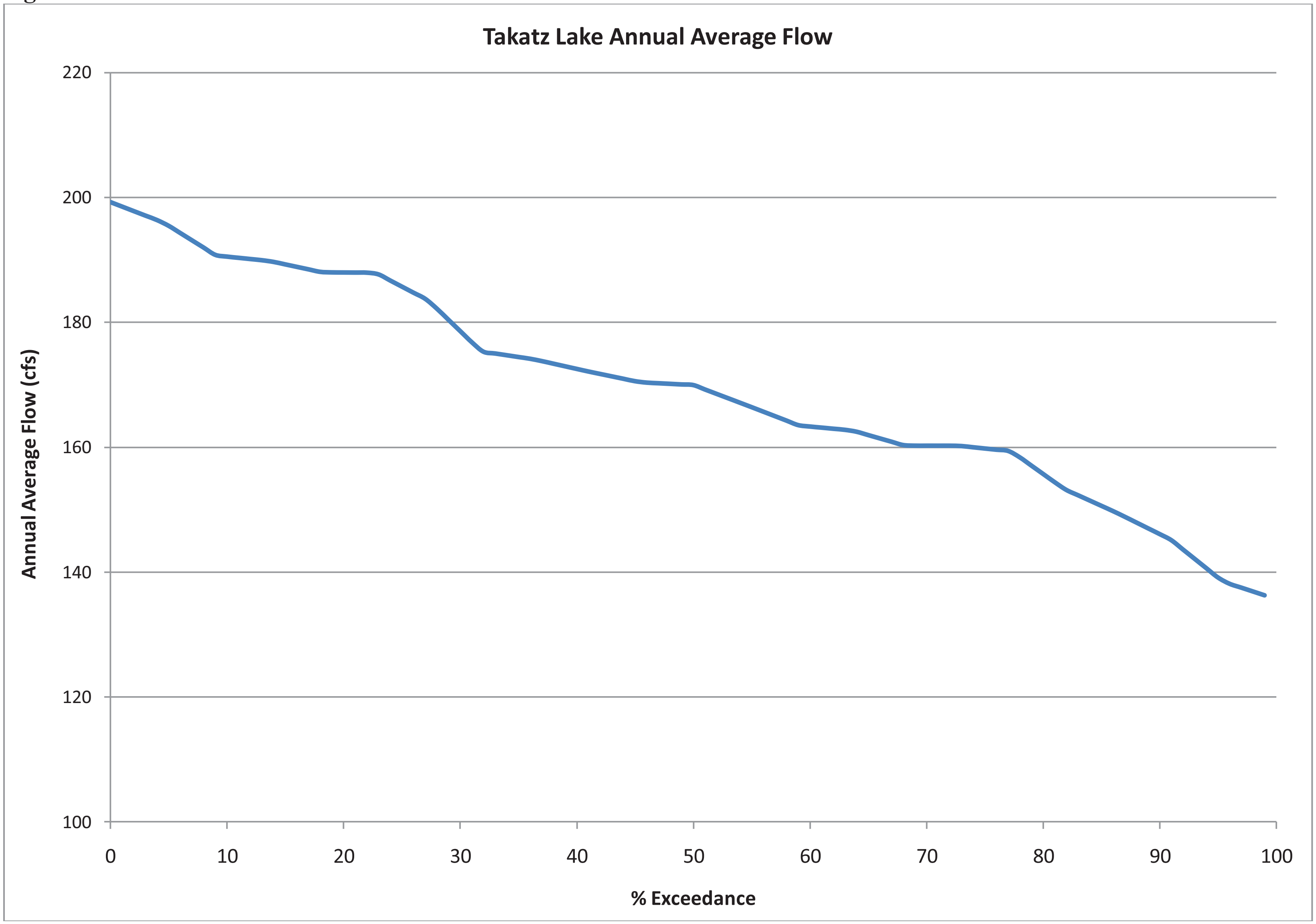
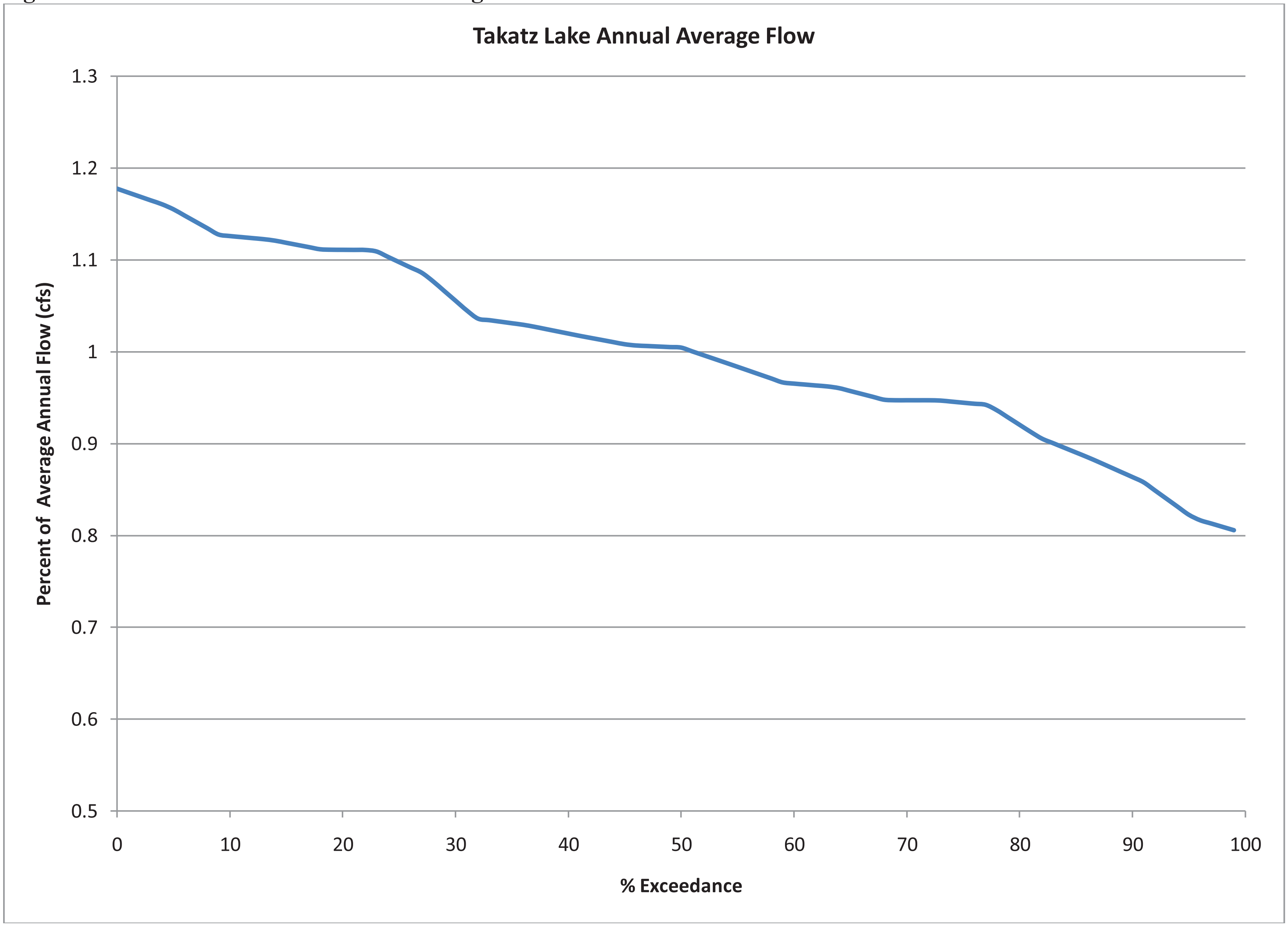


Figure 3-4 Historical Takatz Lake Average Annual Flow Exceedance Curve



SECTION 4 – RESERVOIR REGULATION ANALYSIS

4.1 Industry Norms for Flow Regulation

Reservoir storage in a hydroelectric development is typically used to store reservoir inflows and then release the stored water at a later time as power generation outflows. A hydro project with regular inflows and uniform loads may require only a small active storage volume in its reservoir, while a project that has highly variable inflows and loads may require a significant storage volume. In the hydro industry, the "regulated" outflow provided by a project is typically expressed as a percentage of the average project inflow. If enough storage is provided to regulate the entire inflow, the inflow is then defined as "fully regulated".

A simple "rule of thumb" developed by the USBR stated that a storage volume equivalent to 150 days of the average annual inflow would afford complete regulation of a typical stream. In the 1947 Study Report "Water Powers, Southeast Alaska" the stream run-off and likely regulation characteristics of 51 streams and rivers in Southeast Alaska were reviewed to determine what reservoir storage requirements might be for each of these streams. The study methodology considered both the seasonal and annual variation in runoff. That study found considerable variability in run-off from the 51 streams, such that a full regulation storage volume varied from 115 days inflow (32% of annual flow) to 355 days inflow (97% of annual flow), depending on the stream.

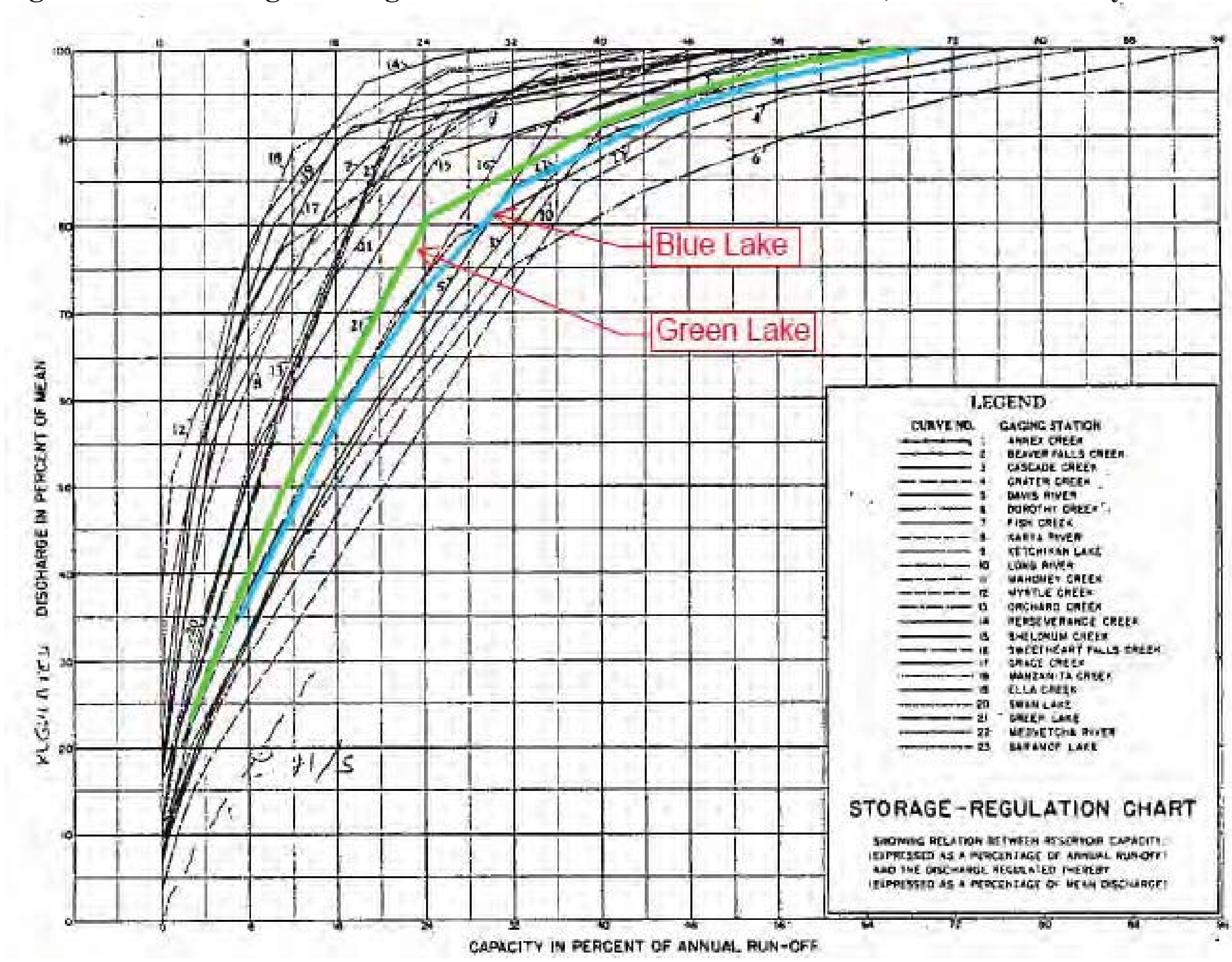
The storage vs. regulation relationship developed in the 1947 Study is presented in Figure 4.1, with the regulation curves for Green Lake and Blue Lake highlighted. Note that Takatz Creek was not included in this chart as it was not gaged at the time of the 1947 study.

In general, the drainage basins with the highest average elevations and high lakes required the largest storage volumes to regulate the inflow. These streams with high elevation basins have more "flashy" runoff characteristics where much of the annual flow is concentrated in a few months in the fall. The curves for these high elevation basins are grouped to the right of the figure and are typified by Dorothy Creek and Crater Creek (one of the reservoirs for the Snetisham Project), both of which have high lakes and high elevation drainage basins somewhat comparable to Takatz Lake.

Streams with lower elevation drainage basins and uniform seasonal runoff require smaller reservoir storage volumes to fully regulate inflows. These low elevation basins are on the left side of the group of curves in the figure.

The 1947 Study suggested that a reservoir storage volume sufficient to regulate 90% of the basin inflow would represent a likely upper economic limit for the typical reservoir size. As shown in Figure 4.1, if a certain storage is sufficient to regulate 90% of the mean inflow, then to regulate the last 10% of inflow would require almost doubling the 90% regulation volume. To obtain this 10% increase in firm power from the project will seldom justify the required additional height of the dam. From figure 4.1 the 90% storage volume requirements at Green Lake is 38% of annual

Figure 4-1 Storage vs. Regulation for 51 Streams in SE Alaska, from 1947 Study



runoff and at Blue Lake is 41% of the annual inflow. If Takatz is considered comparable to Dorothy Creek or Crater Creek, its storage volume could fall in the range of 45% to 57% of inflow.

The average inflows and percent of regulation recommended by the industry rule of thumb and by the 1947 Study are presented in Table 4-1 for the Green Lake, Blue Lake and Takatz Lake drainage basins.

Table 4-1 Reservoir Storage Volumes, from Rule of Thumb and Past Studies

Drainage Basin	Annual Inflow		Recommended Reservoir Storage			
			by "150 day" rule		by 1947 study	
	cfs	ac-ft	% of inflow	ac-ft	% of inflow	ac-ft
Green Lake	316.6	229,230	41%	93,984	38%	87,107
Blue Lake	442.0	320,021	41%	131,515	41%	131,209
Takatz Lake (1,2)	171.0	123,798	41%	50,757	51%	63,137

(1) Annual inflow is based on 10.8 sq mi drainage area.
(2) For Takatz Lake the average of the suggested storage range (45% to 57%) is used in this table.

The industry guidelines for reservoir regulation assume that the reservoir storage is used to create a regular outflow pattern (equal flows each day or each month). This assumption allows the user to then define a "firm power" capability for the project, based on energy generation available from the project in the driest year (or multi-year dry period). This uniform energy demand assumption is not valid for the Sitka electrical system as Sitka's loads vary each month and any excess hydro energy cannot be sold "off island". As a result, any meaningful analysis of reservoir regulation in the Sitka system must include both the variability of inflows and the variation in the electric system's monthly energy demands. The following section of this report considers the monthly distribution of inflows to the Takatz, Blue Lake and Green Lake basins as well as the monthly variation in energy demands within the Sitka electrical system.

4.2 Reservoir Regulation in the Sitka Hydro System

4.2.1 Streamflows Available for Power Generation and Reservoir Storage

The Green Lake project operates with no minimum stream flow releases at Green Lake Dam and no other water uses along the power tunnel or at the powerhouse. As a result, all of the Green Lake basin inflow is available for power generation purposes, either direct use of the water as it arrives in the reservoir, or storage in the reservoir for future use. The average monthly inflow to Green Lake, based on flow records from 1929 to 1957 and 1994 to 2004 is shown in Table 4.2.

The Blue Lake Project provides instream flow releases at the Sawmill Creek campground via the Fish Valve small hydro generating unit (the FVU). This release maintains aquatic and riparian habitat and fish species from the campground area downstream to the mouth of Sawmill Creek. This instream flow release must be at least 70 cfs during the April 15 to June 30 period and 50 cfs during the rest of the year. Typically, Sitka operates the FVU to release slightly more flow than the required minimum, to ensure compliance with the FERC license. Accordingly, as part of this capacity analysis effort, we assumed the scheduled release from the FVU is either 73 or 53 cfs, depending on the time of year.

In addition to the FVU flow release, water is taken from the Blue Lake penstock upstream of the powerhouse for the Sitka municipal water system (approximately 5 cfs average flow) and for industrial use at the Sawmill Cove Industrial Park (approximately 1 cfs). Combined with the FVU flows, these diversions result in about 15% of the annual Blue Lake inflow being unavailable for storage regulation in Blue Lake. The remaining 85% of the basin runoff represents the "net" inflow that can be stored in Blue Lake and ultimately used for generation at the main Blue Lake powerhouse. Table 4.2 lists both the gross monthly average run-off into Blue Lake and the net inflow available for reservoir storage and regulation.

The average monthly inflows to Takatz Lake are also presented in Table 4.2. Current planning for the Takatz Project assumes that no minimum flow release will be required at the dam. Therefore, similar to Green Lake, all of the Takatz inflow is expected to be available for reservoir storage and power generation.

4.2.2 Monthly Distribution of Sitka's Electric Loads

Electric loads in the Sitka area are highest in the winter, driven by electric heat demand and lighting in the long winter nights. Loads in the summer months are the lowest when heating demands are greatly reduced and daylight hours are longest. The 2003 to 2008 historical monthly load distribution, as a percent of the total annual load, is shown in Table 4.2. As shown in this table, inflows to all three lakes are concentrated in the June to October time frame, while the largest electric system loads occur between December and April.

Table 4-2 Monthly Distribution of Reservoir Inflows and Sitka Electric Loads

	Monthly Average Inflow, cfs												
Reservoir	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Green Lake	126	93	68	129	326	525	504	455	584	476	341	160	317
Blue Lake (gross)	183	176	134	220	508	685	634	627	699	708	463	251	442
Blue Lake (net)	124	117	75	151	429	606	575	568	640	649	404	192	379
Takatz Lake	35	28	27	38	152	290	367	302	330	291	110	53	168
	Monthly Inflow as a Percentage of Annual Total, %												
Green Lake	3.4	2.3	1.8	3.4	8.7	13.6	13.5	12.2	15.2	12.8	8.9	4.3	
Blue Lake (gross)	3.5	3.1	2.6	4.1	9.8	12.7	12.2	12.1	13.0	13.6	8.6	4.8	
Blue Lake (net)	2.8	2.4	1.7	3.3	9.6	13.1	12.9	12.7	13.9	14.6	8.8	4.3	
Takatz Lake	1.8	1.3	1.3	1.8	7.6	14.1	18.4	15.1	16.0	14.6	5.3	2.6	
	Monthly Electric System Load as a Percentage of Annual Total, %												
	9.4%	9.5%	8.5%	9.2%	7.7%	7.8%	7.4%	7.5%	8.1%	8.7%	7.3%	8.9%	

Note: The Takatz Lake inflows in this table are based on a 10.6 sq mi drainage area.

Overall, the monthly inflow pattern to Sitka's reservoirs does not match well the demand for power generation by the Sitka electrical system. At the most basic level, water storage in the hydro system reservoirs must be manipulated to release monthly flows that generally equal the monthly energy demand of the energy grid. In other words, in a month that has, say, 9.5% of the annual energy demand, the project should release from the reservoir about 9.5% of the average annual inflow to the project. And, if the reservoir inflow is more or less than 9.5% of the annual volume, then water must be either added or removed from storage to meet the required flow release.

This is sometimes described as a mass-balance type of reservoir operation. This concept assumes that each cfs of water released through the generating plant produces the same power as releases at any other time of the year. Also, it assumes that all three projects share equally in meeting Sitka's loads on a month-to-month basis. This is clearly an oversimplification of the reservoir operating requirements as the energy available from each cubic foot of water varies with the reservoir level and there are numerous limits on lake level operation for stable generating conditions, meeting instantaneous peak loads, municipal water reserves and other factors. However, a mass-balance type operation of the reservoirs is easily understood and instructive to apply to the three projects. It is thus useful in examining how Green Lake and Blue Lake operate now and what size of reservoir might be useful at Takatz Lake, when it is developed.

4.2.3 Green Lake Rule Curves

The Green Lake reservoir was constructed with a maximum storage level (spillway crest elevation) of 395.0 ft, a minimum operating level of el. 285 ft, and a net active storage volume of 75,000 ac-ft. If the reservoir's elevation vs. capacity data is combined with an assumed mass-balance type of operation (reservoir monthly outflow percentage equals the electric system monthly load percentage), then the average monthly reservoir storage additions and withdrawals can be calculated as shown in Table 4-3. This table shows that Green Lake would fill by November of each year, followed by drawdown of the lake from December through April, with the minimum lake level occurring in April or May. The corresponding mass-balance rule curve is shown in Figure 4-2 along with the Sitka's current operating rule curve for Green Lake.

The two curves shown in this figure are quite similar, with variations between the curves of no more than 10 ft of lake elevation throughout the year. Both show the reservoir filling in November and a maximum drawdown in May. The mass balance curve shows slightly less drawdown during the April-May low reservoir period. However, we know that the mass balance curve under-estimates the drawdown needed during low reservoir conditions, due to the lower operating head available at the powerhouse during these months. If this under-estimation of the drawdown is considered, then Sitka's current operating rule curve for Green Lake is actually very similar to that suggested by the mass balance estimating method.

Table 4-3 Mass Balance Operation of Green Lake Reservoir, Monthly Level Changes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inflow, cfs	126	93	68	129	326	525	504	455	584	476	341	160
Outflow, cfs	359	359	322	349	291	298	283	286	306	332	276	339
Flow to Storage, cfs	-233	-266	-254	-220	34	227	222	169	278	144	65	-178
Storage Change, ac-ft	-14,323	-14,758	-15,609	-13,081	2,106	13,516	13,636	10,380	16,539	8,880	3,853	-10,961

Note that the operations model rule curve predicts a maximum drawdown to elevation 297 ft, which equates to a maximum reservoir withdrawal of 69,600 ac-ft. This is 93% of the 75,000 ac-ft active storage volume in Green Lake. This leaves a reserve storage volume of 5,400 ac-ft above the el. 285 ft minimum operating level of the reservoir. (note that the normal minimum level of el. 297 ft has been set by Sitka staff for system frequency regulation considerations. If the Takatz project is developed, the added system stability provided by Takatz may allow the City to draw the Green Lake reservoir down below el. 297 on a regular basis.

4.2.4 Blue Lake Rule Curves

The existing Blue Lake reservoir has a maximum storage level of el. 342.0 ft, a minimum operating level of el. 252.0 and a net active storage volume of 87,742 ac-ft. Design of the Blue Lake Expansion is underway as this Takatz Lake capacity analysis report is being prepared. The Blue Lake expansion anticipates raising the Blue Lake maximum level to el. 425 ft with a new minimum lake operating level of el. 360 ft. The new active storage volume will be 97,280 ac-ft. Table 4.4 shows the average storage withdrawals and additions for Blue Lake, based on net inflows to the lake and monthly outflow percentages equal to the Sitka load system monthly variation.

Figure 4-2 Rule Curves for Green Lake Reservoir

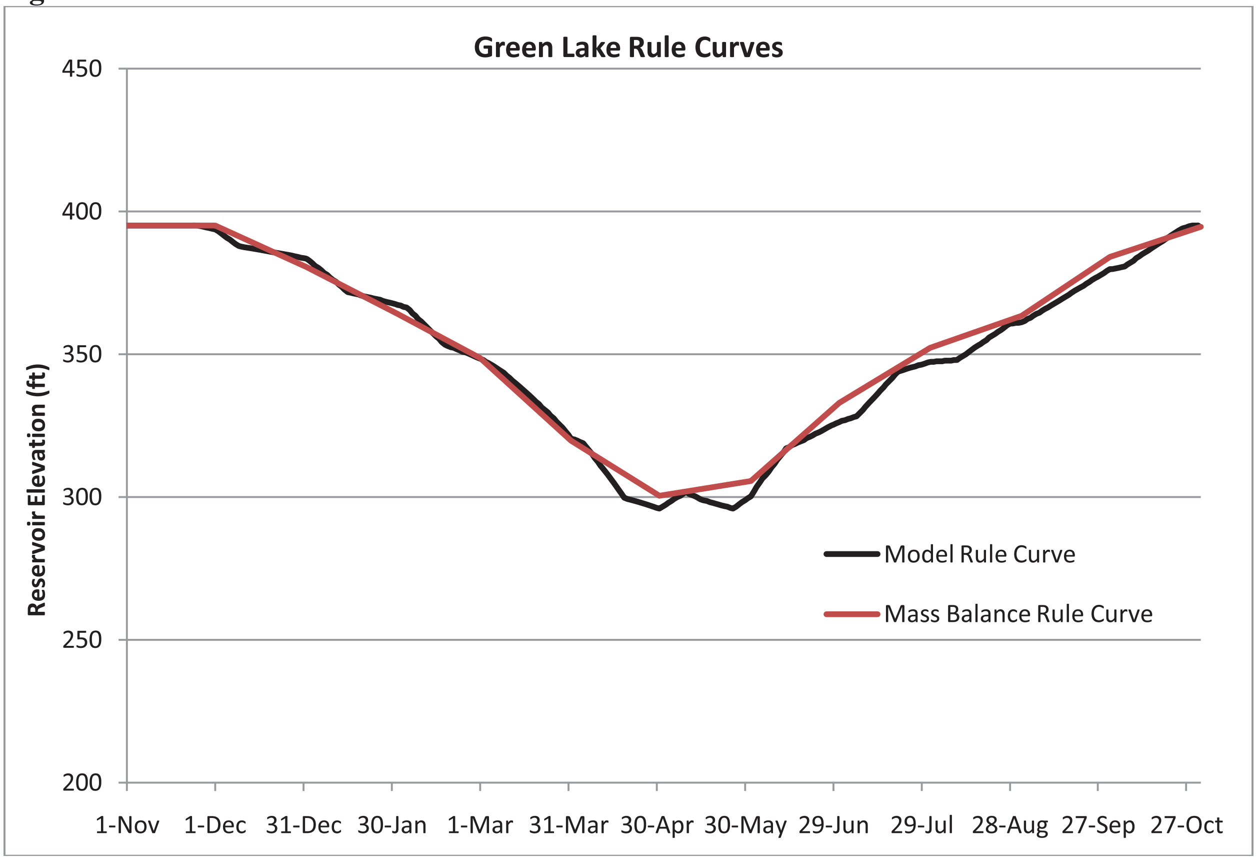


Table 4-4 Mass Balance Operation of Blue Lake Reservoir, Monthly Level Changes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net Inflow, cfs	124	117	75	151	429	606	575	568	640	649	404	192
Outflow, cfs	429	430	385	418	349	356	338	342	366	397	331	405
Flow to Storage, cfs	-305	-313	-311	-267	81	249	236	226	274	252	74	-213
Storage Change, ac-ft	-18,775	-17,363	-19,095	-15,897	4,958	14,843	14,540	13,889	16,333	15,495	4,380	-13,094

City staff have simulated operation of the expanded Blue Lake project, in conjunction with Green Lake, to aid in sizing the Blue Lake dam raise and to determine the likely operating policy for the enlarged Blue Lake reservoir. The operating rule curves based on the City's operations model for the Blue Lake Expansion and the simple mass balance approach described in this study are both shown in Figure 4.4.

Similar to the results for Green Lake, the two rule curves for the expanded Blue Lake reservoir are essentially identical. The mass balance and City-predicted rule curves both show the lake full in November and a minimum drawdown level at the end of April. Variation between the curves is no more than 5 feet of reservoir elevation throughout the year. The mass balance curve under-predicts the maximum lake drawdown by about 4 feet, again due to the mass balance methodology not considering the lower energy output for each cfs of discharge when the lake level is low.

Overall, these comparisons of rule curves for both Green Lake and Blue Lake suggests that the City's current lake operating policy can be closely approximated by the mass balance rule curve approach. Accordingly, the study team elected to apply the mass balance approach to Takatz Lake.

Note that the operations model rule curve predicts a maximum Blue Lake drawdown to elevation 370 ft, which equates to a maximum reservoir withdrawal of 83,500 ac-ft. This is 86% of the 97,280 ac-ft active storage volume in the expanded Blue Lake reservoir. This leaves a reserve storage volume of 13,780 ac-ft above the estimated el. 360 ft minimum operating level of the reservoir.

4.2.5 Takatz Lake Mass Balance Rule Curves

Table 4.5 shows the average monthly inflows to Takatz Lake and the estimated withdrawals from the lake, if outflows match the Sitka electric system monthly distribution. The reservoir storage volume required to achieve this regulation of inflows is 48,359 ac-ft.

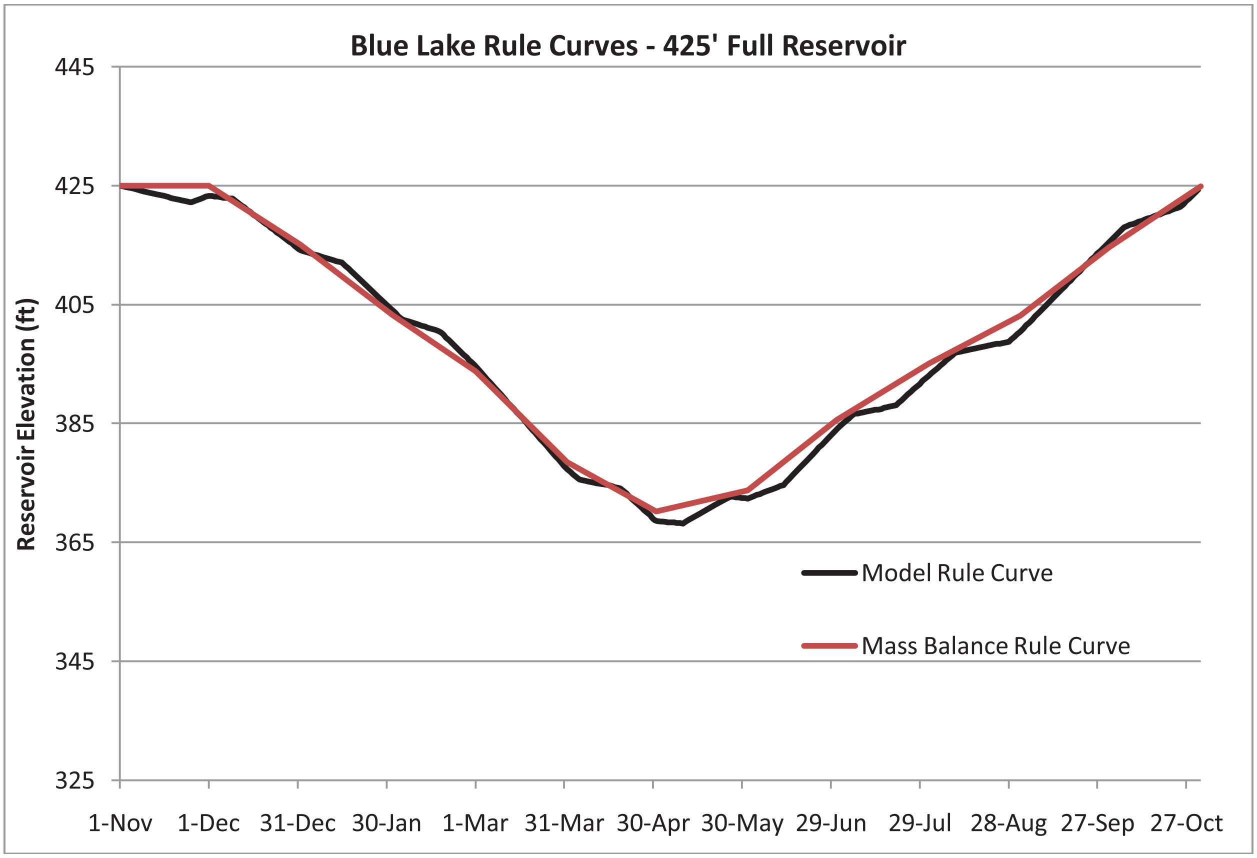
Table 4-5 Mass Balance Operation of Takatz Reservoir, Monthly Level Changes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net Inflow, cfs	35	28	27	38	152	289	367	302	330	291	109	53
Outflow, cfs	191	169	195	156	154	144	154	165	150	169	181	203
Flow to Storage, cfs	-156	-141	-168	-119	-3	145	213	137	180	122	-71	-150
Storage Change, ac-ft	-9,579	-7,809	-10,346	-7,054	-171	8,644	13,086	8,424	10,692	7,513	-4,241	-9,252

The Takatz Lake project concept proposed in the 1968 study includes two arch dams that would raise the lake level from the existing el. 905 to el. 1040, with an active storage volume of 82,400 ac-ft. This is a significant volume, compared to the annual yield of the basin. The 1968 proposed reservoir volume is 70 percent greater than the volume suggested by the mass balance rule curve method and 31% greater than that suggested in the 1947 study.

As noted in Section 2 and as shown in Figure 2-5, the 1968 engineers proposed a reservoir storage volume that could provide significant storage carry-over for dry years, thus providing a large firm energy capability in the project. In 2011, the value of such a large reservoir volume is uncertain, given the City's constantly growing loads, surplus energy sales program, and the unlikely probability that future dry years will coincide with the time when average electric system loads are close to the average generation of the City's hydro generation resources (the average annual combined output of Blue Lake, Green Lake and Takatz Lake).

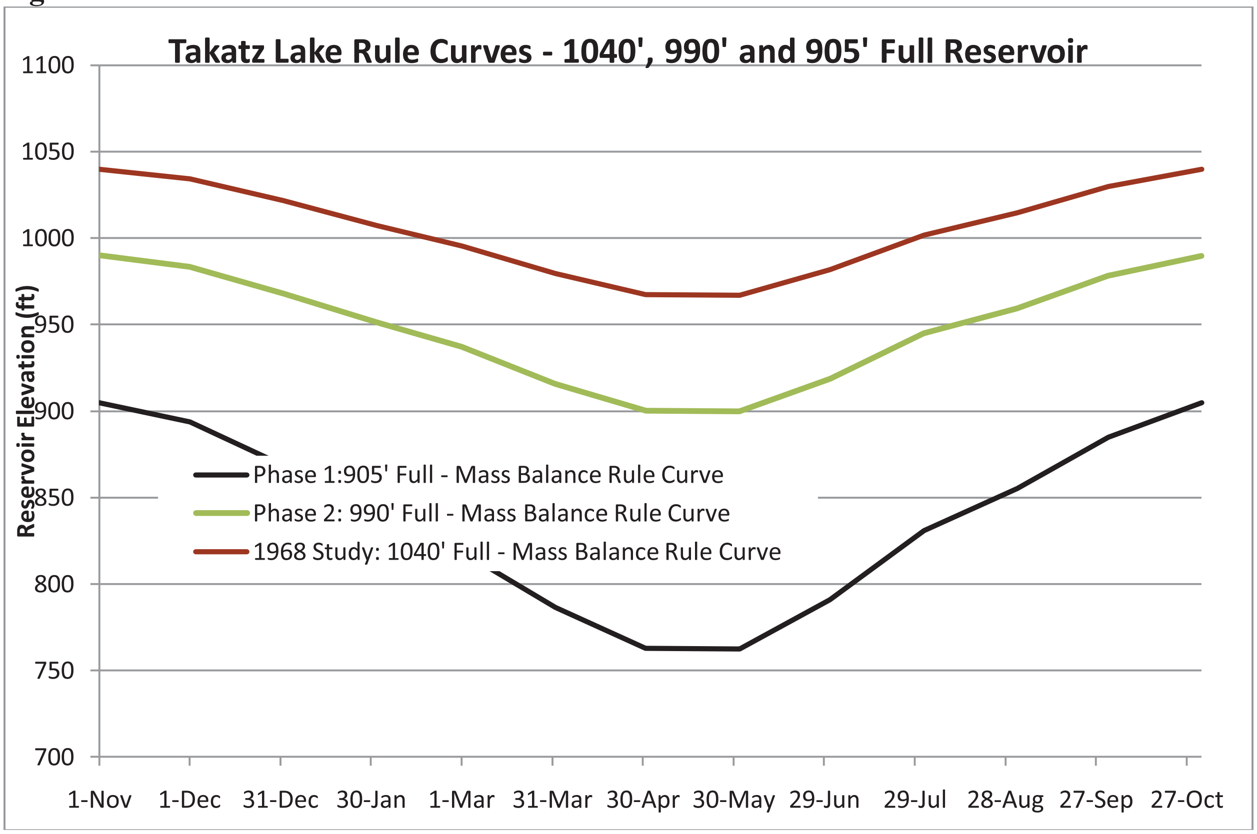
Figure 4-3 Rule Curves for Blue Lake Expansion Reservoir



As described in Section 8 of this report, our study team considered a phased development of the Takatz reservoir, in which the Phase 1 development would not include the dam. For Phase 1, flows from the lake would be provided through a lake tap below the existing lake surface. Assuming the tap could be made at el. 717; a total storage volume of 52,950 ac-ft could be developed between a minimum operating water level at el. 747 ft. and the maximum level of el. 905 ft. This storage range would provide the full mass balance active storage volume of 48,359 ac-ft, above the el. 762 ft level, plus a reserve volume of 4,390 ac-ft between el. 747 ft and el. 762 ft.

A comparison of the mass-balance operating rule curves for the Phase 1 (no dam and maximum lake level of el. 905), Phase 2 (dam at el. 990 ft), and the 1968 Plan of development (two dams with maximum lake level of el. 1040) is shown in Figure 4-4. If a lake tap at el. 717 ft can be developed, the Phase 1 development could regulate essentially all inflows to Takatz Lake under average inflow conditions. Overall, this Phase 1 arrangement would allow the Takatz project to operate in much the same manner as Blue Lake and Green Lake do now. The reserve storage provided in Takatz would be 8% of its total reservoir volume, compared to a 7% reserve volume in Green Lake and 14% in the expanded Blue Lake reservoir.

Figure 4-4 Mass Balance Rule Curves for Takatz Lake



Construction of the Phase 2 dam would provide additional head and a much greater reservoir reserve volume for dry year carry over and system emergencies.

The "1968 Plan" rule curve in Figure 4-4 shows a drawdown of 73 ft from the maximum level of el. 1040 ft. This leaves 34,000 ac-ft of storage below the lowest lake level for dry-year carryover capacity and system reserves during outages. This is a substantial volume which may be more than what is needed.

If the project were developed with a conventional surface intake, constructed at, say, el. 874 ft, then a minimum lake operating level of el. 890 ft would be possible. With this minimum lake level a dam crest of el. 990 ft would develop the 48,300 ac-ft of storage needed to regulate average inflows, plus a small reserve volume of 3,725 ac-ft (a total volume of 52,025 ac-ft). The resulting reservoir rule curve would be essentially identical to the Phase 2 rule curve shown in Figure 4-4; with the exception that very little reserve storage is provided. The 2011 study team evaluated this arrangement as the "single stage" project arrangement, which would entail a project scheme with the main dam, but no lake tap and no saddle dam.

4.3 Reservoir Regulation Strategy for the Future Sitka System

The Sitka electric system currently operates using reservoir rule curves based on average inflow conditions. These rule curves are very similar to the mass balance curves described previously. If inflows are higher than average, then lake levels rise above the rule curve and the City turns on the interruptible loads in the system to increase generation. In these circumstances, the City also encourages its customers to use electric heat in lieu of kerosene or oil. Weather and precipitation patterns are highly variable in the Sitka region. Therefore it is reasonable for Sitka to use the current lake levels, historic electric load data, and average historical reservoir inflows for real-time planning of the reservoir regulation. This is especially true given the City's weekly update of the reservoir level forecasts.

If inflows are below average, lake levels drop below the rule curves, leading the City to stop the interruptible energy sales and ask customers to reduce their electricity consumption. When lake levels fall far below the rule curves (10 to 20 ft), then the City operates its diesel generators to limit further drawdowns of the lakes. On a weekly basis, the City uses its operations modeling tools to forecast future lake levels. Based on whether the predicted lake levels rise above or fall below the rule curve, the City adjusts its use of interruptible power and public requests for use of electric heat.

This reservoir regulation strategy and manipulation of electric heat loads in the electric system is aimed at maximizing hydro generation and limiting the risk of diesel generation. It is a reasonable and straightforward approach to reservoir regulation in this system. A future three-reservoir system could easily be operated using this same strategy, provided the Takatz Project is developed with a reservoir storage capacity of at least 48,300 ac-ft (the volume required for the mass balance rule curve).

Future reservoir regulation strategies for the Sitka system will depend on several factors including:

- How close the average available hydro generation is to the annual system load,
- How large the interruptible loads are, relative to the annual system load.
- The cost of oil and kerosene heat vs. electric heat

In the early years after Takatz is constructed Sitka's average available hydro generation will easily exceed the system load. Thus, in the early years of operation there will be "built-in" reserves for dry year generation and for outages of the Green Lake or Blue Lake projects. During this time the maximum use of interruptible loads should be pursued by the City. Frankly, to maximize generation benefits, the City might pursue expansion of its interruptible load program until the expected annual interruptible load is about one third to one half of the expected Takatz annual output. If this goal were achieved, the Takatz Project could be effectively used as soon as it is completed.

Based on our analysis, we recommend that the City's existing reservoir regulation strategy be used for the future three reservoir system.

4.4 Suggested Takatz Reservoir Capacity

The mass balance rule curve analysis in Section 4 suggests that inflows to Takatz Lake can be effectively regulated with a reservoir storage capacity of 48,300 ac-ft. With this storage volume, Takatz could be operated in essentially the same manner and Green Lake and Blue Lake are now. Storage greater than 48,300 ac-ft would improve the Project's ability to provide carry-over storage for dry years and would ensure that some storage is available in Takatz Lake to provide extra generation if outages of Blue Lake or Green Lake occur in April or May of any year.

For the Phase 1 lake tap alternative, we recommend that a storage volume of 52,950 ac-ft be pursued. This reflects a lake tap at el. 717 ft with no dam construction and a minimum expected operating pool level of el. 747. The 15 ft of reservoir volume between el. 762 and el. 747 provides 4,390 ac-ft of reserve capacity, measured from the minimum annual lake level defined by the mass balance rule curve.

The Phase 2 construction of the dam would increase reservoir storage to el. 990 ft. This increase would allow better capture of inflows during wet years; provide a much larger reserve storage capacity and incrementally greater operating heads at the powerhouse.

If the project is initially constructed without a lake tap and with a conventional intake structure at el. 874 ft (similar to the 1968 Study plan) then the project would not be constructed in stages. If construction of the saddle dam were avoided, the maximum dam crest level would be el. 990 ft. This crest level, with the el. 874 ft intake would allow a maximum lake level variation of about 100 ft, between el. 890 and el. 990. This range provides enough volume to regulate the average-year inflow, with a 3,725 ac-ft reserve capacity.

A discussion of reserve energy requirements and corresponding reservoir storage volumes is included in Section 7 of this report. The recommended reservoir operating levels and corresponding storage volumes for the Phased and single-stage development of the Takatz Project are summarized in Table 4-6.

Table 4-6 Recommended Takatz Reservoir Capacities

Phased Project Development					
	Active Storage, ac-ft	Maximum lake level, ft	Minimum lake level, ft	Intake structure elevation, ft	Notes
Phase 1	52,950	905	747	717	Lake tap
Phase 2	99,300	990	747	717	Main dam only
Single Stage Development with Surface Intake					
	52,025	990	890	874	Surface intake

SECTION 5 – OPERATIONS MODEL

5.1 Overview

While the Mass balance Rule Curve methodology described in Section 4 provides a good approximation of the appropriate amount of useable storage, a more sophisticated model is necessary to estimate project output for the various potential reservoir configurations and operations. Study engineers built an Excel model for Takatz Lake, similar in capabilities to the existing Blue Lake and Green Lake operations model. The Green Lake – Blue lake model is currently used by the City to estimate the combined output of those two projects and to forecast future lake levels and generation. The Takatz Lake model considers the Takatz project in isolation of the other hydro projects. In other words, it does not attempt to operate the three projects together. The Takatz model was built to give a reasonable approximation of the potential output for the project based on the possible reservoir configurations discussed throughout this report.

5.2 Takatz Operations Model Development

The Takatz Lake operations model is an Excel-based spreadsheet tool designed to estimate the project generation given a project arrangement. It operates on a daily time-step taking a daily inflow and calculating daily output, turbine flow and resulting daily reservoir elevation. While the model can be run in a couple of different ways, for this study it was used primarily to determine the turbine flow required to meet a desired output and to then forecast lake levels based on various annual project generation values. The daily desired MWh output from the plant is a function of a user-selected annual load desired from the plant and the monthly load percentages for the City (each month is assigned a percentage of the annual system load). The basic steps followed by the model each day are described below:

1. The daily inflow is determined from the monthly average flows as listed in Tables 3-5 and 3-6. The same inflow is used for each day of the month.
2. The desired daily output in MWh is calculated from the desired annual plant output (as entered by the user) multiplied by the monthly load percentage, divided by the number of days in the month.
3. Given the current reservoir elevation, the model calculates a gross head.
4. With the gross head calculated in step 3 and the desired output from step 2, the model uses the turbine performance data and conduit head loss data to calculate the daily average flow required to meet the desired output.
5. With the outflow calculated in step 4 and the inflow from step 1, the model can now determine the resulting reservoir elevation.
6. The primary output from the model is a daily MWh generation from the plant and an end of day reservoir elevation.

5.3 Model Data

While not an exhaustive list, the following tables summarize the most important inputs utilized by the model.

Monthly tables as shown in Tables 3-5 and 3-6 were used to define the reservoir inflows to Takatz Lake over the 23 year period of record used in the operations model. For project configurations with the saddle dam, inflows from Table 3-5 were used. For the Project arrangements without the saddle dam, Table 3-6 was used.

The City's annual load distribution by month, as used in the model, is shown in Table 5-1. Data in this table is based on historical Sitka loads from calendar years 2005 to 2008.

Table 5-1 City of Sitka, Monthly Distribution of Electric System Loads

Month	% of Annual Load
JAN	9.4%
FEB	8.3%
MAR	9.6%
APR	7.7%
MAY	7.6%
JUN	7.1%
JUL	7.6%
AUG	8.1%
SEP	7.4%
OCT	8.3%
NOV	8.9%
DEC	10.0%

The reservoir elevation vs. storage volume relationship used in the model is shown in Table 5-2. This data was taken from the 1968 Study report's area-capacity curve, which is reproduced in this 2011 study report as Figure 2-6.

Table 5-2 Takatz Lake Elevation vs. Storage Relationship

Elevation	Storage (Ac-ft)
700	0
740	10400
780	22100
820	34900
860	48700
900	63400
905	65400
940	82200
980	105200
1020	131400
1060	160900
1100	193200

The turbine performance data used in the model characterizes a two-unit powerhouse with vertical shaft 6-nozzle Pelton turbines, as described in Section 8. An estimate of the anticipated performance of this configuration was obtained by study engineers from Gilkes (a UK turbine supplier that recently furnished the Bart Lake 6-nozzle Pelton turbine for AEL&P in Juneau) and distilled into a format suitable for use by the model. That model input for Unit 1is shown in Table 5-3 (Unit 2 is identical).

Table 5-3 Takatz Powerhouse Turbine Performance Data

Turbine Performance Data Unit 1

Minimum Net Head		Net Head		Rated Net Head		Net Head	
656		738		820		900	
Flow	**Efficiency**	**Flow**	**Efficiency**	**Flow**	**Efficiency**	**Flow**	**Efficiency**
56.5	60.00%	56.5	68.00%	56.5	72.00%	56.5	72.00%
70.6	71.00%	70.6	80.00%	70.6	80.00%	70.6	79.50%
84.8	80.50%	84.8	85.20%	84.8	85.20%	84.8	84.50%
98.9	84.50%	113.0	87.00%	113.0	87.00%	113.0	87.00%
127.1	85.10%	127.1	87.50%	127.1	87.50%	127.1	87.50%
211.9	86.50%	176.6	88.90%	141.3	88.00%	141.3	88.00%
247.2	86.00%	247.2	87.50%	211.9	89.10%	211.9	88.50%
264.9	85.00%	268.4	86.00%	282.5	86.00%	282.5	86.00%

In the model, the turbine centerline elevation was set at 30 ft (see Section 8 for more on the powerhouse configuration). The generator was assumed to have an efficiency of 97% at all operating points and a 99% efficiency was assumed for the step-up transformers. Note that no station service loads or transmission system losses are included in the model.

The head loss for the power conduit was defined as:
$HL = kQ^2$; with **$k = 0.000148$**

This equation is based on the tunnel and penstock configuration described in Section 8 of this report. At a total conduit flow of 450 cfs, the estimated conduit head loss is approximately 30 ft.

SECTION 6 – POWER STUDIES

The model described in Section 5 was utilized to examine and estimate the project generation capabilities. The reservoir response was also of interest. The results described in this section should be considered preliminary, as there are many opportunities for refinement of the selected operating policy and the resulting generation estimates. For example there are a number of ways the reservoir could be operated, each with different pluses and minuses. However, study engineers believe these results described below to be indicative of the expected output and reservoir response if the Takatz project were operated in a manner similar to the study assumptions. Note that the operating policy described below is similar to the current operation of the Blue Lake and Green Lake projects.

6.1 Operating Scenarios Considered

Four project configurations were examined using the model. In each case, only the reservoir levels (maximum lake levels and minimum lake levels) were being changed for the four alternatives. Table 6-1 summarizes the operating scenarios considered in the modeling work.

Table 6-1 Recommended Takatz Reservoir Capacities

Phased Project Development			
Alternative	Active Storage, ac-ft	Maximum lake level, ft	Minimum lake level, ft
1 - Phase 1	52,950	905	747
2 - Phase 2	99,300	990	747
Single Stage Development with Surface Intake			
3	52,025	990	890
1968 Proposed Plan of Development for Takatz Lake			
4	82,400	1040	900

Following review of the draft results for this capacity analysis, Sitka staff requested that the evaluation also consider the possibility that virtually all of the Takatz generation might be used for electric space heating in the Sitka area. This conversion from oil heat to electric is driving the current (2008 to present) electric load growth in the Sitka area. The increased use of electric heat will continue if oil prices remain high and if the cost of electricity is less than heating oil, on a $/btu basis.

To model this possible use of Takatz energy for space heating, the study team examined a monthly load scenario based on the monthly variation in heating-degree-days (HDD) in the Sitka area. This analysis was carried out only for the Phase 1 project arrangement, to get a sense of whether the same annual energy could be developed with a heating-only monthly load variation. The methodology and results of this electric heat alternative are presented in section 6.5 of this report.

6.2 Model Study Methodology

For purposes of this study, the study team decided that determining a target annual energy output would be the principal concern. In this case the target annual generation is defined by a 90% confidence level that this annual output could be achieved. This mimics the City's criteria for Blue Lake and Green Lake, where those projects are operated based on an average inflow rule curve, with the understanding that the "average" generation of these projects will not be achieved in dry years.

A manual iterative process was used with the Takatz model to zero in on the target annual output. One of the primary model inputs is the desired annual output from the project. We simply stepped up that annual generation value until the model showed the project was unable to meet that goal in 2 out of the 23 years in the hydrologic record. Thus, meeting the annual energy target in 21 out of 23 years defines the "90% confidence" generation value.

6.3 Model Study Results

Each of the four project configurations was then analyzed following the study methodology for determining the target annual output of the project, as described above. The results are summarized in the charts and tables that follow. A reservoir "haze chart" and an energy summary table are included for each alternative. The haze chart titles and notes indicate the target annual output achieved at the 90% confidence level, as well as the average annual output (including "surplus" energy) for all 23 years. Surplus energy is that energy produced when the reservoir is full and water would otherwise be spilled. It is unclear at this time if the surplus energy is actually useable energy. Whether it is useable in the Sitka system will depend on the specific system load and current lake levels at the Blue Lake and Green Lake projects. For the surplus energy to be useable, it would either need to displace generation by Blue Lake and Green Lake (allowing those projects to fill their reservoirs), or there would need to be interruptible loads in the Sitka system that could accept the surplus Takatz generation.

Determining the value of that surplus energy is part of a larger (future) study incorporating the combined operation of the three projects, and is outside of the scope of this study. It should also be noted that, in the suite of modeling results shown below, the operating criteria for the reservoir/project was simply to meet the target annual output. The ability, and in fact the desirability, of refilling the reservoir each year was not considered. For example, if a very large storage volume is developed at Takatz, it may be worthwhile to plan on not refilling the lake in every year. This could allow Sitka to maximize the firm energy from the Project, at the expense of reducing the average annual total generation.

Figure 6-1 Phase 1 Reservoir Haze Chart – 75,000 MWh at 90% Confidence

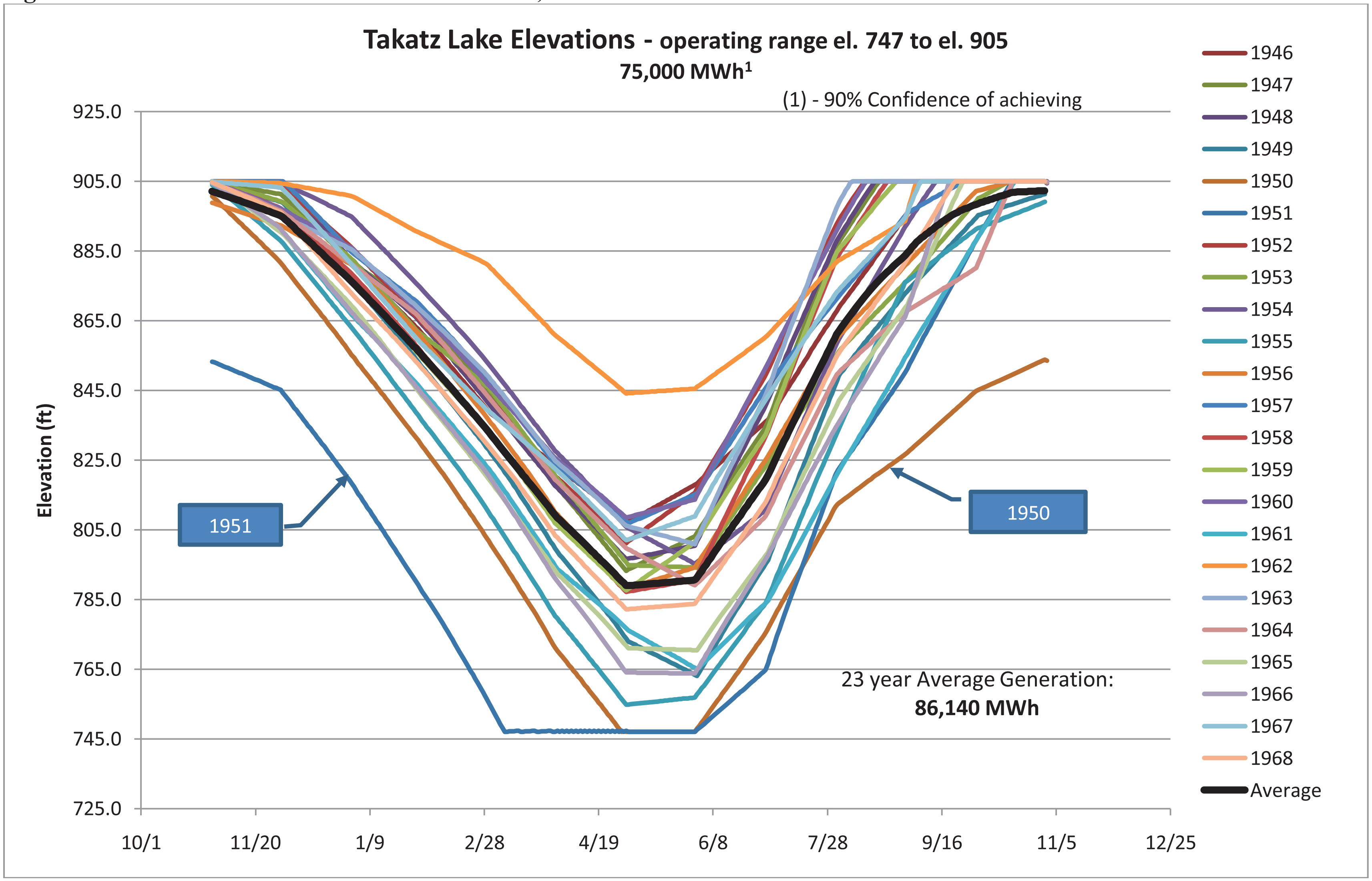


Figure 6-2 Phase 2 Reservoir Haze Chart – 88,000 MWh at 90% Confidence

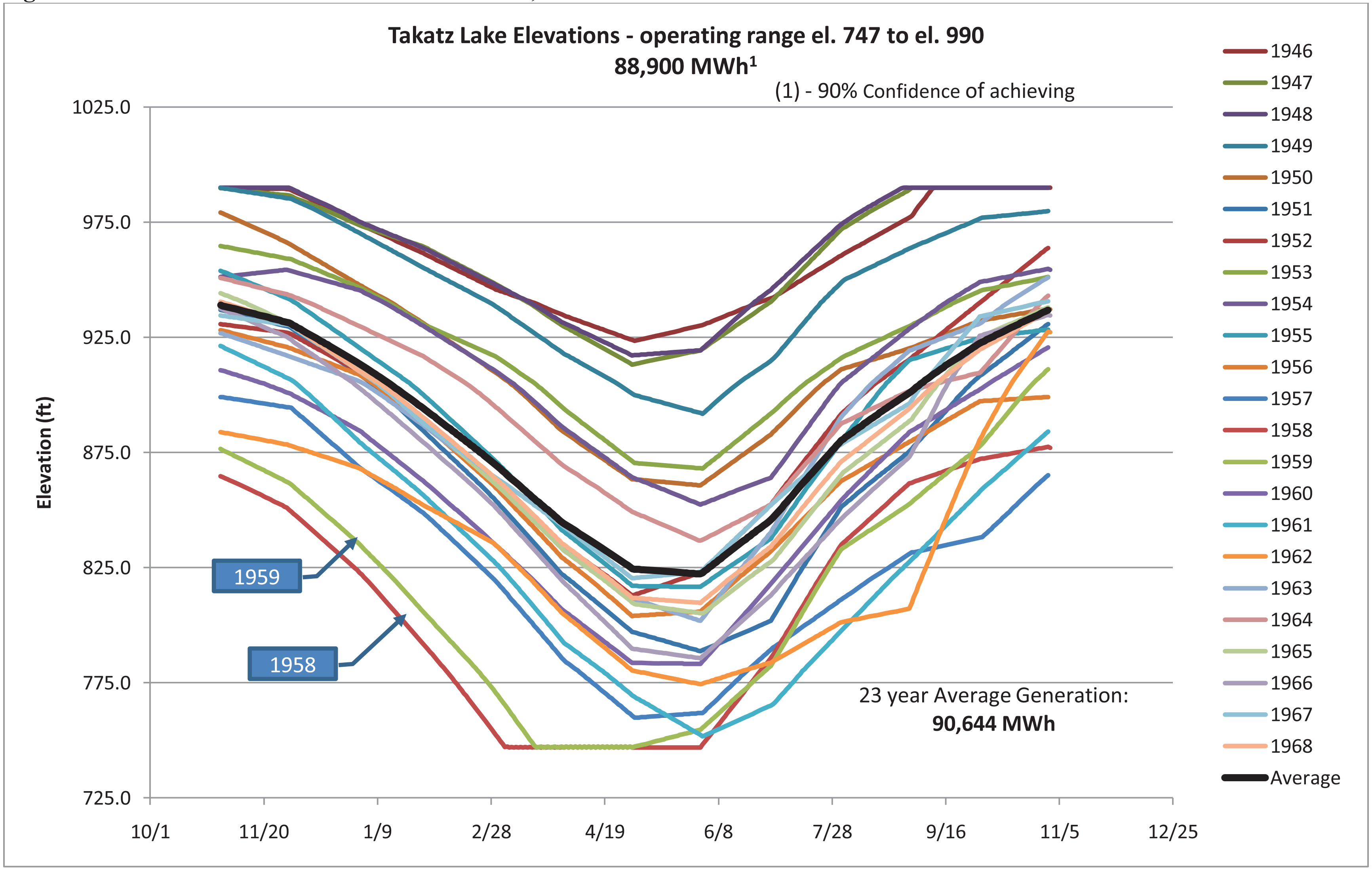


Figure 6-3 Single Stage Reservoir Haze Chart – 85,000 MWh at 90% Confidence

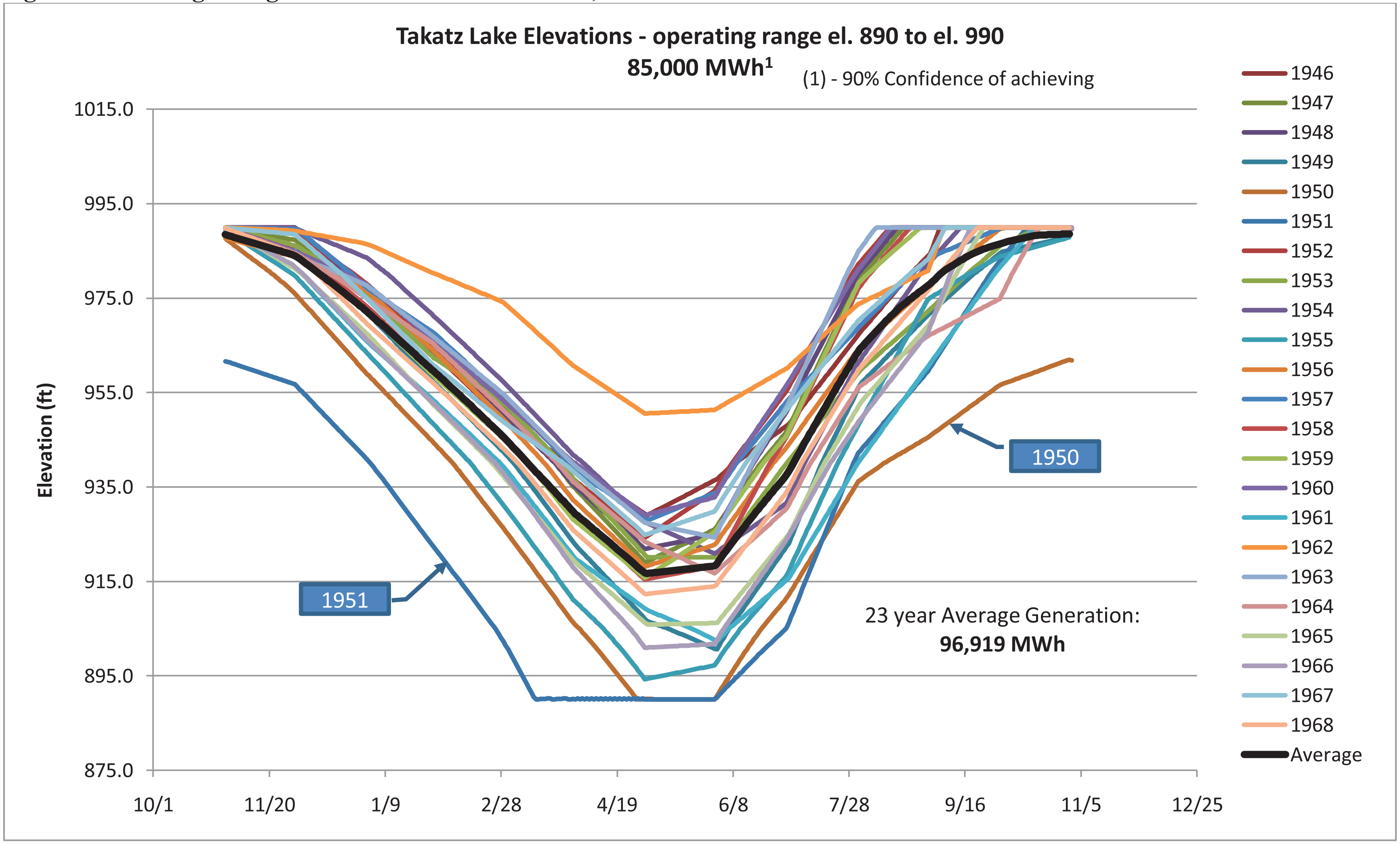
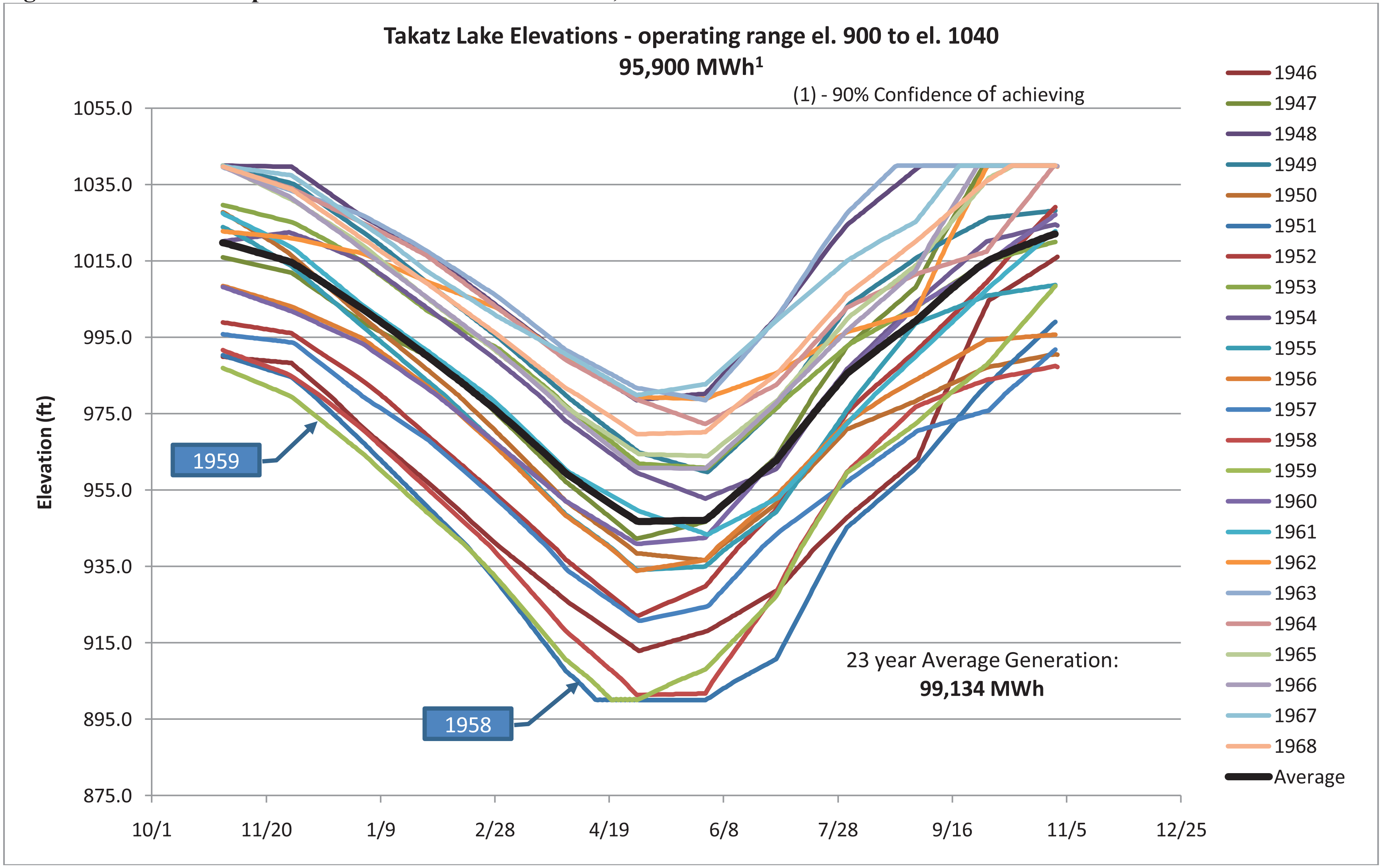


Figure 6-4 1968 Proposed Reservoir Haze Chart – 95,900 MWh at 90% Confidence



In the tables below, the "Firm Gen" was (approximately) the desired, target annual output from the project. "Surplus Gen" is that generation produced with a full reservoir when the project would otherwise be spilling the water. As noted previously, that output may or may not be useable depending on the system load and status of the other hydro projects. The "Total Gen" is the combination of firm and surplus generation. The "Unmet Load" is the summation of the daily inability of the model to meet the target daily output upon reaching the minimum reservoir elevation. Note that it is possible to have both surplus generation and unmet load in the same year. In that case the reservoir reached minimum during a portion of the year (therefore being unable to meet its requested output) and then refilled completely. Also, the reservoir could have started the year full and produced surplus generation before the drawdown of the lake started.

Table 6-2 Phase 1 Project Arrangement - Generation Summary

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	75196	19142	94338	0
1947	74949	24578	99528	0
1948	74949	24950	99900	0
1949	74697	390	75087	0
1950	74296	0	74296	878
1951	64179	4262	68440	10770
1952	74949	25473	100422	0
1953	74697	2100	76797	0
1954	75174	10490	85664	0
1955	74949	0	74949	0
1956	74949	809	75758	0
1957	74697	9241	83939	0
1958	75174	9385	84559	0
1959	74949	19759	94708	0
1960	74949	18910	93859	0
1961	74697	3888	78586	0
1962	75174	25879	101053	0
1963	74949	21820	96770	0
1964	74949	6039	80988	0
1965	74697	8448	83145	0
1966	75174	9657	84831	0
1967	74949	14031	88980	0
1968	74949	9684	84633	0
Avg	74448	11693	86140	506
Max	75196	25879	101053	10770
Min	64179	0	68440	0

Table 6-3 Phase 2 Project Arrangement - Generation Summary

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	89132	17219	106351	0
1947	88840	22127	110967	0
1948	88840	22491	111331	0
1949	88541	411	88952	0
1950	89106	0	89106	0
1951	88840	0	88840	0
1952	88840	0	88840	0
1953	88541	0	88541	0
1954	89106	0	89106	0
1955	88840	0	88840	0
1956	88840	0	88840	0
1957	88541	0	88541	0
1958	76423	0	76423	12684
1959	80628	0	80628	8211
1960	88840	0	88840	0
1961	88541	0	88541	0
1962	89106	0	89106	0
1963	88840	0	88840	0
1964	88840	0	88840	0
1965	88541	0	88541	0
1966	89106	0	89106	0
1967	88840	0	88840	0
1968	88840	0	88840	0
Avg	87937	2706	90644	908
Max	89132	22491	111331	12684
Min	76423	0	76423	0

Table 6-4 Single Stage Project Arrangement - Generation Summary

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	85222	20393	105615	0
1947	84943	26174	111117	0
1948	84943	26588	111531	0
1949	84657	422	85078	0
1950	84360	0	84360	837
1951	74639	5888	80527	10304
1952	84943	26991	111934	0
1953	84657	1757	86414	0
1954	85197	10703	95901	0
1955	84943	0	84943	0
1956	84943	1437	86379	0
1957	84657	9135	93791	0
1958	85197	9697	94895	0
1959	84943	21135	106078	0
1960	84943	19734	104677	0
1961	84657	4731	89388	0
1962	85197	27049	112246	0
1963	84943	22959	107902	0
1964	84943	6297	91240	0
1965	84657	9500	94157	0
1966	85197	10823	96020	0
1967	84943	14607	99550	0
1968	84943	10445	95388	0
Avg	84464	12455	96919	484
Max	85222	27049	112246	10304
Min	74639	0	80527	0

Table 6-5 1968 Proposed Project Arrangement - Generation Summary

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	96150	0	96150	0
1947	95835	7566	103401	0
1948	95835	20804	116639	0
1949	95513	414	95927	0
1950	96123	0	96123	0
1951	90768	0	90768	5067
1952	95835	0	95835	0
1953	95513	0	95513	0
1954	96123	0	96123	0
1955	95835	0	95835	0
1956	95835	0	95835	0
1957	95513	0	95513	0
1958	96123	0	96123	0
1959	93859	0	93859	1976
1960	95835	0	95835	0
1961	95513	0	95513	0
1962	96123	14396	110519	0
1963	95835	16985	112820	0
1964	95835	242	96077	0
1965	95513	3622	99134	0
1966	96123	5803	101925	0
1967	95835	8523	104358	0
1968	95835	4420	100255	0
Avg	95535	3599	99134	306
Max	96150	20804	116639	5067
Min	90768	0	90768	0

6.4 Model Results Analysis

Looking at the model results of the four alternatives it appears that the 4 cases can really be distilled down to two broad categories based on the available storage; moderate storage (Phase 1 and Single Stage), and large storage (Phase 2 and the 1968 Proposed).

6.4.1 Moderate Storage Configurations

Phase 1 and the Single Stage configurations provide storage commensurate with that of the Mass Balance Rule Curve analysis described in Section 4 (~ 50,000 ac-ft). That amount of storage matches the firm (90% confidence) output capability with a reasonable assurance of reservoir refill each year. With the reservoir consistently full each year, a relative large amount of surplus energy is generated. The usefulness of that surplus output will vary, and is worthy of further study. It could be used to help maintain higher elevations at Blue Lake and Green Lake, and the value should increase as the City's load increase over time. The difference in firm generation in these two alternatives is a function of the head increase in the Single Stage configuration vs. the Phase 1 arrangement.

6.4.2 Large Storage Configurations

The Phase 2 and 1968 Proposed configurations provide a significantly larger amount of available storage than that indicated by the Mass Balance Rule Curve analysis (~82,000 to 99,000 ac-ft). That "extra" storage can be used in a number of ways. The batch of results shown above assumed that the storage would be used to maximize the firm output (90% confidence) of the project over the 23 year record. What is the highest annual output that could be achieved over the 23 years with 90% certainty? The results of that operating regime show the reservoir being drawn down continually and only refilling during the wettest of years. Accordingly, that minimizes both the time spent with a full reservoir and the amount of surplus energy. Basically this maximizes the firm energy produced by the project. However, because the reservoirs rarely refill, there is some risk in multiple, successive dry years draining the reservoir to levels that make it very difficult to refill. This is an inherently risky way to operate the reservoir. An alternative method is to focus on the ability of the reservoirs to refill, and that type of operation is discussed below.

6.4.3 Alternative Reservoir Operations – Large Storage Configuration

While the Moderate Storage configurations (Phase 1 and Single Stage) simultaneously satisfy the firm output criteria at the 90% confidence level as well as refilling the reservoir at the same 90% certainty, the Large Storage configurations demand a choice. Either utilize the "excess" storage to provide additional firm power during all years, and subsequently put the refill in jeopardy, or only draw down such that there is reasonable assurance of refilling the reservoir. Using criteria of 90% confidence of refilling Figure 6-5 and Table 6-6 summarize the model output for the Phase 2 project configuration with this alternative reservoir operating strategy.

Figure 6-5 Phase 2 Reservoir Haze Chart – 85,000 MWh at 90% Confidence of Refill

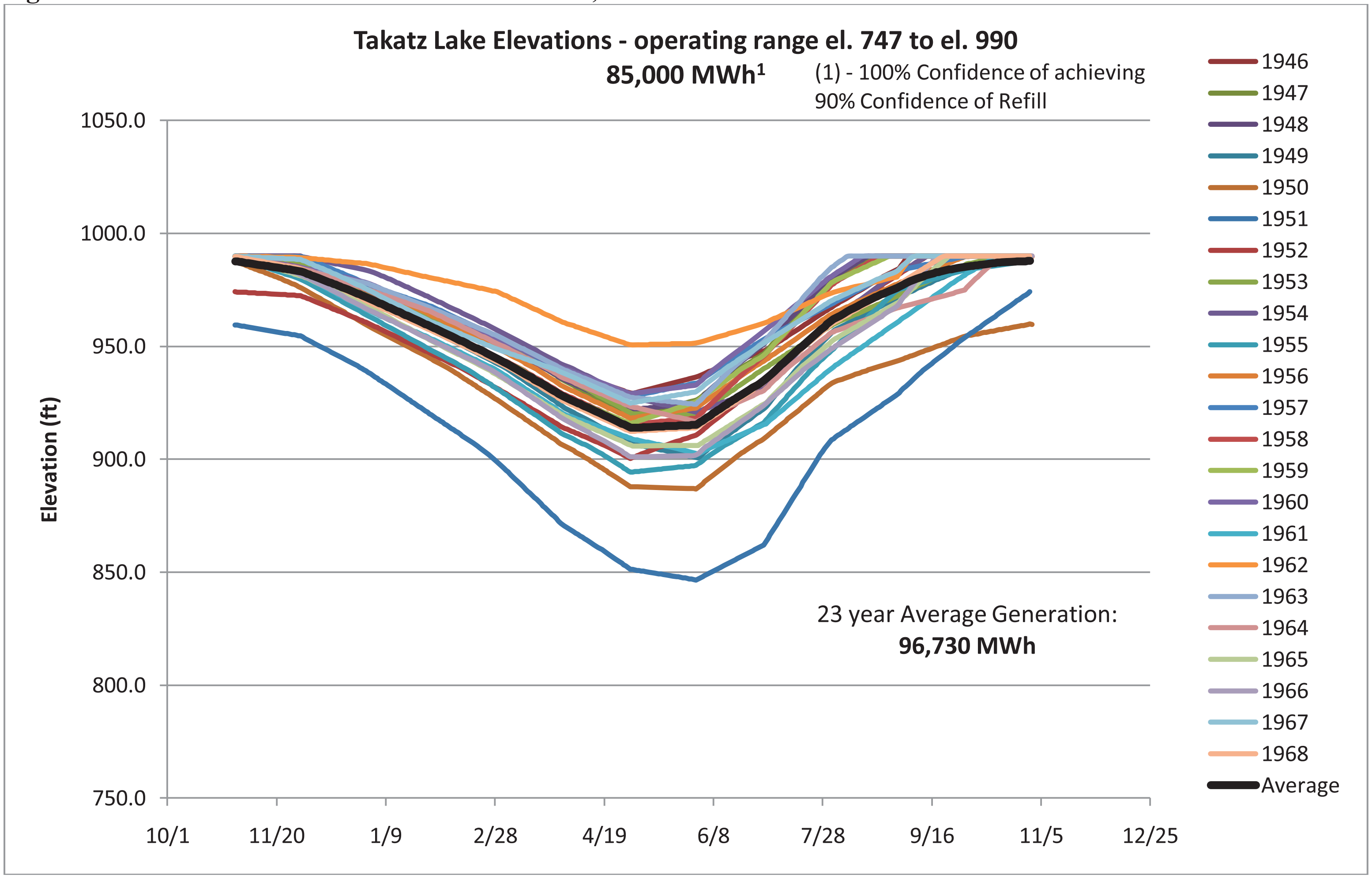


Table 6-6 Phase 2 Project Generation Summary – 90% Refill Confidence

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	85222	20393	105615	0
1947	84943	26174	111117	0
1948	84943	26588	111531	0
1949	84657	422	85078	0
1950	85197	0	85197	0
1951	84943	0	84943	0
1952	84943	17367	102310	0
1953	84657	1757	86414	0
1954	85197	10703	95901	0
1955	84943	0	84943	0
1956	84943	1437	86379	0
1957	84657	9135	93791	0
1958	85197	9697	94895	0
1959	84943	21135	106078	0
1960	84943	19734	104677	0
1961	84657	4731	89388	0
1962	85197	27049	112246	0
1963	84943	22959	107902	0
1964	84943	6297	91240	0
1965	84657	9500	94157	0
1966	85197	10823	96020	0
1967	84943	14607	99550	0
1968	84943	10445	95388	0
Avg	84948	11781	96729	0
Max	85222	27049	112246	0
Min	84657	0	84943	0

The results here start to look similar to the results for the Moderate Storage options. Refill is consistent; therefore, surplus generation increases substantially. Again, the usefulness of any surplus generation is questionable at this time. It should be noted that under this operating criteria (90% confidence of reservoir refill) the reservoir never utilizes all of the available storage; it can't without putting the refill into jeopardy. Comparing the 90% confidence-refill to the 90% confidence-energy model runs (Figure 6-5 compared to Figure 6-2 of power output simulations) it is worth noting that the 90% confidence annual energy drops from 88,900 MWh to 85,000 MWh, but the average annual generation increases from 90,644 MWh to 96,729 MWh.

6.4.3 Future Operations Modeling

The modeling done as part of this 2011 study provides a useful tool to compare the four variations in reservoir storage we considered. This stand-alone model of the Takatz project allows comparisons of the annual generation and capacity that the Project can provide. It also demonstrates what incremental energy and storage capacity is provided with a phased development of the project.

However this stand-alone model does not consider how effectively Takatz could be coordinated with operation of the Blue Lake and Green Lake projects. A key consideration for Takatz is what storage volume is best for the overall Sitka system. It appears clear that the "large storage configurations", i.e., the Phase 2 and 1968 Plan of Development could offer substantial carry over storage for dry years and long term outages of the Blue Lake or Green Lake projects. By the limitations of our stand-alone model, we have not confirmed whether the "moderate storage configurations", i.e. the Phase 1 and Single-Stage storage volumes are truly optimum for the future three-project hydro system.

Future operations modeling of Takatz should be conducted using a system-wide model that allows simulation of the coordinated Blue Lake – Green Lake – Takatz Lake operation, over a long term hydrologic record. Updates of the electric system's monthly load distribution should also be included, to consider added winter generation for electric heating loads. This type of system-wide simulation will provide a more clear definition of the appropriate storage volume that should be carried forward as part of the Takatz Lake development.

6.5 Model Results for Electric Heat Operation of Takatz Lake Phase 1

The electric heat modeling alternative for the Takatz Project assumes the Phase 1 project configuration and a monthly load distribution that mimics the heating-degree-days (HDD) per month in the Sitka area. Sitka staff requested this additional model simulation to help define the worst-case effect of additional electric heating loads. Table 6-7 provides a comparison of the HDD per month and the recent monthly load distribution in the Sitka system.

Table 6-7 Monthly Distribution of Sitka Electric Loads and Heating Degree Days

Monthly Electric System Load as a Percentage of Annual Total, %											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.4%	9.5%	8.5%	9.2%	7.7%	7.8%	7.4%	7.5%	8.1%	8.7%	7.3%	8.9%
Monthly Percentage of Total Annual Heating Degree Days, %											
12.1%	11.1%	12.0%	9.5%	7.3%	5.1%	3.7%	3.3%	4.6%	8.1%	10.3%	12.9%

Notes: 1. Electric load distribution based on 2005 to 2008 Sitka electric system loads.
2. Heating-degree-day distribution is the average of the 2007 to 2010 calendar years.

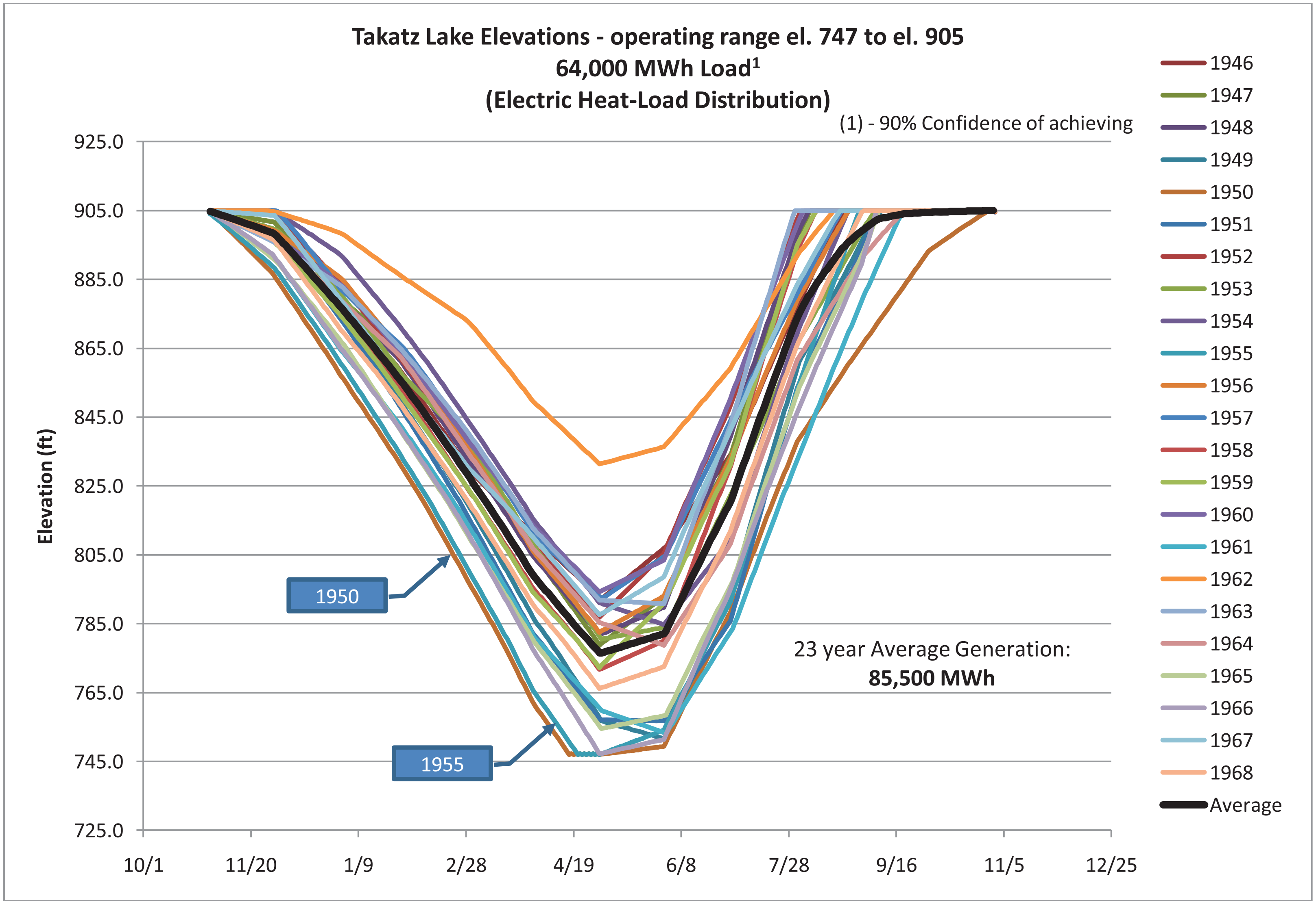
Table 6-7 shows that much more energy would be required from the project in the winter and early spring, compared to "normal" operation to meet overall electric system loads. Operating for electric heat only during the year would result in much larger withdrawals from lake storage at the time of year when inflows are the least. This operating strategy was then expected to put much more demand on the reservoir storage, resulting in less energy generation from the project.

Study engineers used the electric heating load demand schedule and the Phase 1 project configuration to simulate operation lake level variations and energy generation with the 23 years of hydrologic record developed for the study.

Figure 6-6 shows the resulting reservoir level variations with heating-only operation of the Phase 1 Takatz development. This figure can be compared to Figure 6-1, which shows lake levels with Phase 1 operation to supply energy with a monthly distribution matching the normal electric system loads. When operating to supply electric heat, the lake level would drop quickly from full (el. 905) in the early winter to the annual minimum level in April of each year. As was done for the other model cases, Study engineers manually ran the model with gradually increasing annual loads to arrive at a 64,000 MWh annual electric load that could be provided in 21 of the 23 years of record. This annual energy is a 12% drop from the 75,000 MWh predicted for the Phase 1 project operating into the normal seasonal load distribution. While the 90% confidence energy dropped substantially, the 23-year average generation dropped only 1%, from 86,140 MWh to 85,500 MWh.

The 64,000 MWh of annual energy from Takatz with this operating scenario represents the equivalent of 1.86 million gallons of heating oil consumption each year, if all of this energy were used to displace oil heat (based on 138,000 btu/gal oil heat value and an average oil furnace efficiency of 85%). The average annual energy of 85,500 MWh is equivalent to almost 2.5 million gallons of heating oil each year.

Figure 6-6 Phase 1 Reservoir Haze Chart – Electric Heat - 90% Confidence



Note also that Figure 6-6 represents a 90% confidence of supplying the target 64,000 MWh annual load and not a 90% confidence of reservoir refill. With this simulation the lake actually refills in every year. The ability to refill in all 23 years is an artifact of the steep drawdown from November to April each year and the reduced annual target generation value (as compared to Figure 6-1). Table 6-8 shows the annual generation for this operating strategy. Note that the 64,000 MWh target generation is not provided in the 1950 and 1955 calendar years, but that the lake successfully refills at the end of each of these two years.

Table 6-8 Phase 1 Project Generation for Electric Heat – 90% Confidence of Supply

	Firm Gen (MWh)	Surplus Gen (MWh)	Total Gen (MWh)	Total Unmet Load (MWh)
1946	64282	28420	92702	0
1947	64007	34865	98872	0
1948	64007	35187	99194	0
1949	63720	9638	73357	0
1950	61844	272	62116	2385
1951	64007	19870	83877	0
1952	64007	35730	99737	0
1953	63720	12300	76020	0
1954	64229	20764	84994	0
1955	62282	11055	73338	1725
1956	64007	13297	77304	0
1957	63720	19411	83130	0
1958	64229	19614	83844	0
1959	64007	29966	93973	0
1960	64007	29144	93152	0
1961	63720	14319	78039	0
1962	64229	34990	99219	0
1963	64007	32181	96188	0
1964	64007	16215	80223	0
1965	63720	18530	82249	0
1966	64229	18651	82880	0
1967	64007	24027	88034	0
1968	64007	19772	83779	0
Avg	63826	21662	85488	179
Max	64282	35730	99737	2385
Min	61844	272	62116	0

Future plans for the Takatz Project may include a revised annual load shape with a greater percentage of generation in the winter months. Sitka staff noted that the monthly distribution of loads in 2009 and 2010 showed exactly that effect: winter monthly loads were higher than historic winter averages and the highest winter monthly loads corresponded to months with low temperatures and high heating demands. If this trend continues, the recommended reservoir storage volumes described in this study should likely increase. All of these effects should be considered in a system-wide generation modeling effort as part of any final feasibility or design effort for the Takatz Lake Project.

Finally, a word of caution: The rapid rise in electric demand which Sitka is currently experiencing and the projected load growth which may justify construction of the Takatz Project all rely on the basic assumption that electric heat in the future will cost less than oil heat. If the Takatz Project cost is great enough to drive Sitka's retail electric rates above the btu-equivalent cost of oil, then the demand for electric resistance heat will not materialize.

SECTION 7 – OUTAGE ANALYSIS

7.1 Potential Outage Events

7.1.1 Overview

Development of the Takatz Project will provide Sitka with an important improvement in the overall reliability of its electric system. Currently, all of the City's hydro energy is delivered along a transmission corridor from the south, fed from the Blue Lake and Green Lake hydro projects.

The Takatz Lake transmission line is planned to connect to the Green Lake line near Bear Cove, about four miles southeast of the Blue Lake powerhouse. As a result, generation from all three hydro projects relies on the continued operation of the transmission segment from Blue Lake to the city.

An outage of either the Blue Lake or Green Lake powerplants can force the City to rely on back-up diesel generation if the remaining hydro capacity is not adequate for the city loads. In any future outage of the Blue Lake or Green Lake projects, energy from the Takatz Project would be available as a reserve. This section examines several possible outage scenarios and identifies what energy capacity and storage would be appropriate at Takatz to help the City weather an outage of its existing hydro units, or in the transmission line segment from Green Lake to Bear Cove.

7.1.2 Short Term Transmission System Outages

In October 2010, a windstorm moved through the Sitka area resulting in damage to several transmission line structures along the 69kV transmission line between the Blue Lake switchyard and the City of Sitka. Loss of this line separated the Blue Lake and Green Lake projects from the city grid and forced Sitka to rely on the Jarvis Street backup diesel generators. Major statistics for this recent outage are summarized here to help understand the cost of potential outages for which the Takatz project might provide reserve power capacity.

Note that, if an outage occurred in the same location after Takatz were developed, the connection between all three generating plants and the City would be severed. Sitka would be in a similar situation of having to rely on diesel generation. The Study team understands that Sitka is considering alternatives for back-up power supplies for the city. These options include adding a redundant transmission line between Blue Lake and Sitka, to provide an independent transmission path between the generating plants and the City. If this redundant line segment is pursued, the City may want to consider arranging the redundant line so that it could readily be extended from Blue Lake to the future interconnection point with the Takatz transmission line.

7.1.3 Summary of 2010 Transmission System Outage

The 2010 transmission line outage began in the afternoon of October 12, 2010 and lasted for 70 hours. The system load immediately prior to the outage was 15.6 MW. This load exceeds the City's backup diesel generation capacity. During the outage, the City Electric Department was forced to institute rolling blackouts of the major feeders to the north and south of town, in order to limit generation to about 11.5 MW (slightly less than the diesel generators' maximum capacity). These blackouts were in addition to the cut-off of all interruptible loads, standby-generator operation throughout the service area by industrial and commercial customers, and a significant voluntary reduction in loads by the Sitka residential and business community. The major statistics for this outage are presented in Table 7-1.

Table 7-1 Summary of Sitka, Alaska, October 2010 Transmission System Outage

Outage Item[1]	Quantity	Unit Cost	Net Cost
Net Diesel Generation	674.6 MWH		
Lost Generation Sales	262.3 MWH	$90/MWH	$23,600
Diesel fuel - generation	46,876 gal	$2.45/gal	$115,072
Diesel fuel – public works	1,515 gal	$2.76/gal	$4,181
Lube oil	145 gal	$11.81/gal	$1,712
Equipment rental			$5,995
Line Repair Materials			$6,870
Contract Labor			$14,509
Labor, Electric Dept and Pub. Works			$38,275
Approximate Total Direct Cost of 70 hour outage =			$186,500
Average Cost per Hour of outage (direct costs) =			$2,660

The costs presented in Table 7-1 include the City's public works staff labor and diesel fuel required to operate portable generators needed to maintain operation of several sewage lift stations in the parts of town that suffered the rolling blackouts. However, the costs in Table 7-1 do not any costs associated with: 1) wear and tear on the City's diesel generating resources; 2) the cost of diesel fuel paid by self-generating customers; 3) the disruption of business activity during the outage; and 4) the general inconvenience to all of the City's electric utility customers. Sitka estimated these indirect costs to be approximately $214,000. If these indirect costs are considered, the total hourly cost for this outage was approximately $5,700 per hour.

7.1.4 Long Term Equipment Outages

The existing Green Lake and the future Blue Lake Expansion Projects both have reserve generating capability, in that the hydraulic flow capacity of their turbine-generators exceeds the average flow through the powerplant. Therefore, if a long-term outage of a single generating unit occurs, the remaining unit(s) will be able to provide most of the energy generation expected from the project. Long term outages of individual generating units, in a Green Lake – Blue Lake only system might result in some diesel generation to meet peak loads. However, most of the generated energy would still come from the hydro units and diesel fuel costs would be modest.

The principal outage risk from an energy perspective is a long-term complete outage of either the Green Lake or Blue Lake powerhouses. Such an outage could result from damage to common equipment that prevents generation by the entire powerhouse. Examples of possible damage scenarios include:

- Tunnel rock falls, leakage or maintenance that require long outages
- Landslide or flood flow damage to the Blue Lake penstock crossing at Sawmill Creek

[1] Data provided by City of Sitka, email from C. Brewton, March 16, 2011.

- Rock falls into the Green Lake switchyard, damaging transformers or circuit breakers.
- Transformer fires in either switchyard that damage more than one transformer.
- Cable duct fires
- Control Room or in-plant fires that damage common control or support systems
- Flooding of either powerhouse (failure of pressure piping, tsunami, flood discharge over Blue Lake dam, etc)
- Major sedimentation in the Blue Lake powerhouse tailrace, following a flood event
- An extreme ice event that damages long stretches of the Green Lake transmission line

Any outage that requires obtaining specialty materials and equipment from the lower 48 states will likely extend for a period of weeks. Lead times for replacement transformers can range from two to 12 months. However, the use of temporary transformers on a rental or loan basis could likely limit the duration of a transformer-caused outage to a month or two. Fires and floods within the powerhouses would require replacement of the damaged equipment, drying out of the generators and cleaning of equipment and systems near the damage site. A number of outage scenarios are possible that could stretch from 2 to 8 weeks at either project.

For the purpose of estimating a storage reserve volume in Takatz Lake, an outage duration of 30 to 60 days was assumed in our analysis for a serious plant-wide outage of Green Lake or Blue Lake. The estimate also assumes average water year inflows which result in a total 154,000 MWH annual generation from the existing Green Lake and the Blue Lake Expansion project. The annual generation from the Green Lake and Blue Lake Expansion projects is broken down as shown in Table 7.2.

Table 7-2 Average Year Generation, Green Lake and Blue Lake Expansion Projects

Powerplant	Plant Generation, MWH		Average Power, MW
	Annual	Average Day	
Green Lake	55,341	151.6	6.32
Blue Lake Powerhouse	90,402	247.7	10.32
Fish Valve Unit	8,264	22.6	0.94
Total Blue Lake	98,666	270.3	11.26

Note: based on Sitka Operations Model 425 5_2009 new BL reduced turbines ave year 052909.xls

Based on the annual generation figures the 30-day and 60-day outage energy requirements are presented in Table 7-3. These values represent the energy reserves required in the Takatz reservoir, if Takatz is to serve as a reserve power source for a long term outage of either Green Lake or Blue Lake.

Table 7-3 Long-Term Outage Lost Energy for Green Lake and Blue Lake Expansion

Powerplant	Average Power, MW	MWH Lost Energy For Outage Duration of:	
		30 days	60 days
Green Lake	6.32	4,550	9,100
Blue Lake PH only	10.32	7,430	14,860
Total Blue Lake	11.26	8,110	16,220

7.2 Reserve Energy Storage Available at Takatz

The average water level of Takatz Lake could vary widely, depending on which development alternative is selected. In a Phase 1 development, with no dam and a maximum lake level of el 905, the typical level could be in the range of el. 830 to el. 880 ft. In a Phase 2 or full development, with a dam crest at el. 990 ft, the typical operating range could be between el. 930 to el. 980 ft. With a turbine centerline elevation of el. 30 and average head loss of 30 ft, this suggests the average net head at Takatz would range from 770 ft to 820 ft for the phase 1 arrangement and from 870 to 920 ft for the Phase 2 configuration. In order to estimate a rough range of reserve capacity, average net heads of 800 ft and 900 ft were assumed for the Phase 1 and Phase 2 configurations of the Takatz Lake project. Based on these estimated average heads, the predicted reserve storage volumes in Takatz Lake are presented in Table 7.4, for the long-term outage scenarios described above.

Table 7-4 Reserve Storage Volume Required in Takatz Lake, for Long Term Outages

Outage Event	Energy Required, MWH	Takatz Lake Reserve Storage Vol. ac-ft	
		Phase 1	Phase 2
Green Lake – 30 days	4,550	6,660	5,920
Green Lake – 60 days	9,100	13,320	11,840
Blue Lake PH – 30 days	7,430	10,876	9,667
Blue Lake PH – 60 days	14,860	21,752	19,335
Total Blue Lake – 30 days	8,110	11,871	10,552
Total Blue Lake – 60 days	16,220	23,742	21,104

The reserve reservoir capacity suggested for the Takatz Lake Phase 1 development is 4,650 ac-ft, measured from the predicted minimum lake level in an average year. This volume is not adequate to cover a 30-day outage of the Green Lake or Blue Lake powerplants, if the outage occurred between April 1 and June 30 of a given year. If the outage were to occur in the 9 month July 1 to March 31 time frame there would be sufficient water in Takatz Lake to make up the lost generation from a 30-day outage of either Blue Lake or Green Lake. Overall, the suggested reservoir reserve volumes for the Phase 1 and single stage alternatives are adequate during most of the calendar year, based on the volumes suggested by this outage scenario. Future study efforts should re-examine whether this reserve volume is adequate.

If the Phase 2 Takatz development were constructed, the combination of the deep lake tap and the dam would provide significant reserve volumes in the Takatz reservoir. This reserve volume could be used either for outages of the other powerplants, or for reserve generation during dry years. Multi-year power studies of the combined system should be carried out when the final feasibility studies of the Project are completed, to confirm the appropriate reserve storage volume in Takatz Lake.

SECTION 8 – PROJECT ARRANGEMENT ALTERNATIVES

8.1 Dams

For the main dam at the Takatz Lake outlet, no information was developed in this 2011 study to warrant suggesting a different dam site location from that shown in the 1968 Study (see Figures 2-2 and 2-3). Also, the multiple curvature concrete arch dam structure described in 1968 appears very suitable for the site, as it was described. Main dam alternatives considered in 2011 reflect mainly variations in the height of the dam at this location, or for the lake tap alternative, no dam at all.

The reservoir storage volumes defined in this study suggest that an adequate reservoir can be developed with a main dam height of el. 990, for both the Phase 2 and for the single-stage development alternatives. The study team recommends that the single-stage and Phase 2 dams be a multiple-curvature concrete arch dam with el. 990 spillway crest, parapet walls and orientation similar to the dam layout shown in 1968.

If such a dam is constructed following a Phase 1 lake tap, then it is likely that the low-level outlet works valves shown in the 1968 arrangement can be deleted. The large hydraulic capacity available with the recommended turbine-generators and the ability to draw the lake down below the dam invert, both suggest that a separate outlet works in the dam is not needed.

The saddle dam proposed in 1968 is now considered unnecessary as this structure is only required if reservoir storage above elevation 990 were desired. It is possible that more detailed engineering studies may determine that some type of low weir dam may be appropriate at the saddle dam site to allow a maximum reservoir level slightly higher than el. 990. A lower height saddle dam might be possible using a T-wall or gravity dam structure, in lieu of the concrete arch structure proposed in 1968.

The lake tap alternatives discussed in this report (and in the 1968 study) suggest a maximum lake level of el. 905, the current natural lake level. It is obvious that the existing lake's outlet control has to have a sufficient flow cross section to pass the lake outflow while holding a lake level near el. 905. This suggests that the existing channel's outlet invert is several feet below el. 905. Consequently, some type of channel closure or infill is most likely required at the lake outlet to develop an el. 905 maximum lake level, with no spill.

The feasibility of such a low dam or weir, founded on alluvial material, is very uncertain. It may be impossible to achieve an effective cut-off of the reservoir outflow without placing an impervious barrier down to bedrock at the weir site. Based on subsurface borings in 1965, sound bedrock is 40 to 60 feet below the surface at the lake outlet. Consequently, how to stabilize the lake outlet and possibly construct a small dam or weir needs to be fully evaluated in any preliminary design of the project.

The satellite imagery available to the study team suggests that the outlet control may be located in alluvial or glacial sedimentary materials where construction of a permanent structure may be difficult. The requirements for this lake outlet channel closure structure should be included in future studies for the Takatz Lake development. These studies should also consider how spills through the natural channel system might undermine, bypass, or otherwise affect any closure structure.

8.2 Reservoir Levels and Capacities

The recommended reservoir operating levels and capacities are summarized in Table 4-6. Variations from these levels should be expected following additional site studies and analysis of the dam structure and lake tap configuration. Future growth in the Sitka electric system may dictate a different total reservoir storage goal, also affecting the selected storage volume. All of these parameters should be considered in future feasibility studies, leading to confirmation or adjustment of the reservoir levels and storage capacities suggested in this 2011 report.

8.3 Tunnel and Power Conduit

Similar to the dams, no new data was developed for the tunnel and power conduit scheme that would suggest a major relocation of the tunnel system or the powerhouse location from that proposed in 1968 (see Figure 2-2). Our study engineers do however believe that improvements in the power conduit arrangement are possible with more modern tunneling techniques and with development of the lake tap alternative. These possible improvements include:

- Replacing the deep intake gate access shaft with a walk-in valve chamber, providing easier operations and maintenance of the tunnel shut-off equipment.
- A lower elevation alignment for the main tunnel that allows a straight tunnel bearing from the lake to tidewater and the lower tunnel portal to be located near the powerhouse site and base camp.
- The lower tunnel alignment also allows a shorter penstock to be placed inside the tunnel, free of avalanche or rockslide risks and reducing the visual impact of a surface penstock near the shore.
- The lowered portal elevation also eliminates a construction road on the rock face to the el. 787 ft portal as was proposed in 1968.

The tunnel alignment suggested in this study carries some risk in assuring adequate rock confinement of the tunnel near the valve chamber and at the lower portal. Future geologic investigations and studies will be needed to confirm the rock adequacy in these areas and to modify the tunnel alignment, if needed. The tunnel plan and profile suggested in our 2011 study is described later in this section.

8.4 Powerhouse Arrangement

The powerhouse arrangement shown in 1968 (see Figure 2-4) appears very appropriate for a modern development. The structure shown in 1968 included an enclosed structure, located near tidewater that would house the generating units, control room, station electrical and mechanical equipment and some storage and shop areas. Each turbine was fitted with a turbine shutoff valve and independent discharge channel to tailwater. All of this appears reasonable for a modern development. Study engineers assume that the powerhouse structure will be similar to that suggested in 1968.

One small aspect of the 1968 arrangement that should be considered in future final feasibility studies is the selected turbine setting. As shown in 1968, the turbine centerline elevation is e. 16.7, which is only 5 feet above the el. 11.2 maximum tailwater level. The setting above tailwater appears to be not high enough and the maximum tailwater level does not appear to reflect high tide levels in the Baranof Island vicinity. As noted later in this section, our 2011 study assumes a turbine centerline elevation of el. 30.

8.5 Powerhouse Installed Capacity

The total power conduit length at the Takatz development will be on the order of 5,000 ft, regardless of whether the site is developed in a phased or single-stage approach. Much of this length will be in tunnel, where the tunnel diameter is determined by construction access considerations and not by hydraulics. As a result, the power conduit head losses will be small, for most any reasonable range of powerhouse installed capacity that might be considered.

The average annual flow at Takatz Lake is 171 cfs (for the 10.8 sq mi drainage area). Conventional sizing of a powerhouse to fully use this flow would suggest a design hydraulic capacity roughly around twice the average flow, or approximately 342 cfs. However, the low power conduit hydraulic losses and the project's high head will allow development of significant reserve generating capacity at Takatz for a modest incremental cost.

This 2011 report does not have a separate section dedicated to selecting the appropriate Takatz installed powerhouse capacity, in terms of meeting future peak loads in the Sitka system. It is clear that the Takatz site is well suited for installing reserve capacity for the City system. Takatz offers a head approximately 2.5 times greater than Green Lake or Blue Lake combined with low friction losses in the power conduit system. Therefore, the cost of increased capacity at Takatz will be less than virtually any other option available to the City.

Accordingly, the study team recommends that the Takatz powerhouse capacity be based on a two-unit arrangement where each turbine's hydraulic capacity is approximately 130% of the average basin yield. With this unit sizing, one of the two generating units could effectively regulate most of the annual flow of the site, allowing for long-term outages of the second unit. This hydraulic sizing will allow the high-efficiency operating range of one machine to be near the average project flow. In addition, the two-unit output would be large enough to provide significant added generation capacity into the Sitka electric system. This capacity could be used for both daily system peak loads and for major outages of the Blue Lake or Green Lake developments.

The study team recommends that the powerhouse installed capacity for any alternative be based on a two-unit powerhouse with a per-unit maximum flow of 225 cfs at the design head condition. We suggest further that the power conduit penstock, valves, and flow control elements be based on a nominal design tunnel flow rate of 450 cfs. Table 8-1 lists the resulting turbine and generator MW ratings for the phased and single-stage development options.

8.6 Number and Type of Generating Units

When developed, the Takatz Project will likely be the largest single generating resource in the Sitka system. It would be unwise, from a redundancy and reserves perspective, to build the facility with a single generating unit. The study team considered both two-unit and three-unit configurations and determined that either arrangement would meet the City's basic needs for

Table 8-1 Recommended Takatz Powerhouse Installed Capacities

	Turbine Capacity, cfs	Design net head, ft	Generator Output, MW		Generator Rating, MVA
			design	at Max WSEL	
Phased Project Development					
Phase 1	2 x 225	790 [1]	2 x 12.5 MW	2 x 13.33 MW	17.2
Phase 2	2 x 237	875 [2, 3]	2 x 14.6 MW	2 x 15.5 MW	17.2
Single Stage Development with Surface Intake					
	2 x 225	875 [3]	2 x 13.9 MW	2 x 14.8 MW	16.4

Notes: 1) Assumes conduit head loss of 30 ft, unit centerline el 30, and el. 850 design lake level.

2) Phase 1 turbine-generators would be configured for Phase 2 operating conditions without requiring equipment modification or replacement. The higher turbine capacity is due to the higher operating head achieved in Phase 2.

3) Assumes average operating lake level el. 935.

capacity, reserves, and energy generation. The least cost arrangement for any given project capacity is a two-unit powerhouse. As long as the units are sufficiently large to provide full use of the Takatz Lake flows with a single unit (to accommodate long-term outages of any single generating unit), the two-unit arrangement appears preferable.

The head and flow conditions at Takatz would allow use of either a Francis (reaction) type turbine design or a Pelton (impulse) turbine. The site conditions are not considered suitable for a "Turgo" unit (a type of impulse turbine manufactures by Gordon Gilkes of England) as the required per-unit flow capacity is outside the normal range of the Turgo turbine design.

If Francis turbines were selected, the power conduit would likely require addition of a surge chamber to provide pressure relief during generating load rejections and to allow adequate frequency control performance of the project. A surge shaft could readily be developed in the power tunnel, about 800 ft upstream of the powerhouse. The surge shaft could be raised to the surface from this point, using conventional raised-bore mining techniques.

Francis turbines would be more efficient than a Pelton unit and could develop about 10 more feet of head overall, through recovery of the draft head at the powerhouse. These units would be physically compact, with a hydraulic capacity and size actually a bit smaller than the new Blue Lake Expansion turbines. The units would most likely be horizontal shaft units with a unit centerline at about el. 20.

The major drawbacks of Francis turbines are:

- A narrow operating range, due to the turbine type and high head
- The need for a surge chamber
- Higher conduit pressure rise and unit speed rise during load rejections

The Francis turbine's narrow operating range is a major disadvantage. To cover a wide enough operating range for the project could likely require the use of three Francis machines, not two. The operating range limitations and other load-rejection and load-acceptance characteristics led the study team to evaluate the Francis turbines as less attractive than a Pelton type machine.

The combined net head and per-unit flow developed by the lake tap arrangement are near the low end of the application range for Pelton turbines. As a result, a Pelton unit at this site would likely be a vertical shaft 6-nozzle turbine. This machine type would allow a very wide range of high-efficiency operation from about 20% to 100% of rated discharge. These units do not require a surge chamber for load rejection events. However, without a surge chamber the overall load acceptance capability of the project during day-to-day operation would be reduced. (Note that excellent load acceptance performance is possible if the units are operated in what is known as a deflector-control mode. This mode could be used to bring on major blocks of load following system outages).

The study team recommends a two-unit vertical shaft 6-nozzle Pelton turbine configuration for the Takatz project, without a surge chamber. The turbines would be connected to vertical shaft synchronous generators with an MVA rating matched to the maximum turbine output at maximum lake level. The generator should have additional WR^2 rotating inertia for system frequency support. Turbine controls should allow 2-nozzle and 4-nozzle operation along with deflector-based speed governing control for load pick up and system emergencies.

If the project goes forward as a phased development, the Phase 1 generating equipment should be configured for Phase 2 operation. The switch from Phase 1 to Phase 2 lake levels might warrant replacement of the turbine runners, to better match the higher head conditions. However the value of this, and the overall generating equipment arrangement, both need to be evaluated in detail in future final feasibility studies of the project.

8.7 Reservoir Sedimentation Concerns with Phased Development

Appendix A of the 1968 Study included a brief evaluation of sedimentation potential in the Takatz Lake basin. The report noted an extensive sediment delta at the upstream end of the lake, observing:

> *"The main valley floor at the head of Takatz Lake is occupied by an impressive river delta. Much of the surface is unvegetated and there are evidences of frequent channel changes. The delta's pivot point, and the foreset and topset slopes can be identified quite accurately from the USGS 1957 surveys of the lake, scale 1:24,000. A sketch of the delta is shown on Drawing 1113-906-22. Surface materials are medium to coarse-grained gravels, grading into finer gravels and sands near the pivot point. Sources of the sediment are glacial debris and talus slopes along the valley walls."*

Drawing 1113-906-22 is reproduced in this 2010 report as Figure 8-1. As noted in the 1968 narrative, the figure shows an abrupt transition from the topset slope of 0.013 to the foreset slope of 0.50. The meandering channel in the delta deposit has transported the sediment material uniformly to the edge of the delta, resulting in an almost linear lake shoreline at the delta's pivot point.

The 1968 Study (Appendix A, pages A34 to A37) attempted to determine the rate of sediment deposition in Takatz Lake, based on comparisons of the 1929 and 1957 surveys. No variation in the delta shoreline could be determined in this comparison, so that no deposition rate could be defined. A comparison to other Southeast Alaska streams with glacial inflows resulted in an estimated sediment generation rate for the basin of 5.1 ac-ft/sq mile/yr. The corresponding 50 year and 100 year sediment accumulations are 1,735 ac-ft and 3,470 ac-ft respectively. These sediment accumulation volumes were considered small by the 1968 study team, as their report states:

> *"The 100-year value [3,470 ac-ft of sediment] is 4.2 percent of the planned active storage capacity, so no sediment storage allocation is indicated. "*

Sufficient lake soundings were performed in the 1967 Takatz Lake survey to determine that the minimum elevation of the lake bottom is el. 435 ft, or 470 ft below the normal lake surface. The 1957 USGS survey determined that (at the time of that survey) Takatz Lake had a surface area of 403 acres at el. 905 ft, with an area of 243 acres at el. 700 ft. The 1968 Study did not attempt to determine the lake volume below el. 700 ft. To arrive at a gross approximation of the volume below el. 700, the lake floor may be approximated as a regular cone 265 feet high, with area of 243 acres at its top and a zero area at the bottom of the cone. With this gross assumption, there is possibly 21,400 ac-ft of lake volume below el. 700 ft.

The 2009 aerial mapping of the Takatz Lake area was used to estimate the gross surface area of the delta and the present-day lake. As shown in Figure 8-2 the 2009 survey shows a lake surface of 399 acres, which is a reduction in the open-water area of 4 acres (one percent), compared to the 1967 survey. The approximate sediment delta area was estimated based on a survey of the delta area below the el. 1075 ft contour. Assuming this boundary for the upper extent of the delta, the calculated delta surface area is 215 acres.

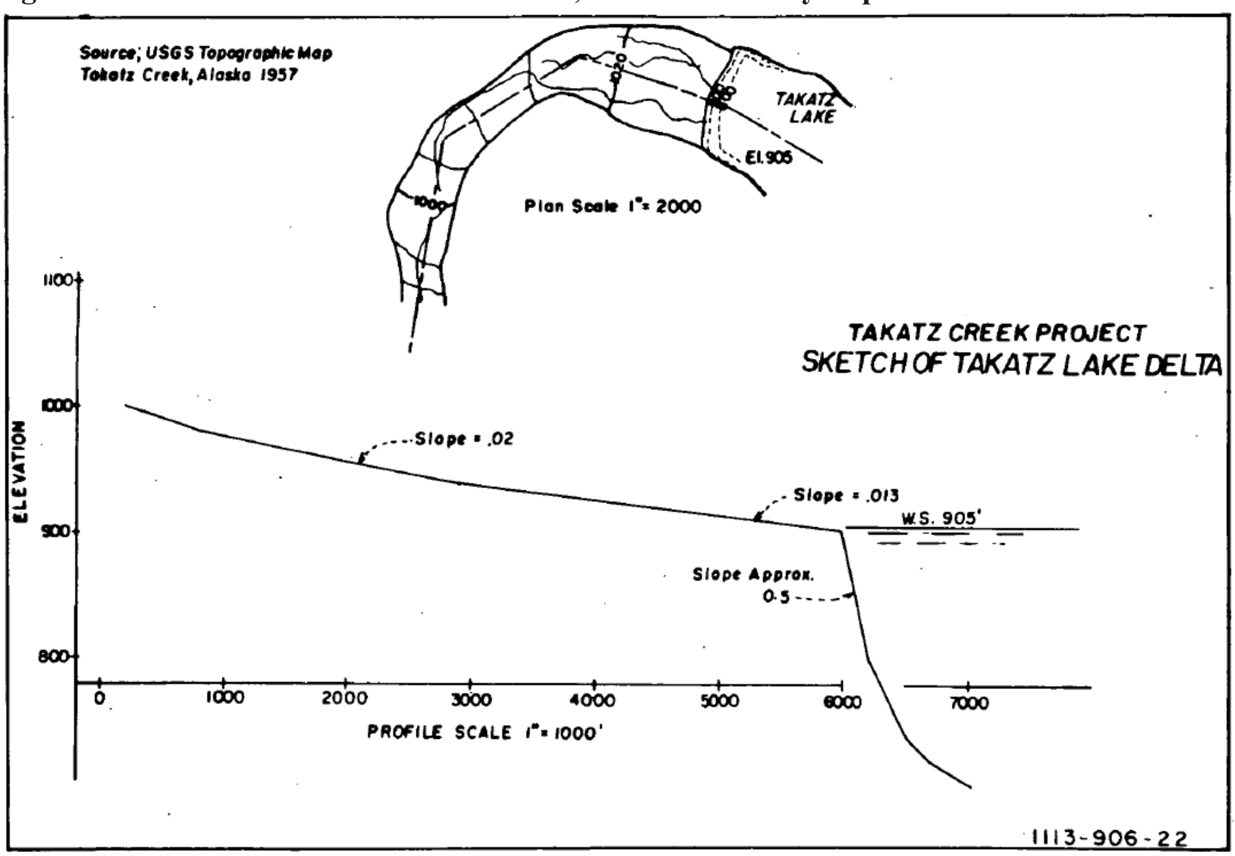
To arrive at a gross estimate of the sediment delta's volume, the 2011 study team assumed the volumetric shape of the delta is similar to the shape of the lake. The lake area of 243 acres at el. 700 is 60% of the 403 acre area at el. 905 (based on the 1967 survey). Assuming the sediment delta area at el. 700 is also 60% of the delta's surface area; then the sediment volume above elevation 700 is in the range of 30,000 to 50,000 ac-ft [a volume of 43,000 ac-ft was estimated, based on a top surface area of 215 acres at el. 950 and a bottom surface area of 129 acres at el. 700].

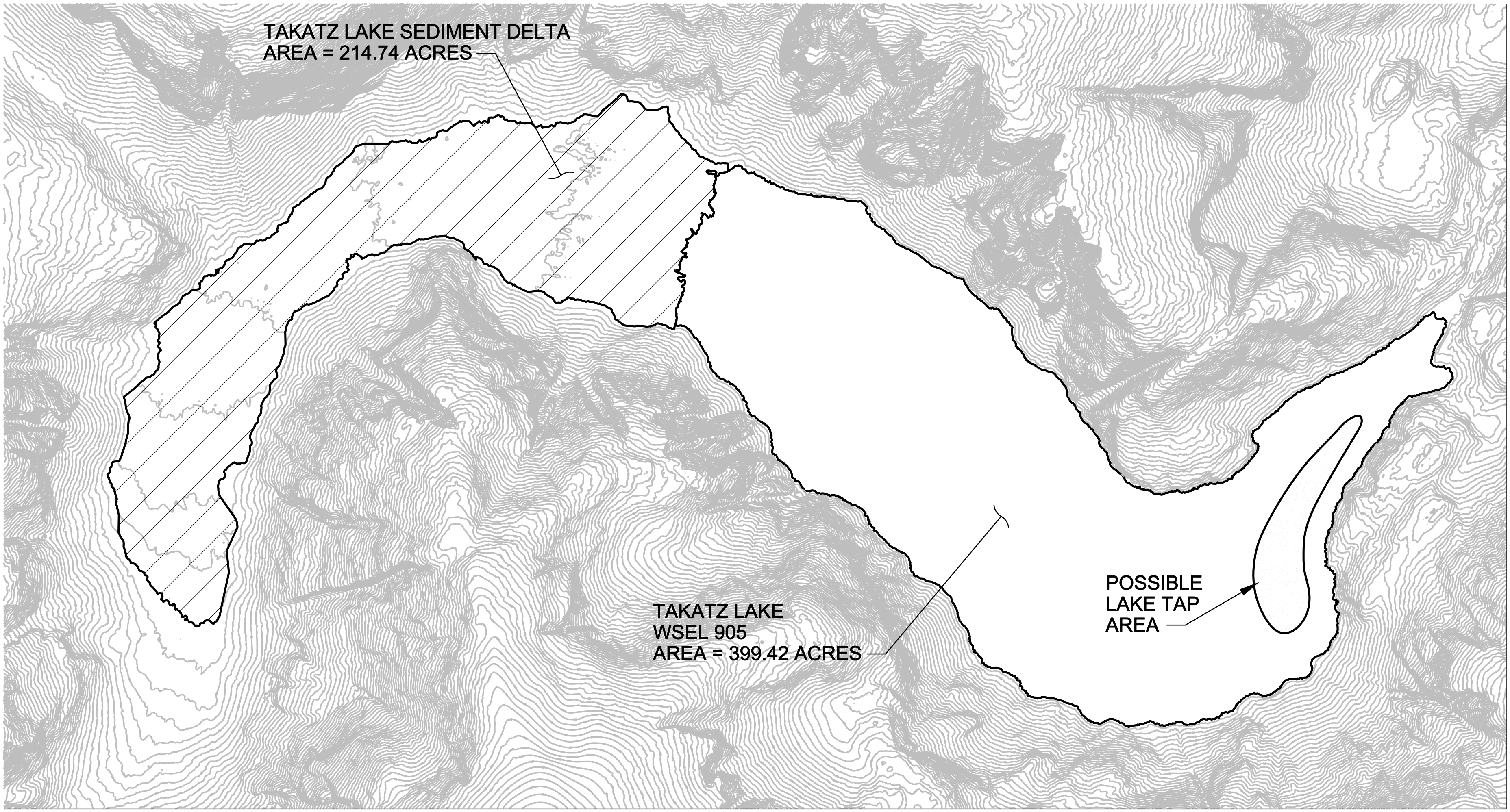
This very rough estimate of the delta's size suggests that the sediment volume in the lake basin is greater than the lake's dead storage below el. 700. The delta materials are highly erodible and will most likely begin an active movement into lower levels of the lake, when the lake is drawn down below the historical water level. A fairly continuous head-cutting and raveling erosion of the delta materials should be expected, whenever the lake surface is drawn down below el. 905. The delta materials likely have a low permeability and may be susceptible to large slope failure events if they are saturated. Finally, if a seismic event occurred while the sediment delta is perched 100 ft or more above a drawn-down lake surface there could be potential for a major liquefaction-slope failure event.

Any lake tap alternative should consider what the volume of sediment is in the basin and what the risk is that movement of these sedimentary deposits could block or otherwise affect flows into the tunnel of a lake-tap intake structure. The risk of sediment blocking the intake is a major uncertainty for the lake-tap alternative at Takatz Lake. The location of the lake tap intake and it's relation to future sediment accumulations in the lower reaches of the lake will be important considerations in the final feasibility assessment and design of the Project.

Note that the Takatz Lake water is heavily clouded with glacial flour. This flour will have an erosive effect on the turbine runners and nozzle-needle assemblies, leading to earlier than normal (but still manageable) wear on these turbine parts. However, the large volume of the lake suggests that any sand or silt materials will settle out before reaching the tunnel intake structure. The major sediment risk is the infill of the lake bottom with sediment to the point where sands and gravels enter the power conduit and are passed through the turbines. If this occurs, it will be a severe problem for the generating equipment and waterway.

Figure 8-1 Sketch of Takatz Lake Delta, from 1968 Study Report





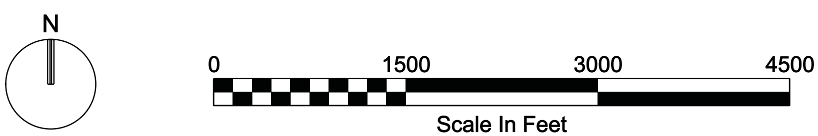


FIGURE 8-2
TAKATZ LAKE OPEN WATER AND SEDIMENT DELTA AREAS

TAKATZ LAKE PROJECT CAPACITY ANALYSIS
MARCH 2011 FINAL REPORT
CITY AND BOROUGH OF SITKA, ALASKA

TOPOGRAPHY SOURCE: AERO-METRIC, INC
SITKA TO TAKATZ SURVEY, APRIL 2009

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8.8 Recommended Arrangement for Phased Project Development

The recommended arrangement for the Phase 1 development is shown in Figures 8-3 and 8-4. In Phase 1 there would be no dam constructed and it is possible that an access road to the lake area would not be required. Thus, as shown in Figure 8-3 the only above-surface feature higher than the powerhouse would be the valve chamber access bench at el. 710 ft.

The power conduit would consist of a lake tap at el. 717 ft. feeding an upper tunnel extending 1100 ft to a valve chamber located in a rock monolith east of the lake. The tap at el. 717 ft would allow a reservoir operating range of 747 to 905 ft. This range provides 52,952 ac-ft of active storage. To fully regulate the lake inflows in an average year requires an active reservoir capacity of 48,359 ac-ft as described in Section 4.2 of this report. Therefore, with the el. 717 tap location, the gross active storage allows full regulation of the average year inflows with a drawdown to about el. 762 ft, plus a reserve storage of 4,593 ac-ft (8.7% of the total storage) between water level el. 747 ft and about el. 762 ft. This reserve volume compares reasonably to that provided at Blue Lake (14%) and Green Lake (7%) as discussed in Section 4.

At the downstream end of the upper tunnel, tunnel shut-off valves, control equipment and a mini-hydro unit would be located in a valve chamber as shown in Figure 8-5. Access to the valve chamber would be provided from an excavated bench in the talus slope to the east of the rock monolith. During construction, this bench area would be used for staging, spoil disposal and material deliveries to allow easier excavation of the upper tunnel and a staging/prep area for installation of the lake tap, tunnel plugs, penstock, valves, and valve chamber equipment.

Study engineers believe the access bench lies at the top of a talus slope, where excavation of this slope could allow development of a bench area to access the tunnel excavation. As shown, an access area as large as 150 by 210 ft could be developed at el. 710, providing ample lay-down areas and helicopter access. If the size (weights) of the penstock sections and valves are managed effectively, the study team believes that a combination of helicopters and the Alimak raised-bore platform system could be used for equipment and material deliveries to the el. 710 bench area. If this approach is used, an access road to the el. 710 bench would not be needed.

From the upper tunnel valve chamber the power conduit would drop in a vertical rock shaft 570 ft to the lower tunnel. The upper tunnel, vertical shaft, and lower tunnel could all be unlined rock conduits, with local lining or rock support as required by the geologic conditions.

The lower tunnel would extend 3,550 ft to its lower portal near the powerhouse at el. 40 ft. A 6 ft diameter steel penstock would be located in the downstream end of the tunnel, extending into the tunnel far enough to provide adequate rock cover for the unlined tunnel section. Based on information available to the study team, we estimate this penstock will need to be 720 ft long. Just downstream of the portal the penstock would bifurcate into two branch pipes connecting to the two 12.5 MW turbine-generators inside the powerhouse.

The powerhouse would be a reinforced concrete substructure with steel framed superstructure. The building arrangement would be similar to that proposed in the 1968 study (see Figure 2-4).

Access to the powerhouse site would be via road from a barge landing developed for the Project. These features would be very similar to the scheme proposed in 1968.

Phase 2 of the project would include construction of the main dam. This study anticipates that the main dam would be located where shown in the 1968 study (see Figure 2-3), with a spillway crest at el. 990 ft. This is the highest dam suggested possible in 1968 without construction of the saddle dam. No diversion tunnel would be required for the dam's construction as the lake could be drawn down well below the dam foundation using the Phase 1 tunnel and powerhouse. Also, we expect that the low level outlet works valves shown for the 1968 main dam would not be required. The Phase 2 dam would thus be a simple, double-curvature concrete arch dam with an el. 990 spillway crest.

As noted in this report's introduction, the transmission line from the project to the City of Sitka is not part of this engineering assessment. Separate feasibility and environmental studies address the transmission line alignment, design, and environmental issues.

8.9 Recommended Arrangement for Full Development, without Phasing

The recommended arrangement for a single-stage development of the Takatz Lake site would include the following major components:

- Concrete arch dam with spillway crest el. 990, similar to the Phase 2 dam described above.
- Concrete intake structure, with bulkhead gate at el. 874, similar to the intake proposed in 1968, sees Figure 2-2.
- Intake gate shaft adjacent to the lake, containing the tunnel intake gate and controls, also similar to Figure 2-2.
- Vertical raised shaft extending below the intake shaft to connect the upper tunnel to a lower tunnel that extends to the powerhouse site.
- A bifurcation and powerhouse arrangement similar to the Phase 1 project arrangement described earlier in this section.

This single stage arrangement would develop an active reservoir storage volume of 52,025 ac-ft between el. 990 and el. 890. This volume is just barely adequate to regulate the lake's inflow in an average year. If this single-stage development is pursued further, the investigation should consider means to increase the active storage developed. This could include a deeper intake or a higher maximum lake level, with a higher main dam and some type of weir or saddle dam at the saddle dam location proposed in 1968.

The powerhouse capacity would be based on a 450 cfs hydraulic capacity with the final reservoir levels. With the higher heads available a turbine-generator rating of 2 x 13.9 MW at the design head of 875 ft would be appropriate. The generator rating, to accommodate full load operation at maximum lake level, would be 16.4 MVA, as shown in Table 8-1.

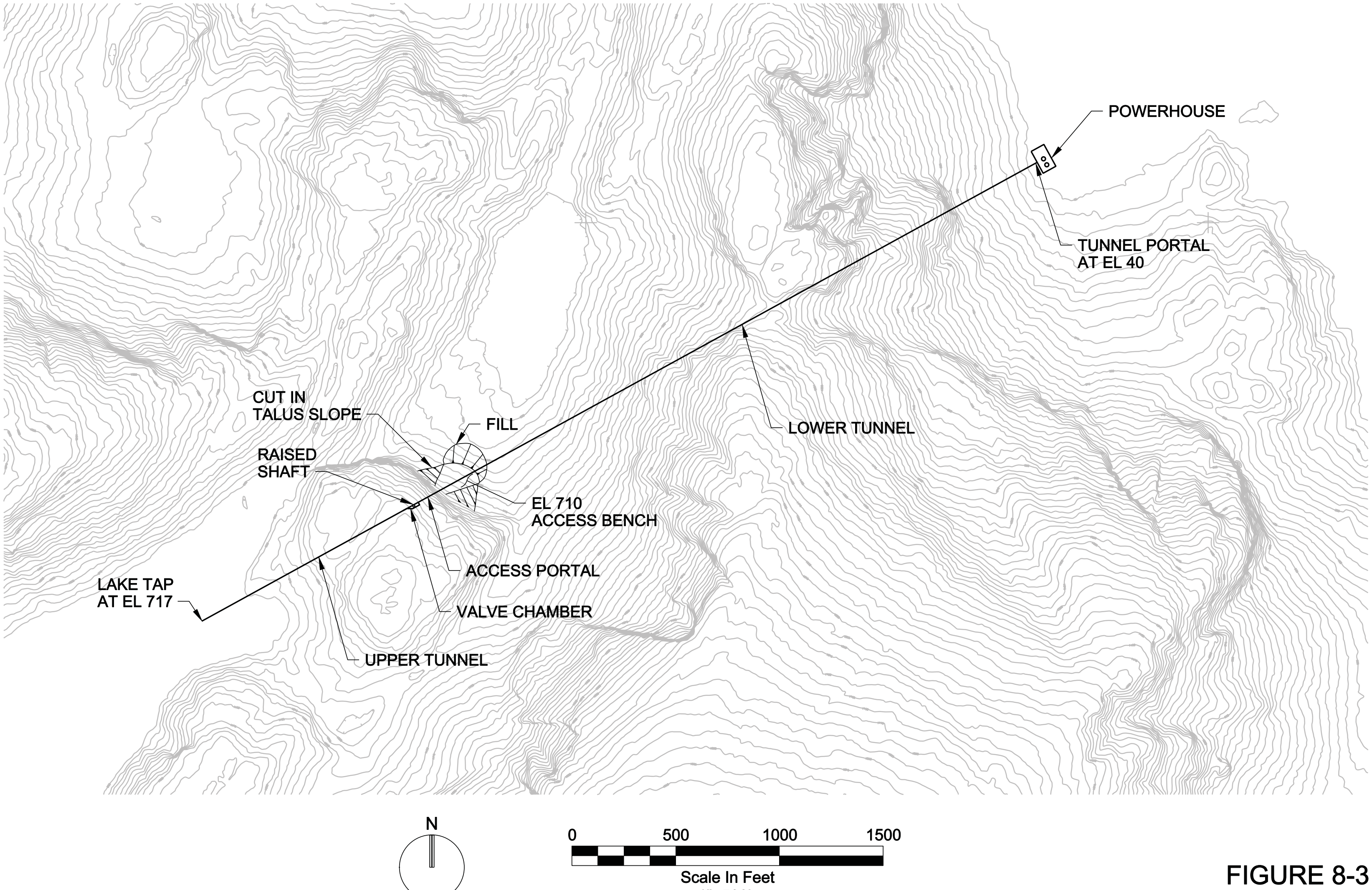

FIGURE 8-3
POWER FACILITIES PLAN - PHASE 1
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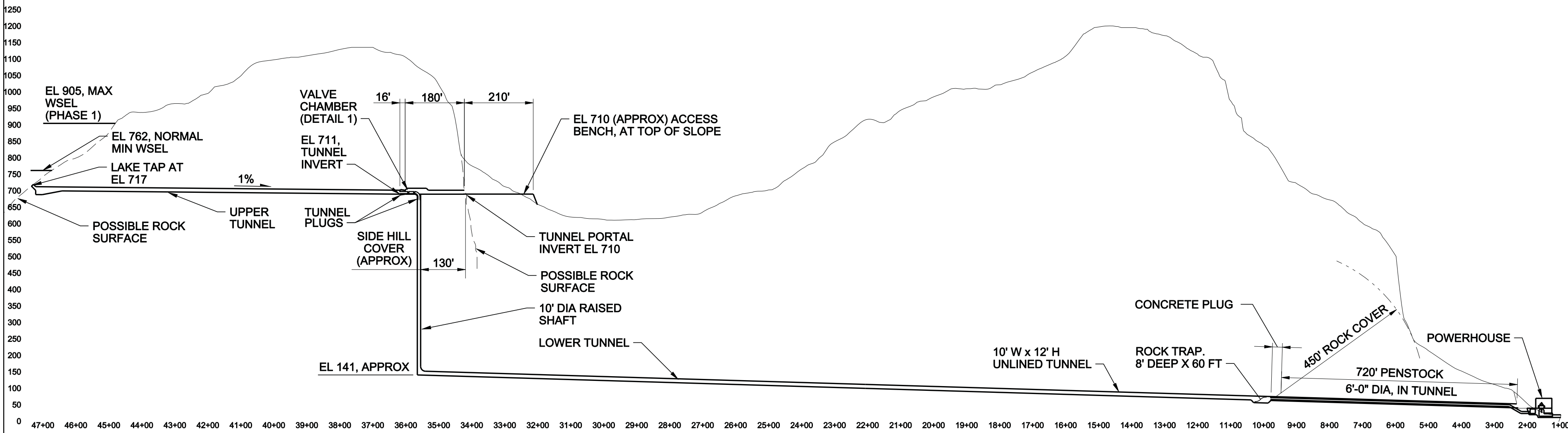

PROFILE THRU WATERWAY

1"=300'

0 150 300 450
Scale In Feet

FIGURE 8-4
PROFILE THRU WATERWAY

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MARCH 2011 FINAL REPORT
CITY AND BOROUGH OF SITKA, ALASKA

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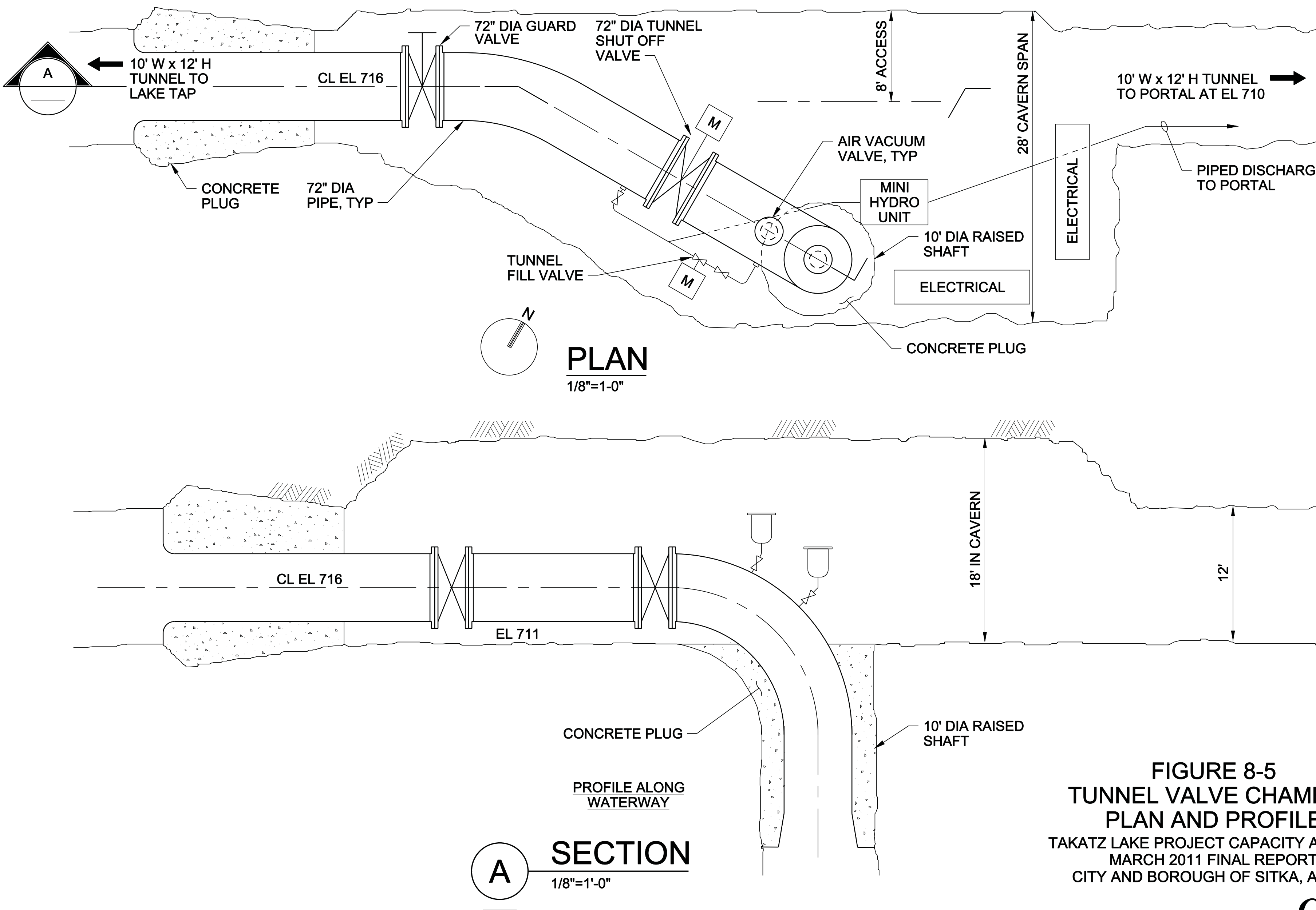

FIGURE 8-5
TUNNEL VALVE CHAMBER
PLAN AND PROFILE
TAKATZ LAKE PROJECT CAPACITY ANALYSIS
MARCH 2011 FINAL REPORT
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SECTION 9 – PROJECT COSTS AND FUTURE STUDIES

9.1 Project Costs and Energy Benefits

Estimating the Project construction cost was outside the scope of our 2011 study effort. Significant additional engineering and site studies will be needed to provide meaningful feasibility level cost estimates for the Project.

City staff did request an assessment of a phased development of the Takatz site, largely to determine whether a phased approach is reasonable. The hope was that a phased development could measurably reduce the initial project cost but still provide significant generating resources, before the dam(s) are constructed at Takatz Lake. While we did not attempt to update any construction costs estimates for the Project, it is useful to look at the historical cost estimates and to compare these to the Phase 1 and Phase 2 generation benefits predicted by our 2011 study effort.

The 1968 Study Report described an evaluation of seven alternatives. That study justified the selected project arrangement based on a valuation of the firm and secondary energy benefits divided by the alternatives' estimated construction cost. That table, from page B-21 of Appendix B of the 1968 report, is reproduced below as Table 9-1.

In Table 9-1 Alternative 7 is comparable to the Phase 1 project arrangement. This alternative 7 indicates a lake level operating range of el. 730 to el. 905. This clearly implies a lake tap with no dam construction. Alternative 7 shows a firm energy generation of 75,900 MWh and a 1968 investment cost of $19.2 million. The Alternative 7 annual energy is quite similar to the 75,000 MWh (90% confidence) value suggested in our 2011 study.

Alternative 6 is possibly a lake tap combined with a single dam to el. 990, similar to the Phase 2 concept. Alternative 6 suggests a firm annual energy of 89,200 MWh (compared to our Phase 2 90% confidence energy of 88,900 MWh) and a 1968 investment cost of $22.9 million. The costs and benefits evaluation in 1968 suggest that adding the dam would increase annual generation by 18% for a project cost increase of 19%. This appears to make the larger project development seem reasonable, on a benefit-cost evaluation. However, the 1968 evaluation did not apparently consider the likely lack of a power sales market for all of the project power in the early years of project operation.

An increase in available system generation of 75,000 MWh on top of an existing hydro capacity of 154,000 MWh (Green Lake combined with the Blue Lake Expansion) would be a 49% increase in system generation. It is doubtful that all of this generation could be sold in the early years after the Takatz Lake Project is constructed. Even if loads in the community are growing at an aggressive 5% per annum rate, it would take 8 years for the system load to grow from 154,000 MWh to 229,000 MWh. If the larger capacity project were constructed, with an 88,900 MWh annual energy, it would take even longer (about 10 years) for an aggressive 5% load growth scenario to begin using the full capacity of the Takatz project.

Consequently it makes sense to defer some of the construction cost, especially if the incremental cost of Phase 2 energy is greater than the Phase 1 development's benefit-cost ratio. The relative construction cost for Phase 1, Phase 2 and the Single-Stage development all must be estimated at a pre-feasibility level to help decide how Sitka should proceed with the project development. Any such cost estimates should also be coordinated with electric system load-growth projections to identify the possible timing of a Phase 2 construction program.

The study team believes there is clear merit in considering a phased development approach for the project. The Phase 1 generation capability would be 86% of the ultimate Phase 2 capacity (25 MW vs. 29.2 MW). Phase 1 energy generation would be 84% of the Phase 2 energy, at possibly 84% of the cost of the Phase 2 development. Note again that these cost values are very uncertain. The likely costs need to be estimated in future studies, to confirm our conceptual comparison of the Phase 1 and Phase 2 costs.

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Table 9-1 Comparison of Seven Project Alternatives, from 1968 Study

Table 1--Summary of Analyses of Effect of Variation of Heights of Takatz Creek Dam and Reservoir Drawdown

Plan	Controlled Reservoir Elevation (feet)		Installed Capacity (kw)	Ultimate Generation (kwh x 10^6)		Project Costs ($1,000)		Comparative Power Value 4/ ($1,000)			Comparative Power Value Cost Ratio
	Max.	Min.		Firm	Secondary	Investment 2/	Average Annual 3/	Firm	Secondary	Total	
1	1,060	900	21,400	103.2	5.5	25,900	1,152	1,181	21	1,202	1.043
2 1/	1,040	900	20,000	97.1	9.8	24,210	1,097	1,121	35	1,156	1.054
3	1,040	860	21,200	102.3	5.6	25,260	1,132	1,172	21	1,193	1.054
4	990	900	17,000	81.8	16.3	21,400	1,002	967	54	1,021	1.019
5	990	860	18,000	86.5	12.5	22,050	1,023	1,014	45	1,059	1.035
6	990	830	18,500	89.2	10.8	22,900	1,052	1,042	40	1,082	1.029
7	905	730	15,750	75.9	12.0	19,210	931	905	44	949	1.019

1/ Selected plan.
2/ Includes interest at 3.125 percent on construction costs with 3-year preconstruction period and 4-year construction period.
3/ Includes operation, maintenance and replacement costs based on Federal operation. Computed on basis of interest at 3.125 and 100-year period.
4/ Based on firm energy at 13.8 mills per kwh and secondary energy at 6.0 mills per kwh.

9.2 Future Engineering Studies

Phased development of the Takatz Lake site depends on whether a lake tap for the power conduit intake is feasible. The lake tap requires that the lake's bottom surface consist of competent bedrock with no overlying alluvial or overburden material at a depth and location that is appropriate for the tunnel intake. No information was available to the study team that allows any meaningful conclusion regarding the lake's suitability for this type of intake. The alternatives discussed in the 1968 study indicated that the 1968 study team considered a lake tap alternative. However, absolutely no supporting information about the lake tap feasibility was found in the 1968 era documents, other than the one table evaluating the cost and benefits of various alternatives.

To confirm preliminary feasibility of the lake tap option, a bathymetric survey of the lake bottom is required. This survey should determine the full bathymetric shape of the lake and should also determine what overburden material exists above competent rock in the eastern third of the lake, where the tap would likely be located. Accordingly, both lake bottom and sub-bottom surface profiles are required from the survey.

The large sediment delta in the western third of the lake poses a risk that migration of this sediment material could potentially block flows into a lake tap intake. Sediment blockage of the intake is a potential fatal flaw in the lake tap concept. An assessment of the sediment volume, it's propensity for movement into a lowered lake, and the possible risk of blockage at any lake tap intake is needed to define what risk the sediment delta poses for the lake tap option. This assessment should possibly include a characterization of the sediment, its cohesion (if any) and the risk of large-scale movement of the sediment mass in a seismic event. As a simplified first step an evaluation of the sediment risk might involve: a) an assessment of the sediment volume vs. the dead storage available in the lake to receive any sediment movement; b) a range of possible lake tap intake locations; and c) the possible shape of a sediment delta that might form with varying lower lake levels.

Additional engineering studies will be required in the future to confirm that the phased project development has a superior cost-benefit ratio compared to the single-stage development. These studies may include: a) preliminary design of the project facilities; b) construction cost estimates; c) system-wide power operations studies to confirm adequate power sales and economics of the alternative project development schemes; and d) system load growth estimates to confirm the likely timing between phases of the development.

Based on the study team's understanding of the FERC licensing process and other environmental and permitting issues, we recommend that the following engineering studies be carried out in 2011 or 2012:

- A bathymetric survey of the lake, with characterization of the bottom surface conditions at the potential lake tap locations.
- A preliminary analysis of the sediment delta volume, risk of movement, and risk of blockage at a group of alternative lake tap locations.

Appendix A - References

Water Powers, Southeast Alaska, 1947, 159 pgs. Federal Power Commission and Forest Service, USDA.

Alaska Power Administration. Plan of Development, Takatz Creek Project, Alaska. U.S. Department of the Interior, January 1968: 367 pgs, including appendices.