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RAYTHEON

MASTER

FEASIBILITY ASSESSMENT

LOWELL HYDROELECTRIC PROJECT

BOOTT MILLS ~~[illegible]~~
RAYTHEON SERVICE COMPANY 9510026
ACRES AMERICAN INCORPORATED ~~[illegible]~~

RAYTHEON | RAYTHEON SERVICE COMPANY

Feasibility Assessment

LOWELL HYDROELECTRIC PROJECT

Boott Mills
Raytheon Service Company
Acres American Incorporated

April 1979

951 0026

Raytheon Service Company
2 Wayside Road
Burlington, Massachusetts

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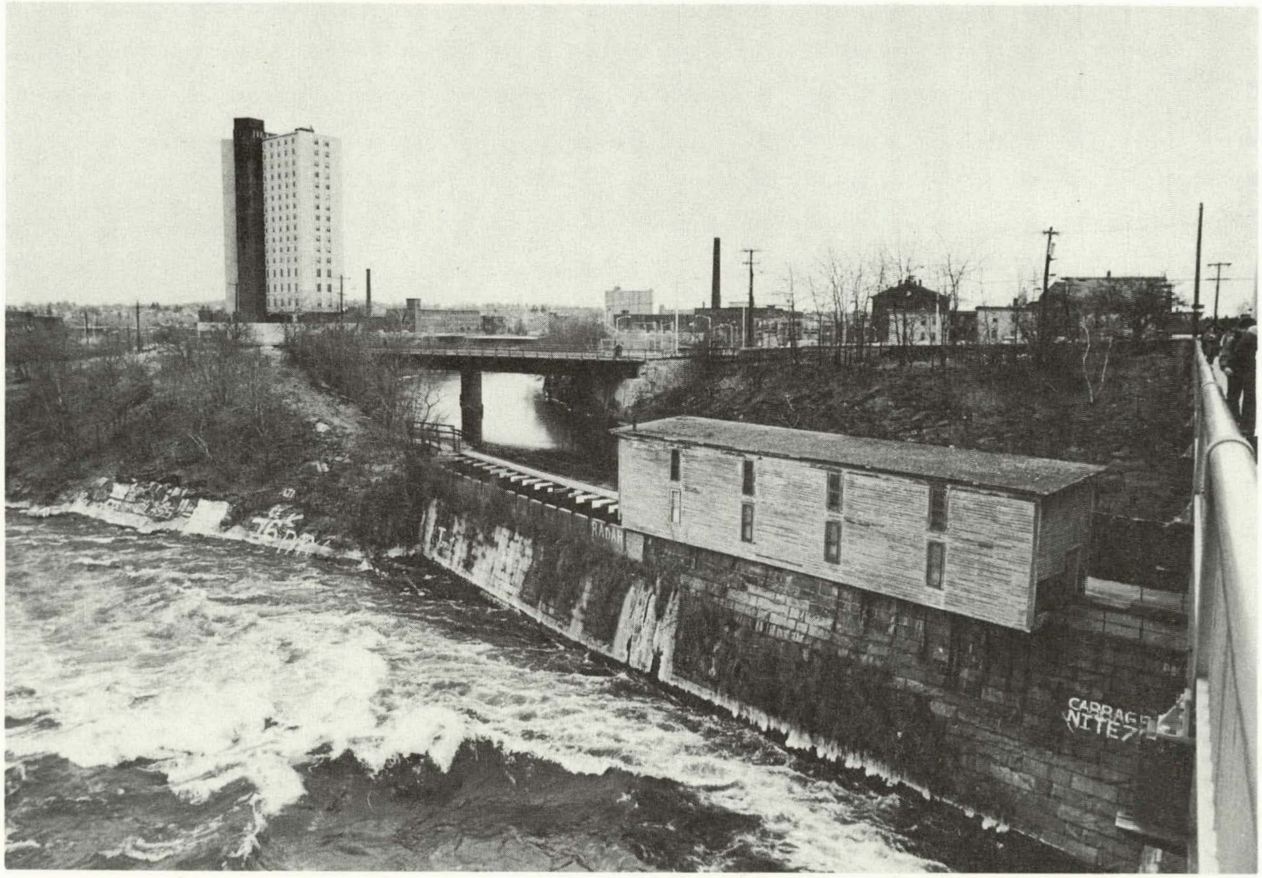


Site of The Projected Hydroelectric Facility

RAYTHEON SERVICE COMPANY

EXECUTIVE SUMMARY

This report presents the results of a feasibility analysis for hydroelectric generating facilities on the Merrimack River at Lowell, Massachusetts. The projected facility would utilize the existing Pawtucket Dam and a portion of the existing Northern Canal. The project has been examined for economic, engineering, and environmental viability, and the results are favorable.

The projected facility would be located within the recently established Lowell National Historical Park. Results of preliminary assessment are that the hydroelectric plant and its associated facilities can accommodate to Park needs and, in addition, make a contribution to the educational objectives of the Park by permitting a comparison of nineteenth and twentieth century methods of utilizing water power.

The feasibility assessment was performed for Boott Mills by the Raytheon Service Company (RSC), with overview and extensive participation by Boott Mills and with the active cooperation of the Massachusetts Municipal Wholesale Electric Company.

Two ownership options are possible, and both were found to be feasible.

In the first, the new hydroelectric facility would be developed jointly by Boott Mills and Massachusetts Municipal Wholesale Electric Company (MMWEC), with rights to the power to be generated being shared by entitlement in a (tentative) 60/40 (MMWEC/Boott Mills) ratio. MMWEC's larger entitlement is based on its supplying all project financing. The benefit-cost ratio for this option is 1.12.

Under this arrangement, MMWEC would purchase approximately 10% of Boott Mills entitlement, bringing its total to 70% of the annual kWh generated. Its costs per kW based upon receiving 70% of the power output would be $1497.

As an alternative, Boott Mills might develop the site itself, with the New England Power Company (NEPCO) being the principal power purchaser. The benefit-cost ratio for this option is .99, or, assuming abatement of half the property taxes, 1.07.

In either case, it appears that the market for the power generated is adequate to support development of the project.

Project cost is estimated, based upon a preliminary design effort, to be $15,720,000 at 1978 price levels. This includes an allowance of $1,000,000 for fish passage facilities and excludes any allowance for the cost of land, water rights, or existing facilities. The capital cost per kilowatt is $1,048.

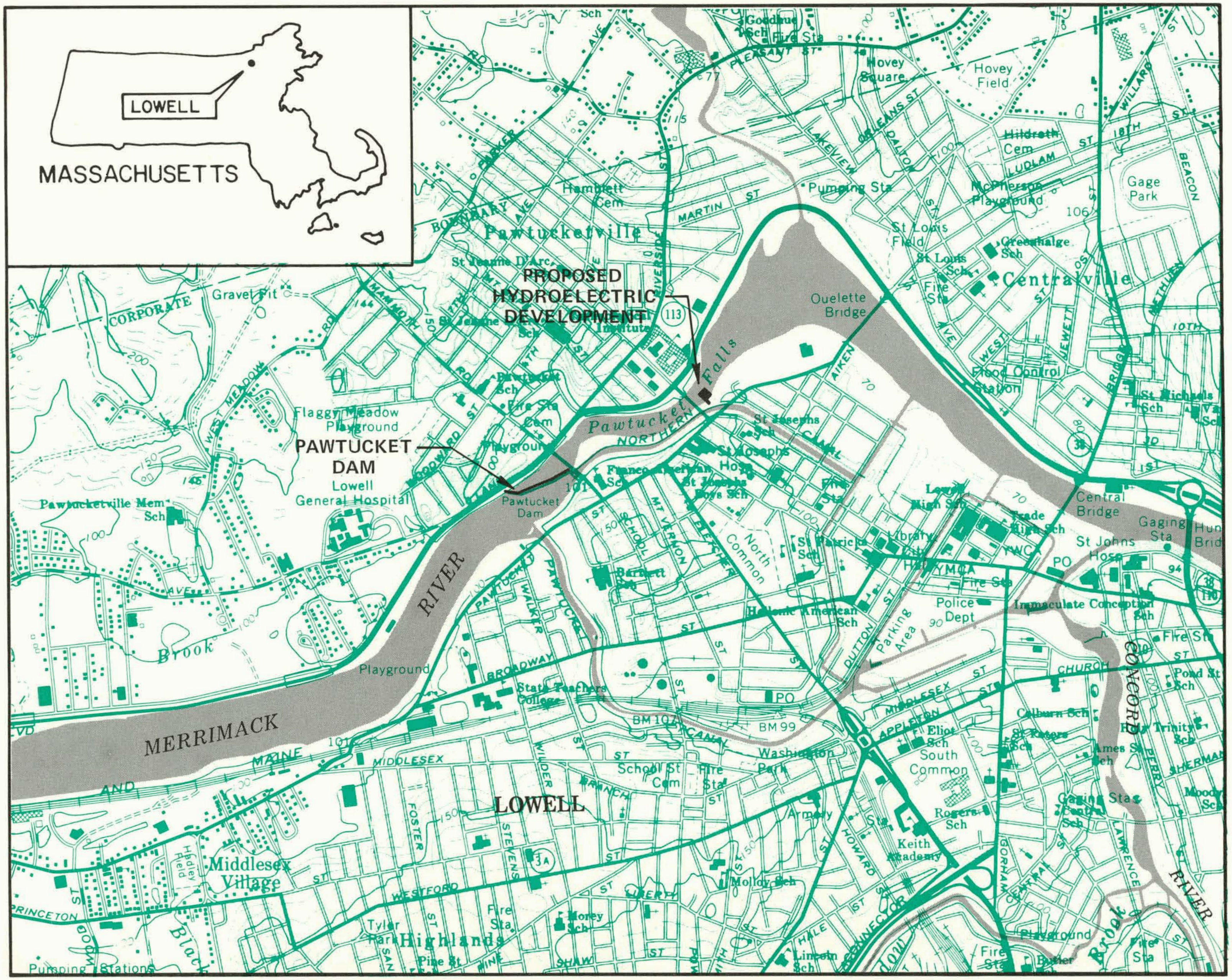
The projected facility utilizes a 4,020 square mile drainage area and has 34.5 feet of gross head developed by the dam, the canal, and additional excavation at the tailrace. The plant would generate 74,250,000 net kilowatt hours of electricity annually with an installed capacity of 15,000 kW.

The site is owned by the Proprietors of Locks and Canals on the Merrimack River, a sister corporation of Boott Mills. Boott Mills currently supplies power to its industrial tenants, using a number of small, older turbines at several locations on the canal system. It would continue as a supplier to these tenants if the new facility were built.

The powerhouse will be located close to the existing canal, on the south bank of the river. It has been found economical to excavate for a tailrace of approximately 1,000 feet to provide additional head. Power will be fed to the local 23 kV electrical system through a tap running one mile via cable and overhead line to an existing substation. The recommended design will bring water through approximately 2,000 feet of the existing canal; the canal will be modified with a control structure and a new canal retaining wall diverting the canal flow to the new powerhouse.

Important environmental considerations include provisions regarding an historic wastegate structure that must be removed, design of a fully adequate fish passage facility and provision for minimum flow requirements in the river below the dam.

The dam and canal are in basically sound condition, and the project economics are favorable. The owners intend to proceed to the next step of negotiating a firm power purchase agreement.



Location of Lowell Hydroelectric Project

RAYTHEON SERVICE COMPANY

1.0 BACKGROUND

This assessment is one of a number sponsored by the United States Department of Energy (DOE) to determine the feasibility of low-head hydroelectric power development at sites with existing dams. Its purpose is to evaluate the economic, engineering and environmental feasibility of development and to present a conceptual design for the site.

The feasibility assessments are part of a national program initiated by DOE to stimulate the extensive utilization of low-head hydroelectric power. This program was begun in response to the problems of increasing costs and availability of energy, especially in areas particularly dependent on foreign oil and gas supplies for production of electricity.

The feasibility assessment is intended to make an initial evaluation of the viability of the proposed hydroelectric project. Economic and engineering alternatives have been analyzed and environmental impacts examined. In accordance with DOE study directives, any significant economic, environmental, social, institutional, or marketing constraints were evaluated regarding their overall impact upon viability of hydropower development. Detailed analysis of the engineering design, the economic analysis and financing arrangements, and measures needed to integrate the project with its environment will be undertaken at a later stage, should the project go forward. Funding was provided by the Department of Energy with some cost sharing by Boott Mills and Raytheon Service Company (RSC). The study award was made by DOE to Boott Mills. Boott Mills contracted with RSC for conduct of the study. Acres American Incorporated provided the technical engineering services under a subcontract to RSC.

As a recipient of the DOE contract award, Boott Mills gave overall direction to the course of the work. In addition, Boott Mills developed much of the data base, participated in meetings with regulatory agencies, and gave generously of its experience with small hydro operations.

The detailed assessment work was carried out under the direction of RSC. RSC was also responsible for the economic and environmental evaluations in addition to providing integration of the study components. In conducting the analysis of economic feasibility, RSC was assisted by United Engineers & Constructors (like RSC, a subsidiary of Raytheon Company). Merrill Lynch White Weld Capital Markets Group provided assistance with certain aspects of the financial analysis.

Acres American performed the engineering analysis, including the conceptual design of the hydroelectric installation and the construction scheduling and costing. Acres also provided the safety analysis.

MMWEC participated in project reviews throughout the course of the assessment and gave important guidance in all aspects of the work.

2. ECONOMIC FEASIBILITY

2.1 PRINCIPAL RESULTS

The Lowell hydroelectric project is economically feasible by all criteria examined in the feasibility assessment. This section presents a detailed review of the economic analysis performed to reach this conclusion.

Several equipment alternatives were investigated, including two-unit bulb, Straflo, and vertical fixed blade propeller installations and a four-unit installation using the largest standardized tube turbines. The lowest estimated project cost was achieved using tube turbines and these costs are used in the economic calculations of Section 2. A final equipment selection has not been made, however. This is reserved until the equipment procurement stage, at which time firm bids can assure the best project price resulting from any of the several equipment alternatives considered.

The feasibility assessment in its entirety consisted of six overlapping tasks performed over a period of nine months.

- Assembly of project data
- Site examination and evaluation
- Conceptual design
- Construction cost estimate and schedules
- Environmental and safety assessments
- Economic assessment.

The purpose of the conceptual design was to establish construction costs and likely environmental impacts. Environmental impacts are discussed later.

Feasibility has been estimated for two different cases:

<u>One hundred percent Boott Mills Ownership</u>. In this case, based on preliminary discussions with the New England Power Company (NEPCO), power is presumed to be purchased by NEPCO at a 1979 maximum price of 40 mills per kWh. The project would be developed with financing at interest rates available to Boott Mills (10.5%), with the loan secured by a long term power sales contract.

Joint Development by the Massachusetts Municipal Wholesale Electric Company (MMWEC) and Boott Mills on a 60/40 Entitlement Basis. Under this assumption MMWEC would supply all project financing, borrowing at a 7.5 percent rate. In return, it would receive an entitlement to 60% of the output from the facility. Boott Mills would operate and maintain the project and would receive an entitlement to 40% of the power in return for land and existing facilities such as the dam and the portion of the canal to be used by the project. An agreement in principle exists between Boott Mills and MMWEC to develop the project on this general basis, with details subject to final negotiation. Of these, the most important is a detailed interpretation of the 60/40 division of rights to the power.

In either case, Boott Mills will continue to sell power to its industrial tenants and certain abutters, thus absorbing about 30% of the power generated annually. The remaining Boott Mills power will either be sold by Boott Mills to NEPCO, or, in the 60/40 ownership case, to MMWEC.

The requirements for the program to be feasible are different under each form of ownership, but they are strightforward:

FOR MMWEC

The project must be able to repay its costs over the bond repayment period of 30 years.

FOR BOOTT MILLS

The project must return more income than is received from its present power generation activities and the additional income must be enough to compensate for undertaking the risks of the new project.

There must be no periods of negative cash flow.

In the case of joint development with MMWEC, income received from the project must justify surrender of 60% of its ownership rights to the Pawtucket Dam and major portions of an important canal system, including locks and real estate.

It was not possible at the level of a feasibility assessment to determine which ownership option is best from the perspective of Boott Mills. This decision can be made only after power sales agreements have been negotiated and compared by the Boott Mills Board of Directors.

Escalation Rates. For any particular rate of continuing price increases, revenues are affected more than costs because financing cost, the largest cost, remains stable. After construction of the project has been completed, the cost curve is relatively flat because only certain costs such as operations and maintenance continue to be affected by inflation.

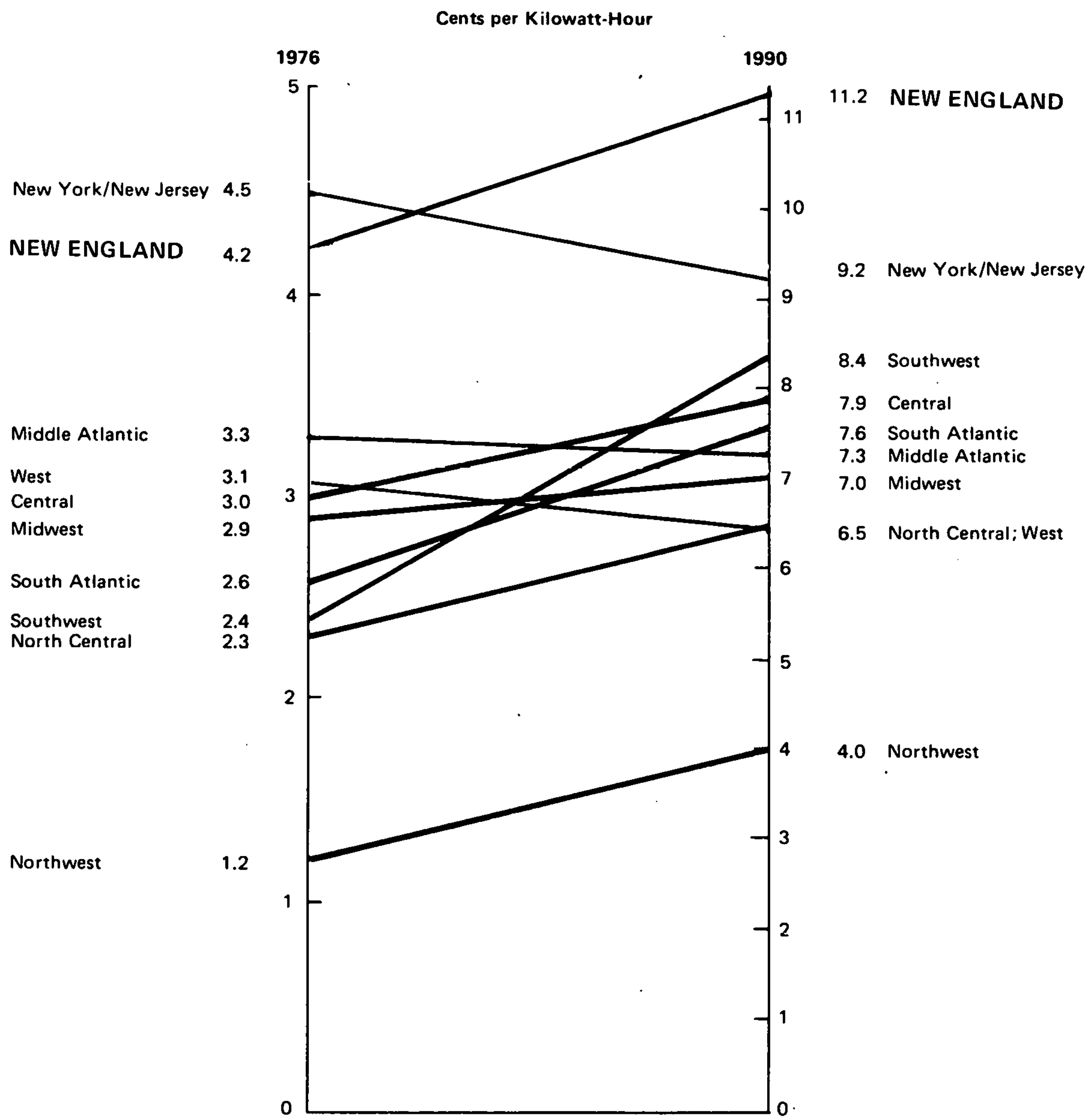
Feasibility has been calculated at Escalation Rates of:

	0%/0% Case	6%/6% Case	6%/9% Case
Annual Operating Costs (other than repayment of principal and interest)	0%	6%	6%
Revenues	0%	6%	9%
Repayment of Principal/Interest	0%	0%	0%

In the cases in which annual operating costs and revenues are escalated, the escalation has been applied over the period of time taken up by construction and then for the first ten years of commercial operation. (Details are given in Section 2.3 below.) Escalating at 6 percent for this period doubles the original values. Escalating at 9 percent more than triples the original values. The 6 percent escalation is believed to be conservative; it is less than a forecast of 6.5 percent by Arthur D. Little* for the annual rate of increase for New England in the price of electricity per kWh for the 1978-1990 period, as shown below.

The A.D. Little study forecast of electrical energy prices for the New England region are summarized below:

*Arthur D. Little, Implications of Lower Electric Power Growth Through 1990, February 1979



Note: Prices are in current dollars; 1990 scale is reduced to compansate for assumed average 6% inflation rate, so that slopes represent real price changes.

Sources: Edison Electric Institute; Arthur D. Little, Inc., estimates.

Average Electricity Prices by Region, 1976 and 1990

	Average Price (¢/kWh)
Actual 1976	4.2
Estimated 1978	4.7
Projected:	
1980	5.4
1985	7.0
1990	11.2

Detailed cost and revenue information is given in Section 2.3. A summary is given below:

Project Cost including Fish Ladders	$15,720,000
Cost of Money	
To Boott Mills	10.5%
To MMWEC	7.5%
Net Annual kWh Produced*	74,250,000 kWh
Power Value to Purchaser	4¢/kWh in 1979 dollars
Property Taxes	50% Assessment, $200 per $1000
Engineering and Construction Time	196 Weeks
Interest during Construction	$1,181,900

Economic feasibility was analyzed in the following steps:

1. The capital cost of the project was determined based upon a selected project design (Figure 3-12).
2. Annual costs were established including:
   a. Principal and interest payments on the bonds used to finance the project capital cost.
   b. Other yearly costs: operations and maintenance, insurance, taxes, water charges, and general and administrative costs.

*Gross annual production is 76,150,000 kWh. Net, approximately 2.5% less, subtracts station needs and losses in transmission to the substation connecting into the main power grid.

3. Revenues were determined based upon a knowledge of annual power output multiplied by the value per kWh of the output.

4. Costs were subtracted from revenues to get net annual cash flow over the 60-year life of the installation.

5. Net present value (NPV) of the 60-year cash flow was calculated by discounting annual cash flows to a present value.

6. A detailed evaluation of 60-year cash flows was accomplished.

Preliminary Feasibility Determination. Net present value was used as a first determination of feasibility for this assessment. Net present value (NPV) was calculated by taking net cash flows from each year of a 60-year cash flow analysis and discounting them back to the present at the financing rate. Thus, when NPV is zero, the investment is a break-even investment and the most basic criterion for economic feasibility is

$$NPV \geq 0$$

That is, the project has at least to break even on a net present value basis to be economically feasible.

NPV is affected by all the factors which influence the level of future revenues (cash income) or costs (cash outflow). For example, if energy costs from alternate sources are projected to escalate with time, this will be reflected in the cash flow analysis as increased revenue, and NPV will go up. Similarly, if costs are escalated with time, net cash flows will decrease and NPV will decrease. This is a convenient way to reject at a very early point in a financial analysis those projects whose NPV is negative. It is also a convenient way to compare the profitability of a project under different conditions of ownership (financing cost) or purchase price received for the power output of the project. However, a positive NPV does not of itself guarantee that a project is feasible. The yearly pattern of cash flows generated by the project must also be acceptable. It is not inconsistent for an investment with a positive NPV to have negative cash flows in early years. If these negative discounted cash flows are more than balanced by positive discounted cash flows in later years, NPV will be positive, but some owners may not be able to survive the early years of negative cash flows. Also, some owners may have a policy of making investments only when the resulting cash flows are positive in every year.

For Boott Mills 100% ownership, the criterion for feasibility is that not only must NPV be positive, but the cash flow in each year of the project must also be positive. For MMWEC, it is highly desirable that cash flow be positive in each year.

In order to facilitate comparison with the results of other Department of Energy feasibility assessments, results are given in terms of benefit-cost ratios (B/C) as well as NPV. These two measures provide much the same information. NPV subtracts (discounted) costs from benefits, and B/C divides (discounted) benefits by costs:

$$\text{NPV} = (b_1 + b_2 \ldots + b_{60}) - (c_1 + c_2 \ldots + c_{60})$$

$$\text{B/C} = \frac{b_1 + b_2 \ldots + b_{60}}{c_1 + c_2 \ldots + c_{60}}$$

where b_t and c_t indicate discounted benefits and costs for each of the 60 years of project life.

Feasibility requires:

$$\text{NPV} \geqq 0$$

$$\text{B/C} \geqq 1$$

NPV is given below for the 100% Boott Mills ownership case and for the 60/40% joint development case. NPV has been calculated with the real estate tax calculated at the full rate and again at half rate. The first year of commercial operation of the facility in which cash flow is positive is also given.

BASELINE CASE (6/6)

	NPV	First Year of Positive Cash Flow	B/C
100% Boott Mills			
R.E. Tax @ Full Rate	-$ 349,000	5	.99
R.E. Tax @ Half Rate	$ 3,709,000	1	1.07
Joint Development			
R.E. Tax @ Full Rate	$ 8,260,000	1	1.12
R.E. Tax @ Half Rate	$13,414,000	1	1.21

Net present value is clearly improved in the joint ownership case, reflecting the lower cost of financing. This would appear to argue for development under the joint ownership option, but it should be borne in mind that the final ownership arrangements will depend upon the exact details of a negotiation among the parties concerned.

2.2 DETAILED CASH FLOW STATEMENTS AND INTERPRETATION

Sixty-year cash flow statements are given in Tables 2-1 - 2-4 for the case assuming costs and revenues both escalate at 6 percent. Columns in the tables, reading from left to right are:

Elect. Income - Income from sale of electricity

O&M - Operations and maintenance costs

G&A - General and administrative costs
(G&A is placed underneath O&M)

H_2O - The cost of water

Ins. - Insurance

Princip - Payments of principal

Interest - Interest on the bonds
(Interest is placed underneath principal)

Double Declin Deprec - Depreciation on the facility, here calculated using the double declining balance method

Prop Tax - Real estate taxes

Mistax - Miscellaneous taxes

Corp Tax (Cum) - Corporate income taxes, and, underneath, corporate income taxes cumulated

Pre-tax Net Income (Cum) - Pre-tax net income, and, underneath, pre-tax net income cumulated. (Net income is based on a gross income that includes both income from sale of electricity and interest income which accrues when payments of principal are made into a sinking fund, as has been assumed in the case of 100% Boott Mills ownership.)

Total Cost, Income - Total cost, and, underneath, total income

Cash Flow Net (Cum) - Net cash flow, and, underneath, net cash flow cumulated

Breakeven Cost - Breakeven cost in mills per kWh (Calculated as total annual costs on a cash basis divided by yearly kWh)

100% Boott Mills Ownership - Full Taxes. Cash flows are negative for the first four years, summing to minus $998,241 by the end of the fourth year. Large negative cash flows also occur in a number of later years. This is beyond the ability of Boott Mills to support. Cash flow analyses run under different assumptions had shown even higher negative cash flows in the early years; only by incorporating a method of financing in which no payments on principal are made during the first five years was it possible to decrease early negative cash flows to what is shown in Table 2-1.

It can be noted in Tables 2-1 and 2-2 that after the tenth year, net taxable income continues to increase even though revenue from sale of electricity and most costs remain constant. This increase results from a continuing increase in interest income earned on the sinking fund and a continuing decrease in depreciation. The increase in net taxable income causes an increase in income taxes and a corresponding decrease in net cash flows.

One Half Taxes. In re-examining the accounts that comprise project expenses, the allowance made for property taxes appears to be excessive relative to actual taxes paid on similar facilities. This was true even though the original estimate had been based upon published tax policies of the City of Lowell. Based upon the rationale presented immediately below, cash flow was re-examined assuming that real estate taxes paid to the City of Lowell would be halved. The results, shown in Table 2-2, are attractive to all parties and are considered realistic.

TABLE 2-1. CASH FLOW

100% BOOTT MILLS OWNERSHIP, FULL PROPERTY TAXES

YR.	ELECT. INCOME	O&M / G & A	H20	INS.	PRINCIP / INTERST	DOUBLE DECLIN DEPREC	PROP TAX / MISTAX	CORP TAX / (CUM)	PRE-TAX NET INCOME / (CUM)	*TOTALS* COST / INCOME	CASH FLOW NET / (CUM)	BREAK EVEN COST
1	3921245	221173	494943	70888	0	1007996	874754	0	-1432653	4345900	-424656	58.53
		311910			2294252		77977	0	-1432653	3921245	-424656	
2	4156520	234443	524640	75142	0	957596	927239	0	-1232237	4468999	-312480	60.19
		330625			2294252		82656	0	-2664890	4156520	-737136	
3	4405911	248510	556118	79650	0	909717	982874	0	-1023638	4599484	-193574	61.94
		350462			2294252		87615	0	-3688527	4405911	-930709	
4	4670266	263420	589485	84429	0	864231	1041846	0	-805908	4737798	-67533	63.81
		371490			2294252		92872	0	-4494435	4670266	-998241	
5	4950482	279225	624854	89495	0	821019	1104357	0	-578039	4884411	66070	65.78
		393780			2294252		98445	0	-5072474	4950482	-932171	
6	5247510	295979	662346	94865	360378	779968	1170618	0	-338953	5400199	-152689	72.73
		417406			2294252		104351	0	-5411426	5247510	-1084859	
7	5562361	313738	702086	100557	360378	740970	1240855	0	-87499	5564933	-2572	74.95
		442451			2294252		110612	0	-5498925	5562361	-1087430	
8	5896103	332562	744211	106590	360378	703921	1315307	71727	177557	5811279	84824	78.27
		468998			2294252		117249	71727	-5321368	5896103	-1002606	
9	6249869	352516	788864	112985	360378	668725	1394225	206120	457542	6130766	119102	82.57
		497138			2294252		124284	277847	-4863825	6249869	-883503	
10	6624861	373667	836196	119765	360378	635289	1477879	348362	753879	6469209	155652	87.13
		526966			2294252		131741	626209	-4109946	6624861	-727851	
11	6624861	373667	836196	119765	360378	603524	1477879	408220	878585	6529068	95793	87.93
		526966			2294252		131741	1034430	-3231361	6624861	-632058	
12	6624861	373667	836196	119765	360378	573348	1477879	472001	1011461	6592848	32012	88.79
		526966			2294252		131741	1506432	-2219900	6624861	-600045	
13	6624861	373667	836196	119765	360378	544681	1477879	540233	1153612	6661081	-36220	89.71
		526966			2294252		131741	2046666	-1066287	6624861	-636265	
14	6624861	373667	836196	119765	360378	517447	1477879	613497	1306245	6734345	-109484	90.7
		526966			2294252		131741	2660164	239958	6624861	-745749	
15	6624861	373667	836196	119765	360378	491574	1477879	692428	1470684	6813275	-188415	91.76
		526966			2294252		131741	3352592	1710643	6624861	-934163	
16	6624861	373667	836196	119765	360378	466996	1477879	777721	1648378	6898569	-273708	92.91
		526966			2294252		131741	4130314	3359021	6624861	-1207871	
17	6624861	373667	836196	119765	360378	443646	1477879	870142	1840921	6990989	-366129	94.15
		526966			2294252		131741	5000456	5199943	6624861	-1573999	
18	6624861	373667	836196	119765	360378	421463	1477879	970529	2050061	7091377	-466516	95.51
		526966			2294252		131741	5970986	7250005	6624861	-2040514	
19	6624861	373667	836196	119765	360378	400390	1477879	1079807	2277723	7200654	-575794	96.98
		526966			2294252		131741	7050793	9527729	6624861	-2616308	
20	6624861	373667	836196	119765	360378	380371	1477879	1198991	2526023	7319838	-694978	98.58
		52666			2294252		131741	8249785	12053753	6624861	-3311285	

TABLE 2-1. (Cont.)

21	6624861	373667	836196	119765	360378	361352	1477879	1329200	2797292	7450047	-825187	100.34
		526966			2294252		131741	9578985	14851045	6624861	-4136471	
22	6624861	373667	836196	119765	360378	343285	1477879	1471666	3094096	7592513	-967653	102.26
		526966			2294252		131741	11050651	17945141	6624861	-510412	
23	6624861	373667	836196	119765	360378	326120	1477879	1627746	3419264	7748594	-1123733	104.36
		526966			2294252		131741	12678398	21364405	6624861	-6227856	
24	6624861	373667	836196	119765	360378	322558	1477879	1792821	3763169	7913669	-1288808	106.58
		526966			2294252		131741	14471220	25127575	6624861	-7516663	
25	6624861	373667	836196	119765	360378	322558	1477879	1973339	4139249	8094187	-1469326	109.01
		526966			2294252		131741	16444560	29266825	6624861	-898589	
26	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	17792381	32102911	6624861	-7175165	
27	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	19140202	34938997	6624861	-5364341	
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		526966			0		131741	23183666	43447256	6624861	68130	
31	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	24531488	46283342	6624861	1878954	
32	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	25879309	49119428	6624861	3689777	
33	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	27227130	51955514	6624861	5500601	
34	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	28574952	54791600	6624861	7311425	
35	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	29922773	57627687	6624861	9122249	
36	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	31270595	60463773	6624861	10933072	
37	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	32618416	63299859	6624861	12743896	
38	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	33966237	66135945	6624861	14554720	
39	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	35314059	68972031	6624861	16365544	
40	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	36661880	71808117	6624861	18176367	

TABLE 2-1. (Cont.)

41	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	38009701	74644203	6624861	19987191	
42	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	39357523	77480289	6624861	21798015	
43	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	40860172	80638935	6624861	23454010	
44	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	42362822	83797580	6624861	25110006	
45	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	43865472	86956225	6624861	26766001	
46	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	45368121	90114870	6624861	28421997	
47	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	46870771	93273515	6624861	30077992	
48	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	48373420	96432160	6624861	31733987	
49	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	49876070	99590805	6624861	33389983	
50	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	51378720	102749450	6624861	35045978	
51	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	52881369	105908095	6624861	36701974	
52	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	54384019	109066740	6624861	38357969	
53	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	55886669	112225385	6624861	40013965	
54	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	57389318	115384031	6624861	41669960	
55	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	58891968	118542676	6624861	43325956	
56	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	60394618	121701321	6624861	44981951	
57	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	61897267	124859966	6624861	46637947	
58	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	63399917	128018611	6624861	48293942	
59	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	64902567	131177256	6624861	49949937	
60	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	66405216	134335901	6624861	51605933	

TABLE 2-2. CASH FLOW

100% BOOTT MILLS OWNERSHIP, HALF PROPERTY TAXES

YR.	ELECT. INCOME	O&M / G & A	H20	INS.	PRINCIP / INTERST	DOUBLE DECLIN DEPREC	PROP TAX / MISTAX	CORP TAX / (CUM)	PRE-TAX NET INCOME / (CUM)	*TOTALS* COST / INCOME	CASH FLOW NET / (CUM)	BREAK EVEN COST
1	3921245	221173	494943	70888	0	1007996	437377	0	-995276	3908523	12721	52.64
		311910			2294252		77977	0	-995276	3921245	12721	
2	4156520	234443	524640	75142	0	957596	463619	0	-768617	4005379	151140	53.94
		330625			2294252		82656	0	-1763892	4156520	163861	
3	4405911	248510	556118	79650	0	909717	491437	0	-532201	4108047	297863	55.33
		350462			2294252		87615	0	-2296093	4405911	461725	
4	4670266	263420	589485	84429	0	864231	520923	0	-284985	4216875	453390	56.79
		371490			2294252		92872	0	-2581078	4670266	915116	
5	4950482	279225	624854	89495	0	821019	552178	0	-25860	4332232	618249	58.34
		393780			2294252		98445	0	-2606938	4950482	1533365	
6	5247510	295979	662346	94865	360378	779968	585309	104751	246356	4919640	327870	66.26
		417406			2294252		104351	104751	-2360581	5247510	1861235	
7	5562361	313738	702086	100557	360378	740970	620427	242305	532929	5186811	375550	69.85
		442451			2294252		110612	347057	-1827652	5562361	2236786	
8	5896103	332562	744211	106590	360378	703921	657653	387401	835211	5469299	426804	73.66
		468998			2294252		117249	734458	-992441	5896103	2663590	
9	6249869	352516	788864	112985	360378	668725	697112	540734	1154654	5768268	481601	77.69
		497138			2294252		124284	1275192	162214	6249869	3145191	
10	6624861	373667	836196	119765	360378	635289	738939	703053	1492818	6084960	539900	81.95
		526966			2294252		131741	1978245	1655033	6624861	3685092	
11	6624861	373667	836196	119765	360378	603524	738939	762911	1617524	6144819	480041	82.76
		526966			2294252		131741	2741157	3272558	6624861	4165134	
12	6624861	373667	836196	119765	360378	573348	738939	826692	1750400	6208600	416261	83.62
		526966			2294252		131741	3567850	5022959	6624861	4581395	
13	6624861	373667	836196	119765	360378	544681	738939	894924	1892551	6276832	348028	84.54
		526966			2294252		131741	4462775	6915510	6624861	4929424	
14	6624861	373667	836196	119765	360378	517447	738939	968188	2045185	6350096	274764	85.52
		526966			2294252		131741	5430964	8960696	6624861	5204189	
15	6624861	373667	836196	119765	360378	491574	738939	1047119	2209623	6429027	195834	86.59
		526966			2294252		131741	6478083	11170320	6624861	5400023	
16	6624861	373667	836196	119765	360378	466996	738939	1132412	2387318	6514320	110540	87.73
		526966			2294252		131741	7610496	13557638	6624861	5510564	
17	6624861	373667	836196	119765	360378	443646	738939	1224833	2579861	6606741	18120	88.98
		526966			2294252		131741	8835329	16137499	6624861	5528684	
18	6624861	373667	836196	119765	360378	421463	738939	1325220	2789001	6707128	-82267	90.33
		526966			2294252		131741	10160550	18926501	6624861	5446418	
19	6624861	373667	836196	119765	360378	400390	738939	1434498	3016663	6816406	-191545	91.8
		526966			2294252		131741	11595048	21943164	6624861	5254873	
20	6624861	373667	836196	119765	360378	380371	738939	1553682	3264963	6935590	-310729	93.41
		526966			2294252		131741	13148731	25208127	6624861	4944144	

TABLE 2-2. (Cont.)

21	6624861	373667	836196	119765	360378	361352	738939	1683891	3536232	7065799	-440938	95.16
		526966			2294252		131741	14832622	28744359	6624861	4503207	
22	6624861	373667	836196	119765	360378	343285	738939	1826357	3833035	7208265	-583404	97.08
		526966			2294252		131741	16658979	32577395	6624861	3919803	
23	6624861	373667	836196	119765	360378	326120	738939	1982437	4158203	7364345	-739485	99.18
		526966			2294252		131741	18641417	36735599	6624861	3180319	
24	6624861	373667	836196	119765	360378	322558	738939	2147512	4502109	7529420	-904559	101.41
		526966			2294252		131741	20788930	41237709	6624861	2275760	
25	6624861	373667	836196	119765	360378	322558	738939	2328030	4878189	7709938	-1085078	103.84
		526966			2294252		131741	23116961	46115898	6624861	1190683	
26	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	24819473	49690924	6624861	3385755	
27	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	26521985	53265949	6624861	5580828	
28	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	28224498	56840975	6624861	7775900	
29	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	29927010	60416001	6624861	9970972	
30	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	31629522	63991027	6624861	12166045	
31	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	33332035	67566052	6624861	14361117	
32	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	35034547	71141078	6624861	16556189	
33	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	36737059	74716104	6624861	18751262	
34	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	38439572	78291129	6624861	20946334	
35	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	40142084	81866155	6624861	23141406	
36	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	41844596	85441181	6624861	25336479	
37	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	43547109	89016207	6624861	27531551	
38	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	45249621	92591232	6624861	29726623	
39	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	46952133	96166258	6624861	31921696	
40	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	48654646	99741284	6624861	34116768	

RAYTHEON SERVICE COMPANY

TABLE 2-2. (Cont.)

41	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	50357158	103316309	6624861	36311840	
42	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	52059670	106891335	6624861	38506913	
43	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	53917011	110788920	6624861	40547157	
44	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	55774352	114686504	6624861	42587401	
45	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	57631692	118584089	6624861	44627645	
46	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	59489033	122481674	6624861	46667889	
47	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	61346374	126379258	6624861	48708133	
48	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	63203714	130276843	6624861	50748377	
49	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	65061055	134174428	6624861	52788621	
50	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	66918396	138072012	6624861	54828865	
51	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	68775736	141969597	6624861	56869109	
52	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	70633077	145867182	6624861	58909353	
53	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	72490417	149764766	6624861	60949597	
54	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	74347758	153662351	6624861	62989841	
55	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	76205099	157559936	6624861	65030085	
56	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	78062439	161457520	6624861	67070329	
57	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	79919780	165355105	6624861	69110573	
58	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	81777121	169252690	6624861	71150817	
59	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	83634461	173150274	6624861	73191061	
60	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	85491802	177047859	6624861	75231305	

It would appear that the City of Lowell might consider a reduction of real estate taxes to be in its best interests. Its overall net tax returns from the property would increase substantially over the estimated 60 year lifetime of the hydro site if the new facility is built. The hydro facility imposes no known demands for additional city services. Tax income, as shown on the cash flow printouts, is summarized below for three possible situations. (This summary applies for either ownership option.)

60 YEAR PROPERTY TAX RETURN TO LOWELL

	Taxes on Existing Facilities	Full Taxes on New Facility	One Half Taxes on New Facility
Continued Operation of the Present Equipment	$2,578,765	N/A	N/A
New Hydro Installation	----	$85,423,848	$42,711,924

As further evidence of the feasibility of property tax reductions, the allowance for local real estate taxes was examined for a recently approved (by FERC) license application for the Lawrence project. The results considering only the first year were:

Lowell	(full taxes)	$825,239
Lawrence	(per FERC application)	$104,000
Difference		$721,239

In addition, and in recognition of the importance of property taxes generally on the feasibility of small hydroelectric projects, bills have been introduced into both houses of the 1978/79 Massachusetts legislature to completely or partially abate real property taxes on small hydro installations.

Variation of Interest Rates. A sensitivity analysis was performed for the private ownership case to determine the effect on the project of a decrease in the interest rate, since the cost of money is volatile (and currently at very high levels). Net present value of the Lowell hydroelectric project is presented as a function of the cost of money used to finance the project, and is shown below for the full property tax case.

Interest Rate	NPV
10.5%	— $ 349,000
9.5%	$1,601,000
8.5%	$3,860,000

MMWEC/Boot 60/40 Joint Ownership. An alternative to 100 percent ownership of the Lowell hydroelectric facility by Boott Mills is that MMWEC would finance the project in return for a 60 percent entitlement to power. A letter of intent has been signed by authorized representatives of MMWEC and Boott Mills to this effect, based on an assumed ratio of new investment to the value of existing properties and rights, but final terms and conditions of the agreement and final definition of the entitlement division remain to be negotiated. The entitlement division as applied to periods of peak demand and low river flow is of particular concern to both parties.

Boott Mills will be entitled to more power than it can use internally under this arrangement. Its own requirements for internal use including sale to present retail customers would consume only about 30 percent of the annual power output of the new facility. Based upon a 40 percent entitlement this leaves 10 percent (7,425,000 annual kWh) to be sold back to MMWEC.

Total project cost per kW is of particular concern to MMWEC because it will be providing project financing. If cost per kW is calculated on the basis of total project capacity of 15 mW, the cost per kW is $1,048. However, as faced by MMWEC, the cost is $1747 per kW based on its 60 percent entitlement (9 mW) or $1497 per kW based on its entitlement plus the additional 10 percent it would be buying from Boott Mills. Whether the $1747 figure, the $1497 figure, or some other number most accurately reflects the cost of capacity to MMWEC depends upon the exact details of the agreement to be negotiated as it applies to rights to power during periods of peak demand and low flow.

For purposes of feasibility analysis it has been assumed that the 60/40 entitlement ratio will actually be negotiated, that Boott Mills' surplus power will be purchased by MMWEC from Boott at 40 mills per kWh (in 1979 prices) and that this rate will be approved by the DPU.

TABLE 2-3. CASH FLOW

JOINT DEVELOPMENT WITH MMWEC, FULL PROPERTY TAXES

YR.	ELECT. INCOME	O&M G & A	H2O	INS.	PRINCIP INTERST	DOUBLE DECLIN DEPREC	PROP TAX MISTAX	CORP TAX (CUM)	PRE-TAX NET INCOME (CUM)	*TOTALS* COST INCOME	CASH FLOW NET (CUM)	BREAK EVEN COST
1	3921245	221173	494943	70888	206405	1007996	874754	0	-739067	3858720	62525	51.97
		311910			1600666		77977	0	-739067	3921245	62525	
2	4156520	234443	524640	75142	221886	957596	927239	0	-561010	3981819	174700	53.62
		330625			1585186		82656	0	-1300076	4156520	237226	
3	4405911	248510	556118	79650	238527	909717	982874	0	-377583	4112304	293607	55.38
		350462			1568544		87615	0	-1677659	4405911	530833	
4	4670266	263420	589485	84429	256417	864231	1041846	0	-188167	4250617	419648	57.25
		371490			1550655		92872	0	-1865825	4670266	950481	
5	4950482	279225	624854	89495	275648	821019	1104357	0	7879	4397230	553251	59.22
		393780			1531423		98445	0	-1857945	4950482	1503732	
6	5247510	295979	662346	94865	296321	779968	1170618	87887	211224	4640527	606983	62.5
		417406			1510750		104351	87887	-1646721	5247510	2110715	
7	5562361	313738	702086	100557	318546	740970	1240855	189330	422563	4906704	655656	66.08
		442451			1488525		110612	277217	-1224158	5562361	2766372	
8	5896103	332562	744211	106590	342437	703921	1315307	294960	642626	5186953	709150	69.86
		468998			1464634		117249	572178	-581531	5896103	3475523	
9	6249869	352516	788864	112985	368119	668725	1394225	405144	872176	5482232	767637	73.83
		497138			1438952		124284	977322	290645	6249869	4243160	
10	6624861	373667	836196	119765	395728	635289	1477879	520266	1112012	5793554	831306	78.03
		526966			1411343		131741	1497588	1402657	6624861	5074467	
11	6624861	373667	836196	119765	425408	603524	1477879	549759	1173456	5823047	801813	78.42
		526966			1381663		131741	2047348	2576114	6624861	5876281	
12	6624861	373667	836196	119765	457314	573348	1477879	579558	1235538	5852847	772014	78.83
		526966			1349757		131741	2626906	3811652	6624861	6648295	
13	6624861	373667	836196	119765	491612	544681	1477879	609782	1298504	5883070	741790	79.23
		526966			1315459		131741	3236688	5110157	6624861	7390086	
14	6624861	373667	836196	119765	528483	517447	1477879	640552	1362609	5913841	711020	79.65
		526966			1278588		131741	3877241	6472767	6624861	8101106	
15	6624861	373667	836196	119765	568119	491574	1477879	671996	1428118	5945285	679576	80.07
		526966			1238952		131741	4549238	7900885	6624861	8780683	
16	6624861	373667	836196	119765	610728	466996	1477879	704246	1495305	5977535	647326	80.5
		526966			1196343		131741	5253484	9396191	6624861	9428009	
17	6624861	373667	836196	119765	656533	443646	1477879	737440	1564460	6010729	614132	80.95
		526966			1150538		131741	5990925	10960651	6624861	10042141	
18	6624861	373667	836196	119765	705773	421463	1477879	771723	1635882	6045012	579849	81.41
		526966			1101298		131741	6762649	12596534	6624861	10621990	
19	6624861	373667	836196	119765	758706	400390	1477879	807246	1709888	6080535	544326	81.89
		526966			1048365		131741	7569896	14306423	6624861	11166317	
20	6624861	373667	836196	119765	815609	380371	1477879	844169	1786811	6117458	507403	82.39
		526966			991462		131741	8414065	16093234	6624861	11673720	

TABLE 2-3. (Cont.)

21	6624861	373667 526966	836196	119765	876780 930291	361352	1477879 131741	882660 9296726	1867000 17960235	6155949 6624861	468912 12142633	82.91
22	6624861	373667 526966	836196	119765	942538 864533	343285	1477879 131741	922896 10219623	1950826 19911062	6196185 6624861	428676 12571309	83.45
23	6624861	373667 526966	836196	119765	1013229 793842	326120	1477879 131741	965067 11184690	2038681 21949744	6238355 6624861	386505 12957815	84.02
24	6624861	373667 526966	836196	119765	1089221 717850	322558	1477879 131741	1003253 12187943	2118235 24067979	6276541 6624861	348319 13306134	84.53
25	6624861	373667 526966	836196	119765	1170913 636158	322558	1477879 131741	1042465 13230408	2199927 26267906	6315753 6624861	309107 13615242	85.06
26	6624861	373667 526966	836196	119765	1258731 548340	322558	1477879 131741	1084617 14315026	2287745 28555652	6357906 6624861	266955 13882198	85.63
27	6624861	373667 526966	836196	119765	1353136 453935	322558	1477879 131741	1129932 15444958	2382150 30937803	6403220 6624861	221640 14103838	86.24
28	6624861	373667 526966	836196	119765	1454621 352450	322558	1477879 131741	1178645 16623603	2483635 33421438	451933 6624861	172927 14276766	86.89
29	6624861	373667 526966	836196	119765	1563718 243353	322558	1477879 131741	1231011 17854615	2592732 36014171	6504300 6624861	120561 14397327	87.6
30	6624861	373667 526966	836196	119765	1680997 126074	322558	1477879 131741	1287305 19141920	2710011 38724182	6560594 6624861	64267 14461595	88.36
31	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 20489742	2836086 41560268	4814037 6624861	1810823 16272419	64.83
32	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 21837563	2836086 44396355	4814037 6624861	1810823 18083243	64.83
33	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 23185384	2836086 47232441	4814037 6624861	1810823 19894066	64.83
34	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 24533206	2836086 50068527	4814037 6624861	1810823 21704890	64.83
35	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 25881027	2836086 52904613	4814037 6624861	1810823 23515714	64.83
36	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 27228849	2836086 55740699	4814037 6624861	1810823 25326538	64.83
37	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 28576670	2836086 58576785	4814037 6624861	1810823 27137361	64.83
38	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 29924491	2836086 61412871	4814037 6624861	1810823 28948185	64.83
39	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 31272313	2836086 64248958	4814037 6624861	1810823 30759009	64.83
40	6624861	373667 526966	836196	119765	0 0	322558	1477879 131741	1347821 32620134	2836086 67085044	4814037 6624861	1810823 32569833	64.83

TABLE 2-3. (Cont.)

41	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	33967955	69921130	6624861	34380656	
42	6624861	373667	836196	119765	0	322558	1477879	1347821	2836086	4814037	1810823	64.83
		526966			0		131741	35315777	72757216	6624861	36191480	
43	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	36818426	75915861	6624861	37847475	
44	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	38321076	79074506	6624861	39503471	
45	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	39823726	82233151	6624861	41159466	
46	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	41326375	85391796	6624861	42815462	
47	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	42829025	88550441	6624861	44471457	
48	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	44331674	91709086	6624861	46127453	
49	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	45834324	94867732	6624861	47783448	
50	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	47336974	98026377	6624861	49439444	
51	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	48839623	101185022	6624861	51095439	
52	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	50342273	104343667	6624861	52751434	
53	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	51844923	107502312	6624861	54407430	
54	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	53347572	110660957	6624861	56063425	
55	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	54850222	113819602	6624861	57719421	
56	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	56352872	116978247	6624861	59375416	
57	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	57855521	120136892	6624861	61031412	
58	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92
		526966			0		131741	59358171	123295537	6624861	62687407	
59	6624861	373667	836196	119765	0	0	1477879	1502649	3158645	4968866	1655995	66.92

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TABLE 2-4. CASH FLOW

JOINT DEVELOPMENT WITH MMWEC, HALF PROPERTY TAXES

YR.	ELECT. INCOME	O&M G & A	H20	INS.	PRINCIP INTERST	DOUBLE DECLIN DEPREC	PROP TAX MISTAX	CORP TAX (CUM)	PRE-TAX NET INCOME (CUM)	*TOTALS* COST INCOME	CASH FLOW NET (CUM)	BREAK EVEN COST
1	3921245	221173	494943	70888	206405	1007996	437377	0	-301689	3421343	499902	46.08
		311910			1600666		77977	0	-301689	3921245	499902	
2	4156520	234443	524640	75142	221886	957596	463619	0	-97391	3518199	638320	47.38
		330625			1585186		82656	0	-399079	4156520	1138223	
3	4405911	248510	556118	79650	238527	909717	491437	0	113854	3620867	785044	48.76
		350462			1568544		87615	0	-285225	4405911	1923267	
4	4670266	263420	589485	84429	256417	864231	520923	32131	332757	3761826	908439	50.66
		371490			1550655		92872	32131	47533	4670266	2831706	
5	4950482	279225	624854	89495	275648	821019	552178	255328	560058	4100380	850101	55.22
		393780			1531423		98445	287459	607591	4950482	3681808	
6	5247510	295979	662346	94865	296321	779968	585309	368836	796533	4336166	911344	58.4
		417406			1510750		104351	656295	1404125	5247510	4593152	
7	5562361	313738	702086	100557	318546	740970	620427	487135	1042991	4584082	978279	61.74
		442451			1488525		110612	1143431	2447116	5562361	5571432	
8	5896103	332562	744211	106590	342437	703921	657653	610634	1300279	4844973	1051130	65.25
		468998			1464634		117249	1754065	3747395	5896103	6622562	
9	6249869	352516	788864	112985	368119	668725	697112	739758	1569288	5119733	1130135	68.95
		49138			1438952		124284	2493824	5316684	6249869	7752698	
10	6624861	373667	836196	119765	395728	635289	738939	874957	1850952	5409306	1215555	72.85
		526966			1411343		131741	3368781	7167636	6624861	8968253	
11	6624861	373667	836196	119765	425408	603524	738939	904450	1912396	5438799	1186062	73.25
		526966			1381663		131741	4273231	9080033	6624861	10154316	
12	6624861	373667	836196	119765	457314	573348	738939	934249	1974478	5468598	1156263	73.65
		526966			1349757		131741	5207481	11054511	6624861	11310579	
13	6624861	373667	836196	119765	491612	544681	738939	964473	2037444	5498822	1126039	74.06
		526966			1315459		131741	6171954	13091955	6624861	12436618	
14	6624861	373667	836196	119765	528483	517447	738939	995243	2101549	5529592	1095269	74.47
		526966			1278588		131741	7167198	15193504	6624861	13531887	
15	6624861	373667	836196	119765	568119	491574	738939	1026687	2167057	5561036	1063824	74.89
		526966			1238952		131741	8193885	17360562	6624861	14595712	
16	6624861	373667	836196	119765	610728	466996	738939	1058937	2234245	5593286	1031574	75.33
		526966			1196343		131741	9252823	19594807	6624861	15627287	
17	6624861	373667	836196	119765	656533	443646	738939	1092131	2303399	5626481	998380	75.78
18	6624861	373667	836196	119765	705773	421463	738939	1126414	2374822	5660763	964097	76.24
		526966			1101298		131741	11471370	24273030	6624861	17589765	
19	6624861	373667	836196	119765	758706	400390	738939	1161937	2448828	5696286	928574	76.72
		526966			1048365		131741	12633308	26721858	6624861	18518340	
20	6624861	373667	836196	119765	815609	380371	738939	1198860	2525751	5733209	891652	77.21
		526966			991462		131741	13832168	29247609	6624861	19409992	

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TABLE 2-4. (Cont.)

21	6624861	373667	836196	119765	876780	361352	738939	1237351	2605940	5771700	853161	77.73
		526966			930291		131741	15069519	31853549	6624861	20263154	
22	6624861	373667	836196	119765	942538	343285	738939	1277587	268966	5811936	812924	78.27
		526966			864533		131741	16347107	34543316	6624861	21076078	
23	6624861	373667	836196	119765	1013229	326120	738939	1319758	2777621	5854107	770754	78.84
		526966			793842		131741	17666865	37320937	6624861	21846833	
24	6624861	373667	836196	119765	1089221	322558	738939	1357944	2857175	5892293	732568	79.36
		526966			717850		131741	19024810	40178112	6624861	22579401	
25	6624861	373667	836196	119765	1170913	322558	738939	1397156	2938866	5931505	693356	79.88
		526966			636158		131741	20421966	43116979	6624861	23272758	
26	6624861	373667	836196	119765	1258731	322558	738939	1439308	3026685	5973658	651203	80.45
		526966			548340		131741	21861275	46143664	6624861	23923961	
27	6624861	373667	836196	119765	1353136	322558	738939	1484623	3121090	6018972	605889	81.06
		526966			453935		131741	23345898	49264755	6624861	24529851	
28	6624861	373667	836196	119765	1454621	322558	738939	1533336	3222575	6067685	557176	81.72
		526966			352450		131741	24879234	52487330	6624861	25087027	
29	6624861	373667	836196	119765	1563718	322558	738939	1585702	3331672	6120051	504810	82.42
		526966			243353		131741	26464937	55819002	6624861	25591837	
30	6624861	373667	836196	119765	1680997	322558	738939	1641996	3448950	6176345	448516	83.18
		526966			126074		131741	28106933	59267953	6624861	2604035	
31	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	29809445	62842979	6624861	28235425	
32	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	31511958	66418004	6624861	30430498	
33	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	33214470	69993030	6624861	32625570	
34	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	34916982	73568056	6624861	34820642	
35	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	36619495	77143082	6624861	37015715	
36	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	38322007	80718107	6624861	39210787	
37	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	40024519	84293133	6624861	41405859	
38	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	41727032	87868159	6624861	43600932	
39	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	43429544	91443184	6624861	45796004	
40	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		52696			0		131741	45132056	95018210	6624861	47991076	

TABLE 2-4. (Cont.)

41	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	4429789	2195072	59.66
		526966			0		131741	46834569	98593236	6624861	50186149	
42	6624861	373667	836196	119765	0	322558	738939	1702512	3575025	429789	2195072	59.66
		526966			0		131741	48537081	102168262	6624861	52381221	
43	6624861	373667	836196	19765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	50394422	106065846	6624861	54421465	
44	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	52251762	109963431	6624861	56461709	
45	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	54109103	113861016	6624861	58501953	
46	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	55966444	117758600	6624861	60542197	
47	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	57823784	121656185	6624861	62582441	
48	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	59681125	125553770	6624861	64622685	
49	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	61538466	129451354	6624861	66662929	
50	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	63395806	133348939	6624861	68703173	
51	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	65253147	137246524	6624861	70743417	
52	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	67110488	141144108	6624861	72783661	
53	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	68967828	145041693	6624861	74823905	
54	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	70825169	148939278	6624861	76864149	
55	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	72682509	152836862	6624861	78904393	
56	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	74539850	156734447	6624861	80944637	
57	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	76397191	160632032	6624861	82984881	
58	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74
		526966			0		131741	78254531	164529616	6624861	85025125	
59	6624861	373667	836196	119765	0	0	738939	1857340	3897584	4584617	2040244	61.74

The principal difference in annual costs between the case of 100 percent ownership by Boott Mills and 60%/40% joint ownership by MMWEC and Boott Mills is that if MMWEC is the borrower the cost of money will be reduced from 10.5% to 7.5%. Real estate taxes are unaffected by the form of ownership because MMWEC, by law, is obliged to make payments in lieu of taxes.

To generate cash flow analyses, RSC was provided with informal guidelines that established an upper limit for the cost of power per kWh by MMWEC. These cannot be published until approved by the MMWEC Board of Directors, so as mentioned previously, the figure of 40 mills per kWh in 1979 prices was used, escalated at 6 percent annually. This is a good approximation of the value of power to MMWEC.

In both tax scenarios the project is beneficial to MMWEC as measured by NPV. In the case of half rate property taxes, MMWEC will experience negative cash flows in the first five years. For full property taxes, MMWEC will experience negative cash flows which accumulate to $3,285,000 by the end of the ninth year. This could be reduced by using a method of financing in which payments on principal were eliminated in early years, but this approach does not correspond to MMWEC's current financing practices.

The net present value (NPV) resulting from two other sets of assumptions (no escalation in cost and revenue, and a 6% cost and 9% revenue escalation) are compared with the 6%/6% case in the table below. NPV is shown in thousands of dollars.

	Cost/Revenue Escalation		
	0/0	6/6	6/9
Joint Development (7.5%)			
NPV, Full Taxes	$ 134	$ 8,260	$18,837
NPV, Half Taxes	$4,410	$13,414	$23,382

The NPV's for private financing are repeated below for convenience of comparison to show the great advantage of lower cost financing.

	Cost/Revenue Escalation		
	0/0	6/6	6/9
100% Boott Mills Ownership (10.5%)			
NPV, Full Taxes	-$6,352	-$ 349	$ 6,756
NPV, Half Taxes	-$2,950	$3,709	$10,690

This can be observed again in different form by comparing the difference in breakeven cost for each year of operation using Tables 2-1 and 2-3, and 2-2 and 2-4, respectively.

Investment Risk. The degree of risk of an investment in the project can be related to net present value as a percentage of total project cost. For example, considering the case with 100 percent Boott Mills ownership and half rate taxes, NPV is 24 percent of project cost. An increase of approximately 7 percent in annual project costs or a decrease of 7 percent in project revenues would reduce NPV to zero. Such a margin indicates some investment risk unless there were upward flexibility in the payment for power or some other means of improving NPV and cash flows.

This indicates that NPV as a percentage of total project cost is a useful indicator of investment risk. These percentages are given below for the public and private financing options at escalation rates for cost and revenue of 0%/0%, 6%/6%, and 6%/9%.

NPV As A Percentage of Project Cost

	0/0	6/6	6/9
100% Boott Mills Ownership			
Full Taxes	-40%	-2%	43%
Half Taxes	-19%	24%	68%
Joint Development			
Full Taxes	1%	53%	120%
Half Taxes	28%	85%	149%

As further examples of how to interpret these figures, for the 6%/6% case and MMWEC financing, the risk factor is even less, since a 12 percent increase in annual cost in the full tax case, or a 21 percent increase in the half tax case would be required to exclude the project from consideration. With private ownership and full taxes, the project would operate at breakeven if annual costs were to decrease by only one percent.

2.3 REVENUES AND COST ELEMENTS

Revenues. For the case assuming 100% Boott Mills ownership, power sales would be made to New England Power Company. The price of power has been taken as equal to 40 mills per kWh in 1979 dollars, a figure obtained informally from NEPCO. (NEPCO will want the 40 mills supported by a cost of service analysis.) For purposes of this feasibility assessment, 40 mills has also been taken as the 1979 base value of the power to MMWEC. Total revenues are equal to the price per kWh times the annual kWh generated, or, at 1979 prices:

4¢ x 74,250,000 net kWh per year = $2,970,000 per year

In cases which used a price escalation factor, escalation was applied for the time period taken up by construction and for the first ten years after commercial operation of the project begins, with values held constant thereafter.

Project Capital Costs. The total estimated project cost at 1978 prices of $14,720,000, exclusive of fishways, is developed in Section 4. An allowance of $1,000,000 has been added for fish passage facilities, making a total of $15,720,000. Construction costs have then been adjusted to the (higher) price levels expected to hold during the construction period of 3 years and 40 weeks. To make this adjustment, construction costs were escalated at a rate of 8 percent through 1980 and 6 percent thereafter through the end of construction, using figures obtained from United Engineers and Constructors.

Project Financing. For the case based on MMWEC participation, the assumptions are those requested by MMWEC: 30-year financing at 7.5 percent with level annual payments and regular retirement of the bonds (as is familiarly done with a mortgage). For the case assuming power sales to NEPCO, the assumptions are those recommended by Merrill Lynch: 25-year financing at 10.5 percent with payments on principal deferred for the first 5 years. Thereafter, there is equal amortization of the principal amount with payments into a sinking fund so that the amount in the fund at the end of 25 years is equal to the sum needed to retire the bonds. In actual practice, the bonds would be retired with payments from the sinking fund over a number of years according to a schedule to be determined.

Interest During Construction. Rates of 7.5 percent for MMWEC financing and 10.5 percent for private financing are again used. The pattern of borrowing during construction is derived from the construction schedule, with estimated construction costs escalated as indicated above under Project Capital Costs. Interest during construction is capitalized, added to total project cost and then, like other elements of project cost, amortized over the life of the project.

Operations and Maintenance. Data based on national averages are given in the USDOE Federal Energy Regulatory Commission publication entitled "Final Draft Hydroelectric Power Evaluation" (August 1978), page 4-22. The data combine manual and automatic plants. Application of the appropriate average costs from the table (for plants 0-25MW and a capacity factor of 40-80 percent) yields an annual cost of $120,000 to $130,000 in 1975 prices.

Based on this figure, its own experience in operating small hydro facilities, and consideration of the nature and setting of the proposed facility, Boott Mills has estimated a figure of $156,000 at 1978 prices for operation and maintenance of the facility, including all associated physical property. Although this value is higher than the FERC data would indicate, it has been used because it accounts for maintenance of 0.4 miles of a canal section and the canal gatehouse and flow control equipment that is not normally encountered in a project of this type. The figure also covers operations and maintenance expenses on the transmission line connecting to the Pawtucketville substation.

General and Administrative. In practice, general and administrative costs are unique to the company concerned, varying according to size and other characteristics. Boott Mills has estimated $220,000 in 1978 prices, based upon allocation of currently incurred power generation expenses.

Cost of Water. A water charge of 4.7019 mills per kWh is included as the opportunity cost to Boott Mills caused by allocating water to the new hydro facility that up to now has been used to run existing older turbines. This charge has precedent in contractual arrangements made to cover the Lawrence hydroelectric project downriver.

Insurance. The FERC estimate for insurance costs for hydroelectric projects, obtained by phone, is 0.2 percent of total project cost (approximately $30,000). Boott Mills now experiences higher insurance costs, and a figure of $50,000 annually has therefore been used in this analysis. This higher figure is also used because the National Park Service desires that tourists be able to visit the project, and this will have the effect of increasing insurance rates.

Real Estate Taxes. The baseline case for local real property taxes has been estimated first at 'full' value: original cost assessed at 50 percent and taxes at a rate of $200 per $1000. (Original cost is based on project costs contained under FERC accounts ## 331 and 332 with pro rata additions for contingencies and engineering and administrative costs.) As an alternative case, real property taxes were taken as half this amount, to bring them more into line with actual taxes on similar properties within the region. This is believed to be appropriate, since in both houses of the Massachusetts legislature bills have been recently introduced (H 3607) to completely or partially abate real property taxes on small hydro installations.

Miscellaneous Taxes and Fees. This item covers an estimated FERC annual license fee of $10,000, local personal property taxes estimated at $35,000, and legal and other fees of $10,000.

Interim Replacements. A separate sinking fund for interim replacements has not been included in the estimates for annual project costs. As noted in Section 3, the first major need for interim replacements, barring unusual breakdowns, will come after the 20th year of project operation. More substantial replacements typically come after the 40th year. Expenditures 20 and 40 years out are discounted heavily enough that the effect on project feasibility would be small. In addition, major expenses are most likely to occur after 25 years when the project is fully amortized and high positive net cash flows are thus readily available to meet replacement needs.

Cost Escalation Rates. A figure of 6 percent has been used for escalation of non-construction costs. This has been applied during the nearly 4-year construction period and for the first ten years thereafter. Estimates on the order of 6 percent are found in numerous government and private studies.

Summary of Escalation Assumptions. Construction costs are estimated as of October 1, 1978. The 196 week period for engineering and construction has been assumed to begin April 1, 1979. Thus construction costs are escalated beginning October 1, 1978 for the six months until the assumed start of the engineering and construction period. Following this, they continue to be escalated until spent according to the schedule set forth in Table 4-3. The last construction payments are made by January 8, 1983. Escalation is at 8 percent until January 1, 1981, and 6 percent thereafter.

Operating costs are also estimated as of October 1, 1978. They are escalated for six months to April 1, 1979, then over the engineering and construction period and for an additional ten years, ending January 8, 1993. Escalation is at 6 percent for this total period, after which costs are assumed to be constant.

Revenues are estimated as of April 1, 1979. Their escalation is over the engineering and construction period and for an additional ten years, ending January 8, 1993. Two rates over this period are used, 6 percent and, alternatively, 9 percent.

Reliability of Cost Estimates. Cost estimating methods for project capital costs are discussed in detail in Section 4. Particular care was taken in estimating turbine-generator costs and civil works costs, which together comprise 82 percent of project total costs prior to adding factors for contingencies and engineering and administration. A contingency factor has been added to account for minor items not included in the engineering estimate and for reasonable cost variation outside of that projected in the unit costs. At the conceptual design level of project development, a 15 percent engineering contingency was considered by RSC and Acres to be appropriate for this project.

The principal element of uncertainty in project capital costs concerns fishway requirements. An allowance of $1,000,000 for fishway costs was included in the calculations of net present value above. However, determination of the design and cost of fish passage facilities that will meet requirements entails more extensive investigation than is possible in a feasibility assessment of this kind, and the final estimate may be higher.

Annual costs have been conservatively estimated. The most significant element of uncertainty is in the estimate for the rate of escalation for revenue and, to a lesser extent, costs. The uncertainty in escalation rates for revenue has been addressed by calculating NPV for a range of escalation rates in Section 2.2 above.

Delay in approval of the FERC license could increase construction costs. The time allowed for license approval is 70 to 85 weeks, approximately the same length of time required for license approval for a site of similar size at Lawrence, Massachusetts. FERC approval for major projects now typically takes nine to twelve months. A longer time has been allowed for the Lowell hydroelectric facility because it must be integrated with the Federal and state parks, and park planning will not be complete for approximately two years.

<u>Cost and Revenue Estimates Used in Concept Design</u>. The Section 3 concept design work was largely completed prior to receipt of all the cost and revenue information used in Section 2. Thus the Section 3 estimates for cost and revenue inputs differ in some respects. Operating costs in Section 3 were taken as equal to FERC national averages. Revenues were taken as equal to the annualized costs of investment in the least costly alternative new source of similar intermediate load power, assumed to be a combined cycle generating plant. Re-working Section 3 using Section 2 costs and revenues would make little difference to the results in Section 3. At most, there would be a small effect on overall sizing of the project.

The methodology of Section 3 also differs in that calculations were made in terms of benefit-cost ratios rather than net present value. This makes no difference to the results, and the somewhat simpler benefit-cost calculations, using levelized costs, are appropriate to the concept design phase of the assessment.

3.0 DEVELOPMENT OF THE DESIGN CONCEPT

3.1 SUMMARY

This assessment has found the development of a new generating site on the Merrimack River at Lowell, Massachusetts to be technically feasible. The location of the projected facility is shown in Figure 3-1. It is to be on the southeasterly side of the Merrimack River immediately downstream of the Moody Street Bridge.

In developing detailed design (and cost) data, the approach using vertical propeller turbines was initially chosen because it is a proven technique with many previously successful applications, and there appeared to be no significant differences in estimates of total costs among any of the alternatives then being considered. After the detailed estimating process was well underway, however, quotations for the tube turbines were received and proved to have a significant cost advantage over the vertical propeller design. Consequently, the concept design and most of the calculations which assume a particular equipment choice given in this section are presented in terms of the tube turbine installation. Data which were initially calculated assuming a vertical propeller installation are given in a few instances where the conclusions drawn would hold for any of the various turbine installations considered.

The development consists of installing a new intake channel extending from an existing canal wall; constructing a control structure within the 80 ft. wide canal to divert flow to the intake; constructing a powerhouse roughly 96 ft. long by 108 ft. wide housing four 3.75 MW hydraulic turbines, gear boxes and generators; and finally, excavating a 60 ft. wide tailrace channel about 1000 ft. long in the rock bed of the river. Figure 3-1 shows the project location, and Figure 3-2 shows the project facility plan.

The facility will have a nominally rated capacity of 15,000 KW at 34 ft. design head in the turbine and a flow of 6000 cfs. The gross generation expected from the project is 76,150,000 kWh per year. Net generation may be up to 2.5 percent less, or 74,246,250 kWh per year. Net generation takes into account plant needs and power losses between the generating facility and the connection to the power grid at the Pawtucketville Substation. Estimated project cost of the facility, as discussed in Section 4 of this study is $14,720,000 (at 1978 price levels), plus a $1,000,000 allowance for fishways.

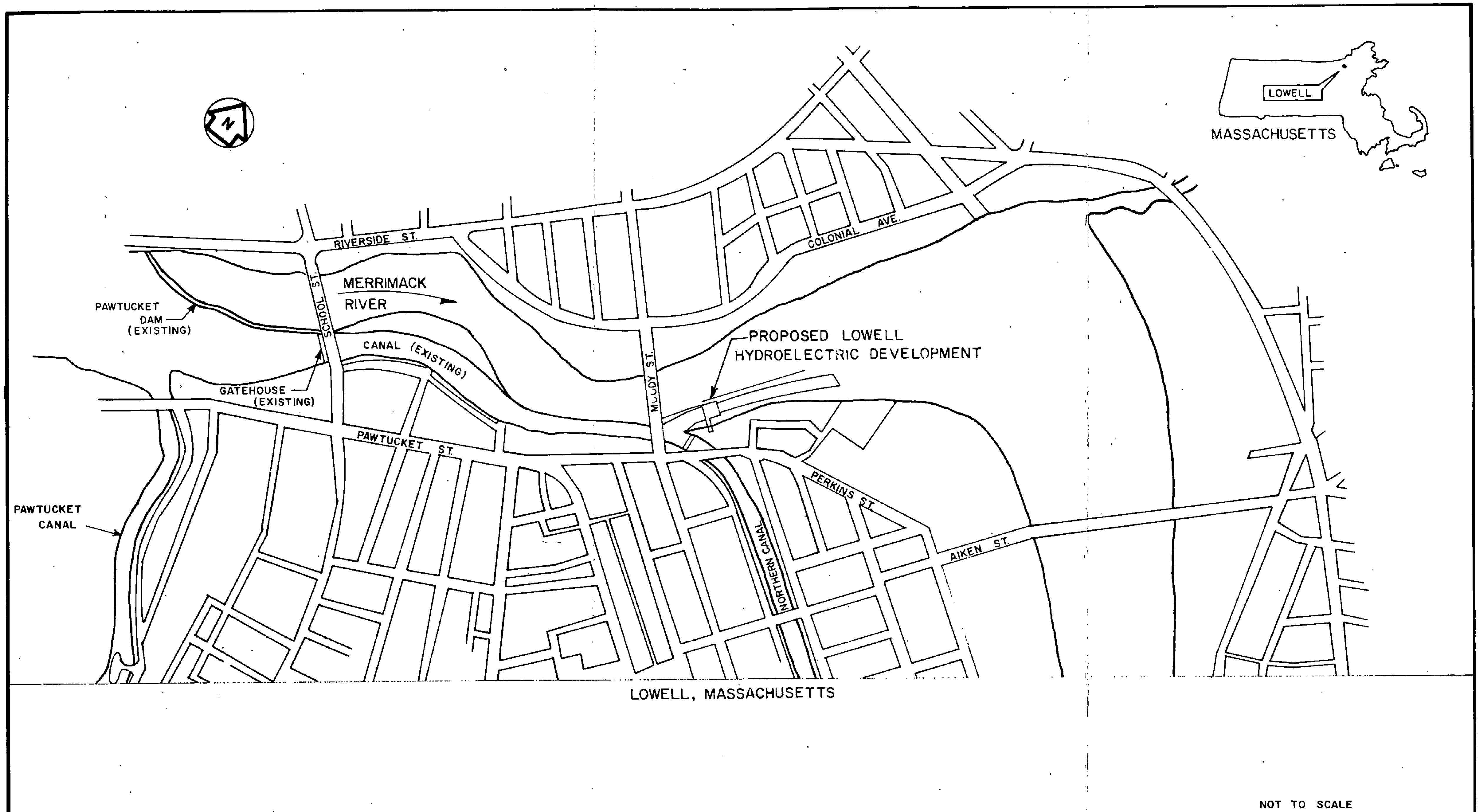


Figure 3-1. Location of Project

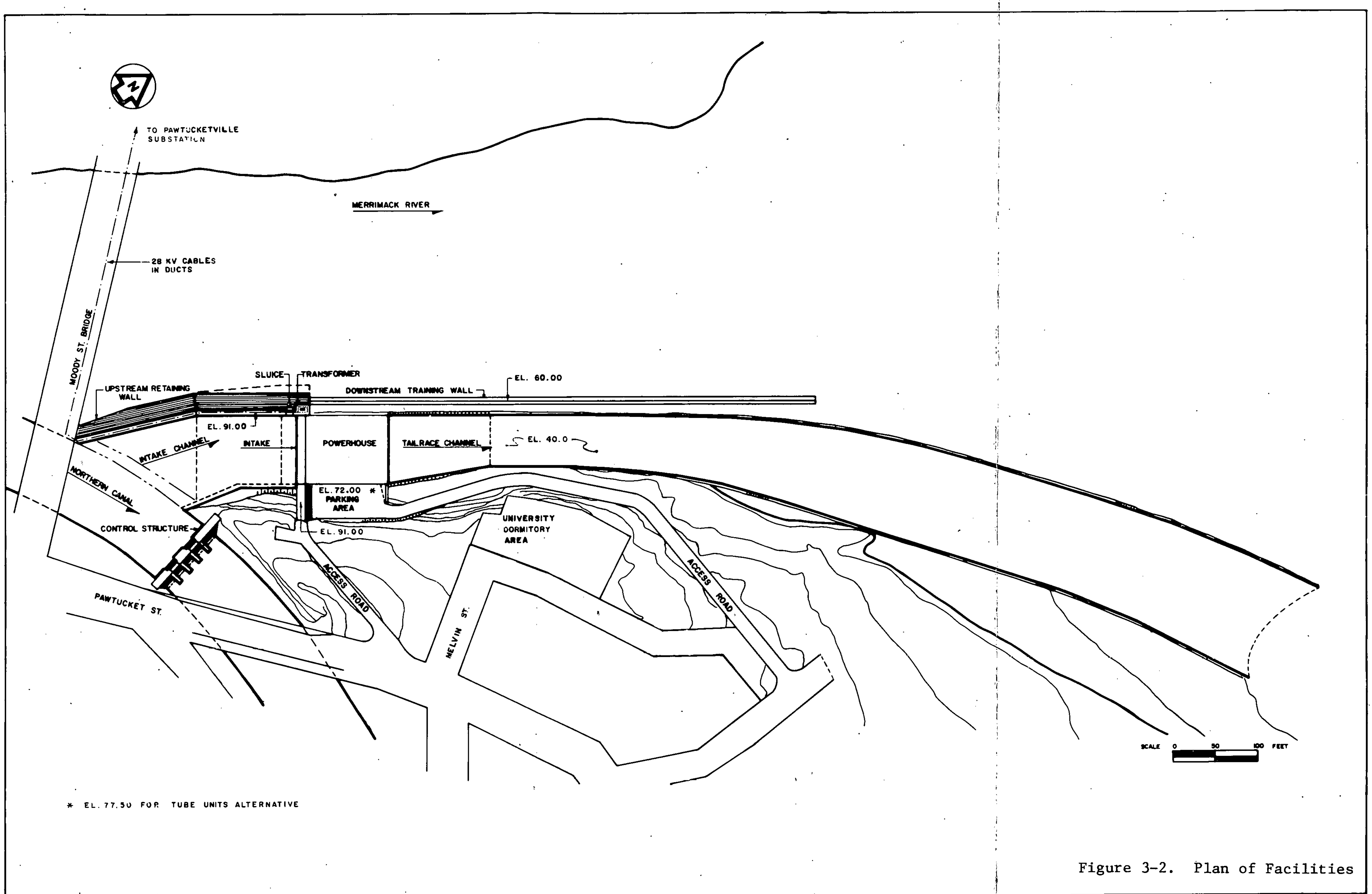


Figure 3-2. Plan of Facilities

It was found that there was sufficient available data to substantiate within a reasonable degree of accuracy the technical feasibility, cost and expected productivity of the projected facility. Further optimization of plant size and more accurate estimation of expected generation is possible with further hydraulic analysis and simulation of flow variations in the river above and below the plant site and in the Northern Canal. However, power purchasers would have to supply more rigorous definition of capacity and energy values for these analyses to be effective in further optimization of plant design.

3.2 PRELIMINARY DESIGN APPROACH

The extent to which the projected hydroelectric facility makes use of the total available river flow is shown in Figure 3-3 below using an annual flow duration curve.

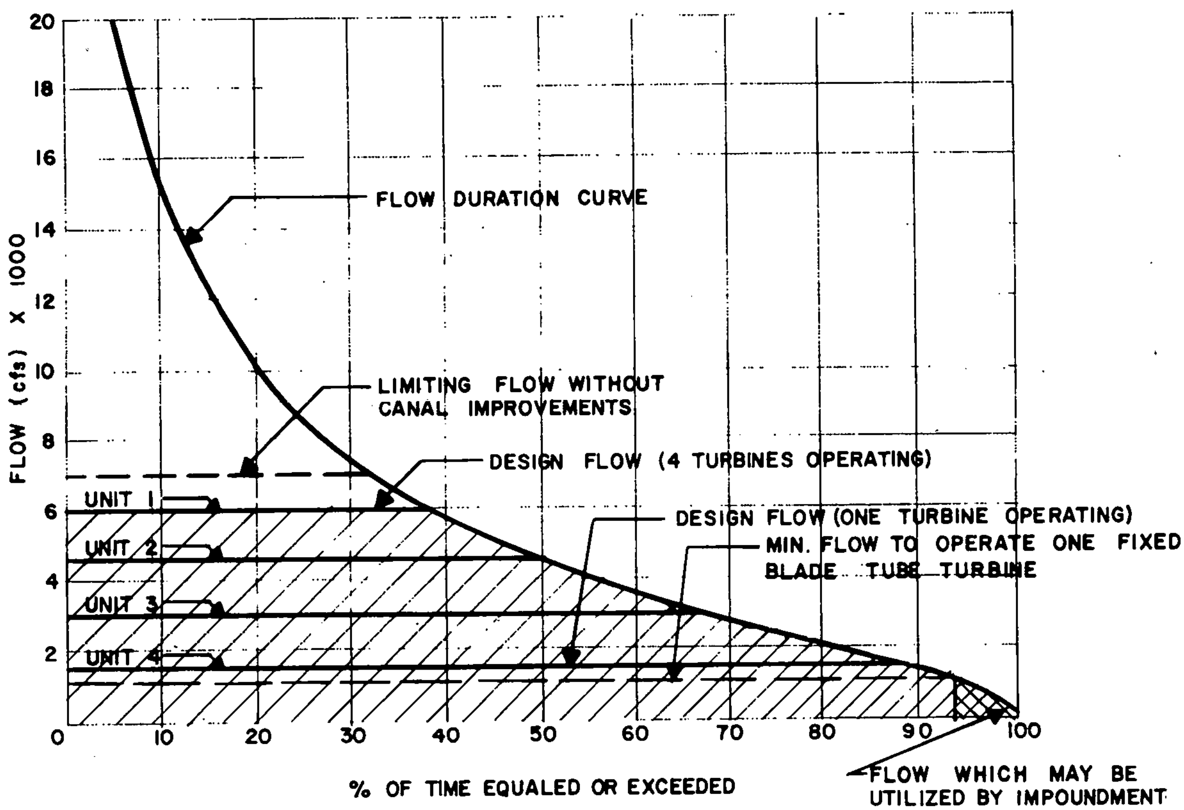


Figure 3-3. Proposed Operating Schedule for Four 3.75MW Tube Turbines

This curve shows that, on the average, only 70% of the total annual river flow can be utilized by the projected new facility. The limitation is imposed not by the facility itself but by the capacity of the Northern Canal in relation to the maximum acceptable velocity. The maximum design velocity of 5.8 fps, which is reached when the hydroturbines are drawing water at their full capacity of 6,000 cfs, is slightly below the velocity at which water becomes turbulent. Higher velocities associated with higher flows would sacrifice available operating head due to friction losses in the canal.

At times when the river flow is greater than 6,000 cfs., excess water can be drawn by the Pawtucket Canal to power existing turbines that otherwise will be held on stand-by. From Figure 3-3, excess river flows will be available for these stand-by generating stations about 38% of the time. (Further consideration of the feasibility of continuing to use existing generating capacity was beyond the scope of this work.)

By integrating the area under the flow duration curve, applying the system efficiency along each point on the curve, and by assuming a fixed schedule or mode of operation, the average annual kilowatt hour output of the system can be determined. A computer program determined that the annual generation would be 76,150,000 kWh gross or 74,250,000 kWh net for four tube turbines. (For greater accuracy, computations were based on monthly flow data.) Net output differs from gross by the subtraction of station needs and losses in transmission to the substation where connection is made to the power grid.

While Figure 3-3 is specific to the tube turbine installation, a similar analysis could be made for other turbine types and configurations. And, indeed this type of analysis was applied to various types and configurations of turbines to optimize the project benefit-cost ratio prior to the detailed costing of a baseline approach to be used in the economic feasibility tests described earlier in this report.

3.3 PROJECT SITE

3.3.1 Site Advantages

The site selected is located on the southeasterly side of the Merrimack River immediately downstream of the Moody Street Bridge and about 2000 ft. downstream of the Pawtucket Dam. The intake channel will draw water from the Northern Canal. Since the Northern Canal is immediately adjacent to the Merrimack River at this location, being separated only by a masonry wall, the structures required for diversion and generation are minimal. While it would be possible to develop up to 25 ft. of head at the base of the masonry wall, the relatively short tailrace which has been added in the design discussed here will increase the operating head to 34 feet. Photographs showing the dam, the Northern Canal and the project site are given in Section 5 below.

Construction of the powerhouse at the bank of the river channel does not require use of otherwise valuable, developable land and offers no greater obstruction to flood flows at this location than does the natural upstream channel.

Ready access to the site is available, and connection to a power substation within a distance of one mile is possible by means of existing conduit and pole line.

3.3.2 Site Conditions Affecting the Work

The site examination was on October 9, 1978. Existing structures and site conditions were examined. A thorough investigation of the existing dam and canal structures and the proposed powerplant site was possible due to low flow conditions, with the pond at one foot above the dam crest and three feet below the top of flashboards. The riverbed below the dam, canal and proposed powerhouse site was effectively dry, providing excellent inspection conditions. However, as a result of inaccessibility of one section of the dam and some leakage through the boards, only partial observation of the dam was possible. The existing structures were all found to be in a sound and tight condition with minor exceptions in portions of the Northern Canal. The location for the proposed power facility was found to be acceptable in terms of efficient use of existing structures and topography without significant upset of present land use. Additionally, access appears to be reasonably good and there are no unusual geological restrictions expected to be encountered.

It was found that there was a need for a control structure across the Northern Canal at the site of the new hydroelectric installation. This structure is needed to allow the Northern Canal level to fluctuate according to plant operating needs without affecting the remaining canal system. A gate will be provided for controlling water supply to the canal together with a bay which will permit the addition of a boat lock at a later date if required by the National Park Service to allow proposed tourist barges to traverse the entire canal system.

3.3.3 Hydraulic Data

Streamflows. The drainage area of the Merrimack River at Pawtucket Dam is 4,020 square miles. Flow upstream of the dam is controlled to a moderate extent by the operation of the Amoskeag Plant, 33 miles upstream, which has a maximum discharge of approximately 5,000 cfs. Streamflow data was available from the U.S. Geological Survey (USGS) WATSTORE system. The USGS stream gage nearest to the dam (NO. 01100000) is downstream at the confluence of the Concord and Merrimack Rivers in Lowell. The drainage area at this gate is 4,425 square miles. All streamflow data were adjusted to represent flow at the dam by using a factor equal to the ratio of the respective drainage areas. The annual flow duration curve is shown in Figure 3-4. Table 3-1 shows the monthly variation of flow duration data. Flow duration curves for each month were used to establish the average monthly flows available for generation.

Flood Flows. The flood discharge curve for flow over the crest of the dam is shown in Figure 3-5, with return periods provided by USGS WATSTORE. A 100-year flood would raise the headwater surface elevation to El.92 (Locks and Canals Datum) or 4 feet below the canal gatehouse non-overflow elevation. The maximum flood of record interpolated from USGS gage records is estimated as 157,000 cfs. This flood rose to El.100 on the upstream side of School Street Bridge, which was apparently the critical control point for the upstream flood stage. The corresponding flood elevation above Moody Street Bridge, near the proposed site, was

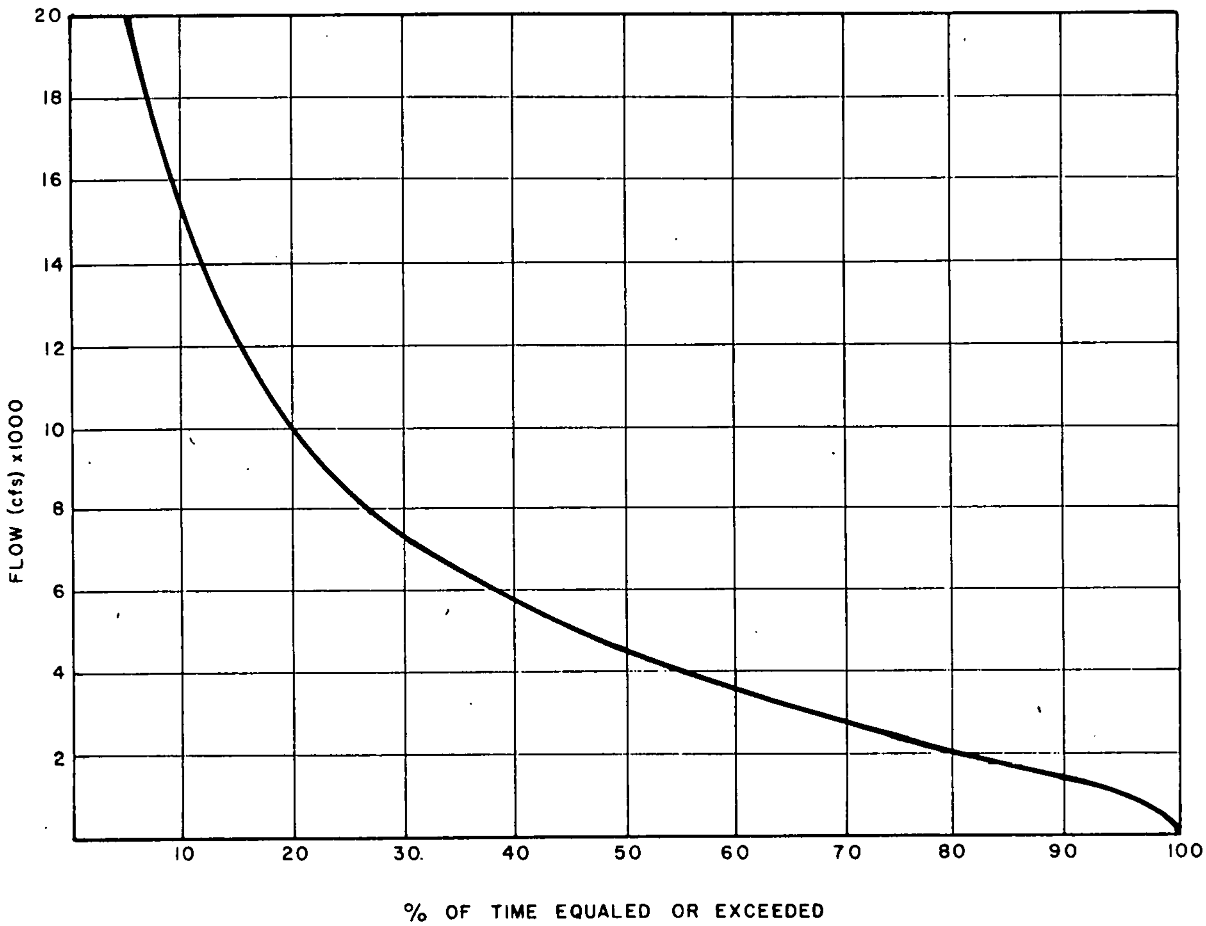


Figure 3-4. Annual Flow Duration Curve

TABLE 3.1

MONTHLY FLOW DURATION DATA

	Percent of Time Exceeded						
MONTH	95%	90%	75%	70%	50%	25%	10%
January	1,730	2,280	3,460	3,730	5,100	7,280	11,830
February	2,000	2,640	3,820	4,100	5,280	7,920	11,830
March	3,640	4,460	6,280	6,730	9.010	13,650	20,930
April	7,190	8,460	10,920	11,830	16,380	22,750	29,120
May	3,640	4,550	6,190	6,730	9,100	14,560	18,200
June	1,460	1,910	2,820	3,090	4,280	6,830	10,920
July	720	1,090	1,640	1,730	2,370	3,550	5,370
August	530	850	1,370	1,460	1,910	2,820	4,370
September	550	870	1,370	1,460	1,910	3,000	4,640
October	620	1,000	1,550	1,730	2,370	3,820	6,190
November	1,090	1,550	2,550	2,820	4,000	6,730	11,830
December	1,730	2,180	3,280	3,550	5,010	8,010	12,740

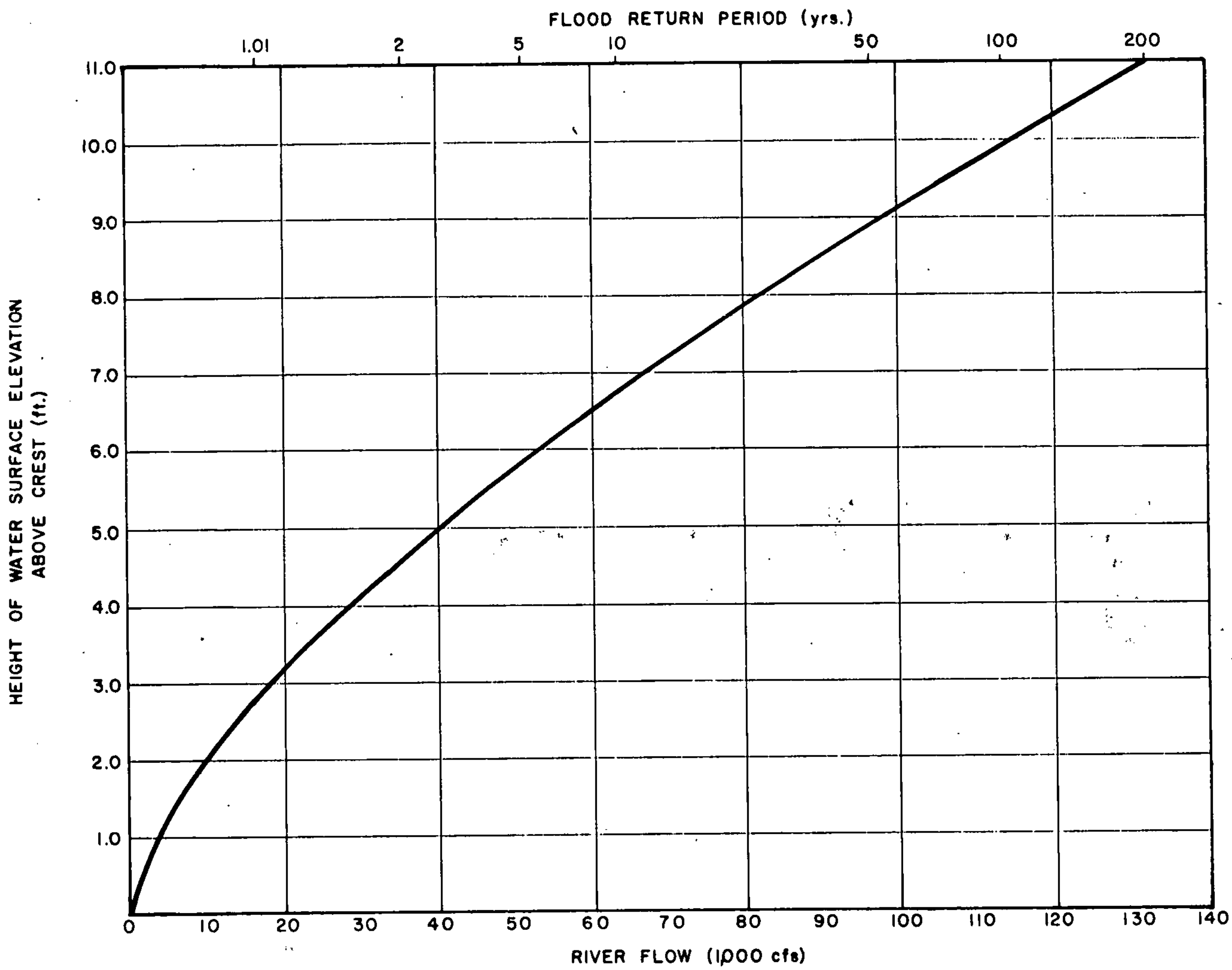


Figure 3-5. Flood Discharge Curve

shown on the Locks and Canals reference contour drawing (dated September, 1936) as El.89± and the downstream USGS gage records show a stage at El.68.4. The riverbed profile between these two points is such that water levels at the site of the proposed powerhouse under the maximum flood condition would have been greater than the maximum project design tailwater level of El.70 which is listed in part (d) below. Raising the tailwater design elevation should be considered in further detail prior to final design of the project.

Pondage. The impoundment behind Pawtucket Dam extends approximately 18 miles upstream. However, the effective pondage, which would contribute to generation flow, was considered to only extend approximately 9 miles upstream to the vicinity of the Massachusetts-New Hampshire border, due to the long narrow nature of the impoundment. The volume of pondage with flashboards on the dam is estimated to be approximately 8,000 cfs-hrs per foot of depth (660 acre-ft/ft).

Hydraulic Design Data. The following hydraulic data was used in the conceptual design of generating facilities:

Headwater Level	maximum	El.89.0
	normal max.	El.86.0 (top flashboards)
	normal	El.85.0
	minimum	El.80.0
Tailwater Level	maximum	El.70.0±
	normal	El.50.5
	minimum	El.49.0
Normal Gross Head		34.5 feet
Normal Net Head		32.5 feet
Average River Flow		6,540 cfs
Design Flow Range		5,500 - 8,000 cfs

A headloss analysis determined the net head available at the powerhouse site. Headloss in the canal was computed using a step method for determining longitudinal river profile. An average canal section was assumed, based on available sectional data on the canal. The canal headlosses were determined for both an 86' and 82' headwater elevation. The resulting total headloss curve is shown below in Figure 3-6.

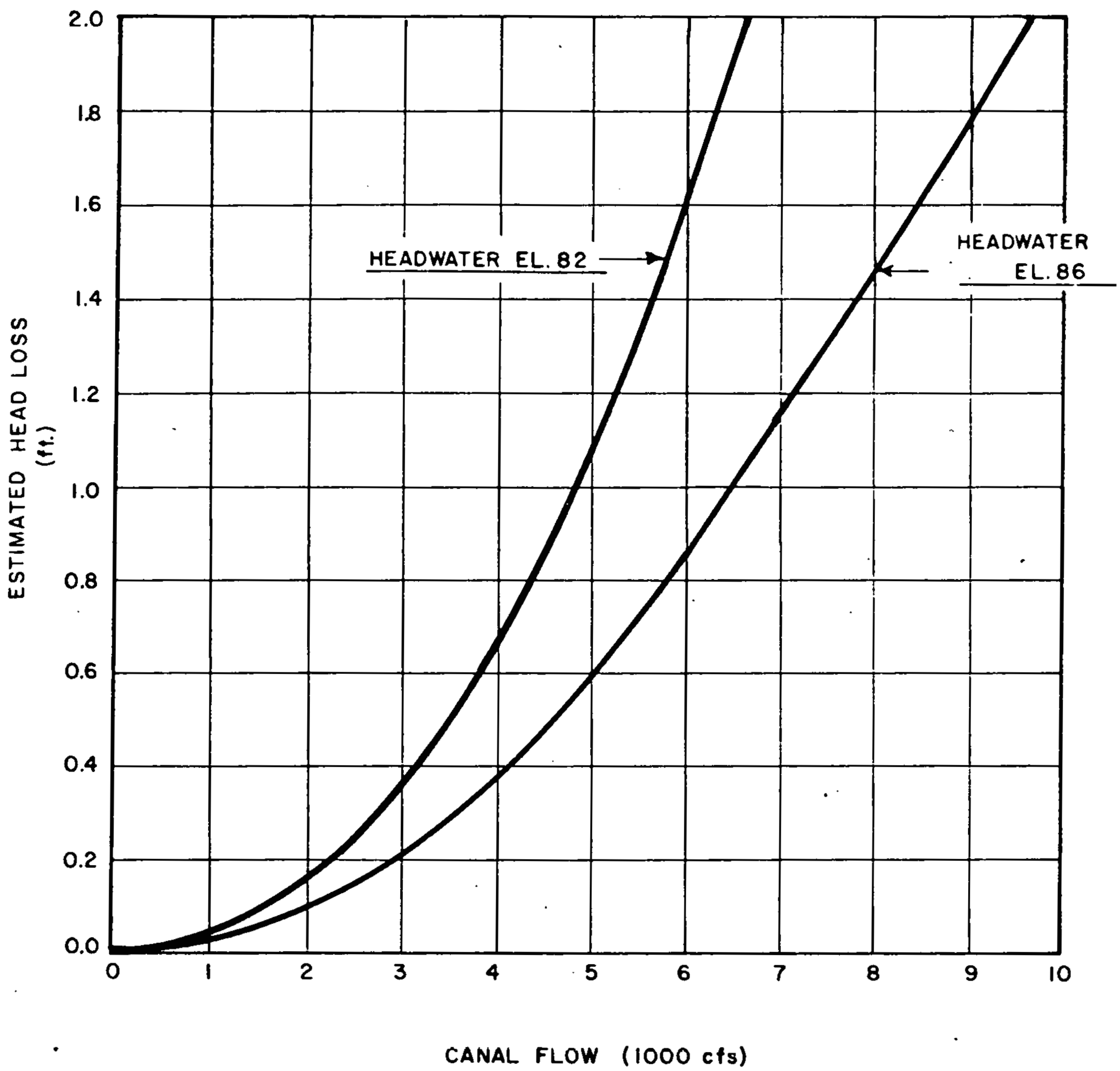


Figure 3-6. Head Loss Through Intake and Canal

A tailwater rating curve was developed from USGS stage-discharge data for the downstream gage. The curve was developed by assuming the same stage-discharge relationship 2 feet higher than the gage through normal flow ranges. The resulting tailwater curve is shown in Figure 3-7.

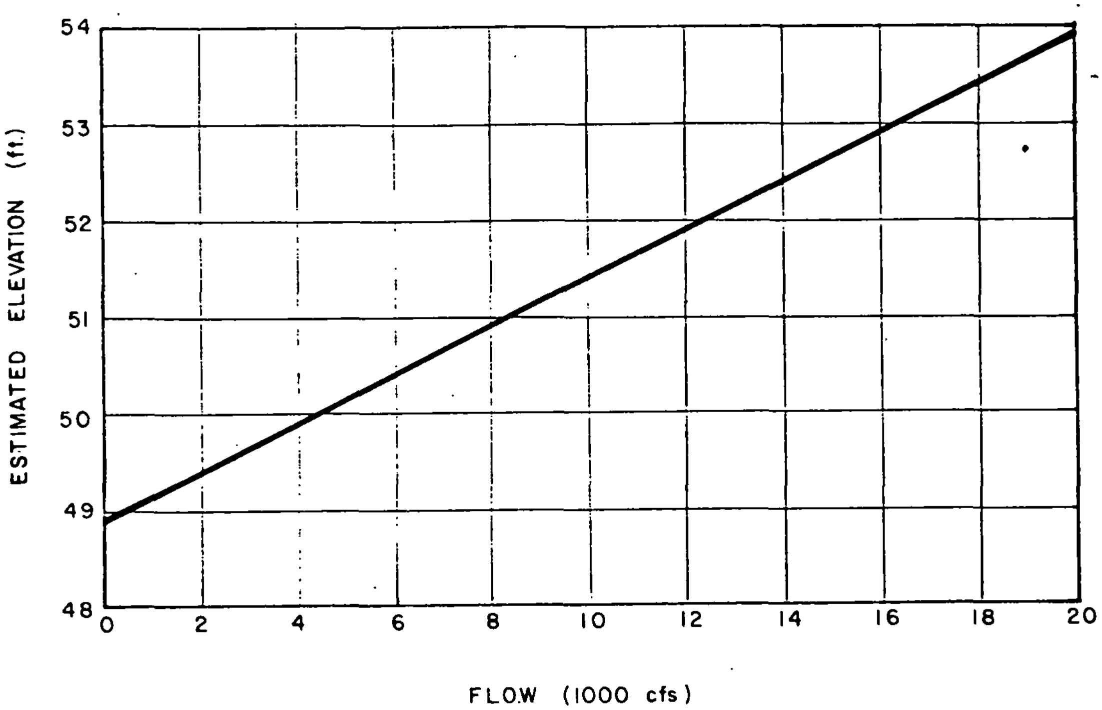


Figure 3-7. Tailwater Rating Curve

3.4 EQUIPMENT SELECTION METHODOLOGY

As noted at the end of Section 2, the economic methodology used in Section 3 differs in some respects from that of Section 2, but not in ways which affect results significantly. There are some differences in cost and revenue assumptions, as specified in Section 2. Also, Section 3 calculations were made in terms of benefit-cost ratios, rather than net present value which was emphasized in Section 2. As noted earlier, use of benefit-cost ratios rather than net present value makes no difference to the results, and use of the somewhat simpler benefit-cost calculation is appropriate to the concept design phase of the assessment.

The benefit-cost ratio of each competing design alternative was computed in order to define the baseline technical approach for the detailed analysis of economic feasibility given in Section 2. The benefit-cost analyses leading to equipment selection were performed using an Acres American computer model. The computer program used flow duration data somewhat more detailed than that presented in Figure 3-4. The cost data used for concept design are FERC national average costs. Levelized costs, identical in all project years, were used, with no consideration given to escalation of costs or revenues. Results were compared with the costs of investment in a combined cycle generating plant (taken as the least costly alternative method of producing similar intermediate load power) as a preliminary measure of feasibility.

For the purposes of the Acres Computer Program, the turbine "rated" output is defined as output at the selected design net head and maximum flow. For preliminary design purposes, all units are assumed to have wicket gates which will be fully open at the "full-gate" or maximum flow condition. Maximum efficiency is assumed to occur at the "best gate" condition, say 90 percent of full gate, for which the flow will be correspondingly less than the maximum for the particular head. The efficiency at full gate, and for all other heads and gate settings, is less than maximum by varying amounts.

In addition, certain rules of operation are assumed, including:

Reservoir operating rules for maximum and minimum water levels, spillway and minimum streamflow releases.

Maximum and minimum periods of plant operation, weekdays and weekends.

Preferred gate settings and minimum operating flows for unit operation.

3.4.1 Site Potential

The generation potential of the project site was calculated on a monthly basis subject to the following conditions:

(1) Four feet of flashboards being maintained during the months of June through December, with no boards for the remainder of the year.

(2) Pondage of 8,000 cfs hrs/ft.

(3) Canal headwater losses as in Figure 3-6.

(4) One foot of headloss through the intake and powerhouse water passages (including racks).

(5) Tailwater based on Figure 3-7.

(6) Maintenance of a river flow of 500 cfs during non-generating periods to account for other flow requirements.

Design flows considered were between 5,500 cfs and 8,000 cfs. Loss of head from friction in the canal is excessive above 6,500 (see Figure 3-6), and as a more conservative figure 6,000 cfs was chosen as the design flow. This corresponds to an installed capacity of 15,000 kW. Table 3-2 below shows annual expected generation as a function of installed capacity. As the right-hand columns show, the increase in generation for larger size installations is small.

TABLE 3-2

ANNUAL EXPECTED GENERATION AS A FUNCTION OF INSTALLED CAPACITY

FLOW cfs	CAPACITY kW	INCREASE %kW	GENERATION MWH	INCREASE (MWH)	%
5,500	13,750		75,177		
6,000	15,000	9%	77,576	2,400	3.2
6,500	16,250	8%	79,818	2,241	2.9
7,000	17,500	7%	81,150	1,332	1.7
7,500*	18,750	7%	84,218	3,068	-
8,000*	20,000	6%	84,512	294	0.3

The estimates of kWh generated given in Table 3-2 are based on a vertical propeller turbine installation. For each rate of flow some variation in generating capacity and kWh output could be expected from different types of equipment. The differences are not great enough, however, to alter the conclusion that 6,000 cfs and 15,000 kW of installed capacity are correct nominal design values at this site.

*Requires canal excavation.

3.4.2 Alternate Locations of Powerhouse

Two plant locations were examined. The first (Moody Street site) is located on the Northern Canal immediately downstream of the Moody Street Bridge and approximately 2,000 feet from the existing gatehouse. The second location is on a canal which would be extended from the first site along the south bank of the Merrimack River. This second site has an additional 10 feet of head relative to the tailwater elevation. However, it is also possible to obtain the additional 10 feet of head at the first site, by excavation of a 15,300 cubic yard tailrace channel. The calculations shown below summarize the benefit-cost analysis which was used to determine that it was more advantageous to develop the extra 10 feet of head at the Moody Street site, rather than use the alternative location. For this reason, the Moody Street site has been selected.

POWERHOUSE LOCATION OPTIMIZATION - COST - BENEFIT ANALYSIS

Head at Moody Street Site (Gross) = 24.5 feet

Additional Head to canal Site = 10 feet

Total Available Head (Gross) = 34.5 feet

INCREMENTAL COST OF DEVELOPING TOTAL HEAD

A. Tailrace Construction (chosen alternative)
Total \$790,000 (including contingency, E+A)

B. Extending Canal Downstream
Total \$2,100,000 (including contingency, E+A)

INCREMENTAL VALUE OF DEVELOPING TOTAL HEAD

Capital Value Per Foot = \$ 600,000/ft.

Total Value of Increased Head = \$6,000,000

BENEFIT: COST RATIO

A. Moody Street Site $\frac{6,000,000}{790,000} = 7.6$

B. Canal Site $\frac{6,000,000}{2,100,000} = 2.9$

3.4.3 Intake and Tailrace Modifications

The existing gate house has 10 headgates, each 8' x 15' with a sill at El.67.0. The loss of head through the gate structure was estimated to be on the order of 0.2 feet. The head losses could not be significantly improved upon by modification of the gate structure. However, it is considered that rehabilitation of all ten gates is probably necessary. No detailed assessment of these requirements has been possible due to limited access to the existing structures during site inspection. A total cost of $70,000, including canal wall repairs, has been provisionally estimated for this work.

The maximum canal flow when the headwater is at El.82 is approximately 6,500 cfs. However, consideration was given to increasing the canal flow at the El.82 head level by excavation. The excavation considered was based on providing the design flow at 6 fps velocity. An excavation of about 22,000 cubic yards of rock (approximately 3.7 feet average depth) from the canal bottom would provide an 8,000 cfs flow with approximately the same head loss as for a 6,000 cfs flow in the existing channel. This amount of work might be expected to have a total estimated construction cost in the order of $1,000,000. However, this alternative was not considered further because of the significant potential of disturbing the existing canal structures during construction or inducing foundation bedrock instability later on in the plant life.

3.4.4 Dam Modification Alternatives

The economic feasibility of increasing the dam height was considered. Four feet of flashboards are currently used on the existing dam. These flashboards fail when they are crested and thus provide increased pond height only during periods of low flow when the boards are not in danger of failure. Maintaining these flashboards is estimated by Boott Mills to cost approximately $10,000 per year.

Four design alternatives were available:

1) Raise the crest of the dam permanently with a two foot high concrete cap and two feet of flashboards. Raising the dam crest with a permanent 2 foot high concrete cap would require 940 cubic yards of concrete and, during construction, a 67,000 cubic yard cofferdam.

2) Raise 693 feet of the dam with two feet of permanent concrete and two feet of flashboards and install Bascule gates on the remaining 400 feet of dam. The Bascule gates would allow the discharge of excess flow over the dam crest at a lower head, thus providing better upstream flood protection. Some 67,000 cubic yards of cofferdam material and 1,200 cubic yards of concrete would be required for the dam modification and Bascule gate installation.

3) Raise the dam crest four feet with a permanent concrete cap. This cap would provide a completely new upstream dam face. A four foot high cap would provide four additional feet of head nor normally available after flashboard failure. The cap and facing would require 4,300 cubic yards of concrete and a 94,000 cubic yard cofferdam during construction.

4) Raise the dam crest four feet with a permanent concrete cap, as in alternative #3) and use an additional foot of flashboard if upstream effects are acceptable.

The benefit-cost analysis summarized below compares these alternatives with continued use of the present flashboard system. Each alternative has a benefit-cost ratio of less than one, indicating that the present system is most cost effective.

	Improvement	Total Cost ($)	Annual Cost ($)	Increased Annual Generation (1) (kWh)	Benefit Cost
(1)	Raise 2'	1,282,000	159,000	3,041,000	0.63
(2)	Raise 2' + 400' Bascule	2,916,000	362,000	3,041,000	0.28
(3)	Raise 4'	2,870,000	356,000	6,523,000	0.60
(4)	Raise 4' + 1' Flashboard	2,870,000	356,000	7,671,000	0.71

(1) Increase over use of flashboards (4' ht.)

3.5 EQUIPMENT SELECTION

3.5.1 Installed Capacity

The projected hydroelectric power installation will take full advantage of the existing site, available head, river flows and power values. The full gate rated capacity of 15,000 kW was selected deductively based on the following considerations:

Selection of Design Flow. The existing Northern Canal structures and channel, being completely rock, can tolerate fairly high velocities without damage. With the water level at the dam crest, velocities will be approximately 5.8 fps at 6,000 cfs, 7.1 fps at 7,000 cfs and more than 10 fps at 8,000 cfs. Referring to the headloss curve of Figure 3-6 it can be seen that 6,500 cfs is about the upper limit for utilizing the existing canal facilities. A design flow of 6,000 cfs would limit velocities to a more conservative level for long term canal maintenance considerations. This also would not restrict operation under the possible occasional need to divert additional flows to the remaining Lowell canal system. The alternative of modifying the canal hydraulic section was discussed in Section 3.4.3 and dismissed, due to the substantial extent of existing structures.

Selection of Design Head. Normal gross head of 24.5 feet is already calculated to be available at the selected power plant location. Development of an additional 10 feet of head to a total of 34.5 feet gross is readily justifiable in the form of a tailrace channel construction as evaluated in Section 3.4.2. Estimated head losses at the plant amount to 2.0 feet, resulting in a normal net design head of 32.5 feet. The selected design head for the units is 34 feet.

Annual Generation. The seasonal and daily variations in river flow are adequately covered by a development utilizing 6,000 cfs. Referring to Table 3-3 below, virtually all of the river flows would produce generation in July through October. For the months of January, February, June, November and December, the median flows are significantly less than the 6,000 cfs generation demand flow that makes full utilization of the 15 mW installed capacity. This means there is only occasional surplus flow during these months. Only in March, April and May would a significant amount of surplus flow be available, and during those periods

TABLE 3-3

EXPECTED GROSS MONTHLY GENERATION

Month	Generation kWh	Capacity Factor %
January	6,834,000	65
February	7,476,000	72
March	8,621,000	82
April	9,289,000	89
May	8,292,000	79
June	7,078,000	68
July	4,119,000	39
August	3,375,000	32
September	3,445,000	33
October	4,343,000	42
November	6,685,000	64
December	8,019,000	77
TOTAL	77,576,000 kWh	

the flashboards would be off the dam resulting in a lower head condition.* Table 3-2, Annual Expected Generation, shows that the aggregate impact of seasonal flow variation and head losses in the existing waterways results in a very small generation increase when considering larger installations. This is due to the increased headloss with the higher operating flows and lack of a significant amount of surplus water to provide additional generation.

3.5.2 Number and Types of Hydraulic Turbines

The alternative generation units considered for the Lowell facility are described below.

No. of Units	Type	Unit Rated kW
1	Vertical Kaplan	15,000
1	Horizontal Bulb (adjustable blades)	15,000
2	Horizontal Bulb (fixed blades)	7,500
2	Vertical Fixed Blade Propeller	7,500
2	Standard Horizontal Straflo (fixed blades)	7,500
4	Standard Horizontal Tube (fixed blades)	3,750

3.5.3 Selection Criteria - Technical

Unit efficiency characteristics did not weigh heavily in generating unit selection. The peak efficiencies of all units, except the standard tube, are within approximately 1 percent. Installations using a single generating unit were rejected because there was no significant cost advantage and because multiple unit designs have greater operating flexibility and advantages during outages or when repair work is needed.

The two unit installations are all comparable. This includes overall structure size, unit efficiencies and expected output, and cost. Dependent upon final manufacturers' bids and optimization of the powerhouse structure, any of these units could potentially provide the lowest cost two unit installation.

*Data in Figure 3.3 are for the vertical propeller turbine, but the same conclusions would hold for other type installations.

The standard configuration consisting of four tube units provided the most potential for cost reduction since it was quoted at approximately $2,000,000 less than competing two unit configurations. This more than offset its lower efficiency.

The operating characteristics of systems composed of two and four generating units can be compared by examining Figure 3-3 above and Figure 3-8 below. It can be observed that there is very little difference in efficiency of water use at the Lowell site, attributable to the fact that the two turbine system benefits by the ability to store large quantities of water in the pondage area behind the Pawtucket Dam.

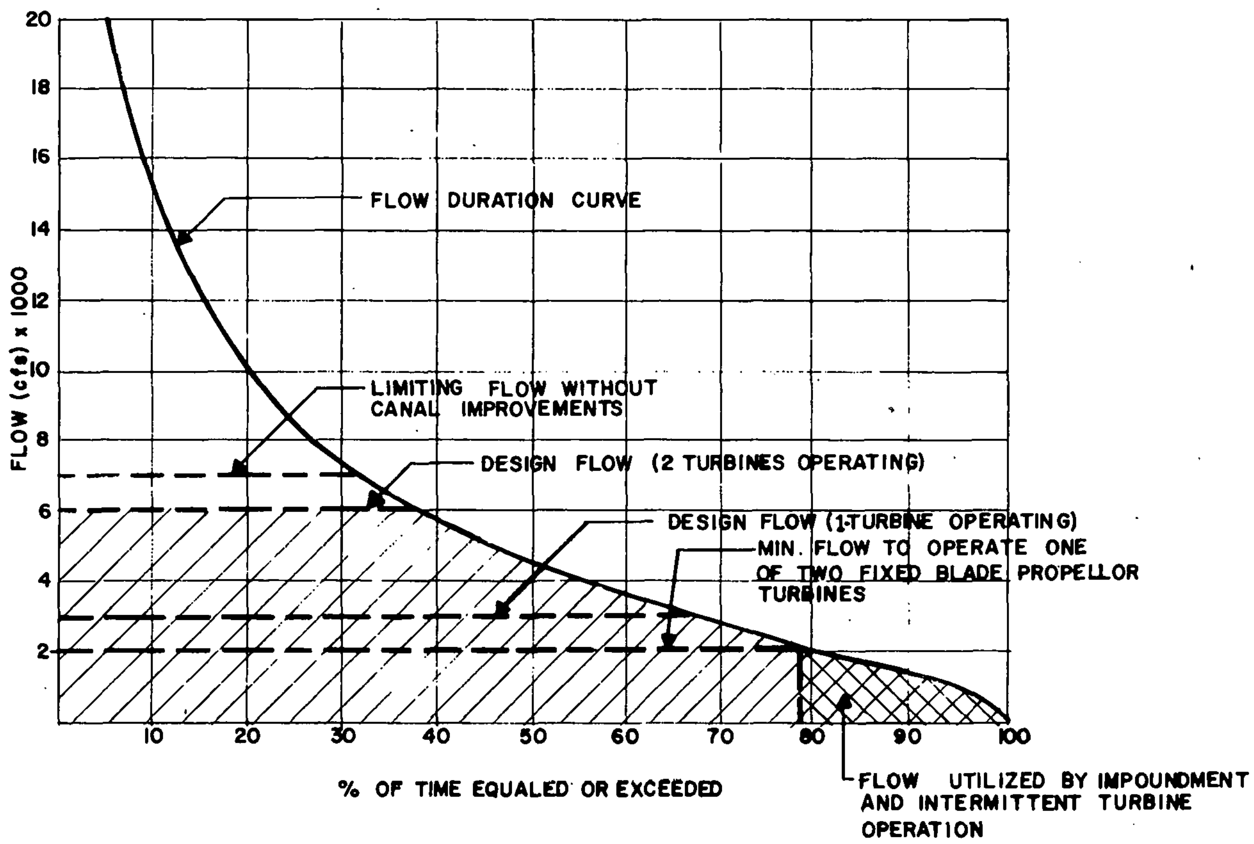


Figure 3-8. Proposed Operating Schedule for Two 7.5 mW Blade Propellor Turbines

Reliability. All units are expected to provide reliable service over the plant's life.

The conventional vertical propeller has by far the most operational history with exceptional durability and performance to be expected. The first significant maintenance items may arise with the wicket gate bushings and stator coil windings, which would normally be expected to last 30 years before repair is necessary. The bulb unit also has a good performance record, but principally in Europe, where it has replaced the vertical propeller as the 'conventional' installation. For the bulb unit a shorter coil life might be expected due to the small generator size and circulation restrictions in the housing.

The Straflo turbine supplied by Escher-Wyss (Sulzer) utilizes rim type generators. Seventy-three of these units were installed at various sites in Germany and Austria between 1937 and 1950. English Electric entered into a research program in the 1960's and in 1970 Escher-Wyss resumed development of the concept. The controlling maintenance factor is the wear of the lip seals. These seals, according to Escher Wyss's (Sulzer) literature, require overhaul intervals of about 2-5 years. The procedure is considered a minor overhaul because the seals are readily accessible.

The standard tube turbines' life expectancy is controlled mainly by the bearings and gear box. According to literature from Bofors-Nohab, life expectancy of both the guide and thrust bearings and speed increasing gear boxes are about 100,000 hours. For Lowell, with a capacity factor of about 60 percent, this life expectancy would be on the order of about 20 years.

3.5.4 Use of Induction Generators

As originally planned, the possible use of induction generators was examined. They proved not to be economic in this installation because the reactance (VAR) requirements would not be met by NEPCO. They would have to be met by adding capacitance to the generators, which would cost as much as $50,000. In addition, the use of switching of the capacitance to protect against overvoltage and over- and underfrequency conditions in case of separation from the system might also be required. In sum, induction generators may be economically feasible in some installations, but not here.

3.6 PRELIMINARY FACILITY DESIGN (Refer to Figure 3-2 above.)

3.6.1 Intake and Tailrace Channels

The intake channel to the powerhouse would be created by constructing a mass concrete gravity section retaining wall between the Moody Street Bridge and the powerhouse location. The new intake channel would be approximately 200 feet long and approximately 110 feet wide at the powerhouse. The bed would be excavated in the existing river channel rock, and would slope downwards from the existing canal to a maximum depth of approximately 20 feet below river bed level. The nominal water depth at the powerhouse intake would vary, from approximately 43 feet for tube units to 68 feet for bulb turbines.

Approximately 160 feet of existing canal wall would be removed at the entrance to the new intake.

As previously mentioned a control structure would be located on the Northern Canal immediately downstream of the site. This would be concrete with a sliding gate to maintain minimum flow and water surface elevation in the canal downstream of the structure. Also, a stop log bay is included which could be utilized for a navigation lock if required in the future.

Since water levels in the remaining canal will not be permitted to rise to an elevation of more than two feet above dam crest, the control structure is a necessity for full flow utilization. It additionally will significantly improve the effective net head at the plant in comparison to subjecting the plant operation to limitations of the whole canal system.

A 1,000 foot long tailrace channel will be created by rock excavation in the existing river bed. The channel excavation will be approximately 60 feet wide by 20 feet deep. The tailrace will be protected from high river flows by a 5 foot maximum height concrete training wall, which will channel river flows away from the tailrace. (Excavation at the powerhouse will be deeper, going to a depth of 28 feet for the tube turbine installation or 35 feet for the propeller unit alternative.)

3.6.2 Powerhouse

Four powerhouse configurations are given in Figures 3-9 through 3-13 respectively, corresponding to the four principal turbine configurations that were considered.

Each powerhouse alternative incorporates a separate conventional intake structure, hydraulically shaped, for each unit. Each intake is equipped with removable trash racks and intake and drift tube gate slots with permanent or bulkhead style gates for emergency shutdown and dewatering purposes. The single and two unit installations include a vertical fixed wheel headgate. For the bulb and Straflo units the headgate is in the draft tube instead of the intake to take advantage of the smaller gate size. Each arrangement includes provision for a single set of bulkhead gates for unit maintenance purposes. In the case of the four tube unit alternative, each standard unit includes a butterfly control valve so that a sliding bulkhead gate (rather than a more expensive automatically operating headgate) will suffice for maintenance.

Gates may be handled by one of a variety of alternative hoist or mobile crane arrangements shown in Figures 3-9 through 3-13 dependent upon powerhouse orientation and design criteria. Gates will normally be stored dogged in their guides.

The powerhouse designs in all but two of the drawings which follow show a superstructure. These have been included because they simplify maintenance, especially during winter weather. However, savings could be achieved by eliminating the superstructure and utilizing either gantry type cranes or temporary cranes. Fixed gantry cranes could be used with the vertical fixed blade propeller and bulb installations. In the tube turbine installation, both the superstructure and crane could be eliminated, and a mobile crane used with access to the equipment by means of hatch type roof covers. Figure 3-12 shows the tube turbine installation with a powerhouse superstructure and Figure 3-13 shows it with the hatch covers. The potential savings are shown in Table 3-4.

TABLE 3-4

POWERHOUSE SUPERSTRUCTURE COSTS

Item	2 Vertical Units Powerhouse	2 Vertical Units No Powerhouse	2-Bulb Units Powerhouse	2-Bulb Units No Powerhouse	4-Tube Units Powerhouse	4-Tube Units No Powerhouse
Superstructure	$240,000	--	$160,000	--	$250,000	--
Crane	200,000	225,000	190,000	205,000	170,000	$ 5,000**
Subtotal	440,000	225,000	350,000	205,000	420,000	--
Total*	635,000	325,000	500,000	295,000	605,000	$ 5,000
Potential Savings		$310,000		$205,000		$600,000

*The total includes 20 percent Contingencies and 20 percent Engineering and Administration
**Rental Cost during construction.

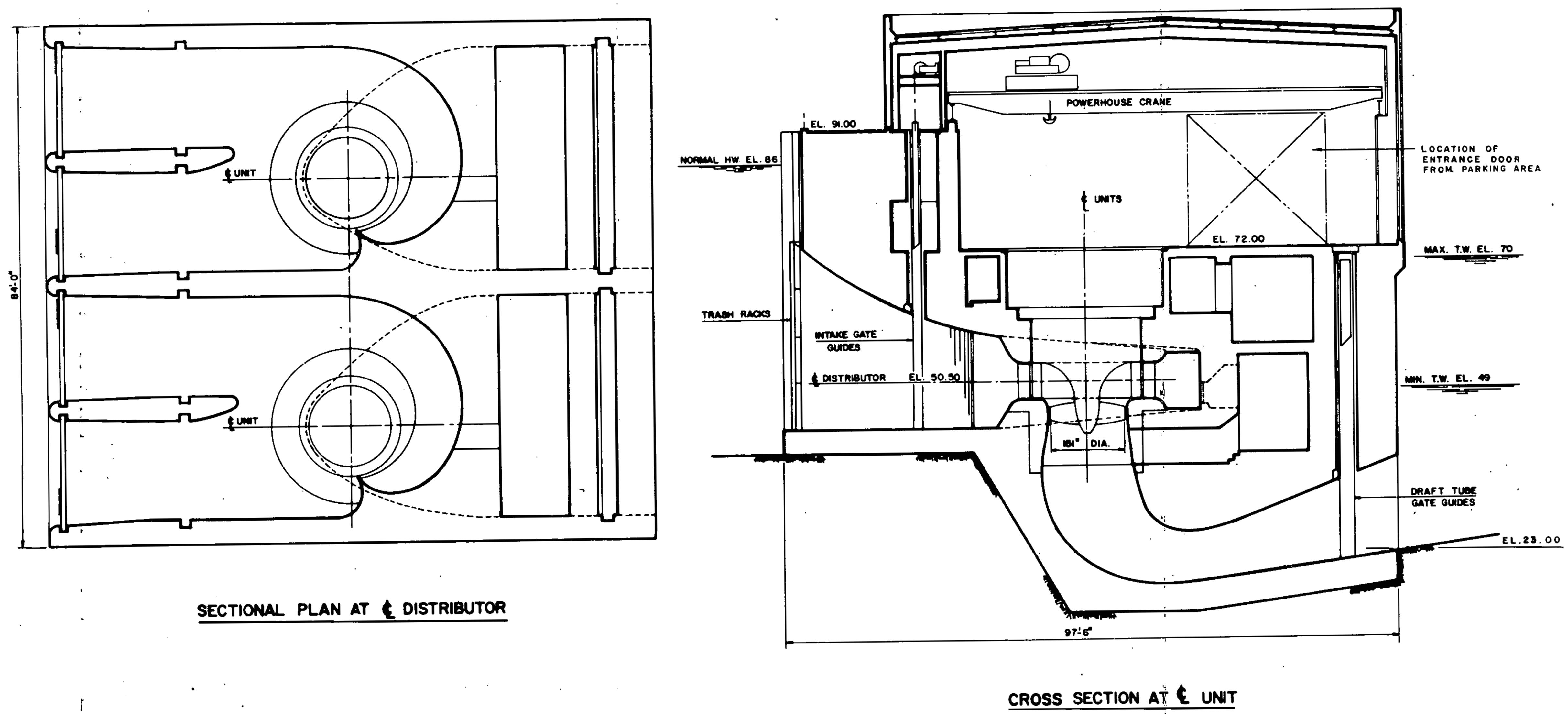


Figure 3-9. 2-7.5 MW Units Fixed Blade Turbine

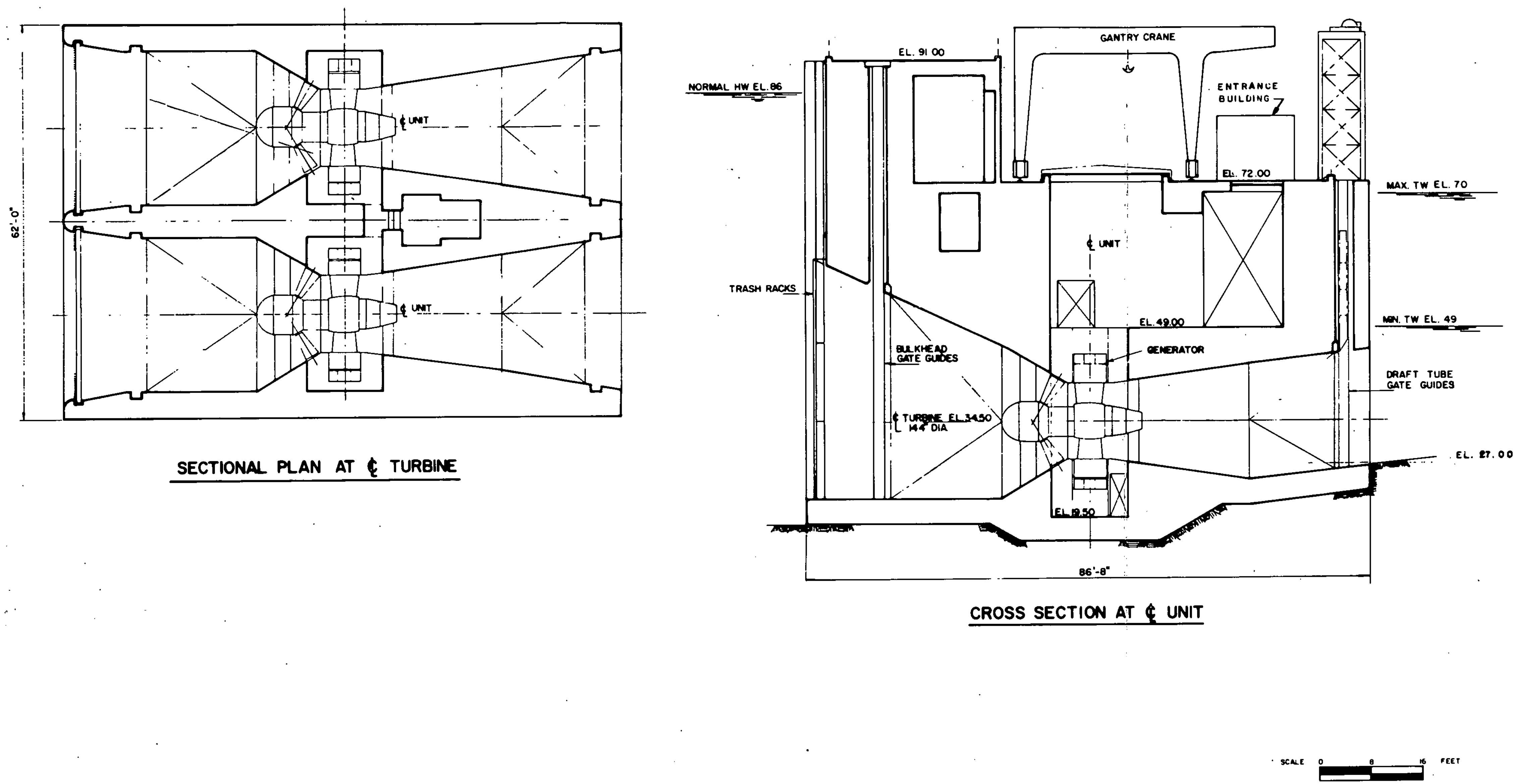


Figure 3-10. 2-7.5 MW Units Straflo Turbine

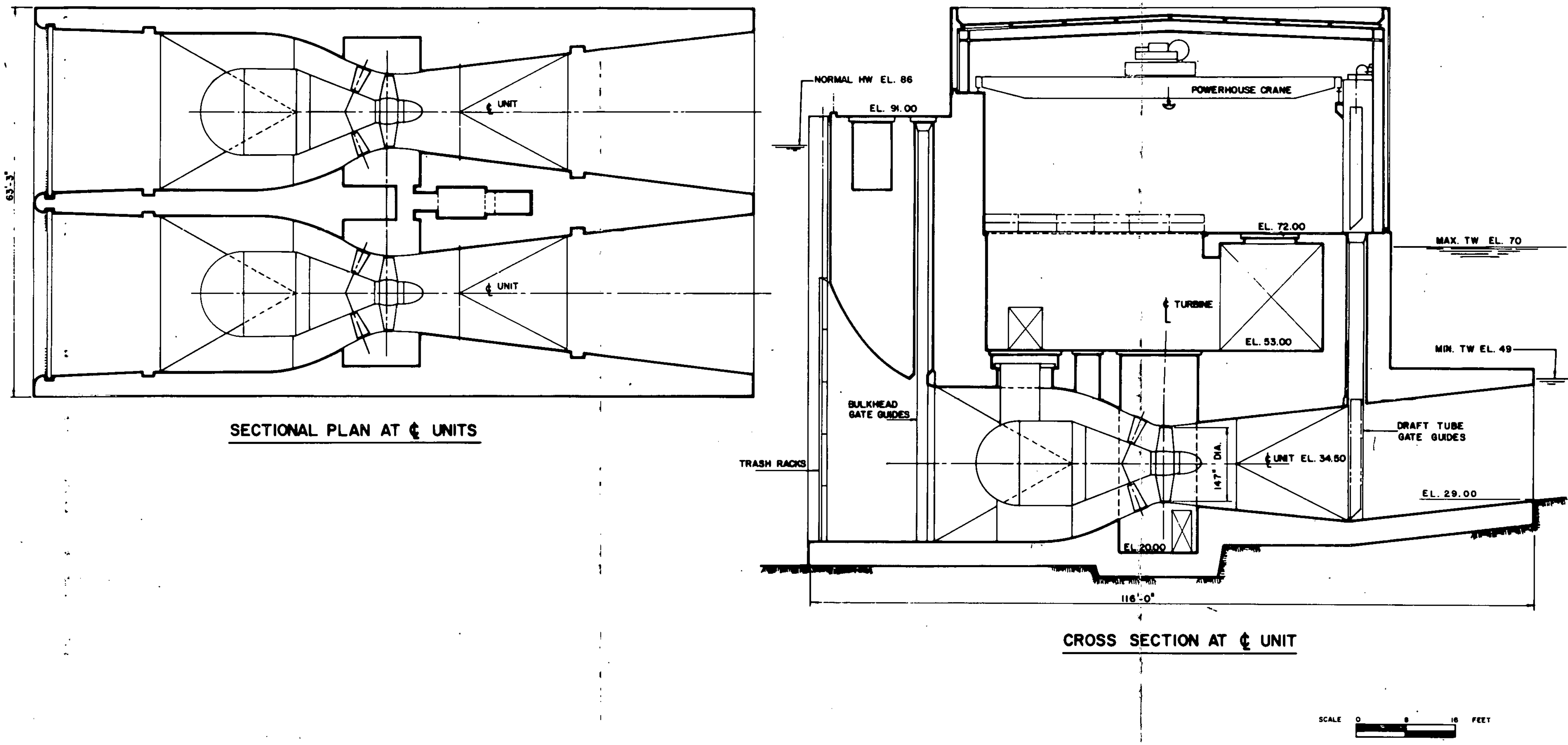
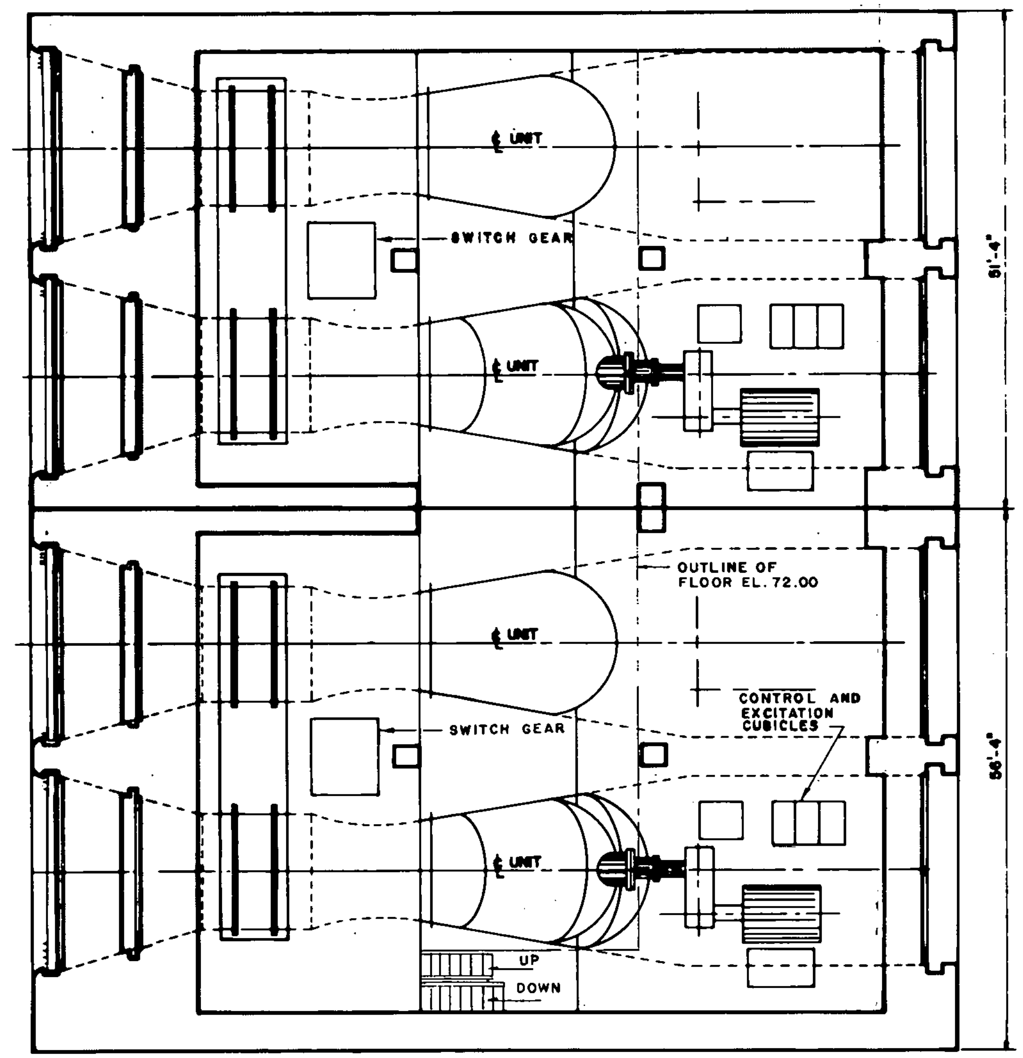
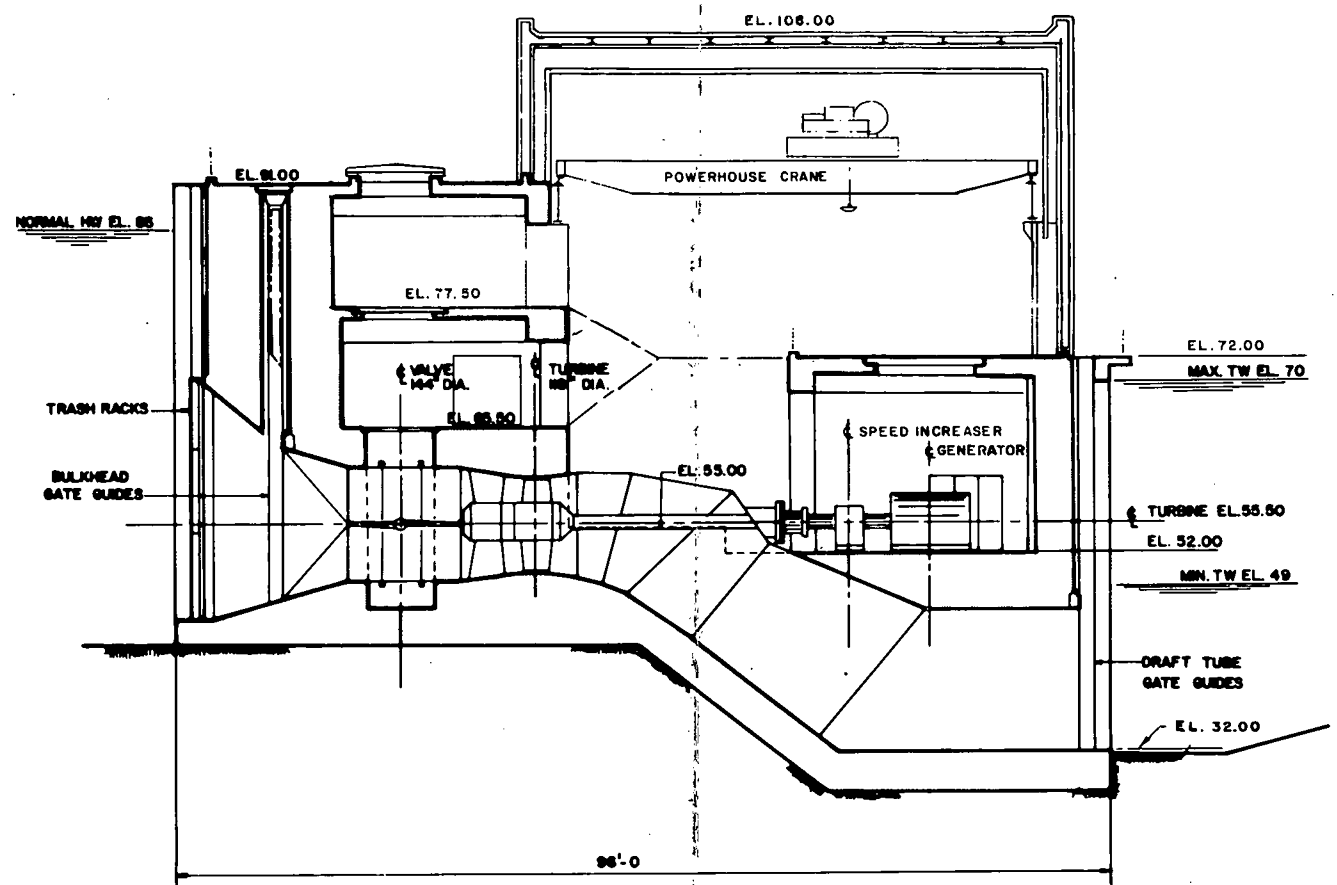


Figure 3-11. 2-7.5 MW Units Bulb Turbine



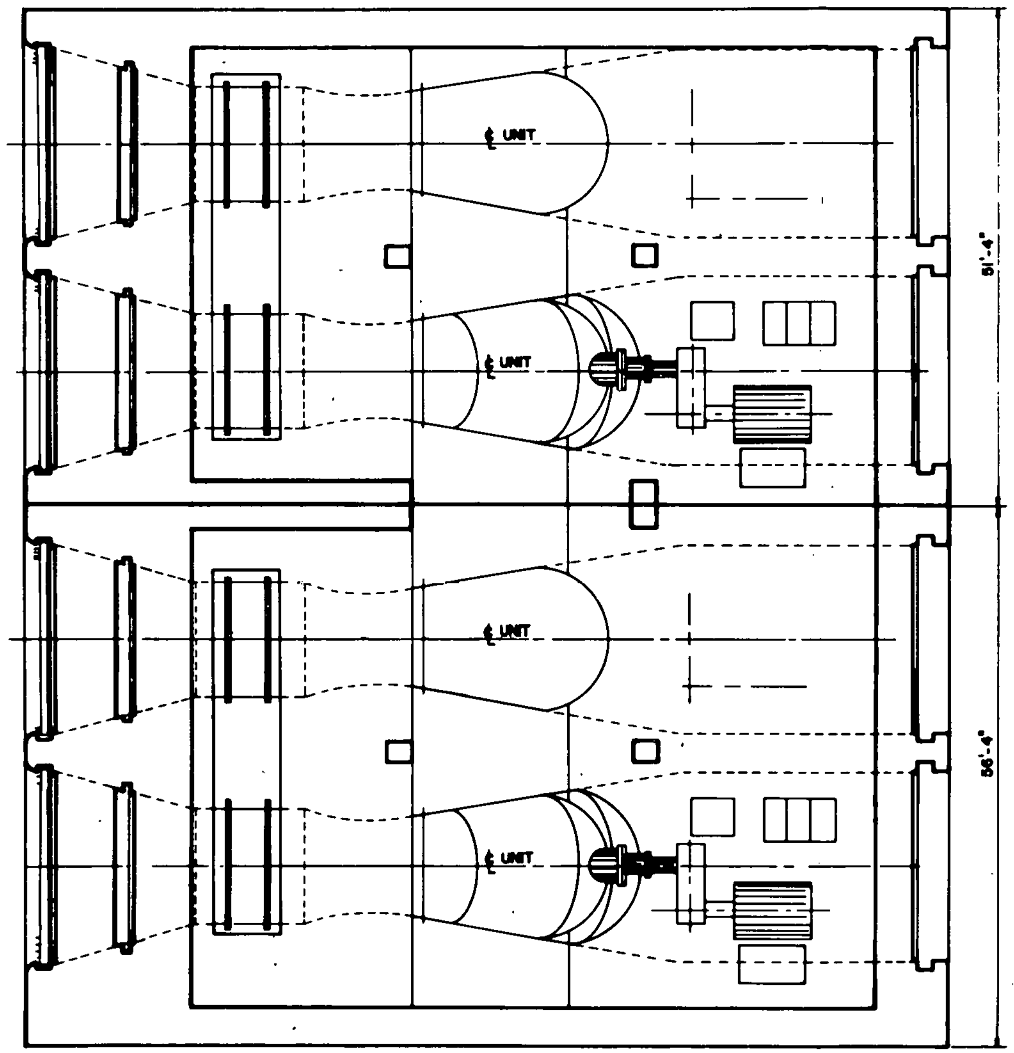
SECTIONAL PLAN ABOVE TURBINE FLOOR



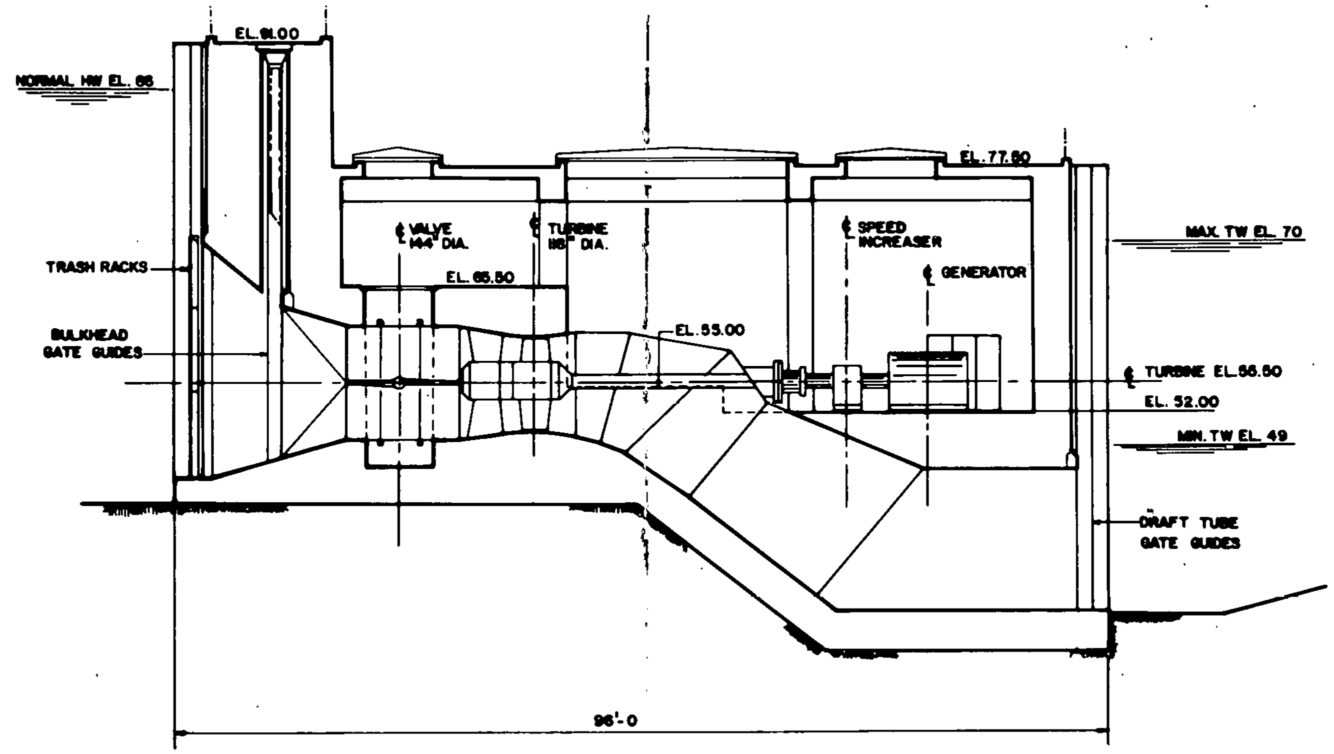
CROSS SECTON AT ℄ UNIT

SCALE 0 5 10 FEET

Figure 3-12. 4-3.75 MW Units Tube Turbine With Superstructure



SECTIONAL PLAN ABOVE TURBINE FLOOR



CROSS SECTON AT ℄ UNIT

SCALE 0 10 FEET

Figure 3-13 4-3.75 MW Units Tube Turbine Without Superstructure

3.6.3 Electrical Equipment

Electrical equipment and station protection equipment are shown in Figure 3-14. The design provides completely automatic station operation with load control on a time clock and a float to measure water level at the dam.

This equipment controls two or four synchronous generators connected via 4.16 kV circuit breakers to a common bus. One station transformer would be connected directly to this bus and deliver power to the system. Protective relaying would comprise one overall differential relaying scheme (with harmonic and percent bias) enclosing within its protected zone the generators, 4.16 kV switchgear and the transformer.

With the exception of the station transformer and the line circuit breaker, all electrical equipment is housed inside the powerhouse structure. The transformer would be placed in a removable enclosure and would not normally be visible. Power would be fed to the NEPCO system via cables in ducts in the new intake channel retaining wall to Moody Street Bridge, where existing ducts can be used to carry the line across the river. Finally, power will move by overhead line to the Pawtucketville Substation approximately one mile northeast of the site. The station transformer will have the normal protective devices, such as lightning surge, gas and winding temperature detectors. Supplies for station metering will be derived from 4.16 kV potential transformers connected to the station bus and current transformers installed in the low voltage connections to the main transformer.

This equipment concept makes it possible to evaluate concepts involving more than one generator by treating the station, electrically, as if there is always only one generator. Economies are thus realized, although when an (infrequent) major electrical fault occurs within the station, the complete station would shut down. When the fault involves one generator unit, it can be isolated and the remaining machines returned to service manually. Each machine, however, has protection against over-current, over-voltage, and unbalanced current. There is also protection against mechanical failure in accordance with the manufacturer's recommendation (e.g. bearing temperature, etc.)

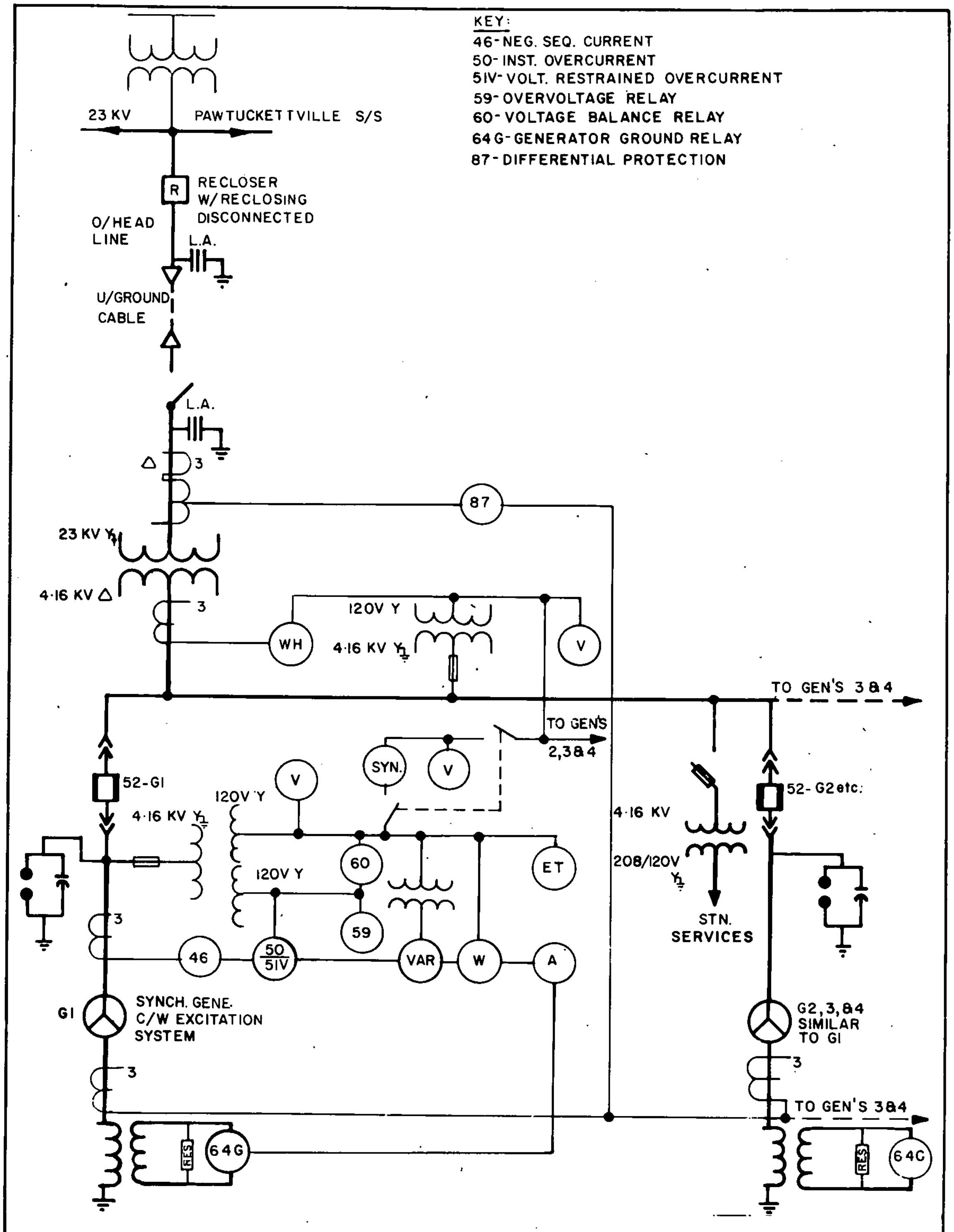


Figure 3-14. Lowell Hydroelectric Project Single Line Diagram

3.6.4 Connection to Existing Distribution System

There are two possible ways to connect the output of the power station to the existing electrical distribution system. The first is a 23 kV connection to the existing New England Power Company (NEPCO) Pawtucketville Substation on Old Meadow Road; the alternative is to connect directly to the four substations from which Boott Mills currently imports and exports power. As suggested by NEPCO, the 23 kV cable would proceed through about 47.0 yards of ducts in the canal wall and under the bridge along Textile Ave., before emerging at the junction of Textile Avenue and Riverside Street. There the cable would connect to overhead transmission lines on existing wooden poles and continue northwest on Textile Avenue to Old Meadow Road. It would then proceed southwest on Old Meadow Road to the Pawtucketville Substation. The length of overhead line would be approximately 1,400 yards, making the total feeder length a little over one mile.

A very preliminary estimate of the cost of this alternative by NEPCO, based on incomplete electrical data, resulted in a figure of $300,000 including installation. An independent estimate by Acres puts this figure at $130,000. The higher figure is incorporated in the estimate of total project costs in all cases except the tables in Appendix C.

The second alternative is to lay submarine cables in the existing canals to the location of the four Boott Mills bulk-supply points. Two of the proposed connection points lie adjacent to canals, and the others would require the excavation of approximately 250 feet of land owned by Boott Mills. The approach would require a total of approximately 30,000 feet of three conductor 23 kV cable. Since this approach is potentially more expensive, it was not considered further.

4.0 ESTIMATED CONSTRUCTION COST AND PROJECTED CONSTRUCTION SCHEDULE

4.1 COST

Table 4-1 shows that the estimated costs of the alternatives considered are between \$14,720,000 and \$19,250,000. (No allowance has been made in these estimates for fish pass facilities, which are estimated to cost an additional \$1,000,000.) As noted at the beginning of Section 3, detailed cost estimates were developed for both the two 7.5 mW vertical fixed blade propeller approach and a four 3.75 mW tube turbine design. The approach using vertical propeller turbines was initially chosen but after the detailed estimating process was well underway, quotations for the tube turbines were received which proved to have a significant cost advantage over the vertical propeller design. Detailed cost comparison data is given in Appendix C for both tube and propeller turbine installations. The tube turbine approach, because of its lower total cost, was used in the economic feasibility analysis presented in Section 2 above.

Cost Estimates. Construction costs are based on cost levels applicable to the type of work involved and on local labor conditions in the Lowell (and Boston metropolitan) area, effective through the third quarter of 1978. Costs for the heavy civil construction activities were estimated to allow for the urban location and associated restrictions pertaining to noise, dust, and space.

The turbines and generators account for about 52 percent of total costs and were obtained from manufacturer quotes. The civil works costs account for about 30 percent additional. The remainder of the costs (28 percent) are less site specific, and were estimated from manufacturer price data and published data on installation labor productivity.

Source information included: U.S. Department of Labor labor statistics; R.S. Means Co., Inc., 1978 Building Construction Cost Data; McGraw Hill Information Systems Co., Dodge Guide for Estimating Public Works Construction Costs; and "Engineering News Record" (1978-Third Quarterly Cost Roundup).

An account for contingencies of 15 percent is included. Engineering and administration costs, estimated at 20 percent, include contractor fees and all costs associated with project management: acquiring permits and licenses, engineering, detailed design, procurement, site construction management and commissioning the station.

TABLE 4-1

LOWELL HYDROELECTRIC PROJECT
COMPARATIVE PROJECT COSTS (THOUSANDS $)

	ALTERNATIVES					
ACCOUNT ITEM	1 BULB	1 VERTICAL	2 BULB	2 VERTICAL	2 STRAFLO	4 TUBE
330 Land and Land Rights	--	--	--	--	--	--
331 Structures & Improvements	1,920	1,860	1,550	2,180	1,430	1,600
332 Reservoirs, Dams & Waterways	3,260	3,010	3,230	3,020	3,210	2,460
333 Turbines & Generators	6,600	8,100	6,600	6,000	6,200	5,400
335 Misc. Powerplant Equipment	300	300	330	340	340	310
336 Access Road	30	30	30	30	30	30
334, 352, 353 Electrical Facilities	300	300	380	380	380	520
356, 358 Transmission (3)	300	300	300	300	300	300
Sub-Total	12,710	13,900	12,420	12,250	11,890	10,620
Contingencies (15%)	1,910	2,080	1,860	1,840	1,780	1,590
Engineering & Administration (20%)	2,920	3,200	2,860	2,820	2,730	2,440
Total Project Capital Cost	$17,540	$19,180	$17,140	$16,910	$16,400	$14,650
Expense Item Costs (1)	70	70	70	70	70	70
Total Project Costs (2)	$17,610	$19,250	$17,210	$16,980	$16,470	$14,720

(1) Includes demolition and canal repairs.
(2) These costs do not include any estimate for fish passages facilities.
(3) See text discussion in Section 3.

Equipment Costs. The following U.S. and foreign manufacturers were contacted for preliminary costs and data on hydroelectric generating equipment consisting of turbines and generators:

Sulzer Brothers Incorporated

Neyrpic

Allis-Chalmers

Bofors-Nohab

Dominion Engineering Works

Their responses are summarized in Table 4-2.

Single unit installations were not considered after cost data had been received because there were no cost savings over other alternatives and the multiple unit configurations offered advantages in terms of system availability.

The four unit standard tube turbine equipment cost from Allis-Chalmers, at $5,400,000 installed, has the lowest equipment cost of all the designs. This is presumed to be attributable to the standardization of design and manufacture, along with the use of speed increasers and 900 rpm standard synchronous generators. The cost per installed kW of capacity is also lowest for this unit, even though its output is a full 2 percent lower than the annual energy produced by two fixed blade units operating under the same conditions.

Table 4-3 presents the construction cash flow schedule by quarter for a 196 week period. It was calculated assuming a 7.5 percent annual cost of money and end of period payment. (In Section 2 calculations made assuming a 10.5 percent cost of money; interest during construction was adjusted accordingly.) The cost is based on prices current as of the end of September 1978 without allowance for escalation. Escalation costs, however, were incorporated into the detailed economic feasibility analysis given in Section 2. Data is presented only for the tube turbine alternative.

TABLE 4-2. GENERATING EQUIPMENT DATA

Type of Equipment	2 - Vertical Fixed Blade Propeller		2 - Horizontal Bulb		4 - Horizontal Standard Tube	2 - Standard Horizontal Straflow	1 - Vertical Kaplan		1 - Horizontal Bulb with Kaplan Runner	
Manufacturer	Allis-Chalmers	Dominion Eng. Works	Allis-Chalmers	Sulzer Bros.	Allis-Chalmers	Sulzer Bros.	Allis-Chalmers	Dominion Eng. Works	Allis-Chalmers	Sulzer Bros.
OPERATING CHARACTERISTICS										
Best Efficiency	93.1%	92.0%	92.8%	--	--	--	93.6	93.0	93.0	--
Fullgate Efficiency	90.5%	90.9%	92.3%	--	87%	--	91.0	89.3	92.3	--
Synchronous Speed	163.6 rpm	128.6 rpm	180 rpm	156.8 rpm	136 rpm	156.5 rpm	112.5 rpm	90 rpm	128.6 rpm	116.1 rpm
Runner Dia.	130"	147"	125.4"	140"	118.1"	140"	185"	210"	181.6"	197"
Runner Setting	El.33	El.55	El.30	El.34.5**	El.55	El.34.5**	El.33.0	El.51	El.28.3	--
Generator Rating	7,400 kW	7,400 kW	7,400 kW	7,400 kW	4,000 kW	7,400 kW	14,800	14,800	14,800	14,800
Generator Speed	163.6 rpm	128.6 rpm	180 rpm	156.8 rpm	900 rpm	156.5 rpm	112.5 rpm	90 rpm	128.6 rpm	116.1 rpm
COSTS										
Generator Cost	1,575,000	2,300,000*	1,340,000	--	--	--	1,550,000	3,400,000	1,200,000	--
Turbine Cost	4,200,000	2,500,000	3,800,000	--	--	--	5,450,000	3,100,000	3,000,000	--
Subtotal	5,775,000	4,800,000	5,140,000	--	4,740,000	--	7,000,000	6,500,000	4,200,000	--
Options					31,000		--	--	--	--
Installation	1,300,000	1,200,000	1,465,000		640,000		1,575,000	1,625,000	1,197,000	--
Total	7,075,000	6,000,000	6,605,000	7,200,000	5,411,000	6,200,000	8,575,000	8,125,000	5,397,000	7,800,000
Delivery										
Imbedded parts	18-24 months	14-16 months	18-24 months				18-24 months	14-16 months	18-24 months	
Complete	30-36 months	22-24 months	30-36 months		9 months		30-36 months	22-24 months	30-36 months	

*Price estimate for G.E. synchronous generator from Acres, Buffalo.
**Calculated values not from manufacturers.

TABLE 4-3

LOWELL HYDROELECTRIC PROJECT

PROJECT CASH FLOW

Year	Period*	Construction Payments ($1,000)	Cumulative Construction Payments	Interest** During Construct. ($1,000)	Cumulative Interest
1	1	150	150	0	0
	2	150	300	2.8	2.8
	3	150	450	5.7	8.5
	4	150	600	8.6	17.1
2	5	250	850	11.6	28.7
	6	350	1,200	16.5	45.2
	7	550	1,750	23.3	68.5
	8	750	2,500	34.1	102.6
3	9	1,120	3,620	48.8	151.4
	10	1,808	5,428	70.7	222.1
	11	2,388	7,816	105.9	328.0
	12	2,073	9,889	152.7	480.7
4	13	1,436	11,325	194.4	675.1
	14	1,660	12,985	225.1	900.2
	15	675	13,660	260.3	1,160.5
	16***	830	14,490	21.4	1,181.9

*Periods are in quarters, i.e., 13 weeks

**Interest during construction at 7.5 percent annual interest, end of period payments, accumulating through in-service date.

***Commercial Service Date - Week 196 or first week of Period 16.

4.2 PROJECTED CONSTRUCTION SCHEDULE

The project schedule is given in two parts. Figure 4-1 shows the Engineering Schedule and Figure 4-2 gives the Construction Schedule.

Engineering Schedule. The length of the engineering schedule is determined by the time that has been estimated as needed to obtain a FERC license. Early receipt is shown 70 weeks from the time of filing the application and late receipt is given at 85 weeks from the filing date. To this must be added the time necessary to prepare application documents, 15 weeks, making a total time for licensing of 85 to 100 weeks. Additional engineering activities, including contracting and various procurements, extend the total engineering period to 120 weeks.

Construction Schedule. The construction schedule assumes that construction will start in the spring when weather conditions and river flow will favor the project activities for the next eight to ten months. This will preclude problems including abandonment of cofferdam facilities, winter concrete operation, overtime and extra shift operations, and many other possibilities for which contingency planning is nevertheless required.

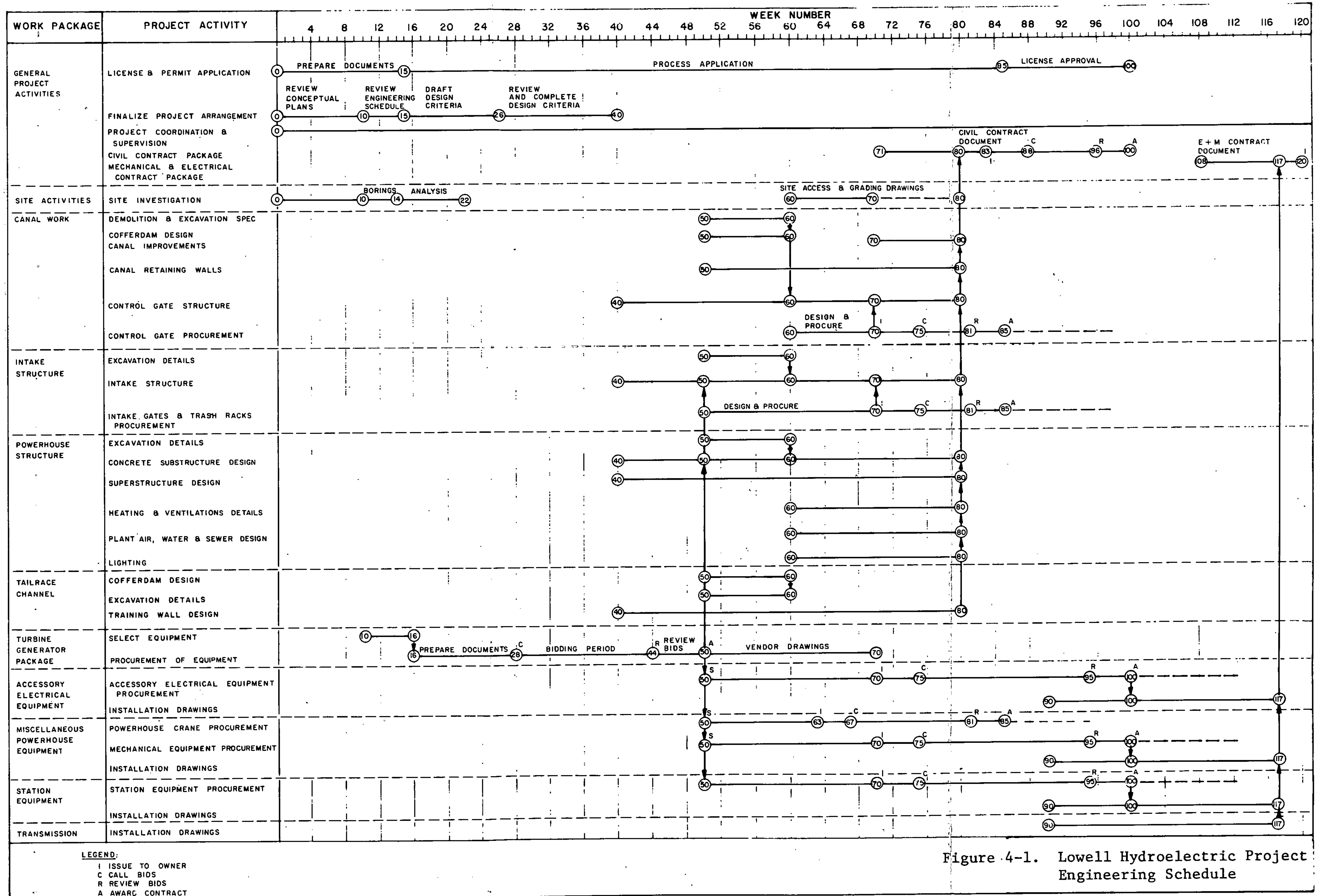
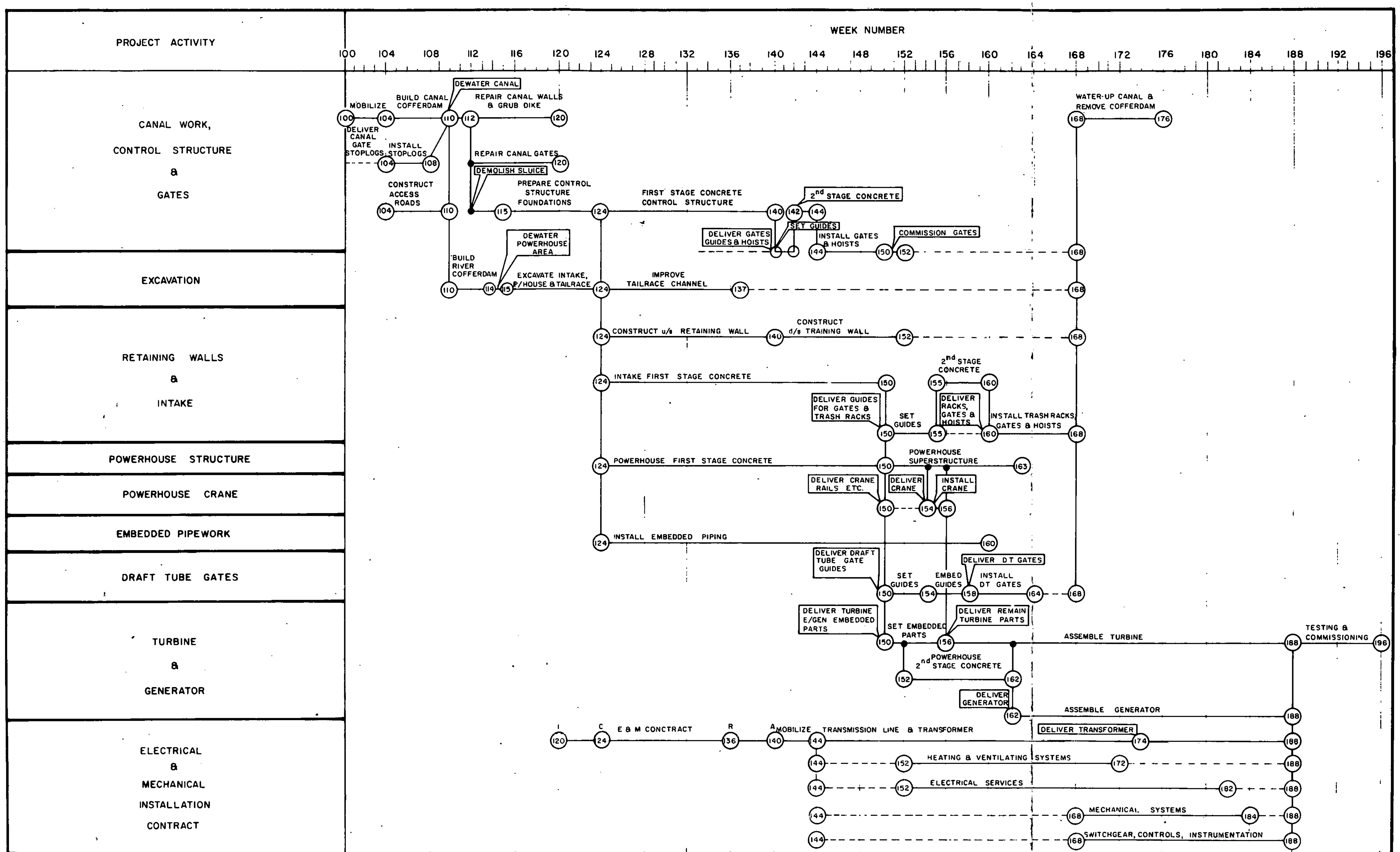


Figure 4-1. Lowell Hydroelectric Project Engineering Schedule



LEGEND
I ISSUE TO OWNER
C CALL BIDS
R REVIEW BIDS
A AWARD CONTRACT

Figure 4-2. Lowell Hydroelectric Project Construction Schedule

5. ENVIRONMENTAL AND SAFETY ASSESSMENTS AND REGULATORY REQUIREMENTS

5.1 ENVIRONMENTAL SUMMARY

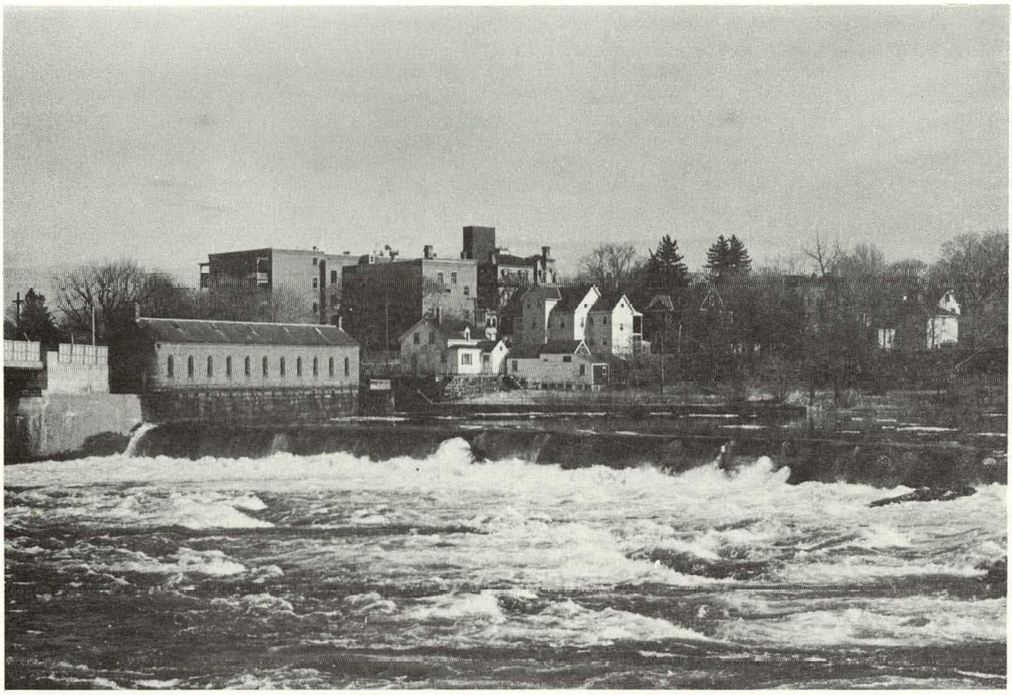
Environmental quality would be maintained and possibly enhanced through the construction of the Lowell Hydroelectric Project. The proposed project can comply with all regulatory requirements, based upon conclusions drawn as the result of this feasibility analysis.

The principal regulatory issues are the provision for a fishway, minimum flow requirements for the river, and the removal and disposition of the Northern Canal Wastegates. In addition, and of overriding importance, it will be necessary to maintain a currently attractive river view, to meet all state and National Park requirements, and to carry out the project so that tourist canal barges proposed by the National Park Service will be able to completely circumnavigate the existing canal system. Further, the project must protect the ability of the Lowell Museum - a related, privately funded, cultural development - to have a working exhibit of hydroelectric power generation using vintage equipment.

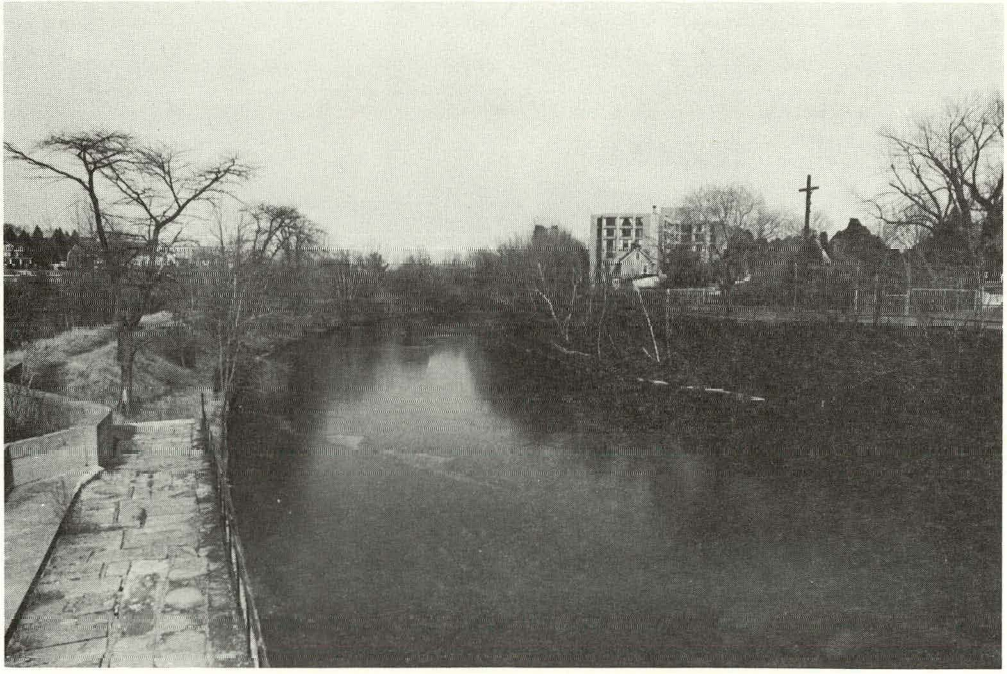
5.2 EXISTING SITE CONDITIONS

Site information and data was compiled through site inspections, interviews with representatives of licensing and planning agencies, and through extensive contacts with knowledgeable persons and organizations in Lowell.

The dam, canal and project site are shown in Photographs 5-1 through 5-4. Photograph 5-1 shows approximately one-third of the Pawtucket dam and the gatehouse controlling the flow of water into the Northern Canal. Photograph 5-2 is taken at a spot just after the water has come through the gatehouse and under School Street. One can see the Northern Canal looking downstream in the direction of the project site. In Photograph 5-3 the photographer is standing just downstream from the powerhouse site and on the same (south) side of the river. The view is

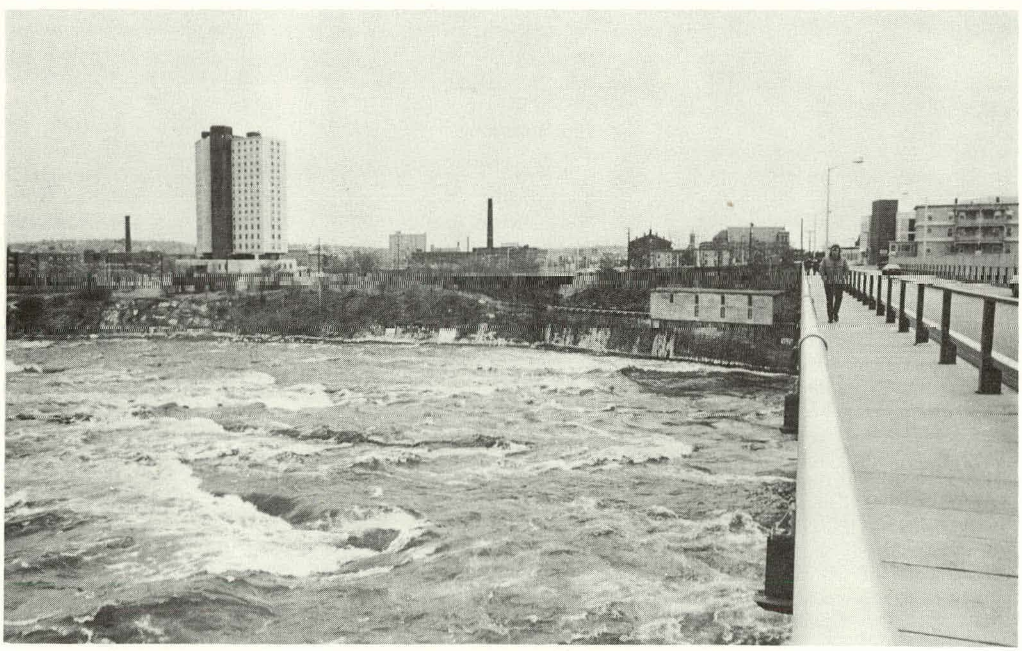


Photograph 5-1. Pawtucket Dam and Gatehouse



Photograph 5-2. Northern Canal Near the Gatehouse

Photograph 5-3. Hydroelectric Site, Moody Street Bridge and Great Wall



Photograph 5-4. Hydroelectric Site and Lowell University Student Union Building

upstream, directly facing the power house site. The intake structure connected to the powerhouse will lead off from the canal at the point where the old frame building (the control structure for the Northern Canal Wastegates) sits on the canal wall. The Moody Street Bridge and the Great Wall of the canal also show. Photograph 5-4 shows the project site from the far end of Moody Street Bridge. The tailrace and tailrace training wall will stretch from the powerhouse downstream along the bank of the river. Figure 5-1 shows the locations from which each photograph was taken.

Photographs 5-5 through 5-8 show a sequence of views of the project site moving in a circle around it. Photographs 5-5 and 5-6 are taken from the same side of the river and look down across both the canal and the project site towards the far side of the river. In Photograph 5-5, the view is looking upstream and shows the Moody Street Bridge and a classroom building of Lowell University. In Photograph 5-6, the view is downstream. The tailrace will go the length of the rapids which show here, on the right-hand side. Photograph 5-7 is taken from the near end of Moody Street Bridge and looks almost directly down on the site. Photograph 5-8 is taken from the far side of the river looking upstream across the rapids to the site. The view as indicated in Photographs 5-5 through 5-7 would be seen often by pedestrians. The view as in Photograph 5-8 would not be seen frequently, but it is shown to indicate the buildings behind the site, which would be seen behind the project when viewed from the classroom building.

There is a sharp slope of the land downward from Pawtucket Street to the Merrimack River, and this will provide the most comprehensive view of the project (Photographs 5-5 and 5-6). The new control structure at the location of the Northern Canal Wastegates would be most prominent in the foreground view from the south. The low profile power house in the river bed channel, the tailrace and the training wall at the tailrace would also be visible.

Several manmade landmarks are visible from various points in the area. The remaining and largely unaffected dominant landmarks are the structure of the Moody Street Bridge, the University of Lowell dormitories and the high rise tower of the student center. Subordinate landmarks are the structure of the canal and the Northern Canal Wastegates structure and catwalk. The wastegates structure and catwalk will be removed and the projected hydroelectric facility should harmonize well with the other buildings.

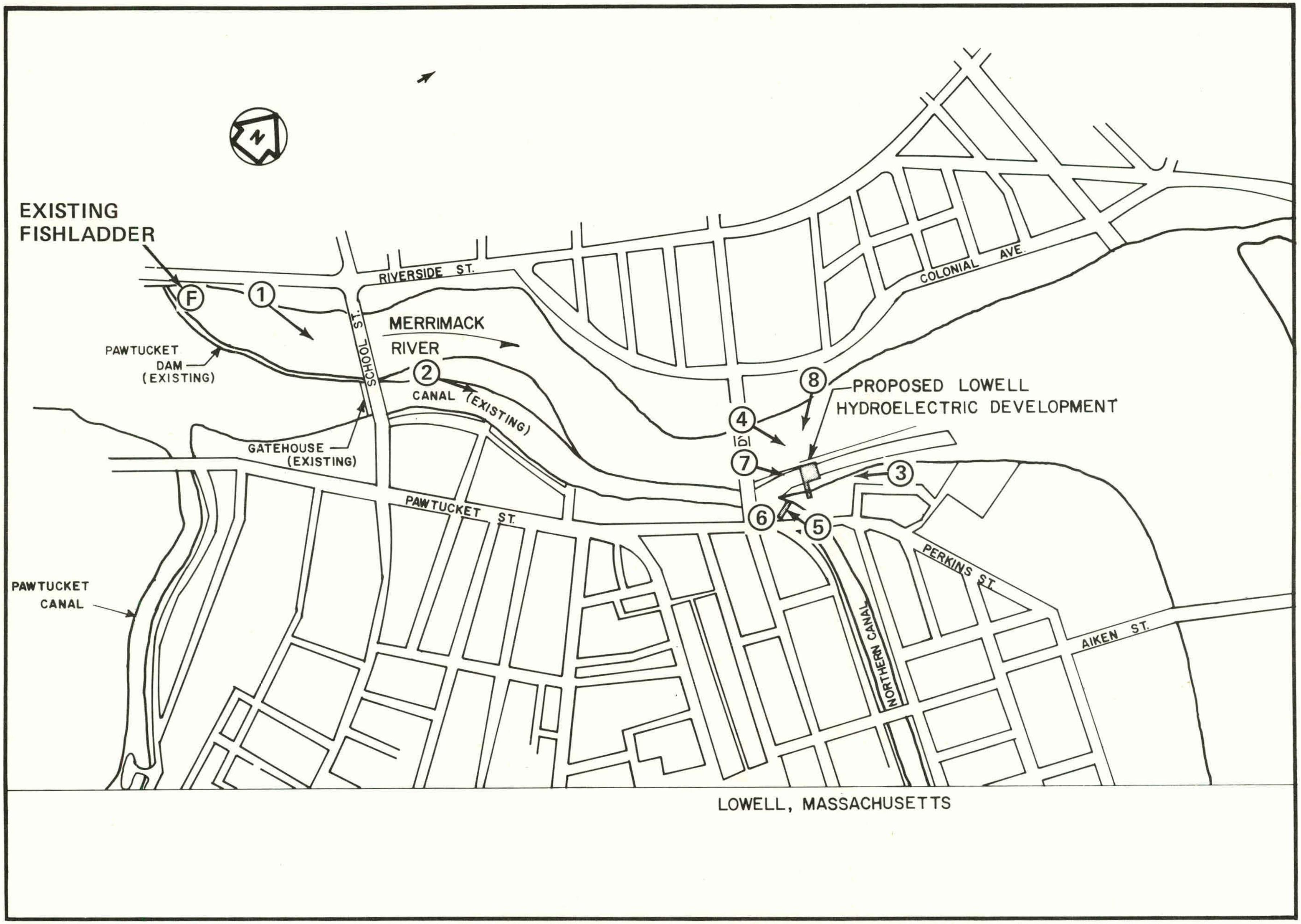
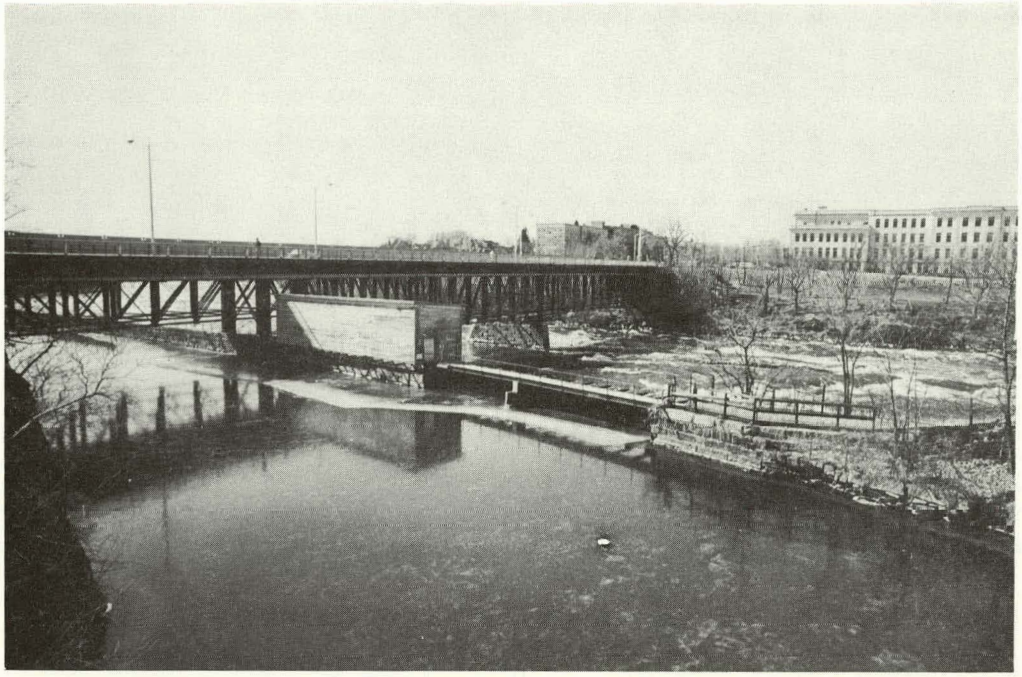
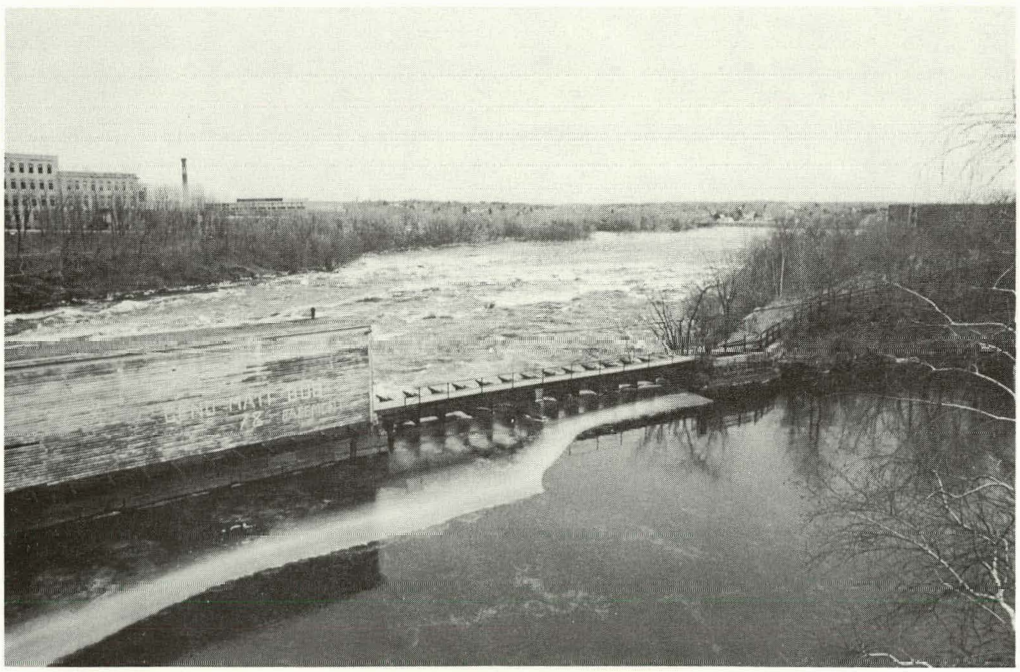


Figure 5-1. Key To Photographs

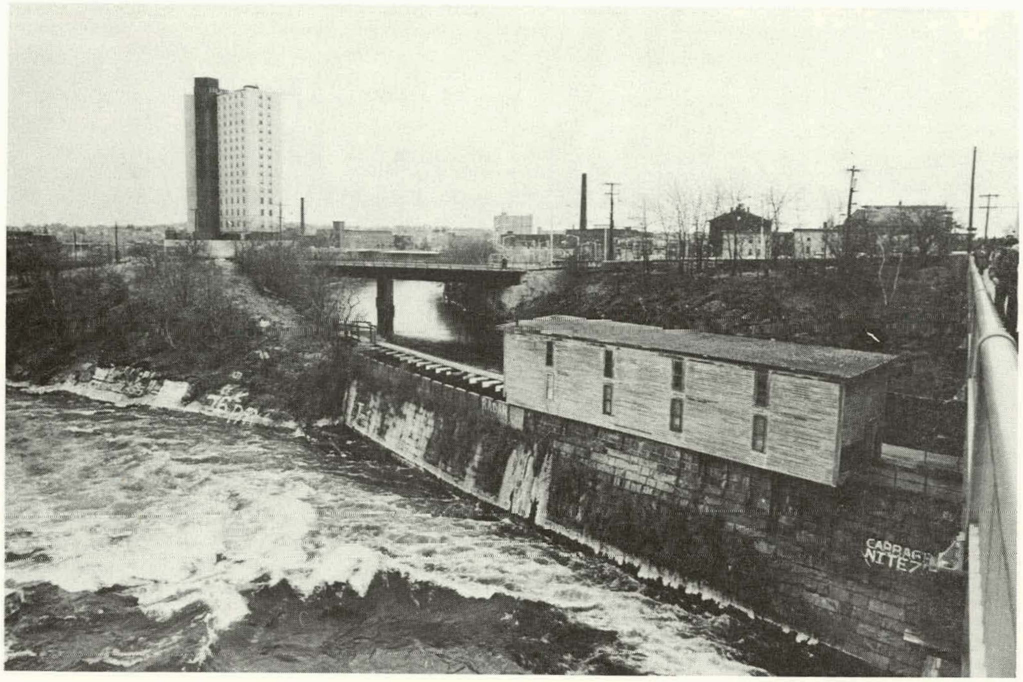
RAYTHEON
RAYTHEON SERVICE COMPANY



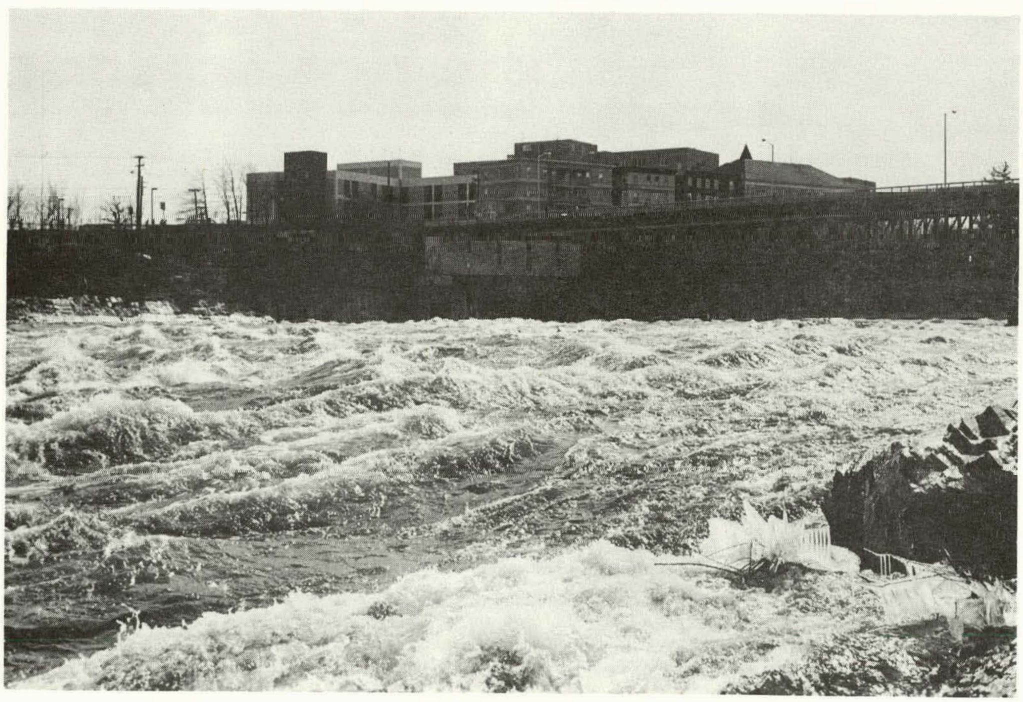
Photograph 5-5. Northern Canal, Site, and Rapids, Looking Upstream



Photograph 5-6. Northern Canal, Site, and Rapids, Looking Downstream



Photograph 5-7. Hydroelectric Site Viewed From Moody Street Bridge



Photograph 5-8. Hydroelectric Site Viewed From Across the River

Lowell National Historical Park. The site for the projected hydroelectric facility is within the Lowell National Historical Park, which was established 5 June 1978 under Public Law 95-290. The hydroelectric generating site is on the Northern Canal, shown on the map of Figure 5-1. The Northern Canal is an important feature of the Park in the report of the Lowell Historic Canal District Commission.[1] Situated at the site of the intake for the projected hydropower facility is the Northern Canal wastegates structure. This is a two story frame structure, finished with gray clapboards, as shown in Photographs 5-5 through 5-8. Housed within the structure is the machinery for operating wastegates. The four wastegates were built in 1848. Their only current use is to assist in emptying the canal, which is done from time to time for inspection and maintenance. Construction of the hydroelectric project will require removal of the wastegates and wastegate structure. The structure and the wastegate mechanisms are of historic interest, and appropriate arrangements would be made for their preservation and relocation.

The Merrimack River. The Merrimack River is New England's second largest river. The Merrimack River basin extends from the White Mountains of northern New Hampshire, southward into east-central Massachusetts. It is the fourth largest river basin in New England, with a maximum length of 134 miles and a maximum width of 68 miles. The basin has an area of 5,010 square miles. 76 percent of the area lies in New Hampshire and 24 percent in Massachusetts.

The Merrimack River proper is formed by two tributaries, the Pemigewasset and Winnepesaukee Rivers, meeting in Franklin, NH. The river has a total length of 116 miles, of which the lower 22 are tidal. The total length of the Merrimack and the Pemigewasset River, the principal tributary, is approximately 180 miles.

[1] Lowell Historic Canal District Commission, Report of the Lowell Historic Canal District Commission to the Ninety Fifth Congress of the United States of America, U.S. Government Printing Office Washington, D.C., January, 1977, p. 31.

Total elevation drop of the river, from its headwaters to the ocean, is 2,700 feet, an overall average of 15.0 feet per mile. The elevation drop in the Pemigewasset River, from its source to its confluence with the Winnepesaukee River at Franklin, is 2,450 feet. This contrasts to the Merrimack River, which falls only 245 feet or an average of 2.6 feet per mile, from Franklin to the ocean.

At the Pawtucket Falls in Lowell, there is a drop of about twenty feet over small natural falls and rapids extending over a distance of approximately three-fourths of a mile. In 1792, a company was chartered to construct a canal and locks for use by river boats to bypass the falls. Later, the canal system was enlarged and the Pawtucket Dam built at the top of the natural falls. Total length of the canals is roughly 5 miles, with several gates and locks to control flow. The hydroelectric project discussed here would involve the use of only about three-quarters of a mile of the Northern Canal, to a point where it no longer runs parallel to the Merrimack River.

The Pawtucket Dam is located just west of the main part of the city. The pool formed by the dam is one of the region's largest, extending approximately 18 miles to the vicinity of Cromwell's Falls, between Nashua and Manchester, NH. The impoundment from the Essex Dam, 9.5 miles downstream from Lowell in Lawrence, reaches to the mills at Lowell.

The Merrimack River basin has a history of flooding, with most major floods caused by a combination of heavy rain and melting snow in the months of March, April and May. The basin's flood of record occurred in March, 1936. Four flood control reservoirs, all in the New Hampshire portion of the basin, have been completed since that date. These are Franklin Falls Dam, partially controlling the Pemigewasset River, Edward MacDowell and Blackwater Dams, on tributaries to the Contoocook River, and Hopkinton-Everett Lakes, controlling the Contoocook and Piscataquog Rivers. A new hydroelectric facility at Lowell would have no impact upon flood control systems either locally or on the river basin.

Existing Use of the River. The Merrimack is a highly regulated river. Besides being a source for municipal water supplies and for discharging municipal and storm wastes, the river is used extensively in hydroelectric power generation. There are over 100 water power developments in the Merrimack River Basin. On the main stem, below Franklin, NH, 18 plants utilize 161 feet of the total river fall and account for nearly half of the total hydroelectric power supplied within the basin.

The river is also a major recreational resource for New Hampshire and Massachusetts. The river itself is used extensively for boating. As water quality improves, recreational fishing will become more important. Water quality improvement will also permit the resumption of swimming.

Boating is the principal river-based recreational activity. A boat club is located above the Pawtucket Dam. Motor boat races are held each year, drawing entries from many states. Sailboat racing is also held in the pool. Flat water canoeing is conducted along many river sections and on tributaries. One of the tributaries, Beaver Brook, is noted for canoeing. Boat ramps are provided at several locations along the Merrimack.

An additional use of the river is for seaplanes. Small seaplane bases have been established in the pool above the Pawtucket Dam[2], in the Essex Dam pool below Lowell[3], and below the Essex Dam[4].

According to studies of future recreational needs by the Department of Interior, use of the river is expected to double by 1980 from the 1960 level, and to double again by the year 2000.

Besides the activities directly involved with the river, land adjacent to the river is used for such functions as conservation, parks, and boating-related activity. There is no known concern for any of these uses resulting from the

[2] Larson Seaplane Base, Tyngsboro, MA

[3] Merrimac Valley Seaplane Base, Methuen, MA

[4] Haverhill-Riverside Seaplane, Haverhill, MA

[5] Bureau of Outdoor Recreation and the Bureau of Sports Fisheries and Wildlife, the North Atlantic Regional Water Resources comprehensive framework study.

installation of a new hydroelectric facility at Lowell because current water levels and regulatory policies will not be affected.

Water Quality. In 1974, over 125 million gallons of wastes were discharged each day into the Merrimack River and its tributaries[6]. In the city of Lowell, storm run-off and raw sewage, according to the state Water Pollution Control Division, is released into the canals and river at many locations[7].

At the Pawtucket Dam above Lowell, the Merrimack River meets all state water quality specifications for a Class B rating[8], except for coliform. After passing through the city of Lowell, the river is very polluted, a condition which will exist until the Lowell regional sewage treatment plant, to be located below the junction of the Merrimack and Concord Rivers, goes on-line. This plant is scheduled for operation in 1982.

Vegetation, Fish and Wildlife. The proposed hydroelectric power plant is environmentally related to a 20-25 mile section of the Merrimack River. This may be broken into several subsections: (1) the pool impounded by the Pawtucket Dam, reaching some 18 miles upstream and into New Hampshire, (2) the Pawtucket Falls, from the dam to the bottom of the rapids, which is the location of the tail race outflow of the proposed facility and is approximately three-fourths of a mile in length, (3) the stretch of river running through the mill section of Lowell to the pool formed by the Essex Dam in Lowell, 1-2 miles in length, depending upon the state of the pool, and (4) the upper reach of the Essex Dam pool as affected by the outflow of the proposed facility.

[6] "Merrimack Wastewater Management", Appendix 1, page 9; the New England Division of the Army Corps of Engineers and the New England Institute Water Pollution Control Commission, November, 1974.

[7] Telephone call to the State Division of Water Pollution Control, February 3, 1979.

[8] Commonwealth of Massachusetts fresh water designation: Class B Suitable for recreation including swimming and water contact sports, and for agriculture and certain industrial and cooling process uses; acceptable for public water supply with appropriate treatment, and for an excellent fish and wildlife habitat and aesthetic value.

The Pawtucket Dam pool is predominately lined with trees and is bordered by private residences, highways, and open land. The area surrounding the rapids is mostly open and institutional land. The river from the rapids to the Essex Dam impoundment is lined with mills on the south side and trees and residences on the north side.

The area surrounding the river from above the dam to the Essex Dam pool is urban, with little natural habitat for wildlife.

The Merrimack River, south of Manchester, NH is classified as a warm water aquatic community. Predominant fish include chain pickerel, pumpkin seed and yellow perch. Additionally, white perch, small and largemouth bass, and brown bullheads are found in this region.

The Merrimack River is also classified according to its distribution of benthic organisms[9]. Portions of the Merrimack River have been classified as either having a bottom fauna consisting of organisms highly tolerant to pollution, or having a bottom fauna intermediately tolerant to pollution. No reaches of the Merrimack that have been studied contain predominantly benthic organisms sensitive to pollution. On the main stem of the Merrimack River, highly tolerant organisms predominate in a short reach below Franklin, NH, from north of Concord to Hooksett, NH, and in the entire reach of the river from Manchester, NH, through Lowell, to below Haverhill, MA.

A major activity associated with the ecological improvement of the Merrimack River is the restoration of anadromous fish[10]. This program is coordinated by the Technical Committee for Fisheries Management of the Merrimack River Basin, which is composed of fish and wildlife department personnel of Federal and State agencies. This program is actively underway, with the release of young salmon and shad into various locations of the upper river and the tracking of transmitter-equipped adult salmon to determine down-stream survival. As water quality improves and improved conveyance facilities become operational at the various dams, this

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[9] Benthic organisms are those found at the bottom of rivers or other bodies of water.

[10] Anadromous fish are, like salmon and shad, those that spend part of their lives in the ocean and then go up river to spawn.

program should re-establish the migrating fish patterns which disappeared in the mid 19th century. This program defines the need for fish passage facilities at the new Lowell hydroelectric site as described in some detail in Section 5.4.1.

5.3 REGULATORY REQUIREMENTS

The most comprehensive licensing procedure involved is that of the Federal Energy Regulatory Commission (FERC). Before FERC will grant a license, it obtains the advice and consent of numerous other Federal agencies. Most of these Federal agencies cooperate with State agencies having similar areas of authority, sometimes as a matter of law and sometimes as a matter of practical convenience. The total pattern of agency interaction is complex, and is summarized in diagram form in the information which follows.

5.3.1 Federal Requirements

The Federal Energy Regulatory Commission (FERC). The Federal Energy Regulatory Commission licenses hydroelectric facilities and is the lead Federal agency in their regulation. This hydro installation will come under FERC jurisdiction.

At 15 mW, the Lowell project will be classified as a major project by FERC. Recent improvements in the licensing process have resulted in FERC estimates that the time required from receipt of an application for a major project to the granting of a license will be between nine and twelve months. (Due to the interrelationship between the Lowell hydroelectric project and the planned National Historical Park, however, between 70 and 85 weeks have been allowed in project schedules for the FERC license.)

The information required from applicants is set out in Title 18 of the Code of Federal Regulations. Engineering, economic and environmental information is required in some detail. From the information provided to it, FERC determines whether an Environmental Impact Statement (EIS) is needed, and if so prepares a draft EIS. Substantial additional information may be required after a FERC review of the original submission.

Before FERC gives approval to a project and issues a license, it must obtain comment from numerous other Federal agencies. The scope of Federal review is shown by a partial list of Federal departments and commissions to which FERC sends copies of the application:

Department of Interior

Department of Agriculture

Department of Commerce

HEW

HUD

EPA

The Nuclear Regulatory Agency

The Corps of Engineers

Federal Regional Planning Councils and River Basin Commissions

An outline of the FERC application process is given in Figure 5-2.

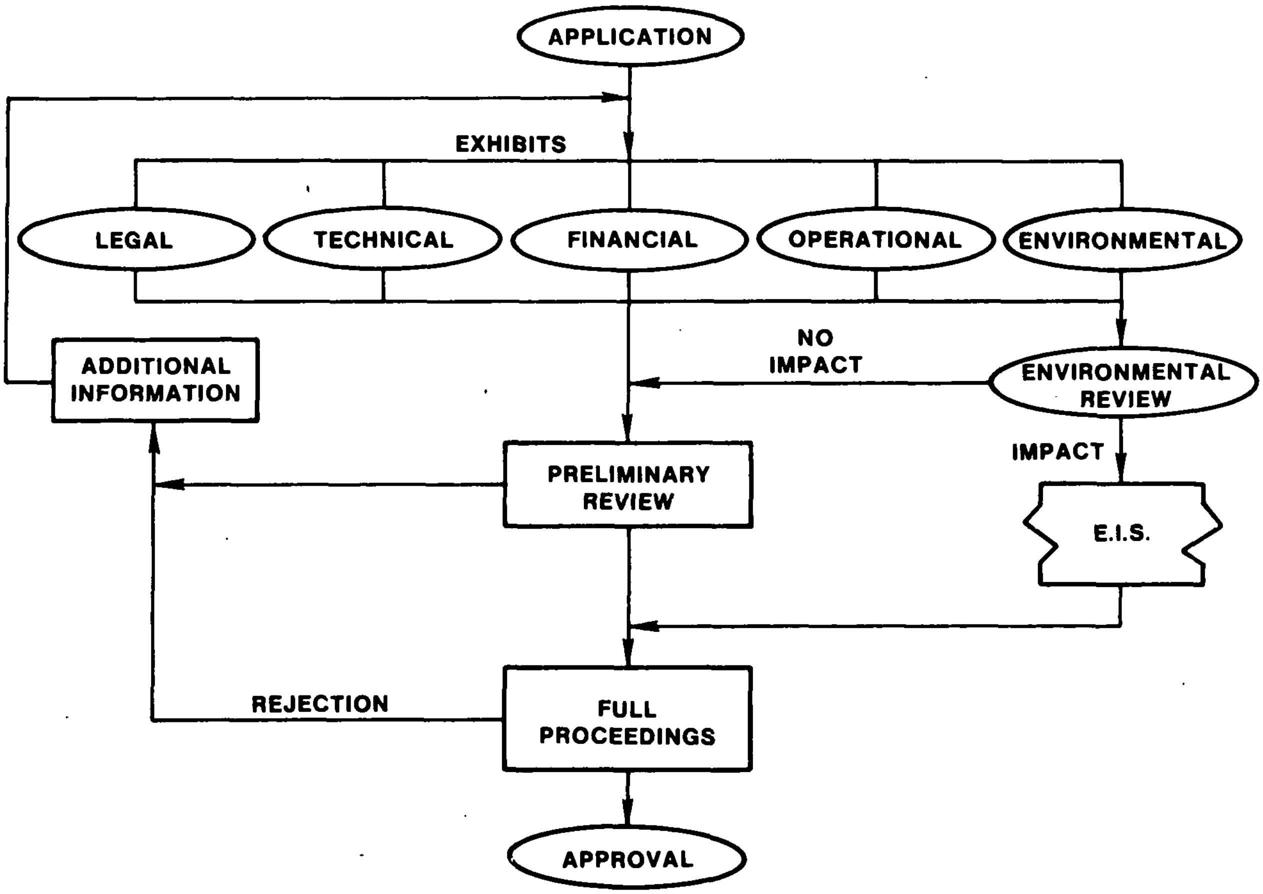

Figure 5-2. Hydroelectric License (FERC)

CEQ/EPA: NEPA and EIS Requirements. The Council on Environmental Quality (CEQ) is responsible for overseeing Federal efforts to comply with the National Environmental Policy Act (NEPA). Under Executive Order 11991, issued on May 24, 1977, the CEQ was directed to replace 70 different existing agency regulations with a single set of uniform standards applicable throughout the Federal Government for conducting environmental reviews. At the same time, the CEQ was also directed to prepare standards that would reduce paperwork, result in less delay, and produce better decisions. The CEQ issued the final regulations to implement the National Environmental Policy Act on November 29, 1978. These simplified regulations are to go into effect on July 30, 1979, and should apply to the Lowell project.

Under the new regulations, time limits on the NEPA process may be set, categorical exclusions of actions from environmental review requirements are provided, and - if there is no significant impact on the human environment - an agency may, on this basis, waive the requirement for preparing an Environmental Impact Statement (EIS).

Under the new regulations the written length of the EIS will be reduced and emphasis will be placed on "real alternatives." Material which is relevant, but not of central importance, may now be incorporated by reference. Federal agencies have also been instructed to assist private parties, prior to review, by advising applicants "of studies or other material foreseeably required by later Federal action." This new approach should considerably reduce the time and cost of an EIS for the Lowell project, if one is required.

Fishways at Hydroelectric Power Projects. Section 18 of the Federal Water Power Act of June 10, 1920, as amended, requires the construction, maintenance, and operation by a licensee at the latter's own expense of such fishways as may be prescribed by the Secretary of the Interior. Section 10 of the Act further requires that a hydroelectric project be developed in conformance with a comprehensive plan for beneficial uses, including recreational purposes.

As previously stated, the Merrimack River has been designated by the Department of Interior for restoration of anadromous fish. This program reinforces the Federal statutes for fish conveyance facilities, water quality improvement, and fish stocking. As implemented, a Federal/State interagency committee must make recommendations on the approval of the design of fish passage facilities. No unusual requirements have been identified, although the current trend in New England is to require increasingly more elaborate facilities. Therefore, in anticipation of a requirement to provide for fish passage facilities, the cost estimates for this project have included $1 million to cover construction of them.

Water Pollution Control. No pollutant discharges result from the Lowell hydroelectric project. Scheduling of water flow at the Pawtucket Dam is currently performed by a sister corporation of Boott Mills. This organization (Proprietors of Locks and Canals on the Merrimack River) considers that the new project will cause no additional difficulties with flow regulations that would affect the ability to obtain a discharge permit.

To obtain a discharge permit, one of two procedures can be followed. These are:

1. Application for Permit to Discharge - Short Form C (EPA Form 7550-8), or
2. A written statement detailing the nature of any pollutants and information about volume and scheduling of flow.

Water pollution control in waters of the Commonwealth of Massachusetts is a joint responsibility of both the Environmental Protection Agency (EPA) and the Division of Water Pollution Control (DWPC) of the State Department of Environmental Quality Engineering. The Federal Water Pollution Control Act Amendments of 1972 are the major Federal enabling legislation. The intent of the law is to allow the state to be the permitting authority; however, in Massachusetts the EPA writes the permit, based on state input, and both the state and the EPA jointly sign the permit.

EPA is responsible for granting discharge permits for discharges into the waters of the U.S., the oceans, and of any contiguous zone. Their authority is derived from the Federal Water Pollution Control Act Amendments of 1972 (Public Law - 92-500, Section 402). Dams, at the present time, are not included as discharge sources. However, the EPA interprets the law for low-head hydroelectric power facilities to include the control of miscellaneous pollutants. In addition, the EPA imposes intake screen cleaning and refuse disposal requirements on low-head hydroelectric power facilities. The EPA's major consideration in granting a permit is to require the facility to provide a continuous minimum flow in the river. The Region 1 office is using a seven-day, ten-year minimum continuous flow requirement as a reference. This criterion has not been used exclusively, apparently having been open to negotiations in some instances. If the formal requirement were adopted, approximate calculations show that a flow of 862 cfs would have to be maintained below the Pawtucket Dam. Calculations in this assessment have assumed a minimum flow of 500 cfs. The effect of minimum flow requirements is to restrict ponding during certain times of low flow. Were the higher minimum of 862 cfs required, project output would be reduced by up to 2,200,000 kWh annually or approximately 3 percent of annual power output.

The application process is described in Figure 5-3 below. Initial contact with the EPA and the DWPC have indicated that a four to six month time period will probably be needed to obtain the permit.

The steps are:

1. The EPA and the DWPC jointly review the application to determine controls.

2. The applicant, EPA and DWPC review the controls in a joint conference.

3. When the three parties agree on conditions of the permit, the EPA issues a public notice of intent to issue a permit.

4. If the EPA receives no public objection, no public hearing is held, and the permit is issued, subject to agreed-upon conditions. Public objection would create the need for public hearings and further agency review.

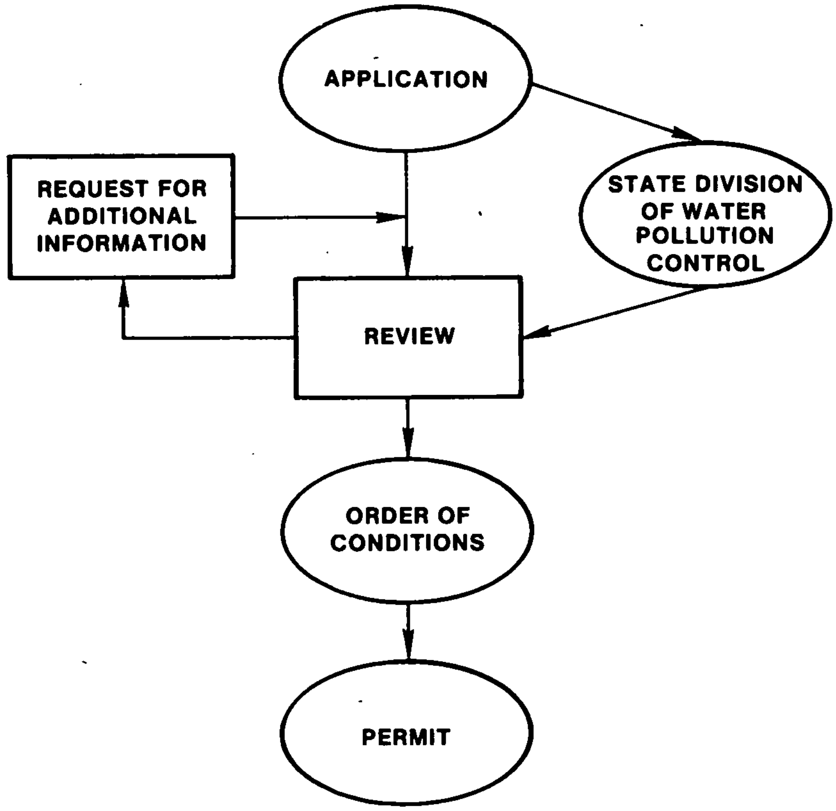

Figure 5-3. National Pollution Elimination Permit to Discharge

<u>Permit for Structure, and Work in Navigable Waters</u>. The Merrimack is a navigable river. Section 10 of the River and Harbor Act of 1889, Section 404 of P.L. 92-500 and Section 103 of P.L. 92-532 requires permits authorizing structures and work in or affecting navigable rivers. Under this authority, the Corps of Engineers issues permits.

It is anticipated that the COE will require a permit to be issued for the Lowell hydroelectric power project. This is based upon the plan to: (1) construct a tailrace; (2) construct the inlet and; (3) place the power plant on the bank of the river. No difficulty is foreseen in obtaining the permit. The process is described below in Figure 5-4. Elapsed time for the granting of permits is approximately three months, in situations such as this where no problem exists.

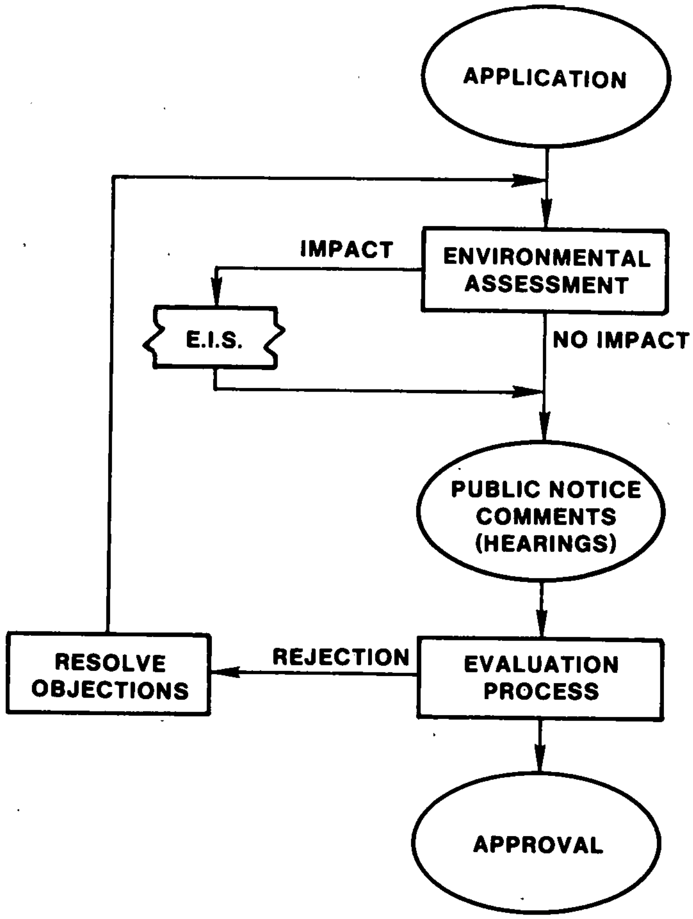

Figure 5-4. Department of Army Permit (Corps of Engineers)

First, the COE determines whether a permit is required upon receipt of an application for a work permit on navigable waters. If it is determined that a permit is required, the COE review begins with an initial environmental assessment by the Corps. This would be followed by the issuance of a public notice of the project, including mailing the notice to approximately 200 addresses (Government agencies, private groups, contractors); holding a public hearing; evaluating the application; and approval or denial.

Lowell National Historical Park. The proposed hydroelectric facility will come under the purview of Public Law 95-290, the act that established the Lowell National Historical Park. This act seeks to preserve and interpret various sites, buildings, structures, and facilities in Lowell exemplifying its character as "...the most significant planned industrial city in the United States, symboliz(ing) in physical form the Industrial Revolution."

Included among the sites and structures protected by this Act are all parts of the five-and-six-tenths-mile power canal system. The canal system is, in fact, the principal focus of the park. The Act establishes the boundaries of the National Park and creates a preservation district under the administration of both the Secretary of Interior and a Commission. The administrative structure and the powers and roles of the Secretary and the Commission are set forth in the Act.

The major thrust of the Act is as follows:

1. Federal agencies that may engage in activities directly affecting the park or preservation district are required to coordinate such activities with the Secretary and the Commission.

2. No Federal entity may grant a license or permit for an activity within the park or preservation district unless the Federal entity determines that the proposed activity will be conducted in accordance with the standards and criteria established pursuant to the Act.

3. The Secretary may enter into agreements with property owners relating to interpretive exhibits, programs for visitors, and minor improvements to property.

4. The Secretary may withold funds provided to the City of Lowell to develop the park and preservation district if the city grants any building permit or zoning variance inconsistent with the standards and criteria established by the Commission.

5. The Secretary has veto power over the Park Preservation Plan prepared by the Commission, and over any change in the Plan.

As of this writing, the administrative framework is being instituted and work on the Park Preservation Plan, the Park Management Plan, and the standards and criteria are being initiated. No apparent conflicts between the hydroelectric project discussed herein and these standards are evident.

The review process that will finally determine whether the Lowell hydroelectric project is compatible with the National Park is shown below.

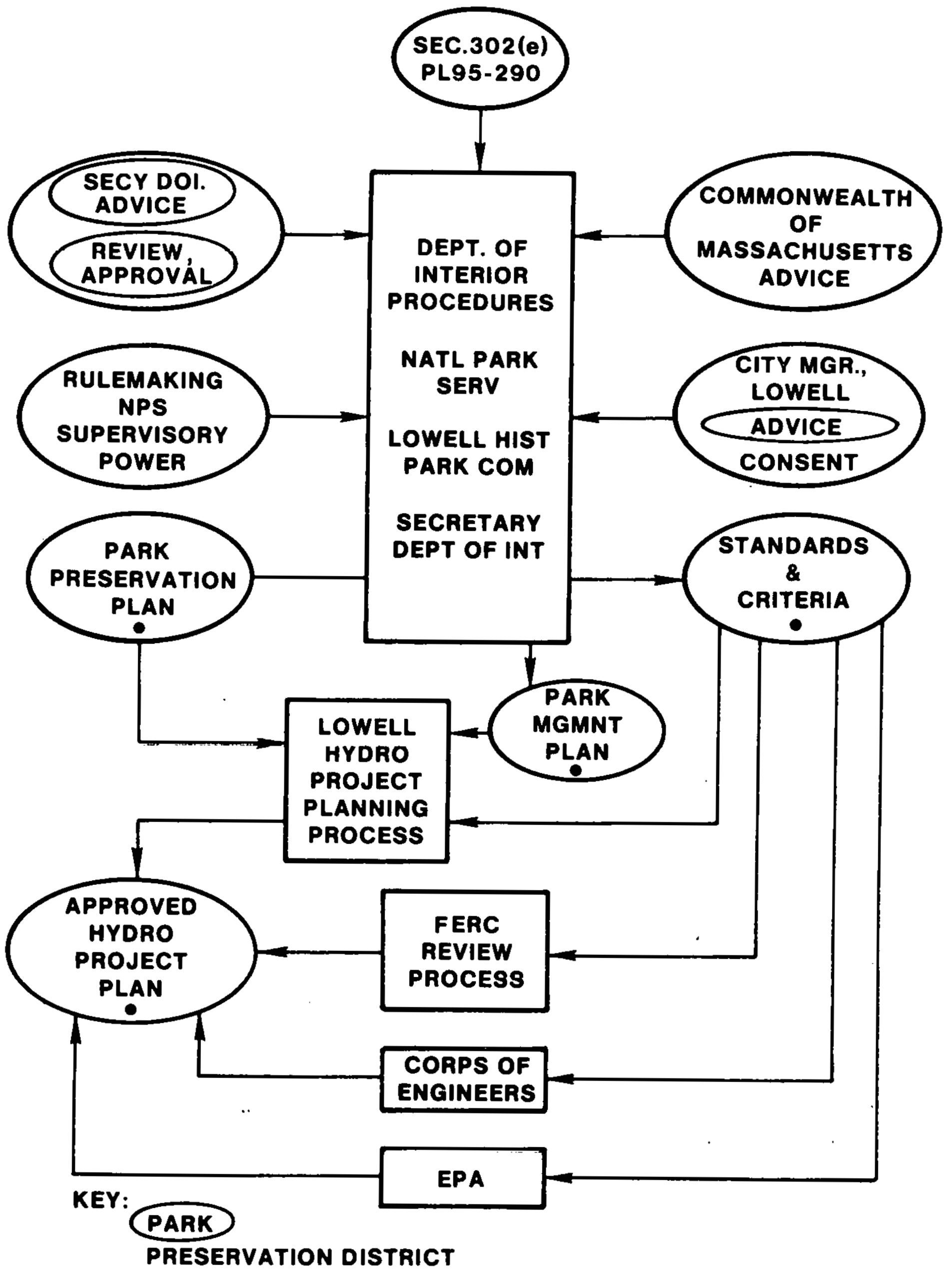

Figure 5-5. Lowell National Historical Park Review

Dots indicate that an action must be completed before proceeding to the next stage as indicated by arrows. In some instances, the same office has different levels of authority. For example, the Lowell City Manager gives his consent to standards and criteria established for the preservation district but his advice to standards and criteria established for the park. The latter is indicated by a small oval within the larger ovals.

The Lowell Museum. The Lowell Museum is a privately endowed, non-profit organization located in the Wannalancit Mill Properties. The Museum location is less than a half mile from the project site. The Museum has a high level of local, state and Federal support, and its plans are coordinated with the Federally sponsored Lowell National Historical Park and with the State Heritage Park. The Museum is dedicated to preserving Lowell's heritage as America's first planned industrial city, placing the emphasis of its passive and working exhibits upon Lowell's history as a giant among New England's textile cities. It is the desire of the Board of Trustees to add a working exhibit that will demonstrate electrical power generation on vintage equipment. These plans are supported by the National Park Service and State Park Planners and also by the senior management of Boott Mills and Locks and Canals. (The latter contributed a significant portion of the original capital used to organize the Lowell Museum and continues to support its objectives.)

It has been concluded that the new hydro facility would have no impact upon the Museum. Whether or not the new hydroelectric facility is constructed, the management of Boott Mills and Locks and Canals Corporation will permit the generation of electric power at the museum for non-profit purposes during the hours that the Museum is open to the public. However, during the peak tourist season, it is likely that generation will be minimal because it is during this season that water flow on the Merrimack River is at its lowest. During these times, the amount of water flow available is the amount needed to flush the canals, so the needs of the Museum would have to be met with a water flow of about 5 cfs.

Considering that the head is only 12 feet at the Museum, this indicates that only about 3.5 kW could be generated at the Museum during the peak tourist season.

5.3.2 State Requirements

Waterway Licenses. A license is required under Chapter 91 of the Massachusetts General Laws if a dam or structure is proposed in, over, or upon waters, below the high water mark of certain rivers, and on rivers where channel clearance or flood control projects have been built. The Waterways License under Chapter 91 is somewhat similar in purpose and requirements to the Corps of Engineers permit, although the programs are completely separate. The procedure for obtaining a Waterways License is shown in Figure 5-6. The Division of Waterways in the Department of Environmental Quality Engineering of the Commonwealth of Massachusetts is the responsible agency.

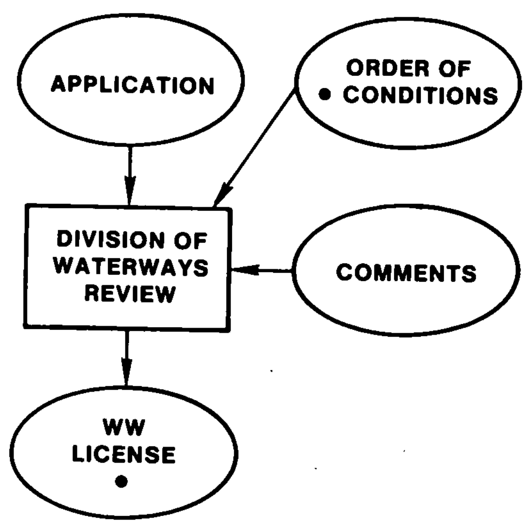

Figure 5-6. Waterways License

The application must include plans for the proposed structure, showing the extent and method of construction and the extent of fill and/or dredging, if any. Although the Division of Waterways is responsible for its processing and grants the permit, the application is circulated to other agencies including the Water Resources Division, the Water Supply Bureau, and the Army Corps of Engineers for their review and comment. Upon approval of the application, the license and the accompanying plan is recorded in the County Registry of Deeds. No difficulties are foreseen in obtaining a Waterways License.

DEQE Wetlands Permit. If the Department of Environmental Quality Engineering (DEQE) determines that the river, streams, or drainage patterns would be affected by the proposed hydroelectric facility, it will be necessary for Boott Mills to obtain a wetlands permit from DEQE. It is anticipated that such a permit will be needed. Under G.L. Chapter 131, Section 40, the applicant must first file a written Notice of Intent with the Conservation Commission and the Massachusetts Department of Environmental Quality Engineering (DEQE). This application must provide detailed plans, including maps and engineering drawings of the site and proposed structures, and must include an Environmental Data Form describing sewage disposal, ground water characteristics, water supply, etc. The impact of the proposed actions and alternatives must be described.

A public hearing is held 21 days after the receipt of the Notice of Intent. If the local Conservation Commission finds there is significant impact, the Commission imposes an order of conditions indicating how environmental quality and public interests are to be protected. When the requirements are met, a wetlands permit is issued by DEQE with the prior approval of the local Conservation Commission. Appeal from the actions of the Commission may be initiated by the applicant, aggrieved parties, an abutter, ten city residents, or the Commissioner of DEQE. The entire process is shown in Figure 5-7. No problems are anticipated because the regulation of water flow at the Pawtucket Dam will be substantially the same as the current operations.

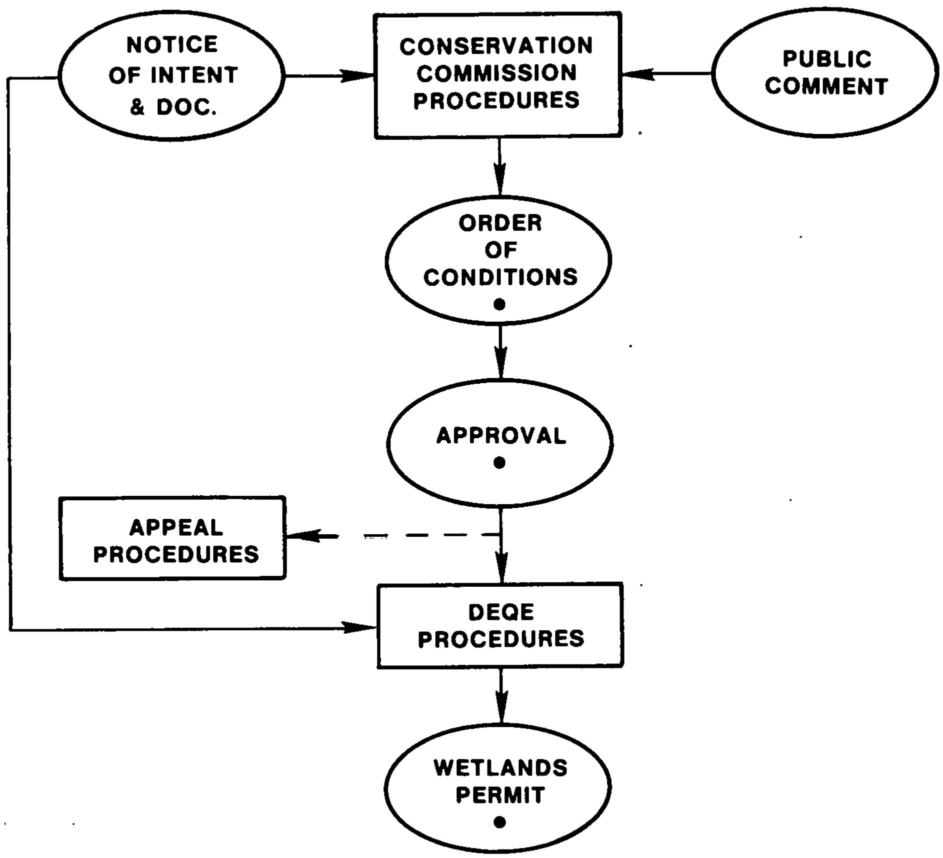

Figure 5-7. Wetlands Permit

Executive Office of Environmental Affairs-MEPA Review. Pursuant to the Massachusetts Environmental Policy Act the Executive Office of Environmental Affairs (EOEA) overseas the functions of most Massachusetts commissions, departments and boards granting licenses or permits to assure compliance with environmental laws.

The first step in the MEPA review process is to file an Environmental Notification Form (ENF) no later than 10 days after the first application to a state agency for a license, permit, or financial assistance. The ENF must describe the project and state the proposed scope or range of environmental issues that may be involved, including the impact on historic resources, open space, recreation, fish and wildlife, vegetation, wetland areas, flood hazard areas, geologically unstable areas, agricultural and forest lands, water quality, and esthetics. Upon receiving the ENF, a meeting is held by the Executive Office of Environmental Affairs (EOEA) and the various state agencies that are to review the document. These include the MEPA unit of EOEA, DEQE, the Massachusetts Historical Commission, and the Waterways Division of DEQE. Other state and local agencies may be invited depending upon the factors involved.

The Secretary of Environmental Affairs has 30 days from the date of publication of the ENF to consult with the developer and participating agencies and to issue a certificate stating whether an Environmental Impact Report (EIR) will be required, and, if so, what its scope must be. The EIR must be submitted to the Secretary of Environmental Affairs, the State Clearing House in the Office of State Planning, the regional planning commission and any participating or other agencies listed in Appendix B of "Regulations Governing the Implementation of the Massachusetts Environmental Policy Act." The EIR must be submitted and reviewed first as a draft and then in final form in accordance with a procedure that includes publication of a notice of availability in the Environmental Monitor, a 30-day comment period and a short period for the Secretary to issue a judgment of the adequacy of the EIR. The overall process of the MEPA review is shown in Figure 5-8. No difficulties are expected to result from this process.

Massachusetts Historical Commission. The Massachusetts Historical Commission has been given the responsibility for reviewing all public actions which may have an impact on historical, cultural, and archeological resources. It is particularly concerned with buildings and sites that have been placed on the National Register and with archeological remains which meet the eligibility requirements of the Massachusetts Historical Commission and the Advisory Council on Historic Preservation established under the National Historic Preservation Act (PL89-665, 16 USC 470, as most recently amended by PL94-442) 1966.

The Massachusetts Historical Commission is notified of a proposed project through the State Clearinghouse, the EQEA, and through the local community. The Commission is one of the reviewing agencies in the MEPA process.

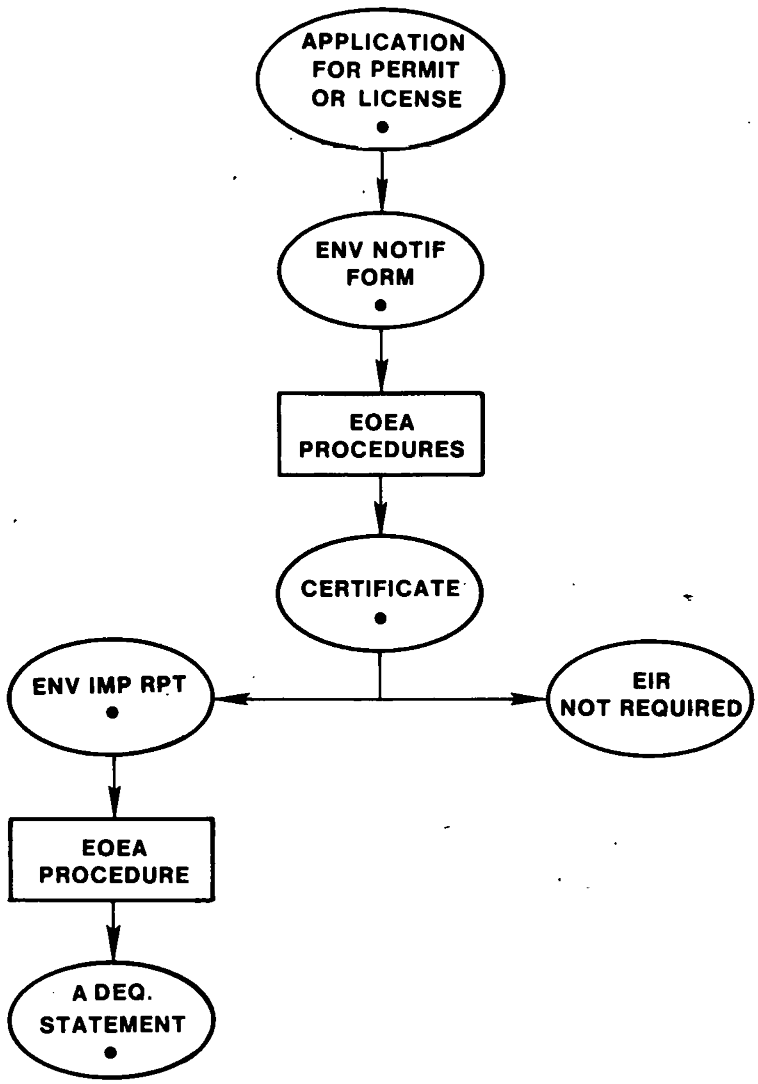

Figure 5-8. MEPA Review

The Historical Commission is expected to require that the old wastegate mechanisms, located at the site of the projected new construction, be preserved. The possibilities for preservation include relocation, in whole or in part, at the project site or elsewhere, according to the preferences of the local, state, and Federal agencies concerned, though funds for this have not been included in project cost estimates.

State Clearinghouse. The Massachusetts State Clearinghouse is within the Office of State Planning. Its purpose is to insure that all levels of government-local, state, and Federal-would be aware of Federally funded and licensed projects and programs (OMB A-95 revised). The Clearinghouse notifies all reviewing agencies and provides opportunities for review and comment as a means of intergovernmental cooperation. It is necessary to keep the Clearinghouse informed of the existance of this projected activity in order for them to carry out their responsibilities. The Clearinghouse, in itself, imposes no additional requirements.

5.3.3 Local Requirements

Lowell Conservation Commission. The procedures of the Lowell Commission have been included in the description of the process which leads to a DEQE Wetlands Permit.

Lowell Building Department. The Lowell Building Department reviews plans and specifications for buildings and structures for compliance with local building and zoning ordinances, and the Department issues building permits. Plans and specifications submitted to the Building Department must be prepared by architects and engineers registered in the state of Massachusetts. This should be a routine project from the point of view of this Department.

Lowell Zoning Board of Appeals. The Lowell Zoning Board of Appeals sits as a quasi-judicial board to act upon requests for variances from the zoning ordinances and to issue special permits. No variance requests are expected to result from this project.

Lowell Historical Commission. The Lowell Historical Commission inventories historical buildings, sites and archeological remains in the city. It advises other municipal offices, such as the Planning and Development Office and the Public Works Department, on projects and actions that may disturb historical and cultural artifacts or areas. The Lowell Historical Commission works closely with the Massachusetts Historical Commission, and is expected to have a similar interest in the preservation of the wastegates.

5.4 PRELIMINARY ENVIRONMENTAL ASSESSMENT

5.4.1 Environmental Effects

Building Construction and Site Work. The hydroelectric facility, if constructed, would require removal of the Northern Canal wastegates and the construction of a new section of canal retaining wall and water control structure to divert canal flow into the new powerhouse. The powerhouse would be located at the water's edge on the south bank of the Merrimack River in proximity to the canal. The water will flow into an intake structure, through the turbines within the powerhouse and out into a tailrace approximately 1000 feet long. A training wall in the river will separate the tailrace from the river, because the tailrace will be lower than the river bed by about 10 feet in the immediate vicinity of the powerhouse. The tailrace channel is excavated in this way to provide additional head for the facility.

Electrical power from the facility will connect into the local electrical distribution system by running beneath the Moody Street Bridge, probably attached to the bridge structure so as to be virtually invisible.

The new control structure in the Northern Canal will be more aesthetically pleasing than the present structure. It will be provided with a flow control gate and a stop log bay. In the future, if it is desired to allow boat traffic through this point, the stop log bay has been designed to be readily removed and replaced with a canal navigation lock.

Access to the powerhouse is to be provided by driveways which will partially cross land owned by the University of Lowell. This is not a problem since the land is not developable.

The proposed facility, if designed properly, would strengthen the visual coherence of important landmarks in proximity to the site. These include the Moody Street Bridge, the University of Lowell buildings, and the Northern Canal structures.

The view of the site and the proposed facilities from the Moody Street Bridge will be an important one. From the bridge, the entire north wall of the powerplant building would be seen as well as the tailrace and training wall in the river. The sloping bank of the river would be a backdrop for the facility.

It is likely that the power plant site would be the terminus of the Northern Canal Walk being planned as part of the Heritage Park. In this case, parts of the plant may also be visible from vantage points on the Northern Canal. If the Park Service requests, and provisions are made for the public to visit the hydroelectric facility, closeup views would also become significant, and factors such as landscaping in the immediate vicinity of the powerhouse will become more important than in most other locations.

Distant views of the facility are obtained from the opposite bank of the river on the University of Lowell campus, and the existence of the powerhouse should add interest to the scene.

New modern construction will be directly connected to the granite construction of the old canal system. This new construction may obscure the original nature of the old canal system. This is more likely to take place if an attempt is made to imitate the old construction, e.g., using granite blocks of the same size and texture as the old construction.

Skillful engineering, architectural, and landscape design should be used to clearly demarcate the new and old construction. Contrasts may be used to dramatize and clarify the relationship between structures from the two different historical periods. From a visual standpoint the new construction can be more attractive than the present wastegates. Although it is interesting and significant from an historical point of view, the frame structure on top of the Northern Canal wall is visually unattractive and has no architectural merit. It represents a utilitarian and nondescript industrial structure common in its own time and still found to some extent today.

Therefore, it is concluded that the overall visual impact of the site will be at least maintained and, most probably, improved, should the hydroelectric project be implemented.

<u>Fish Passage Facilities</u>. The regulatory requirement to provide a fish conveyance facility is a significant part of the total project cost. A complex fish passageway might be needed to meet the detailed physical layout of river, dam and canals. General requirements of a fish passage facility are: 1) means

to allow adult fish to pass upstream during the upriver migration periods, 2) passage for both adult and juvenile fish to migrate downriver, and 3) means to prevent fish from entering the canals on their downward migration. Design population of fish for a fish passage facility for Lowell is estimated to be 720,000 shad and 11,000 salmon.[1)]

It is likely that the principal fish conveyance facility will be at the proposed powerplant and that fish will then swim upstream through the Northern Canal and control gate into the Pawtucket pool.

The principal types of fish passages considered for Lowell are ladders and elevators. A fish ladder exists at the present time at the upstream end of the Dam (see Figure 5-1). This structure is inadequate for shad and may have to be completely replaced as the major upstream conveyance facility. If modified, the existing facility could possibly serve as a secondary up-river conveyance during high water and as a down-river migration facility in order to reduce the expense of a primary facility.

The powerplant outflow will have a fish collection gallery with sufficient water flow to attract fish into the passage structure. The fish collection gallery will extend across the mouth of the excavated canal and will have gates or ports to allow fish to enter into the gallery. Water flow direction through this gallery is engineered to direct fish to the passage structure. This fish attraction gallery will require different amounts of flow at various times of the upstream migration period. During low flow periods, minimal attraction water may be required with only the passageway water itself drawing the fish. During high flow periods, attraction water will be drawn from a penstock through the canal wall (i.e., water not available for hydroelectric generation).

Any fish passage structure must also be designed with a sufficiently large fish holding and counting gallery. State fisheries, biologists and Fish and Wildlife personnel will man this area during peak migration periods to obtain a census of upstream migration. Sufficient space would be dedicated to an observation area for the public to watch the upriver fish migration and the biologists' counting

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1) Dalley, Fish Passage Facilities Design Parameters for Merrimack River Basin, U.S. Fish and Wildlife Service, 1978.

procedures. A sampling port to remove selected fish (especially salmon to be transported to a hatchery for spawning) would be designed: one typical design consists of a means of stopping upstream and downstream flow and hydraulically removing a quantity of fish and the surrounding water from the counting gallery.

One million dollars has been budgeted for fish passage facilities. Although there are no problems accommodating the facility to fisheries requirements, at the one million dollar cost, fish accommodations will add approximately 5% to total project cost at the Lowell site.

Water Distribution and Use. At the present time, water from the Pawtucket Dam is used to: (1) generate hydroelectric power by Boott Mills, (2) flush raw sewage, storm runoff and municipal waste from the canal system, (3) provide the municipal water supply of the City of Lowell, and (4) support recreational boating in the impounded pool. In addition, the river serves as a visual focus and as a center of passive recreational and conservation uses.

Projected uses include: (1) generation of hydroelectric power at the projected facility as considered herein, (2) the provision of a minimum flow for water quality purposes as mandated by the EPA, (3) water supply of the City of Lowell, (4) water for migrating fish conveyances, (5) improved quality of the river for passive recreation and conservation in parks and wetlands along the river, and (6) improved esthetic quality of the river.

These uses are not mutually exclusive, and, in most cases, several purposes are served at once.

The National Park Service is considering use of powered, passenger-carrying barges for visitor tours of the Northern and Western Canals. Changes in the canals that might interfere with barge operation are of concern to park personnel.

Therefore, the water control structure located in the canal will be built to allow the later addition of a lock to permit passage of barges without substantially disturbing flow into the power plant intake. The Division of Marine Safety of the U.S. Coast Guard was contacted and provided information relative to the feasibility of operating barges in a current flow of about 6 ft./sec. Their reply was that with proper design of barges and with trained operators, no problems should be encountered. As a passenger-carrying operation, the proposed barge operations come under the authority of the Coast Guard, barges have to be certified for safety, and barge operators are required to be licensed. Therefore, no unusual restrictions are imposed by the hydro plant.

During periods of low flow, there will be cyclical drawing upon the storage pool behind the Pawtucket Dam. This causes periodic lowering and raising of both levels of the pool and water in the river below the powerplant. This fluctuation of water level occurs with present power generation at Lowell; operation of the new facility will follow the present patterns.

Placement of the power plant and intake structure where they extend into the river bed will alter the cross section of the channel under flooding. This is not an important factor, however, since the cross sectional area of the powerplant is small compared to the flood level cross sectional area of the river at that point.

5.4.2 Social, Economic, and Cultural Aspects

Displacement. The proposed project will make use of vacant land owned by Boott Mills' sister corporation, Proprietors of Locks and Canals. There will be no displacement of families or businesses and no social or economic disruption associated with the project.

Educational/Cultural. The proposed construction will require the removal of the Northern Canal Wastegates, which are described above in Section 5.2. Various measures were considered which would mitigate the impact of this action. The alternatives considered included moving the intake and power plant to a different location, and removal and preservation of the wastegates elsewhere. The former alternative was rejected because of serious difficulties in cost and construction procedures that would result. Several possibilities exist, however, for preservation of the wastegates by incorporating them into an exhibit which would show the manner of their historic operation. This could be carried out at the hydroelectric project site, elsewhere in the Park, or at the Lowell Museum, according to the wishes of the State and local Historical commissions and the Park Service. No funds have been included in the cost estimates for this.

Municipal Services. A hydroelectric generating plant such as the proposed facility would be constructed by a substantial local labor force, but maintained and operated by full-time personnel. Other than minimal fire and police protection, there would be no increased demand for municipal services. Because the construction period is short, it is unlikely that there would be an added load on schools, health facilities or housing.

Economic. The Lowell hydroelectric project would have an installed capacity of 15,000 kW generating 76,150,000 gross kWh/yr. The total cost of the project, exclusive of fishways, in 1978 dollars is expected to be $14,720,000. Fishway requirements will add another $1,000,000. The total includes construction work of approximately $5,060,000, which could be undertaken by local contracting firms and local labor.

Construction of the hydroelectric project would have a beneficial effect on Lowell's economy. Assuming that the facility would be built using local firms and labor, the multiplier effect - through the round-by-round process of purchase and sale of goods and services - may triple the effect on Lowell's businesses.

Increase in the available electrical generation capacity would help Lowell in meeting increases in demand by industrial and commercial users. In addition, the hydroelectric project would be a step toward the use of renewable domestic resources as a replacement for foreign oil. Over 6,000,000 gallons would be needed to generate the power that this hydro facility will provide.

5.4.3 Impact During Construction

The construction impact on the environment will be temporary. It consists of dust and vehicle emissions, blasting and construction equipment shock and noise, river siltation, and local traffic disruption. While temporary deterioration of air quality, background noise levels and water quality will inevitably occur, adherence to state and local regulations will minimize this. The short-term negative impact may be seen in the context of a trade-off for the long-term generation of hydroelectric power, which is favorable environmentally as compared with most other sources of electric power.

Lowell University will be most affected by construction activity. This will principally be the result of blasting and removal of excavated materials, which will be required at the intake, tailrace channel, and powerhouse foundation. These activities will result in noise and heavy truck traffic on local streets.

The high-rise dormitory will be the closest residential and work area to the construction site. Temporary access through Lowell University property will be required.

The Lowell University Nuclear Center operates a one megawatt reactor located across the river from the projected hydroelectric site. Construction blasting will therefore require approval by the Nuclear Regulatory Commission. Detailed calculations will be needed to assure safe procedures, and it is possible that individual blasting charges will need to be smaller than otherwise because of the proximity of the reactor. However, preliminary analysis indicates that a more stringent constraint on blasting procedures will stem from the proximity of some University dormitories, which are on the same side of the river as the power plant site. Calculations setting forth safety requirements for blasting are given in Appendix A. The safety precautions needed are familiar, and no unusual difficulties are anticipated.

Construction activity will affect the National Park, but the effects will be limited in scope. A short section of the Northern Canal will be drained during construction. Heavy truck traffic will occur on some of the local streets. Visitors will be restricted from the immediate construction area. Blasting noise and shock will be present, but located at some distance from most park visitor activity.

The major effect on the environment from construction activity will be caused by the excavation and transportation of approximately 20,000 cu. yd. of material. Excavation for structures will be mostly in bedrock, creating the need for blasting; however, working in bedrock will reduce potential river siltation.

Construction will include the intake channel and structure, tailrace channel and training wall, canal control structures, powerhouse, switchyard, and access roads. Construction noise will be associated with construction equipment, including loaders, cranes, compressors, jackhammers, pumps and vehicle-related activity. These noise sources, being sited close to the rapids, should have little impact.

Construction practices should be employed, as needed, to prevent or minimize possible adverse effects. If necessary, water will be applied to access roadways and aggregate piles when not in use to reduce dust particulate pollution. Movement of construction equipment and excavated material over public ways will be in accordance with regulations. In some cases, activities can be scheduled so as to reduce undesirable effects. The fill to be disposed of is clean and not noxious.

Any site selected for disposal of excavated material must be approved by Federal, state, and local agencies. Approval is granted only after evidence is presented to show no detrimental effect on the surroundings. The permit granted by the Corps of Engineers and the Waterways License issued by the State Department of Environmental Quality Engineering (DEQE) are the Federal and State required authorizations.

Some temporary detrimental impact to the water quality of the Merrimack River may result from excavation. Siltation should be small, and measures will be used to control it. Construction techniques, scheduling and materials will be in accordance with requirements to control erosion. No significant impact is foreseen on wildlife or fish by the excavation and construction.

5.5 SAFETY ASSESSMENT

The development of the Federal and state parks on the existing canal system and their interaction with the hydroelectric project will require consideration from the standpoint of safety. If there is to be public access to the project, the facility design must incorporate safety features and restrict the public to safe areas.

There are no unusual characteristics of the Lowell project which would require special consideration from the standpoint of safety. Good engineering practice, including careful drawing and specification reviews, coupled with sound, well understood construction practices and operation and maintenance procedures will ensure a safe project.

These considerations are set forth in detail in Appendix A.

RAYTHEON SERVICE COMPANY

APPENDICES

APPENDIX A. SAFETY ASSESSMENT

A.1 SUMMARY

Appendix A provides the safety assessment required by the DOE contract. Appropriate considerations during design of the project facilities include: (1) development of design criteria consistent with identified potential safety problems and applicable codes, and (2) specific attention to safety considerations during review of drawings and design documents.

The development of the Federal park on the existing Lowell canal system and its interaction with the Lowell Hydro project is an important public safety issue requiring detailed planning. During, or prior to, the design phase of the project, the detailed plan for public access to and use of the project structures must be settled with the local park commission, National Park Service and Boott Mills so that proper public safety facilities and procedures can be implemented in the project design.

During construction of the project, all occupational safety requirements under existing federal, state and local regulations must be complied with. Each contractor should be required to provide an accident prevention plan with his work proposals. This plan would cover general public safety measures such as site security and traffic control, as well as construction safety methods and facilities.

Operation of the facility will have some potential impact on occupational safety and public safety considerations. Occupational safety relates to the operation and maintenance of the facility. Unsafe conditions may exist when working on the dam and canal structures, on machinery or on electrical facilities. For the most part, unsafe conditions should be minimal for normal operating activities due to appropriate design of the facilities. However, unsafe conditions cannot be completely prevented for unusual activities in operating and maintaining the station. Safe work practices and regular safety training must be integral parts of the operations routine.

Public safety considerations include: (1) proper security of the dam, powerhouse and switchyard from unauthorized access by the public, and (2) proper warning devices and procedures for normal or abnormal operating flow conditions. This should include an emergency action plan for structural failure or malfunction of major project components and specific warning signs or, if applicable, audible warning devices for change in operating discharges.

A.2 SAFETY EVALUATION

A.2.1 Project Design Safety Issues

Potentially unsafe conditions should be identified before detailed design activities commence to make safety issues an integral part of the design effort. Additionally, applicable federal, state, local and industrial codes and standards must be complied with to insure a safe facility from the aspect of structural adequacy and personnel safety features.

Particularly important safety issues specific to the project which must be addressed during design are:

(i) Stability of the project structures under applicable loadings, including hydraulic, seismic, ice and wind loads as well as other dead and live loads.

(ii) Design flood conditions and the interrelationship of the project facilities, the existing flood channel and existing structures.

(iii) Specific construction procedures and restrictions necessary, based on design requirements (e.g. demolition and blasting criteria, care and handling of river flows, cofferdams and excavation restrictions.)

(iv) Security and protection of dangerous project facilities for which fences, barriers, warning alarms, or other devices are necessary.

(v) Public access facilities, safety measures and operating procedures as applicable in coordination with the development of the Federal Park Program at Lowell, to restrict the public to defined safe areas.

(vi) Appropriate clearances, guards, apparatus, special tools, and safety systems to provide personnel with a safe structure in which to perform operating and maintenance functions.

(vii) Procedures and means by which dewatering and inspection of facilities and removal of major equipment components for servicing can be undertaken later in the plant life under safe conditions.

The recommended method for incorporating safety considerations into the design program involve the careful preparation of a Design Criteria Manual in the early stage of the detail design activity. The manual, covering each engineering discipline and project facility, would define basic design requirements based on the site data and the preliminary engineering plan. The design requirements would incorporate applicable criteria from (or reference to) pertinent design, building and safety codes (including standards and regulations).

The impact of the manual on the completed design will be assured through the application of normal engineering practice. All engineering personnel should be educated before the job begins on engineering safety and design requirements. As the design procedes, engineering supervisors will check the work in process to assure continued compliance with the design criteria. Finally, before construction documents are released for bidding, a thorough, final review of the package by a safety engineer should be accomplished.

A.2.2 Construction Safety Issues

In addition to normal heavy civil construction safety practices, the construction of the Lowell facilities will require particular attention to traffic control, blasting procedures, demolition, water handling, and site security due to the project site conditions and existing structures. Blasting procedures must be approved by the Nuclear Regulatory Commission because of the proximity of the Lowell University demonstration nuclear reactor. Technical blasting considerations are discussed in Section A.2.3 below. Other than this, the principal regulatory safety requirement during construction is compliance with standards of the Occupational Safety and Health Act (OSHA) which places the responsibility for safety on the site supervisor and requires rectifying action where unsafe conditions exist or unsafe actions occur. The site safety standards include requirements for reporting accidents, periodic site inspections and weekly safety training.

Site activities must also comply with all other federal, state and local regulations which are applicable to health and safety or any special conditions on licenses or permits for construction of the project.

It is recommended that each construction contractor be required to submit an "Accident Prevention Plan" as a part of his proposal which will define his project safety policy, procedures and facilities, to comply with OSHA and other safety and health regulations.

Inspectors representing the contractor should be trained in the detection and correction of safety deficiencies, and they should check the contractor's compliance with his own accident prevention plan.

A list of representative construction safety requirements is presented in Section 3 of this Appendix. The list is representative of the type of measures which will have to be taken during construction, but should not be regarded as a complete list.

A.2.3 Technical Blasting Considerations

Rock blasting required to accommodate the intake structure, the powerhouse, and the tailrace channel is typically 20 ft. deep over an average area of 800 ft. by 60 to 40 ft. in width. The proposed area is flanked by the University dormitory on the top of the river bank adjoining the powerhouse site and the nuclear facility across the river several hundred feet away. Due to the close proximity of the dormitory, the anticipated explosive charge will be estimated relative to safe levels at that location.

The structural damage is best correlated with the intensity of ground motion in terms of (i) maximum displacement, (ii) maximum particle velocity, (iii) maximum acceleration, and (iv) maximum frequency. After these parameters are established, the damage criteria is expressed by an Energy Ratio which is defined as the square of the ratio of maximum acceleration in feet per second^2 to maximum frequency in cycles per second. Using the relationships for sinusoidal motion, this criteria can also be expressed in terms of maximum velocity.

Usually damage criteria are established on the basis of existing information before commencing blasting. However, in the absence of a given intensity of the ground motion which an existing structure can tolerate, an Energy Ratio of 3 or less is considered safe. This translates to 3.3 inches per second in terms of maximum particle velocity.

A more commonly adopted and more conservative approach is to utilize an Energy Ratio of 1.0 which corresponds to a peak particle velocity of 1.9 inches per second. Therefore a value of 2.0 inches per second is commonly used. This damage criterion is frequency independent; however, it is known that damage is less at higher frequencies due to smaller displacements. The characteristics of ground motion can be related by a triaxial plot known as a response spectrum relating acceleration, particle velocity, frequency and displacement.

The actual particle velocity to be expected at a site due to blasting is interrelated with (i) the transmission characteristics of the rock mass, (ii) the distance between the detonation and the monitoring point, and (iii) the weight of explosives detonated per delay (assuming a minimum delay period of 25 milliseconds). The particle velocity is generally empirically related to the charge and the distance by either square or cube root scaling in which the particle velocity and the scaled distance are combined on a log-log plot.

Using the concept of scaled distance, the maximum permissible charge can be determined for a criterion of 2.0 inches per second particle velocity adjacent to the dormitory. This permits using a charge of 4.0 lbs. per delay at the closest point (40 feet from the dormitory structure) and a maximum charge of 1000 lbs. per delay at the farthest point from the dormitory. Attenuating this to greater distances, it is likely that the maximum particle velocity at the nuclear facility will be in the order of 0.1 to 0.2 inches per second.

The frequency of the vibrations cannot be accurately predicted, but will be in the range of 5 to 500 Hz. In the hard, compact, crystalline gray quartzite it is expected that vibration frequencies will fall in the mid to lower range.

In addition to the precautions described above, conventional techniques will be used to contain the noise and projectile rocks stemming from drilling, blasting, and loading operations.

A.2.4 Operation and Maintenance Safety Issues

Operation and maintenance of the project will have some potential impact on occupational and public safety issues. Occupational safety is principally regulated under OSHA and implemented by the plant owner. Public safety related matters involving dam safety and operations will be regulated under specific conditions of the FERC license and will be based on the public access plan established with the local park commission and National Parks Service.

An operating manual providing procedures for start-up, shutdown, cleaning, isolating, tagging, teardown and other aspects of operation and maintenance of the plant facilities and equipment should provide a key source for identifying and neutralizing potentially dangerous conditions or actions. This would supplement the basic supervisory/worker instructional safety program required under OSHA and the specific safety requirements instituted by Boott Mills.

Public safety considerations include: (1) proper security of the project dam, powerhouse and switchyard from access by the public, and (2) proper warning devices and procedures for normal or abnormal operating flow conditions, and (3) careful design of access facilities related to the existence of the park.

Security at the dam, which presently includes fencing at the dam abutments and shore in the immediate area of the intakes, and a highly visible boom to keep boaters from the project structures, appears adequate. Security of the switchyard transformer and powerhouse entry by barricade, fencing and warning signs should be in accordance with applicable American National Standards Institute (ANSI) codes. These facilities would be a part of the design responsibilities discussed in Section A.2.1. Downstream, in the river reach affected by the project, warning signs should be placed to warn of fast rising water levels due to plant operations.

Depending upon the type of public access facilities to be provided, particular access, parking, walking routes, exhibits and operating rules may be required. From a safety standpoint, access by the public to the canal and powerhouse area should be discouraged, since it is an industrial activity area with high voltage electrical equipment, rotating machinery, precipitous drops and fast water currents, providing potential danger areas to the curious public. When public access is provided, the degree of security to control access to dangerous areas must be increased.

An emergency action plan should be devloped for the project to quickly provide the operator, the Boott Mills supervisor and local regional emergency forces with procedures to follow in case of major structural failure, fire or accident. The plan must include a procedure in case of a dam failure to comply with normal conditions contained in FERC licenses. All such plans should be updated on a regular basis and periodic training sessions should be conducted to ensure that operating personnel are aware of their emergency tasks.

A.3 CONSTRUCTION SAFETY LIST

The facility safety aspects of this project address the hazards and risks during the construction of a hydroelectric facility at the Lowell site.

Adequate safety protection must be provided, at all times, for the walking public, vehicle traffic and private property during the construction phase as well as during the operational phase of this facility.

The Contractor's working and equipment storage area must be enclosed as appropriate with either a solid plywood fence or an 8 foot chain link fence with three strands of antipersonnel wire at the top.

Signalmen must be provided to regulate and control the flow of construction vehicles and materials into and out of the facility site during construction. Safe access shall be provided to all working areas.

Provisions must be made to keep the access approach to any main streets or sidewalks clear, clean and free from spoils or muck being removed from the site by the Contractor.

Appropriate signs, conforming with local regulations, identifying the Project, the Owner, the Contractor and giving a warning to the public of the safety hazards involved must be provided.

The provisions of the Occupational Safety and Health Act of 1970 must be adhered to.

During the construction of cofferdams, bulkheads, or any work involving floating equipment or working on driven pile trestles, U.S. Coast Guard Approved Life Vest or equipment must be worn. Ring buoys and safety skiffs must be provided.

When explosives are employed in the demolition and removal of any existing structure or natural formations, all local, state and federal safety requirements must be complied with regarding the transportation, handling, storage, firing and inspection after blasting.

An inspection of all buildings, structures, or utility services in the immediate area that could be damaged as a result of vibrations or any demolition work must be made and the conditions of same recorded prior to any work on this project.

Sanitation facilities meeting all local, state and OSHA requirements must be provided.

Medical facilities including First Aid stations, ambulance service and medical personnel available for prompt attention to the injured, and for consultation on matters of occupational health must be arranged for prior to the commencement of any work. Approved First Aid kits must be provided.

An emergency plan to minimize the consequences of any accident or natural disaster must be developed.

Personal protective apparel, clothing and safety equipment shall be used as required by all local, state and federal requirements.

Emergency and outdoor lighting complying with all local, state and OSHA requirements must be provided.

Material handling, storage and disposal must comply with all local and state requirements.

Fire protection shall be provided where needed and must be inspected and maintained in accordance with all local and state requirements.

Temporary electrical service installations shall comply with the National Electrical Safety Code, National Electric Code or applicable United States Coast Guard regulations.

All hand tools and power tools shall be kept in good repair and used only for the purpose for which designed.

The use of ropes, slings and chains shall be in accordance with the safe usage recommendations of the manufacturer.

Machinery and mechanized equipment shall be inspected and tested by a competent mechanic of the owner and certified to be in safe operating condition prior to being placed in use or service.

All motor vehicles employed at the facility must be inspected and found to be in a safe operating condition, meeting all local regulations before being used.

All temporary trestles, ramps, scaffolds or other similar load bearing structures shall be designed, constructed and maintained with a safety factor of not less than 4.

The design of all cofferdams, bulkheads or other supporting structures employed in the excavation of materials in this project shall be based on calculations of forces and their directions with adequate consideration for surcharges, angle of internal friction of materials and other pertinent properties of the material to be retained in place.

When tight sheeting or sheet steel piling is used, full loading due to ground water table shall be assumed.

All designs will be submitted to the engineer for approval of any modification of work.

If diving is required, all diving equipment and procedures shall be in conformance with the requirements of the United States Diving Manual NAVSEA 0994-LP-001-9010, available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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APPENDIX B. SITE EXAMINATION AND EVALUATION REPORT

DATE - October 9, 1978

ATTENDEES - Melvin G. Lezberg - Manager, Boott Mills
Arthur B. Slater - Program Manager, Raytheon
Ralph B. Tucker - Project Manager, Raytheon
Peter H. Tucker - Project Engineer, Acres
Sher Bahadur - Geotechnical Engineer, Acres
Robert Beal - Construction and Estimating Engineer, Acres

B.1 AGENDA

A brief meeting of attendees was initially held at the Boott Mills office to discuss overall aspects of project ownership, site conditions, operating limitations and study input.

This was followed by site examination of (1) the dam and intake structures, (2) the impoundment in the proximity of the project facilities, (3) the canal structures and banks, (4) the proposed site of the power house near the Moody Street Bridge to the tail-water pond and (4) the river channel below the site to near the Concord confluence.

The site examination did not include (1) inspection of the complete impoundment, which supposedly backwaters approximately 18 miles, (2) inspection of the existing canal structures and equipment not included in the project, or (3) any detailed survey data collection.

The inspection for electrical facility location and line routing will be held at a later date when MEC representatives are available.

B.2 SUMMARY

A reasonably thorough investigation of the existing dam and canal structures and the Moody Street site was possible due to low flow conditions (pond at +1' = El:83). The existing structures were all found to be in a sound and tight condition with only minor exceptions in portions of the Northern Canal. The location for the proposed power facility was found to be quite adequate in terms of efficient use of existing facilities and topography without significant upset of present land use. Additionally, access appears to be reasonably good, and there are no unusual geological restrictions expected in either the project design or construction.

The site investigation and discussions resulted in identification of specific limitations and potential problems relative to this phase of the project and areas which will require further definition in the next project phase as listed below:

B.2.1 Limitations (presented by M. Lezberg)

(a) The existing canal system water surface elevation (except the Northern Canal to the Moody Street site) must be maintained to no more than 2 feet above crest maximum and normally no less than 1 foot below crest.

(b) The complete canal system must be available for navigation, although navigation facilities will be designed and provided by others.

B.2.2 Potential Problems (for consideration in subsequent phases)

(a) A demonstration nuclear reactor is located at the top of the river bank on the opposite (North) shore from the Moody Street site which could limit construction explosive excavation procedures depending upon the reactor's status and regulatory restrictions. Raytheon will investigate this matter.

(b) Construction would be in close proximity to the local university facilities overlooking the site. Construction access requirements over this property, dust and noises and explosive excavation vibration may upset normal activities and should be discussed with the appropriate individuals to develop a positive attitude toward the project. This would be the responsibility of Raytheon and Boott Mills.

B.2.3 Items Requiring Further Definition (pre-licensing phase)

(a) Transportation corridors including limitations on bridges, streets and railroad clearance and loading for construction equipment and material delivery should be defined.

(b) Aerial and ground survey mapping of the complete project area with specific detail at the dam and area of impact for the site, for permits, easements, and construction input.

(c) Detailed cross sectional data of the river bed below the site to the USGS gage 7,000 feet downstream and the same detail for the power canal to develop more precise net head data.

(d) Collect field data and develop a mathematical model of the impoundment's effective storage to simulate plant operations for various flow conditions.

(e) Determine the adequacy of freeboard in the pond for maintaining a higher fixed crest elevation at 3 feet and 4 feet above present crest and maintaining a flashboard crest to 5 feet above present crest.

(f) Determine the adequacy of freeboard in the existing canal system for maintaining a permanent elevation greater than El.84 which would lift the limitation of item 1a above.

(g) Define the extent of minimum releases required for the fish ladder facilities and uses in the existing canal system. This will further define operating restrictions and losses.

(h) Undertake a foundation drilling and testing program at the site for detailed project design input.

(i) Perform a detailed inspection of intake and canal structures in a dewatered condition or alternatively (not preferably) perform an underwater diver's inspection of same. This is to insure that no undetected structural problems exist in these structures.

(j) Perform a detailed stability analysis on all hydraulic structures or alternatively an analysis comparable to that required under the National Dam Safety Program.

The current Engineering Feasibility Study will proceed with the limitations described in Item 1. Where detailed data is lacking as identified in Item 3 above, assumptions which are made will be specified in the Task 1 summary.

B.3 SITE EXAMINATION FINDINGS

B.3.1 Geology

The bedrock in the area is fine to medium grained, gray quartzite characterized by outcrops along the river banks and in the river channel. The rock is hard, impervious, strong, and competent, showing no evidence of any chemical decomposition. The outcrop exhibits an extremely well developed joint set with strike direction N50°E and a dip ranging from 50° to 75°. The joint planes are tight, devoid of chemical deterioration or clay filling, and have a frequency of 2 to 3 feet.

B.3.2 Dam

The dam is of dressed masonry gravity construction with 1,092.5 feet crest length and an average height of approximately 15 feet. Based on project drawings 5174B008 (0), the masonry was ashlar laid dry with a mortared masonry upstream face at 1:1 slope, two feet thick capstone and the bed course laid in mortar. It was built in two sections in 1847 and 1875--the latter (western portion) being grouted during construction. The dam is shown resting on the bedrock except for a short section on "hard pan." A fishway is located at the western dam abutment and the intake structure and Northern Canal are at the eastern abutment. At the time of examination, the pond level was one foot onto the four feet of flashboards with a crest leakage along the dam length. The dam was observed from both abutments, showing no visible sign of displacement or differential settlement. The dam appeared tight with no signs of excessive leakage through the dam. All masonry blocks, as well as the crest cap, appeared to be soundly in place, although the upstream face and portions of the toe were not visible.

The flashboards were erected to their normal four feet height with solid bar pins at close spacing (approximately 1 1/2" @ 2' c/c). It was reported that they begin to fail with about 6 inches to one foot of water over the top.

They are annually erected as spring flows subside in May or June (normally) and would be expected to be taken out by ice in December.

With the possible exception of theoretical stability considerations, the dam and foundation should provide an acceptable base for increasing the dam height to a maximum permanent crest elevation of 86 (presently 82). For consideration of maintaining the existing flashboard arrangement, there is no specific dam repairs considered necessary at this time, outside routine annual maintenance of the flashboards and dam estimated by M. Lezberg to cost about $10,000 per year.

B.3.3 Impoundment

The impoundment above the Pawtucket Dam is presently used for pleasure boating. A float barrier extends across the river between the dam and the Pawtucket canal intake. This barrier is used to keep pleasure craft away from the dam crest and the inlets to the Northern and Pawtucket Canals.

The pondage effect is reported by M. Lezberg to extend approximately eighteen miles upstream. The shoreline was not specifically investigated except at the structures. However, it might be expected that permanently raising the dam crest could impact adjoining property uses and expected flood damage.

B.3.4 Intake

The canal intake structure is principally constructed of dressed masonry with concrete over lintels. Ten 8' x 15' motor operated timber sliding gates feed the Northern Canal. Another small intake opening feeds a presently unused wheel which formerly powered the gate mechanisms through a line shaft. The structure's water passages are nearly 80' in length due to the School Street Bridge being an integral part of the structure.

A modest amount of the intake substructure was visible for examination. Similar to the dam, there was no settlement, dislodgment or significant deterioration apparent in the substructure or masonry superstructure. The water passages were not visible and should be inspected at some future time if the project proceeds to construction. Portions of the downstream side and bridge piers were visible and had no sign of any significant deterioration. The bridge was not specifically addressed. A small amount of leakage was noted as coming through the bay containing the auxiliary turbine.

The intake gates and guides were not visible and were reported to have not been inspected in years. The gate operator gears are worn and about four gates were down and are not operated due to worn gear wear. Provision for gate rehabilitation will be made in the feasibility cost.

The navigation lock opening abutting the intake is bulkheaded, apparently with a permanent concrete wall.

B.3.5 Canal

The Northern Canal to the Moody Street site is about 2,000 feet in length, with masonry or bedrock lining its complete length. The first 1,000 feet combines masonry walls and an earth dike (with masonry core) as the river wall and the second length is a dressed masonry gravity structure to the Moody Street site. (This structure is approximately 30 feet in height.)

There was no leakage visible along the toe of the dike, and all slopes appeared stable with a fair amount of tree and shrubbery growth. The upstream masonry dike and shore walls were generally intact except approximately 150 feet of length in aggregate on each side of the canal. Along this length dislodged blocks for either one or two courses have fallen into the canal and need to be replaced. This is expected to be the result of frost action only, since blocks below the water level seemed to be in place.

Some minor leakage was observed along the base of the masonry gravity portion of the canal retaining wall. The structure was seen to be in very good condition with little deterioration and no apparent sign of settlement.

Rock exposure was visible from a distance along much of the bank. It exhibits the similar competent character shown by outcrops in the river channel, and the steeply angled slopes appeared stable. There was no sign of chemical decomposition or mechanical weathering.

Remedial work which would be required as a part of a new hydro project would include a complete dewatering for thorough inspection, cleaning the channel of debris and sedimentation, clearing grubbing and partially armoring the dike, and repairing all damaged masonry dike and shore walls.

B.3.6 Moody Street Site

The proposed site for powerhouse and tailrace construction is from Moody Street Bridge downstream approximately 1,000 feet to a pool where the river changes directions, following along the easterly river bank. Bedrock at about elevation 55 to 60 is completely exposed in this area; the bank rock face immediately rises to a developed area including a college dormitory and laboratory overlooking the river bed. There is sufficient room for basic access to the upper level from the canal crossing and to the river bed from the dormitory parking lot and other nearby points. However, the site is quite restricted and will require some added consideration to construction scheduling procedures.

The competent rock present in the area should be able to develop sufficient bearing capacity to support the proposed powerhouse without causing major geotechnical problems. The rock should also be able to provide stable slopes for the tailrace channel to be excavated in the river bed. Due to very steep inclination of joint planes, the requirements for rock bolting or any other rock support will be minimum. As the rock is homogeneous, hard, and brittle, no special problems are anticipated in excavating the tailrace channel by conventional blasting. However, the presence of a nuclear facility in the vicinity may necessitate some restrictions in blasting, and therefore, further investigations should be addressed in this direction.

The elevation differential in water surface from Moody Street Bridge pier to the lower pool was hand level measured showing an additional head increase of 10 feet by excavating for a tailrace to the pool. All facilities would have to hug the east bank to minimize flood stage problems due to constricting the river cross section.

The river bed down stream of the pool was viewed and found to present an additional head loss between the Moody Street site and the USGS gaging station. Under normal flow ranges of a 6,000 cfs magnitude it could be expected to cause an additional backwater on the order of two feet. This is difficult to predict accurately without further river sectional data and observations under various conditions.

APPENDIX C. DETAILED COST DATA

Detailed cost data are given by FERC account for two equipment alternatives, the four 3.75 MW tube turbine system and the two 7.5 MW fixed blade propeller turbine system. The former is the system with the lowest estimated costs and these costs are used as the basis for the economic calculations in Section 2. Detailed cost estimates for the propeller turbine design were developed at an earlier point in the assessment when it appeared that no equipment alternative would have a significant cost advantage. They are included here for purposes of comparison. Additionally, as noted in Section 3, the estimated costs for several equipment alternatives are close enough that a final choice among alternatives should not be made until firm bids are received from equipment manufacturers. Only then can it be definitively determined which alternative is best.

DESCRIPTION OF FERC ACCOUNTS

Account No. 330.00 Land and Land Rights

Description: The Proprietors of Locks and Canals, a sister corporation of Boott Mills, own all necessary land and rights for the Lowell project works. Where adjoining easements will be necessary for construction access it is assumed that they will be granted free gratis. No moneys have been set aside for this account.

Account No. 331.00 Structures and Improvements

Description: The powerhouse substructure and superstructure and the integral concrete intake structure is included in this account. Also included is the plant plumbing, heating and lighting.

Account No. 332.00 Reservoirs, Dams and Waterways

Description: This account includes all improvements on the existing canal and the proposed new retaining structures, intake facilities and tailrace channel. There is no work proposed for the existing dam structure. Work on the canal includes new gates at the canal gatehouse, handrails along the canal walls and construction of the control structure to separate the Northern Canal from the remaining canal systems. Work at the powerhouse intake includes rock excavation, cofferdam construction, an extension of the canal river wall to the new intake some 270 feet, the retaining wall from the powerhouse to the right abutment and intake gates, hoists, and trackracks. The tailrace work includes excavation and channel improvement for approximately 1000 feet downstream and a training wall separating the riverbed and tailrace channel.

Account No. 333.00 Waterwheels Turbine and Generators

Description: The turbines, governors and associated piping and the generators, exciters (voltage regulators) and appurtenances are included in this account. The costs include procurement installation and commissioning.

Account No. 334.00 Accessory Electrical Equipment

Description: Included is all electrical equipment, conduit, cable and appurtenances between the generator terminals and the transformer low voltage bushings. This principally includes all control metering and relay devices, the main bus and switchgear, the station service transformer and station batteries.

Account No. 335.00 Miscellaneous Power Plant Equipment

Description: This account includes the station bridge crane and various power plant systems including compressed air, dewatering facilities, fire protection and oil handling.

Account No. 336.00 Roads and Railroads

Description: Included are the access roads with gravel surface to the intake deck and to the powerhouse entrance.

Account No. 353.00 Station Equipment

Description: Included is procurement and installation of the station 23/4.16 Kv power transformer and high side fuses and disconnects.

Account Nos. 356.00 and 358.00 Conductors

Description: In account 356.00 is the 4200 feet long overhead portion of the powerline tap from the proposed plant to Pawtucketville Substation including the recloser at the sub. Account 358.00 includes the 1400 feet of underground line from the plant transformer to Textile Avenue and the ducts in the new canal wall.

TABLE C-1. COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
	SUMMARY OF ESTIMATE						
330.00	LAND & LAND RIGHTS				-0-		
331.00	STRUCTURES & IMPROVEMENTS				1,600,000		
332.00	RESERVOIRS, DAMS & WATERWAYS				2,460,000		
333.00	WATERWHEELS, TURBINES & GENERATORS				5,400,000		
334.00	ACCESSORY ELECTRICAL EQUIPMENT				365,000		
335.00	MISC. POWER PLANT EQUIPMENT				310,000		
336.00	ROADS & RAILROADS				30,000		
353.00	STATION EQUIPMENT				155,000		
356.00	OVERHEAD CONDUCTORS				70,000		
358.00	UNDERGROUND CONDUCTORS				60,000		
	CONSTRUCTION SUBTOTAL				10,450,000		
	CONTINGENCIES (15%)				1,570,000		
	ENGINEERING & ADMINISTRATION (20%)				2,400,000		
	TOTAL PROJECT CAPITAL COST				14,420,000		
	EXPENSE ITEM COST (1)				70,000		
	TOTAL PROJECT COSTS (2) (3)				14,490,000		

(1) Includes $36,000 for demolition and $34,000 for canal repairs.
(2) These figures do not include costs of fish passage facilities, estimated to be $1,000,000.
(3) This total is less than the estimate of $14,720,000 due to a change in Account 356.00 and 358.00. See text discussion at Section 3.6.4.

TABLE C-2. DETAIL COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
331.00	Power Plant Structures and Improvements						
331.1	Powerhouse						
.11	Cofferdam and pumping						Included in Acct. 332.31
.12	Excavation, Rock	7,000	c.y.	25.00	175,000		
.13	Foundation preparation						Included in Acct. 331.12
.15	Substructure						
.1510	Concrete	6,800	c.y.	90.00	610,000		
.1511	Forms	52,000	s.f.	5.00	258,000		
.1512	Reinforcing steel	542,000	lb.	0.50	271,000		
.159	Miscellaneous		L.S.				
.16	Superstructure	(185,000)	c.f.				
.161	Structural steel frame	123,000	lbs.	0.75	92,000		
.162	Walls	8,100	s.f.	5.50	45,000		
.1630	Roof	64.5	sq.	350.00	23,000		
.1631	Roof covering	21.5	sq.	170.00	4,000		
.164	Interior partitions,floor		L.S.		2,000		
.165	Doors and windows		L.S.		15,000		
.166	Plumbing and Sewage		L.S.		20,000		
.167	Heating and ventilating		L.S.		50,000		
.168	Lighting		L.S.		15,000		
.169	Miscellaneous		L.S.		20,000		
	Total Power Plant Structures and Improvements					1,600,000	
332.00	Reservoirs, Dams and Waterways						
.1	Reservoir						
.2	Dams - Canal Walls						
.21	Cofferdam and Pumping						
.211	Structure	9,000	c.y.	10.00	90,000		
.212	Pumping	--	L.S.	--	30,000		
.22	Core drilling	--	l.f.	--			Included in Engineering
.23	Excavation, Rock	--	c.y.	--			Included in Acct. 332.541
.24	Foundation preparation	--	s.f.	--			Included in Acct. 332.541

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TABLE C-2. DETAIL COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
.250	Concrete						
.251	Forms	39,300	s.f.	4.25	167,000		
.252	Reinforcing steel	388,000	lbs.	0.45	175,000		
.253	Concrete	7,300	c.y.	100.00	730,000		
.3	Dams-Canal Control Structure						
.31	Cofferdam and Pumping						
.311	Structure	4,000	c.y.	8.00	32,000		
.312	Pumping	--	L.S.	--	1,000		
.32	Core drilling	--	l.f.	--			Included in Engineering
.33	Excavation, Rock	100	c.y.	150.00	15,000		
.34	Foundation preparation	--	s.f.	--			Included in Acct. 332.33
.35	Concrete						
.351	Forms	7,700	s.f.	10.00	77,000		
.352	Reinforcing steel	80,000	lbs.	0.50	40,000		
.353	Concrete	1,000	c.y.	70.00	70,000		
.4	Dams - Appurtenances						
.41	Control Gates and Hoists						
.411	Sliding Gate	21,000	lbs.	1.40	29,000		
.412	Stoplogs	--	L.S.	--	3,000		
.5	Waterways						
.54	Canals						
.541	Excavations	7,800	c.y.	25.00	195,000		Structure included in Acct. 331.1
.6	Intake						
.61	Intake gates & Appurtenances						
.611	Gates, Guides & Hoists	50,000	lbs.	2.20	110,000		For canal gatehouse
.612	Trash racks	100,000	lbs.	1.00	100,000		
.62	Forebay booms	--	--	--	--		
.63	Intake valves	--	--	--	--		Included in Acct. 333.0
.69	Miscellaneous	--	L.S.	--	50,000		Includes handrail along canal walls

TABLE C-2. DETAIL COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
.9	Tailrace						
.91	Excavation, Rock	14,000	c.y.	25	350,000		
.92	Rip rap						
.93	Gates, hoists & Appurtenances	140,000	lb.	1.40	196,000		Bulkhead Style
	Total Reservoirs, Dams & Waterways					2,460,000	
333.00	Water Wheels, Turbines & Generators						
.1	Turbines, Governors, Pumps, and Piping		H.P.				
.101	Supply	4	L.S.	--	4,750,000		
.102	Install & Commission	--	L.S.	--	650,000		
.2	Generators, Exciters & Appurtenances		kW				
.201	Supply	--	--	--			Included in 333.101
.202	Install & Commission	--	--	--			Included in 333.102
	Total Water Wheels, Turbines, & Generators				5,400,000		
334.00	Accessory Electric Equipment						
.1	Connections, Supports & Structures						Included in Acct. 334.2
.2	Switchgear & Control Equip.		L.S.		250,000		
.203	Control, Meter, Relay		L.S.		75,000		
.26	Auxiliary power equipment						
.262	Station Battery		L.S.		20,000		
.29	Miscellaneous		L.S.		20,000		
	Total Accessory Electric Equipment		L.S.			365,000	

TABLE C-2. DETAIL COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
353.00	Substation Equipment						
.21	Transformer Supply		L.S.		125,000		
.211	Install		L.S.		30,000		
	Total Substation Equipment					155,000	
356.00	Overhead Conductors						
.1	Insulators & Hardware		L.S.		15,000		
.2	Conductors		L.S.		30,000		
.3	Miscellaneous		L.S.		25,000		
358.00	Underground Conductors						
.1	Insulators, Hardware		L.S.		20,000		
.2	Conductors		L.S.		40,000		
	Total Transmission (Acct. 356 & 358)					130,000	N.E. Power Co. Estimate of $300,000 was used in Summary Tables.
335.00	Miscellaneous Power Plant Equipment						
.1	Auxiliary Equipment						
.11	Unwatering & low level drainage system	--	L.S.	--	45,000		
.14	Compressed air system	--	L.S.	--	45,000		
.15	Fire protection equipment	--	L.S.	--	10,000		
.16	Cranes	--	L.S.	--	170,000		
.17	Oil Handling	--	L.S.	--	10,000		
.18	Protective Coatings	--	L.S.	--	15,000		
.19	Miscellaneous	--	L.S.	--	15,000		
	Total Miscellaneous Power Plant Equipment					310,000	

TABLE C-2. DETAIL COSTS FOR FOUR 3.75MW TUBE TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
336.00	Roads and Railroads		L.S.		30,000		
.1	Roads, Gravel						
	Total Roads and Railroads					30,000	

UNITS

c.y.	cubic yards
s.f.	square feet
L.S.	Lump Sum
lb.	pounds
c.f.	cubic feet
sq.	per square (100 s.f.)
l.f.	lineal feet
H.P.	Horsepower
kW	kilowatts

TABLE C-3. COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
	SUMMARY OF ESTIMATE						
330.00	LAND & LAND RIGHTS				-0-		
331.00	STRUCTURES & IMPROVEMENTS				2,180,000		
332.00	RESERVOIRS, DAMS & WATERWAYS				3,020,000		
333.00	WATERWHEELS, TURBINES & GENERATORS				6,000,000		
334.00	ACCESSORY ELECTRICAL EQUIPMENT				225,000		
335.00	MISC. POWER PLANT EQUIPMENT				340,000		
336.00	ROADS & RAILROADS				30,000		
353.00	STATION EQUIPMENT				155,000		
356.00	OVERHEAD CONDUCTORS				70,000		
358.00	UNDERGROUND CONDUCTORS				60,000		
	CONSTRUCTION SUBTOTAL				12,080,000		
	CONTINGENCIES (15%)				1,810,000		
	ENGINEERING & ADMINISTRATION (20%)				2,780,000		
	TOTAL PROJECT CAPITAL COST				16,670,000		
	EXPENSE ITEM COST (1)				70,000		
	TOTAL PROJECT COSTS (2) (3)				16,740,000		

(1) Includes $36,000 for demolition and $34,000 for canal repairs.
(2) These figures do not include costs of fish passage facilities, estimated to be $1,000,000.
(3) This total is less than the estimate of $16,980,000 due to change in Account 356.00 and 358.00. See text discussion in Section 3.6.4.

TABLE C-4. DETAILED COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
331.00	Power Plant Structures and Improvements						
331.1	Powerhouse						
.11	Cofferdam and pumping						Included in Acct. 332.31
.12	Excavation, Rock	8,200	c.y.	25.00	205,000		
.13	Foundation preparation						Included in Acct. 331.12
.15	Substructure						
.1510	Concrete	10,100	c.y.	90.00	909,000		
.1511	Forms	65,000	s.f.	5.00	325,000		
.1512	Reinforcing steel	808,000	lb.	0.50	404,000		
.159	Miscellaneous		L.S.				
.16	Superstructure	(250,000)	c.f.				
.161	Structural steel frame	160,000	lbs.	0.75	120,000		
.162	Walls	13,000	s.f.	5.50	72,000		
.1630	Roof	63	sq.	180.00	11,000		
.1631	Roof covering	63	sq.	170.00	11,000		
.164	Interior partitions, floor		L.S.		2,000		
.165	Doors and windows		L.S.		15,000		
.166	Plumbing and Sewage		L.S.		20,000		
.167	Heating and ventilation		L.S.		51,000		
.168	Lighting		L.S.		15,000		
.169	Miscellaneous		L.S.		20,000		
	Total Power Plant Structures and Improvements					2,180,000	

TABLE C-4. DETAILED COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
332.00	Reservoirs, Dams and Waterways						
.1	Reservoir						
.2	Dams - Canal Walls						
.21	Cofferdam and Pumping						
.211	Structure	9,000	c.y.	10.00	90,000		
.212	Pumping	--	L.S.	--	30,000		
.22	Core drilling	--	l.f.	--			Included in Engineering
.23	Excavation, Rock	--	c.y.	--			Included in Acct. 332.541
.24	Foundation preparation	--	s.f.	--			Included in Acct. 332.541
.250	Concrete						
.251	Forms	39,000	s.f.	4.25	166,000		
.252	Reinforcing steel	390,000	lbs.	0.45	175,000		
.253	Concrete	7,300	c.y.	100.00	730,000		
.3	Dams - Canal Control Structure						
.31	Cofferdam and Pumping						
.311	Structure	4,000	c.y.	8.00	32,000		
.312	Pumping	--	L.S.	--	1,000		
.32	Core drilling	--	l.f.	--			Included in Engineering
.33	Excavation, Rock	100	c.y.	150.00	15,000		
.34	Foundation preparation	--	s.f.	--			Included in Acct. 332.33
.35	Concrete						
.351	Forms	7,700	s.f.	10.00	77,000		
.352	Reinforcing steel	80,000	lbs.	0.50	40,000		
.353	Concrete	1,000	c.y.	70.00	70,000		
.4	Dams - Appurtenances						
.41	Control Gates and Hoists						
.411	Sliding Gate	21,000	lbs.	1.40	29,000		
.412	Stoplogs		L.S.	--	3,000		
.5	Waterways						
.54	Canals						
.541	Excavations	6,800	c.y.	25.00	170,000		Structure included in Acct. 331.1

TABLE C-4. DETAILED COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
.6	Intake	6,800	c.y.	25.00	170,000		
.61	Intake gates & Appurtenances						
.611	Gates, Guides & Hoists (1)	--	L.S.	-	630,000		Intake gates-fixed wheel
.612	Trash racks and rakes	85,000	lbs.	1.00	85,000		
.62	Forebay booms	--	--	--	--		
.63	Intake valves	--	--	--	--		
.69	Miscellaneous	--	L.S.	--	50,000		Includes handrail along canal walls
.9	Tailrace						
.91	Excavation, Rock	15,300	c.y.	25.00	382,000		
.92	Rip rap						
.93	Gates, hoists & Appurtenances	175,000	lb.	1.40	245,000		Bulkhead Style - 1 set
	Total Reservoirs, Dams & Waterways					3,020,000	
333.00	Water Wheels, Turbines & Generators						
.1	Turbines, Governors, Pumps, and Piping		H.P.				
.101	Supply	2		1,250,000	2,500,000		
.102	Install & Commission				625,000		
.2	Generators, Exciters & Appurtenances		kW				
.201	Supply	2		1,150,000	2,300,000		
.202	Install & Commission				575,000		
	Total Water Wheels, Turbines, & Generators					6,000,000	

(1) Includes $520,000 for powerhouse intake gates and $110,000 for replacement of canal gatehouse gates.

TABLE C-4. DETAILED COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
334.00	Accessory Electric Equipment						
.1	Connections, Supports & Structures						Included in Acct. 334.2
.2	Switchgear & Control Equip.		L.S.		135,000		
.203	Control, Meter, Relay		L.S.		50,000		
.26	Auxiliary power equipment						
.262	Station Battery		L.S.		20,000		
.29	Miscellaneous		L.S.		20,000		
	Total Accessory Electric Equipment		L.S.			225,000	
353.00	Substation Equipment						
.21	Transformer Supply		L.S.		125,000		
.211	Install		L.S.		30,000		
	Total Substation Equipment					155,000	
356.00	Overhead Conductors						
.1	Insulators & Hardware		L.S.		15,000		
.2	Conductors		L.S.		30,000		
.3	Miscellaneous		L.S.		25,000		
358.00	Underground Conductors						
.1	Insulators, Hardware		L.S.		20,000		
.2	Conductors		L.S.		40,000		
	Total Transmission (Acct. 356 & 358)					130,000	N.E. Power Co. estimate of $300,000 was used in Summary Tables.

TABLE C-4. DETAILED COSTS FOR TWO 7.5MW FIXED BLADE PROPELLER TURBINE SYSTEM (Cont)

No.	Description	Quantity	Unit	Cost/ Unit	Amount	Totals	Remarks
335.00	Miscellaneous Power Plant Equipment						
.1	Auxiliary Equipment						
.11	Unwatering & low level drainage system		L.S.		45,000		
.14	Compressed air system		L.S.		45,000		
.15	Fire protection equipment		L.S.		10,000		
.16	Cranes		L.S.		200,000		
.17	Oil Handling		L.S.		10,000		
.18	Protective Coatings		L.S.		15,000		
.19	Miscellaneous		L.S.		15,000		
	Total Miscellaneous Power Plant Equipment					340,000	
336.00	Roads and Railroads						
.1	Roads, Gravel		L.S.		30,000		
	Total Roads and Railroads					30,000	

UNITS

c.y.	cubic yards
s.f.	square feet
L.S.	Lump Sum
lb.	pounds
c.f.	cubic feet
sq.	per square (100 s.f.)
l.f.	lineal feet
H.P.	Horsepower
kW	kilowatts

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